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# COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE (2000/60/EC)

## Guidance document No. 26

## GUIDANCE ON RISK ASSESSMENT AND THE USE OF CONCEPTUAL MODELS FOR GROUNDWATER

EUROPEAN COMMISSION

environment

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A great deal of additional information on the European Union is available on the Internet.
It can be accessed through the Europa server (http://ec.europa.eu).

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# FOREWORD

The Water Directors of the European Union (EU), Acceding Countries, Candidate Countries and EFTA Countries have jointly developed a common strategy for supporting the implementation of the Directive 2000/60/EC, "establishing a framework for Community action in the field of water policy" (the Water Framework Directive). The main aim of this strategy is to allow a coherent and harmonious implementation of the Directive. Focus is on methodological questions related to a common understanding of the technical and scientific implications of the Water Framework Directive.

In particular, one of the objectives of the strategy is the development of non-legally binding and practical Guidance Documents on various technical issues of the Directive. These Guidance Documents are targeted to those experts who are directly or indirectly implementing the Water Framework Directive in river basins. The structure, presentation and terminology are therefore adapted to the needs of these experts and formal, legalistic language is avoided wherever possible.

In the context of the above-mentioned strategy, several guidance documents directly relevant to groundwater have been developed and endorsed by the Water Directors. They provide Member States with guidance on e.g. the identification of water bodies (CIS Guidance No. 2), the analysis of pressures and impacts (CIS Guidance No. 3), monitoring (CIS Guidance No. 7) etc. in the broad context of the development of integrated river basin management plans as required by the WFD.

As a follow-up, and in the context of the new Groundwater Directive (2006/118/EC) developed under Article 17 of the Water Framework Directive, Member States have expressed the need to clarify a range of issues, which resulted in the development of new guidance documents complementing the existing series, focusing on aspects covered by both the WFD and the Groundwater Directive, namely Groundwater Monitoring (CIS Guidance No. 15), Groundwater in Drinking Water Protected Areas (CIS Guidance no. 16), Prevention of Direct and Indirect Inputs of Pollutants (CIS Guidance no. 17) and Groundwater Status and Trend Assessment (CIS Guidance No. 18).

To complement these guidance documents and in order to support the ongoing implementation process of the WFD, it was decided to set up recommendations about the generic elements of risk assessment, the use of conceptual models and their specific implementation for groundwater under the WFD building upon the experience and knowledge gained within the RISKBASE project funded under the 6$^{th}$ Framework Programme. For this purpose, an informal drafting group has been established under the umbrella of the CIS Working Group on Groundwater (WG C). This drafting group has been coordinated by Austria (RISKBASE), DECHEMA, and Arcadis (NICOLE), and involved a range of experts from other Member States and from stakeholder organisations.

The present Guidance Document is the outcome of this drafting group. It contains the synthesis of the output of discussions that have taken place since 2007. It builds on the input and feedback from a wide range of experts and stakeholders that have been involved throughout the procedure of Guidance development through meetings, workshops, conferences and electronic media, without binding them in any way to this content.

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**LIST OF USED ABBREVIATIONS**

DWPA – Drinking Water Protected Area
GWD – Groundwater Directive (2006/118/EC)
RBMP – River Basin Management Plan
TV – Threshold Value
WFD – Water Framework Directive (2000/60/EC)

# 1. INTRODUCTION

Under Article 5 of the Water Framework Directive (WFD), in 2005 Member States developed and reported on the first risk assessment for groundwater bodies and the likelihood of meeting or failing the WFD's environmental objectives, including good status (see WFD Art. 4b) by 2015. As a further preparation for the first cycle of River Basin Management Plans (RBMP), which were due to be published in December 2009, monitoring programs and threshold values have been established. Within this first management plan period (2009–2015) a review of risk assessments is due to be performed by December 2013 and thereby prepare for the second river basin management plan starting in December 2015, as noted in Figure 1. The relationship between the Article 5 risk assessment and the status assessment is noted in Chapter 2.4 and Figure 4.

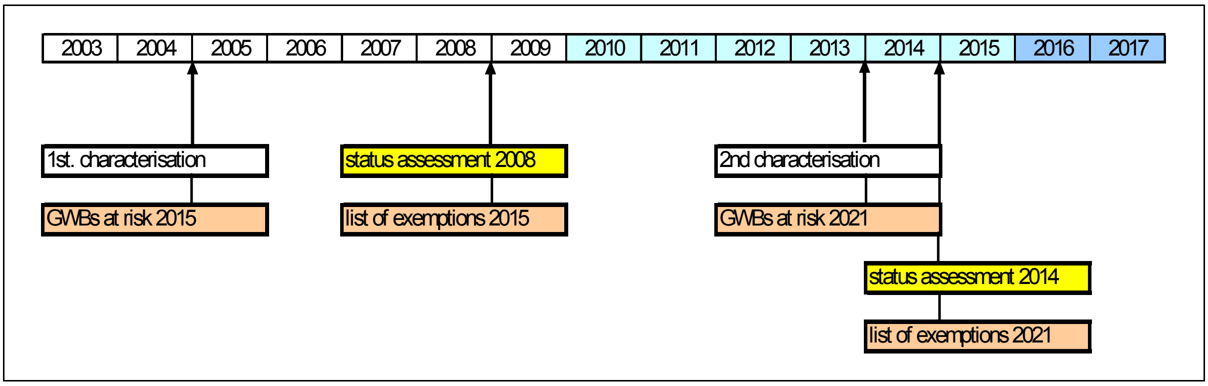


*Figure 1: Implementation of the WFD – Timetable 1st and 2nd cycles.*

This guidance document describes the generic elements of risk assessment, the use of conceptual models and their specific implementation for groundwater under the WFD. Emphasis is given to the broader notion that characterisation and risk assessment concern five objectives defined within Article 4 (see Chapter 3). Accordingly the document on hand provides insight in risk assessment and the use of conceptual modelling in a holistic manner. Aiming to reframe the context it does not describe a restricted procedure or a step-by-step recipe.

Risk assessment tries to draw a causal chain linking the origin of a hazard or pressure (e.g. an identified or estimated loading of a polluting substance) along an environmental pathway to consequences for human health or the environment (using concepts such as vulnerability, exposure and impact assessment). It should also provide some assessment of the probability of, and confidence in, such a forecast. Scientifically this is generally known as the 'source-pathway-receptor' paradigm (SPR). Risk assessment procedures in practice have to address a variety of topics and scales. Therefore the applied procedures vary and need to be suitable for purpose.

The procedures recommended in this guidance are based on experience and lessons learnt since the first WFD Article 5 reports (e.g. as discussed at the WG C Workshop in January 2004). Such procedures need also to take into account and refer to the first results of the monitoring programs implemented under the WFD.

The main focus of this document is to describe a coherent approach on how to assess risks caused by different pressures (such as diffuse and point source pollution with respect to groundwater quality and abstraction with respect to groundwater quantity) at different scales ranging from site scale (local) up the scale of a groundwater body. Therefore the document is complementary to Guidance Documents Nos. 15 (Monitoring), 16 (Groundwater in Drinking Water Protected Areas), 17 (Direct and Indirect Inputs) and 18 (Groundwater Status and Trend Assessment).

During the process of assessing SPR relationships a conceptual understanding and/or a series of hypotheses will be built up based on the available evidence. This conceptual model may be tested and progressively refined as new data are obtained. The use of conceptual models as an essential tool in groundwater risk and status assessment is recognized by the new Groundwater Directive (GWD, 2006/118/EC) and is discussed in Chapter 3 of this guidance.

It is important to recognize the role of risk assessment in groundwater management, including the preparation of information and data to enable the planning of monitoring systems and the development of remedial measures. A prerequisite to groundwater risk assessment is a sound understanding of groundwater systems, which is supported by Conceptual Models and needs to be developed and adapted to the cycles of groundwater management.

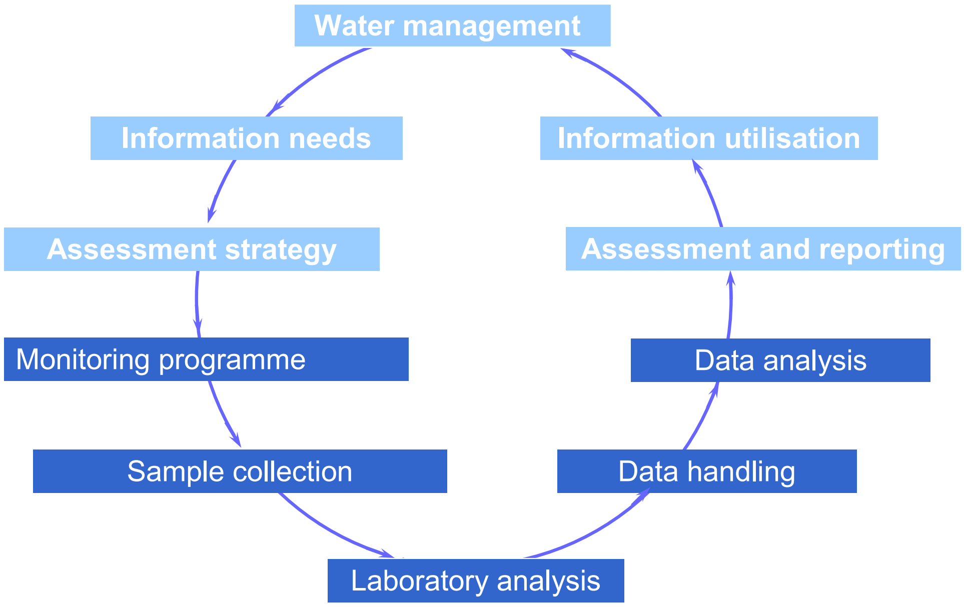


*Figure 2: The water management cycle (Ref 9)*

## 2. RISK ASSESSMENT OVERVIEW

### 2.1 Scope

This guidance document is concerned with the use of 'risk' and 'risk assessment' in the WFD and GWD as noted in Annex I. Thus, in the context of this guidance document, risk needs to be understood specifically as risks not to achieve the environmental objectives of the WFD (see 2.3 and 3) and not in its classic perspective of possible risks for human health and the environment. The first cycle of river basin planning under the WFD started in December 2003 when the WFD had to be implemented into national law. The first River Basin Management Plan for the period of 2009–2015 (RBMPs) had to be published in December 2009. The preparation of the next RBMP cycle starts very soon as at least three years before the beginning of the period to which the plan refers (by 2012), Member States have to publish a timetable and work programme for the production of the plan. The review of the risk assessment according to Article 5 WFD is due in 2013. Further risk characterisation for groundwater during the next planning cycles will also consider monitoring data and the status assessment procedures (including the use of threshold values set by Member States).

### 2.2 Towards risk-based management - integrating assessments and management

Drawing on an analysis of established approaches to risk management, the International Risk Governance Council (IRGC) has developed a Risk Governance Framework whose purpose is to help policy makers, regulators and risk managers both understand the concept of risk governance and apply it to their handling of risks. A detailed description of the framework was published in IRGC's White Paper "Risk Governance – Towards an Integrative Framework" in 2005[1]. An introduction to the framework is available on the IRGC website[2].

In its 2005 White Paper on Risk Governance, the IRGC has put forward a model of inclusive Risk Governance (see Figure 3), which offers a structure for an integrative process regarding assessing and managing risks. The framework comprises four phases: Pre-Assessment, Risk Appraisal, Characterisation and Evaluation, and finally Management (informed decisions and implementation). A fifth, Risk Communication, runs parallel to these phases.

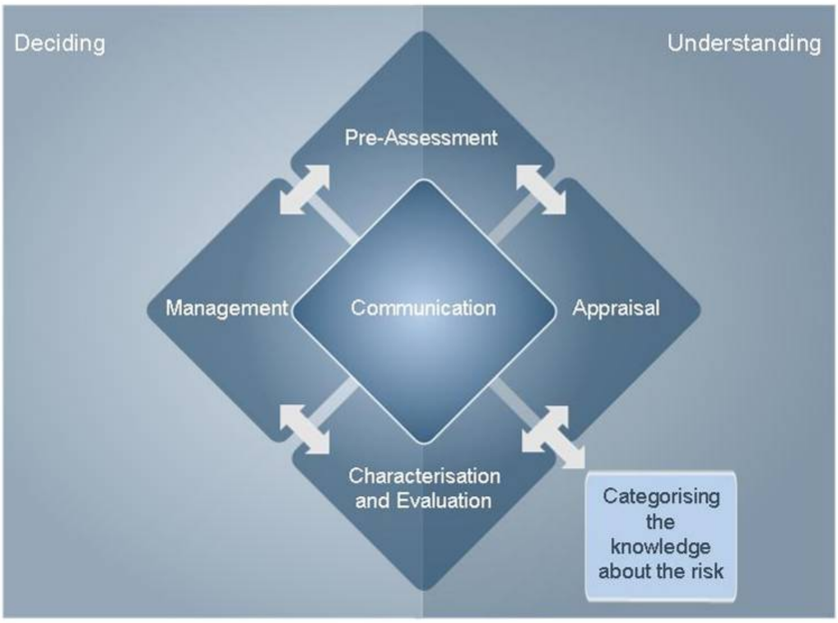


*Figure 3: Basic Model of Risk Governance (IRGC 2007a)*

1 IRGC White Paper No1 "Risk Governance – Towards an Integrative Approach", IRGC, Geneva, 2005. The full text of this document can be downloaded from www.irgc.org

2 http://www.irgc.org/IMG/pdf/An_introduction_to_the_IRGC_Risk_Governance_Framework.pdf

In terms of the IRGC framework groundwater risk assessment within the implementation of the WFD can be understood as representing the pre-assessment phase, which is a prerequisite to establish an integrated and coherent information and data collection process for ending up with a sound understanding at the characterisation and evaluation phase (phase 3). This phase can be understood as being equal to the status assessment. Importantly it is to recognize that the evaluation according to the IRGC framework puts emphasis on having an acceptability and tolerability judgement.

RISKBASE[3], a Coordination Action on Risk Based Management of River Basins, understands the WFD as being risk-based, ecologically centred and recognizing the need to balance improvements to water and ecosystems quality with economic benefits (Brils J. and Harris B, Eds. 2009). Asking for well-designed, coordinated and monitored 'learning catchments' to transform the general framing and develop best practice the risk governance framework described by the International Risk Governance Council is recommended as a source of inspiration to integrate assessments and management.

## 2.3 Objectives defined by the WFD

Underlying the many references to risk within the WFD (see Annex 1) is the concept that we are assessing the impact of human activity on the environment and specifically those impacts that threaten our ability to meet the objectives of the WFD (as set out in Article 4[4]).

Article 4 contains five objectives for groundwater:

1. Prevent or limit the input of pollutants;
2. Prevent the deterioration of status of groundwater bodies;
3. Achieve good groundwater status (both chemical and quantitative);
4. Implement measures to reverse any significant and sustained upward trend;
5. Meet the requirements of protected areas.

WFD objectives apply at different scales and so the Source-Pathway-Receptor (SPR) model for each of these objectives will also be scale dependent. This will have a direct effect on the scope and scale of the conceptual models that are an essential part of describing and assessing risks.

For groundwater quantity, risk assessment is focused on objectives 2, 3 and 5 and in particular quantitative status as defined in Annex V, 2.1.2 of the WFD. Taking account of all the elements of this definition requires assessment of risks at scales varying from local (impacts on individual dependent surface waters or terrestrial ecosystems) to groundwater body scale (available resource balanced against the recharge and abstraction).

Taking in account the description of good qualitative status in WFD Annex V all the objectives of Article 4 apply for groundwater quality. The relationships between these objectives are more complex and interdependent, as described below and in CIS Guidance Documents nos. 17 and 18 (Refs 1, 2). Risks need to be assessed for a wide range of SPR relationships at scales from the very local (for example, consideration of whether engineering design and operational controls applied to storage of hazardous substances in a tank are sufficient to prevent their release from the storage system and entry into groundwater) through to medium scale (for example, impacts on individual abstraction boreholes or terrestrial ecosystems) and finally to whole groundwater bodies (whether a body achieves good status).

## 2.4 Temporal scale of groundwater risk assessment

We also need to consider the time horizons over which risks need to be assessed. In order to manage risks on a day to day basis the primary focus for the prevent or limit objective is the immediate impact

3 Integrated risk-based Management of the water-sediment-soil system at river basin scale; funded under the EC 6th RTD Framework Programme (FP6), reference GOCE 036938

4 In the case of Groundwater Chemical status this includes meeting the requirements of Article 7 (Drinking Water Protected Area objective; CIS Guidance Document no. 16).

of an activity on groundwater with a view to maintaining existing good controls, improving management where necessary, restricting or prohibiting that activity as most appropriate. In contrast, the ability to achieve good groundwater status has to be evaluated taking into account the typically long time-scales associated with hydrogeological processes at the groundwater body scale. Risk management measures may take many years (or even decades) to have a significant impact on status.

Status assessment (the classification of water bodies) is formally undertaken and reported once every six years and is based on monitoring data collected over the previous river basin planning cycle. The current status of the water body reflects any effects resulting from measures that have been undertaken in previous plan periods. In contrast, the risk assessments for all the Article 4 objectives (considering both chemical and quantitative status), as described in Article 5 of the WFD (obligation to submit a report according to Article 15 of the WFD) and noted in Figure 4, looks forward a couple of years and attempts to predict what the condition of the groundwater body will be at the end of the next river basin management plan period. Based on this assessment and the procedures noted in Articles 4 and 11 of the WFD, measures may be put in place. These measures, which should reflect the risks identified in the Article 5 report, may comprise strategic planning, remediation schemes, abstraction controls and "prevent or limit" measures mentioned above.

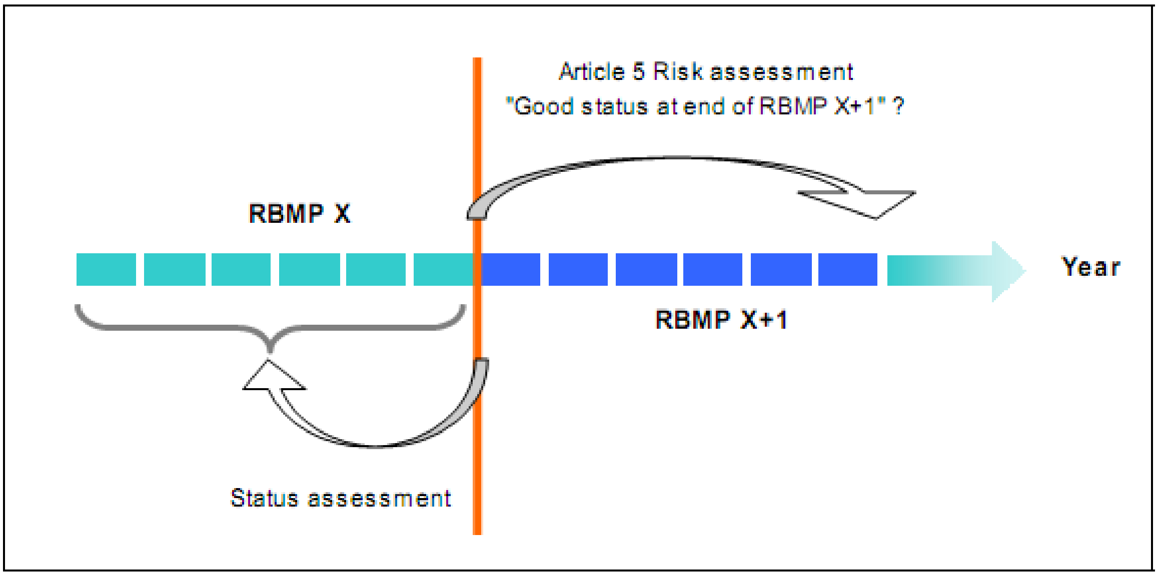


*Figure 4: Risk assessment regarding the status objective looks into the future whereas status assessment looks back on the performance (from CIS Guidance document No.18)*

## 2.5 Considering uncertainty

Uncertainty affects all stages of the risk assessment and management processes. Analysing the sources and magnitudes of uncertainties can help to identify knowledge gaps and inform decision makers on the most appropriate risk management measures, including whether or not precautionary action is necessary. When making decisions on risk management options it is important to understand how different sources of uncertainty (in data, from sampling, environmental variability, lack of knowledge and in models) contribute to the variation in the final risk estimates. Sensitivity analysis (varying parameter values in the risk model to examine the variation in outcomes) is very useful in this respect.

