This project is implemented through the CENTRAL EUROPE Programme co-financed by the ERDF.
http://transenergy-eu.geologie.ac.at

Methodology for joint groundwater management

Title Methodology for joint groundwater management
Creators Joerg Prestor, Annámaria Nador, Andrej Lapanje in cooperation with GeoZS, ŠGÚDŠ, GBA, MÁFI
Date 29 -FEBRUARY-2012

Status Final

Type Text

Description This document contains overview on current management practise in partners' countries, overview of management principles, overview of principles of geothermal resource assessment, indicators for management sustainability benchmarking, and good practice examples.

Format PDF

Language En

Project TRANSENERGY –

Transboundary Geothermal Energy Resources of Slovenia, Austria, Hungary and Slovakia

Work package WP3 Utilization aspects

WP 3.3 Legal aspect of transboundary aquifer management
3.3.2. Methodology for joint groundwater management

Index

Annex

List of figures

List of tables

Methodology for joint groundwater management

1 Introduction

The main aim of the project is the common characterization of transboundary thermal groundwaters in the Transenergy area between Austria, Hungary, Slovakia and Slovenia. We also intend to make recommendations to design the most effective monitoring system which will take into account of the great depth of thermal groundwater. Additionally, we will make recommendations to the authorities and regulators on how they can improve the management of thermal groundwater.

We put into consideration different tools, directions and guidelines for improvement of management, more active involvement of stakeholders and improved public information. It is necessary to follow the international guidelines to manage water resources within the natural boundaries of river basins – that is on a transboundary level, not just for each country individually. All partner countries have prepared their first cycle national river basin management plans according to the Water Framework Directive for the period 2009 – 2015. In the first part of this document we represent the current management practises in partners' countries according to these plans. However the national practices (e.g. delineation of groundwater bodies, principles of their classification, definition of thermal groundwater bodies, if at all, etc) differ from country to country, therefore the descriptions do not follow a standard pattern, but reflect the country specifics.

The overview of principles of integrated water resources management, especially thermal groundwater and principles of geothermal resource assessment based on a wide spectrum of related recommendations, guidelines, conventions and directives developed all over the world by different organisations build the central part of this report. In these chapters the issues which have to be considered in the joint management of transboundary aquifers are given. On that basis of that we elaborated the template for the standardized description of transboundary thermal groundwater and recommendations for its management, which will be used for the five selected pilot transboundary areas within Transenergy partner's territory in the frame of WP 6 activities at the end of the project. This will be complemented by the area specific information gained during the geological, hydrogeological and geothermal modelling of the areas, which will help to make explicit management considerations and recommendations at the end of the project.

In the annex three good practice examples for thermal water management, one example of temperature, pressure and flow measurement experience, outcomes of three similar projects and a template for description of transboundary groundwater body (UNECE) are attached.

1 Principles of thermal groundwater management

1.1 Introduction

The aim of our project is the common characterization of transboundary thermal groundwater resources in the Transenergy area between Austria, Hungary, Slovakia and Slovenia, and to provide recommendations for its sustainable utilization including enhanced growth of geothermal energy. We also intend to propose recommendations related to transboundary management of thermal groundwater to our governmental institutions together with the design of its most adequate monitoring. We put into consideration different tools, directions and guidelines for improvement of management, more active involvement of stakeholders and improved public information. It is necessary to follow the international guidelines to manage water resources within the natural boundaries of river basins – that is on a transboundary level, not just for each country individually.

In the following chapter we present the main principles that have to be taken into consideration for the transboundary management of thermal groundwater. They are selected from the most significant international conventions, which were already discussed in the Report 3.3.1. on the overview of legislation, and for which references are given. On that basis we adopted the template for the standardized description of transboundary thermal groundwater and recommendations for its management (Annex IV Templates for description of transboundary groundwater body).

All of the principles, described in the following chapters, will be used for the five selected pilot transboundary areas within Transenergy partner's territory in the frame of WP 6 activities at the end of the project. The common recommendations for transboundary management and monitoring will be proposed and ready to submit to the responsible authorities, to bilateral or multilateral water management commissions.

1.2 Environmental aspect (Water Framework Directive – WFD and River Basin Management Plan - RBMP)

Basic principles

DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL (WFD) establishing a framework for Community action in the field of water policy (adopted 23 October 2000) is a firm and definite step away from "water treatment principle" towards the "precautionary principle". It introduces "sustainable development" principles also, as defined in Brundtland report, in the field of water management. This means that no actual cost (economic, environmental and social) of water use should be postponed to the next generation. Furthermore, following the "entropy definition" of sustainability and preventing the concentration of flows (mass, information, money) in narrow and closed systems, the management should be an open system, widely involving the public, stakeholders and sectors. The principle of recovery of the costs of water services, including environmental and resource costs associated with damage or negative impact on the aquatic environment, should be taken into account in accordance with, in particular, the "polluter-pays principle". By the Water Framework Directive coming into force, groundwater became for the first time part of an “integrated water management system”. Nevertheless, the Water Framework Directive is concerned by the management of water itself. In the case of groundwater this means the water within the aquifer. For this reason, the term “groundwater body” is introduced and defined as a “distinct volume of water within an aquifer or aquifers”. Soil, geological layers that build up aquifers, biota, and other components of the environment, are managed by other directives and regulations. Consequently, the water management has to be an integrated process including all relevant sectors. Therefore, the knowledge of hydrogeological structure and conditions within the aquifer is absolutely essential for delineation and characterization of the distinct water body for the management purpose.

