

Nutrient loads in the Arda River Basin



What is the contribution of different point sources and diffuse sources to nutrient loads in the Arda River Basin?

Vivian van den Bosch
August 2006



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Preface

During my Bachelor study Environmental Sciences at the Van Hall Larenstein, I focussed on Water management and GIS. The study ends with a graduating project. This report is the thesis of the graduating project. The project is within the scope of the European Water Framework Directive (WFD) and is about modelling nutrient loads (specifically phosphorus and nitrogen) in the Bulgarian part of the Arda River Basin with a GIS oriented nutrient emission model (Moneris-approach).

To have the opportunity to carry out an international oriented project in Bulgaria was a great learning experience, because many new aspects came up for me. Therefore I would like to thank ARCADIS region (north-east) and Euroconsult, the EAS-RBD and the EVD, since it has been made possible by them.

During this project, I have met many people who supported me with information supply, providing expert knowledge and inspiration; I would like to thank every body for that. I would like to thank the guidance that I have had from: Erik Meijles, Erik Leunissen, Andrea Swenne, Hans Aalderink, Jordan Kosturkov, Maria Babukchieva and Marin Marinov. In particular, I would like to thank Miloslava Mihaylova from the EAS-RBD; she supported me with many things like translation, providing and explaining information, and support with GIS. Further, I would like to thank all the colleagues from the EAS-RBD and other people that I've met during this project.

Vivian van den Bosch
August, 2006

Abstract

Bulgaria is seeking to join the European Union and therefore has to implement requirements of the Water Framework Directive (WFD) in order to reach a good ecological status. In order to fulfil requirements of the WFD, the human pressures and impacts on nutrient emissions have to be assessed, because an overload of nutrient emissions to surface water may cause problems to reach a good ecological water quality status.

Nutrients undergo various processes and reach surface water via different pathways, what makes it difficult to determine the contribution of the original sources to nutrient loads in the river system. Therefore, several models have been developed in order to estimate nutrient input to river systems like the nutrient emission model “Moneris”.

The aim of this project is to analyse the impact and pressures of human activities on nutrient loads (specifically nitrogen and phosphorus) in surface waters of the Arda River Basin using a Moneris-approach. The main research question is: **“What is the contribution of different point sources and diffuse sources to the overall emission loads of phosphorus and nitrogen (in tones/annual) at the outlet of different sub-catchments of the Arda River Basin?”** The Moneris-approach for the Arda River Basin, estimates the average multi-annual nutrient loads (N, P) emitted to surface water through various pathways for 6 sub-catchments over the hydrological period of 1994-1998.

The Moneris-approach is an empirical model, for large river basins (preferable $> 500 \text{ km}^2$). The model is based on average measured total runoff data (m^3/s), precipitation data, statistical data (i.e. inhabitants, nutrient surplus, and information about sewerage) and geographical data (e.g. the soil map, DEM, erosion and atmospheric deposition). The model consists of Excel files linked to each other. Moneris is a steady-state model and does not have a dynamic capability and therefore estimates the average annual load over a hydrological period of 5 years. The model estimates emissions and immisions (= emission of nutrient loads minus retention and loss processes). The Moneris-approach estimates the emissions of nutrients via the following pathways:

- Atmospheric deposition;
- Surface runoff;
- Ground water;
- Erosion;
- Point sources (industries and waste water treatment plants (WWTP's), although in the Arda region, the contribution of industries emitting nutrients are negligible and WWTP's did not exist from 1994-1998);
- Urban areas
- Tile drainage (in the Arda River Basin, tile drained areas do not exist).

In order to know what part of the total emission is due to the natural background, the model is used to simulate the emissions under a natural condition unstressed by human. From the remaining emissions is investigated what the contribution of original sources are in terms of agricultural activities, urban areas and other diffuse sources (like atmospheric deposition caused by burning fossil fuels for domestic heating, traffic and industries and NH_x volatilizing from agricultural areas).

According the modelled results, 80% of nitrogen loads in the whole Arda River Basin is reaching surface water via the pathway ground water. The second largest input of nitrogen is via urban systems (13%). The main sources of nitrogen emission are other diffuse sources (42%) than agricultural areas (22%) and urban areas (13%). The contribution of urban areas is mainly due to sewerages not connected to a WWTP. The natural background of nitrogen emission is 23%.

In the Arda basin, 77% of the phosphorus load is emitted to surface water via the pathway erosion. Agricultural activities are the main source of phosphorus emission (80%), followed by urban areas (15%). The natural background of phosphorus is 5%.

Based on the desired and 'current' status and the analysis of the contribution of different sources emitting nutrient loads, useful and logical measures can be proposed. With the operational Moneris-approach for the Arda River Basin, the relative effect of measures can be estimated.

There are different possibilities to reduce nutrient inputs. Distinction can be made between source management and transport management of nutrients. Considering the measured concentrations of nitrogen and phosphorus, it can be concluded that probably nitrogen is not a direct risk to fail requisites of the WFD (based on comparison with initial thresholds for nitrogen and phosphorus concentrations from the article 5 report: the River Basin Overview, 2005), opposite to the high concentrations of phosphorus. Therefore, the effects of two scenarios to reduce P-loads are estimated as well as one scenario to reduce nitrogen loads and phosphorus loads.

1. The first measure is aimed to reduce emissions of both nitrogen and phosphorus from urban areas, by placement of a WWTP near Kardjali, located in catchment 4 (source management). The nitrogen load will be decreased with 26% and the phosphorus load will be decreased with 7%, both through a decrease of nutrient emissions from urban areas.
2. The second measure is aimed to reduce total-P emissions from agricultural areas, by reducing the P-content of the topsoil with 10% (source management). The effect is a reduction of 8% from the total phosphorus emission loads in the whole Arda River Basin, due to lower input via erosion.
3. The last measure is aimed to reduce mainly P-emissions, by preventing erosion (transport management) by erosion control of 50% in the whole Arda Basin. This scenario results in a reduction of 24% of P-emission via erosion and 1% of reduction of nitrogen emissions.

The first measure seems useful in order to reduce nitrogen and phosphorus emissions. But a WWTP is expensive and therefore further investigation to this possibility is required. According the calculations of the P-content in the Arda River Basin, the average P-content is 1050 mg/kg, which is quite high. It should be further investigated if this value is realistic (on the base of P-surplus calculations or soil samples) and if it is possible to reduce the P-content by better management of farming, and manure and fertilizer use. It should be further investigated if erosion control is possible and to what extent by better land use management.

A model is an approach of reality and many uncertainties can influence the reliability of the outcome of the model. Before using the model as a decision-support system to quantify the effect of measures by using scenarios, the deviation of the model with reality should be considered. Not enough data was available to calculate the measured load and to compare the results with the modelled loads. In most cases, no discharges were measured and the monitoring stations where quantity and quality was measured, were not located at the same place as the hydrological stations. In addition, only from the year 2003 total-N and total-P concentrations are measured, till then only DIN and PO₄-P concentrations were measured.

Addition data collection (measured discharges and total-P and total-N concentrations) is required to compare the modelled results with reality and to have a better idea about the deviation of the model. However, the model can be used to determine the relative effect of measures compared with each other. This first operational is also suitable to assess the most important data in order to estimate nutrient loads including source apportionment with the Moneris-approach or comparable models. In order to optimize the model, more reliable data for precipitation (for a period of 5 years), measured discharges (for a period of 5 years), and the N and P surplus (and P-content topsoil) is require

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Abbreviations

(Total) N	(Total) Phosphorus
(Total) P	(Total) Nitrogen
DEM	Digital Elevation Model
DIN	Dissolved Inorganic Nitrogen
DNMI	Norwegian Meteorological Institute
EAS-RBD	East Aegean River Basin Directorate
EMEP	European Monitoring and Evaluation Programme
EVD	Agency for International Business and Cooperation of the Netherlands
ExEA	Executive Environmental Agency
GIS	Geographical Information System
IMH	Institute of Meteorology and Hydrology
IMPRESS	Impacts and pressures Analysis (of human activity on surface- and ground waters)
ISPRA	Institute for Environment and Sustainability
IWP	Institute for Water Problems
MoEW	Ministry of Environment and Water
MONERIS	Modelling Nutrients Emissions in River Systems
NIS	National Institute of Statistics
PESERA	Pan European Soil Erosion Risk Assessment
PO4-P	Phosphate
RBD	River Basin Directorate
RBO	River Basin Overview
RBMP	River Basin Management Plan
RIEW	Regional Inspectorates on Environment and Water
RL	Regional Laboratories
SWB	Surface Water Body
USDA	United States Department of Agriculture
WFD	Water Framework Directive
WWTP	Waste Water Treatment Plants

1 Introduction

1.1 Background and problem description

Bulgaria is seeking to join the European Union, and in doing so must conform to EU regulations. When Bulgaria wants to join the European Union, it has to fulfil the requirements of the Water Framework Directive (WFD). In accordance with WFD requirements, Bulgaria has already organized the administration of water management into four river basin districts, each having a separate Competence Authority (River Basin Directorate). One of them is the East Aegean Sea River Basin Directorate, which is divided into three different sub-basins: the Maritsa River Basin, the Tundja River Basin and the Arda River Basin.

The EVD¹ started a project to assist Bulgaria with the implementation of the WFD. The EVD invited ARCADIS Euroconsult to carry out the project called “*Institutional strengthening of the East Aegean Sea River Basin Directorate (EAS-RBD) in Bulgaria for the implementation of some main requirements of the Water Framework Directive 2000/60/EC in the Arda pilot river basin.*” The main project purpose is to assist the EAS-RBD (beneficiary) with the formulation of a river basin management plan (RBMP), which has to be finished in 2009.

One of the components of the RBMP is the pressures and impact analysis (IMPRESS). Each district has to carry out an analysis of the impact of human activities on the water bodies within that district, and in particular, the identification of pressures that such activities might cause. Human activities can cause pollution (via diffuse and point sources) as well as a reduction by implementing measures. The IMPRESS analysis will be used to assess whether or not the surface- and groundwater bodies are at risk of failing to meet a ‘good ecological water status’ by 2015. The IMPRESS analysis is focussing on the quantitative status and the qualitative status (biological and chemical) concerning ground water as well as surface water. Part of the IMPRESS analysis is to assess the contribution of the nutrients nitrogen and phosphorus in surface water bodies. An initial IMPRESS analysis is carried out by the EAS-RBD, results see appendix J. In order to have a better insight in different sources and pathways contributing to nutrient emissions and to choose effective measures, nutrient emission models like Moneris can be used.

The problem definition: *As part of the overall project, a Moneris model approach has to be implemented in order to assess the impact of nutrients (phosphorus and nitrogen) in the Arda River Basin.* The main task is to show the opportunities and possibilities of the model. It is important to show what data is required and what the effect of missing data is and to use the model to define effective measures or to collect data in a more efficient way.

1.2 Aim and research objectives

The aim of this project is to analyse the impact and pressures of human activities on nutrient loads (specifically nitrogen and phosphorus) to surface water of the Arda River Basin using a Moneris-approach. The main question is: **“What is the contribution of diffuse sources and point sources to the overall emission loads of phosphorus and nitrogen (in tones/annual) at the outlet of different sub-catchments of the Arda river basin?”**

The contribution of diffuse sources and point sources to the total loads of nutrients can be estimated with an approach of the model Moneris, as well as the effect of measures, using scenarios. The reliability of the results mainly depends on data availability and data quality. The model can give information about most important data and data requirements in order to assess impact on nutrient

¹ EVD is the Netherlands Agency for International Business & Cooperation; part of Ministry of Economic Business.

loads. Ultimately, managers can use the model as a decision making tool to formulate suitable measures (combination of successful results regarding reduction of nutrients and the cost effectiveness) to fulfil the objectives and requirements of the WFD according to nutrients. Alternatively, when the model is not yet suitable as decision-making tool, recommendations on additional data collection or improvement of data collection can be made. To answer the main question, the research is divided into four research objectives:

1. Obtaining an operational nutrient emission model according a Moneris-approach for the Arda River Basin, based on available data.
2. Estimate the measured immision and the modelled immision loads of nutrients (in t/a) for each sub-catchment, in order to compare the modelled results with reality and to define the deviation and reliability of the model.
3. Estimate the annual emission loads of nitrogen and phosphorus (in t/a) for each sub-catchment in the Arda river basin, including distinction between the contribution of different point sources and diffuse pathways.
4. Consider measures to reduce the amount of nutrients. Calculate the effect of the measures with the Moneris-approach.

1.3 Obtained products and scope of the project

The products that have been obtained are:

1. Operational Moneris-approach model for the Arda based on available data in order to calculate nutrient loads;
2. Overview of required, available and used data (see chapter 5 and appendix G) and recommendations about further data collection (see chapter 11);
3. Overview with the loads of total-N and total-P, including contribution of different diffuse and point sources, for different catchments in the Arda basin (see chapter 6 and 7);
4. Evaluation of possible effective measured to reduce nutrients (see chapter 8);
5. Presentation in Varna and in Leeuwarden to clarify the progress of modelling and the results;
6. A final report and Homepage detailing the results.

In the following text is described what is outside the scope of the project.

First, only the Bulgarian part of the Arda River Basin, is the study area to model nutrient loads, since this is the pilot area of the overall project. This Arda River Basin is divided into 6 different sub-catchments (see chapter 4.2) and the nutrient loads will be assessed as a multi-annual average (1994-1998) per catchment.

The operational model is based on available data obtained within the period of the project. An old Moneris-approach has been used and no calibration or validation has been carried out. The Moneris-approach for the Arda River Basin is a first approach of a nutrient emission model for the Arda Basin, and is therefore not supposed to be a scientific model. The obtained model is a pragmatic approach, to show the possibilities with the model and the current data availability. Therefore, no quantitative analysis of the total uncertainties of the modelled results will be carried out.

This Arda Moneris-approach does not consider emission via snow runoff, because the existing equation leads to 0-values, even though in some catchments snow plays an important role. In the obtained model, tile drainage and wastewater treatment plants (WWTP) are not included, because these sources are non-existent in the Arda River Basin within the period of 1994-1998. Real calculations about the surplus of nutrients are not included in this project since this analysis requires comprehensive data and expert knowledge.

1.4 Reading instructions

The next chapter contains a basic description of the area, in order to have an idea about the Arda River Basin, the system that is being modelled. Basic characteristics that influence nutrient emissions to the river system are globally described.

The third chapter contains information about the model used to estimate nutrient loads in the Arda River Basin. In this chapter, the choice of the model is explained (3.1), the pathways and processes that are important for modelling nutrient loads, are mentioned briefly in relation to the model that is used (3.2) and the last two sections (3.3 and 3.4) describe the base of the model in terms of characteristics and outcome of the model.

The fourth chapter explains the methodology which is used to model nutrient loads in the Arda River Basin. Chapter 5 gives an overview with required, available and eventually applied data for obtaining the Moneris-approach model for the Arda Basin (research objective 1). In addition, appendix G contains the explanation of the methodology used to convert available data to input of the model and the results for input of the model.

Sections 6.1 to 6.3 are presenting the outcome of the model (modelled emission and immision loads) in relation to the measured immision loads (research objective 2). The results with the estimation of nitrogen and phosphorus emissions from different point sources and diffuse pathways and sources are presented in section 6.4 and 6.5 (research objective 3). Appendix C and D include geographical maps with the results per catchment. Section 6.6 is examining the concentrations of nitrogen and phosphorus in relation to compare this with initial thresholds for chemical substances to fulfil WFD requirements.

The results are explained and discussed per catchment in chapter 7. On the base of the results, suggestions for effective measures are used for scenario calculations with the model. The scenarios and the results are presented in chapter 8 (research objective 4).

Chapter 9 starts with the discussion of the results for the Arda Basin as a whole (section 9.1) and after that, the model and methodology and its uncertainties of obtaining the model will be discussed in section 9.2. The conclusions and recommendations are described in respectively chapter 10 and 11.

In addition, this report contains a list with the explanation of abbreviations (page 12) and a glossary to describe the technical words (page 57). A detailed topographical overview map of the Bulgarian part of the Arda River Basin is included in appendix A.

2 Area description

This chapter contains a basic description of Arda River Basin, in order to have an idea about the system that is being modelled.

2.1 Topography

The Bulgarian part of the Arda River Basin, with a surface area of 5200 km² is situated in the southern part of Bulgaria in the Eastern Rhodope Mountains, see figure 2-1. A detailed topographic overview of the Arda River Basin is presented in appendix A, for a clear readability.

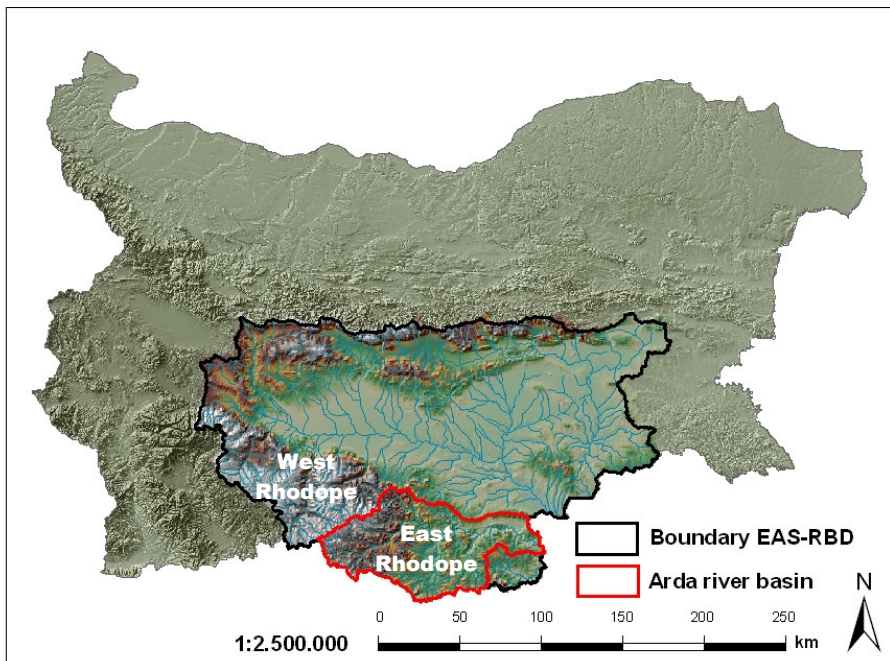


Figure 2-1 Map of Bulgaria with the location of respectively the EAS-RBD and the Arda River Basin

The main river is the Arda River with a length of 240 km in Bulgaria and a further 30 km in Greece. The main tributaries are the Krumuvitsa (60 km) and the Varbitsa (100 km), see appendix A. The Arda River finally discharges in the Maritza River in Greece. The river initiates at a height of 1730 m from a number of gullies that gather (<http://www.bluelink.net/>, 2006). The general flow direction is from the North-Eastern Rhodope Mountains to the South-Eastern Rhodope Mountains. The average elevation is 636 m and the average slope is 18%.

Three big dams and contributory reservoirs are located along the valley of the Arda River: dam Kardjali, dam Studen Kladinets and dam Ivaylovgrad. The water storage reservoirs are used for production of electricity and irrigation purposes.

2.2 Geology, climate and soil

In tectonic respect, the whole Arda Basin is situated in the Eastern Rhodope region, which is built up from pre-Cambrian, Paleogene and Quaternary rocks. In small parts, also metamorphosed Mesozoic rocks and Neogene layers can be found (<http://www.bluelink.net/>, 2006). The Trace mass is consisted of crystal formations such as gneiss, granite and volcanic rocks. The geosynclines part of the Arda valley consists from sand, clay and limestone (More information: Zinke *et al.*, 2004). In general, the Arda basin is a karst-limestone area. Limestone contains many joints and fractures that rapidly transport water, particles, and solutes to the subterranean drainage system. These characteristics of

limestone karst terrain make the rapid movement of phosphorus or nitrogen possible (Boyer *et al.*, 2000), but it is difficult to predict. More information about limestone and karst, see: <http://www.geography.learnontheinternet.co.uk/>.

The Arda Basin is mostly influenced by Mediterranean climate. During the spring, the climate is typical continental and changeable. The average precipitation depends on the elevation. In low land areas, the precipitation is between 550 and 620 mm and in mountain regions between 900 and 1100 mm. The maximum is observed usually in May and June, while the minimum is observed in July and August and in some years February (Zinke *et al.*, 2004). In the southern parts of Bulgaria, the evaporation averages to 820-850 mm (Slavov *et al.* 2006).

The soil types present in the Arda Basin are mainly brown forest and leached cinnamonic forest, according the Russian soil classification, see figure 2-2. In the Arda River basin, these soils are shallow and found at a relatively small depth (60-70 cm) of the profile. Both soil types are present on slope terrains and subjected to water erosion (Kosturkov, 2006 *unpublicized*). An extended explanation for each soil type is given appendix H. A short description of each is given below on the base of appendix H.

Leached cinnamonic forest consists of a humus-accumulative A horizon (humus content 1,5 -4%) and the metamorphic B(t) horizon (low humus content). The thickness of the humus-accumulative horizon is small – usually less than 40 cm, and has a heavy sandy-clayey composition (with high clay content). The metamorphic B(t) horizon is characterized by clayey composition, low water permeability and high water-retention capacity and thus low infiltration capacity. Therefore in this soil, nitrogen is not leaching easily to groundwater, but phosphorus accumulates in the humus layer (see chapter 3.2).

Brown forest soils are characterized by a low bulk density and high porosity and contain of fragmented rock pieces. This soil type is sensitive for leaching of nitrogen to groundwater and accumulation of phosphorus in the top soil (see chapter 3.2). Usually, the soils contain a high amount of organic matter (humus 7-10%) in the topsoil (0-20 cm). Brown forest consists of the L horizon (forest litter or cover), the A horizon (humus-accumulative horizon) and B_m + C horizon, consisted of bedrocks.

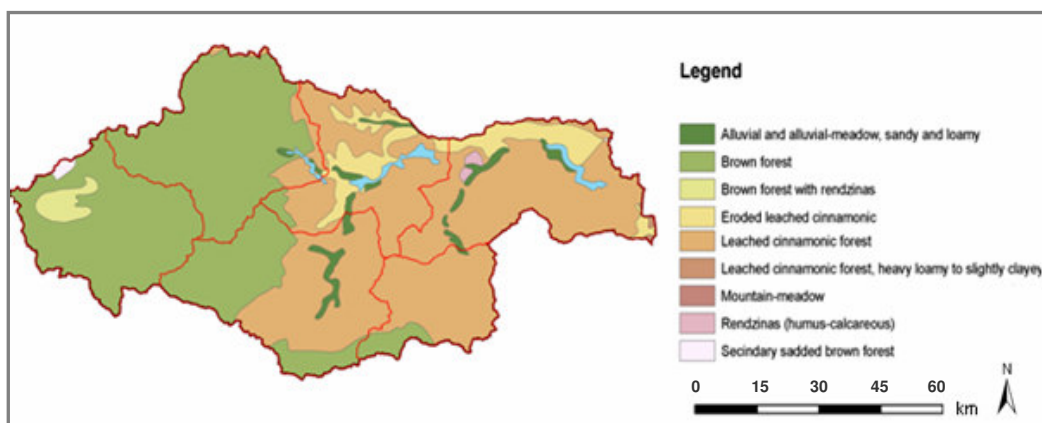


Figure 2-2 Soil types in the Arda River Basin

2.3 Land use

In the Arda River Basin, about 50% of the area is covered by forest (see figure 2-3), mainly coniferous and low-growing forest. The Arda Basin used to be one of the most densely afforested basins in Bulgaria, but because of the random cutting and usage in the past, a big part of the forests in the area have been cut down, which in addition can cause erosion.

About 25% of the area consists of arable land, used for production of cash crops, mainly tobacco, but also grapes and potatoes are important. In a smaller amount than crop production, husbandry of cattle

and sheep takes place in the Arda Basin. Most of the agricultural land is cultivated in small family plots. Because of the mountains, there are not many large areas suitable for commercial farming. “*In the case of Bulgaria, local landowners do not have sufficient skills or the equipment for commercial farming and therefore most of the productions on private lands are non-mechanical and simple* (www.rodope.org)”. A main concern is new privatized landowners that want to start farming but do not have guidance on how to use the individual land in both economic terms as well as from an environmental prospective. Incorrect land use and farming can cause undesirable and unnecessary spill of nutrients into the environment and surface waters.

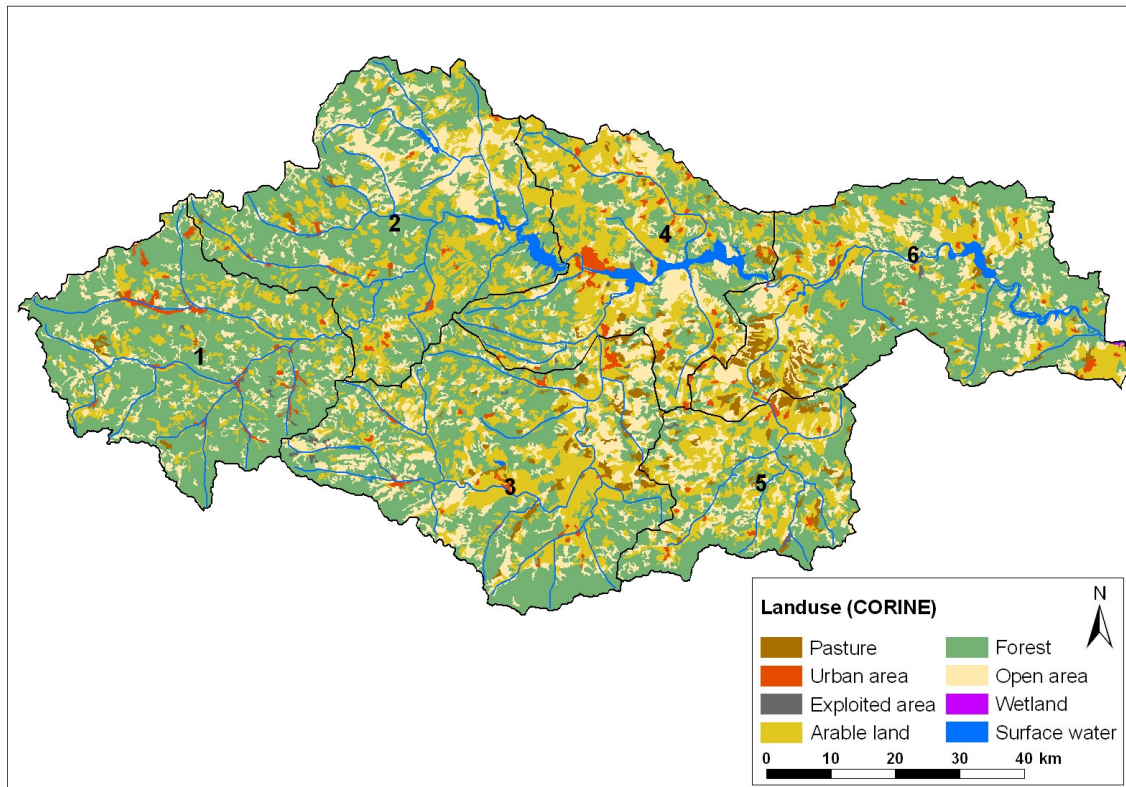


Figure 2-3 Land use Arda Basin (CORINE landcover 2000, after classification according appendix I)

2.4 Urban areas and demography

Parts of the districts of Plovdiv, Smolian, Kardjali and Haskovo are situated within the Arda River Basin and 15 municipalities are situated in the Arda Basin, from which 10 municipalities entirely within the basin. The area is not densely populated; most people live in the main cities Kardjali, Smolian and Momtjilgrad, see the map in appendix B with the regions, municipalities and inhabitants. The total amount of inhabitants in the Arda is about 250 000 (according NIS, 2001). The last years, more people migrate from small villages to cities. In Bulgaria, the total the amount of inhabitants is decreasing slightly.