Compared with most environmental media, the groundwater environment is rather inaccessible, highly heterogeneous and difficult to observe/monitor. The movement of pollutants in three spatial dimensions and over the long timescales that are typical of many groundwater environments make predictions difficult. As a consequence a large degree of uncertainty is inherent in many hydrogeological assessments, particularly with respect to pathways. For example, movement through and attenuation in the unsaturated zone is a key factor in determining the risk to groundwater quality from an activity on the land surface. Yet this pathway by its nature is one of the most difficult to monitor.

Risk assessment and uncertainty analysis are of wide application in groundwater protection. They can act as a counterbalance to the costs and practical difficulties in directly observing pollutant linkages. For many subsurface processes a statistical or deterministic approach to risk assessment may not be necessary or feasible and a “weight of evidence”[5] approach may either be sufficient or the best we can achieve. In both circumstances conceptual models (see chapter 3 and Annex II) are an essential supporting tool to risk assessments in these circumstances.

## 2.6 Tiered risk assessment

Rarely in groundwater assessments do we have sufficient data to make reliable predictions in outcomes. Tiered risk assessment combined with a simple assessment of confidence can assist in focusing resources on those areas of highest uncertainty and of utmost relevance to risk management decisions.

A typical example of tiered assessment is given in Figure 5. Here the risk assessment aims to divide a group of groundwater bodies into those that are “at risk” or “not at risk” failing to meet good status. Risk screening is used to pragmatically divide the groundwater bodies in an efficient course of action into those where there is high confidence that the body is “not at risk” or is “at risk” failing to meet the status objective (based on monitoring and hazard data and clear environmental standards). What remains in the centre of the figure is a group of bodies where there is relatively low confidence (substantial uncertainty) in the assessment. Qualitative assessments as well as semi-quantitative assessments are pressure and parameter-specific (e.g. evidence for parameter A, uncertainty and further investigation necessary for parameter B) and prepare the final classification.

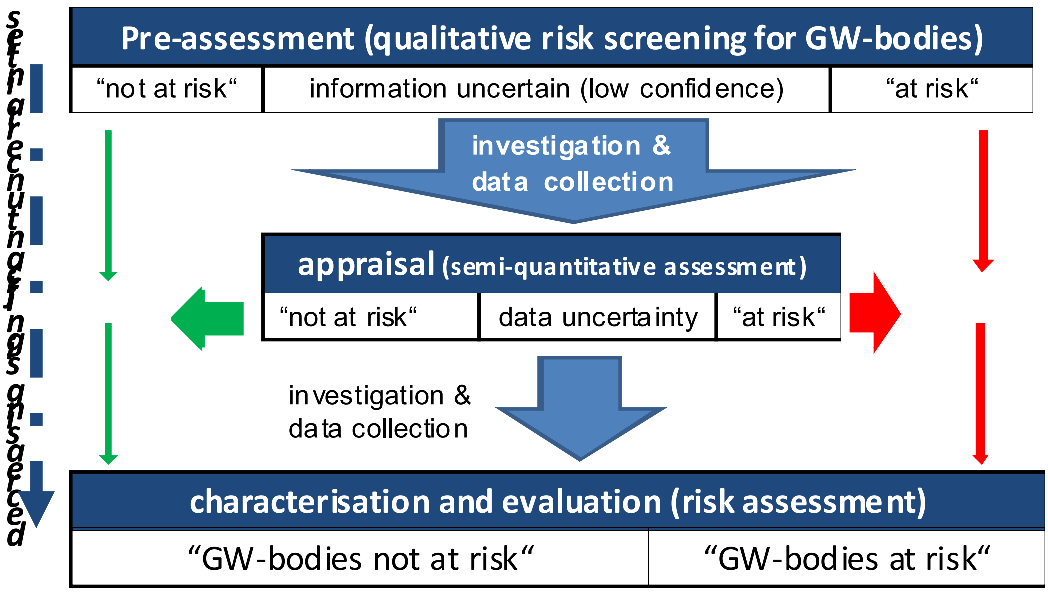


*Figure 5: Tiered approach for risk assessment (from Technical Report on Groundwater Risk Assessment – adapted)*

At the next level of assessment (appraisal often termed as semi-quantitative assessment) further data collection and analysis are focused on the remaining bodies. These are then further divided into “not at risk”/”at risk” bodies where there is now sufficient confidence in the assessment, leaving a further tranche of bodies where there is still significant uncertainty. The process is then repeated until all bodies can be assessed with an acceptable degree of uncertainty. It follows that additional investigation and monitoring should be focused on those areas where there is most uncertainty rather

5 The use of whatever data are available to make an assessment of the most likely outcome or the ‘direction of travel’ in the assessment.

than those areas where there is confidence that groundwater is in a good or poor condition in relation to the "at risk" assessment. If significant data uncertainties remain the characterization and evaluation needs to follow a transparent 'weight of evidence'-approach to classify a groundwater body as being "at risk" or not.

Tiered assessment is implicit in the overall WFD river basin planning process. The initial characterization is often based on little data but is conservative. Where risks are identified further characterisation is required to identify the likely pressures and impacts and areas of uncertainty. From the second cycle onwards uncertainty should diminish because monitoring data, from the WFD monitoring programme will be available. These data in turn can be used to improve the risk assessment. Figure 2 shows that the monitoring strategy, measures and status assessment (including the setting of threshold values) take place after risk assessment. So for the planning cycle (n+1), the knowledge gathered during the previous planning cycle (n), should be used to review monitoring strategy, measures and threshold values.

## 2.7 Risk Assessment and the precautionary principle

The approach taken by the European Commission in applying the precautionary principle is elaborated in a communication document from 2000[6]. In the Rio Declaration[7] the precautionary principle was interpreted as follows:

*"Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."*

Following this principle it is not acceptable to delay taking action because of uncertainty where there is a risk of serious harm. The use of risk assessment can sometimes seem to be in conflict with this principle. In reality risk assessment can be employed to clarify issues and identify impacts that are serious enough to warrant precautionary action.

The use of the precautionary principle presupposes a scientific evaluation of the risks which, because of the insufficiency of the data, their inconclusive or imprecise nature, makes it impossible to determine with sufficient certainty the risk in question[8].

Conversely risk assessment can also identify where impacts are unlikely to occur and/or be serious. If further investigation would significantly improve our knowledge and confidence and provide better focus for risk management measures, action may be delayed, providing no serious or irreversible harm would result.

The principle should be considered within a structured approach to analysis of risk which comprises three elements: risk assessment, risk management and risk communication. Where action is deemed necessary, measures based in the precautionary principle should be, inter alia:

- subject to review, in the light of new scientific data, and
- capable of assigning responsibility for producing the scientific evidence

necessary for a more comprehensive risk assessment.

The prevention of the input of hazardous substances to groundwater is an example of where a precautionary approach has been adopted. Substances are classified as hazardous based on their inherent toxicity, persistence and bioaccumulative properties. Despite this fact, there are circumstances where evidence of hazardous substances in groundwater does not contradict the precautionary principle. Given a risk assessment (supported by monitoring data) can demonstrate that such inputs are environmentally negligible and all necessary and reasonable measures to prevent have been taken, they are tolerable under the GWD and in accordance with the precautionary principle.

6 "Communication from the Commission on the precautionary principle", COM(2000) 1

7 United Nations Conference on Environment and Development, 1992

8 COM (2000) 1 final, p. 14

## 2.8 Improved risk assessment through the river basin planning cycles

The first Article 5 reports submitted by Member States (in accordance with Article 15) had to make predictions based on relatively sparse data and often with only a broad knowledge of the operational requirements of the WFD Article 4 objectives. For example, at the time the first Article 5 reports were compiled the detailed requirements for groundwater quality (and in particular groundwater chemical status) were unknown as these were subject of the GWD and CIS guidance (Ref 2). The first risk assessments will therefore be associated with substantial uncertainties.

Member States now have the benefit of both clarity on objectives and operational requirements, with several years of monitoring data and the first status assessments (classifications). Conceptual models can now be used to assimilate and focus new risk assessments on areas of greatest uncertainty. By this process we can build on the work of the previous river basin planning cycle and improve our future risk assessments.

Through time, the scope and scale of risk assessments (and associated uncertainties) should decrease, reflecting better data and the impact of measures, unless new threats to the environment appear. A minimum level of risk assessment will always be necessary as the WFD will continue to require forward predictions of complex environmental conditions and processes.

# 3. CONCEPTUAL MODEL OVERVIEW

## 3.1 What are conceptual models and what are they used for?

A conceptual model is the basis for reliable decisions in groundwater risk assessment and management. The aim is to have an instrument for:

- Experts discussing, developing and complementing their understanding of the groundwater system
- Communication with the public and decision makers: making non-experts understand how an aquifer system is working;
- Understanding and visualization of both simple and complex groundwater bodies, depending on the purpose;
- Assessing risks related to groundwater;
- Visualisation of how, where and when risks may impact groundwater;
- Planning of monitoring systems and measures to protect or remediate groundwater;
- Prediction of the effects of measures;
- Providing a reliable basis for simulating and predicting processes in groundwater with mathematical or numerical (computer) models;
- To help an assessor identify whether a groundwater body achieves its Article 4 objectives;
- To identify the reasons why a groundwater body fails any status objectives;
- To allow short-listing of the potential measures that are most likely to remedy the situation in an effective and sustainable manner;
- Justifying exemptions/alternative objectives where there is a risk of failing to achieve good groundwater status.

In the new Groundwater Directive as well as in several of the CIS Guidance Documents the use of 'conceptual models' is mandatory or recommended (see chapter 3.3). The term 'conceptual model' is not defined in the Groundwater Directive, nor is there a common definition by the Guidance Documents that recommend its use (different definitions see Table 2). The circumstances under which conceptual models can be applied may vary widely, from detailed assessments by hydrogeologists to a simplified picture of interacting processes for communication purposes with stakeholders. The fact that the use of conceptual models is recommended in several Guidance Documents, emphasises that conceptual models are *important* tools in groundwater management.

First experiences with the characterisation reports and status assessments indicate that Member States use very different approaches. *Working Group C has initiated this Guidance with the aim of creating a common understanding of conceptual models and risk assessment and the use of conceptual models within groundwater management*. The term conceptual models have been introduced in several Guidance documents before, to support different purposes. This Guidance intends to complement these earlier documents and gives an overview of available knowledge on this subject, relating it to the different steps of groundwater management.

It is also not the intention to choose a 'correct' definition of the term 'conceptual model' but rather to discuss how models, including conceptual ones, can assist in groundwater management. The philosophy behind the WFD is to start thinking about (ground)water management with all available knowledge (no matter how little), then focus on what are or may be environmental or human risks and then collect information where needed to improve understanding. In this process, one may start with a schematic description, then point out possible risks, start monitoring and use the monitoring results to improve the understanding of the system and the effectiveness of measures. If necessary for a better understanding, or for a selection of the most appropriate measures, the conceptual models may evolve into (complex) numerical models. The starting schematic model can definitely be called a *conceptual* model. A complex numerical model is definitely *not* a *conceptual* model anymore. For the purpose of groundwater management it doesn't really matter to what extent models are still called *conceptual models*. What counts is that simple models are sufficient for the initial phase of groundwater management, and that more complex models need to be used only if and when appropriate within the management process.

*Definition of conceptual model*

In the context of this guidance, a conceptual model is a means of describing and optionally quantifying systems, processes and their interactions. A hydrogeological conceptual model describes and quantifies the relevant geological characteristics, flow conditions, hydrogeochemical and hydrobiological processes, anthropogenic activities and their interactions. The degree of detail is based on the given problems and questions. It is one of the basic steps for the management of groundwater bodies.

Conceptual models are needed to describe groundwater quantity (linked to quantitative status) as well as chemical composition (chemical status) of groundwater, as referred to in the WFD.

Conceptual models can be developed to different degrees of complexity, from simple qualitative descriptions of the geology to complex combinations of qualitative and quantitative descriptions of the hydrogeological processes and the impacts. To cover the different needs for management of groundwater bodies, spatial investigation scales vary from small (10-100's $m^2$ ) to large ($km^2$) and time resolution from hours/days to month/years. It depends on specific tasks and problems (e.g. groundwater quantity, chemical composition, point source pollution, diffuse pollution, interaction with surface waters, land use). For transboundary groundwater bodies it is highly recommended that jointly agreed conceptual models are developed.

Annex II describes a way of setting up a conceptual model. Depending on the special requirements of the different WFD activities described above, a basic three step procedure is suggested, with differing data requirements, scales and complexity.

## 3.2 Role of conceptual models within groundwater management

The management of groundwater systems consists of steps in a continuous cycle as described in the Introduction (see Figure 2). Within the cycle of groundwater management conceptual models can be used in different phases with a different purpose, such as risk assessment, monitoring strategy and status assessment (see Figure 6).

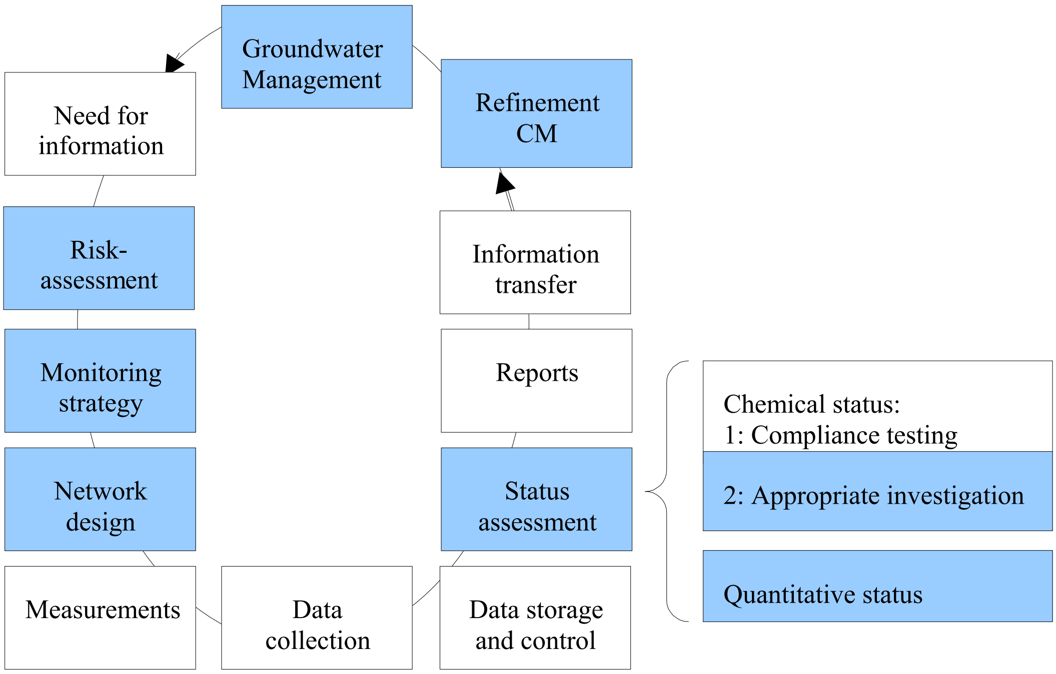


*Figure 6: Role of conceptual models in groundwater management in blue the steps where conceptual models can be useful or may be even essential)*

In the *first phase* of the implementation of the WFD, groundwater bodies had to be delineated and characterised (Groundwater Body System). The main emphasis was on the general description of the hydrogeological system, including the chemical and quantitative conditions in the groundwater body. This system could mostly be understood and made transparent to the public with the help of basic (simple) conceptual hydrogeological models:

- These models should roughly describe groundwater flow directions in relation to the main watercourses and the position of important terrestrial and aquatic ecosystems within the groundwater body, as well as the distribution of relevant land uses.
- It is a good starting point for planning a monitoring strategy and developing a representative monitoring network - by comparing the number and distribution of existing monitoring stations with hydrogeological and hydrochemical data, the distribution of (potential) inputs and the receptors that could be affected.
- Existing conceptual models may be refined and the need for more detailed (hydro)geological data at a more local scale can be assessed. New hydrogeological data and the results of monitoring may lead to more complex conceptual hydrogeological models at more detailed scales if necessary.

In the *second phase*, during the first status assessment in 2009 additional data (hydrochemical monitoring data, groundwater level data, recharge and abstraction rates) were collected:

- Additional data can now be integrated into the existing conceptual models.
- Based on the results of the first status assessment and a refined conceptual model, the future development of groundwater status (quantitative and chemical) can be assessed.

In the *third phase*, the assessment of the future development of groundwater status leads to a prediction of whether the good quantitative and chemical status of groundwater can be achieved by the end of the (next) plan period. If not, (additional) measures have to be undertaken by a Member State:

- In predicting the effectiveness of measures in time and space, sometimes more specific data are needed. In particular, the behaviour of seepage water in the unsaturated zone and groundwater flow times can be added to a conceptual model and may lead to incorporation of a more sophisticated mathematical model.

## 3.3 Use of conceptual models and references in CIS guidance documents

### *3.3.1 Use of conceptual models within the WFD*

The WFD does not contain the term 'conceptual model', but implicitly requires the set-up of conceptual models, by requesting Member States to characterise all water bodies. For each water body it has to be determined whether there is a risk of failing to meet the objectives at the end of the plan period. A conceptual model is indispensable for this purpose. The most important parameters to be taken into account in characterisation are listed in WFD Annex II, paragraphs 2.1 and 2.2 (see Look-Out-Box below) and discussed in Chapter 5 of this guidance.

## LOOK OUT!

Annex II of the Water Framework Directive

2. GROUNDWATERS

**2.1. Initial characterisation**

Member States shall carry out an initial characterisation of all groundwater bodies to assess their uses and the degree to which they are at risk of failing to meet the objectives for each groundwater body under Article 4. Member States may group groundwater bodies together for the purposes of this initial characterisation. This analysis may employ existing hydrological, geological, pedological, land use, discharge, abstraction and other data but shall identify:

– the location and boundaries of the groundwater body or bodies,
– the pressures to which the groundwater body or bodies are liable to be subject including:
  - diffuse sources of pollution
  - point sources of pollution
  - abstraction
  - artificial recharge,
– the general character of the overlying strata in the catchment area from which the groundwater body receives its recharge,
– those groundwater bodies for which there are directly dependent surface water ecosystems or terrestrial ecosystems.