Status of thermal groundwater

Water Framework Directive established important milestones in 2015 when the environmental goals have to be reached, i.e. there is a sufficient quantity of groundwater of good status. The sustainability principles require that good status is not only defined by the suitability of water for the human consumption, but also to maintain good status for the ecosystem.

Groundwater is in good quantitative status if the available groundwater resource is not diminishing by the long-term annual average rate of abstraction. Alterations to flow direction resulting from level changes may occur temporarily, or continuously in a spatially limited area, however such reversals do not cause saltwater, or other intrusion, and do not indicate a sustained and clearly identified anthropogenically induced trend in flow direction likely to result such intrusions in the future.

The good chemical status of groundwater is reached when concentrations of pollutants do not exhibit the effects of saline or other intrusions, do not exceed the quality standards, or diminishes the ecological quality of surface water and do not cause any significant damage to terrestrial ecosystems.

Thermal groundwater abstraction could provoke the alteration of natural water level regime in such a way that natural springs discharge is diminished and the conditions for certain dependent ecosystems could become unfavourable. Overexploitation of thermal groundwater could cause “mining” of water resources (i.e. without natural replacement from recharge) and therefore diminishment of available groundwater resource, or could cause the intrusions of less suitable water from neighbouring aquifers. Thus inadequate management of thermal groundwater could deteriorate the chemical and quantitative status of a groundwater body.

Reinjection of thermal waste water

The first EU regulation on groundwater (Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances) had its actions limited on the control over emission of substances from industry and urban sources (“emission principle”). WFD and the actual daughter DIRECTIVE 2006/118/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the protection of groundwater against pollution and deterioration (adopted 12 December 2006 – Groundwater Directive GWD) is definitely establishing the “emission” principle. This means that any pressure (emission, input) to the water body should not cause any significant actual or future impact on the groundwater body. One of the most important and pretentious tasks of the

WFD is to prevent the input of any dangerous substances in the groundwater, and limit the input of any other substance that could cause significant actual or future impact on the quality of groundwater. Any direct discharges of pollutants into groundwater is prohibited, while reinjection into the same aquifer of water used for geothermal purposes may be authorized under specific conditions provided that such discharges do not compromise the good status of groundwater. The issues of re-injection are discussed in more details in Chapter 3 (geothermal resource assessment, especially under 3.4.)

Thermal groundwater in river basin water management plans

In the river basin management plans for groundwaters the programme of measures has to be specified to reach the environmental goals. In order to be operational, the programme implements the necessary measures to:

- prevent or limit the input of pollutants into groundwater and to prevent the deterioration of the status of all bodies of groundwater, protect, enhance and restore all bodies of groundwater until 2015,
- ensure a balance between abstraction and recharge of groundwater with the aim of achieving good quantity status groundwater,
- reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity in order to progressively reduce pollution of groundwater.

Member states have to reach the environmental goals for groundwaters using basic and additional or supplementary measures that should be defined in river basin management plans (RBMP). These plans have to be resumed in six years periods. The actual water management cycle 2009 – 2015 has to ensure the adequate measures to be operational no later than 2012, justifying any eventual exemptions of lower objectives or extensions of deadlines (till 2021 / 2027).

The task of ensuring good status of groundwater requires early action and stable long-term planning of protective measures, owing to the natural time lag in its formation and renewal. Such time lag for improvement should be taken into account in timetables when establishing measures for the achievement of good status of groundwater and reversing any significant and sustained upward trend in the concentration of any pollutant in groundwater (L 327/3).

Programme of measures could be established specifically for each individual groundwater body, including thermal groundwater bodies.

Where groundwaters do not fully follow a particular river basin, they shall be identified and assigned to the nearest or most appropriate river basin district (WFD, Article 3, Coordination of administrative arrangements within river basin districts).

Transboundary water bodies (WFD, Article 3)

Member States shall ensure coordination with the aim of producing a single international river basin management plan in the case of an international river basin district. Where such an international river basin management plan is not produced, Member States shall produce river basin management plans covering at least those parts of the international river basin district falling within their territory to achieve the objectives of the WFD.

Member States shall ensure that a river basin covering the territory of more than one Member State is assigned to an international river basin district. Where appropriate, a Member State may adopt measures applicable to all river basin districts and/or the portions of international river basin districts falling within its territory.