In the Arda basin is on average 40% of the inhabitants connected to sewerage, mainly present in bigger cities. The sewerages are not connected to wastewater treatment plants in the Arda Basin, but sewage is mostly discharging in (dry) gullies or directly into surface water. The remaining inhabitants not connected to sewerage, mostly use individual purification systems, like a septic tank.

3 Moneris-approach Arda

Nutrient input in surface water may cause problems for reaching a good water quality. In order to fulfil requirements of the WFD, the human pressures and impact of nutrient inputs have to be assessed. When the human impact is analysed and the source investigated, specific measures can be taken. However, after input of nutrients into the environment, these substances undergo various processes and reach surface water via different pathways. Especially, when nutrients do not flow directly into the surface water (diffuse sources) it is difficult to predict what amount of nutrients will reach the surface water, in which time equivalent and via which pathway(s). With the aim of taking effective measures, it is required to identify the source of the nutrient inputs, the pathway(s) and particular circumstances that contribute significantly to nutrient loads in the surface water. It is complex to assess these aspects and therefore, several different nutrient emission models are developed and applied today (*Fogelberg, et al., 2001*).

In section 3.1 it is first described why a Moneris-based model is chosen to model nutrient loads in the Arda River Basin. The pathways and processes that are important for modelling nutrient loads, are explained briefly in relation to the model that is used (section 3.2) and the last two sections (3.3 and 3.4) describe the base of the model in terms of characteristics and outcome of the model.

3.1 Why Moneris approach?

There are several different models developed to estimate nutrient inputs into river basins, which can be used as a decision support model. The Moneris model (Modelling Nutrients Emissions in River Systems) can be used to investigate input of nitrogen and phosphorus via various point sources and diffuse pathways. The Moneris model was developed and applied to estimate the nutrient input into river basins of Germany (*Nunneri, et al., 2000*).

In this project for the Arda River Basin, a Moneris-approach is applied. This Moneris-approach is based on an old operational Moneris model for German river basins. This German model has been modified by using specific data for the Arda River Basin and some routes of nutrient emissions are excluded, since they do not play a role in the Arda Basin, see the next section. The model is applied without supervision of the developer and for this reasons cannot be mentioned as Moneris. Meanwhile the original model is updated and extended to new insights, which are not taken into account in the Moneris-approach for the Arda River Basin.

Water quality experts from the project team of the overall project “*Institutional strengthening of the EAS-RBD in Bulgaria for the implementation of some main requirements of the WFD in the Arda pilot river basin*”, decided to apply a Moneris-approach in order to estimate nutrient loads of nitrogen and phosphorus in different catchments of the Arda River Basin. The reasons were threefold:

1. Moneris (as well the as Moneris-approach) does not need very extensive data compared with other nutrient emission models, because the model uses average data for a hydrological period of 5 years. This is a very important reason because for the Arda River Basin there is a lack of data, especially daily data, which is not required to apply Moneris;
2. To develop a Moneris-approach is relatively cheap, because the initial German model (received via Kosturkov, 2006) was made available free of charge by the developer of the model (H. Behrendt);
3. The model is less complex than dynamic models, because the model works with average annual runoff data instead of daily time series (*Fogelberg, et al., 2001*);
4. The model is relatively easy to apply, because it is based on an open Excel structure.

3.2 Pathways & processes of nutrients from pollution source to river system

The Moneris-approach for the Arda River Basin, estimates the average loads over the period between 1994-1998 emitted to surface water through point sources and diffuse pathways. After input of nutrients, nitrogen and phosphorus undergo different processes before reaching the surface water. The different sources, pathways and processes that play a role in nutrient transport to surface water in the Arda Basin, are basically visualised in figure 3-1 and 3-2 and further explained in this section. In the text is referred to figure 3-1 by use of letters for different pathways.

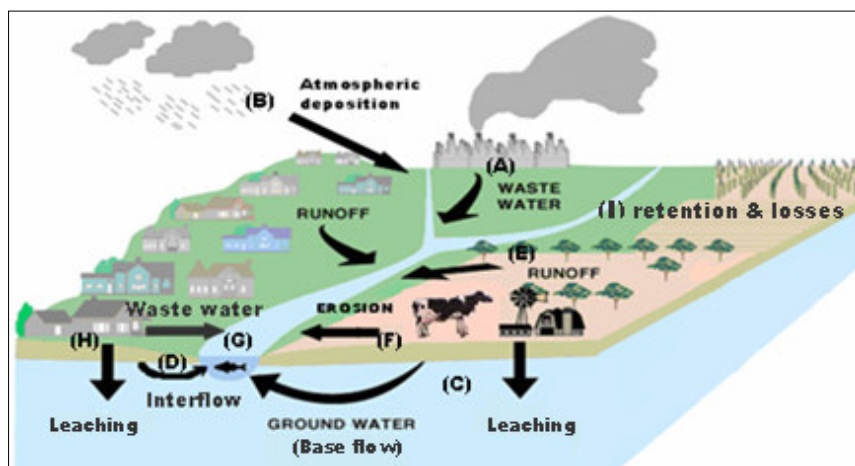


Figure 3-1 Pathways of nutrients in Moneris-approach Arda (After USGS, 1999)

The point sources that can be taken into account separately in the model for the Arda Basin are waste water treatment plants (WWTP's) and direct industrial discharges (A). However, the Arda Basin does not contain WWTP's and the contribution of industrial discharges for the total Arda Basin are less than 0,2 t/a (source: data from the EAS-RBD) and therefore negligible compared with other sources and will not be taken into account further more.

The atmosphere (B) is a diffuse source of nitrogen and phosphorus emission, due to emissions to the air via volatilisation originating from burning fossil fuels (for traffic, industries and domestic housewarming) and agricultural activities. Nutrients deposit on non-paved areas or reach directly the surface water via precipitation or dry deposition. Nitrogen deposition from the air appears in nitrogen oxides (NO_x^-) and ammonia (NH_4^+). Phosphorus emissions are principally caused by burning coal and wind-erosion (Behrendt *et al.*, 2000). Phosphorus is difficult to measure (Moneris uses an assumption) and appears in the form of dissolved inorganic phosphorus and organic phosphorus (Andersen *et al.*, 2004).

Nutrient input via agricultural areas are estimated on the base of the nutrient surplus (is the net nutrient addition from fertilizers, manure and atmosphere minus uptake from crops) in the topsoil of agricultural areas (Behrendt *et al.*, 2000). Nutrients in the topsoil are transferred to surface water via:

1. Leaching of nutrients to the subsurface and via interflow to surface water (D) and leaching of nutrients to groundwater and via base flow to surface water (C)²;
2. Surface runoff³ by rainfall (or melting snow), washing away nutrients from the topsoil (E). In the Moneris-approach only dissolved nutrients are taken into account via overland flow;
3. Transport of eroded soil and sediments containing nutrients via water erosion (F);

² In the model, these 2 routes are summarized as input via ground water. In the Arda Basin tile drained areas do not exist.

³ Surface runoff is transport of precipitation over land. Part of the surface runoff is infiltrating in the soil dependent on land characteristics; the net flow after infiltration is called the overland flow (Behrendt, 2006).

Nutrient input from urban areas reach surface water directly (G) or via ground water (H). The emissions caused by inhabitants connected to sewerage, but not to WWTP's are flowing directly to surface water or reach the ground water via dry gullies (G, H). Emissions from inhabitants not connected to sewerage, reach the surface water directly or via ground water (G, H) (Behrendt *et al.*, 2000).

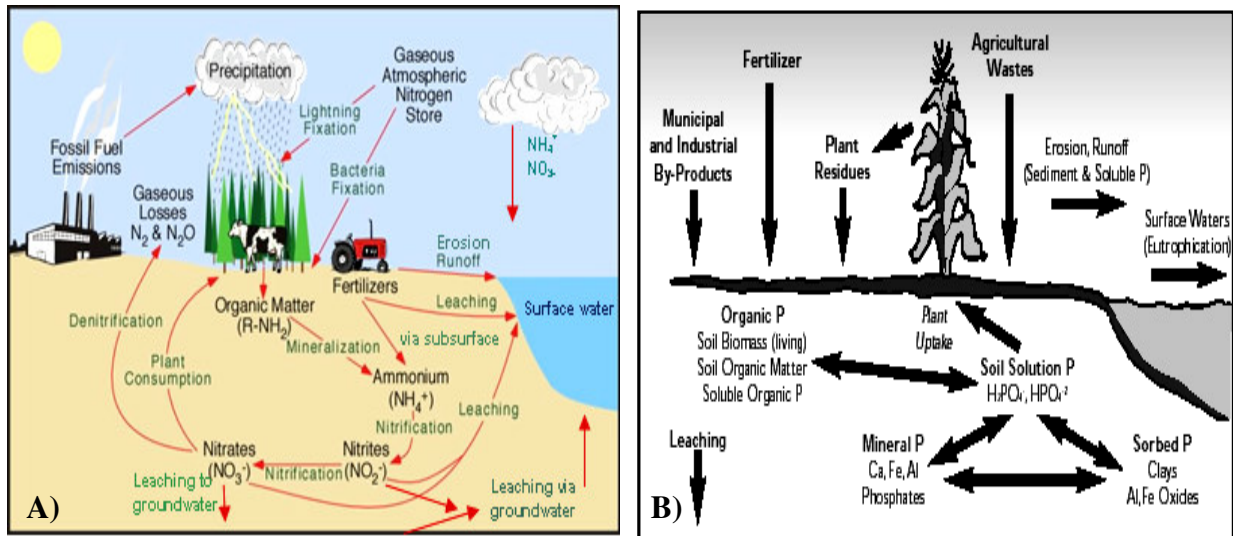


Figure 3-2 A) Nitrogen processes (after Pidwirny, 2006) B) Soil phosphorus cycle (Mullins, 2001)

The process of nitrification in soil can transform nitrogen in ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-) (see figure 3-2 A). Primary concern of impact of nitrogen is the possibility of nitrate leaching into ground water (USDA/NRCS, 1997). Nitrate is very soluble and can leach rapidly to ground water via moist soils, mainly dependent on water flow and soil type (sand is more sensitive for infiltration than clay). This makes that nitrogen is mainly transported via ground water instead of erosion and surface runoff. Usually nitrite does not accumulate in soil, because it is rapidly transformed into nitrate. Ammonium is more easily adsorbed by clay particles or organic matter and is less likely to leach (USDA/NRCS, 1997). Current inputs of nitrogen can take many years to reach deep ground water, because the water flow direction is in most cases horizontal instead of vertical. Ground water moves very slowly and therefore contamination of surface water via ground water may persist for decades.

Phosphorus added to the soil reacts with soil minerals, become immobilised and unavailable for take up by plants. Most phosphorus is lost to surface water via erosion or surface runoff and to a lesser extend via leaching to ground water. Phosphorus is present in three forms (see figure 3-2 B):

- Organic as part of living organisms or plant residue (principle form of P in manure is organic);
- Soluble available inorganic phosphorus;
- Bound to soil and minerals like iron, aluminium and calcium.

Contrary to nitrogen, leaching of phosphorus is in most cases not a significant concern (Wiederholt *et al.*, 2005), because phosphorus immediately bounds to soil particles, especially clay and organic matter, which causes accumulation of phosphorus in the soil. When the soil becomes saturated with phosphorus, this leads to more phosphorus in soluble form and in combination with a high ground water level, this makes leaching to ground water possible.

Most phosphorus is present in the top layer of the soil. Due to weathering and precipitation, dissolved phosphorus is transported via overland flow to surface water and particulate phosphorus bound to the soil or organic matter is transported via erosion. The intensity of erosion and runoff is dependent on many factors, like soil type (fine soil particles are more likely to erode than coarse sand), vegetation cover, slope, precipitation intensity etc. The contribution of overland flow is mostly not very high, but significant, because dissolved inorganic phosphorus is immediately available for take up by algae and

able to cause eutrophication. Particulate phosphorus is a long-term source of phosphorus, when delivered to surface water (USDA/NRCS, 1997).

The total sum of emissions of nutrients to surface waters in a river basin is normally larger than the nutrient load at the outlet of the catchment. This is due to different retention and loss processes (I) taking place after input of nutrients into the river via different pathways. The nutrients also undergo different processes in the river system and in the sediment during transport. Retention is a collective name for a large number of biogeochemical and hydrological processes that temporarily decrease, decay, degrade, transform (like (de)nitrification), or permanently retard or remove the substance from a river basin. Nutrient retention capacity in a catchment is dependent from various chemical, physical and biological factors, *e.g.* trophic status, depth, water residence time and denitrification activity, etc. (Wassmann *et al.*, 2004). The remaining load from the sum of emissions at the outlet of a catchment is called the immision.

3.3 Basic model characteristics

The Moneris-approach is an empirical model, for large river basins (preferable > 500 km²). The model uses geographical information on catchment level, *e.g.* averages for land use, elevation soil etc. The model consists of Excel files linked with each other. There is no GIS integration, but with GIS, average values for a particular catchment can be analysed and the results have to be imported in the Excel sheets manually. Moneris is a steady-state model and does not have a dynamic capability, which means in this case a time-period of 5 years has been used to estimate 5-year average nutrient emissions

instead of a change over time by using daily data. The model does not make distinction between optional and obligatory data and does not contain default values.

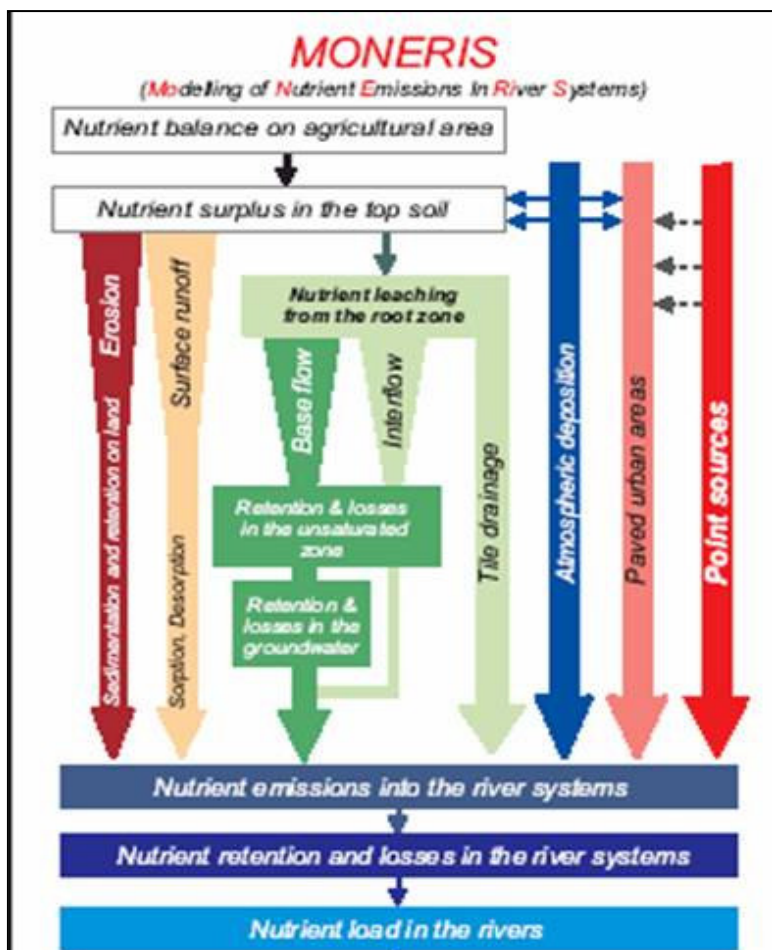


Figure 3-3 Scheme Moneris (Behrendt *et al.*, 2000)

The contribution of emission pathways of nutrients mentioned in the previous section are each separately estimated like in the original Moneris model. The structure of the model is nearly the same as the original Moneris model, except input via tile drainage and point sources, see figure 3-3.

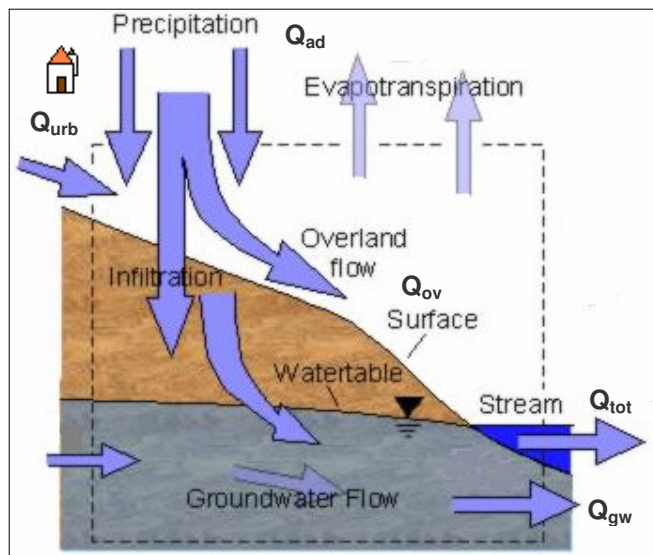
In the case of the Arda Basin, input via urban systems is a mix of diffuse pollution and point source pollution. The diffuse pollution comes from inhabitants not connected to sewerage, but instead for example a septic tank. The point source pollution comes from direct input of sewage effluent not treated by WWTP's.

The model is based on average measured runoff data (the measured river discharge m³/s), statistical data (i.e. inhabitants, nutrient surplus, and information about sewerage) and geographical data (like soil map, river system, DEM, erosion and atmospheric deposition). Data about water quality is used to

compare the modelled immision loads with measured (immision) loads. More about data requirements and used data for development of the operational model for the Arda River Basin, see chapter 5.

The base for the model is the water balance based on average measured total runoff (Q_{tot}) over a period of 5 years, according the following formula: $Q_{tot} = Q_{gw} + Q_{ov} + Q_{ad} + Q_{urb}$, see figure 3-4.

Figure 3-4 Water balance (after *Hermance, 2000*)



The ground water flow (Q_{gw}) is derived from the difference between the measured total runoff and the runoff from the other routes. The ground water flow includes base flow from deep ground water and interflow from the subsurface. The overland flow (Q_{ov}) is the runoff from non-paved areas. Water flow from direct atmospheric deposition to surface water minus evapotranspiration (Q_{ad}) is calculated on the base of precipitation and empirical equations. The runoff from paved urban areas is (Q_{urb}).

The next step is to estimate the surplus on agricultural areas, including long-term changes. The surplus is one of the

most sensitive variables (*Fogelberg, 2001*). This analysis cannot be carried out with the Moneris-approach, but the OECD model (*OECD, 1997*) is required. Before calculating the total loads, the retention and losses have to be determined in order to estimate the immision out of emission. In the Arda model, this is calculated on the base of the parameter the hydraulic load⁴ and further more according the default calculations of the model described in the report of Behrendt et al., 2000. The retention and losses are dependent on a correct surface water area calculation, since a higher surface water area, results in a higher retention and loss (e.g. in lakes). Thereafter, the modelled results for immisions can be compared with measured immision loads.

The original Moneris model is validated in other projects and from that was concluded that the model is also applicable for Austria (*Schilling, et al., 2003*), Sweden with a deviation of less than 30% (*Fogelberg, et al., 2001*) and the Danube region (*Schreiber et al., 2003*), including the Lesnovska River in Bulgaria (*Kosturkov, 2005*). The Moneris-approach for the Arda River Basin is not calibrated or validated. Comparison of measured immision loads with modelled immision loads can provide information about the reliability of the model for the Arda. In general, for small-scale catchment modelling of nutrient loads, a deviation of 30% is acceptable (*Behrendt et al., 2000*). It is mainly dependent on the data availability if a Moneris-approach is applicable for the Arda basin, but also specific conditions in the Arda basin influence the applicability of the model, like hydropower stations, big water reservoirs, extreme fluctuation in temperature and water level and mountain areas (< 2000 m). These specific conditions may not comply with initial formulae of this Moneris-approach. Therefore, to optimise the model, calibration might be required, however is out of consideration within this project.

The outcome of the operational Moneris-approach for the Arda River Basin is:

1. The average multi-annual (1994-1998) emission loads of phosphorus and nitrogen (in tones/annual) per net and total catchment (see next section), including the contribution of different sources and pathways;
2. The average multi-annual (1994-1998) immision loads (retention and losses) of phosphorus and DIN (dissolved inorganic nitrogen) per total catchment.

⁴ The hydraulic load is the specific runoff divided by surface area of surface water per catchment.

Once the model is operational (filled with data) it can be used to identify pathways that contribute significantly to nutrient loads in the river. Based on these results, useful suggestions of measures can be made and the model can be used to estimate the effect of measures to reduce nutrient loads by using scenarios.

3.4 Net and total catchments and specific and total runoff

The model calculates the emissions for the total catchment as well as each net catchment. A catchment is an area of land from which the total runoff from upstream rivers, flow through the mouth of the river at the outlet of the catchment (Zoete, 2005, *unpublicised*). The total catchment (*e.g.* the whole Arda Basin) can be divided into sub-catchments. In the case of the Arda Basin, the total basin is divided into 6 sub-catchments. Figure 3-5 and table 3-1 present the net and total catchments schematically including the measured net runoff (specific runoff) and the total runoff (m^3/s). In catchment 1, 3 and 5, no water from other areas are discharging and therefore the net catchment is equal to the total catchment. All water from the other sub-catchments gathers at the outlet of catchment 6, which is the total drainage area of the Arda Basin. The specific runoff is the net discharge of one catchment and forms the base for the calculations of net loads per catchment. Moneris presents results for each net catchment, as well as results for the total catchments.

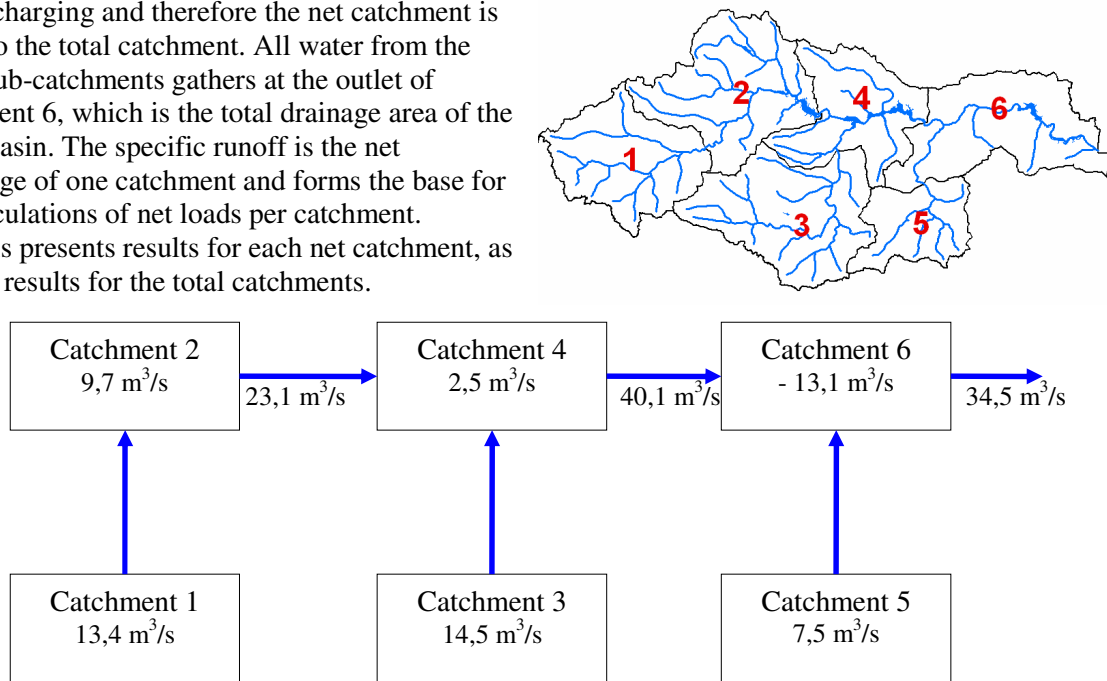


Figure 3-5 Schematic view of catchments pilling on top of each other

Table 3-1 Table 1 Specific and total runoff in relation to the net and total catchment

Net catchment	Specific runoff (m^3/s)	Total catchment	Total runoff (m^3/s)
Catchment 1	13,4	Catchment 1	13,4
Catchment 2	9,7	Catchment 1 + 2	23,1
Catchment 3	14,5	Catchment 3	14,5
Catchment 4	2,5	Catchment 1 + 2 + 3 + 4	40,1
Catchment 5	7,5	Catchment 5	7,5
Catchment 6	-13,1 ⁵	Catchment 1 + 2 + 3 + 4 + 5 + 6	34,5

⁵ The specific runoff is negative, which can be declared because of storage of water in the reservoir Ivaylovgrad for more than one year. Data is used for only 1997 and 1998 instead of a period of 5 years (see chapter 5.3 data availability).

4 Methodology

This chapter describes the followed methodology in order to fulfil the research objectives, mentioned in the introduction. The research method is represented in a schematic way, figure 4. In this chapter, each step is explained in further detail.