**2.2. Further characterisation**

Following this initial characterisation, Member States shall carry out further characterisation of those groundwater bodies or groups of bodies which have been identified as being at risk in order to establish a more precise assessment of the significance of such risk and identification of any measures to be required under Article 11. Accordingly, this characterisation shall include relevant information on the impact of human activity and, where relevant, information on:

– geological characteristics of the groundwater body including the extent and type of geological units,
– hydrogeological characteristics of the groundwater body including hydraulic conductivity, porosity and confinement,
– characteristics of the superficial deposits and soils in the catchment from which the groundwater body receives its recharge, including the thickness, porosity, hydraulic conductivity, and absorptive properties of the deposits and soils,
– stratification characteristics of the groundwater within the groundwater body,
– an inventory of associated surface systems, including terrestrial ecosystems and bodies of surface water, with which the groundwater body is dynamically linked,
– estimates of the directions and rates of exchange of water between the groundwater body and associated surface systems,
– sufficient data to calculate the long term annual average rate of overall recharge,
– characterisation of the chemical composition of the groundwater, including specification of the contributions from human activity. Member States may use typologies for groundwater characterisation when establishing natural background levels for these bodies of groundwater.

The initial characterisation had to be carried out for all water bodies. Therefore the data listed according to WFD, Annex II, paragraph 2.1, should be available for all groundwater bodies. Many of the data required for developing conceptual models can be derived from the initial characterisation. Often this will be sufficient for at least basic conceptual models. Further characterisation (see Look-Out-Box and WFD Annex II, paragraph 2.2) only needs to be conducted for groundwater bodies that are considered to be ‘at risk’ of failing the WFD’s environmental objectives following the initial characterisation. (Note that, as explained in chapter 2, in case of doubt a groundwater body should be declared ‘at risk’.)

One aim of using conceptual models is to *describe the relation* between groundwater quality/resources, the local (geogenic) conditions and anthropogenic inputs/impacts *in an understandable way*. In the case of no or only little groundwater (monitoring) data the conceptual model contains basic information, e.g. on land use distribution within the area of the groundwater body, a rough estimation on depth to groundwater, characteristics and thickness of the overlaying soil and groundwater flow direction. Nevertheless with this more generic information it is already possible to give a first rough estimation on what kind of impacts (pollution, damage caused by abstraction) could be expected in which region of the groundwater body. At this stage the role of the conceptual model is to provide the basis for a reasonable set-up and extension of a monitoring network.

Subsequently, monitoring data is used to check the assumptions made for the first conceptual model. This improvement of the conceptual model is an important element in the groundwater management process in order to increase system understanding and to develop effective planning and control measures. This check and (re)balance may have various outcomes:

- In the case of a good correlation between the conceptual model assumptions and the measured data (especially when no risk of deterioration of good status can be observed[9]), usually there is no further need to refine the conceptual model or collect additional data.
- Where there is significant divergence, this has to be explained. This requires the collection of more data (e.g. extension of monitoring network, increased monitoring frequency) or additional data (e.g. input of substances, degradation/retention capacities, flow/spreading velocities in groundwater/leachate). This process may need to continue until the improved conceptual model can describe the measured data in a consistent way, with sufficient certainty.
- To find impartial criteria with sufficient certainty is difficult (see also section 3.6). Resolving the uncertainty sufficiently may be difficult, but it is better to invest in a good conceptualisation than to base measures on a weak conceptual model, with the risk that those measures may be ineffective in meeting WFD objectives or are simply unnecessary.

### *3.3.2 'Conceptual models' in guidance documents*

Conceptual models are mentioned in several previously published guidance documents as listed in Table 1. In some of these documents, a definition is given (see table 2). Several of the documents stress the iterative process of developing conceptual models and refining them where necessary. They note that conceptual models are useful in:

- understanding the significance of pressures;
- design of a monitoring network;
- interpreting monitoring data;
- evaluating the monitoring network;
- establishing threshold values;
- status assessment;
- trend assessment.

9 Note that, according to Article 5.2 of the Water Framework Directive, the characterisation "shall be reviewed, and if necessary updated". That implies that a complete re-characterisation is not always needed.

*Table 1: Overview of EU guidance documents relevant for groundwater. Indicated is whether the document holds definitions and/or recommendations for conceptual models. Taken from Spijker et al., 2009.*

| CIS Guidance document | Definition | Recommendation |
|---|---|---|
| No 3, Pressures and Impacts | - | + |
| No 7, Monitoring | + | + |
| No 12, The role of Wetlands | - | - |
| No 15, Groundwater Monitoring | + | + |
| No 16, Drinking Water Protected Areas | - | - |
| No 17, Guidance on Preventing or Limiting Direct and Indirect Inputs | + | + |
| No 18, Guidance on Groundwater Status and Trend Assessment | + | + |

*Table 2: Definitions of conceptual models given in four guidance documents.*

**Guidance document on Monitoring:**
'A conceptual model is a simplified representation, or working description, of how the real hydrogeological system is believed to behave. It describes how hydrogeologists believe a groundwater system behaves'

**Guidance document on Groundwater Monitoring:**
'Conceptual models are simplified representations, or working descriptions, of the hydrogeological system being investigated'

**Guidance document on Preventing or Limiting Direct and Indirect Inputs:**
'A conceptual hydrogeological model is the schematization of the key hydraulic, hydro-chemical and biological processes active in a groundwater body'

**Guidance document on Groundwater Status and Trend Assessment:**

'Conceptual models are (...) a working understanding of the geological and hydrogeological system being studied'

This guidance document deals with risk assessment, one of the areas for which conceptual models can be applied. Therefore the remaining part of this chapter as well as Annex II, focus on the use of conceptual models in risk assessment.

## 3.4 Properties of conceptual models

### *3.4.1 Spatial and temporal scale*

Before developing a conceptual model, it is important to determine its areal extent and its boundaries. A conceptual model for a groundwater body looks different than a model for a catchment area of one abstraction site. In both cases however, it is important to realise that an effect which is observed at one point, can be caused by a pressure at some distance. Therefore the spatial boundaries of the model should be chosen carefully and in 3 dimensions. In case of doubt, it is better to choose the boundaries well beyond the area of interest albeit they may subsequently be reduced as hydrogeological/physical information allows the zone of potential influence to be delineated (e.g. as groundwater flow direction or the geological boundaries of an aquifer system are established); the iterative process described before will lead to a better understanding of the relevant area. Similarly, it is important to consider the temporal scale relevant for the model.

Annex II describes this in more detail.

### *3.4.2 Main points during set-up of a conceptual model*

Four aspects are important during set-up of a conceptual model.

1. Main characteristics:
    a. Scope and questions to be answered - to determine the degree of detail and complexity of the conceptual model.
    b. Determination of the relevant area.
    c. Definition of vertical and horizontal structuring units (hydrogeological units).
    d. Land use distribution

2. Parameterisation/quantification:
    a. Description and quantification of important hydraulic, geochemical and hydrochemical parameters introduced *where possible and necessary*.
    b. Consideration of processes with slow kinetics (e.g. solution processes, unsaturated zone flow, changes in surface conditions, climate variations).
    c. Description of the most important climatic and unsaturated zone parameters.
    d. Identification of emerging issues that could pose a potential risk.

3. Dealing with uncertainties: we need to assess potential uncertainties, variability, and whether data are representative.

4. Evaluation of a conceptual model: it is advisable to start with a simple model, then analyse its performance and, by stepwise improvements, make a more complex model if the simpler model is not sufficient. It might be necessary to return to a previous step if it turns out that the conceptual model is not consistent with actual data.

Corresponding to these systematic issues it is important to recognise that establishing and refining a conceptual model is an iterative process and all relevant parties should be involved this process.

## 3.5 Look out for visualisation

It is important to document all steps of the conceptual model. The complexity of the visualisation is dependent on the scoping questions and the potential audience. It can extend from simple 2D maps to more elaborated cross sections and 3D pictures. Annex II gives a more detailed description of the procedure, with proposals for an appropriate level of visualisation.

An example of visualisation is taken from www.wfdvisual.com (see Figure 7) and completed with labels describing the most relevant information. A three-dimensional basic picture like this without exact scale can be used for information of politicians, stakeholders and the interested public to help visualise the hydrogeological situation and the data needed. This picture shows the spatial distribution of an aquifer and the overlying unsaturated zone, the flow and direction of groundwater and surface water and hydrogeological features of the aquifer, such as aquifer type (fissured), lithology (sandstone), permeability etc. By combining the hydrological components - precipitation, groundwater recharge, surface water and groundwater - in one picture, the (conceptual) relationships can be shown. Also shown are the pressures (both for chemical quality and quantitative status) as well as the relevant receptors.

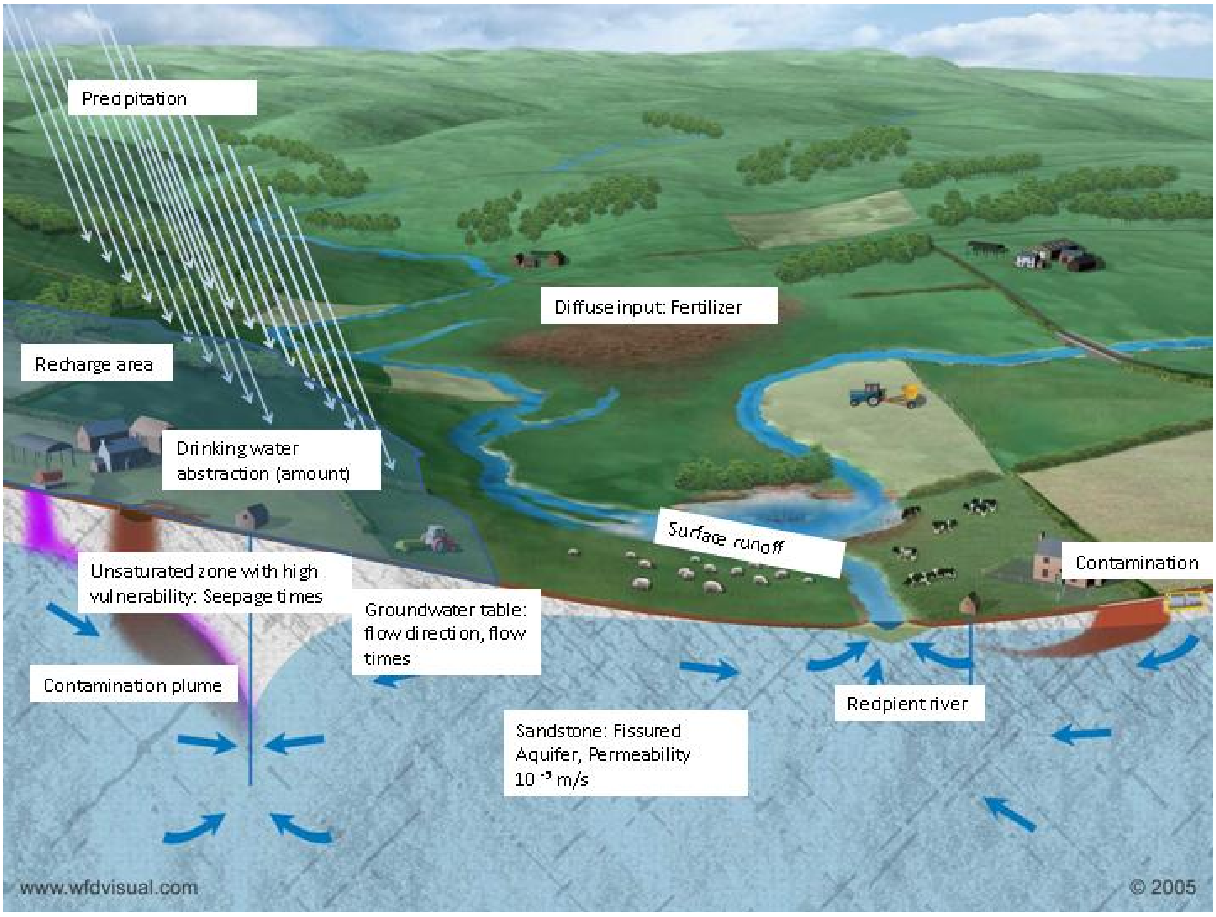


*Figure 7: Visualisation example for a conceptual model. Reproduced with permission from WFDVisual.com (www.wfdvisual.com).*

### 3.6 Validation and quality assurance of conceptual models

A conceptual model is dynamic, evolving with time as new data are obtained and as the model is tested. Its development and refinement should adopt an iterative approach. Before re-characterisation takes place, the conceptual model should be evaluated, refined and validated. All data concerning the nature of the groundwater body collected during the characterisation process should be tested against the conceptual model, both to refine the model and to check for data errors. In doing so, the distance to target should be kept in mind: the closer a groundwater body gets towards poor status the more accurate the conceptual model should be in order to carry out a correct compliance test.

Wherever possible, validation of a conceptual model should be based on sufficient monitoring data. Where this is not possible, an analysis of the characteristics of the pressures and receptors combined with monitoring data can be a suitable validation method. Following the approach applied to the selection of relevant substances (CIS Guidance Document No. 3), one can analyse the pressures on a groundwater body (top-down), analyse the observed effects on receptors (bottom-up), and compare these, taking into account travel times within the environment. This comparison offers insight in the validity of the conceptual model. Overall, the weight of evidence should support the conceptual model.

In general it is important to plan and log the validation steps that will be carried out, taking into consideration aspects such as availability of data and the distance to the final objective.

## 4. WFD OBJECTIVES AND RISK ASSESSMENT

This chapter discusses the use of risk assessment with respect to the five objectives of Article 4 (see Chapter 2.3). For the objectives prevent or limit (1), good groundwater status (3) and protected areas (5), a lot of information is already available. Especially relevant are the following:

- CIS Guidance Document No.3 'Analysis of Pressures and impacts' (2003):
  - (page 25–50) chapter 3 describes a 'general approach for the analysis of pressures and impacts'
  - (page 63–65) section 4.5.3 deals with tools to assist the analysis of pressures and impacts, especially for groundwater
  - (page 70–76) sections 5.2 and 5.3 deal with 'information needs and data sources' when analysing pressures and impacts.
- Technical Report on Groundwater body characterisation (2004):
  - (page 6 and 7) extracts about initial and further characterisation are especially useful for *how* risk assessment can be performed. These deal with chemical and quantitative status as well as with inputs.
- Technical Report on Groundwater Risk assessment (2004):
  - (page 13 and 14) extracts about initial and further characterisation (sections 2.4.1 and 2.4.2)
  - (page 14–18) chapter 3, 'specific guidance', sections 3.1, 3.2 and 3.3. Deals with:
    - identifying driving forces and pressures;
    - identifying significant pressures;
    - assessing the impacts of pressures
  - (page 19) evaluating the risk of failing the objectives
- CIS Guidance Document No.16 'Guidance on Groundwater in Drinking Water Protected Areas' (2007)
- CIS Guidance Document No.17 'Guidance on preventing or limiting direct and indirect inputs' (2007)

The above documents are not legally binding, but they are a result of discussions between many practitioners involved in implementing the groundwater aspects of the WFD and therefore represent a common understanding.

### 4.1 Prevent or limit the input of pollutants

This objective can apply at all scales from local (for point sources) to groundwater body (mostly for diffuse sources) and is described in detail in Guidance Document 17 (Ref 1). "Prevent or limit" measures are the first line of defence and are the most effective mechanism for protecting groundwater quality. If we correctly assess risks to meeting the 'prevent or limit' (P/L) objective and then implement appropriate risk management measures, in time all the other WFD groundwater quality objectives will be met.

The risk assessments for inputs of hazardous substances (which we must prevent) and non-hazardous substances (which we must limit to avoid pollution) are distinct.

For hazardous substances the risk assessment is curtailed in the sense that it has previously been determined (by the WFD and GWD) that, subject to the exemptions in Article 6 of the GWD, any entry into groundwater is undesirable and should be prevented[10]. In effect all sources (hazardous substances) are assumed to have similar characteristics and the target or receptor in all cases is the water table. SPR characterisation therefore is confined to the source (volume and physico-chemical properties) and the pathway linkages, in particular the ability of unsaturated zone (where this is present) to attenuate the inputs.

For non-hazardous substances a full SPR characterisation is needed as the sources may vary in terms of inherent hazard and the target may be groundwater in the vicinity of the input (in the case of a sensitive and valuable groundwater resource) or a receptor some distance down-gradient of the input, such as an abstraction or dependent aquatic or terrestrial ecosystem. What constitutes harm at the

10 Guidance Note No.17 describes what prevent means in the context of this objective.

targets (receptors) will vary according to the nature of the pollutant as well as to uses and the sensitivity of the receptor. The procedure for making this assessment is outlined in CIS guidance (Ref 1).

In terms of conceptual modelling only a relatively simple, site specific model may be sufficient to understand a local groundwater system and to assist the assessment of the risk of point source inputs to the P/L objective. The wider scale of diffuse inputs may require a more complex model to support the risk assessment.

Due to the very wide range of potential hazards and the multiple points of compliance, it is difficult to map the risks to the P/L objective for the purposes of the WFD Article 5 reports. Maps of potential sources of contamination can only give an initial hazard assessment at a large scale. Effective systems of permits or other controls may be in place. In this way risks are being managed to meet the P/L objective and it would be misleading to indicate that there is a risk of not meeting that objective. It is suggested that Article 5 P/L "at risk" maps should focus primarily on releases (point sources or delineated diffuse sources) that may not be under sufficient control to meet WFD objectives. There would then be a more direct relationship between the risk maps and the need to implement additional measures during river basin management planning.

## 4.2 Prevent the deterioration of chemical status of groundwater bodies

The risks of not meeting this objective comprise two elements:

- Those risks associated with a failure to have sufficient P/L measures (for both diffuse and point sources) in place – in other words, are all existing activities (potential hazards) under control?
- Risks arising from sources of contamination in the ground, where the original activity has ceased or is now under control but there is residual contamination that could impact in time on the status of water bodies.

The latter risk is particularly common in hydrogeological situations where flow is slow in the unsaturated zone or in the groundwater body, in deep aquifers and where recharge is low. It is particularly important in these cases to have a conceptual model that looks at historic as well as current activities and examines different time lines/temporal scales.

Because of the time lags (delays) between inputs at the land surface and impacts on the groundwater environment it is possible that some groundwater bodies may deteriorate from good to poor chemical status even when all necessary and reasonable measures to prevent or limit further inputs have been taken. Modelling may be necessary to make a full appraisal of the risks in such cases and these models will need to be supported by a validated conceptual model.

## 4.3 Achieving good groundwater status

CIS Guidance Document 18 describes the requirements for meeting good status. A number of tests or elements apply to both chemical and quantitative status as noted in Figure 1 of that document.

In order to undertake the "at risk" assessment for the next planning cycle, an assessment of the risks of not meeting good status for each test will be necessary. Initially the baseline conditions from which this assessment can take place must be defined. This will consist of an assessment (based on monitoring data) of both the current condition within the groundwater body and any significant trends in quality and/or level/flow conditions. This will then need to be combined with data on current and predicted land and water uses and inputs to groundwater (source characterisation).

A significant risk to any one of the elements of status will cause the groundwater body to be at risk of failing either groundwater quantitative or chemical status. This system is simple but a resulting map of risk for all the tests combined may not present a clear view of actual risks. It is recommended that risk maps for each element or test for good status are presented so that these can be directly compared to the status (classification) maps. The greater the number of pressures the more detailed the supporting conceptual model will need to be.

For some tests an assessment of deterioration is part of the test for good status (Drinking Water Protected Area and Saline intrusion tests), so there can be overlaps with the risk assessments for deterioration in status and the trend assessment.