Within a river basin where use of water may have transboundary effects, the requirements for the achievement of the environmental objectives established under WFD, and in particular all programmes of measures, should be coordinated for the whole of the river basin district. For river basins extending beyond the boundaries of the Community, Member States should endeavour to ensure the appropriate coordination with the relevant non-member States. WFD is to contribute to the implementation of Community obligations under international conventions on water protection and management, notably the United Nations Convention on the protection and use of transboundary water courses and international lakes, approved by Council Decision 95/308/EC (1) and any succeeding agreements on its application.

- Review of the impact of human activity on transboundary groundwaters

For those bodies of groundwater which cross the boundary between two or more Member States, the following information shall, where relevant, be collected and maintained for each groundwater body:

a) *the location of points in the groundwater body used for the abstraction of water with the exception of:*
    a. *points for the abstraction of water providing less than an average of 10 m3 per day, or,*
    b. *points for the abstraction of water intended for human consumption providing less than an average of 10 m^3 per day or serving less than 50 persons,*
b) *the annual average rates of abstraction from such points,*
c) *the chemical composition of water abstracted from the groundwater body,*
d) *the location of points in the groundwater body into which water is directly discharged,*
e) *the rates of discharge at such points,*
f) *the chemical composition of discharges to the groundwater body, and*
g) *land use in the catchment or catchments from which the groundwater body receives its recharge, including pollutant inputs and anthropogenic alterations to the recharge characteristics such as rainwater and run-off diversion through land sealing, artificial recharge, damming or drainage (L 327/30).*

- Monitoring of transboundary groundwater

Transboundary water bodies shall also be monitored for those parameters which are relevant for the protection of all of the uses supported by the groundwater flow (WFD L327/63).

The network shall include sufficient representative monitoring points and monitoring frequency to estimate the groundwater level in each groundwater body or group of bodies taking into account short and long-term variations in recharge and in particular for groundwater bodies within which groundwater flows across a Member State boundary, ensure sufficient monitoring points are provided to estimate the direction and rate of groundwater flow across the Member State boundary (L 327/60).

1.3 Transboundary aspect (UNECE, WFD, ICPDR)

General approach to integrated water resources management (IWRM)

Integrated water resources management is an approach that promotes the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in equitable manner without compromising the sustainability of vital ecosystems (**Cap-net, 2010).**

Policy regarding groundwater management should not be separated from that of other water resources, although there may be some policy elements that are specific to the groundwater context.

- An integrated approach to (ground)water management has to set goals to: - balance increasing resource demands with the needs of aquatic or terrestrial ecosystems and base flow in upper river reaches as appropriate. - take into account two-way relationships between macro-economic policies, broader social and environmental goals, and (ground)water development, management and use.
- Consider **cross-sectoral** integration in *policy development*. This helps to enforce decisions on priorities, e.g. basic drinking water supply. Cross sectoral coordination allows representation of (ground)water interests in non-water sectors such as land-use management. Moreover, put into effect the relation between water abstraction permits and wastewater discharge controls.
- Consider the **value of water** in all its uses to support efficient, equitable and sustainable (ground)water use, as well as its relationship with surface water abstraction where appropriate.
- Careful attention should be paid to the delineation of (ground)water **management boundaries** reconciling the hydrogeological setting, political/administrative boundaries, river basin management structures/ systems, etc., and resource management issues/ needs (Module 1). **Management targets** as well as monitoring and reporting operate at catchment level. Water management units (both surface water and groundwater) tend to be at this scale, so that connectivity properties need to be aggregated to this level to be incorporated into water management plans. Similarly, water quality targets (such as end-of-valley salinity targets) also operate in the catchment context.
- Decentralization, privatization and role of government have to be adequately addressed.
- Build **stakeholder** awareness (‘bottom-up’) and provide an enabling legal and economic climate (‘top-down’) to strengthen (ground)water governance.
- Demand-side actions should be equally involved in technical strategies for (ground) water management in urban and rural settings.