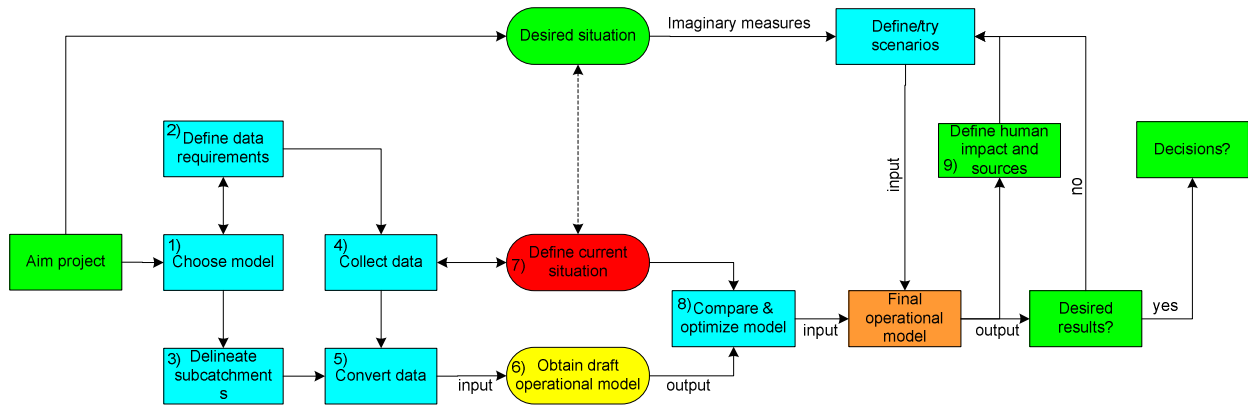


Figure 4-1 Schematic overview of methodology

4.1 Step 1 & 2 Choose the model and study area and define model requirements

It has been decided to use a Moneris-approach in order to calculate nutrient loads and the contribution of different emission sources and pathways, see section 3-1. The Bulgarian part of the Arda River Basin is the study area, since the overall project mentioned in chapter 1, is using the Arda as pilot basin.

The data requirements are defined on the base of literature research and the data input-file of the Moneris model. The choice of the model is also based on a first impression about the data requirements.

4.2 Step 3 Delineating Arda river basin in sub-catchments

The base of calculating nutrient loads, in a spatially related way, is dividing the river basin into different catchments and setting up a water balance based on the measured total runoff m^3/s for every catchment.

For this project the Arda River Basin is divided into 6 catchments (see appendix A), based on:

1. Available hydrological quantity data at the outlet of every catchment for a period of 5 year (in this case, quantity data was only available from 1994 to 1998, that is why this hydrological period has been chosen);
2. Elevation;
3. Main and secondary river system;
4. Available water quality data;
5. Preferable to have sub-catchments around or bigger than 500 km^2 (Behrendt *et al.*, 2000);
6. Integration of existing water bodies for WFD.

To set up the water balance, the measured discharge (the total runoff) is required for every outlet of a catchment. In the case of reservoirs, data is required about the inflow and outflow, to set up a correct water balance. For the first two dams Kardjali and Studen Kladinets (outlet catchment 2 and catchment 4), data was available for inflow and outflow over a period of 5 years. For the last dam Ivaylovgrad (at the outlet of catchment 6) this data was not available, but inflow data is used for 1997 and 1998. The

inflow and outflow over a period of 5 years (1994-1998) for the first two dams has been compared with each other and the difference was less than 5%, which means no significant amount of water is stored in the reservoir or transferred to another area. Further details about the division into six catchments, see appendix G.

4.3 Step 4 & 5 Data collection & data input

Data has been collected according the data requirements (step 2). To collect data, contact with different institutes and experts was necessary. When data was not available in the format that complies with the model requirements or when no data was available at all, assumptions or expert judgement has been used. It is important to write down exactly what data has been used; therefore this information is described in appendix G 'From data to input Moneris-approach Arda River Basin'.

In most cases, the data is not available in the required format or according to the quality standards of the model. After data collection, conversion of data is necessary. The Moneris-approach requires data on a catchment level, so GIS analyses are necessary to calculate average values per catchment.

4.4 Step 6, 7, & 8 Obtain and optimise the model

Step 6 Obtain draft model

When the data is suitable to use as input for the model, this model automatically calculates the emission and immision loads per catchment and the contribution of different point sources and diffuse pathways. The model is operational after complete input of the required data.

Step 7 Define the current situation

In order to define the reliability of the model, the deviation between the outcome of the model and the 'current' situation (1994-1998) is examined, so far possible with the current data availability. To calculate a 5-year average immision load of total-P and DIN⁶, monthly data for the concentration of DIN, total-P and the discharge, measured at the same day from monitoring stations at the outlet of every catchment, is required. The average annual load over a period of 5 years can be determined using formulae 1 and 2 (Kosturkov, 2005). The exact methodology for calculating loads in the Arda River Basin based on available data is described in appendix F.

$$L_y = \frac{\sum_{i=1}^n C_i Q_i}{n}$$

$$L_a = \frac{1}{p} \sum_{i=1}^p L_{y,i}$$

L_y (g/s) is the annual load;
 C_i (mg/l) is the concentration measured in sample i ;
 Q_i (m³/s) is the corresponding flow for sample i ;
 n is the number of samples taken in the year;
 L_a (g/s) is the average annual load over p years;
 p is the number of years

Formulae 1 and 2 Annual load and average annual load over a period of p years

Step 8 Optimise model

A model is an approach of reality and therefore it is important to compare modelled results with the current situation. The closer the results are to the reality, the more reliable the model is. The first step to optimise the model is to have insight in the most important variables that influence the results by using sensitivity analysis. Different methods were used:

1. Using the minimum and maximum range of a variable (when known) and calculate the difference and the maximal possible range;
2. Increase or decrease the variable with a certain value (or first with 100, than 200 etc.) and check the influence.

⁶ The model estimates the immision of total-P and DIN instead of total-N

These methods are used to define the most important data for the model and to give recommendations for additional data collection (see chapter 11).

After this, calibration and validation is important, although not part of this project. The last (optional) step is additional data collection. During this project, only the current available data is used and the existing Moneris-approach, see scope of the project, section 1.4.

4.5 Step 9 Evaluate the results of final operational model

After finishing the model, the results are evaluated and discussed. The first results are the emissions of different point sources and diffuse pathways and the total immisions per catchment. To have insight in the contribution of human impact of certain activities on the nutrient emissions, distinction is made between emissions via natural background, agricultural activities, urban areas and other diffuse sources of pollution (*i.e.* emission via atmosphere due to burning fossil fuels for traffic, domestic heating, industry etc.). The contribution of human impact and different sources is estimated on the base of scenarios. The following indentation describes the steps and assumption that are taken. For a detailed description including results is referred to appendix E.

1. The natural background condition

With the operation model, the natural background has been estimated by simulating a situation without pressures and impacts from human. Therefore, the following assumptions have been made:

- Nutrient inputs from point sources and urban areas are non-existent;
- Areas, which are agricultural or urban today, are considered as forest, because in the past mostly forested areas are converted into agricultural land (www.rodope.org);
- No input of nutrients via natural erosion⁷;
- There are no inhabitants and thus also no people connected to a sewerage;
- The deposition rate of nitrogen is assumed to be 1 kg/(ha.a) (*EPA, 2004*);
- The parameter for phosphor deposition is assumed to be 0,1 kg/(ha.a) (*Behrendt, et al., 2000*)

2. The contribution of agricultural activities has been estimated by the difference between the total emissions and the emissions from the simulation of a system without agricultural area. This simulation is based on the following assumptions:

- Areas, which are agricultural, are considered as forest;
- No information is available about the contribution of agricultural activities in the Arda Basin to the total atmospheric deposition. Therefore, the deposition of nutrients is remained the same.

3. The contribution of urban areas is initially estimated by the model.

4. The contribution of other diffuse sources is estimated on the base of the total emissions minus background emissions, minus agricultural emissions and minus emissions from urban areas.

The concentrations of DIN and total-P (mg/l) in surface waters are calculated on the base of the measured and modelled immision loads (t/a) and the measured discharges (m³/s). The concentrations are used define if there is a risk of failing the requirement of the WFD, by comparing the concentrations with the initial threshold for water quality, presented in table 6-7. This information can be used to define the order of importance to take measures to reduce nutrient emissions.

4.6 Step 10 From current situation to desired situation

Based on information about the biggest source contributing to nutrient loads in a particular catchment (step9), useful suggestions for measures can be given. Based on assumptions for measures, the model is used to predict the effect of measures on reduction of nutrient emission loads by use of scenarios.

⁷ This is to simplify the method, because in reality there is natural erosion, because the Arda River Basin is a mountainous area liable to erosion, but it is unknown where and how much as well as the N and P content of eroding soil not subjected to human pressures.

5 Data

This chapter describes the required data (section 5.1), the available data and the actual used data including assumptions for missing data (section 5.2). For a detailed description of the followed method to convert available data to input of the model is referred to appendix G. Research objective 1, obtaining an operational model for the Arda River Basin, is fulfilled after input of the data.

5.1 Required data and available data

Table 5-1 Required data for modelling nutrient loads with Moneris-approach and available data

Theme	Data requirements Moneris	Available data	Scale/resolution / amount	Source	Year
River	River network	Main river network scale 1:5000000 and the secondary river network scale 1:100000 Both data comes from MoEW.	1:5000000 1:100000	MoEW	2003
Quantity	Average monthly quantity data on the base of daily measurements for a period of 5 year.	1. Table with average monthly discharges (m ³ /s) from 1961-1998 on the base of daily measurements for different hydrological stations from IMH. The data is presented in litres, and based on an equation with an accuracy of 5% (based on velocity of water flow and depth). The equation per hydrological station should be checked when the cross section of the river has changed. If the formulae are checked regularly is unknown. 2. Table with average monthly inflow and outflow (m ³) for the 2 dams Kardjali and Studen Kladinets from the IWP. 3. Data about inflow (m ³) for the 3 dams from MoeW, from 1997-2000.	6 stations 2 stations 3 stations	IMH IWP MoEW	1961-1998 1983-1998 1997-2000
Elevation	Digital Elevation Model (DEM)	Available is a DEM raster for Bulgaria. In addition, a file is available with 13000 elevation points unequally scattered over the whole of Bulgaria.	50m*50m 13 000 points	Unknown MoEW	Unknown 2003
Catchments	Catchment boundaries (> 500 km ²)	These boundaries are produced on the base of other data.	6 catchments	-	2006
Administrative boundaries	Administrative boundaries from regions and municipalities.	Both available from ministry.	1:100000	MoEW	2003
Land use	Land use	CORINE Land Cover 2000 - Bulgaria, scale 1:100 000 is produces as part of the project I&CLC and made available by the ExEA.	1:100000	ExEA	2000
Hydrogeology	Information about (un)consolidated rocks and (im)permeability	Geology map was available and a scanned and geo-referenced hydrogeology map (scale 1:200 000) is available.	1:200000	Unknown	Unknown
Soil	Soil map and clay content	A soil map was available based on a different soil classification as used in Germany. Data for content of silt, sand and clay (in %) per Bulgarian soil type was made available by J. Kosturkov from the IWP.	Unknown	Unknown	Unknown

Nutrient Loads in the Arda River Basin

Erosion	Erosion map for soil loss due to water erosion.	1. European erosion map from PESERA project, European Commission - ISPRA; Institute for Environment and Sustainability. 2. Erosion map from ExEA is available, based on the USLE model.	1km*1km 50m*50m	ISPRA ExEA	2004 Unknown
Nutrient content top soil	Nutrient content of nitrogen (%) and phosphorus (mg/kg) in top soil.	Data for content of nutrients per soil type was made available by J. Kosturkov from the Institute of Water problems. This data is based on field research in 2004.	-	IWP	2004
Surplus	Data is needed about long-term changes in surplus of P and N on agricultural area and the yearly average surplus of P and N. In order to calculate this according the OECD method, extensive information on e.g. crops, fertilizers, manure and cattle's (age, sex, and specie) is required.	The real surplus analysis will not be carried out because of lack of data, time and knowledge. Data is available about applied artificial fertilizers on agricultural area (based on thresholds for fertilizer use), livestock, crops and manure, all on region level and calculations on the base of expertise.	Data was available on county level	EAS-RBD	Unknown
Precipitation	Yearly average long-term precipitation (at least 10 year). For a period of 5 year, average monthly data for precipitation per catchment. Average precipitation preferably calculated on the base of Krigging GIS interpolation method.	An analogue Bulgarian atlas contained a map about long-term precipitation from 1845-1945. Source: unknown. From literature research, a relationship between elevation and long-term precipitation in the Rodopi area for 1931-1985 was available (<i>Koleva et al., 1990</i>). Average monthly data for Kardjali and Krumovgrad for 1997 and 1998 was available from the IMH.	Unknown Unknown 2 stations	Unknown Koleva IMH	1845-1945 1990 1997, 1998
Evaporation	Average evaporation per catchment.	For the three dams, data is made available by J. Kosturkov from IWP.	3 stations	IWP	Unknown
Atmospheric deposition	Data about the deposition rate of oxidized and reduced nitrogen is needed.	On the EMEP Internet site from the DNMI, data is available for the deposition rate of oxidized and reduced nitrogen.	50km*50km	DNMI	1995, 2000
Urban areas	Total inhabitants per catchment. Connected inhabitants to sewerage per catchment. Data about combined and separated sewerage system and sewer length. Data about WWTP's.	Analogue data with the amount of inhabitants per settlement is used. Available from the EAS-RBD, by NIS, 2001. Letters from municipalities within the Arda basin were available with the percentage of connected inhabitants to sewerage. The date of these letters varied. Separate sewer systems don not exist in the Arda river basin as well as WWTP's.	Per settlement Municipality level	NIS EAS-RBD	2001 Different, (between 2000-2005)
Industry	Industrial discharges and the direct load of nitrogen and phosphorus discharged into the river system	Analogue data from 1998 was available but difficult to convert. Different tables were available with industrial discharges. 1 with 79 industries, including former industries; one with 13 significant industries (thresholds of Bulgaria are exceeded) and one table with 28 industries (2003). The GIS layer (2005) contained 52 points (representing location of industrial plants). Data is made available by regional inspectorates (RIEW).	Different	EAS-RBD & RIEW	1998, 2003, 2005
Quality	Monthly quality data (concentration of total phosphorus, DIN and discharge measured the same day) for 5 years to measure loads and compare the modelled loads.	Quality data was available from 1990 to 2005, but this data is full of gabs and inconsistency. For overview of available data from different monitoring stations, see appendix L.	Many stations, but frequency is varying	Regional laboratories (RL)	From 1990-2006

5.2 Base data input operational model for the Arda basin

Table 5-2 Description of used data

Theme	Description used data	Scale/resolution/frequency	Source	Year
River	The main and secondary river network are used for the catchment delineation.	1:5000000 1:100000	MoEW	2000
DEM and sub-catchments	The catchment delineation is based on data from hydrological stations, the main and secondary river network, the raster DEM (50m*50m) for the whole of Bulgaria and the water bodies for the WFD (by EAS-RBD).	6 sub-catchments	-	2006
Quantity	Data from different sources is used for the runoff per catchment for a hydrological period of 5 years. Data from 1994-1998 from the IMH is used for the outlet of catchment 1, 3 and 5. Data about inflow and outflow from the IWP for the dams Kardjali and Studen Kladinets is used for 1994-1998 for the outlet of catchment 2 and 4. For the inflow of the last dam at the outlet of catchment 6, data from the MoEW is used for the period of 1997-1998.	3 stations 2 stations 1 stations	IMH IWP MoEW	1961-1998 1983-1998 1997-2000
Land use	For information about land use, the CORINE Landcover map is used and according the method described in the Danube report (Schreiber, 2003) reclassified according Moneris requirements, see appendix I.	1:250000	ExEA	2000
Soil	The clay content is needed for the surplus estimation of phosphorus and since this analysis will not be carried out (see chapter 1.4), this data is not needed anymore. Data about the soil is not available in the required format of Moneris in order to assess the soil texture, and the soil texture cannot be derived from the soil types according the Bulgarian soil map. The difficulty in developing data on soil texture arises from differences in defining textural fractions between the Russian and FAO/ST method (IIASA & RAS, 2002). Therefore, on the base of previous field research about the content of sand, silt and clay per soil type (from Kosturkov, IWP), the texture has been defined using the USDA soil triangle. This texture types are reclassified according model requirements using a classification method found in literature (Brown, 2003). GIS analysis is used to define the average soil texture in km ² per catchment for agricultural area.	Unknown	Source soil map: unknown and content clay/silt/sand per soil type from IWP (by J. Kosturkov)	Unknown
Erosion	For data about water erosion, data from the ExEA is used. This data is probably more accurate than the European PESERA soil loss map. The PESERA also provided very low values for soil loss (<0,05 kg/ha/a) compared with the Bulgarian erosion map.	50m*50m	ExEA	Unknown, received in 2006
Surplus	A value for nitrogen surplus per catchment is derived by using data about the average applied fertilizers per ha per region in the Arda Basin for used agricultural area (based on thresholds for application of fertilizer). Assumed is that the average applied fertilizer per catchment is 30% of the total surplus. Normally, the P-content of the topsoil is estimated on the base on the P-surplus and the clay content. But the P-surplus was not available; instead of this, real measured values for the P-content of topsoil from arable land per soil type is used to estimate the average P-content per catchment in arable land (see appendix G). The N-content of the topsoil is calculated in the same way as the P-content of the topsoil.	Data about fertilizer use was available on county level Content topsoil per soil type	EAS-RBD IWP	2005 2004
Evaporation	For evaporation one value of 1000 mm for all catchments has been used, defined on the base of the average evaporation of data from the three catchments. The model showed some problems by using different values per catchment and therefore one value for all catchments is used.	3 stations	IWP	Unknown

Nutrient Loads in the Arda River Basin

Atmospheric deposition	For the contribution of atmospheric deposition, data about the deposition rates of oxidised and reduced nitrogen from 1995 and 2000 from the DNMI is used. Data for the specific period of 1994 to 1998 was not available and thus the average between 1995 and 2000 is used. The data from EMEP was available on Internet in text format.	50km*50km	DNMI	1995, 2000
Precipitation	Data about long-term precipitation was not available and therefore a relationship (from Bulgarian literature <i>Koleva et al., 1990</i>) between elevation and long-term precipitation (1931-1985) for the Rodopi mountain area has been used to calculate on the base of the DEM the average long-term precipitation per catchment. Data for two rain monitoring stations (one station located in catchment 3, Kardjali, and one in Krumovgrad, catchment 5) from the IMH are used. An assumption for precipitation is made for catchment 1 and 2, because this is mountain area and thus the precipitation is higher than in the other catchments. For the yearly average precipitation, a value of 900 mm is used, with an average summer precipitation of 300 mm and a winter average of 600 mm. Assumed is that the value for precipitation in catchment 1 = equal to catchment 2, precipitation in catchment 3 = equal to catchment 4 and precipitation in catchment 5 = equal to precipitation in catchment 6. This is due to a lack of data.	Unknown 2 stations	Koleva et al. IMH	1990 1997, 1998
Urban areas	The amount of inhabitants per catchment is based on analogue data for inhabitants per settlement in 2001. The percentage of connected inhabitants to sewerage per settlement is defined on the base of letters from municipalities (2000-2005). The amount of connected inhabitants is calculated based on this percentage and the amount of inhabitants per settlement in 2001 from the analogue map, even though the letters from municipalities presented a value for total inhabitants as well. In this case, most of the time deviation existed between the two sources. The analogue maps from 2001 are most reliable according local experts. The last years, the situation for percentage of people connected to sewerage has not changed significantly, according local experts.	Per settlement Municipality level	NIS EAS-RBD	2001 Different (between 2000 – 2005)
Industry	Different data for industrial discharges was available with a lot of inconsistency. Together with the local expert is decided which table to use and the reliability of the results are discusses with the expert. Analogue data for the period from of 1994 to 1998 was available but not easy to use, according the local expert. Therefore, data from 2003 is used, containing data about big and significant industrial discharges (28 points). Only a few industries discharge wastewater and some of them deliver a low contribution in discharging nitrogen and phosphorus to surface water. The total industrial discharge is less than 0,01 t/a and therefore negligible.	Data was available per significant or big industry	Regional inspectorates, collected by EAS-RBD	2003
Hydrogeology	Hydrogeology data is required with information about (un)consolidated rocks and (im)permeability. The available data was not suitable, because the Bulgarian classification of geology and geohydrology is based on an Old Russian method, based on other characteristics than the German (and Western European) method. Assumptions by expert judgement were required to gain information about average values for the percentage of four geohydrology types per catchment (see appendix K). According the expert: “ <i>Reclassifications is made using lithology of rocks (from geological map of Bulgaria (scale 1:100.000), hydrogeological map of Bulgaria (scale 1:200.000).</i> ”	Per catchment	Expert knowledge geohydrologist from EAS-RBD	2006
Quality	Quality data from monitoring stations is used for the years 1994-1998 and 2003-2005. The data is full with gabs and a lot of inconsistency exists. An overview of available quality data from all the monitoring station is attached in appendix L. This data is used to compare the modelled results with the current situation (from 1994-1998).	5 stations	Regional laboratories	From 1994-2005

6 Results

This chapter presents the measured and modelled loads. Section 6.1 to 6.3 contains the results of the measured and modelled immision loads in order to define the deviation and reliability of the model (research objective 2). Section 6.4 presents the modelled emissions and the contribution of different pathways. Section 6.5 presents the human impact and contribution of different sources to nutrient loads in term of the natural background, agricultural activities, urban areas and other diffuse sources. In order to know if the loads can cause problems to fulfil WFD requirement, the concentrations of nitrogen and phosphorus are outlined in section 6.6.

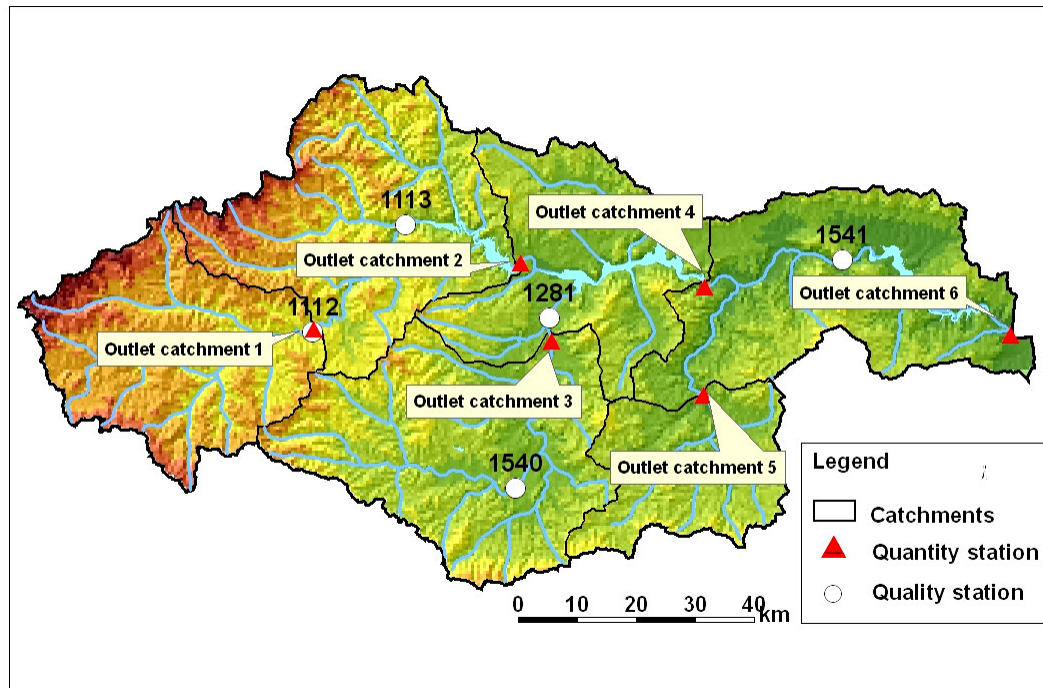


Figure 6-1 Overview catchments and monitoring points

6.1 Measured total immision loads

The immision loads of nitrogen and phosphorus are calculated for the monitoring stations presented in figure 6-1. The calculation is based on available data for quality and quantity data according the method described in section 4.4, step 7 and appendix F.

Table 6-1 Measured immision loads total-N and total-P for the year 1998 for the total catchments

Monitoring station	Total runoff ⁸	Total immision load DIN	Total immision load total-P
	(m ³ /s)	(t/a)	(t/a)
1112	3,7	116	48
1113	21,3	586	1160
1540	0,57	26	14
1281	6,02	260	153
1541	70,9	2328	3713

⁸ Not based on daily measurements, but a few irregular monthly discharges, see available data appendix L.

6.2 Modelled total emission and immision loads and retention

The immision is the remaining nutrient load from the emission after retention and loss processes, results see table 6-2. The modelled immision is based on the hydraulic load (see *Behrendt et al., 2000*). The immision load of DIN is modelled instead of the total-N immision and therefore the actual retention of total-N cannot be calculated. The runoff is also presented in this table, since the load is partly dependent on the runoff. The loads are multi-annual averages from 1994-1998.

Table 6-2 Modelled emission and immision loads DIN, total-N and total-P for total catchments

Total catchment	Total runoff	Modelled total-N emission	Modelled DIN immision	Modelled total-P emission	Modelled total-P immision	Retention & losses total-P
	(m ³ /s)	(t/a)	(t/a)	(t/a)	(t/a)	%
1	13,3	717	609	66	57	14
2	23,1	1389	1044	163	110	32
3	14,5	941	768	110	89	19
4	40,1	2789	2148	359	257	28
5	7,5	410	345	46	40	13
6	34,4	3909	3009	449	322	28

6.3 Total modelled and measured immisions per catchment

This section presents the total measured and modelled immisions. Only in catchment 1, the monitoring station is located at the outlet of the catchment (see figure 6-1) and therefore, this is the only catchment where the loads can be compared with each other. Reading this section, it should be taken into account that the measured loads are based on an incomplete data set (see section 9.1.1), thus it is not possible to define the deviation of the model (research objective 2). The loads are presented to have an idea about the values. The results and difference are explained per catchment in chapter 7.