Where there is a risk of failing to achieve good groundwater status, the conceptual model and risk assessments will play an integral part in justifying exemptions/alternative objectives.

## 4.4 Implement measures to reverse any significant and sustained upward trend

The risk assessment for this objective will be closely linked to the assessment of deterioration noted above – in many cases the monitoring data that will assess compliance will come from the same monitoring network. The main difference will be that in order to assess risks of not meeting this objective, we need to not only assess deterioration in quality but also when this deterioration will cease and when the trend will be reversed. Predictions will be over long time scales (probably several river basin management plan periods) and will be inherently uncertain.

A key part of the risk assessment will be consideration of not only the impact of past and current land use activities but what are also the likely future land uses that may have an impact on the predicted trends. Planned measures will need to be factored in to the assessment. Climate change could be a significant factor that may influence such long term trends. For example, changes in recharge or farming practices could reverse (or assist) the measures already taken to reverse upward trends. A series of future land use scenarios may need to be considered using the conceptual model of the groundwater body to assess in principle the potential impacts. This may extend to quantitative modelling to assess the effectiveness of any remedial measures under these different scenarios.

## 4.5 Meeting the requirements of protected areas

For both chemical and quantitative status, protected areas in practice come within the status objective via the requirement to assess the risks to dependent ecosystems. In addition, compliance with Article 7.3 (Drinking Water Protected Area objective) is one of the elements of meeting good groundwater chemical status.

In order to carry out a risk assessment for drinking water abstraction sites all information within the catchment area on inputs, groundwater characteristics (geohydrology and -chemistry) should be analysed in connection with each other. An initiative such as a Drinking Water Protection File can be a suitable platform for this (Wuijts et al., 2007; see Annex III). This approach can be applied to the analysis of dependent ecosystems as well.

## 5. ELEMENTS TO CONSIDER DURING THE 2ND PLANNING CYCLE

### 5.1 How to consider information and data of the previous planning cycle

#### *5.1.1 Key issues*

As noted in the introduction to this guidance, planning for the second cycle of WFD RBMPs starts soon after the delivery of the first RBMPs. The preparation period is significantly reduced from the 9 years of the first cycle (2000–2009) to 6 years (2010–2015), with the first key deliverable, the next Article 5 characterisation report, due in December 2013. Whilst Member States can (and must) build on the work undertaken during the first cycle it will be a significant challenge to undertake second cycle planning whilst simultaneously implementing first cycle measures.

The key elements of second cycle characterisation and risk assessment will be:

- Refinement of water body delineation, where necessary;
- Review of pressures and risks to identify changes and new pressures;
- Factoring in climate change;
- Refinement of characterisation procedures to ensure consistency of approach with classification (status assessment).

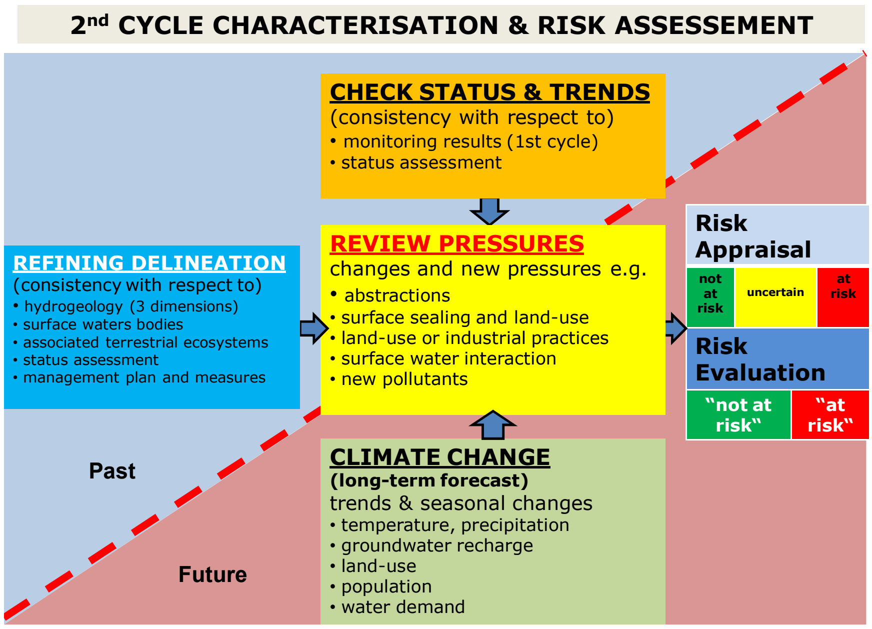


*Figure 8: Key elements to consider during the 2nd planning cycle*

#### *5.1.2 Water body delineation*

The delineation of water bodies, although subject to CIS guidance is not prescribed in detail in the WFD and therefore many different approaches have been adopted by Member States. Water bodies are management units and therefore their delineation should reflect management issues at the river basin district level.

With the benefit of experience from the first planning cycle, Member States may wish to change water body boundaries. However, in doing so, they should consider the consequent changes in status assessment/classification that may then follow. Radical changes in boundaries may affect the ability to provide a stable baseline against which the effectiveness of measures and progress in meeting WFD status objectives can be assessed – it will be difficult to assess compliance between RBMP cycles.

All groundwater bodies need to be associated with dependent surface water bodies - groundwater status is in part determined by the condition of these dependent water bodies. Therefore, changes in the delineation of both groundwater and surface water bodies must be taken into consideration. Potentially changes in status (both deterioration and improvement) could occur simply by changes in boundaries, whereas in practice there may be no environmental changes.

As a general guide it is advisable not to make whole scale changes in groundwater body boundaries from one river basin management plan to another unless this is essential to manage these water bodies and meet WFD objectives.

The WFD only requires the reporting of groundwater body boundaries in two dimensions and in some cases Member States may not have defined the third (depth) dimension for their groundwater bodies. However, it is advisable that the full spatial extent of groundwater bodies is defined and incorporated in conceptual models for the second river basin planning cycle, even if this is not formally reported.

The maximum depth of the groundwater body may be governed by purely hydrogeological factors or a consideration of whether there are any resource issues within a deep aquifer. As they are management units, it is not necessary to define groundwater bodies in deep aquifers that are not exploited by man and have limited connection to dependent ecosystems. Status assessments may serve no purpose in such circumstances but there is still a requirement to protect groundwater quality under the ‘prevent or limit’ objective.

### *5.1.3 Characterisation of groundwater bodies*

The characterisation within the second planning cycle has to take into account all the information gathered during the initial and further characterisation exercises in the first planning cycle. In addition all the data and information obtained from monitoring and other investigatory activities should be integrated in the new assessment.

First of all it has to be checked whether the delineation of groundwater bodies and dependent surface water bodies has changed. Then initial characterization (see Look-Out-Box chapter 3.3), should be conducted for any newly defined groundwater bodies or simply updated for existing groundwater bodies. These data are then used to assess whether a groundwater body is “at risk” of failing WFD objectives (including good status) at the end of the second management plan period (see chapter 4).

For groundwater bodies previously assessed as not being “at risk” checks must be made as to whether there are existing or planned changes in land use, abstraction or other factors causing a risk for the groundwater body itself, or for risks to directly dependent surface water ecosystems or terrestrial ecosystems or the risk of impairment of human and other legitimate uses that could prevent the achievement of WFD objectives.

Further characterisation must be carried out for all “at risk” groundwater bodies (see Look-Out-Box, chapter 3.3).

### *5.1.4 Monitoring data*

In the first planning cycle some Member States may have had little or no monitoring data on some of the significant pressures and impacts. With the implementation of WFD monitoring requirements all Member States should now have improved data which can be used to assess the accuracy of the first cycle risk assessments and to update the conceptual model of the groundwater body and/or the risk assessment. Based on any additional data gained to support the second cycle of characterisation, monitoring strategies and networks should be reviewed and if necessary revised. However, in refining monitoring networks checks must be made to ensure that monitoring to assess the effectiveness of measures and long term compliance with WFD objectives is not disrupted and the necessary consistency and comparability of data with previous cycles is maintained.

## 5.2 How to consider changes

### *5.2.1 Changes in land use*

The first cycle of initial and further characterisation should have set a baseline against which the measured and predicted future effects of new developments on groundwater quality and quantity can be assessed. If this baseline is incomplete, it should be further developed during the second cycle characterisation and risk assessment.

A key focus should be changes in agriculture and its water demand, due to e.g. future increasing production of biofuel or increasing monocultures for the production of fast growing firewood. Also important is the prediction of changes in population and future land use (e.g. growing towns, decreasing population in the countryside, changes in transport infrastructure, industrial activities, connectivity and interaction to surface water).

Groundwater quantity is often influenced by changes in land use. The sealing of the soil by building new traffic infrastructure and new settlement areas can have significant consequences for groundwater recharge. In addition to this, there can be an increase of water abstractions in the vicinity of settlements due to higher drinking water demand for population and industry. Changes in agriculture can cause a higher groundwater abstraction due to higher needs of irrigation.

Changes in land use also affect groundwater quality: ploughing up grassland mobilises the store of nitrogen. Higher needs in irrigation could be responsible for an increased leaching of nutrients from the soil. Growing new sorts of crop can cause a higher demand on fertilizers and pesticides. In this case it is very important to estimate the protection properties of the soil and the unsaturated zone and to avoid the cultivation of crops with high fertilizer or pesticide demand on high vulnerability soils and aquifers.

### *5.2.2 Climate change*

Groundwater resources and their long-term replenishment are controlled by long-term climate conditions. Climate change will therefore have a great impact on groundwater resources during the next decades. Although time scales of climate change and river basin planning cycles are different it is of importance to describe expected changes systematically already now.

Climate change can cause very different impacts on groundwater systems, from droughts and water scarcity in the Mediterranean region to increases in recharge in the mid-European countries. In humid regions, more frequent and intense precipitation incidents and longer dry periods may occur.

Groundwater will be less directly and more slowly impacted by climate change as compared to e.g. rivers. This is because rivers get replenished on a shorter time scale, and drought and floods are quickly reflected in river water levels. Groundwater, on the other hand, will be affected more slowly and sometimes by different patterns of precipitation. Only after prolonged droughts (particularly with reduced winter rainfall) groundwater levels will show declining trends.

Seasonal changes in precipitation are one important effect of climate change. Predictive models (e.g. Germany) forecast an increase of precipitation in the winter months and a decrease in the summer months. For agriculture, this has an effect on the irrigation demand in the summer months. Even if there is a higher groundwater recharge for the whole year, the increasing of groundwater abstraction in summer due to irrigation and a higher demand of public water supply may locally cause a long term trend of declining groundwater levels with all its consequences e.g. risks for terrestrial ecosystems and influences on the chemical quality of groundwater. Also irrigation itself can have impacts on groundwater quality, as more nutrients can be washed out of the soil.

Increased variability in rainfall may also decrease groundwater recharge in humid areas because more frequent heavy rain will result in the infiltration capacity of the soil being exceeded, thereby increasing surface runoff. In semi-arid and arid areas, however, increased rainfall variability may also increase groundwater recharge, because only high-intensity rainfalls are able to infiltrate fast enough before evaporating, and alluvial aquifers are recharged mainly by inundations during floods. (Groundwater and Climate Change: Challenges and Possibilities, BGR and GEUS, 2008).

For the second cycle of WFD Article 5 risk assessment, a consideration of the predicted changes in precipitation and groundwater recharge and the influence of its consequences (higher drinking water consumption in summer, rise in irrigation measures, surface runoff) is considered essential. The data of the dynamic regional climate modelling CLM / REMO could be used to estimate the effects of climate change in Europe. Climatic water balances using forecasted precipitation and temperature data can provide regional groundwater recharge data for the future. In connection with predictions of the development of population, water demand and changes in land use, the impact on quantity and quality of the GWB should be evaluated for the coming periods of the RBMP.

## 5.3 Risk assessment, Status and the use of threshold values.

### *5.3.1 Alignment of characterisation and status assessment methods*

The characterisation exercise for the first planning cycle was carried out before the requirements of the new Groundwater Directive (2006/118/EC) and therefore the detailed requirements for groundwater chemical status assessment were known. The use of threshold values in status assessment is a further key development, as noted below.

We also now have supporting guidance (e.g. CIS Guidance Document No 18). As a result there may be wide divergence between the first cycle characterisation and classification assessment methods - the Article 5 reporting of pressures and impacts may not necessarily align with the elements or tests of good status. It is recommended that the future risk assessments undertaken as part of characterisation should take into consideration the status elements defined in the new Groundwater Directive and its associated guidance.

### *5.3.2 The Groundwater Directive*

The Groundwater Directive in its preamble point 7 states that '(..) threshold values should be established, (..) , in order to provide criteria for the assessment of the chemical status of bodies of groundwater.' The chemical status is defined in the Water Framework Directive, Annex V, Table 2.3.2. Good groundwater status, according to that definition, refers to a situation where:

- no saline or other intrusions take place;
- quality standards are not exceeded (the Groundwater Directive set standards for nitrate and pesticides);
- the quality of groundwater does not lead to failure to achieve the environmental objectives for associated surface waters nor any significant diminution of the ecological or chemical quality of such bodies;
- the quality of groundwater does not lead to significant damage to terrestrial ecosystems which depend directly on the groundwater body;
- changes in conductivity do not point to intrusions.

According to Article 3.7 of the GWD, the European Commission has to prepare a report on the establishment of these threshold values within Europe. This report was published in March 2010 (Ref 8) which is a first important step of the implementation of the Directive.

The Groundwater Directive also specifies how threshold values should be used in determining the groundwater chemical status (Article 4.2). Basically, if groundwater quality standards or threshold values are not exceeded anywhere in the groundwater body by (time-averaged at each sampling site) the measurements, the body is in good status. In all other cases, the groundwater body does not immediately get assigned as "poor status", but Member States shall carry out an 'appropriate investigation'. In that investigation, Member States shall determine whether:

- the exceedance represents a 'significant environmental risk';
- the conditions for good chemical status of table 2.3.2 of the WFD are met;
- (for groundwater bodies from which water is abstracted for human consumption) the requirements of Article 7.3 of the WFD are met (avoiding deterioration in order to reduce the level of treatment required);

- the ability of the groundwater body to support human uses has not been significantly impaired by pollution.

In addition to the definition of the good chemical status from the WFD, the GWD explicitly mentions ‘significant environmental risk’, the requirements of Article 7.3 and the human use of groundwater in the context of good chemical status.

### *5.3.3 Guidance document on groundwater status and trend assessment*

Referring to the Groundwater Directives, CIS Guidance Document 18 (Groundwater status and trend assessment) further elaborates the assessment of status, including the ‘appropriate investigation’. The guidance document also deals with confidence in the status assessment and suggests the introduction of a surface criterion of 20% to quantify the ‘significance of an environmental risk’. This would mean that, provided the other tests have been met, an exceedance of less than 20% of the area does not lead to a poor status of the groundwater body. Nevertheless it needs to be recognized that besides this generic recommendation, specific considerations on pressures (e.g. land-use), the characteristics of groundwater bodies and possible receptors (e.g. surface water) are the necessary assumptions to derive a surface criterion more specifically.

### *5.3.4 Implications for risk assessment*

Although there is a framework for the use of threshold values in CIS Guidance Document No.18, the selection and precise use of threshold values (TVs) is determined by Member States and must be reported in their RBMPs. Threshold values should be derived for those pollutants responsible for the ‘at risk’ declaration of a groundwater body and must be set at a level whereby if no threshold value is exceeded, this means that there is no significant impact on the receptors noted in the definition of good chemical status. This in effect sets a potential upper limit to a threshold value. In contrast, there is little constraint on the lower limit to which a threshold value is set within the Directive itself. This is down to a variety of practical considerations and the level of precaution that the responsible body within the Member State wishes to adopt. In effect this means that, in terms of risk assessment, threshold values may be set at any level from a risk screening level (no risk to the receptor) through to a risk management level (higher values would result in damage to the receptor).

For the above reasons great care has to be exercised in applying threshold values to the risk assessments undertaken during characterisation – their application must take into account the status assessment method within which they have been used by the Member State. A further consideration is that whilst Member States may have reported (minimum) overall TVs for a groundwater body, they may have used different values in the assessment of each of the component elements of status. Environmental standards will vary between receptors and any risk assessment undertaken during characterisation needs to take account of such variations.

It is also important to note that initial characterisation is conducted to determine whether the groundwater body is “at risk” of failing any of the WFD’s environmental objectives, of which status is only a part. In the context of the WFD this is a precautionary risk screening exercise, which is quite distinct from the need to assess whether there is actual damage to a groundwater body from human activity (i.e. poor status) and therefore whether remedial action (measures) should be taken.

What does this all mean for the use of TVs in risk assessment? If TVs have been set at the risk screening level, then they can be used as such during characterisation to identify those groundwater bodies that are definitely not at risk, as far as the status and trend objectives are concerned. However, in many cases this will not be the case and risk screening values for the “at risk” assessment may have to be set a lower level than the reported TVs for groundwater bodies.

Whilst TVs may be a useful indicator for the risk assessment they should not be used in isolation. New substances may need attention, changes in land use may lead to new risks (or earlier risks may have been reduced), recent monitoring data may shed a new light on risks known before, and so on. The pressures and impact analysis from the previous planning cycle must be fully updated.

Special attention should be paid to the way Article 7 is included in the risk assessment. Since the Groundwater Directive also sets objectives for the human uses of a groundwater body, this should be part of the risk assessment. For abstractions within a groundwater body the groundwater quality in the abstraction wells should be evaluated in relation to the standards of the Drinking Water Directive and the risk of deterioration, by trend assessment (Article 7.3) (ref. to Guidance on DWPAs).

## 5.4 Risk assessment, measures and exemptions

It is important to highlight that this chapter is focused on the relation of the RA and exemptions for 2021 and not for the 2015 period.

The 1st risk assessment (2004) based on Pressures and Impacts Analysis was prepared principally without benefit of a status assessment and with little knowledge of limits and methods of groundwater body's classification. Status assessment, the derivation of TVs and trend assessment was conducted in the second half of 2008. The forecast of exemptions in 2015 (groundwater bodies failing the environmental objectives in spite of planned measures) was also needed. The time period between characterisation and the publication of the River Basin Management Plan (RBMP) was long enough to enable the collection of more data and the development or refinement of the assessment methods including exemptions.

Risk assessment for the 2nd RBMP should not be the same as for the first RBMP (2004). We have better knowledge, new methods and more data. The role of risk assessment is also different.

The same steps are required by the WFD in the 2nd river basin planning cycle but the time available for assessment is shorter: the results of river basin characterisation should be available by the end of 2013 and the status assessment and list of exemptions in 2021 must be prepared by the end of 2014 (see figure 1). GWBs which will not reach their environmental objectives by 2021 must be listed even where measures have been applied. The justification of proposed exemptions is an obligatory part of the RBMP according to the WFD requirements.

The time schedule has not been the only reason for paying more attention on role of RA in further exemptions assessment. The main characteristic of the risk assessment is the forecast of the groundwater status at the end of the management plan period. This is also the basis of the exemptions assessment. In 1st RBMP 4 years between the risk assessment (2004) and the status assessment (2008) allowed time to get both more quantitative and qualitative data. In the 2nd RBMP only 1 year is available for the same exercise.

Another main difference between the initial risk assessment and the list of exemptions in the next planning cycles is probably the uncertainty of status assessment results and planned measures. The low degree of the reliability and high level of uncertainty in the impact of planned measures in 1st Planning cycle are the most important gaps. Data from monitoring, using new approaches and methodology from the start of the second planning cycle can reduce such gaps.