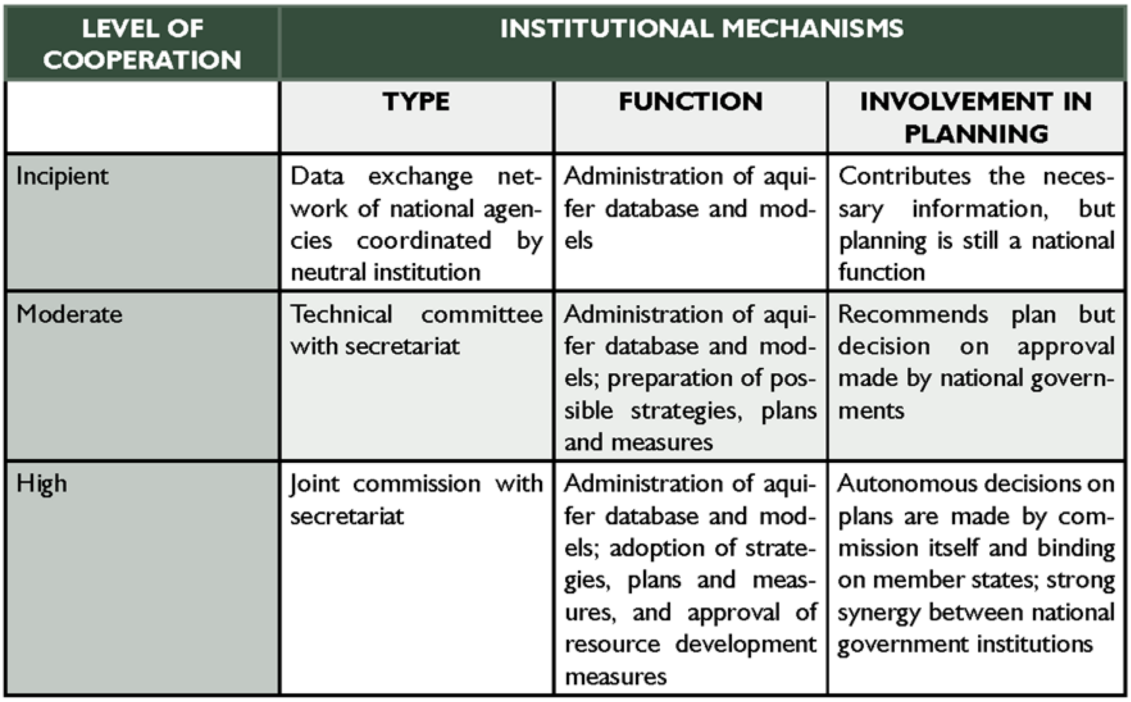
General approach to cooperation for transboundary groundwater (Cap-net, 2010)

There are only limited examples to track international cooperation in the management of shared groundwater resources, although it is increasingly recognized that such cooperation is beneficial and should be institutionalized if conflicts are to be avoided. Efforts to develop international legal rules on the subject are only recent, and generally do not extend to groundwater planning as such.

In the case of international groundwater resources it is not possible to adopt a uniform approach. Under given circumstances – for instance mining of non-renewable aquifer reserves — it would be advisable to develop an international groundwater resource plan which includes a ‘depletion exit strategy’ (GW-Mate Briefing Note 11). But the effects of much smaller scale groundwater development (for example in rural subsistence and small-town water supply) will only be felt very locally, so that there would be no need for a plan of the entire international aquifer system.

Different institutional mechanisms may be selected to plan and manage international groundwater resources, depending on the existing level of cooperation among the states concerned (Table 1) and on the type and urgency of issues to be addressed. It should be noted that an institutional mechanism may evolve from a simple agreement for handling and exchanging data to an international river basin, or aquifer commission that makes autonomous decisions in the interest of the member states. This latter mechanism would be expected to have strong synergy with national governments.

Table 1. Levels and evolution of International institutional mechanisms for groundwater resources planning and management.



LEVEL OF COOPERATION	INSTITUTIONAL MECHANISMS		
	TYPE	FUNCTION	INVOLVEMENT IN PLANNING
Incipient	Data exchange network of national agencies coordinated by neutral institution	Administration of aquifer database and models	Contributes the necessary information, but planning is still a national function
Moderate	Technical committee with secretariat	Administration of aquifer database and models; preparation of possible strategies, plans and measures	Recommends plan but decision on approval made by national governments
High	Joint commission with secretariat	Administration of aquifer database and models; adoption of strategies, plans and measures, and approval of resource development measures	Autonomous decisions on plans are made by commission itself and binding on member states; strong synergy between national government institutions

Identification of transboundary groundwater flow

Transboundary groundwater flow could be initially identified unilaterally by one country, while the neighbouring country does not have such information. The interested public could than publish the knowledge, especially scientific expertise and also unilaterally assess the significance of the transboundary groundwater flow. The expert communication between both sides of the border is expected. However, the cooperation between the countries regarding water management can start with specific challenges or common goals, with regional or community dynamics, or a risk of conflict.

In the case that cross border groundwater flow is significant, the conceptual model of this flow is a convenient and recommendable tool for verifying the assessed significance. The conceptual model has to implement only the existing and referenced knowledge of the natural conditions, assessment of level of certainty of this knowledge, weakness and then threats to the groundwater flow and opportunities to act (similar to SWOT analysis). This would be the basis to call for a further collaborative assessment involving all stakeholders in neighbouring countries.

For this purpose, the framework for a conceptual model available as a questionnaire prepared by UNECE (see Annex IV) is well considered, very convenient and a recommendable tool. It could be used initially by unilateral application and upgraded upon bilateral reconsideration in the next step. This conceptual model could be used on the expert level as a preliminary assessment and expert basis to initiate a transboundary river basin organization/body. The information provided by the conceptual model shall be used to activate the political and operational role of local and regional authorities.