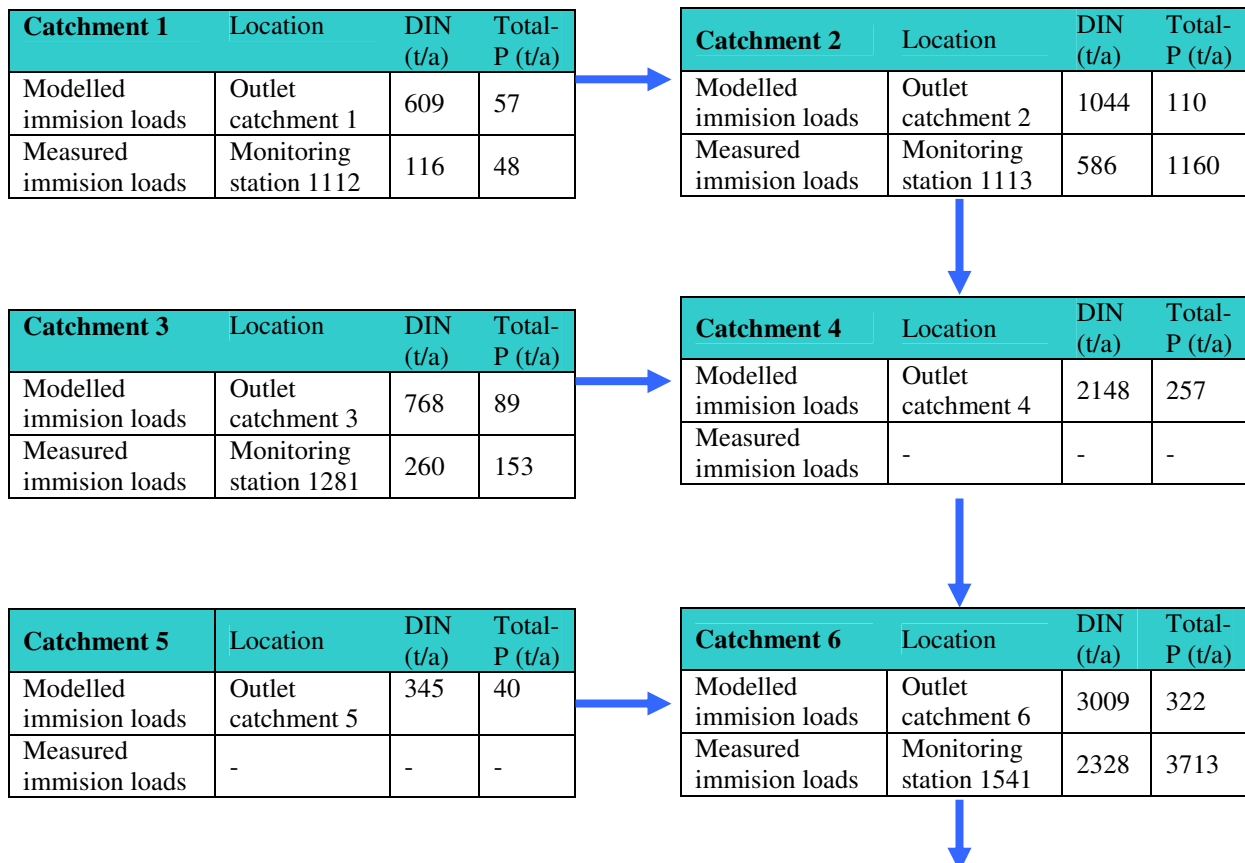


Figure 6-2 Overview of increasing immision load from catchment 1 to catchment 6

6.4 Modelled net emission loads and contribution of different pathways

Table 6-3 and 6-4 present the modelled emission loads per net catchment for total-N and total-P and the contribution of different pathways to the nutrient loads (research objective 3). The nutrient load is influenced by the runoff, so the specific runoff of every catchment is presented in tables as well. The loads are average multi-annual values over a period of 5 years (1994-1998). Table 6-5 presents the specific emission load of total-N and total-P. This is the load emitted per km², because in a bigger catchment is the total runoff mostly higher, thus it is interesting to know the load per km². The specific emissions per catchment of respectively nitrogen and phosphorus are spatially presented in appendix C and D.

Table 6-3 Modelled net emission loads total-N including contribution different pathways

Catchment	Specific runoff	Atmospheric deposition		Overland flow		Erosion		Ground-water		Urban systems		Net total-N Emission	
	(m ³ /s)	(t/a)	(%)	(t/a)	(%)	(t/a)	(%)	(t/a)	(%)	(t/a)	(%)	(t/a)	(%)
1	13,3	3	0	15	2	15	2	537	75	147	21	717	100
2	9,7	17	3	11	2	33	5	577	85	33	5	671	100
3	14,5	5	1	13	1	42	4	778	83	104	11	942	100
4	2,5	21	5	0	0	45	10	218	47	175	38	459	100
5	7,5	2	0	1	0	21	5	353	87	33	8	410	100
6	-13,1	17	2	0	0	29	4	646	91	18	3	710	100
Total Arda	34,4	65	2	40	1	185	5	3109	79	510	13	3909	100

Table 6-4 Modelled net emission loads total-P including contribution different pathways

Catchment	Specific runoff	Atmospheric deposition		Overland flow		Erosion		Ground-water		Urban systems		Net total-P Emission	
	(m ³ /s)	(t/a)	(%)	(t/a)	(%)	(t/a)	(%)	(t/a)	(%)	(t/a)	(%)	(t/a)	(%)
1	13,3	0	0	2	3	39	60	5	8	20	29	66	100
2	9,7	1	1	3	3	85	88	4	4	4	4	97	100
3	14,5	0	0	3	3	86	78	7	6	14	13	110	100
4	2,5	1	1	0	0	60	70	2	2	23	27	86	100
5	7,5	0	0	0	0	38	82	4	9	4	9	46	100
6	-13,1	1	2	0	0	37	84	4	9	2	5	44	100
Total Arda	34,4	3	1	8	2	345	77	26	6	67	15	449	100

Table 6-5 Specific emission load TN and TP

Catchment	Total-N	Total-P
	[kg/(km ² .a)]	[kg/(km ² .a)]
1	833	77
2	641	93
3	884	103
4	596	111
5	847	96
6	713	45
Total Arda	748	86

6.5 Human impact and contribution of different sources to nutrient emissions

In order to suggest effective measures to reduce nutrient loads (objective 4) it is important to know which human activities contribute to the emissions via the pathways mentioned in the section above. The following sources are determined according the method described in section 4.5 and appendix E:

1. The natural background condition;
2. The contribution of agricultural activities to nutrient loads;
3. The contribution of urban areas;
4. The remaining loads: due to other diffuse sources.

The results of the contribution of these different sources are presented in table 6-6. Appendix C and D contain maps with the contribution of every source to respectively nitrogen and phosphorus emissions per catchment and in relation to the specific nutrient load per catchment [t/(km².a)].

Table 6-6 Contribution of different sources to emission N and P

Contribution different sources	Total-N		Total-P	
	(t/a)	(%)	(t/a)	(%)
Urban areas	520,3	13,3	68,7	15,3
Other diffuse sources	1660,3	42,5	2,9	0,6
Agricultural activities	843,3	21,6	357,5	79,7
Background emissions	880,9	22,6	19,8	4,4
Total emissions	3904,8	100,0	448,9	100,0

6.6 Concentrations of total-P and DIN

In order to check the water quality on presence of nutrients in the river, a map is prepared (figure 6-3) with the measured concentrations of total-P and DIN at different locations in the Arda River Basin (white boxes). The concentrations calculated on the base of modelled loads and contributory average discharges are presented in this map as well (red boxes). The total-P concentrations are based on empirical equations, since total-P was not measured before 2003, see available data appendix L. The concentrations of nutrients are compared with Bulgarian initial norms for a good water quality status in order to fulfil the WFD requirements, see table 6-7. This information can be used to suggest useful measures.

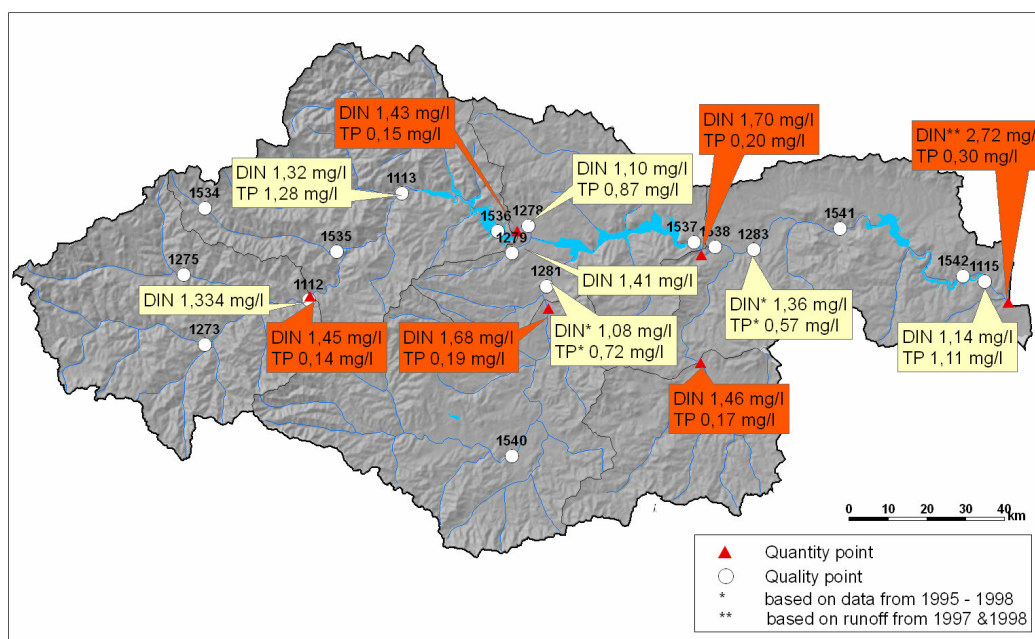


Figure 6-3 Measured and modelled concentrations of total-P and DIN

6.6.1 Measured concentrations

DIN

The concentrations of DIN do not exceed the norm for a good quality status (2,36 mg/l), see table 6-7. There is an increase of DIN concentration between the outlet of catchment 2 and 4 (from 1,10 mg/l to 1,36 mg/l). From a monitoring point (1283) situated after inflow of water from catchment 5, to the outlet of catchment 6 shows an decrease of concentration down streams the Arda River (from 1,36 to 1,14 mg/l). However, the monitoring points are located at a large distance from each other (>30 km) and therefore it is difficult to predict at what location the concentration is increasing or decreasing.

Total-P

The measured loads for total-P are exceeding the norms (0,2 mg/l) for a good water quality status according table 6-7. The average measured loads of total-P over a period of 4 or 5 years from 1994-1998, vary from 0,57 to 1,11. In addition, the PO₄-P concentrations are compared with the norms and from that can be concluded that also PO₄-P concentrations are exceeding the norms at all monitoring stations.

6.6.2 Concentration based on modelled loads

DIN

The concentrations based on modelled loads exceed the norms for a good quality at the end of catchment 6 (2,72). There is an increase in concentration of DIN between the outlet of catchment 2 and 4 (1,43 to 1,70). The concentration of DIN in surface water flowing from the outlet of catchment 5 into catchment 6, has a lower concentration than water flowing from the outlet of catchment 4 into 6.

Total-P

The concentration of total-P based on modelled loads vary from 0.14 to 0,30. At the outlet of catchment 6, the concentration (0,3 mg/l) is exceeding the norm of 0,2 mg/l. The concentration of total-P is increasing from 0,15 at the outlet of catchment 2, to 0,20 mg/l at the outlet of catchment 4. From catchment 4, the concentration of total-P is increasing from 0,20 to 0,3 at the outlet of catchment 6, even though inflow of water from catchment 5 has a lower concentration of 0,17 mg/l.

Table 6-7 Bulgarian national water quality classification for the IMPRESS review (RBO, 2005)

CLASS LIMIT VALUES	DETERMINANTS IN WATER					
		Reference CLASS-high	TV-good	2 x TV	5 x TV	> 5 x TV
	unit	I	II	III	IV	V
NH ₄ ammonium - N	mg/l	0.05	0.3	0.6	1.5	>1,5
NO ₂ nitrite - N	mg/l	0.01	0.06	0.12	0.3	>0,3
NO ₃ nitrate - N	mg/l	0.8	2	4	10	>10
DIN*	mg/l	0.86	2.36	4.72	11.8	>11.8
Total-N*	mg/l	1.5	4	8	20	>20
PO ₄ ortho - P	mg/l	0.05	0.1	0.2	0.5	>0,5
Total-P	mg/l	0.1	0.2	0.4	1	>1

* A limit for DIN and total-N does not exist in the Bulgarian water quality classification for the IMPRESS review. Limit for DIN is based on the sum of limits for ammonium, nitrite and nitrate. The limit for total-N is according to the water quality classification published in the ICPDR report "Water quality in the Danube River basin-TNMN yearbook 2001".

This table contains thresholds for chemical substances (in this case only N and P are presented in this table) from which is assumed that under the condition of concentrations below TV-good II, no ecological risk exists to fail WFD requirements (RBO, 2005).

7 Evaluation and discussion results

In order to use the model to define effective measures, the meaning and value of the results will be explained in this chapter. The results will be evaluated per catchment for the following aspects:

- The measured immision load based on available data (see appendix F) will be evaluated and compared with modelled immision loads of DIN and total-P;
- The sources and pathways contributing to N and P emissions per catchment;

For an overview of concentrations of DIN and total-P in the Arda Basin is referred to figure 6-3.

Appendix C and D contain geographic maps with the contribution of different sources to the emissions of N and P per catchment and the specific emission load per catchment. The discussion and evaluation of the results for the total Arda River Basin is described in chapter 9.2.

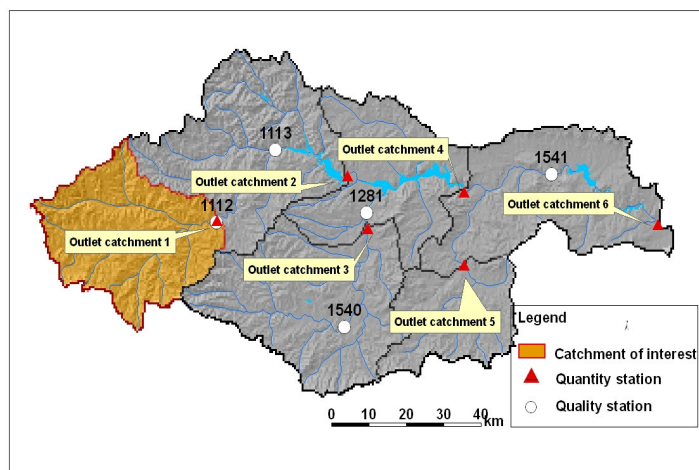
7.1 Catchment 1 Arda river at Vechtino

Catchment 1 is the best catchment to compare measured loads with modelled loads, because no other rivers discharge water in this catchment and for point 1112 some data is available for concentrations of DIN and PO₄-P as well as the discharge. However, the measured loads are based on only 3 summer months in 1998: July, August and September. The load is dependent on the season, because the concentration and discharge are also dependent on the season.

Different aspects cause seasonal variation in nutrient loads, for example:

- Seasonal fertilizer application;
- Seasonal flow variation influencing the total runoff and the stream velocity. Nutrients in the environment are mostly transported by move of water and therefore high rainfalls and high runoff cause higher input of nutrients from diffuse pathways (e.g. (top) soil, groundwater, atmosphere, erosion etc.) to surface water (Hoos, *et al.*, 2005). In addition, a higher discharge is causing a higher load (m³/s)⁹.
- The temperature is effecting the processes of nitrification, volatilization and secondary eutrofication;
- During summer, the concentration of bioavailable nutrients may decrease (Hoos, *et al.*, 2005) caused by growth of aquatic plants, especially in lakes and reservoirs with a long residence time of water and a low stream velocity and less turbulence;
- In addition, the location in the river where is measured, is also influencing the measured concentration.

Using only summer data is probably causing an underestimation of the average load in 1998. The average discharge over these 3 months in 1998 was 3,8 m³/s while the average discharge at the outlet of catchment 1 over a period of 5 years is 13,4 m³/s.



Catchment 1	Location	DIN (t/a)	Total-P (t/a)
Modelled immision loads	Outlet catchment 1	609	57
Measured immision loads	Monitoring station 1112	116	48

⁹ which does not mean a higher concentration, because this is dependent on the current concentration in surface water and the concentration of inflowing water

The measured immision load for DIN is lower than the modelled immision load, but shall probably be higher when discharge data for the whole year was available. The total-P load for both measured and modelled are very close, but it is possible that the measured P load has been underestimated using only summer discharges and concentrations.

According the model, the main pathway that contributes to emission of nitrogen to surface water, is via ground water (75%) and for phosphorus via erosion (60%). The source emitting nitrogen is for 21% due to urban systems; the rest is due to the natural background (25%) and other diffuse sources (at least 54%).

7.2 Catchment 2 Arda river at dam Kardjali

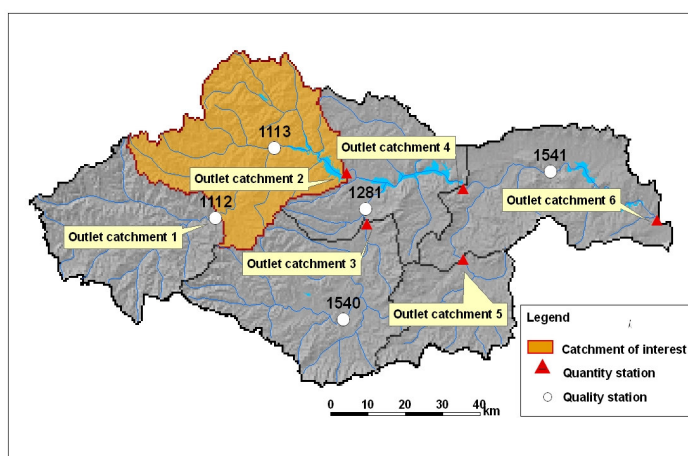
The measured loads are based on quality data at monitoring station 1113. If there was a monitoring station with enough data to calculate loads at the outlet of catchment two, probably (also dependent on concentration) the load would have been higher, because there is inflow of another river after monitoring point 1113.

The difference in measured and modelled load of DIN is already less than 50%. If the load was measured at the outlet of catchment 2 and if the load was higher, the deviation with the model would have been smaller.

The measured load of phosphorus is quite high, almost double as high as the DIN load. Different reasons are possible, like an unreliable measured P-concentration, or an unreliable discharge or an unpredictable P-input. These reasons are described and explained in the following points:

1. The total-P concentration is calculated on the base the PO₄-P concentration and an empirical equation, (see appendix F), this can cause an overestimation of the total-P concentration.
2. Secondly, the measured discharge is a random indication and was in some months very high, what is causing a high measured load. The average measured discharged was in some cases much higher than the discharge based on daily measurements.
3. The third reason can be an unknown phosphorus input, causing a very high P-load, which is not taken into account in the model.

According the model, the main pathway that contributes to emission of nitrogen to surface water, is via groundwater (85%) and for phosphorus via erosion (88%). The source emitting nitrogen is only for 22% due to agricultural activities and urban systems; the rest is due to the natural background (26%) and other diffuse sources (at least 52%).

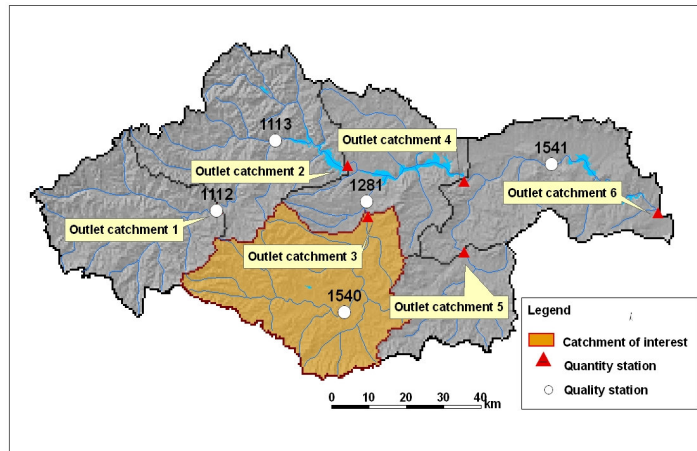


Catchment 2	Location	DIN (t/a)	Total-P (t/a)
Modelled immision loads	Outlet catchment 2	1044	110
Measured immision loads	Monitoring station 1113	586	1160

7.3 Catchment 3 Varbitsa River at Djebel

Monitoring station 1281 is most representative for catchment 3 and is located in catchment 4, after inflow of another river. The measured loads will be used to have an idea about the order of magnitude of loads in this region.

The measured load in 1540 is based on 6 measurements in 6 months in 1998, with an average discharge of 0,57 m³/s. The measured load in 1281 is based on 5 months, with an average discharge of 6,0 m³/s. The average discharge at the outlet of catchment 3 is 14,5 m³/s. The load at point 1281 should be higher or around the load at the outlet of catchment 3. This is not the case, because the modelled load is almost 3 times higher. This might be due to an underestimation of the discharge (causing an underestimated measured load) or because of an overestimation of the DIN load by the model.



Catchment 3	Location	DIN (t/a)	Total-P (t/a)
Modelled immision loads	Outlet catchment 3	768	89
Measured immision loads	Monitoring station 1281	260	153

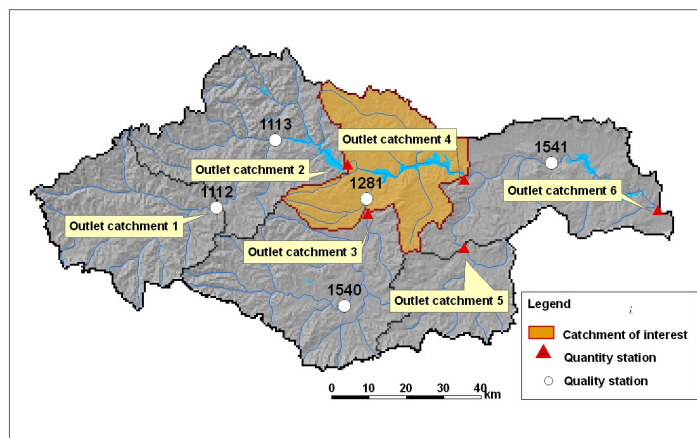
According the model, the main pathway that contributes to emission of nitrogen to surface water, is via groundwater (83%) and for phosphorus via erosion (78%). The source emitting nitrogen is for 20% due to agricultural activities and for 11% to urban systems; the rest is due to the natural background (24%) and other diffuse sources (at least 45%).

7.4 Catchment 4 Arda River at dam Studen Kladinets

In catchment 4, no representative monitoring point is located in order to compare the modelled loads with the measured loads.

According the model, the main pathways that contribute to emission of nitrogen to surface water, is via groundwater (47%) and via urban systems (38%) and for phosphorus via erosion (70%).

The source emitting nitrogen is for 39% due to urban systems, 21% by agricultural activities and the rest is due to the natural background (14%) and other diffuse sources (26%). The contribution of urban systems is quite high, probably because the biggest city Kardjali is located in this catchment. This city which is counting about 50 000 inhabitants (NIS, 2001), contains sewerage but not yet a WWTP.



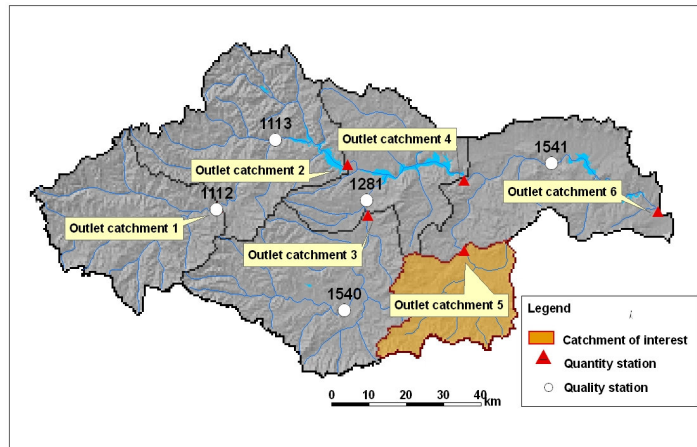
Catchment 4	Location	DIN (t/a)	Total-P (t/a)
Modelled immision loads	Outlet catchment 4	2148	257
Measured immision loads	-	-	-

7.5 Catchment 5 Krumovitsa River at Krumovgrad

No monitoring stations are located in or around catchment 5. Therefore, no comparison can be made with the measured loads.

According the model, the main pathway that contributes to emission of nitrogen to surface water, is via groundwater (87%) and for phosphorus via erosion (82%).

The source emitting nitrogen is for 29% due to agricultural activities, only 8% by urban systems and the rest is due to the natural background (24%) and other diffuse sources (39%).

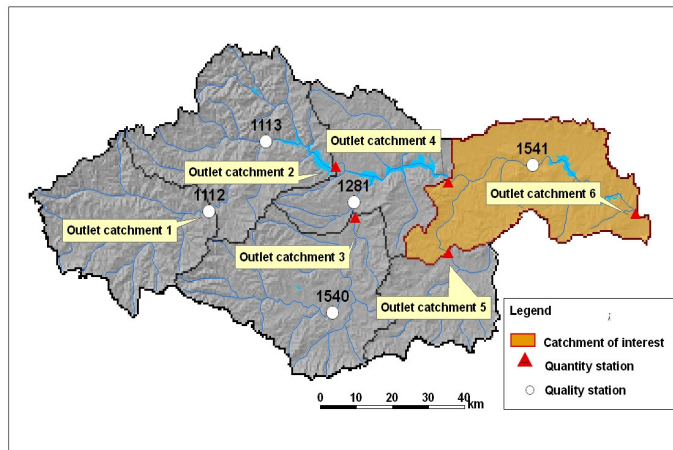


Catchment 5	Location	DIN (t/a)	Total-P (t/a)
Modelled immision loads	Outlet catchment 5	345	40
Measured immision loads	-	-	-

7.6 Catchment 6 Arda River at the border of Arda RBD

In the last catchment is situated the last big dam and reservoir 'Ivaylovgrad'. The modelled immision and emission load is based on quantity data for 2 years: 1997 and 1998. The model needs 5- year averages. Therefore, it is difficult to judge the results; however, it can be used to have an idea about the total load.

The measured load at monitoring station 1541 is most representative for catchment 6. After 1541, two relatively small tributaries are discharging in the Arda River, therefore the load shall probably be higher at the outlet of catchment 6 (if there is not a bigger retention and loss). The deviation between modelled and measured DIN load is 23% and will be lower if the measured load at the outlet of catchment 6 is higher. The measured total-P loads are extremely high, due to a high concentration and discharge (see appendix F). This high P-load is probably not realistic, because this load is compared with the initial IMPRESS analysis higher than the estimated total P-emission for the whole EAS-RBD (see appendix J).