Risk assessment in the 2nd planning cycle can, as a part of characterisation, reflect status assessment results from 2008-2009 but clearly cannot use the results from the second status assessment (due in 2015). On the other hand water bodies identified as being at risk (2nd cycle) are all the bodies where environmental objectives will not be met in 2021 without measures. Exemption assessment will be focused on water bodies in poor status (or with significant upward trend etc.) where we have to evaluate whether or not the planned measures will be effective. For this purpose, information about status assessment or other environmental objectives from 2014–2015 and the list of planned measures will be available. This means the same tool (or approach) can be used for risk assessment as for exemption assessment. Figure 9 presents the relation between the RA, exemptions and programmes of measures. The planning process should be made in an integral manner, since each part of the cycle influences other parts. Programmes of measures should be based on the risk assessment results, while using the conceptual models and other relevant tools increases the reliability in predicted outcomes.

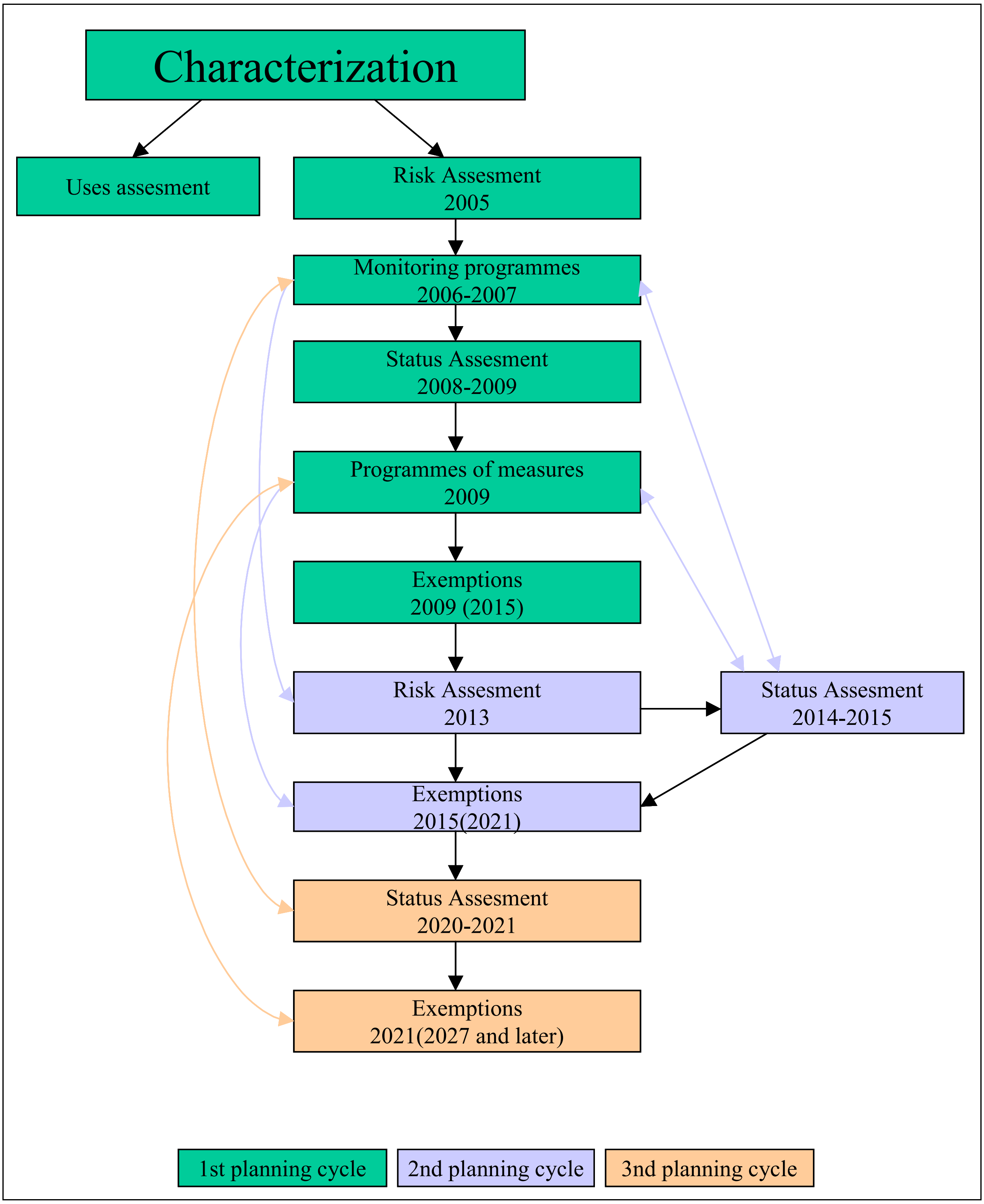


*Figure 9: Relation between the RA, exemptions and programmes of measures*

The RA is indirectly mentioned in the Guidance on exemptions (No. 20, 2009). The separate approach has been described in the text as well as in figures (e.g. figures 10). The figures also take into account the link between the measures and different types of exemptions. The list of exemptions should be reviewed every 6 years in the RBMP.

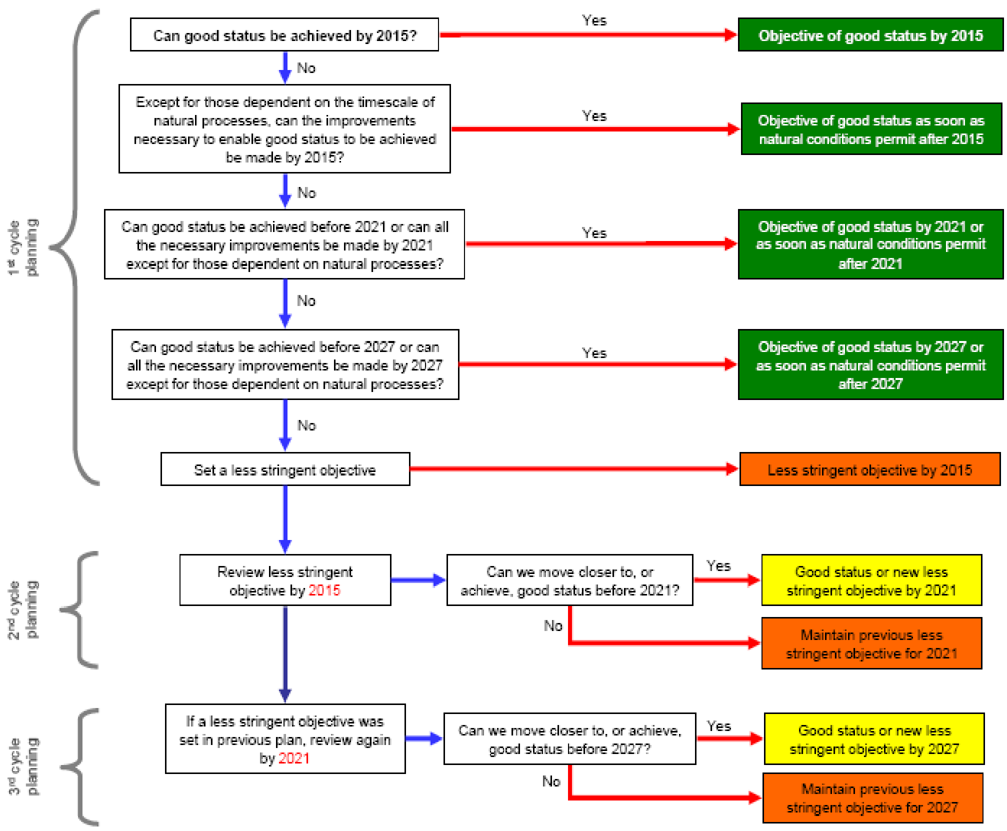


***Figure 1: Stepwise thinking process for the considerations of exemptions from good status. The orange boxes refer to Art 4.5, the green except the first box to Art 4.4. For water bodies designated as heavily modified or artificial, references in the Figure to 'good status' should be taken to mean 'good ecological potential and good surface water chemical status[16]. Note, if the objective of "good status" is aimed for (green boxes), the achievement of "good status" needs to be confirmed by monitoring data.***

*Figure 10: Scheme of the exemptions requirements and requirements of current RA (Link between measures and exemptions) (Guidance Document No. 20)*

# 6 References


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2. Brils J., Harris B. (Eds.), 2009: Towards Risk-Based Management of European River Basins: key-findings and recommendation of the RISKBASE project, EC FP6 reference GOCE 036938, December 2009, Utrecht, The Netherlands.
3. CIS Guidance Document No.17, 2007: Guidance on preventing or limiting direct and indirect inputs in the context of the Groundwater directive 2006/118/EC. Technical Report 2007 – 012.
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5. CIS Guidance Document No.16, 2007: Guidance on Groundwater in Drinking Water Protected Areas. Technical Report 2007 – 010.
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9. European Commission, 2008: Groundwater Protection in Europe.

# ANNEX I

## SUMMARY OF QUOTATIONS RELATED TO "RISK" IN THE WATER FRAMEWORK DIRECTIVE

| WFD | Quotation | Related topic | Related documents |
|---|---|---|---|
| Recital (44) | In identifying priority hazardous substances, account should be taken of the precautionary principle, relying in particular on the determination of any potentially adverse effects of the product and on a scientific assessment of the risk. | Prevent and limit | Guidance Document No 17 - Direct and indirect inputs |
| Article 11 l) | any measures required to prevent significant losses of pollutants from technical installations, and to prevent and/or to reduce the impact of accidental pollution incidents for example as a result of floods, including through systems to detect or give warning of such events including, in the case of accidents which could not reasonably have been foreseen, all appropriate measures to reduce the risk to aquatic ecosystems. | Prevent and limit | Guidance Document No 17 - Direct and indirect inputs |
| Article 16.1 | The European Parliament and the Council shall adopt specific measures against pollution of water by individual pollutants or groups of pollutants presenting a significant risk to or via the aquatic environment, including such risks to waters used for the abstraction of drinking water. For those pollutants measures shall be aimed at the progressive reduction<br><br>and, for priority hazardous substances, as defined in Article 2(30), at the cessation or phasing-out of discharges, emissions and losses. Such measures shall be adopted acting on the proposals presented by the Commission in accordance with the procedures laid down in the Treaty. | Prevent and limit<br><br>Priority substances | Guidance Document No 17 - Direct and indirect inputs |
| Article 16.2 | The Commission shall submit a proposal setting out a list of priority substances selected amongst those which present a significant risk to or via the aquatic environment. Substances shall be prioritised for action on the basis of risk to or via the aquatic environment, identified by | Priority substances<br><br>Non-specific for groundwaters | |
| Article 16.2 a) | risk assessment carried out under Council Regulation (EEC) No 793/93 (1), Council Directive 91/414/EEC (2), and Directive 98/8/EC of the European | Priority substances | Council Regulation (EEC) No 793/93 (1), Council Directive |

| WFD | Quotation | Related topic | Related documents |
|---|---|---|---|
| | Parliament and of the Council (3) | Non-specific for groundwaters | 91/414/EEC (2), and Directive 98/8/EC of the European Parliament and of the Council (3) |
| Article 16.2 b) | targeted risk-based assessment (following the methodology of Regulation (EEC) No 793/93) focusing solely on aquatic ecotoxicity and on human toxicity via the aquatic environment. | Priority substances<br><br>Non-specific for groundwaters | Regulation (EEC) No 793/93) |
| Article 16.2 | When necessary in order to meet the timetable laid down in paragraph 4, substances shall be prioritised for action on the basis of risk to, or via the aquatic environment, identified by a simplified risk-based assessment procedure based on scientific principles taking particular account of | Priority substances<br><br>Non-specific for groundwaters | |
| Annex II 2.1 | Member States shall carry out an initial characterisation of all groundwater bodies to assess their uses and the degree to which they are at risk of failing to meet the objectives for each groundwater body under Article 4.<br><br>Member States may group groundwater bodies together for the purposes of this initial characterisation. This analysis may employ existing hydrological, geological, pedological, land use, discharge, abstraction and other data but shall identify: | Risk assessment | Technical report on groundwater body characterisation issues as discussed at the workshop of 13th October 2003 |
| Annex II 2.2 | Following this initial characterisation, Member States shall carry out further characterisation of those groundwater bodies or groups of bodies which have been identified as being at risk in order to establish a more precise assessment of the significance of such risk and identification of any measures to be required under Article 11. Accordingly, this characterisation shall include relevant information on the impact of human activity and, where relevant, information on: | Risk assessment | Technical report on groundwater body characterisation issues as discussed at the workshop of 13th October 2003 |
| Annex II 2.3 | For those bodies of groundwater which cross the boundary between two or more Member States or are identified following the initial characterisation undertaken in accordance with paragraph 2.1 as being at risk of failing to meet the objectives set for each body under Article 4, the following information shall, where relevant, be collected and maintained for each groundwater body: | Risk assessment | Technical report on groundwater risk assessment issues as discussed at the workshop of 28th January 2004 |

| WFD | Quotation | Related topic | Related documents |
|---|---|---|---|
| Annex V 2.2.2 | for groundwater bodies identified as being at risk of failing to achieve environmental objectives under Article 4, ensure sufficient density of monitoring points to assess the impact of abstractions and discharges on the groundwater level, | Quantitative status assessment | Guidance Document N°15_Groundwater Monitoring Guidance |
| Annex V 2.2.3 | for groundwater bodies identified as being at risk of failing to achieve environmental objectives under Article 4, ensure sufficient frequency of measurement to assess the impact of abstractions and discharges on the groundwater level, | Quantitative status assessment | Guidance Document N°15_Groundwater Monitoring Guidance |
| Annex V 2.4.2 | bodies identified as being at risk following the characterisation exercise undertaken in accordance with Annex II,<br><br>Bodies which are identified in accordance with Annex II as being at significant risk of failing to achieve good status shall also be monitored for those parameters which are indicative of the impact of these pressures | Chemical status | Guidance Document N°15_Groundwater Monitoring Guidance<br><br>Guidance Document No 18 - Groundwater Status and Trend Assessment |
| Annex V 2.4.3 | establish the chemical status of all groundwater bodies or groups of bodies determined as being at risk<br><br>Operational monitoring shall be carried out for all those groundwater bodies or groups of bodies which on the basis of both the impact assessment carried out in accordance with Annex II and surveillance monitoring are identified as being at risk of failing to meet objectives under Article 4. The selection of monitoring sites shall also reflect an assessment of how representative monitoring data from that site is of the quality of the relevant groundwater body or bodies. | Chemical status<br><br>Chemical status | Guidance Document N°15_Groundwater Monitoring Guidance<br><br>Guidance Document No 18 - Groundwater Status and Trend Assessment |

## SUMMARY OF QUOTATIONS RELATED TO "RISK" IN THE GROUNDWATER DIRECTIVE

| GWD | Quotation | Related topic | Related documents |
|---|---|---|---|
| Recital (4) | Decision No 1600/2002/EC of the European Parliament and of the Council of 22 July 2002 laying down the Sixth Community Environment Action Programme (5) includes the objective to achieve water quality levels that do not give rise to significant impacts on, and risks to, human health and the environment. | General | |
| Recital (14) | It is necessary to distinguish between hazardous substances, inputs of which should be prevented, and other pollutants, inputs of which should be limited. Annex VIII to Directive 2000/60/EC, listing the main pollutants relevant for the water environment, should be used to identify hazardous and non-hazardous substances which present an existing or potential risk of pollution. | Prevent and Limit | Guidance Document No 17 - Direct and indirect inputs |
| Article 3 b | threshold values to be established by Member States in accordance with the procedure set out in Part A of Annex II for the pollutants, groups of pollutants and indicators of pollution which, within the territory of a Member State, have been identified as contributing to the characterisation of bodies or groups of bodies of groundwater as being at risk, taking into account at least the list contained in Part B of Annex II. | Chemical status | Guidance Document No 18 - Groundwater Status and Trend Assessment |
| Article 3.6 | Threshold values can be removed from the list when the body of groundwater concerned is no longer at risk from the corresponding pollutants, groups of pollutants, or indicators of pollution. | Chemical status | Guidance Document No 18 - Groundwater Status and Trend Assessment |
| Article 4 2 c i) | on the basis of the assessment referred to in paragraph 3 of Annex III, the concentrations of pollutants exceeding the groundwater quality standards or threshold values are not considered to present a significant environmental risk, taking into account, where appropriate, the extent of the body of groundwater which is affected; | Chemical status | Guidance Document No 18 - Groundwater Status and Trend Assessment |
| Article 5.1 | Member States shall identify any significant and sustained upward trend in concentrations of pollutants, groups of pollutants or indicators of pollution found in bodies or groups of bodies of groundwater identified as being at risk and define the starting point for reversing that trend, in accordance with Annex IV. | Chemical status | Guidance Document No 18 - Groundwater Status and Trend Assessment |

| GWD | Quotation | Related topic | Related documents |
|---|---|---|---|
| Article 5.2 | Member States shall, in accordance with Part B of Annex IV, reverse trends which present a significant risk of harm to the quality of aquatic ecosystems or terrestrial ecosystems, to human health, or to actual or potential legitimate uses of the water environment, through the programme of measures referred to in Article 11 of Directive 2000/60/EC, in order progressively to reduce pollution and prevent deterioration of groundwater | General | |
| Article 5.3 | Member States shall define the starting point for trend reversal as a percentage of the level of the groundwater quality standards set out in Annex I and of the threshold values established pursuant to Article 3, on the basis of the identified trend and the environmental risk associated therewith, in accordance with Part B, point 1 of Annex IV. | Environmental risk | |
| Article 5.5 | Where necessary to assess the impact of existing plumes of pollution in bodies of groundwater that may threaten the achievement of the objectives in Article 4 of Directive 2000/60/ EC, and in particular, those plumes resulting from point sources and contaminated land, Member States shall carry out additional trend assessments for identified pollutants in order to verify that plumes from contaminated sites do not expand, do not deteriorate the chemical status of the body or group of bodies of groundwater, and do not present a risk for human health and the environment | Prevent and limit | Guidance Document No 17 - Direct and indirect inputs |
| Article 6.1.b | for pollutants listed in Annex VIII to Directive 2000/60/EC which are not considered hazardous, and any other non hazardous pollutants not listed in that Annex considered by Member States to present an existing or potential risk of pollution, all measures necessary to limit inputs into groundwater so as to ensure that such inputs do not cause deterioration or significant and sustained upward trends in the concentrations of pollutants in groundwater. Such measures shall take account, at least, of established best practice, including the Best Environmental Practice and Best Available Techniques specified in the relevant Community legislation. | Prevent and limit | Guidance Document No 17 - Direct and indirect inputs |
| Article 6.3.e i) | measures that would increase risks to human health or to the quality of the environment as a whole; or | General | |

| GWD | Quotation | Related topic | Related documents |
|---|---|---|---|
| Article 10 | Without prejudice to Article 8, the Commission shall review Annexes I and II to this Directive by 16 January 2013, and thereafter every six years. Based on the review, it shall, if appropriate, come forward with legislative proposals, in accordance with the procedure laid down in Article 251 of the Treaty, to amend Annexes I and/or II. In its review and in preparing any proposal, the Commission shall take account of all relevant information, which might include the results of the monitoring programmes implemented under Article 8 of Directive 2000/60/EC, of Community research programmes, and/or of recommendations from the Scientific Committee on Health and Environmental Risks, Member States, the European Parliament, the European Environment Agency, European business organisations and European environmental organisations. | General | |
| Annex I.2 | The results of the application of the quality standards for pesticides in the manner specified for the purposes of this Directive will be without prejudice to the results of the risk assessment procedures required by Directive 91/414/EEC or Directive 98/8/EC. | Risk assessment | Directive 91/414/EEC and Directive 98/8/EC |
| Annex II A | Member States will establish threshold values for all pollutants and indicators of pollution which, pursuant to the characterisation performed in accordance with Article 5 of Directive 2000/60/EC, characterise bodies or groups of bodies of groundwater as being at risk of failing to achieve good groundwater chemical status.<br><br>Threshold values will be established in such a way that, should the monitoring results at a representative monitoring point exceed the thresholds, this will indicate a risk that one or more of the conditions for good groundwater chemical status referred to in Article 4(2)(c)(ii), (iii) and (iv) are not being met.<br><br>all pollutants which characterise bodies of groundwater as being at risk, taking into account the minimum list set out in part B; | Chemical status | Guidance Document No 18 - Groundwater Status and Trend Assessment |
| Annex II C | information on the number of bodies or groups of bodies of groundwater | Chemical status | Guidance Document No 18 - |

| GWD | Quotation | Related topic | Related documents |
|---|---|---|---|
| | characterised as being at risk and on the pollutants and indicators of pollution which contribute to this classification, including the observed concentrations/ values;<br><br>information on each of the bodies of groundwater characterised as being at risk, in particular the size of the bodies, the relationship between the bodies of groundwater and the associated surface waters and directly dependent terrestrial ecosystems, and, in the case of naturally-occurring substances, the natural background levels in the bodies of groundwater; | | Groundwater Status and Trend Assessment |
| Annex III | The assessment procedure for determining the chemical status of a body or a group of bodies of groundwater will be carried out in relation to all bodies or groups of bodies of groundwater characterised as being at risk and in relation to each of the pollutants which contribute to the body or group of bodies of groundwater being so characterised | Chemical status | Guidance Document No 18 - Groundwater Status and Trend Assessment |
| Annex III 4 e) | The risk from pollutants in the body of groundwater to the quality of water abstracted, or intended to be abstracted, from the body of groundwater for human consumption | DWPAs | Guidance No 16 - Groundwater in DWPAs |
| Annex IV A | Member States will identify significant and sustained upward trends in all bodies or groups of bodies of groundwater that are characterised as being at risk in accordance with Annex II to Directive 2000/60/EC, taking into account the following requirements: | Trend assessment | Guidance Document No 18 - Groundwater Status and Trend Assessment |
| Annex IV B 2 | once a starting point has been established for a body of groundwater characterised as being at risk in accordance with Section 2.4.4 of Annex V to Directive 2000/60/EC and pursuant to point 1 above, it will not be changed during the six-year cycle of the river basin management plan required in accordance with Article 13 of Directive 2000/60/EC; | Trend assessment | Guidance Document No 18 - Groundwater Status and Trend Assessment |