The concept and content of conceptual models and what are they used for is accurately explained in the WFD-CIS Guidance 26 (definition below).

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;*
- *Visualization 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 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.*

When neighbouring countries recognize the significance of the transboundary groundwater flow and express the willingness to cooperate regarding water management, they are faced with mutual obligations. These obligations also have to be taken account during the recommendations for Transenergy countries to be elaborated at the end of the project.

The transboundary management requires neighbouring countries to fulfil complementary and mutually sustaining obligations (The Water Convention (http://www.unece.org/?id=26343)):

- to prevent, control and reduce adverse transboundary impacts on the environment, human health and socio-economic conditions;
- to manage shared waters in a reasonable and equitable manner using the ecosystem approach and guided by the precautionary principle and the polluter-pays principle;
- to preserve and restore ecosystems; and
- to cooperate through the establishment of agreements between transboundary Parties that foresees joint bodies responsible for joint management.

The transboundary management has to include provisions on monitoring, research and development, consultations, warning and alarm systems, mutual assistance, exchange of information, and access to information by the public.

Preparation process of Transboundary Management plan

The preparation process of Transboundary Management plan should follow four phases, each with defined tasks (IWRM):

PHASE I: Definition of basin; definition of the institutional framework and mechanisms for coordination.
PHASE II: Analyses of basin characteristics, pressures and impacts and economic analyses.
PHASE III: Development of monitoring networks and programmes.
PHASE IV: Development of the Management Plan including the Joint Programme of Measures (JPM) (ICPDR, Danube River Basin Management Plan).

To carry through these phases, the institutional framework and mechanisms for coordination have to be established by River Basin Organization (for example, bi-, multi- lateral commission). The River Basin Organization relevant for the TE project Countries is International Commission for the Protection of the Danube River (ICPDR).

A transboundary River Basin Organization can be defined as a permanent institutional arrangement dedicated to all or part of the management of shared waters between at least two countries. This covers a wide range of organizational types performing various functions. The legal framework and the statute of these institutions are often determined by the basin’s context and history as well as by the mandate given to the body established by the neighbouring countries.

Three levels of general mandates for transboundary basin organizations can be roughly distinguished, in ascending order of importance:

- a mere informational mandate, focusing on the exchange of data and tasks mainly technical and execution (incipient level of cooperation);
- a consultative mandate, where the body is an institution complementary to the States, but has no decisional power (moderate level of cooperation); and
- a decisional mandate, implying indeed a partial loss of the States’ sovereignty to the benefit of the organization in the field of shared waters (high level of cooperation).

The bilateral water commissions were established between all neighbouring Countries in the TE project area. These commissions are at incipient level of cooperation.

Usually, the creation of a permanent body follows an agreement between the riparian countries of the basin, an agreement that, in most cases, is limited to part of the territory of the countries concerned, since the basin limits do not correspond to the borders of each country. Globally, when water is shared by several countries, it is advisable that the cooperation agreement provides for the creation of a transboundary basin body, based on an inventory and prioritization of the problems in the basin. In addition, it is important to define cooperation issues using a basin-scale approach and to ensure the participation of all the riparian countries, no matter their importance, in the organization.

The ICPDR covers the management issues of all surface and ground water in the Danube River Basin. Currently the management of surface water has a higher level of cooperation, while the joint groundwater management is still in its initial stage (characterisation).

In the case of a mere governmental representation in a “commission” (or “Joint Commission”), there is often no Transboundary Basin Organization (no executive body) and activities are limited to meetings of officials of the countries. This is the first step to consolidate the political will to cooperate, learn to work together, build trust among members and promote the exchange of information and data. But this system should, if possible, evolve into a permanent basin body, to enable the establishment of a permanent secretariat which would enhance coordinated management and support implementation of the agreement. Over time, changing practices of cooperation between the riparian countries of a basin, change in the mandate, level of activities and management tasks and experience may lead to a change of statute of the body (GWP / INBO, 2012).

When the transboundary River Basin organization has the mandate for the preparation process of Transboundary Management plan it has *to ensure the appropriate coordination between experts and stakeholders on both sides to take coordinated actions in the frame and level of the given mandate.*

In the frame of **PHASE I**: Definition of basin, the more detailed delineation of identified transboundary groundwater flow has to be performed.

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 (Guidance 26). These different approaches are clearly reflected in the national groundwater body delineations and characterizations of the Transenergy countries provided in Chapter 2).

Based upon this delineation, each country has to reveal the appurtenance of a newly characterized transboundary groundwater flow to the groundwater body delineated in the existing (1st cycle) national water management plan. Neighbouring countries could then compare methodologies of its characterization, pressures and impacts analyses and risk assessment between the national management plans.