Catchment 6	Location	DIN (t/a)	Total-P (t/a)
Modelled immision loads	Outlet catchment 6	3009	322
Measured immision loads	Monitoring station 1541	2328	3713

According the model, the main pathway that contributes to emission of nitrogen to surface water, is via groundwater (91%) and for phosphorus via erosion (84%). The source emitting nitrogen is for 47% due to agricultural activities, only 3% by urban systems and the rest is due to the natural background (20%) and other diffuse sources (31%). In catchment 6, there is relatively the most pasture, which might cause higher contribution of agricultural activities.

8 Scenarios

In order to reach the objectives of the WFD, it is important to prevent too high amounts of nutrients in surface waters, because this might risk failing the requisite of a good ecological status of water bodies. Based on the desired and ‘current’ status (in 1994-1998) and the analysis of the human impact on nutrient loads, useful and logical measures can be proposed. With the Moneris-approach model for the Arda River Basin, the effect of measures can be predicted. In this chapter is described how to define useful measures, by illustration of a few examples (research objective 4).

8.1 *Different types of measures*

There are different possibilities to reduce nutrient inputs. Distinction can be made between source management and transport management of nutrients. First, it is possible to prevent input of nutrients by focussing on the pathways that contribute to nutrient emissions. For example, when the nutrient input via erosion is very high, it is possible to prevent erosion by planting trees. However, a big nutrient input is reaching surface water via groundwater. How do you prevent input via groundwater? The best answer is to reduce the source of nutrient input itself.

In the previous chapter, distinction is made between nutrient emissions via the natural background, agricultural activities, urban areas, and other diffuse sources. Assumed is that the natural background cannot be influenced. The input caused by diffuse sources like atmospheric deposition via traffic, domestic heating of non-agricultural areas and industries (“other diffuse sources”) are difficult to reduce and to influence on Arda Basin scale, because this is dependent on world-scale conditions. In the case of preventing input via ground water, it should be mentioned that from the background calculation it became clear that a lower atmospheric deposition of nutrients has a huge impact on reduction of nutrient input via ground water. However, since it is difficult to influence the atmospheric deposition of nutrients and secondly once nutrients have reached the ground water via leaching, the (very slow) flow of nutrients can deliver nutrients for many years after the original time of nutrient input, and therefore it is not very effective on a short time period to start with reducing the atmospheric deposition.

Consequently, the best idea is to focus on reduction of emissions via agricultural activities or/and urban areas. By reducing agricultural activities, it should be taken into account that a further reduction of the nitrogen surplus in countries with a surplus below 25 kg/(ha.a) is not realistic (*Behrendt et al, 2004*), because a low surplus mostly exists in developing countries that have to establish a stable economic situation with enough food supply and therefore there is no money to use expensive fertilizers or other measures in order to reduce the surplus of nitrogen.

Considering the concentrations of nitrogen and phosphorus, for both measured and modelled results, it can be concluded that nitrogen is probably not a direct risk to fail requisites of the WFD, opposite to the high phosphorus concentrations. Therefore, the effects of two scenarios to reduce P-loads are estimated as well as one scenario to reduce both nitrogen and phosphorus loads via measures to reduce the contribution of the sources urban areas and agricultural activities.

8.2 *Proposal for measures and prediction of the effect by use of scenarios*

Because of the reasons mentioned in the previous section, the focus on measures mainly emphasizes measures to reduce phosphorus emissions. Three scenarios will be highlighted:

1. The first measure is aimed to reduce emissions of both nitrogen and phosphorus from urban areas, by placement of a WWTP near Kardjali, located in catchment 4 (source management);
2. The second measure is aimed to reduce total-P emissions from agricultural areas, by manipulating the P-content of the topsoil (source management);
3. The last measure is aimed to reduce mainly p-emissions, by preventing erosion from agricultural areas (transport management).

8.2.1 Scenario 1) Effect of placing a WWTP in Kardjali

In catchment 4 (770 km²) is the main city Kardjali located and according the results from chapter 6.4, table 6-3 and 6-4, the contribution of urban systems in this catchment to nitrogen emissions is 38% and to phosphorus emissions 27%. From the nearly 42.000 inhabitant of Kardjali, about 90% is connected to sewerage (source: information from municipalities and the NIS), but not connected to a purification system, which means all the effluent from the sewerage system, containing high amounts of dissolved nutrients, is discharging directly into surface water or (dry) gullies. Therefore, it is interesting to estimate the effect of placement of a WWTP in Kardjali. Assumptions are made on the base of a comparable Danube catchment¹⁰.

- Not all inhabitant connected to a sewerage are connected to a WWTP (but about 95%) and therefore is assumed that from the 41.000 inhabitants, 40.000 are connected to a sewerage and WWTP;
- The WWTP is discharging 10.000 kg P/annual and 50.000 kg N/annual (values around the same order as for the Danube catchment)

The results are presented in figure 8-1. The nitrogen load will decrease with 26% (figure A) and the phosphorus load will decrease with 7% (figure B) both through a decrease from urban areas.

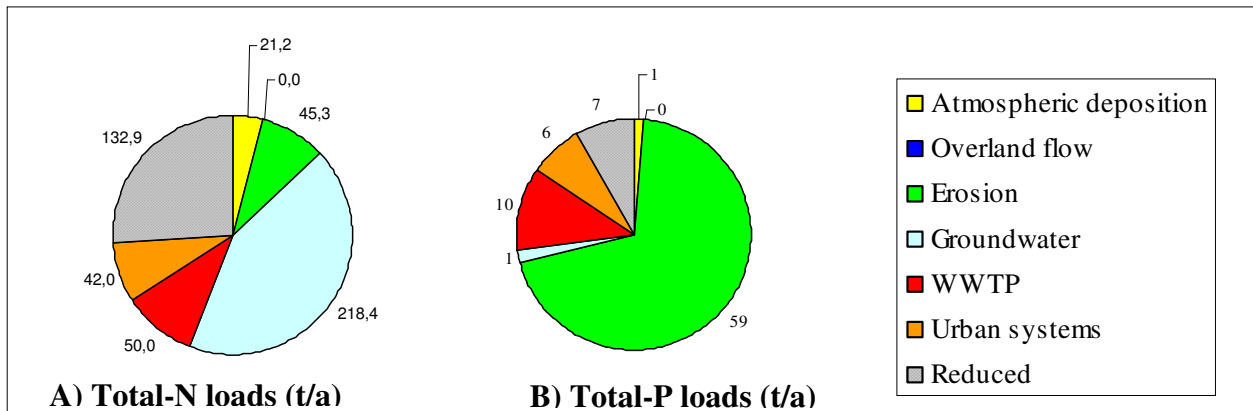


Figure 8-1 Reduction of total-N (A) and total-P (B) in t/a due to placement of a WWTP in catchment 4

8.2.2 Scenario 2) Reduction of P-content in the topsoil

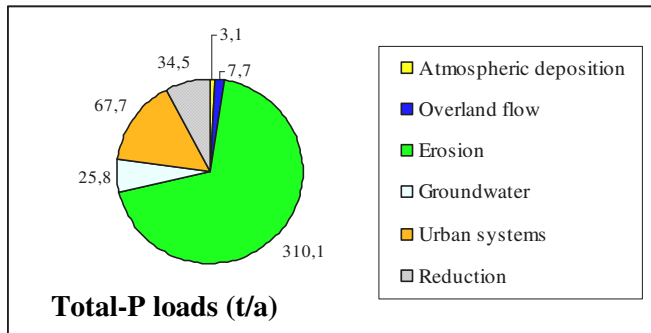
While it may not be able to reduce the intensity of agricultural activities in view of social-economic reasons, it is possible to reduce input of phosphorus to the soil, by better management of phosphorus input via manure use by example, because manure contains high amounts of phosphorus in relation to nitrogen, which is causing a high amount of remaining phosphorus (not taken up by crops). Rise of P-content in the topsoil increases potential leaching of P to groundwater¹¹ or P-transport via erosion or overland flow and do not provide agronomic benefits. Therefore, it is important to manage input of P via different sources. Several measures can be taken, (mainly based on fact sheet *Zhang et al, 2004*):

- Manipulating feed of livestock by specific enzyme additives, which increase the ability of the cattle to take up phosphor from plants. This results in lower needs for mineral phosphor addition and eventually a lower contribution of P to the topsoil by reducing input of P to topsoil.
- Specific manure application, by deciding where, when (which time of the year) and how much manure to apply, and taking into account the type of crop and specific land characteristics;
- Extracting P from the topsoil via exhaustive cropping with grass (with e.g. *Lolium perenne*) (*Werner et al, 2006*) with as a result a decrease in P-content of the topsoil.

¹⁰ German catchment (804 km²) located around Ilz River, part of the Danube basin. Connected inhabitants to sewerage: 58361; connected inhabitants to sewerage and WWTP: 57474; discharge total-P from WWTP (kg/a): 11080; discharge total-N from WWTP (kg/a): 56125 (source: *Behrendt et al., operational Danube model, 2005*)

¹¹ A higher P-content may cause a higher amount of dissolved P after saturation of the soil, because the bound capacity to soil particles decreases when the amount of phosphorus in the soil increases.

For assessment of the effect of managing phosphorus input and stimulating P-extraction from the topsoil, assumed is a scenario with a reduction of 10% from the P-content of the topsoil in the whole Arda Basin, because the P-content of the top soil seems quite high. The effect is a reduction of 8% from the total phosphorus emission loads in the whole Arda Basin, due to lower input via erosion, see figure 8-2.



The average P-content of the topsoil in the Arda River Basin is 1050 mg/kg (on the base of calculation, see appendix G) which is high compared with the average German values of 750 mg/kg (source: *operational German Moneris model, 2000*).

Figure 8-2 Influence of reduction P-content in topsoil with 10% on total-P loads (t/a) in Arda basin

8.2.3 Scenario 3) Reduction of erosion

The main pathway contributing to total-P emissions is erosion. Therefore, the last scenario is concentrating on preventing transport of total-P via erosion. This is closely interacted with prevention of surface runoff, since runoff takes away soil. Different measures can be taken to prevent erosion and surface runoff. In order to prevent decrease in agricultural activities, the land use of existing agricultural land cannot be changed into forest. Other measures to reduce erosion are:

- Preventing too intensive surface runoff (causing additional erosion) by increasing water infiltration capabilities by maintaining crop residues on runoff-sensitive areas (*Zhang et al, 2004*);
- Maintaining vegetated buffer strips between agricultural land and surface water. The size of the buffer strip depends on intensity of agricultural activities. Buffer strips prevent input of agricultural soil containing high amounts of P to surface water and vegetation cover prevents erosion;
- Eventually manure should not be applied on steep slopes (>15%) and landscape alterations can slow down runoff, increase water infiltration and prevent erosion of soils (*Morse et al, 2003*).

To estimate the effect of reducing erosion on nutrient emissions, a scenario of erosion control with a reduction of 50% of soil loss in the total Arda Basin is used. This scenario results in a reduction of 24% of the P-emissions and 1% of the nitrogen emissions, see figure 8-3.

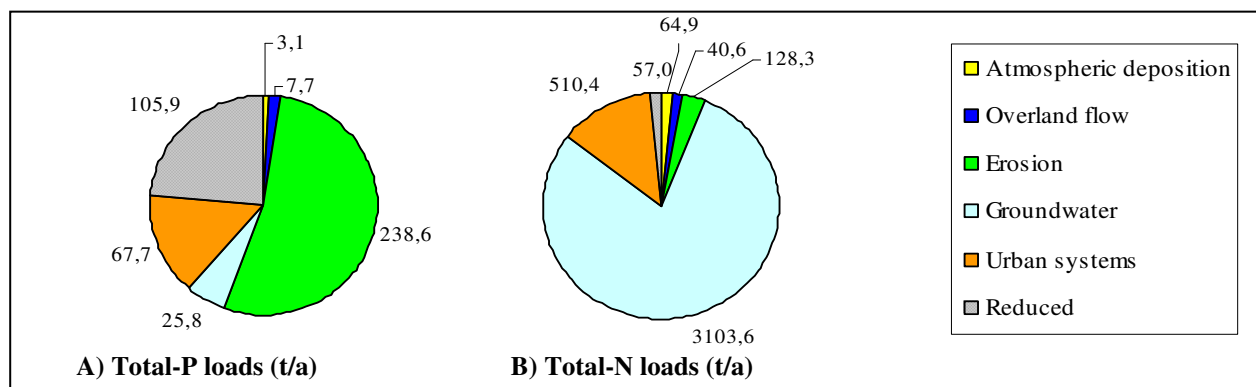


Figure 8-3 Influence reduction of erosion by 50% on nutrient emission in t/a (A) Total phosphorus emissions t/a (B) Total nitrogen emissions t/a

8.2.4 Comparison of different measures

The first measure, placement of a WWTP in Kardjali seems useful in order to reduce both nitrogen and phosphorus emissions. But a WWTP is expensive and therefore further investigation to this possibility is required.

According the calculations of the P-content in the Arda River Basin, the average P-content is 1050 mg/kg, which is quite high. A reduction of 10% shows already a reduction of 8% to the P-load in the Arda River Basin. It should be further investigated if the data used for the P-content is realistic (for example on the base of literature research, P-surplus calculations or soil samples) and if it is possible to reduce (and to what extent) the P-content or prevent input of phosphorus via better management of farming, and manure and fertilizer use. The way of farming and the use of manure and fertilizers should be adapted to the local situation in terms of crop type, soil characteristics, ground water table, slope etc. This measure is sustainable for the environment and the social-economic situation. For example, a more precise fertilizer application may have economical benefits as well as environmental advantages.

The last measure, an erosion control of 50% in the whole Arda Basin is an intensive measure and it is unknown if this is realistic. Erosion control is a transport measure preventing input of soils containing high amounts of phosphorus, but the most sustainable option is to reduce the source itself, in this case the high P-content. However, especially erosion of agricultural soils, deliver a high contribution of phosphorus input to river systems and can be easily reduced by use of buffer strips between agricultural areas and surface water. It should be further investigated if erosion control is possible by better land use management and to what extent.

In figure 8-4, the measures are plot in graph together, in order to see the relative effect of different measures. However, it has to be taken into account that the intensity or realism of the measures can be different and therefore not comparable. The effect of placement of a WWTP (figure 8-4) is the effect on reduction of the nitrogen and phosphorus load in catchment 4. To compare this measure with other measures, assumed is that this effect on the reduction of nitrogen and phosphorus is equal for the whole Arda Basin when all sewerages are connected to a WWTP, but this should be further investigated.

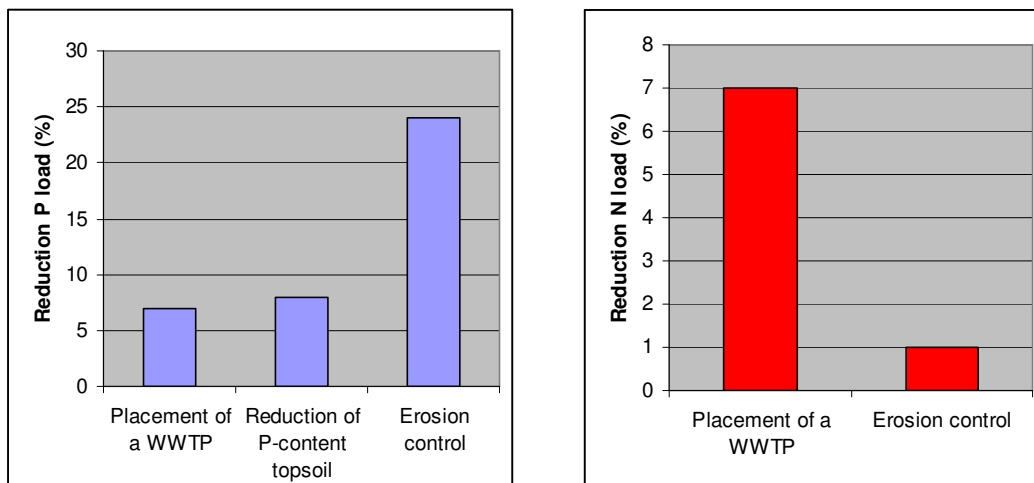


Figure 8-4 The relative effect of different measures on the nitrogen and phosphorus load

9 Discussion

Section 9.1 starts with an explanation and discussion of the results in general for the whole Arda River Basin. After that, the uncertainties in obtaining the model will be discussed in section 9.2.

9.1 Discussion results

9.1.1 Measured immision loads and comparison with modelled loads

Not enough data was available to calculate reliable measured loads which are comparable with the modelled loads. The data from monitoring stations is incomplete and there is a lot of inconsistency. At most stations, no discharges are measured, except for some months in 1998 (see appendix L). This makes it impossible to calculate reliable average multi-annual loads. In addition, the monitoring stations where quantity was measured, were not located at the outlet of the catchments, except for catchment one. Before 2003, no concentrations of total-N and total-P were measured, but only DIN and PO₄-P concentrations. Sometimes, extreme high values for PO₄-P or DIN were observed, and it is questionable if these values are representative.

One measurement of the concentration or discharge in one month is a random indication and might not be representative for the whole month, or not even for that day. Seasonal fluctuations in concentrations and discharges influence the load (see section 7.1). It is very important to use realistic average discharges and concentrations over the whole year in order to calculate a reliable yearly immision load, since one measurement can have huge influence on the results.

9.1.2 Contribution of pathways and sources to nutrient emissions in the Arda

According to the modelled results, 80% of nitrogen loads is reaching surface water via ground water. This is because nitrogen in the form of soluble nitrate can leach very easily to the groundwater (see section 3.2), rather than accumulating in soil. Especially in soils with a high porosity like brown forest. The second largest input of nitrogen is via urban systems (13%). This is mainly due to sewerages not connected to a waste water treatment plant (WWTP).

For the calculations of the contribution of different sources to nutrient emissions, several assumptions are used, *e.g.* to simulate a world without humans or agricultural activities. These assumptions should be further investigated. The main sources of nitrogen emission are other diffuse sources (42%) than agricultural areas (22%) and urban areas (13%). The other diffuse sources are mainly caused by atmospheric deposition of NO_x and NH_x on unpaved areas, originating from fossil fuels, industry, domestic heating and agricultural activities, which reach surface water mostly via ground water. The contribution of urban areas is higher in areas with relatively big cities containing sewerage but not a WWTP. The natural background is 23%, which is within the same range as the natural background of 24% in the Danube River Basin (Schreiber *et al.*, 2003).

The main pathway contributing to phosphorus emission to surface water is via erosion. In the Arda basin, 77% of phosphorus is emitted via erosion. Phosphorus easily binds to soil particles and therefore accumulates in the topsoil, especially in topsoils containing organic matter and clay, like in brown forest and leached cinnamonic forest present in the Arda River Basin. In the Arda Basin there are large sloped areas covered with these soil types, subjected to water erosion and accumulation of phosphorus. The contribution of overland flow is low, only 2%. However, this is a relatively significant input, because the overland flow only takes into account dissolved inorganic phosphorus, which is immediately available for take-up by plant and algae and therefore able to cause eutrophication.

Agricultural areas are the main source of phosphorus emission (80%), followed by urban areas (15%). In agricultural areas, the content of phosphorus is relatively high, due to application of fertilizers and

manure. Especially erosion of agricultural soil contains high amounts of particulate phosphorus. Particulate phosphorus is not available for take-up, until converted into the soluble form, but particulate phosphorus is therefore a long-term source of phosphorus. The natural background of phosphorus is 5%, which is in the same range as the natural background of 9% in the Danube River Basin (Schreiber *et al.* 2003). The natural background is probably higher in mountainous areas, because there is higher natural erosion and thus loss of phosphorus, since phosphorus is naturally originating from weathering of rocks (Fareed, 2005).

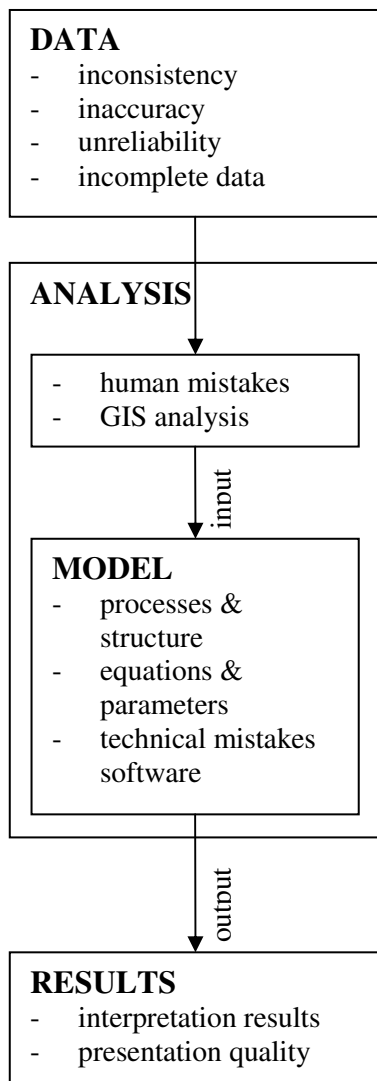
9.1.3 Scenarios

In order to predict the effect of measures, assumptions for scenarios have been made. For example, assumptions are made for the remaining content of nitrogen and phosphorus in WWTP effluent after treatment, but the effectiveness of treatment is mainly dependent on the type of WWTP.

An assumption for a reduction of 10% of the P-content in topsoil is made to estimate the effect on the total loads. Suggestions are given how to reduce the P-content, but it should be investigated if a reduction of 10% is realistic and what measures are most (cost-) effective. This is not only dependent on the type of measures, but also on the current situation of the P-content of topsoil, and the current management of fertilizer and manure use. The same counts for the scenario to reduce erosion.

9.2 Discussion model and methodology

Figure 9-1 Uncertainties of a model



A model is an approach of reality. Before using the model as decision-support system, the uncertainties should be considered. The uncertainties are due to different aspects that are part of the modelling process, presented in figure 9-1. The uncertainties are not quantified in this project, but important aspects that came across during the project, will be further explained in this section.

9.2.1 Data uncertainties

The input of data is very important for reliable results of the model. However, it should be taken into account that the model needs average values per 500 km², which is not very accurate. Many different data is used in order to fill the model for the Arda Basin. Based on available quantity data, is decided to model yearly average nutrient loads over a period 5 year (1994-1998). In an optimal situation, the administrative data and geographical data contains data for the same period. However, data from other years is used as well, like the amount of inhabitants in 2001. Demographic information and expert knowledge is used to have insight in the development of amount of inhabitants. According local experts, the last years a small decrease of inhabitants exists and migration from small villages to cities. The influence is assumed to be negligible.

In the organisation of the EAS-RBD, a Data Management System does not exist yet, and this is the reason that many different versions of data exist. Most of the time it is unknown which data presents the most reliable data. Local experts are used to define which data to use and to decide if the results are representative.

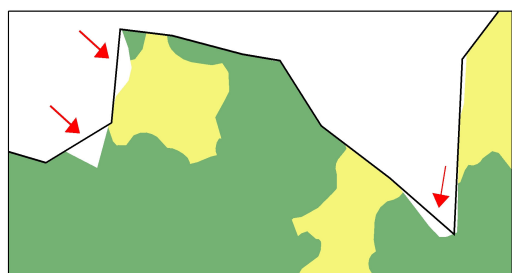
Unfortunately, there was a lack of some important data for modelling nutrient loads, *e.g.* runoff data (discharge and precipitation) and data about the surplus of nutrients. At the outlet

of the last catchment (after the dam Ivaylovgrad), runoff data for 2 years is used, which is incorrect because a hydrological period of 5 years is required (1994-1998 in this case). In addition, this data was about inflow instead of the outflow; what makes it impossible to set-up a reliable water balance for the last catchment (and thus the whole Arda Basin as total catchment). There was also a lack of precipitation data, because for the average precipitation per catchment, at least data from one rain station per catchment (from 1994-1998) is required. Data was only available for 2 rain stations (located in Kardjali and Krumuvgrad) from 1997-1998. Assumptions for precipitation in the other catchments are used (see appendix G), but more reliable data is required. Calculations for the surplus of nitrogen and phosphorus are extensive and excluded from this project. Instead, simple approaches and assumptions have been used. It should be investigated if the values are realistic.

Data about erosion was available from two different sources, quite different from each other. Data from ISPRA was available on European scale and data from the ExEA on Bulgarian scale. The scale can be the reason for the difference or the different models used to derive erosion. The Bulgarian data is used, since data on a smaller scale (thus larger area) is usually less accurate compared with data on a large scale (smaller area). Sometimes data was available in another format than the model requirements and difficult to convert, for example for soil texture and hydrogeology. Experts judgement was required to gain information about hydrogeology types per catchment (see appendix K). The only other option was field research.

9.2.2 *Uncertainties data analysis*

When data is available, most of the time additional analysis are required to convert the data into required format of the model. In the first place, this means calculating average values per variable with GIS for each catchment. During the GIS analysis (or other analysis), many uncertainties can occur due to mistakes by human (a simple example is typing errors, but mistakes by using a wrong interpolation method or classification method is also possible), or due to the software itself.



During the calculation of the surface area per soil type, a problem arose, because the Arda boundary of the soil map was different compared with the real boundary of the Arda Basin. Combining these two layers, area is missing, see figure 9-2. The soil type was important to define the nutrient content of the topsoil for arable land, but the effect of this inaccuracy on the results was negligible (see appendix G).

Figure 9-2 Missing surface area between two layers

9.2.3 *Uncertainties in model and results*

In general, a model is a simplification of reality and according the idea of the developer of the model, only the most important processes have been taken into account. This means, there is a risk that not all processes, which may influence the results, are included in the model. Uncertainties can also be caused by the unpredictability of nature, change in the social-economic situation, or technical developments (NMV, 2000). The empirical equations of the Moneris-approach of the Arda River Basin are developed under German conditions. It is possible that some of these empirical equations are not suitable for the Arda River Basin.

The results of the model can be presented in different ways. The way of presenting results, influence the information that can be taken out of it. If only the results for the total Arda Basin are presented, information about the specific situation in different catchments is missing. Most of the time only a selection from the results is presented, in a way the user thinks it is right. However, it is possible that the results are incorrectly interpreted.

The results can also be transformed, to get new information. In this case, the contribution of human impact and different sources is estimated on the base of calculations and scenarios. Transformations of the outcome of the model may cause additional uncertainties.

10 Conclusion

The research objectives of the project “Modelling nutrient loads in Arda River Basin using a Moneris-approach” consisted of four main goals. The conclusions from the results are described in this chapter.

10.1 Comparison of measured and modelled immision loads

The first objective included the development of a Moneris-approach for the Bulgarian part of the Arda basin, based on available data, in order to estimate annual emission loads of nitrogen and phosphorus (in t/a) for different sub-catchments, including the contribution of different point sources and diffuse pathways. In addition, the model estimates the immision of DIN and total-P (this includes retention and loss processes) in order to compare the modelled results with reality (the measured immision).