# ANNEX II

## Setting up Conceptual Models for Groundwater Systems


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# 1. INTRODUCTION TO THE CM ANNEX

In the new Groundwater Directive as well as in several Guidance Documents, the use of 'conceptual models' is mandatory or recommended, for various purposes. The term 'conceptual model' is not defined in the Groundwater Directive.

In this Annex an approach to set up conceptual models for purposes related to the WFD and GWD and assist in groundwater management is described.

*Definition of conceptual model*

In the context of this guidance, a conceptual model is a means of describing and optionally quantifying systems, processes and their interactions. A hydrogeological conceptual model describes and quantifies the relevant geological characteristics, flow conditions, hydrogeochemical and hydrobiological processes, anthropogenic activities and their interactions. The degree of detail is based on the given problems and questions. It is one of the basic steps for the management of groundwater bodies.

Depending on the specific problems/questions to be addressed for groundwater, a conceptual model (I) is an evolving system that is starting simple and may grow in complexity and (II) starts with a basic descriptive approach of structures and processes and may reach up to their parameterization. The CM is a knowledge based approach that is evolving during development and use.

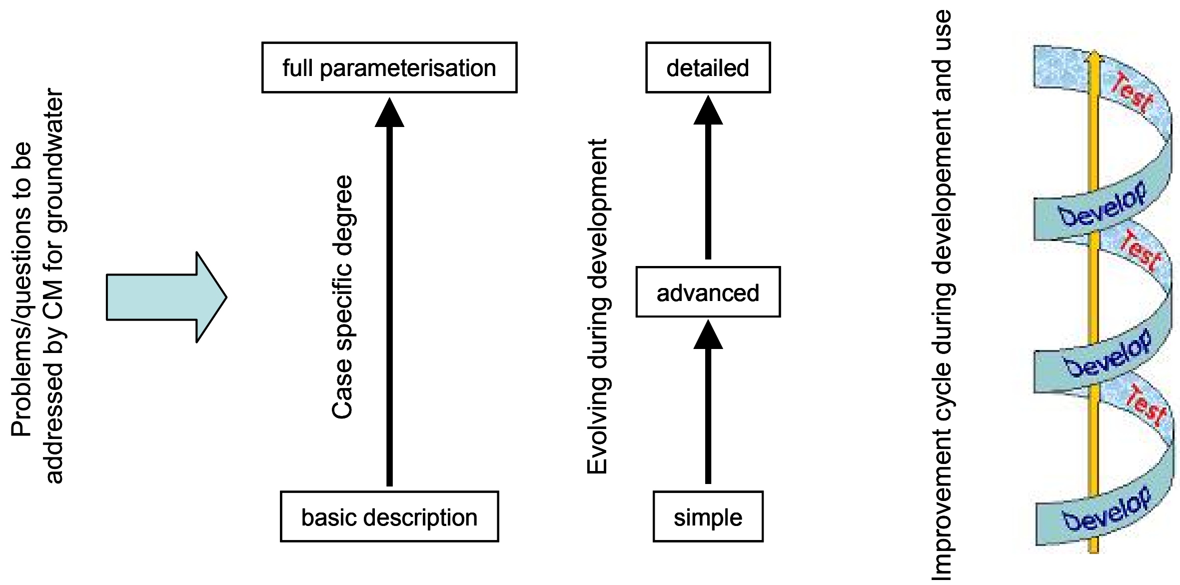



*Figure 1: The application requirements determine the CM's degree of parameterization and complexity.*

It can be concluded that the use of conceptual models is recommended for various purposes. Its cyclic nature (stepwise approach) is emphasized: start simple, refine later if necessary.

## 2. BASIC PROCEDURE

For many purposes CM in different degrees of elaboration and complexity are already existing. Mostly, they are a good basis to build on. Nevertheless, the complete procedure of setting up a CM is described here.

To address the different aims for Conceptual Models a stepwise approach is suggested. Within the steps there is a follow up of a qualitative description (e.g. what structures, processes are there) and a quantitative description of parameters (e.g. flow rates, concentrations):

Step 1, basic CM for the groundwater body

- Step 1a, qualitative CM
- Step 1b, Quantification of parameters in the CM

Step 2, to include risk assessment aspects into the CM[11]

- Step 2a, qualitative description of impacts (anthropogenic)
- Step 2b, quantitative description of impacts

Step 3, to include risk management aspects into the CM

- Step 3a, description of effects of existing measures
- Step 3b, prediction of effects of existing and future measures

Dependent on the aims a consequent follow up of these steps is not mandatory.

[11] Step 2, especially the quantitative consideration is quite similar to the assessment of groundwater bodies

# 3. INITIAL CONSIDERATIONS FOR SETTING UP A CONCEPTUAL MODEL

## 3.1 Scope and questions to be answered by a CM

The management of groundwater systems holds by its nature various steps in a continuous cycle (see figure 6 chapter 3.2 in the main document). Within the cycle of groundwater management conceptual models can be used in different phases with a different purpose. Each step gives rise to different questions to be answered. For instance:

- *Information and communication*: To allow an integration of and communication to no expert stakeholders
- *Status assessment*:
  - What is the interaction between groundwater and ecosystems?
  - How can MS inform risks and the effect of action plans to the public?
  - Do the groundwater bodies meet the environmental objectives of the WFD (Article 4)?
- *Monitoring*: What is the best design of a monitoring network within the frame of the WFD?
- *Risk assessment*: What is the risk of not meeting the environmental objectives of the WFD (Article 4)?
- *Risk management*: Where to initiate which measures and what are their effects in time and space.

Depending on the questions to be addressed different degrees of detail and complexity are required in the development of a CM (see figure 1).

The questions to be answered by a conceptual model also set demands upon the scale in time and space to be considered. For instance when evaluating the effect of inputs on abstractions, one typically studies a local scale, while for the design of monitoring network a regional scale is in place. It should be kept in mind that independent from the scale of interest, in all considerations for a conceptual model, hydrogeological boundaries determine the extension of the areas to be considered. For instance, for studying again the effect of inputs on abstractions, the catchment area should be taken into account when setting up the conceptual model.

## 3.2 Spatial scale

The whole system of aquifers, aquicludes, unsaturated zone, etc. is under consideration in this guidance. This approach covers e.g. the surface water interaction and unsaturated zone interaction.

For the delineation of a conceptual model it is obligatory to move from an overview scale like groundwater bodies to a detailed scale considering several aspects, e.g. the recharge area of a sampling site: In the first case, the groundwater body as a whole is the area of the conceptual model. In many cases only parts of a groundwater body are the origin of poor status (depending on e.g. high abstraction areas, land use). It is helpful to define the water balance for the area covered by the conceptual model. If parts of the groundwater bodies are negatively influenced e.g. by point sources, only those areas that might be affected have to be considered in the CM more detailed. The smallest scale of CM is the catchment area of a sampling point.

In general this means that different scales have to be considered when setting up a CM. A varying depth of data is needed, from only basic data in the overview scale to more specific data in the detailed scale where the CM should provide a reliable basis for description, risk-assessment and -management. This allows to reduce data needs in areas that are not affected.

## 3.3 Temporal scale

Temporal scale is very important in the CM elaboration, because it touches e.g. basic information on groundwater dynamics (like infiltration rates, geogenic changes of physical/chemical groundwater properties).

Temporal aspects can be distinguished into natural variations (e.g. seasonal effects) and anthropogenic influences like rising concentrations, decreasing groundwater levels).

## 3.4 Main points during CM set-up

Based on the previous considerations in chapter 2 and 3 the following main points can be summarized:

Basic delineation

- Scope and questions to be answered determine the degree of details and complexity of the CM (chapter 3.1).
- Definition of the investigation area based on the regional hydrogeological situation including relevant geological and tectonic structures, characterisation of main groundwater and surface water catchment areas (chapter 3.2)
- Definition of the balance and target area, based on sufficient geohydraulic boundary conditions (chapter 3.2)
- Vertical and horizontal structuring units (hydrogeological units) have to be defined. Formations with comparable hydrogeological characteristics (see chapter 5.1) have to be combined and important heterogeneous areas have to be kept.

Description, parameterisation and quantification

- Description and Quantification of important hydraulic, geochemical and hydrochemical parameters where possible and necessary. They have to be transferred from point to areas of parameter zones, without misrepresenting driving processes and interactions.
- Consideration of processes with slow kinetics (e.g. solution processes, unsaturated zone flow, changes in surface conditions, climate variations…)
- Description of the most important climatic and unsaturated zone parameters
- Delineation of land use distribution
- Identification of emerging areas that could pose a potential risk (chapter 5.2)
- Evaluation and assessment of potential uncertainties, variability, and representatives in data and structures (chapter 5.2).

Cyclic approach

- The setting up of a CM is not a static process, it requires several iteration steps during development (e.g. by aligning it with new field data), application (e.g. a numerical model serves to verify whether complex interacting processes are appropriately described), and maintenance (see Figure 2).
- Be aware that it might be necessary in one of the CM development steps, e.g. step 2b (chapter 5.2) to get back in one of the previous steps in case it turns out that actual data show that the CM is no longer consistent or shows new gaps.

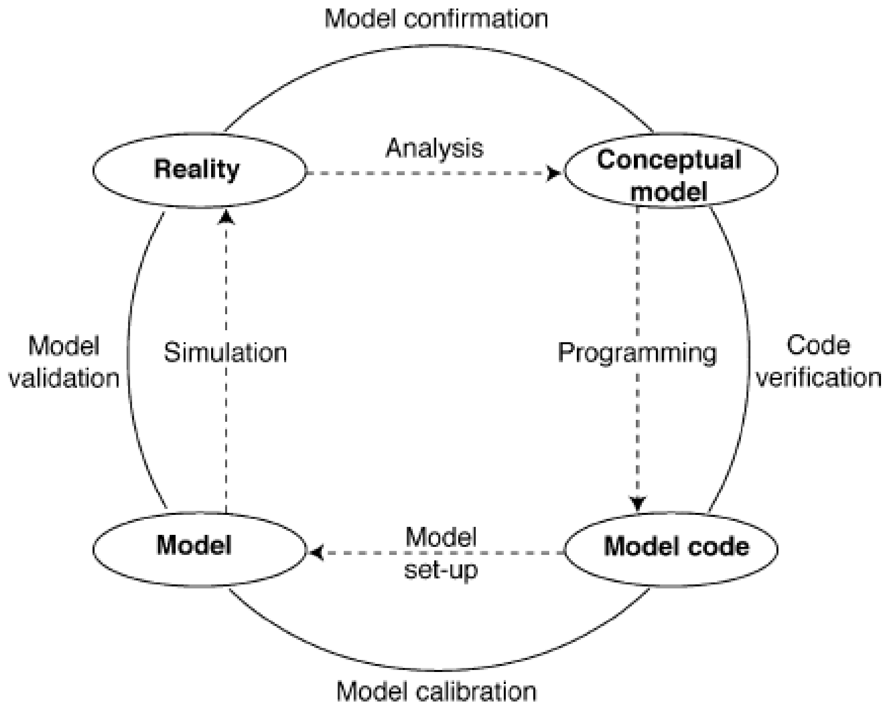



*Figure 2: Cyclic approach for developing a conceptual model*[12]

[12] Refsgaard, J. C., Henriksen, H. J. r. (2004). Modeling guidelines - terminology and guiding principles. Advances in Water Resources, vol. 27, no. 1, pp. 71-82.

## 4. DATA

During setting up a CM the requirements defined in chapter 3 determine the need for screening existing data from various sources or to collect new data.

It is important to be aware that, in addition to the WFD and GWD, groundwater monitoring data are collected for the purposes of other European and national programmes or Directives. These data can be used within the CM. They can be very valuable, as they provide quite often long lasting existing data sets and as future data out of these programmes can be integrated in the CM as well. Their use also avoids an unnecessary collection of new data. Thus a wide range review of existing data and data collection activities is very important.

Setting these data in the context of a CM gives an added value to them.

### 4.1 Data check list

The data checklist provides a comprehensive overview of information that might be needed. In practice, depending on the questions to be answered (chapter 3.1), only a limited selection of these data is needed. Tables with examples (without claiming completeness) for the data needed are given below.

<u>Step 1, basic CM for the groundwater body</u>

<u>Step 1a Qualitative CM:</u>

Step 1a is to give an overview on the aquifer geometry and basic characteristics. It has to consider topographic information, geology and hydrogeology in a qualitative, descriptive way.

<u>Step 1b Quantification of parameters</u>

Step 1b quantifies the elements described in step 1a. It considers e.g hydraulic, geochemical hydrochemical and soil data and values. It may occur that for this quantification step further detailed data of step 1a are useful.

*Table 1: Conceptual Model – qualitative description (step 1a)*

| | |
|---|---|
| **Topography**<br>• Morphology<br>• Surface waters (stream flows, lakes, springs)<br>• Surface water catchment areas | **Geology**<br>• Lithology<br>• Tectonics<br>• Stratigraphy |
| | **Hydrogeology**<br>• Groundwater catchment area<br>• Aquifer geometry<br>• Hydrogeological units<br>Aquifer type (porous, fissured, karst etc.)<br>Geochemical type (silicious, calcareous etc.)<br>Permeability (rough estimation high, medium low)<br>Confined/unconfined<br>Consolidated/unconsolidated rock<br>• Groundwater (chemical) typology<br>• Single/multi-aquifer system<br>• Unsaturated zone<br>• Estimation of flow directions<br>• Local uses of groundwater |

*Table 2: Conceptual Model – quantification of parameters (step 1b)*

| | |
|---|---|
| **Geochemical data**<br>• Clay content<br>• Organic carbon content (in soil/aquifer matrix)<br>• Mineralogical composition of soil/aquifer matrix | **Hydraulic data**<br>• Hydraulic conductivity<br>• Porosity (total/effective)<br>• Groundwater levels<br>• Hydraulic gradients<br>• Direct recharge (rainfall)<br>• Indirect recharge/discharge (interaction with surface waters, drainage and sewers) |
| **Basic hydrochemical data**<br>• Temperature<br>• pH<br>• Conductivity<br>• Redox potential<br>• Alkalinity<br>• Dissolved oxygen<br>• Dissolved organic carbon<br>• Mineral content ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$, $NH_4^{+}$, $HCO_3^{-}$, $Cl^{-}$, $SO_4^{2-}$, $NO_3^{-}$) | **Specific hydrochemical data**<br>• Compounds related to age determination (e.g. $^{3}H$)<br>• Trace compounds |
| **Soil (pedology)**<br>• Soil type distribution<br>• Depth of development | |

**Step 2, to include risk assessment aspects into the CM[13]**

Step 2a Qualitative description of impacts (anthropogenic)

Step 2a is to delineate different types of land use, receptors and potential impacts/risks.

*Table 3: Conceptual Model – qualitative description of impacts (step 2a)*

| **Land use and potential stress factors and risks[14], e.g.** | **Receptors e.g.** |
|---|---|
| • Agriculture<br>• Industry<br>• Infrastructure<br>• Abstraction and infiltration points<br>• Heat storage or extraction points | • Protective zones (e.g. water supply facilities, wetlands, ecotopes) |

13 Step 2, especially the quantitative consideration is quite similar to the assessment of groundwater bodies

14 For an overview on land use distribution maps based on CORINE land use data, NATURA 2000, etc. can be used

Step 2b Quantitative description of impacts

Step 2b is to quantify emission, immissions and uses.

*Table 4: Conceptual Model – quantitative description of impacts (step 2b)*

| | |
|---|---|
| **Emission of anthropogenic sources**<br>• Agriculture (e.g. N surplus)<br>• Industry<br>• Infrastructure<br>• Mining (including mines, tailing dams and spoil heaps)<br>• Waste management activities<br>• Diffuse soil contamination (e.g. caused by atmospheric deposition) | **Inputs to groundwater by anthropogenic sources**<br>• Case-specific pollutants (e.g. CHC, TPH, BTEX, oxygenates, HM, PAHs, pesticides, creosotes, nitrate, sulphate, ammonia)<br>• Corresponding degradation products<br>• Additional potential electron acceptors and nutrients ($Mn^{2+/4+}$, $Fe^{2+/3+}$, P)<br>• Indicators of biodegradation ($Mn^{2+}$, $Fe^{2+}$, $CH_4$)<br>• metals |
| **Groundwater use**<br>• Abstraction or infiltration rates<br>• Heat storage or extraction | |

**Step 3, to include risk management aspects into the CM**

Step 3a Description of effects of existing measures

In step 3a existing data of groundwater quality and quantity are used to derive information on parameters (e.g. travel times) that impact the effects of existing measures. This might be information that results out of the interpretation of time dependent data (e.g. nitrate travel times calculated out of concentration peaks in two monitoring wells). For measures related to groundwater quantity effects on groundwater level and groundwater related ecosystems due to changes in an abstraction regime can be calculated.