As data collection for the first WFD reporting cycle happened for the first time and such data on groundwater have never been collected in transboundary river basins before, differences in the progress of WFD implementation in neighbouring countries became obvious. Countries used a broad spectrum of different approaches for the delineation of GW-bodies, their characterization, for the assessment of the risk of failure to reach good status, for the establishment of threshold values and for the status assessment. An analysis would be helpful to understand the differences in the national approaches in order to further harmonize the different methods. Short identification of differences in the national approaches is given in chapter 2.5. Data gaps and inconsistencies have become apparent in the underlying data resulting in uncertainties in the interpretation of the data. In addition, some countries have identified the need to expand the current monitoring networks to include monitoring stations along the national borders, where transboundary GW-bodies are located. In some cases, countries have assessed the need to adapt their current monitoring programmes to collect better information on water quality and quantity. This entails the need for intensive bi- and multilateral cooperation to achieve a harmonization of data sets for transboundary GW-bodies. At the moment no harmonized system for coding of the different layers of GW-bodies is available. The aspect of different groundwater horizons needs further discussion and clarification.

To reveal the significance of stated differences in methodologies and, eventually, different definitions of groundwater horizons, the conceptual model again is the recommendable tool to avoid unnecessary time consuming studies and efforts. This would be the second level conceptual model, combining the national conceptual models from the first water management cycles. It should represent the basis for the mutually reconciliated Analyses of basin characteristics, pressures and impacts and economic analysis in the PHASE II.

Planning for the second cycle of WFD RBMPs starts soon after the delivery of the first RBMPs. The preparation period is significantly reduced from 9 years of the first cycle (2000–2009) to 6 years (2010–2015), with the first key deliverable; the next Article 5 characterization report is 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 characterization and risk assessment will be (CIS-WFD Guidance 26) (Figure 1):

- refinement of water body delineation, where necessary;
- review of pressures and risks to identify changes and new pressures;
- factoring in climate change; and
- refinement of characterization procedures to ensure consistency of approach with classification (status assessment).

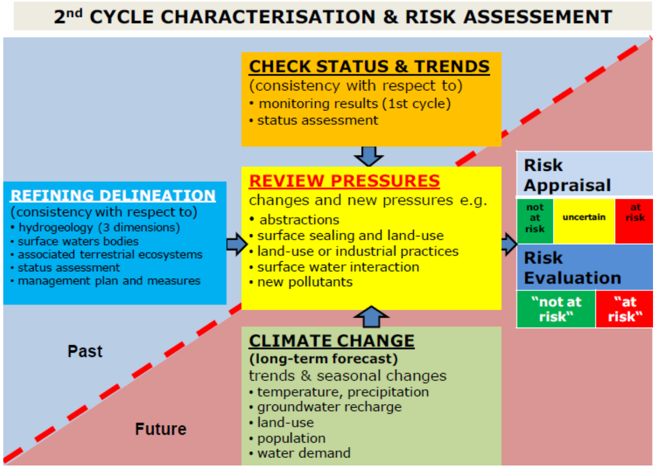


Figure 1. Key elements to consider during the 2nd planning cycle (Guidance Document No. 26. Risk Assessment and the Use of Conceptual Models for Groundwater (2010))

Ongoing related scientific projects and their outcomes should have a guiding role. Therefore, existing Danube River Basin scientific activities, such as Transenergy are the basis for the further development of measures.

In the further conduction of transboundary water management process following issues will have to be addressed by the transboundary River Basin organization:

- water issues have to be placed at the centre of public policy, in particular education and health,
- collaborative management involving all stakeholders in all countries,
- integration of the energy/water/food security nexus for all stakeholders,
- the creation of a knowledge and expertise tool available to parliamentarians (politicians?),
- governance of the tool of knowledge and expertise that will be available to parliamentarians,
- reaffirm the fundamental political and operational role of local and regional authorities to ensure sustainable and equitable management of water and sanitation services and protect water resources, and
- establishing a mechanism for the monitoring and evaluation of solutions / decisions, available to all stakeholders, in particular, to parliamentarians (6th World Water Forum - Marseille, 15-16 March 2012, Manifest).

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 (CIS-WFD Guidance 26).

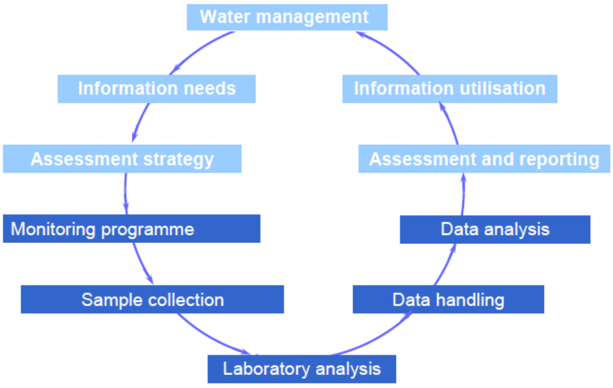


Figure 2. The water management cycle (European Commission, 2008: Groundwater Protection in Europe.)