From the data availability, can be concluded that there is a lack of data to calculate a reliable multi-annual (1994-1998) average measured immision load. Therefore, a good comparison of the deviation and reliability of the model with the real situation was not possible, which was research objective two.

10.2 Modelled emission loads and the human impact

The third objective was to estimate the annual emission loads of nitrogen and phosphorus (in t/a) for each sub-catchment in the Arda river basin, including distinction between the contribution of different point sources and diffuse sources.

According the modelled results, 80% of the nitrogen loads in the whole Arda River Basin is reaching surface water via the pathway ground water. The reason for a high contribution of nitrogen via ground water is the capability of nitrogen to leach easily to ground water. The main sources of nitrogen emission are other diffuse sources (42%) than agricultural areas (22%) and urban areas (13%). The contribution of urban areas is mainly due to sewerages not connected to a WWTP. The natural background of nitrogen emission is 23%.

In the Arda basin, 77% of the phosphorus load is emitted to surface water via the pathway erosion. The reason for a high contribution of phosphorus via erosion is the capability of phosphorus to accumulate in the topsoil because of a high bound-capacity to soil particles (especially clay and organic matter). Agricultural activities are the main source of phosphorus emission (80%), followed by urban areas (15%). The natural background of phosphorus is 5%.

In order to know if the emission are causing problems to fulfil the objective of the Water Framework Directive (WFD) to reach a good ecological quality status, the concentrations of nitrogen and phosphorus in surface water of the Arda River Basin have been examined. Based on the measured concentrations and the initial threshold to fulfil the requirements of the WFD (see Article 5 River Basin Overview EAS-RBD, 2005), it can be concluded that probably the norms for DIN will not be exceeded, opposite to the norms for phosphorus and phosphate concentrations. The concentrations derived from the modelled immision loads and the measured runoff, are not exceeding the norms for nitrogen and phosphorus except at the last catchment.

10.3 Predicted effect of measures on nutrient emission loads

The last objective was to use the model to estimate the effect of measures on reduction of nutrient emission loads in order to fulfil WFD requirements and to reach a good ecological water quality status. Therefore, the sources and human impact contributing to nutrient loads and the concentrations of nitrogen and phosphorus have been examined. This information is used to define useful measures.

There are different possibilities to reduce nutrient inputs e.g. via source reduction and transport reduction. The effects of three scenarios on reduction of nutrient emissions are predicted with the Moneris-approach for the Arda.

1. Placing a waste water treatment plant (WWTP) in Kardjali (in catchment 4) can result in a decrease of 26% of total-N load and 7% of total-P load, both through a decrease of emissions from urban areas.
2. A reduction of 10% from the P-content of the topsoil in the whole Arda basin, leads to a reduction of 8% from of phosphorus emission (in t/a) in the whole Arda basin, due to lower input via erosion.
3. A reduction of 50% of soil loss in the total Arda basin will results in a reduction of 24% of P-emission via erosion and 1% of nitrogen emissions.

On the base of those three scenarios can be concluded that in order to reduce both nitrogen and phosphorus, placement of a WWTP, is most effective. Secondly, reducing the P-content seems to be an effective measure and is reducing the source itself instead of the pathway, like in the case of erosion control. However, a reduction of phosphorus emission via prevention of erosion from agricultural areas by use of buffer strips can be very effective and is a relative easy measure. It should be taken into account that the scenarios are based on assumptions and therefore it should be further investigated if these measures are realistic.

11 Recommendations

This chapter contains recommendations on how to optimise and to use the obtained operational model.

11.1 *How to improve the model?*

On the base of the current data availability within this project, it was not possible to calculate reliable values for the measured load and therefore the modelled results cannot be compared with reality. This makes it difficult to improve the model, because it is unknown if the current results are close to reality or not.

Therefore, the most important recommendation is to collect additional data in order to calculate a realistic measured immision load of nitrogen and phosphorus at the outlet of every catchment for the same period as the Moneris calculations. The required data for this calculation is:

1. At least, monthly concentrations of total-N and total-P (mg/l) for a period of 5 years;
2. At least, monthly discharges (m^3/s), measured on the same day as the measurements of the concentrations for a period of 5 years;

The concentrations and discharges should be as reliable as possible. Therefore, daily measurements are most optimal. In order to improve the consistency of the measured data, there should be monitoring standards to take measurements and in addition the data should be stored and organised according standards.

Further recommendations for additional data collection to improve the model are based on the quality of the data that is used for the Moneris-approach and the sensitivity of variables on the results. However, before collecting more accurate data, it should be taken into account that the Moneris-approach uses average values for all variables for a surface area bigger than 500 km^2 . This is not very accurate and accurate data will lose its accuracy when averaged for such large areas.

1. The most important data for the model is the measured discharge (m^3/s) and precipitation data, in order to set up the water balance. For the discharge, average multi-annual values for a period of 5 years, based on daily measurements, are required. For precipitation, monthly average values for a period of 5 years are required. In order to have accurate precipitation values per catchment, data from at least one station per catchment is required and the Krigging interpolation method can be used to estimate the average precipitation per catchment.
2. Very important for nutrient emissions from agricultural areas are the surplus of nitrogen and phosphorus and the content of these nutrients in the topsoil. For the Arda basin, a reliable estimation or assumption of the P-content of the topsoil and the surplus of phosphorus is important, because high concentrations of phosphorus have been observed.

Another way to define the reliability of the model and to optimise the model is to involve experts on nutrient transport to river systems, who are in the mean time familiar with the Arda River Basin. They can judge the results and the base of the model. Further research is required in order to know if the formulae, empirical relationships and parameters are suitable for the Arda.

11.2 *How to use the obtained model?*

How the model can be used, depends on the accuracy and the reliability of the model. Dependent on the aim it should be decided which uncertainties are acceptable. The model cannot be used for an exact quantification of nutrient loads as long as the reliability of the model is unknown, but the model can be used in other ways. First of all, the model can be used to define what data is required to estimate nutrient loads and to improve efficient data collection. Secondly, the model gives a clear insight to the system and the pathways via which nutrients flow into the river. This makes the model suitable to predict the relative effect of measures compared with each other.

Glossary

Accuracy	In science, engineering, industry and statistics, accuracy is the degree of conformity of a measured or calculated quantity to its actual, nominal, absolute, or some other reference, value.
Base flow	Stream or river flows consisting entirely of ground water contributions
Catchment	An area in which all surface water (mainly from precipitation, groundwater and runoff) drains to a common point, the outlet of a catchment. A catchment is also called a 'watershed' or 'drainage basin'.
Denitrification	Process of transforming nitrate in streams back into atmospheric nitrogen.
Diffuse sources	A diffuse source of pollution that cannot be attributed to a clearly identifiable, specific physical location or a defined discharge channel.
Discharge	Flow of water in a river or stream; expressed as cubic meters per second (m ³ /s).
Dynamic model	Any model with an explicit time dimension. To be meaningfully dynamic, however, it should include variables and behaviour that, at one time, depend on variables or behaviour at another time. Models may be formulated in discrete time or in continuous time.
Emission	Refers to pollution being released or discharged into the environment from natural or man-made sources.
Empirical equation	A relationship based on observation rather than theory: that is, there is no theoretical reason to believe that a relationship should be as claimed; only data that indicates it is.
Erosion	The disruption and movement of soil particles by wind, water, or ice, either occurring naturally or as a result of land use.
Eutrophication	The process of excess nutrients accelerating the growth of algae, oftentimes ultimately depleting the water of oxygen.
Evapotranspiration	The sum of evaporation and transpiration.
Fertilizer	Organic or inorganic plant foods which may be either liquid or granular used to amend the soil in order to improve the quality or quantity of plant growth.
Humus	A general term for the more or less decomposed plant and animal residues in the lower organic soil layer.
Hydraulic load	The amount of water transferred per surface water area (km ²).
Immision load	Remaining nutrient load from the emission load of nutrients, minus retention and losses of nutrients in surface water systems.
Interflow	The subsurface flow of ground water between catchments.
Karst	A limestone-rich landscape characterized by chemical erosion producing various sinkholes, fissures, underground streams, and caverns.
Leaching	The process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water to ground water or surface water.

Load (nutrients)	The mass (of nutrients) carried by water into surrounding waterways, over a period of time (usual in tones/annual).
Manure	Animal manure, as well as human sewage contains bacteria and microscopic organisms that cause disease.
Model	Mathematical representation or simulation of an actual situation.
Nitrification	The process to which bacterial populations under aerobic conditions, gradually oxidize ammonium to nitrate with the intermediate formation of nitrite.
Point sources	A source of pollution that can be attributed to a specific physical location; an identifiable, end of pipe "point". The vast majority of point source discharges for nutrients are from wastewater treatment plants, although some come from industries.
Retention	A large number of biogeochemical and hydrological processes that temporarily decrease, decay, degrade, transform (like (de)nitrification), or permanently retard or remove the substance from a river basin.
Runoff	Rainfall water which flows from a catchment into a river, stream, lake or reservoir.
Scenario	Estimation of the influence of an imaginary situation or action.
Static model	A model that has no explicit time dimension. A static model abstracts from the process by which equilibrium or an optimum might be reached only over time, as well as from the dependence of the variables in the model itself on a changing past or future.
Surplus N or P	The surplus or deficit of N or P is the difference between applied nitrogen and phosphorus to soil minus the uptake of N or P by plants.
Texture	The relative proportions of clay, silt and sand (less than 2mm in diameter) within the soil.
Topsoil	The upper surface soil layer (about 20 cm).
Tributary	A creek, stream, or river that feeds a larger stream or river or lake.
Water balance	Balance of the water resources of a region, comparing precipitation and inflow with outflow, evaporation, and accumulation of water.
WWTP	A facility designed to receive the wastewater from domestic sources and to remove materials that damage water quality and threaten public health and safety when discharged into receiving streams or bodies of water.

The definitions of the terms in the glossary are mainly based on the following websites:

<http://www.riversmallies.com/>
<http://www.nps.gov/plants/restore/library/glossary.htm>
<http://www.greenhouse.gov.au/>
<http://mvhs1.mbhs.edu/riverweb/glossary.html>
<http://www.nsc.org/>
<http://en.wikipedia.org/>

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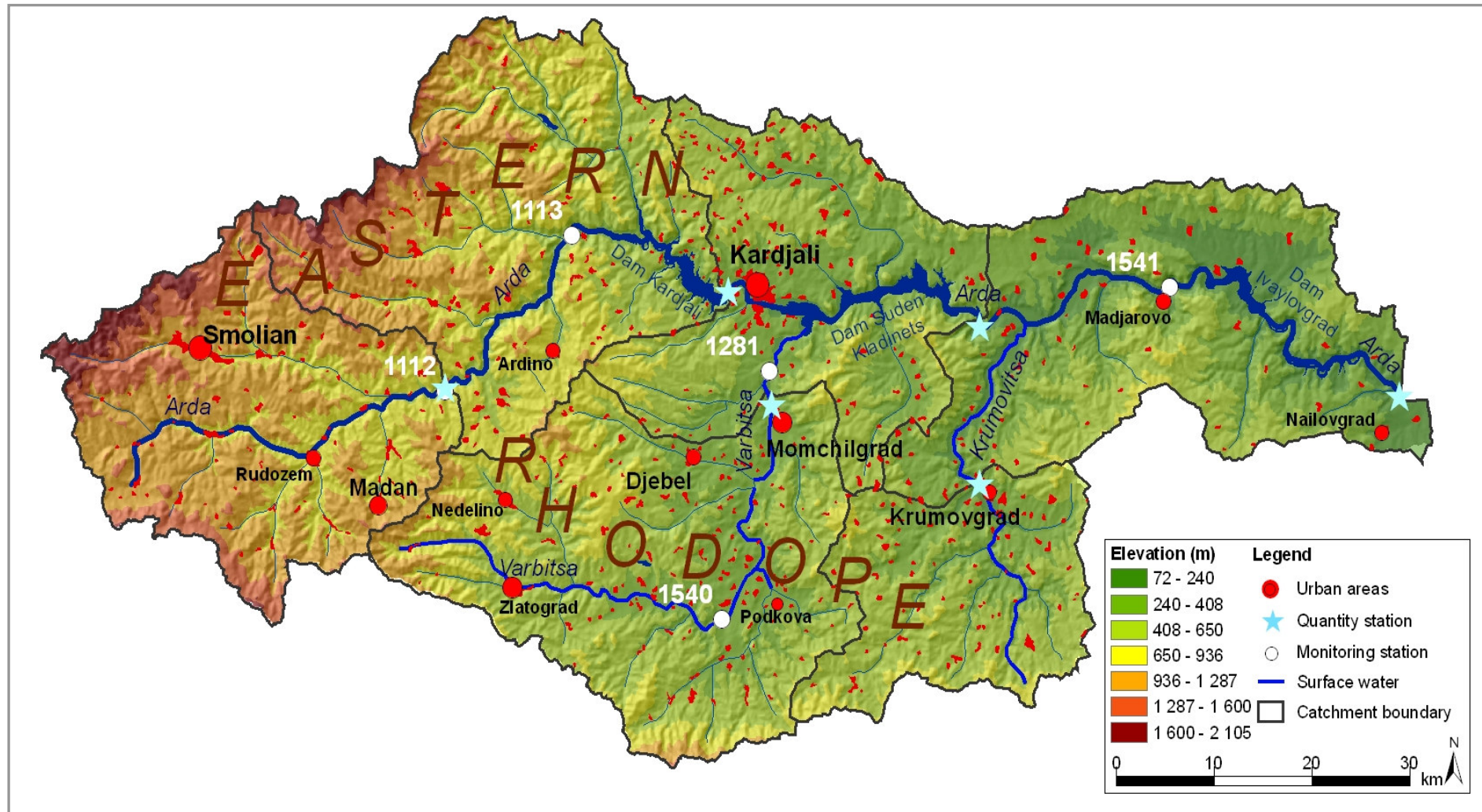
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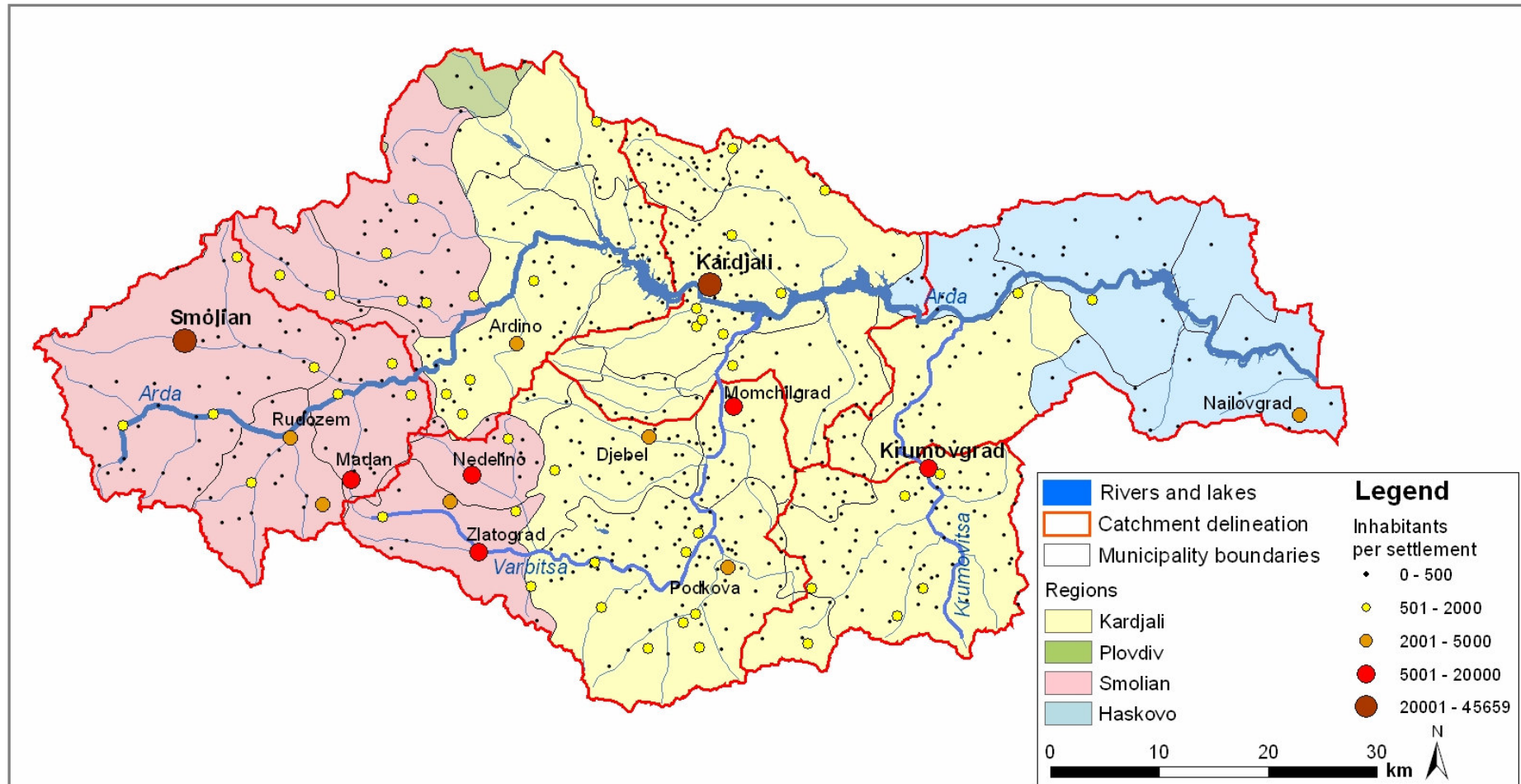
<http://www.bluelink.net/>
<http://www.rodope.org>
http://reports.eea.eu.int/COR0-landcover/en/tab_content_RLR
<http://danubs.tuwien.ac.at/>
http://www.emep.int/index_data.html
http://www.emep.int/Model_data/trend_data.html
<http://www.watersee.net/>
<http://www.riversmallies.com/>
<http://www.nps.gov/plants/restore/library/glossary.htm>
<http://www.greenhouse.gov.au/>
<http://mvhs1.mbhs.edu/riverweb/glossary.html>
<http://www.nsc.org/>
<http://en.wikipedia.org/>
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Appendixes

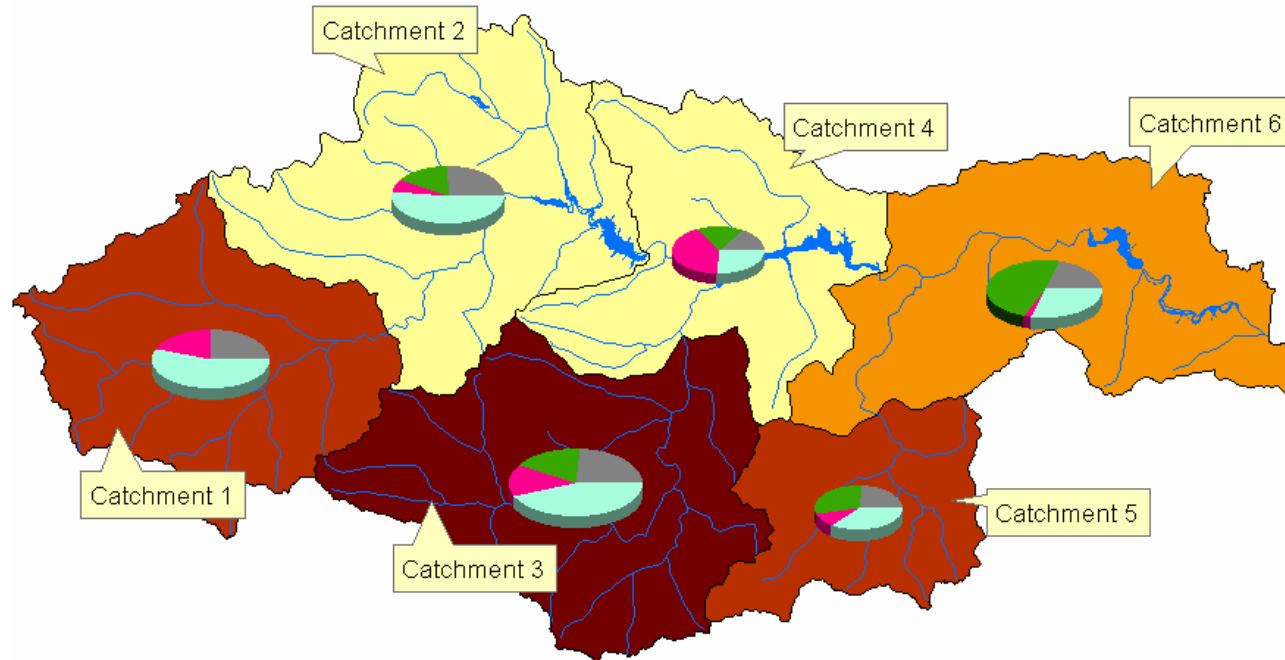
A Topographic overview Arda River Basin



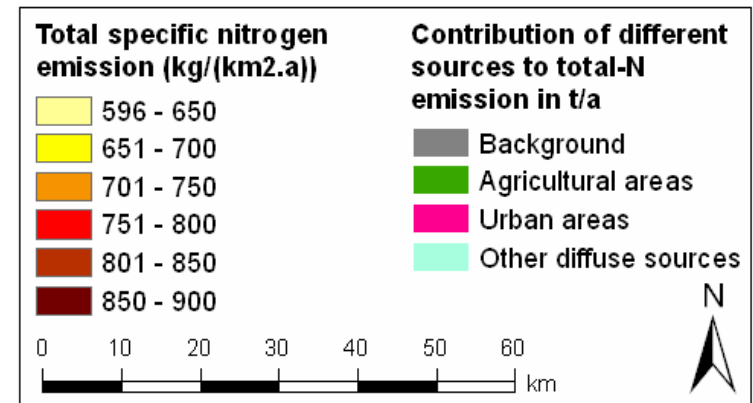
B Urban areas and administrative boundaries



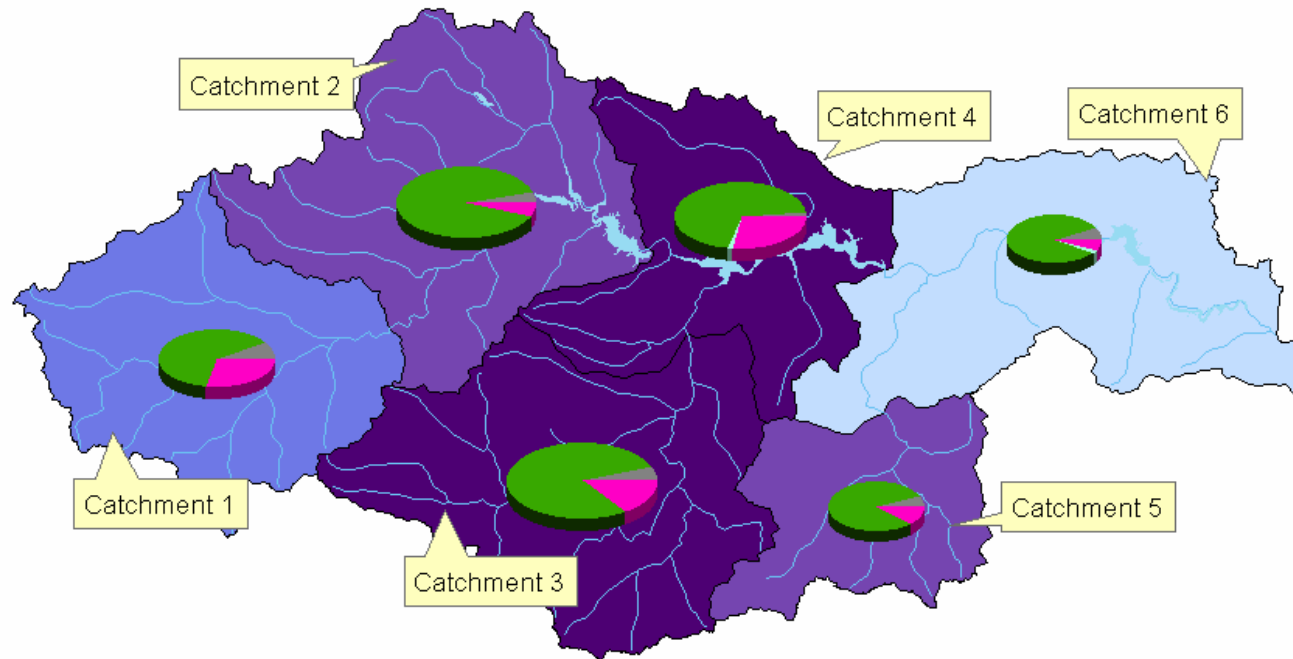
C Modelled emission loads nitrogen



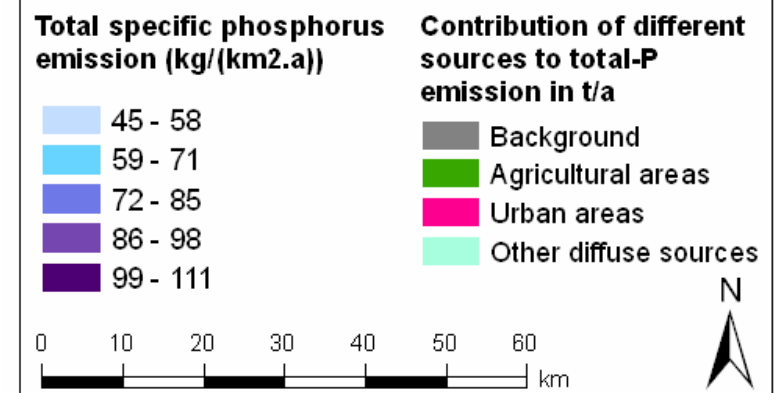
Catchment number	Background		Agricultural activities		Urban areas		Other diffuse sources		Total	
	t/a	%	t/a	%	t/a	%	t/a	%	t/a	%
1	180,4	25,1	-2,7	-0,4	147,9	20,6	391,8	54,7	717,4	100
2	175,1	26,1	116,0	17,3	34,1	5,1	346,0	51,5	671,2	100
3	224,2	23,8	183,2	19,5	106,0	11,3	427,5	45,4	940,9	100
4	62,9	13,7	97,7	21,3	179,6	39,1	118,6	25,9	458,8	100
5	97,3	23,8	118,4	29,0	33,9	8,3	158,8	38,9	408,5	100
6	141,0	19,9	330,7	46,8	18,7	2,6	217,6	30,7	707,9	100
Total	880,9	22,6	843,3	21,6	520,3	13,3	1660,3	42,5	3904,8	100



D Modelled emission loads phosphorus



Catchment number	Background		Agricultural activities		Other diffuse sources		Urban areas		Total	
	t/a	%	t/a	%	t/a	%	t/a	%	t/a	%
1	4,8	7,3	41,7	63,2	-0,1	-0,1	19,5	29,6	65,9	100
2	3,7	3,8	88,2	91,0	0,7	0,7	4,5	4,5	97,0	100
3	5,1	4,6	90,8	82,6	0,0	0,0	14,1	12,8	110,0	100
4	1,2	1,4	58,9	69,2	1,3	1,5	23,8	27,9	85,1	100
5	2,4	5,2	39,4	85,0	0,0	0,1	4,5	9,7	46,4	100
6	2,7	6,0	38,4	86,5	0,9	2,1	2,4	5,4	44,4	100
Total	19,8	4,4	357,4	79,7	2,9	0,6	68,7	15,3	448,9	100



Nutrient Loads in the Arda River Basin

E Calculating source apportionment emitting nutrients

The operational model can be used to define the contribution of different pathways to the total nutrient emissions to surface water, see table E-1.