*Table 5: Conceptual Model – description of existing measures and effects (step 3a)*

| **Measures for groundwater quality** | **Measures for groundwater quantity** |
|---|---|
| • existing concentration data rows for calculation (in relation to river basin management plan) of travel times in unsaturated/saturated zone<br>• temporal and spatial development of anthropogenic input (e.g. fertilizer)<br>• results of tracer tests<br>• calculated/measured degradation/reaction rates | • existing data on groundwater/surface water levels<br>• existing data on groundwater abstraction<br>• results of tracer tests |

Step 3b Prediction of effects in future of existing and future measures

Step 3b has to provide data that allow the prediction of effects of existing and future measures. These data are based on the data collected for step 3a and also includes data collected in steps 1 and 2, especially the quantifying data. Thus step 3b marks the transition from the conceptual model to the mathematical and numerical model.

*Table 6: Conceptual Model – forecast on effects due to measures (step 3b)*

| **Future effects of measures for groundwater quality** | **Future effects of measures for groundwater quantity** |
|---|---|
| • calculated (in relation to river basin management plan) travel times in unsaturated/saturated zone<br>• calculated degradation/reaction rates<br>• scenarios of climate development<br>• scenarios of future developments in land use, population and water demand | • calculated effects to groundwater level and groundwater related ecosystems by changes in abstraction regime<br>• scenarios of climate development<br>• scenarios of future developments in land use, population and water demand |

## 4.2 Data review

By implementing or following several national and European programs and guidelines related to groundwater, soil, surface water and related fields a large data base is available that should be considered carefully before initiating new data collection activities.

When comparing or combining data out of different sources a quality check e.g. in terms of collection method, scale and temporal aspects should be made.

## 4.3 Data collection/acquisition

New data should only be collected, if, after careful consideration, existing data turned out not to be sufficient related to the target group to be addressed and the questions to be answered. (See also Chapter 3 of main document)

# 5. CONCEPTUAL MODEL DEVELOPMENT

## 5.1 Basic CM for the groundwater body, step 1 qualitative and quantitative CM

Description of Step1a. qualitative parameters in the CM

The task is to define a first understanding of the spatial scale to be considered (chapter 3.2) based on topographical data and definition of surface water catchment area. This is followed by the development of a hydrogeological understanding out of geological data.

The main knowledge increase of this step is:

⇨ Definition of hydrogeological properties

⇨ Derivation of hydrogeological units.

These outcomes allow a refinement of the investigation area and a first estimation of the groundwater balance area as interface to step 1b.

*At the end of step 1a a first overview on the hydrogeological system should already be possible (principle maps/sketches)*

The results of this step can be shown as e.g. cross sections, maps, block diagrams, providing:

- Spatial distribution/delineation of hydrogeological units in the area delineated for the CM
- Description of monitoring network (see Monitoring guidance)
- Integrate information on groundwater flow (directions)

Description of Step1b, Quantification of parameters in the CM

*Hydraulics:*

The hydraulic characteristics are described by integrating measured soil (pedological) and hydraulic data (e.g. groundwater levels, gradients, permeabilities, recharge, discharge, level of drainage)

The main knowledge increase of this step is:

⇨ Groundwater balance for draft balance area

⇨ Adjustment of balance area related to groundwater balance

⇨ A first estimation if the existing monitoring network is sufficient

The results of this step can be shown as e.g. cross sections, maps, block diagrams, providing:

- Quantified Water balance, split to different components of discharge and recharge
- GW flow directions
- Depth to GW table
- Travel times of seepage and groundwater
- Other refined products of step 1a.

*Hydrochemistry:*

The aim is to elaborate a spatial and temporal distribution of basic and, specific (where necessary) hydrochemical data (natural groundwater composition).

The main knowledge increase of this step is:

⇨ understanding and quantification of natural hydrochemical processes

⇨ e.g. allows to identify natural background level (according to Guidance on Groundwater Status and Trend Assessment)

⇨ further confirmation of balance area

⇨ further confirmation of flow regime

The results of this step can be shown as e.g. maps, diagrams, providing:

- Groundwater chemistry characterisation in time and space
- Natural background levels
- Refined products of step 1a and 1b hydraulics.

## 5.2 Risk based requirements – step 2, including risk assessment aspects

Description of Step 2a, qualitative description of impacts (anthropogenic)

In this step, different types of land use and receptors are delineated (according to Guidance on Groundwater Status and Trend Assessment and Guidance on the application of the term 'direct and indirect inputs' in the context of the Groundwater Directive 2006/118/EC).

Also, a delineation of risks is done by identifying specific points or areas that could pose a risk and the identification of types of actual or potential inputs (direct/indirect, point/diffuse, actual/historical, permanent/periodic) has to be done in this step.

The main knowledge increase of this step is:

⇨ Identification of the location of anthropogenic inputs (hazards)

⇨ Identification of the location of (potential) receptors

⇨ Identification of plausible pathways between hazards and receptors

⇨ Identification of actual risks (magnitude and probability of unacceptable impacts at receptors)

The results of this step can be shown as e.g. maps, providing:

- Distribution of different types land use
- Distribution of different anthropogenic impacts
- Distribution of different receptors

Description of Step2b, quantitative description of impacts

Emissions, immissions and uses are described in this step. Aims are the definition of monitoring data requirements, (type of parameter characterising the impacts, where to measure, frequency of measurements) and the temporal and spatial distribution of substances measured in the groundwater caused by anthropogenic impacts (e.g. landfill contamination plume). For groundwater quantity, temporal and spatial variations of anthropogenic influences on the hydraulic system (e.g. drinking water abstraction) are to be considered.

The main knowledge increase of this step is:

⇨ the spatial delineation of concentrations and fluxes

⇨ the variability of concentrations and fluxes in time

⇨ identification (quantification?) of mobility relevant processes (attenuation, dilution, see Guidance on Groundwater Status and Trend Assessment)

The results of this step can be shown as e.g. maps and diagrams, providing:

⇨ the delineation of areas and receptors affected

⇨ the reconstruction of the impacts from past events until today

⇨ first predictions of the future development of the impacts

## 5.3 Risk management based requirements (step 3)

In step 3, the CM development process is directly linked to the program of measures of the WFD. It is necessary to distinguish measures regarding groundwater quality and quantity.

Description of Step3a, description of effects of existing measures

*Measures for GW quality:*

With the help of time series analysis, the effects of existing measures can be described by estimations of travel times in the unsaturated and saturated zone and by delineating the impact on the kinetics of degradation and attenuation processes. The impact of measures addressing temporal and spatial development of past anthropogenic inputs can be described.

This is the basic instrument for the understanding of the processes described in step 2 and the knowledge base to provide a basis for the prediction of future processes in step 3b.

*Measures for GW quantity:*

Here, a description of past and ongoing measures (e.g. changes in abstraction regime) and their effects to groundwater level and groundwater related ecosystems is made.

The main knowledge increase of this step is:

- an understanding of the effects of measures on groundwater quantity and quality.
- a knowledge base to decide, if a good status can be achieved in principle?

The results of this step can be shown as:

- maps of the spatial and timely development in impact areas, where measures have been taken already
- diagrams of the development of risk related parameters due to existing measures.

Description of Step3b, description of effects of existing measures

Based on the information in Step 3a, step 3b provides data sets for future scenarios that can feed into mathematical or numerical models.

*Measures for GW quality:*

With the help of calculations of travel times in the unsaturated and saturated zone it is possible to compare the effects of measures in time and space to deadlines defined in river basin management plans. In this step, also scenarios considering the future climate and land use development, population and water demand can be elaborated.

*Measures for GW quantity:*

Mainly, the effects to groundwater level and groundwater related ecosystems by different scenarios of measures focusing on the abstraction/infiltration regime is calculated. Like for groundwater quality, scenarios considering the future climate and land use development, population and water demand can/should be elaborated.

The main knowledge increase of this step is:

- if proposed/planed measures in principle are sufficient to reach the RBMP goals
- the time of reaching a trend reversal
- the time of reaching a good status/natural background level
- advise, if there is a need for prolongation of deadlines or less stringent environmental objectives

The results of this step can be shown as diagrams and maps together with a text description.

## 5.4 Documentation/Visualisation

It is important to have aggregated documentation of all steps of a CM. It should be clearly shown, where improvement loops are situated. The complexity of the visualisation is dependent on the scoping questions and the people addressed. Data sources used have to be documented.

Appropriate media for publishing are e.g. pictures, diagrams, maps, block diagrams, cross sections, text, Slide shows, Web Map Services, viewer.

# 6. VALIDATION OF CM, QUALITY ASSURANCE

## 6.1 Introduction

A conceptual model is dynamic, evolving with time as new data are obtained and as the model is tested. Its development and refinement should adopt an iterative approach. Before the conceptual model can be used, it has to be calibrated. Before re-characterisation takes place, the conceptual model should be evaluated, refined and validated. All data concerning the nature of the groundwater body collected during the characterisation process should be tested against the conceptual model, both to refine the model and to check for data errors. In doing so, the distance to target should be kept in mind: the closer a groundwater body gets toward a good status the more accurate the conceptual model should be in order to carry out a correct compliance test. If there is uncertainty about the reliability of the results, the groundwater body is at-risk beforehand.

Four types of data will have to be included in the calibration and validation process:

1. process data: e.g. groundwater to surface water interactions, steady state or transient state
2. structure : e.g. geological structure, boundary conditions
3. inputs: e.g. rainfall, groundwater recharge, evapotranspiration
4. parameters: e.g. permeability, storage coefficient

The main difference between calibration and validation is the timing when those processes take place:

- Calibration is executed before the conceptual model can be considered finished : it is the process where the values of all the parameters that can vary have been chosen in such a way that the calculated groundwater levels, velocities, concentrations,… are as close as possible to the real ones;
- Validation is executed after the conceptual model is finalised an when a significant set of new data is obtained; in this stage one can check if the new data are well predicted; if not one should restart the calibration process.

The validation of a conceptual model can be based on monitoring data if there is sufficient data available. Quite often this is not the case. Then an analysis of the characteristics of the pressures and receptors combined with monitoring data can be a suitable validation method. Following the approach applied to the selection of relevant substances (Guidance no. 3, 2003), one can analyse the pressures on a groundwater body (top-down), analyse the observed effects on receptors (bottom-up), and compare these, certainly taking into account a travel time distribution. This comparison offers insight in the validity of the conceptual model.

In general it is important to plan and log the validation steps that will be carried out, taking into consideration aspects such as availability of data and the distance to the target.

## 6.2 Validation of conceptual models

Within CM setup the first step in validation is to put existing data consistently together to a conceptual model. As CM is not a static image, new information that can feed into the CM appears over time (e.g. monitoring data, information construction measures…) when these new information can be constantly put into your CM this validates that the actual design of the CM is right. In case of conflicts, both the conceptual model design and the quality of the new information have to be reviewed, to come up with a consistent solution. The validation by monitoring data and new information is the most common way.

Besides this validation by monitoring data, it is also possible to make use of mathematical models (usually computer based) for validation. A first way is, if the existing conceptual model can be reproduced by a mathematical model (e.g. reproduction of measured groundwater levels or hydrographic curves). A second but more time consuming way is to compare the forecasting of CM based mathematical models with later monitoring data of the groundwater body.

## 6.3 Quality assurance

Errors in the development of a CM will be perpetuated throughout the other steps of setting up the CM and are likely to result in developing a sampling and analysis plan that may not achieve the data required to address the relevant issues. It is important to identify theories and assumptions underlying the CM to ensure adequate transparency. If the problem is complex, it may be considered breaking it into more manageable pieces, which might be addressed by separate studies. Priorities may be assigned to individual segments of the problem and the relationship between the segments examined.

There are two primary types of intended uses of the data: data for *decision making* and data necessary for *making estimations.* Models can be used to generalise point information to information for areas.

*Decision problems*

- Does the concentration of contaminants in groundwater exceed acceptable levels?
- Does the pollutant concentration exceed a standard?
- Does a contaminant pose a human health or ecological risk?
- Is the contaminant concentration significantly above background levels?
- Etc.

*Estimation problems*

- What is the average rate of groundwater flow in the aquifer?
- What is the distribution of pollutant groundwater concentrations over space and time?
- What are the sizes of endangered species populations within the habitat of concern?
- How do the background contaminant concentrations vary over space and time?
- Etc.

In order to minimize the possibility of either making erroneous conclusions or failing to keep uncertainty in estimates to within acceptable levels *performance or acceptance* criteria should be derived that the collected data will need to achieve. *Performance* criteria, together with the appropriate level of common Quality Assurance practices, will guide the design of new data collection efforts, while *acceptance* criteria will guide the design of procedures to acquire and evaluate existing data relative to the intended use. Therefore, the method to use and the type of criteria to be set will, in part, be determined based on the intended use of your data.

The Data Quality Objective Process (Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4, February 2006) can be used to develop *performance* and *acceptance* criteria (or data quality objectives) and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to set up a conceptual model.

The DQO Process is a series of logical steps that gives guidance to a plan for the resource-effective acquisition of environmental data. It is both flexible and iterative, and applies to both decision-making (e.g., compliance/non-compliance with a standard) and estimation (e.g., ascertaining the mean concentration level of a contaminant). The DQO Process is used to establish *performance* and *acceptance* criteria, which serve as the basis for designing a plan for collecting data of sufficient quality and quantity to support the goals of the study. Use of the DQO Process leads to efficient and effective expenditure of resources; consensus on the type, quality, and quantity of data needed to meet the project goal; and the full documentation of actions taken during the development of the project.

In general, *performance* criteria represent the full set of specifications that are needed to design a data or information collection effort such that, when implemented, generate newly-collected data that are of sufficient quality and quantity to address the project's goals. *Acceptance* criteria are specifications intended to evaluate the adequacy of one or more existing sources of information or data as being acceptable to support the project's intended use.

When evaluating scientific and technical information, the EPA recommends using the five General Assessment Factors (GAFs) documented in Table 7.

*Table 7: EPA General Assessment Factors*

| |
|---|
| **Soundness:** The extent to which the scientific and technical procedures, measures, methods or models employed to generate the information are reasonable for, and consistent with, the intended application. |
| **Applicability and Utility:** The extent to which the information is relevant for its intended use. |
| **Clarity and Completeness:** The degree of clarity and completeness with which the data, assumptions, methods, quality assurance and analyses employed to generate the information are documented. |
| **Uncertainty and Variability:** The extent to which the variability and uncertainty (quantitative and qualitative) in the information or the procedures, measures, methods or models are evaluated and characterized. |
| **Evaluation and Review:** The extent of independent verification, validation, and peer review of the information or of the procedures, measures, methods or models. |

These general assessment factors can be used to describe the Quality Assurance of the conceptual model.

# 7. GLOSSARY

A comprehensive glossary of terms on Groundwater can be found on the webpages of "The Groundwater Foundation":

http://www.groundwater.org/gi/gwglossary.html

## 8. LITERATURE

J. Spijker, R. Lieste, M. Zijp, T. de Nijs, 2009. Conceptual Models for the Ground Water Directive. See www.rivm.nl/bibliotheek/rapporten/607300010.html) .

EU (1980). Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances. Official Journal of the European Union, L 20.

EU (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Union, L 327/1.

EU (2006). Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration. Official Journal of the European Union, L 372/19.

# ANNEX III - Examples

## A CONCEPTUAL MODEL TO CHARACTERISE A GROUNDWATER BODY

### GWB Leibnitzer Feld - Location and boundaries

The groundwater body "Leibnitzer Feld" is situated in the Austrian province of Styria to the south of Graz in southeast Austria. It is a single groundwater body in a porous medium, extending in a north-south direction and covering 103 $km^2$ at altitudes ranging between 157 and 340 m a.s.l. (above Adriatic Sea level).

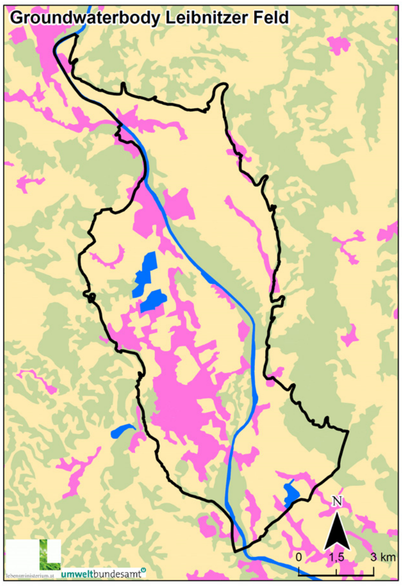
Morphologically, the groundwater body is clearly delineated by mountains to the north, east and west. To the south, the river "Mur" marks the delineation.

### Land use and pressures

On the basis of evaluations of CORINE Landcover 2000 data (CORINE, 2000), the following distribution of land usage across the groundwater body Leibnitzer Feld was obtained, as shown in Table 1 (in % of total area). Main pressures are due to water abstraction, agriculture, industrial sites and contaminated sites (see also anthropogenic impact).

*Table 1: Leibnitzer Feld - land use according to CORINE Landcover (2000).*

| ***Land use*** | ***%*** |
|---|---|
| Artificial surfaces | 19.4 |
| Agriculture | 61.3 |
| Forests and semi-natural areas | 14.8 |
| Surface waters | 4.5 |




*<u>LEGEND:</u>*

*Pink: artificial surfaces*

*Yellow: agricultural areas*

*Green: forests and semi-natural areas*

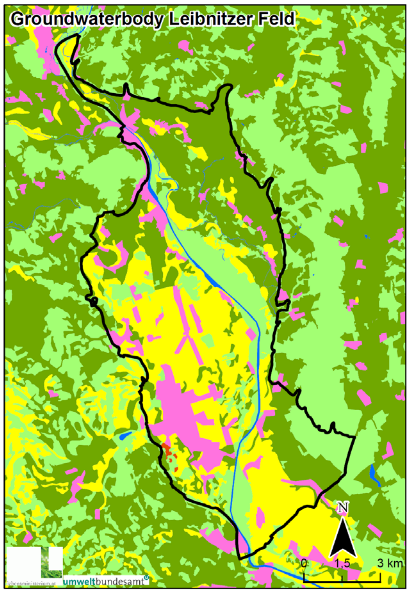
*Light blue: wetlands*

*Blue: surface water*

*Figure 1: Land use according to CORINE (2000) in the groundwater body Leibnitzer Feld (Data source: Water Quality Monitoring Ordinance, Federal Legal Gazette No. 479/2006 as amended; Federal Ministry of Agriculture, Forestry, Environment and Water Management, Department VII/Unit 1 National Water Management; Offices of the Provincial Governments, Umweltbundesamt GmbH)*

### Overlying strata

Confining layer and depth to groundwater table: More than 75% of the groundwater body is covered with confining layers, mostly clays of varying thickness. The thickness of the overlying strata varies in dependence of the surface morphology, ranging from less than 2 m in the valley floodplains to more than 8 m on the upper terraces in the northeast. In the west of the Leibnitzer Feld the thickness of the overlying strata varies between 4 and 7 m at mean groundwater levels. The confining layers in the Mur area are characterised by low nitrate retention (see figure 2), as are large parts in the south and southwest of the groundwater body.