PHASE III: Development of monitoring networks and programmes.

The monitoring programme has to include both quantitative and chemical (quality) monitoring and shall provide the necessary information to:

- assess groundwater status,
- identify trends in pollutant concentrations,
- support GW-body characterization and the validation of the risk assessment,
- assess whether water protection area objectives are achieved,
- support the establishment and assessment of programmes of measures, and
- effective targeting of economic resources.

Steps of monitoring design:

- development of conceptual models of GW-bodies;
- achievement of harmonized monitoring networks; and
- establishing of criteria for the selection of parameters.

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 characterization, monitoring strategies and networks should be reviewed and if necessary revised. However, in refining monitoring networks revisions must be made to ensure that monitoring is able 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 (Guidance 26).

PHASE IV: Development of the Management Plan including the Joint Programme of Measures (JPM).

Some principles that improve the efficiency of the transboundary organization and cooperation should be emphasized during the development of the Management Plan including the Joint Programme of Measures. These are:

- a wide responsibility of the joint body to allow for Integrated Water Resources Management implementation;
- a clearly defined mandate and institutional organization to allow for the adoption of decisions and their implementation;
- a gradually consolidated legal framework;
- efficient mechanisms for cooperation between the national authorities and the transboundary basin body;
- mechanisms for reporting;
- the availability of funds to support joint programmes and structures; and
- mechanisms to stimulate public and stakeholders participation in the activities of the joint body.

Development of the Management Plan relies on mutual data collection and utilization. Finally, the transboundary management plan is based on data delivered by the neighbouring countries. Where countries do not deliver data, other data sources could be used if available. Sources other than the competent authorities have to be clearly identified in the Plan. A more detailed level of information is presented in the national Plans. Hence, the transboundary management plan should be read and interpreted in conjunction with the national Plans. Where inconsistencies may occur, the national Plans are likely to provide the more accurate information. Some countries are not able to provide all the information needed for the ambitious report, and these gaps could be noted in the text. Where data have been made available, it has to processed and presented to the best of the available knowledge. Nevertheless, inconsistencies cannot be ruled out.

Depending on the mandate of the transboundary organizations, the management plan will be developed in three steps. The choice of the tasks of the basin organization must result from a detailed analysis of the tasks already fulfilled nationally. The implementation of management tools is a particularly crucial feature.

1st level management: focusing on the exchange of data and tasks mainly technical and execution;

''Exchange of data and tasks'' is the management level where each country follows its national river basin management plan and program of measures. Neighbouring countries have not yet defined specific common goals or targets; the goals and targets are more or less general. They follow the environmental objectives from WFD, regularly exchange the actual basic information and consultation about selected parameters of management efficiency. The main activity is observation. Results of the observations are common directions to coordinate expert activities of neighbouring countries and theirs reporting to the transboundary organization.

Analysis of data management abilities have to be provided including identification of the stakeholders and inventory of existing data sources (metadata catalogues). Given the diversity of the topics to be dealt with (surface water, groundwater, quantity and quality aspects, users, uses, infrastructure, socio-economic and environmental data, geographic information, etc.) the number of organizations that produce data at regional, national and local levels can be high. Therefore, it is recommended to start with an inventory of producer organizations and analyze their geographical area of intervention, the topics on which they operate and their various collection processes.

Searching for data on water and understanding how they can be helpful often result in lost time and expenses, which may be major obstacles to effective use of existing data. Thus, an inventory of data sets and existing information is essential for:

- identifying existing data and information, and whether they are accessible or not;
- determining the rules of exchange and accessibility (free / limited access) to data; and
- checking that the quality of available data meets the 1st level management needs.

An inventory should be a collaborative activity. When inventories involve online metadata catalogues, the parties can directly integrate the data they manage. They can also assign to each users' group specific rights of access to metadata and data sets. Users can find and identify data through simple multi-language interfaces by using keywords and / or through geographic interfaces; and download data, or access to interactive maps, according to the access rights given by the data providers.

Data exchange activities have to follow the reporting requirements Transboundary Basin > users > local authorities > regional authorities > National RBMP > ICPDR > EC WFD > UNECE. The standards and recommendations shall be followed to WISE (Water information system for Europe) and INSPIRE Directive.

2nd level transboundary management: a consultative level without decisional power;

The second level of transboundary management comprises consultations and discussions about specific targets set in national plans (for example, threshold values, critical values, significant water management issues). Consequences of differences in these values or parameters between countries and the need of eventual advanced harmonization are discussed. Certain common activities are proposed and coordinated to overpass the uncertainties and possible conflicts. Decisions are made on individual country level.

3rd level transboundary management: a decisional level

In the decisional level, transboundary organizations take the responsibility to make decisions and interventions to exploration permitting procedures and water rights granting.