Table E-1 Total emissions of nitrogen and phosphorus in the Arda River Basin

Total emissions: the sum of the natural background and human activities				
Pathways	Total-N		Total-P	
	[t/a]	[%]	[t/a]	[%]
Atmospheric deposition	65,0	1,7	3,2	0,7
Ground water	3103,2	79,5	25,8	5,7
Overland flow	40,7	1,0	7,7	1,7
Erosion	185,3	4,7	344,5	76,7
Urban systems	510,4	13,1	67,7	15,1
Total emissions all sources	3904,6	100,0	448,9	100,0

When the aim is to define effective measures to reduce nutrient emissions, it is important to have insight in the original source of pollution. Therefore, it is important to have insight in the emissions caused by natural background conditions and by human activities (including type of activities). The sources of nutrient emissions due to human activities (causing pressures and impact) can be distinguished in:

1. Emission from agricultural activities;
2. Contribution through urban systems;
3. Point sources, like WWTP and direct industrial discharges (this sources do not play a role in the Arda, because WWTP's don't exist and industrial discharges are negligible);
4. Contribution by other diffuse sources.

In this appendix is explained how the contribution of each source is determined. The calculation is carried out for the total Arda Basin. The results per catchment are presented spatially in appendix C and D.

Calculating natural background

With the operation model, the natural background has been calculated by simulating a situation without pressures and impacts from human. Therefore, the following assumptions have been made:

- Nutrient inputs from point sources and urban areas are non-existent;
- Areas, which are agricultural or urban today, are considered as forest;
- No input of nutrients via erosion;
- There are no inhabitants and thus also no people connected to a sewerage;
- The deposition rate of nitrogen is assumed to be 1 kg/(ha.a) (EPA, 2004);
- The parameter for phosphor deposition is assumed to be 0,1 kg/(ha.a) (Behrendt, et al., 2000);

The natural background condition for emission loads are presented in table E-2.

Table E-2 Emissions of nitrogen and phosphorus originating from the natural background

Background emissions				
Pathways	Total-N		Total-P	
	[t/a]	[%]	[t/a]	[%]
Atmospheric deposition	17,1	1,9	0,9	4,5
Groundwater	856,5	96,8	16,9	84,9
Overland flow	11,0	1,2	2,1	10,6
Erosion	0,0	0,0	0,0	0,0
Urban systems (total)	0,0	0,0	0,0	0,0
Total emissions	884,9	100	19,9	100

Calculating contribution of agricultural activities

In order to calculate contribution of agricultural activities, the model is used to simulate a situation without agricultural areas, using the following assumption:

- Areas, which are agricultural, are considered as forest;
- Agricultural activities do not influence the deposition of NO_x or NH_x from the atmosphere, so the deposition of nitrogen is remained the same.

The difference between the results for total emissions (table E-1) and the results for a situation without agricultural areas (table E-2), is the emission caused by agricultural activities, see table E-3.

Table E-3 Emissions of nitrogen and phosphorus without the existence of agricultural areas

Total emissions including natural background, but without agricultural areas				
	Total-N		Total-P	
	[t/a]	[%]	[t/a]	[%]
Atmospheric deposition	86,6	2,1	4,2	3,6
Ground water	2420,4	79,8	16,9	18,9
Overland flow	37,9	1,2	1,6	1,8
Erosion	0,0	0,0	0,0	0,0
Point sources and urban systems	520,3	16,8	68,7	75,7
Total emissions excluding agricultural area	3065,2	100,0	91,4	100,0

Table E-4 Emissions of nitrogen and phosphorus originating from agricultural areas

Agricultural emissions				
Pathways	Total-N		Total-P	
	[t/a]	[%]	[t/a]	[%]
Atmospheric deposition	(-21,6)	0	-1,0	0
Groundwater	682,8	78,4	8,9	2,5
Overland flow	2,8	0,3	6,1	1,7
Erosion	185,3	21,3	344,4	96,4
Urban areas	(-9,9)	0	-1,0	0
Total emissions agricultural activities	870,9	100,0	357,4	100,0

Calculation contribution of other diffuse sources and urban areas

The last step is to define the contribution of respectively urban areas and other diffuse sources. This can be calculated by calculating the difference of “total emissions including background, but without agricultural areas” minus “background conditions”. The other diffuse sources are the sum of remaining emissions from atmospheric deposition, groundwater and overland flow, see table E-5. The emissions from other diffuse sources are mainly due to deposition of NO_x from traffic, industry and domestic heating on non-agricultural areas and NH_x from agricultural areas.

Table E-5 Emissions originating from other diffuse areas

Total emissions - natural background and agricultural area = emissions from other diffuse sources				
Pathways	Total-N		Total-P	
	[t/a]	[%]	[t/a]	[%]
Atmospheric deposition	47,9	2,9	2,2	3,1
Groundwater	1563,9	95,4	0,0	0
Overland flow	26,9	1,6	-0,5	0
Erosion	0,0	0,0	0,0	0
Rest	-	-	2,1	2,9
Sum other diffuse sources	1638,7	100,0	3,8	5,3
Urban systems	510,4	100,0	67,7	94,7
Emission without agricultural activities and background emissions	2149,1	100	71,5	100

F Calculation of measured immision loads of DIN and total-P

The following methodology has been used to calculate the measured loads for the Arda catchments.

Step 1

Choose monitoring points to calculate loads (most important: quantity and quality data should be available for the same day and second: the monitoring point should be near or at the outlet of a catchment.). Unfortunately, for the period 1994-1998 no measurements are available for total phosphorus. Also for most months no data is available for the discharge and sometimes no data is available for phosphate or dissolved inorganic nitrogen ($\text{DIN} = \text{NH}_4, \text{NO}_2, \text{NO}_3$). The table in appendix L gives an overview with available data for every monitoring point. Every monitoring point has a number and the location of this monitoring point is shown in the map in figure 6-1.

In order to compare the measured immision load with the modelled immision load, monitoring points near or at the outlet of every catchment should be used. The best monitoring points are in this case: 1112, 1278, 1538, 1115 and 1281. (No monitoring station is located at or near the outlet of catchment five.) Unfortunately for most of the monitoring stations no discharges have been measured at all. The second option is to choose monitoring points where discharges are available (in this case 1112, 1113, 1540, 1541 and 1281). Only for some months in 1998, discharges were available, and these discharges will be used to calculate the loads.

Step 2

The second step is to calculate the concentration of total phosphorus, because in this period these substances have not been measured. From 2003 in some months total-P is measured as well as phosphate. Linear regression analysis is applied to investigate the relationship between these substances per monitoring point. Most of the linear relationships were significant ($p < 0,05$) and therefore the empirical equations are applied to calculate the total-P concentration for points where data is available about the discharge and the concentration of $\text{PO}_4\text{-P}$ (only in 1998, for points: 1112, 1113, 1540, 1541 and 1281). Assumed is that the relationship between $\text{PO}_4\text{-P}$ and total P in 2003-2005 is the same as in 1998. The relationship between those two substances is dependent on the location, thus for every monitoring point, the relations have been determined.

Step 3

The last step after calculation of total N and total P is to calculate the load in tones/annual. First the load can be calculated using formula 4-1, after that the results have to be multiplied by 31,536 (60 sec * 60 minutes * 24 hours * 365 days / 10000). The calculations are presented per monitoring point in the following section.

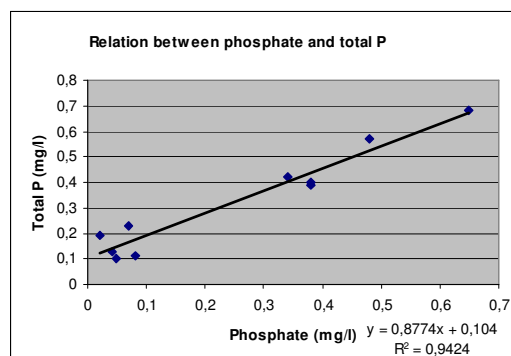
Monitoring point 1112

To calculate total P from $\text{PO}_4\text{-P}$ the empirical equation **Total P = $0,8774 \cdot \text{PO}_4\text{-P} + 0,104$** derived from linear regression analysis (see figure F-1) is used.

Table F-1 Calculation loads – monitoring point 1112

Month 1998	July	Aug	Sept	Average
$\text{PO}_4\text{-P}$ (mg/l)	0,26	0,47	0,63	0,45
DIN (mg/l)	1,35	0,82	2,1	1,42
Q (m ³ /s)	7,7	2,0	1,6	3,77
Calculated total P (mg/l)	0,33	0,52	0,66	0,50
Calculated total N (mg/l)	3,375	2,05	5,25	3,56
Total load P (g/s)	2,54	1,03	1,02	1,53
Total load N (g/s)	25,82	4,1	8,14	12,7
Total load P (t/a)	80,13	32,57	32,10	48,27
Total load N (t/a)	814,22	129,3	256,6	400,05

Figure F-1 Relation $\text{PO}_4\text{-P}$ and total-P

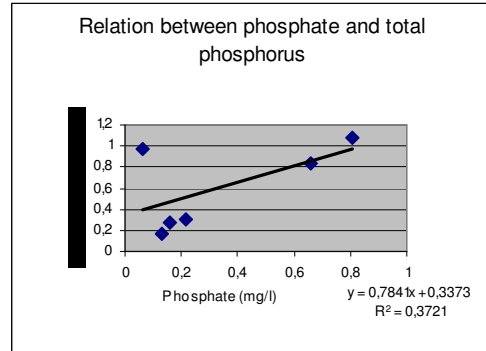


Monitoring point 1540

To calculate total P from PO₄-P the empirical equation **Total P = 0,7841*PO₄-P + 0,3373** derived from linear regression analysis (see figure F-2) is used.

Table F-2 Calculation loads – monitoring point 1540

Month 1998	Jul	Aug	Sep	Oct	Nov	Dec	Average
Q (m ³ /s)	0,05	0,21	0,18	1,00	1,00	1,00	0,57
DIN (mg/l)	0,83	1,44	0,76	1,54	1,25	1,74	1,26
PO ₄ (mg/l)	0,34	0,61	0,75	1,25	0,11	0,21	0,55
Total N (mg/l)	2,08	3,59	1,90	3,84	3,12	4,34	3,15
Total P (mg/l)	0,60	0,82	0,93	1,32	0,42	0,50	0,77
Load N (g/s)	0,10	0,75	0,34	3,84	3,12	4,34	2,08
Load P (g/s)	0,03	0,17	0,17	1,32	0,42	0,50	0,44
Load N (t/a)	3,27	23,79	10,76	121,10	98,47	136,79	65,70
Load P (t/a)	0,95	5,40	5,25	41,55	13,36	15,83	13,72

Figure F-2 Relation PO₄-P and total-P**Monitoring point 1541**

To calculate total P from PO₄-P the empirical equation **Total P = 2,28*PO₄-P + 0,4122** derived from linear regression analysis (see figure F-3) is used.

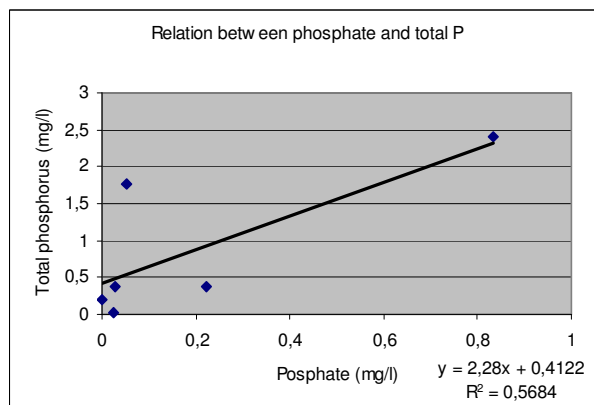
Figure F-3 Relation between PO₄-P and total P – monitoring point 1541

Table F-3 Calculation loads – monitoring point 1541

Month 1998	Feb	Mar	Jul	Aug	Sep	Oct	Nov	Dec	Average
Q (m ³ /s)	202,70	132,70	85,26	0,53	1,47	1,40	6,28	137,00	70,9
DIN (mg/l)	0,75	0,44	1,39	3,92	1,09	0,72	0,99	1,84	1,39
PO ₄ -P (mg/l)	0,63	0,48	0,20	0,72	0,36	0,99	0,18	0,72	0,54
Total N (mg/l)	1,87	1,09	3,48	9,80	2,72	1,80	2,48	4,60	3,48
Total P (mg/l)	1,85	1,51	0,87	2,05	1,23	2,67	0,82	2,05	1,63
Load N (g/s)	378,54	144,31	296,70	5,19	4,01	2,53	15,55	629,86	184,6
Load P (g/s)	374,71	199,93	74,02	1,09	1,82	3,75	5,16	281,37	117,7
Load N (t/a)	11937,71	4551,00	9356,88	163,53	126,55	79,64	490,50	19863,19	5821,13
Load P (t/a)	11816,89	6304,86	2334,38	34,26	57,31	118,11	162,86	8873,30	3712,75

Monitoring point 1113

To calculate total P from PO₄-P the empirical equation **Total P = 1,5886*PO₄-P + 0,2765** derived from linear regression analysis (see figure F-4).

Figure F-4 Relation between PO₄-P and total P – monitoring point 1113

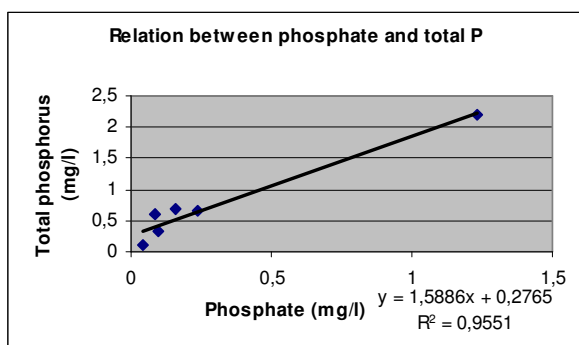


Table F-4 Calculation loads – monitoring point 1113

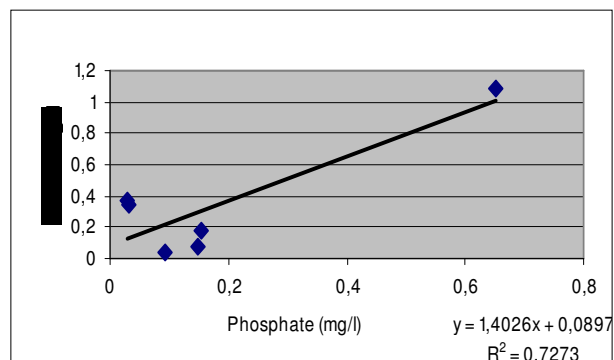
Month 1998	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Q (m ³ /s)	31,12	34,56	30,47	73,37	11,08	5,50	2,15	3,32	4,44	8,25	30,00	21,3
PO ₄ -P (mg/l)	0,52	0,46	0,22	1,70	1,27	0,65	0,89	0,59	-	0,14	0,18	0,66
DIN (mg/l)	0,53	0,61	0,52	0,75	0,83	2,67	1,27	1,60	1,37	1,13	1,62	1,17
Tot P (mg/l)	1,10	1,01	0,63	2,98	2,29	1,31	1,69	1,21	-	0,50	0,56	1,33
Tot N (mg/l)	1,32	1,53	1,31	1,87	2,08	6,66	3,17	3,99	3,43	2,82	4,06	2,93
Load P (g/s)	34,31	34,81	19,07	218,43	25,42	7,21	3,63	4,03	-	4,12	16,87	36,8
Load N (g/s)	41,08	52,70	39,92	136,84	23,02	36,67	6,81	13,25	15,23	23,29	121,80	46,42
Load P (t/a)	1082,06	1097,79	601,52	6888,45	801,57	227,22	114,61	127,08	-	129,80	532,12	1160,22
Load N (t/a)	1295,45	1662,07	1258,78	4315,23	725,92	1156,44	214,76	417,75	480,27	734,34	3841,08	1463,83

Monitoring point 1281

To calculate total P from PO₄-P the empirical equation **Total P = 1,4026*PO₄-P + 0,0897** derived from linear regression analysis (see figure F-5) is used. The loads are presented in table F-5.

Table F-5 Calculation loads and figure F-5 Relation between PO₄-P and total P – monitoring point 1281

Month 1998	Jul	Aug	Oct	Nov	Dec	Average
PO ₄ (mg/l)	0,63	0,54	1,12	0,15	0,51	0,59
DIN (mg/l)	1,84	1,17	1,67	1,07	1,37	1,42
TP (mg/l)	0,97	0,85	1,66	0,30	0,81	0,92
TN (mg/l)	4,60	2,93	4,18	2,68	3,43	3,56
Q (m ³ /s)	1,50	0,30	2,00	4,00	22,30	6,02
Load P (g/s)	1,46	0,25	3,32	1,20	17,95	4,84
Load N (g/s)	6,90	0,88	8,35	10,70	76,38	20,64
Load P (t/a)	46,04	8,01	104,74	37,85	566,14	152,56
Load N (t/a)	217,60	27,67	263,33	337,44	2408,64	650,93



G From data to input Moneris-approach Arda River Basin

Data collection has been carried out based on the data requirements of Moneris, see chapter 5 table 5-1. In this section is described what data is used, which assumptions and choices have been made and a detailed description of how the data is converted into Moneris requirements.

The base: catchment delineation, net and total catchments, and the water balance

The Arda Basin is divided into 6 sub-catchments, in order to calculate nutrient loads for different areas. The base for this nutrient balance is the water balance. Therefore the outflow of water (measured discharge or runoff in m³/s) is required for every catchment. The delineation of the catchments is based on different criteria:

1. For every catchment, the average measured runoff (over a period of 5 years on the base of daily measurements) at the outlet of the catchment is required;
2. Elevation;
3. Main and secondary river system;
4. Available water quality data (to compare measured loads with modelled loads);
5. Preferable to have sub-catchments around or bigger than 500 km²;
6. Integration of existing water bodies for WFD.

Table G-1 Average slope

Catchment	Slope (%)
1	24,31
2	24,36
3	17,27
4	13,54
5	14,92
6	13,59
Total Arda	18,00

From the location of a hydrological station, the drainage area is determined on the base of the flow direction, river network and the elevation. As described in chapter 3.4, the model calculates the nutrient loads and the runoff for the total drainage area (total catchment and total runoff) and for a net catchment (specific runoff). The surface area per catchment is calculated with GIS. The average slope per catchment is calculated on the base of the elevation map, using *Spatial Analyst*.

Land use

The land use is important to calculate nutrient loads, because the land use strongly influences the release of nutrients into the river. The Bulgarian CORINE landcover 2000 has been reclassified to the requirements of Moneris (see appendix I). Per catchment de surface area of every land use type is calculated with GIS (Arc GIS 9.1). The boundary of the CORINE landcover for the Arda region is not exactly the same as the boundary of the Arda Basin; some surface area is missing (7,6 km²), but the model corrects 0-areas according method described in the report of Behrendt et al., 2000.

Table G-2 Land use types per catchment in km²

Catchment	Urban area	Arable land	Pasture	Forest	Surface water	Exploitation area	Open area	Wetland	Total
1	21,85	106,56	4,28	622,15	0,00	1,74	104,79	0,00	861,36
2	10,21	237,93	3,12	587,52	16,26	0,29	191,52	0,00	1046,85
3	13,92	283,35	36,77	511,97	1,28	3,29	214,39	0,00	1064,98
4	25,33	283,98	16,30	260,80	25,36	1,21	156,39	0,00	769,37
5	6,02	157,74	19,03	205,51	0,00	1,64	92,55	0,00	482,48
6	13,26	228,60	41,63	499,44	20,17	0,78	188,34	0,56	992,78
Total Arda	90,59	1298,16	121,13	2687,39	63,07	8,95	947,98	0,56	5217,82

Hydrogeology

The hydrogeology map is different from the German or western European hydrogeology maps because the Bulgarian maps are based on an Old Russian classification system. There is not a systematic way to convert this geology types into another system by reclassification. Therefore expert judgment (on the base of lithology and Bulgarian hydrogeology map) is used to estimate the percentage of (un)consolidated rocks with high and low porosity and close (<5 m) or not close to groundwater (expert assessment see appendix K).

Precipitation

The assessment of long-term precipitation is made on the base of the mean altitude per catchment and a graph representing the relationship between multi-annual precipitation data (1931-1985) and altitude for the Rhodope Mountains (*Koleva, et al., 1990*).

Catchment	Long term average precipitation (mm/a)
1	866
2	791
3	704
4	666
5	678
6	641
Total Arda	724

Table G-3 Long term precipitation (mm/a)

The average yearly, summer and winter precipitation is based on data of two monitoring stations for two years (1997-1998 Kardjali and Krumovgrad). The values for catchment 1 and 2 are based on an assumption. Assumed is: catchment 4 is representative for catchment 3 and catchment 5 is representative for catchment 6. The summer months are: May, June, July, August, September, and October. The winter months are: November, December, January, February, March and April.

Table G-4 Average precipitation 1997-1998 (mm/a)

Catchment	Average yearly (1997-1998) precipitation (mm/a)	Average summer (1997-1998) precipitation (mm/a)	Average winter (1997-1998) precipitation (mm/a)
1	900	300	600
2	900	300	600
3	853	281	572
4 (Kardjali)	853	281	572
5 (Krumovgrad)	638	240	398
6	638	240	398
Total Arda	797	274	523

Atmospheric deposition and evaporation

The deposition rate for dry and wet nitrogen is based on data from DNMI (EMEP). The data is available on the Internet in ASCII-format, consisting of longitude and latitude values (is converted to x, y-coordinates), values for NO_x and NH_x and projection information. The data is converted into dbf-format and imported in GIS and afterwards the features are converted to raster and the usual projection and coordinate system (for the Arda Basin UTM35 / WGS84).

Table G-5 Deposition rate nitrogen (mgN/m²)

Catchment	NH4 95 (mgN/m ²)	NOX 95 (mgN/m ²)	NH4 2000 (mgN/m ²)	NOX 2000 (mgN/m ²)
1	842	622	520	457
2	695	614	397	446
3	697	599	408	422
4	591	543	347	388
5	577	499	381	374
6	518	488	324	358
Total Arda	653	561	396	408

Table G-6 Mean evaporation (mm/a)

Catchment	Mean evaporation (mm/a)
1	875
2	875
3	1223
4	1223
5	914
6	914
Total Arda	1004

The assessment of the evaporation is made on the base of measurement data for the 3 reservoirs Kardjali (assumed to be representative for catchment 1, 2), Studen Kladinets (assumed to be representative for catchment 3, 4) and Ivaylovgrad (assumed to be representative for catchment 5, 6) (*Kosturkov, 2006, unpublicized*).

Urban areas: Inhabitants, sewerage and WWTP

Analogue maps were available with the amount of inhabitants per settlement in the EAS-RBD. On the base of administrative letters from municipalities, the percentages of connected inhabitants to sewerage per settlement have been used to determine the amount of connected inhabitants per

Catchment	Inhabitants	Connected inhabitants
1	63133	31867
2	24066	2765
3	57121	18015
4	69329	41127
5	17901	5645
6	12466	1204
Total Arda	244016	100623

settlement. In the GIS-layer with settlements, 2 new fields in the attribute table have been generated with the amount of inhabitants per settlements and the amount of connected inhabitants to sewerage per settlement. Information about the total sewer length in the Arda was available (near 250 km) and therefore a sewer length of 50 km per catchments is used. (The sewer length did not influence the results at all). In the Arda Basin, between 1994-1998 there were no WWTP's.

Table G-7 Inhabitants per catchment and inhabitants connected to sewerage

Industry

For data about point sources, Moneris needs information about industrial discharges and loads of N and P. Analogue data for the period from 1998 was not easy to get, therefore data from 2003 is used. Different tables were available, one with 79 industries, one with 13 significant industries (thresholds of Bulgaria are exceeded) and one table with 28 industries. The GIS layer contained 52 industrial plants (only data about the location). The table with 79 industrial plants is about every single activity (for example also three women making cloths) and it is not known which activities are still active and which are not. The table with 28 industrial plants is used to define the industrial activities per catchment. This table is compared with the GIS layer (names were compared from attribute table and the analogue table), and after that the data about discharges of waste water and N loads and P loads are added in the attribute table. After that the discharge and loads of nitrogen and phosphorus per catchment from emitters has been calculated.

The total discharge for the whole Arda River Basin of total-N per year was less than 0,19 tones and for total-P also less than 0,18 tones. The N and P loads from industrial discharges are not presented in the results, because compared with the other sources, the contribution is negligible. The total discharge of waste water is used for the water balance; which is around 10 million m³/year.

Surplus

The surplus calculation is a comprehensive analysis which needs extensive information (about fertilizers, manure per type of animal, harvested crops, forage etc.). Therefore, not real surplus calculations were carried out.

The P surplus is required for calculation of the p-content of the top soil, but instead of the P surplus, real data for the P-content is used (on the base of soil samples, see table G-10). The nitrogen surplus values are estimated on the base of applied artificial fertilizer. For the Arda Basin, data was available on region level for used agricultural area, calculated based on thresholds for application of fertilizers. The average amount of applied fertilizer per ha agricultural area per region has been defined. With GIS the surface area of every region per catchment (sometimes a catchment is located in 3 regions) is defined. After that, the surface area of agricultural area is defined and based on the applied fertilizers in kg N/ha agricultural area/region, the applied kg N from fertilizers per catchment is calculated. The

Catchment	Surplus N (kg/(ha.a))
1	7,0
2	20,0
3	22,0
4	25,0
5	24,0
6	51,0
Total Arda	25

results from the Lesnovska project have been used to determine the relation between used N-fertilizer and total surplus. The range between the percentages of fertilizers from total surplus was between 20 – 45% (on average around 30%). Therefore, assumed is that the surplus consists for 30% out of fertilizers (having in mind there is no strong correlation; correlation coefficient = 0,32).