*LEGEND:*

*Red: Very low nitrate retention capabilities (i.e. highest risk for groundwater)*

*Yellow: Low nitrate retention capabilities*

*Green: Medium to high nitrate retention capabilities*

*Blue; surface waters*

*Lime: Forest; partly-forest*

*Pink: Settlement*

*Figure 2: Nitrate retention capabilities of the confining layers in the Leibnitzer Feld (Data source: Water Quality Monitoring Ordinance, Federal Legal Gazette No. 479/2006 as amended; Federal Ministry of Agriculture, Forestry, Environment and Water Management, Department VII/Unit 1 National Water Management; Offices of the Provincial Governments – Nitrate retention: Institute for Land and Water Management Research, Petzenkirchen (IKT)).*

### Characteristics of soils

*Table 1: Soil types in the Leibnitzer Feld according to FAO Soil Type Units classification (H2O-Fachdatenbank [H2O database], 2009).*

| **FAO - Soil Type Units** | **%** |
|---|---|
| Be - Eutric Cambisol | 77.6 |
| Je - Eutric Fluvisol | 5.8 |
| Wd - Dystric Planosol | 9.2 |
| We - Eutric Planosol | 7.4 |

### Geological characteristics

Water level of the aquifer: unconfined.

Petrography of the aquifer: The average thickness of the Quaternary gravel terraces (sandy gravel with fractured rock) is 6-10 m. Most of the lower terrace is composed of slightly silty, sandy gravel and fractured rock. The Mur floodplains are also composed of slightly silty and sandy gravel, which is – in contrast to the lower terrace – overlain by an alluvial clay layer with a thickness of 1.5 to 3 m. The thickness of the sediments of the floodplain layer ranges mostly between 4 and 6 m. Small channels, filled with fine sediment, are a common characteristic of the areas near the Mur.

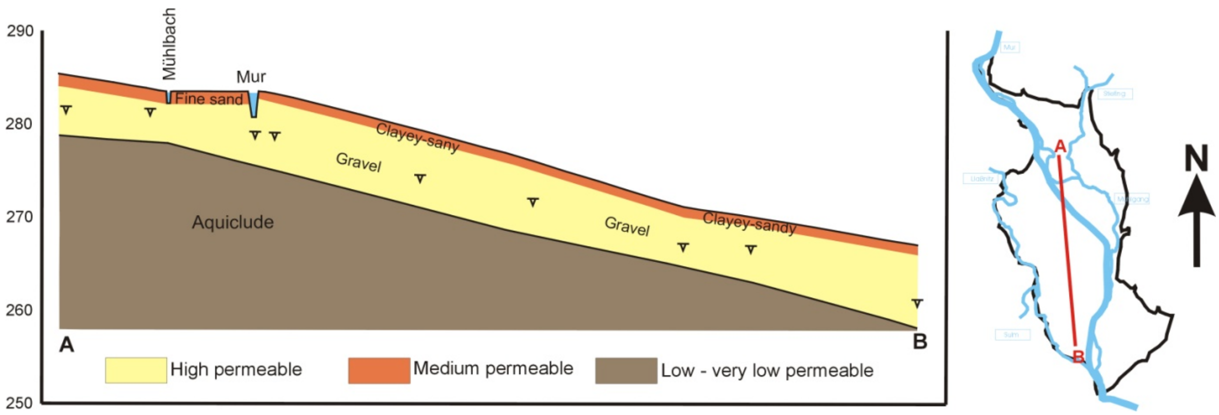



*Figure 3: Schematic cross-section through the groundwater body Leibnitzer Feld*

Thickness of the groundwater body: At mean groundwater levels, the thickness of the shallow Quaternary groundwater body varies between less than 2 m in boundary areas near bedrock and more than 8 m in small-scale areas near the Mur (see figure 3). A groundwater thickness of more than 4 m is only reached in the northeast of the Leibnitzer Feld and in the west of the Leibnitzer Feld (H20-Fachdatenbank, 2009).

Aquiclude: The configuration of the relief underlying the Quaternary bedrock valley sediments is relatively consistent, and the gradient corresponds more or less to today's course of the river Mur. The flat undulating bedrock relief with zones of consistently shallow and wide depressions shows only a few signs of hollows consistent with the character of deep chutes. The pre-Quaternary underground is mostly composed of silty-sandy rocks or clayey rocks dating from the Neogene. In the northeast of the Leibnitzer Feld Leitha limestone below the Quaternary gravel were detected.

### Hydrogeological characteristics

Groundwater flow directions: The northeast part of the Leibnitzer Feld is characterised by groundwater flow in the southeast direction (parallel to the Mur). At the eastern boundary of the Leibnitzer Feld groundwater flowing down from surrounding slopes gains more and more importance. The flow direction in this area is from northeast to southwest, coinciding with the groundwater flow parallel to the Mur river. The flow direction in the western part of the Leibnitzer Becken is, in general, from northwest to southeast. In some of the westernmost parts the Lassnitz and Sulm rivers become the receiving waters for the groundwater.

Hydraulic conductivity – flow velocities: Overall, differences in hydraulic conductivity tend to be small in the groundwater body, ranging mainly between 2E-3 and 7E-3 m/s except in some local zones, with generally higher permeability in the valley floodplains of the Mur and Sulm. The usable porosity of the terraces varies between 6 and 9%, and between 9 and 18% in the floodplains (*H2O-Fachdatenbank*, 2009). Flow velocity ranges between 0.4 and 8.5 m/d.

Groundwater balance: At mean groundwater level, the groundwater flux at the level of the town of Leibnitz (in the southwest) is 125 l/s (Fank, 1998).

Precipitation: Total long-term annual mean precipitation in the Leibnitzer Feld is 902 mm, ranging between 848 and 939 mm. The proportion of winter precipitation is low (*H20-Fachdatenbank*, 2009).

**Surface water interaction and recharge**

Interaction between surface waters and groundwater: There are strong interactions between different rivers, streams and the groundwater. In many parts of the floodplains, surface waters drain the shallow groundwater. Some surface waters are of vital importance for groundwater recharge in the northeast of the Leibnitzer Feld, with groundwater alimentation strongly depending on the flow conditions in the surface waters. Bank filtrate of the Mur is considerably alimenting groundwater.

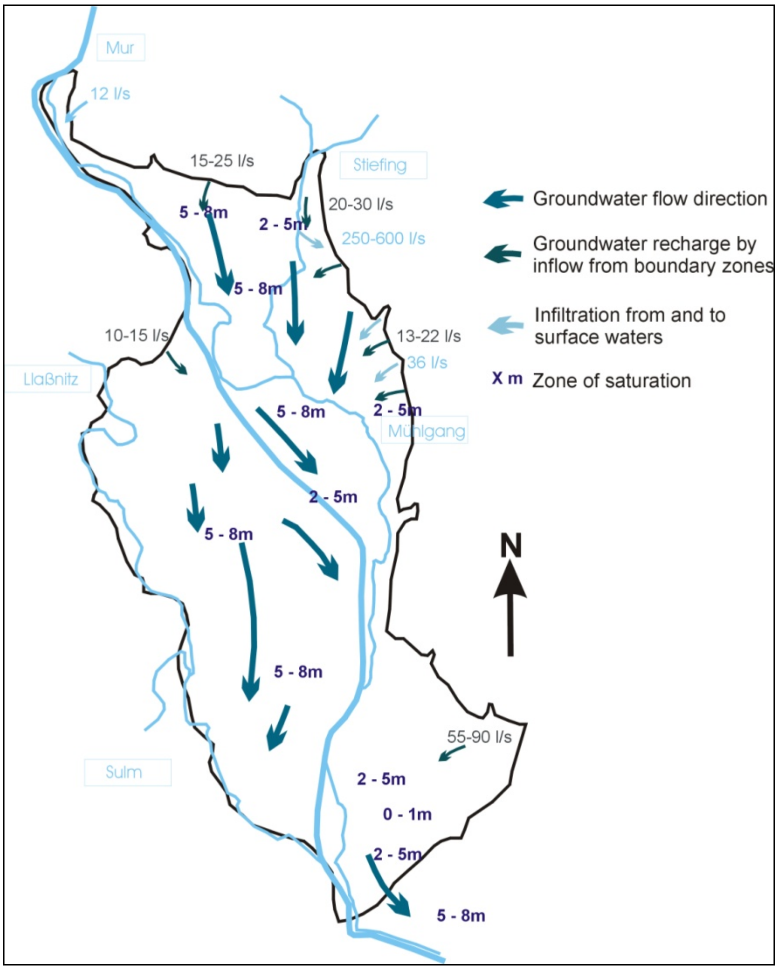



*Figure 5: Groundwater body Leibnitzer Feld - Schematic illustration of hydrogeological characteristics, surface water interaction and recharge.*

Groundwater recharge: According to the groundwater model "Leibnitzer Feld" (simulation period 1987), recharge from percolating precipitation (340 mm/a, average value for the years 1971-1990) amounts to about 28 million m3 (71%), followed by infiltration from surface waters (18%) and inflow (groundwater) from boundary zones with 4.4 million m3 (11%).

With a total area of 103 km2, an assumed mean groundwater thickness of 4 m and a storage coefficient of about 13%, the groundwater volume is about 54.6 million m3. The average volumetric discharge of flow through groundwater recharge within the Leibnitzer Feld is 10 l/s km2 (*H2O-Fachdatenbank*, 2009).

**Groundwater chemistry and anthropogenic impacts**

Groundwater chemistry: Geochemistry in the groundwater body is silicate/carbonate dominated (*H2O-Fachdatenbank*, 2009).

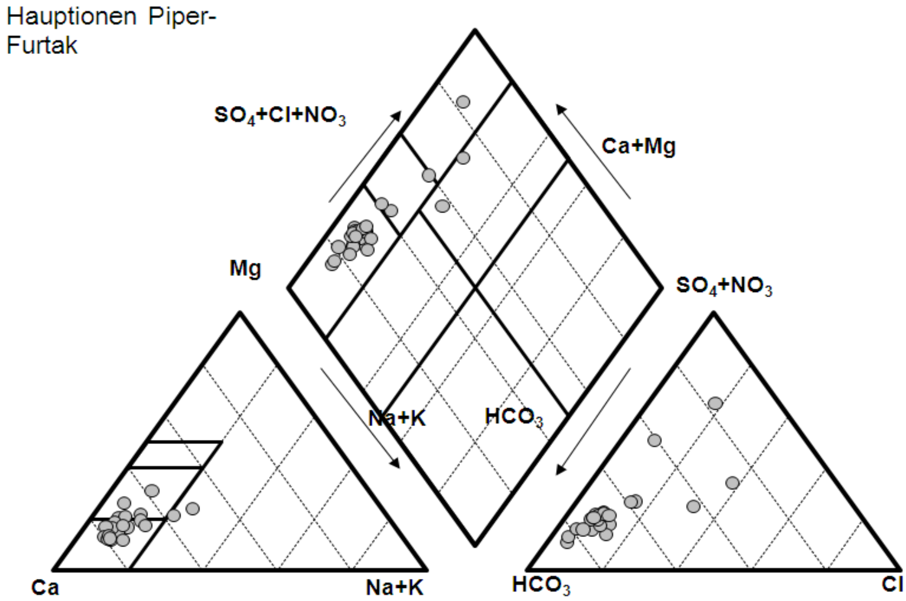



*Figure 4: Major ions illustrated in a Piper-Furtak diagram.*

Anthropogenic impacts: Anthropogenic impacts on groundwater include water abstraction, constructions, industrial sites and designated contaminated sites, as well as tourism, agriculture and forestry (H2O-*Fachdatenbank*, 2009). Groundwater is used on a large scale for drinking water and also for commercial purposes. Major interference with the former flow regime along the Mur due to power stations is evident.

Due to a number of drinking water and other uses particular efforts to protect groundwater resources are necessary and established.

**Literature**

Fank J. et al., 1993: Hydrogeology und groundwater model Leibnitzer Feldes (only available in German)

H2O-database, 2009 (H2O-Fachdatenbank, 2009)

# B Drinking Water Protection File: an approach for risk assessment on a local scale

## Introduction

The Water Framework Directive sets, among others, objectives for water intended for human consumption (Article 7). These objectives hold both preserving the current status of the resource quality as well as an aimed improvement of quality in time, all in relation to the quality standards of the Drinking Water Directive (98/83/EC). The characterization of water bodies therefore holds an assessment of the risk of failing to meet the drinking water objectives. The Netherlands developed an instrument named the Drinking Water Protection File with the aim to carry out such a risk assessment for an abstraction site on a local scale. This instrument was developed two years ago and has since then been tested for several sites. The experiences with the instrument have led to the intention to implement it on a nationwide scale. The results should contribute to the program of measures of the second implementation cycle of the WFD (2015-2021).

## Description of a DWPF

In a Drinking Water Protection File (DWPF) all information is collected that is relevant for the water quality at the abstraction site now and in the future. Based on this information measures can be developed that are effective with respect to water quality and costs of measures. The DWPF complements the existing protection policy and offers an instrument to implement Article 7 of the WFD. Decisions upon the measures to be carried out will be taken by the competent authorities, laid down in their plans and consequently summarized in the river basin management plans. In the preparation of a DWPF the relevant stakeholders are involved, such as water managers (provinces and water boards), water companies, and municipalities. The provinces are leading this process. The number of parties involved depends upon the type of abstraction (surface water or groundwater) and the location and size of the catchment area.

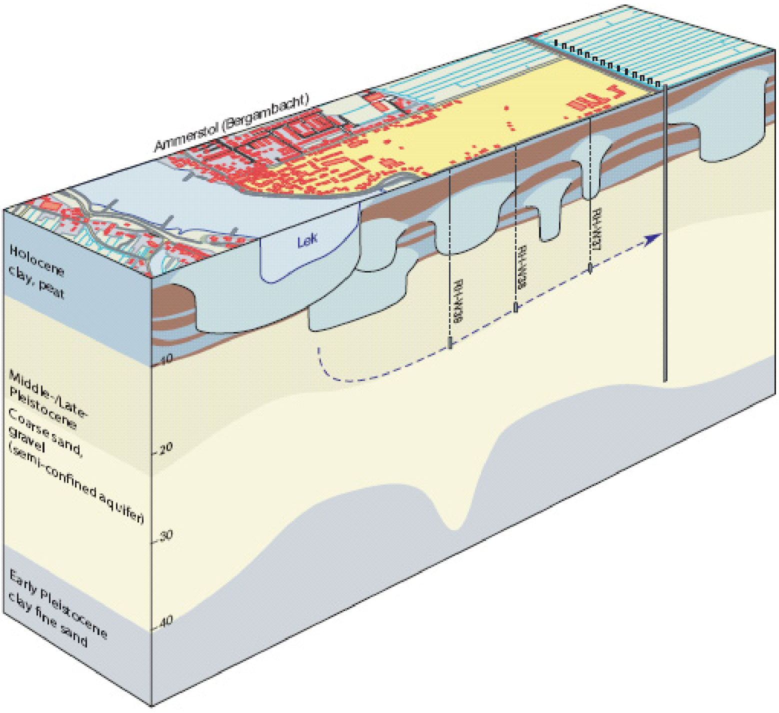
A Drinking Water Protection File holds at least the following elements:

- Information on the abstraction itself and the water system (quality and quantity);
- Information on activities that influence water quality (pressures);
- Identification of relevant substances. What are possible pollution sources?
- Current protection policies and practices. Where are the bottlenecks?
- What are the most (cost) effective measures for dealing with relevant substances?

## Example

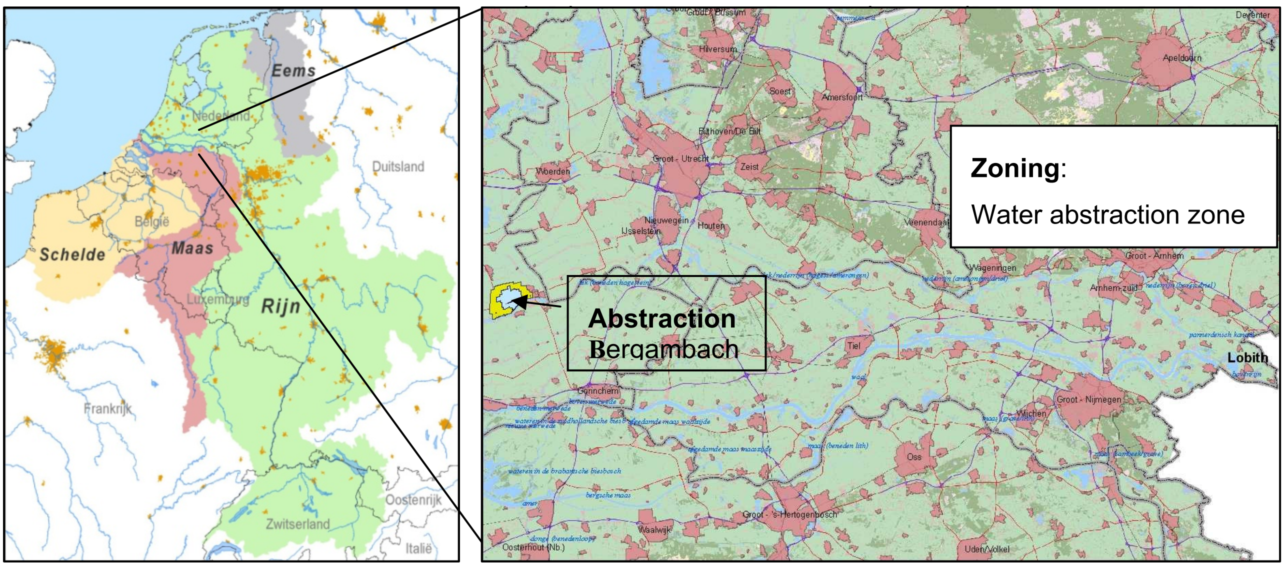
The DWPF-instrument has been tested for several abstraction sites. In this case we present an overview of the DWPF for the Bergambacht abstraction site. The Bergambacht site supplies drinking water to 280,000 consumers in the Netherlands. Surface water from the Lek river (a Rhine branch) infiltrates to the groundwater and is abstracted at 500-1000 m from the river bank. The soil passage ensures attenuation and dilution of substances present in the subsurface water. The quality of the abstracted water is primarily determined by the quality of the infiltrated river water (80-90%) and for the remaining 10-20% by the groundwater quality of the surrounding polder (Bergambacht). For groundwater intended for human consumption no specific standards are in place. In the DWPF the abstracted water is therefore compared to the drinking water standards. This does not mean that groundwater abstracted for human consumption has to comply to the drinking water standards. In the Netherlands all water companies have a facility in place to treat the water up to the drinking water standards.

In the current situation the car fuel additive MTBE, the solvent diglyme and volatile chlorinated hydrocarbons, are found in the abstracted groundwater in concentrations exceeding Dutch standards for drinking water. In order to meet the standards, the water company applies water treatment by activated carbon filtration.




In addition, concentrations of other substances, such as several pharmaceuticals and pesticides, appear to be rising, although not yet exceeding drinking water quality standards. Water quality data from local surface water, the river Lek and the upstream Rhine indicate that the pollutants originate from industrial and sewage effluent, storm water overflow spills and agriculture in both the Netherlands and upstream countries. The DWPF demonstrates that it is important to discuss these substances on a river basin level, but that there are possibilities for improvement within the Rhine Delta as well. Possible measures are more stringent regulation with respect to pesticides, reduction of spills of untreated sewage water, adjustment of effluent discharge permits and high-performance sewage water treatment.

With the in-depth analysis provided by a DWPF, a common understanding is created of the risks at drinking water abstraction sites. From there, actions supported by the relevant parties can be formulated.



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