Table G-8 Surplus nitrogen (kg/(ha.a))

P-, N-content of topsoil per catchment

The calculation of the average N- and P-content of the topsoil per catchment depends on the available data. No data was available for surplus of phosphorus; therefore data about measured P-content per soil type in arable land is used. The formula in Moneris is replaced by a column with values for P-content of topsoil instead of calculating this value based on surplus and clay content. Data about the N-content and P-content of topsoil per soil type is delivered in tabular form (see table G-9) (source: *Kosturkov, 2003, unpublicized*) based on previous field research.

Table G-9 P- and N-content of topsoil per soil type for arable land

Name soil type	Total P in topsoil, mg/kg	Total N in topsoil %
Leached cinnamonic forest heavy loamy to slightly clayey	750	0,3
Alluvial and alluvial-meadow sandy and loamy	830	0,1
Eroded leached cinnamonic	670	0,2
Leached cinnamonic forest	700	0,1
Brown forest	1650	0,15
Brown forest with rendzinas	1500	0,12
Secondary saddled brown forest	850	0,25
Mountain-meadow	2000	0,50
Rendzinas (humus-calcareous)	1100	0,3

The content of phosphorus or nitrogen in the topsoil of arable land depends on the soil type. Per catchment for arable land, the percentage of every soil type has been calculated according the following 4 steps using GIS and Excel.

- Three GIS layers a, b and c are combined using the GIS-tool “*Union*”:
 - Sub-catchments (with unique ‘catchment number’)
 - Soil types (with unique ‘soil type name’)
 - Arable land (with unique code like “Ag” for all agricultural areas). This file has been produced using the CORINE landcover and selecting only agricultural area (“*select by attribute*”). Make new layer from this selection and export this data to a new shape file. Add a new field in the attribute table (like: “agri_or_not”) and give a unique code to every record to show it is agricultural area.
- Every record in the new shape file (the union of file a, b and c) has a value or code for soil type, a catchment number and a code which shows if this area is agricultural area or not. And for every record (polygon) the surface area is calculated in hectares
- Insert the dbf table from this shape file in Excel and use a ‘pivot table’ to calculate the surface area of every soil type per catchment for only arable land.
- Calculate the percentage of every soil type per catchment, like 77244 hectare of brown forest is 90% of the corrected total area of catchment 1 (= total area without ‘lakes’ and missing area).
- Calculate the average values for P- and N-content per catchment (per agricultural area??) based on percentage of every soil type per catchment and values for P- and N-content per soil type.

Based on the percentage of every soil type per catchment for arable land, the average value for N-, and P-content for can be calculated according the following formula (results see table):

$$\text{Average P/N - content} = \frac{x\% \text{ soil type}_1 * \text{value P/N - content of soil type}_1}{100} + \frac{y\% \text{ soil type}_2 * \text{value P/N - content of soil type}_2}{100}$$

One problem calculating the percentage of the soil types per catchment is the inaccuracy of the soil map. The soil map is missing area when the total surface area of the soil map of the Arda is compared with the total area of the Arda based on the total surface area of the sub-catchments. The difference is 1225 hectare and this area is situated near the outside boundary of the Arda basin (see chapter 9.2.2). This area has not a soil type, so part of this area can be Eroded leached cinnamonic soil (with lowest value for P-content, “best-case scenario”) but it can be Mountain-meadow as well (with highest P-

content of topsoil “worst-case scenario”). If this area is ignored, this can influence the actual average value for P-content of the topsoil.

To calculate the maximum mistake or possible deviation, a worst-, and best-case scenario is carried out. For catchment three the missing area of 5 km² is first assumed to be Mountain-meadow soil (worst-case) and secondary to be Eroded leached cinnamonic soil. In the worst case the average P-content increased with 4,5 mg/kg (which is less than 1 % from the total value) and in the best case the average value decreased from 2,25 mg/kg. For N-content of the topsoil the difference was beyond 2 decimals (so < 0,01 %). The worst and best case scenarios don't differ a lot. Another inaccuracy in the soil map was overlap of two soil types, but this area was almost nothing, the influence will be insignificant.

Table G-10 Input Moneris P- and N-content of the topsoil

Average P-, N-content of topsoil for arable land		
Catchment	P-content (mg/kg)	N-content (%)
catchment 1	1629	0,15
catchment 2	1519	0,14
catchment 3	935	0,11
catchment 4	724	0,13
catchment 5	770	0,10
catchment 6	720	0,13
Total Arda	1050	0,13

Soil

Moneris requires information about the soil texture. In Bulgaria the soil map classification (based on Russian system) is different from the Western European soil classification. Expert judgement and previous soil research is used to define the average percentage of the content of silt, sand and clay per soil type. Using the USDA triangle the texture per soil type has been defined and according to reclassified into Moneris texture types. Eventually, for the agricultural area per catchment, the average texture in km² is defined using GIS (tools: *Clip*, *Area km²* and *Intersect*).

Table G-11 Content of sand, silt and clay per soil type

Soil types present in Arda	Leached cinnamonic forest	Alluvial and alluvial-meadow	Eroded leached cinnamonic	Leached cinnamonic forest	Brown forest	Brown forest with rendzinas	Secondary saddled brown forest	Mountain-meadow	Rendzinas
Clay %	41	22	23	16	15	19	12	16	46
Silt %	32	37	34	20	25	29	19	25	33
Sand %	26	42	43	64	60	51	69	59	21
Texture	clay	loam	loam	sandy loam	sandy loam	loam	sandy loam	sandy loam	clay
Moneris	clay	loam	loam	loam	loam	loam	loam	loam	loam

Table G-12 Soil texture Moneris classification and table G-13 Erosion per catchment

Soil texture – USDA system	Soil texture - MONERIS	Catchment	Soil loss t/(ha.a)
sand	sand	1	1,64
loamy sand	sand	2	2,05
sandy loam	loam	3	3,95
loam	loam	4	3,87
silt	loam	5	5,39
silt loam	loam	6	2,60
sandy clay loam	loam	Total Arda	3,25
clay loam	loam		
silty clay loam	loam		
sandy clay	clay		
silty clay	clay		
clay	clay		

Spatial Analyst Arc GIS 9.1 (tool: *Zonal Statistics*) is used to calculate the average soil loss per catchment on the base of data from the ExEA.

H Description brown forest and leached cinnamonic forest

By J. Kosturkov, 2006 Academy of Sciences and Institute for Water problems.

Leached cinnamon forest soils

The leached cinnamon forest soils were formed under the conditions of transitional-continental climate with Sub-Mediterranean influence, which is characterized by dry hot summer and humid warm winter and hence by sharp annual changes of the water regime. The natural vegetation under which this soil type was formed in the past was represented by relatively sparse and dry (xerophytic) deciduous tree and shrub species of South European type, alternating with forest-free spaces occupied by a number of herbaceous species. The leached cinnamon forest soils were formed in regions with carbonate rocks. The soil-formation rocks, representing the substrate of the leached cinnamon forest soils, are Pliocene and Old Quaternary sediments originating from weathered materials from riolites, granites, andesites, limestones, etc.

In the Arda River catchment these soils are shallow and found at a relatively small depth (60-70 cm) of the profile. Two clearly expressed genetic horizons constitute their profile: humus-accumulative (horizon A) and metamorphic (horizon B(t)). The thickness of the humus-accumulative horizon is small – usually less than 40 cm, and has a heavy sandy-clayey composition (with high clay content). The metamorphic horizon B(t) is characterized by clayey composition, low water permeability and high water-retention capacity. The aqueous properties of the leached cinnamon forest soils vary with the depth of the profile but it could be assumed that this soil type possesses relatively good water-retention capacity and satisfactory to low filtration (0.08 – 0.3 m/24 h). The leached cinnamon forest soils are characterized by low humus and nitrogen content. The humus content is within the range of 1.5-4 %. The greater part of it is found in the humus-accumulative horizon, while its content sharply decreases in the metamorphic horizon. In compliance with the low humus content, the total nitrogen content is also lower – it varies in the topsoil from 0.03 % to 0.11 % for non-arable lands and from 0.10 % to 0.20 % – for arable lands. The range of variation of the total phosphorus content in the topsoil is still greater – from 0.04 % to 0.38 %. There are large areas covered with leached cinnamon forest soils on sloped terrains, which are subjected to water erosion.

Brown forest soils

The brown forest soils in the Arda River catchment were formed under the conditions of moderately cool and relatively humid mountain climate. They were formed under beech and coniferous and/or mixed beech-coniferous forests with subforest of blueberries and a number of herbaceous species. The bedrocks consist of diverse but mainly carbonate-free varieties – granites, gneisses, schists, sandstones, etc. The products of the physical weathering of these silicate rocks – loose eluvium, slope proluvium and colluvium, represented the soil-formation materials of the brown forest soils.

The brown forest soils in the Arda River catchment are shallow and have a relatively small depth of the profile. They are characterized by low bulk density and high porosity and contain different quantities of rock pieces, i.e. they are fragmented, and the amount of rock pieces increases with the depth of the profile. The existence of a B_m horizon of the cambic type with contemporary in-situ weathering processes (metamorphism) of the minerals is a specific feature of these soils. Their profile consists of the following genetic horizons: L (forest litter or cover) + A (humus-accumulative horizon) + B_m + C (bedrock). These soils are characterized by high organic substance content and with low decomposition and mineralization of organic substances, which is reflected on the low humification of the soil profile. The C:N ratio exceeds 15-20. The humus is concentrated (up to 7-10 %) in the top soil layer (0-20 cm) and its content sharply decreases with depth. The total nitrogen amount is low. The range of total nitrogen changes in the topsoil is from 0.01 % to 0.25 %, and of total phosphorus – from 0.03 % to 0.38 %. Similarly to the leached cinnamon forest soils, the greater parts of the brown forest soils in the Arda River catchment occupy slope terrains and are subjected to water erosion.

Used references (Bulgarian literature):

1. Slavov, D., (2000) Nitrogen, nitrogenous fertilizers and nitrogenous fertilizing, Ambrozia, Sofia.
2. Soils in Bulgaria (1960), Government publishing house for agriculture literature, Sofia.
3. Atlas of soils in Bulgaria (1998), Zemizdat, Sofia and data from field studies.

I Land use classification

CORINE Code	CORINE Codes (aggregated)	CORINE Description ¹²	Moneris classification Land use ¹³
11	111, <u>112</u>	Urban Fabric	Urban area
12	<u>121, 122</u> , 123, 124	Industrial, commercial and transport units	Urban area
13	<u>131, 132</u> , 133	Mine, dump and construction sites	Exploitation area
14	<u>141, 142</u>	Artificial non-agricultural vegetated areas	Urban area
21	<u>211</u> , 212, 213	Arable land	Arable land
22	<u>221, 222</u> , 223	Permanent crops	Arable land
23	<u>231</u>	Pasture	Pasture
24	241, <u>242, 243</u> , 244	Heterogeneous agricultural area	Arable land
31	<u>311, 312, 313</u>	Forest	Forest
32	<u>321, 322</u> , 323, <u>324</u>	Shrub and/or herbaceous vegetation associations	Open area
33	<u>331, 332, 333</u> , 334, 335	Open spaces with little or no vegetation	Open area
41	<u>411</u> , 412	Inland wetlands	Wetlands
42	421, 422, 423	Coastal wetlands	Wetlands
51	<u>511, 512</u>	Inland wetlands	Surface water
52	521, 522, 523	Marine wetlands	Surface water

This table presents the method for classification of the Bulgarian CORINE Land Cover (2000) land use map. The red underlined CORINE codes are land use types present in the Arda river basin. The other types do not exist in the Arda basin.

¹² Source: http://reports.eea.eu.int/COR0-landcover/en/tab_content_RLR

¹³ Source: Schreiber et al., 2003

J Initial IMPRESS analysis Arda River Basin

In 2004, the EAS-RBD delivered the WFD Article 5 report 'River Basin Overview (RBO) for the East-Aegean River Basin, consisting of three sub-river basins: the Maritza, Tundja and the Arda River Basin. In this section, only results from the IMPRESS analysis of the Arda (or in some cases the total EAS-RB) with regard to surface water and nutrient input of phosphorus and nitrogen is described.

The first step was to define if a surface water body (SWB) is at risk, possible at risk or not at risk. This is carried out by expertise assessment, using the thresholds in table 6-7 (further information see: *RBO*, 2005). The substances that are taken into account and that cause the 'at risk' status of SWB are:

- Organic compounds (mainly due to sewerage and sometimes industry)
- Nutrients: nitrogen and phosphorus (mainly due to sewerage, WWTP, urban areas without sewerage, agricultural activities and industries)
- Priority substances and other dangerous substances (mainly due to industry and sewerage)

An assessment for the source causing pollution of a SWB that is 'at risk', has been made on the base of expert judgement. The Arda Basin consists of 60 SWB (rivers and lakes) and 11 SWB are at risk of failing a good ecological status, caused by the following (mostly because of more than one) sources:

- 7 SWB at risk due to point sources: industry and sewerage
- 7 SWB at risk due to diffuse sources: agricultural areas and urban areas without sewerage
- 6 SWB at risk due to morphological alterations and water flow
- 1 SWB at risk due to water abstraction

For information about the methodology of the assessment of the contribution of different diffuse and point sources to the substances mentioned above is referred to the RBO report (*RBO*, 2005).

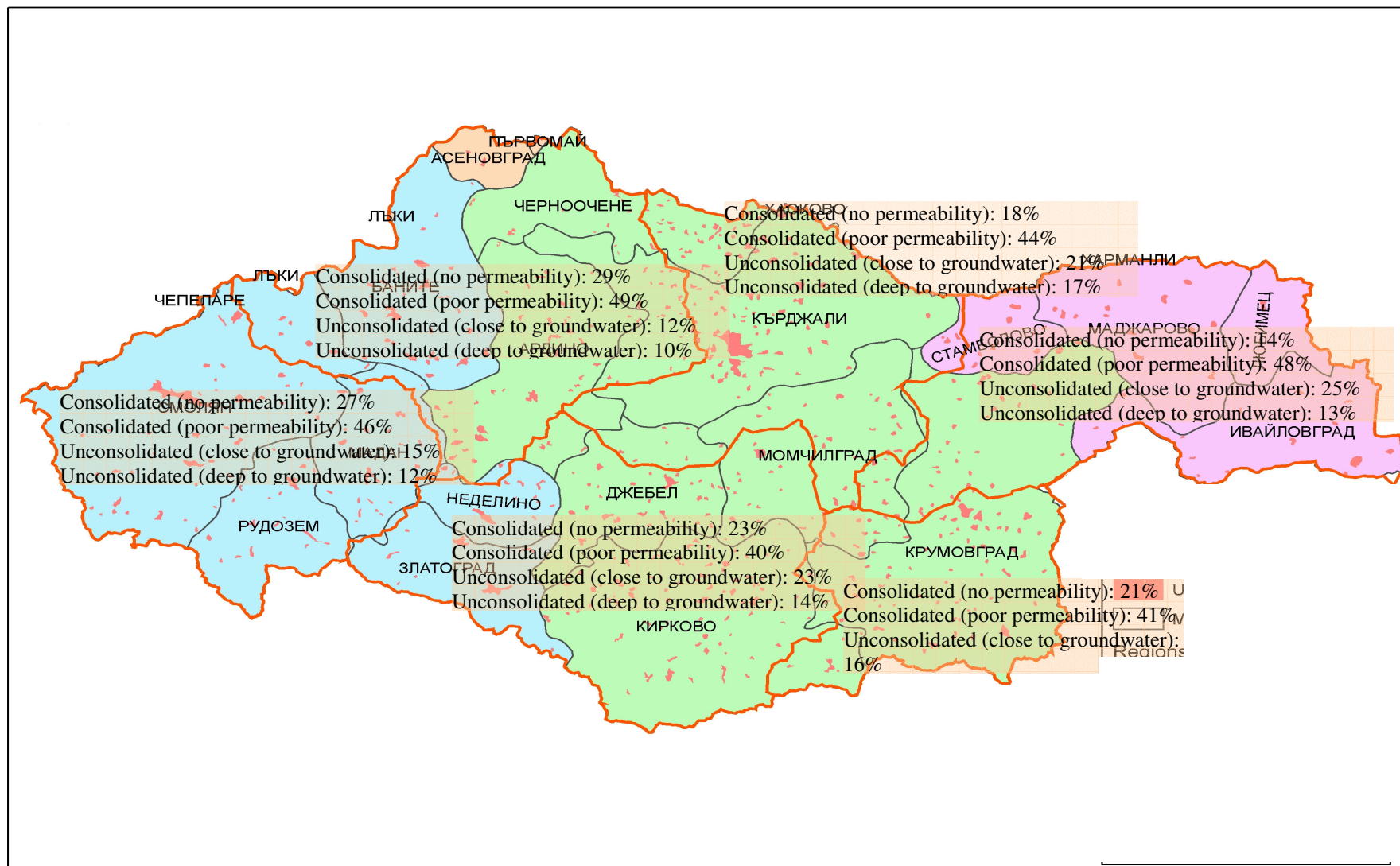
For the whole EAS-RBD, it is assessed which activities contribute to respectively nitrogen and phosphorus in surface waters.

- Point sources delivering nitrogen and phosphorus are mainly due to sewerage (P = 92% and N = 95%); the remaining part is due to industry (in the Arda Basin this part is very small).
- Diffuse sources delivering nitrogen and phosphorus are mainly due to agricultural areas (P = 92% and N = 87%), the rest is due to urban areas without sewerage. However, in the Arda basin, from the SWB polluted by diffuse sources, 86% is caused by urban areas without sewerage; the rest is due to both agricultural areas and urban areas (14%). This means that the contribution of diffuse sources to nitrogen and phosphorus in the Arda, probably mainly is due to urban areas without sewerage.

Total loads of nutrients from diffuse and point sources in the total EAS-RBD are:

- 5756 t/a nitrogen by point sources and 39006 t/a by diffuse sources
- 716 t/a phosphorus by point sources and 11600 t/a by diffuse sources

K Expert assessment hydrogeology Arda River Basin



Nutrient Loads in the Arda River Basin

L Available data monitoring station

Monitoring point	Available data per month per year							
1112	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	jul/aug/sept	every month	every month	jan-apr
NH4	not in jan-apr/dec	not in apr-jun/dec	apr/dec	jan/mar/may/jun	every month	every month	every month	jan-jun/aug/nov
NO2	not in dec	not in apr-jun/dec	apr/dec	jan/mar/may/jun	every month	every month	every month	jan-jun/aug/nov
NO3	not in dec	not in apr-jun/dec	apr/dec	jan/mar/may/jun	every month	every month	every month	jan-jun/aug/nov
PO4	no	no	no	no	every month	every month	every month	jan-jun/aug/nov
Total P	no	no	no	no	no	aug/nov	feb/may/aug/nov	feb/may/aug/nov
Total N	no	no	no	no	no	aug/nov	no	feb/may/nov
1113	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	every month except jan	jan-aug/oct/nov	feb-aug/nov/dec	not in jul/sept
NH4	may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept
NO2	may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept
NO3	may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept
PO4	may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month except oct	every month	every month	not in jul/sept
Total P	no	no	no	no	no	no	may/aug/nov	aug/nov
Total N	no	no	no	no	no	no	may/aug/nov	aug/nov
1115	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	no	no	no	no
NH4	every month	every month	every month	jan/may-jul/oct-dec	feb/may/jul-dec	every month	every month	every month
NO2	every month	every month	every month	jan/may-jul/oct-dec	feb/may/jul-dec	every month	every month	every month
NO3	every month	every month	every month	jan/may-jul/oct-dec	feb/may/jul-dec	every month	every month	every month
PO4	every month	every month	every month	jan/may-jul/oct-dec	feb/may/jul-dec	every month	every month	every month
Total P	no	no	no	no	no	no	may/aug/nov	feb/may/aug/oct/dec
Total N	no	no	no	no	no	no	may/aug/nov	aug/oct/dec
1278	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	no	no	only dec	no
NH4	feb/may/aug-dec	feb/may/aug/sep	jan/mar/may/jun/aug/nov	may/nov/dec	feb/may/aug/sep	feb/may/aug	feb/mar/may-dec	jan-may/aug/nov
NO2	feb/may/aug-dec	feb/may/aug/sep	jan/mar/may/jun/aug/nov	may/nov/dec	feb/may/aug/sep	feb/may/aug	feb/mar/may-dec	jan-may/aug/nov
NO3	feb/may/aug-dec	feb/may/aug/sep	jan/mar/may/jun/aug/nov	may/nov/dec	feb/may/aug/sep	feb/may/aug	feb/mar/may-dec	jan-may/aug/nov
PO4	feb/may/aug-dec	feb/may/aug/sep	jan/mar/may/jun/aug/nov	may/nov/dec	feb/may/aug/sep	feb/may/aug	feb/mar/may-dec	jan-may/aug/nov
Total P	no	no	no	no	no	no	may/aug/nov	feb/may/aug
Total N	no	no	no	no	no	no	aug/nov	Aug
1279	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	feb/mar	no	no	no
NH4	not in sep/oct/dec	not in jul/sept	not in jan/mar/may/jun	jan/may-jul/oct/nov	every month	every month	jan/feb/apr/may/aug/nov	feb/may/aug/oct/dec
NO2	not in sep/oct/dec	not in jul/sept	not in jan/mar/may/jun	jan/may-jul/oct/nov	every month	every month	jan/feb/apr/may/aug/nov	feb/may/aug/oct/dec
NO3	not in sep/oct/dec	not in jul/sept	not in jan/mar/may/jun	jan/may-jul/oct/nov	every month	every month	jan/feb/apr/may/aug/nov	feb/may/aug/oct/dec
PO4	not in sep/oct/dec	not in jul/sept	not in jan/mar/may/jun	jan/may-jul/oct/nov	every month	every month	jan/feb/apr/may/aug/nov	feb/may/aug/oct/dec
Total P	no	no	no	no	no	no	may/aug/nov	feb/may/aug/nov
Total N	No	No	No	No	No	No	may/aug/nov	Aug

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1281	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	jul/aug/oct-dec	every month	every month	jan-apr
NH4	no	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept/nov
NO2	no	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept/nov
NO3	no	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept/nov
PO4	no	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept/nov
Total P	no	no	no	no	no	no	may/aug/nov	feb/may/aug/nov
Total N	no	no	no	no	no	no	may/aug/nov	aug
1283	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	no	no	no	no
NH4	no	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept/oct/dec
NO2	no	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept/oct/dec
NO3	no	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept/oct/dec
PO4	no	feb/may/aug/nov	feb/may/aug/nov	may/nov	every month	every month	every month	not in jul/sept/oct/dec
Total P	no	no	no	no	no	no	may/aug/nov	may/aug/nov
Total N	no	no	no	no	no	no	feb/may/aug	aug
1535	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	jul-sept	every month	every month	jan-apr
NH4	no	no	no	no	not in jan and jul	every month	every month	jan-jun/aug/nov
NO2	no	no	no	no	not in jan and jul	every month	every month	jan-jun/aug/nov
NO3	no	no	no	no	not in jan and jul	every month	every month	jan-jun/aug/nov
PO4	no	no	no	no	not in jan	every month	every month	jan-jun/aug/nov
Total P	no	no	no	no	no	aug/nov	feb/may/aug/nov	feb/may/aug/nov
Total N	no	no	no	no	no	aug/nov	no	feb/may/nov
1536	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	no	no	no	no
NH4	no	no	no	no	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
NO2	no	no	no	no	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
NO3	no	no	no	no	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
PO4	no	no	no	no	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
Total P	no	no	no	no	no	no	may/aug/nov	feb/may/aug
Total N	no	no	no	no	no	no	may/aug/nov	aug
1537	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	no	no	no	no
NH4	no	no	no	no	feb/may/jun/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
NO2	no	no	no	no	feb/may/jun/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
NO3	no	no	no	no	feb/may/jun/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
PO4	no	no	no	no	feb/may/jun/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
Total P	no	no	no	no	no	no	may/aug/nov	feb/may/aug
Total N	no	no	no	no	no	no	may/aug/nov	aug
1538	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	no	may	no	no
NH4	no	no	no	no	mar/aug	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
NO2	no	no	no	no	mar/aug	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
NO3	no	no	no	no	mar/aug	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
PO4	no	no	no	no	mar/aug	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
Total P	no	no	no	no	no	no	may/aug/nov	feb/may/aug

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Total N	no	no	no	no	no	no	may/aug/nov	aug
1540	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	jul-dec	feb/may/aug/nov	feb/may/aug/nov	feb
NH4	no	no	no	no	every month	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
NO2	no	no	no	no	every month	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
NO3	no	no	no	no	every month	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
PO4	no	no	no	no	every month	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
Total P	no	no	no	no	no	no	may/aug/nov	feb/may/aug
Total N	no	no	no	no	no	no	may/aug/nov	aug
1541	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	feb/mar/jul-dec	not feb/may	every month	not in jul/sept/oct/dec
NH4	no	no	no	no	every month	every month	every month	not in jul/sept/oct/dec
NO2	no	no	no	no	every month	every month	every month	not in jul/sept/oct/dec
NO3	no	no	no	no	not in oct	every month	every month	not in jul/sept/oct/dec
PO4	no	no	no	no	not in may	every month	every month	not in jul/sept/oct/dec
Total P	no	no	no	no	no	no	may/aug/nov	feb/may/aug
Total N	no	no	no	no	no	no	may/aug/nov	aug
1542	Year 1994	Year 1995	Year 1996	Year 1997	Year 1998	Year 2003	Year 2004	Year 2005
Q m3/s	no	no	no	no	no	no	no	no
NH4	no	no	no	no	jan/feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
NO2	no	no	no	no	jan/feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
NO3	no	no	no	no	jan/feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
PO4	no	no	no	no	jan/feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov	feb/may/aug/nov
Total P	no	no	no	no	no	no	may/aug/nov	feb/may/aug
Total N	no	no	no	no	no	no	may/aug/nov	aug

Explanation table:

‘Jan/feb/may/aug/nov’ means data is available for the months: January, February, May, August and November. ‘No’, means no data is available this month. ‘Not in feb/may’ means no data is available for February and May. ‘Jul-dec’ means data is available for the months July, August, September, October, November and December.