The third level of transboundary management is introduced when common goals and targets are specifically and precisely defined, when the feasibility of the implementation of programme of measures is reached and the efficiency of measures could be mutually controlled. Mutual action plan has to be previously prepared on the basis of reconcilliated communication plan, SWOT analysis and benchmarking. Benchmarks to observe the sustainability of common management plan are recommended to be set up.

Decisional level have to be set up when mutual expert arbitrations would be needed, common evaluations and tools development to control the pressures and impacts.

Definition of transboundary organization's mandate and the level of transboundary water management

The management of groundwater systems consists of steps in a continuous cycle as described in the Introduction. 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 (Guidance 26) (Figure 3).

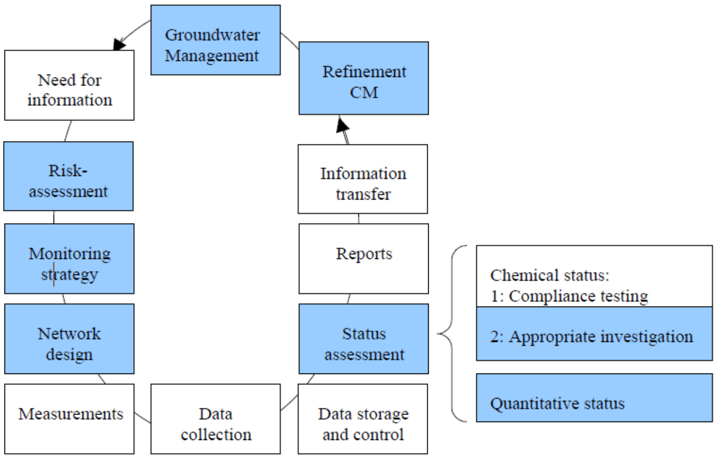


Figure 3. Role of conceptual models in groundwater management in blue the steps where conceptual models can be useful or may be even essential (Guidance 26)

Consequently this cycle, or better spiral, principle has important role also in the definition of mandate to transboundary organization and level of transboundary groundwater management. Starting from the last refinement of conceptual model we should set up conceptual questions and answers about equilibrium and level of groundwater development.

For sustainable groundwater management, the water balance need to be established for a given unit system (hydrologic/ river basin, groundwater basin or aquifer unit) over a given period of time. Where possible, the water balance should be undertaken for the aquifer system itself as a single hydrological unit, bearing in mind that it is an integral part of the whole hydrological / groundwater basin. If the equilibrium is disturbed by increased groundwater pumping, the system gradually adjusts to a new equilibrium, requiring either:

- increased inflows (e.g. by artificial recharge);
- reduced outflows in parts of the system; or
- a combination of the above two.

New flow equilibrium is also likely to be accompanied by changes in groundwater levels/ pressures in at least parts of the system. Understanding water balance and how it changes in response to human activities is an important aspect of groundwater system characterization, especially for thermal groundwater reserves, where this delicate balance can be often disturbed by over-exploitation. A water balance provides a means of testing, confirming or refining our hydrological understanding of the system. However, it cannot provide definitive determination and prediction of the implications of groundwater abstraction impacts. The modelling approach may be a useful tool to refine our understanding of the system.

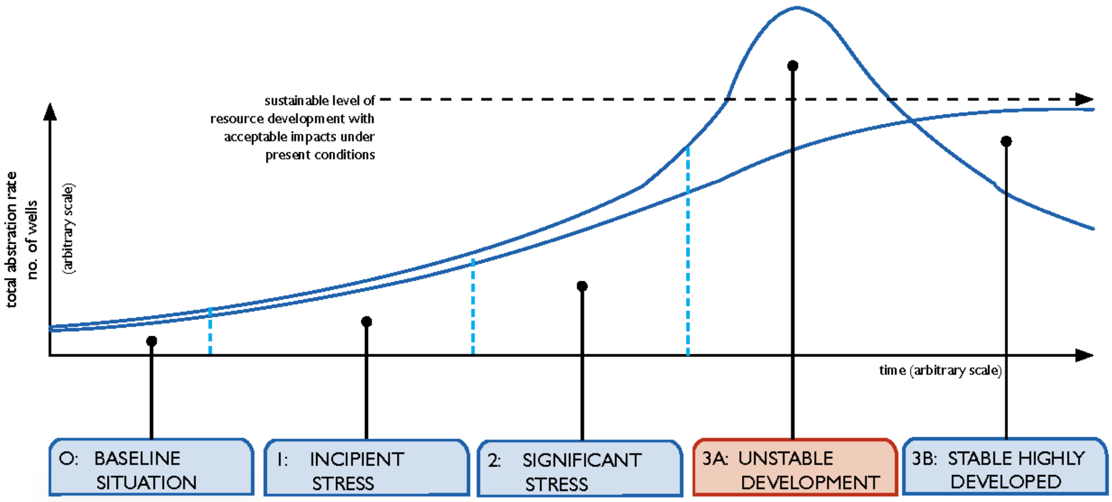
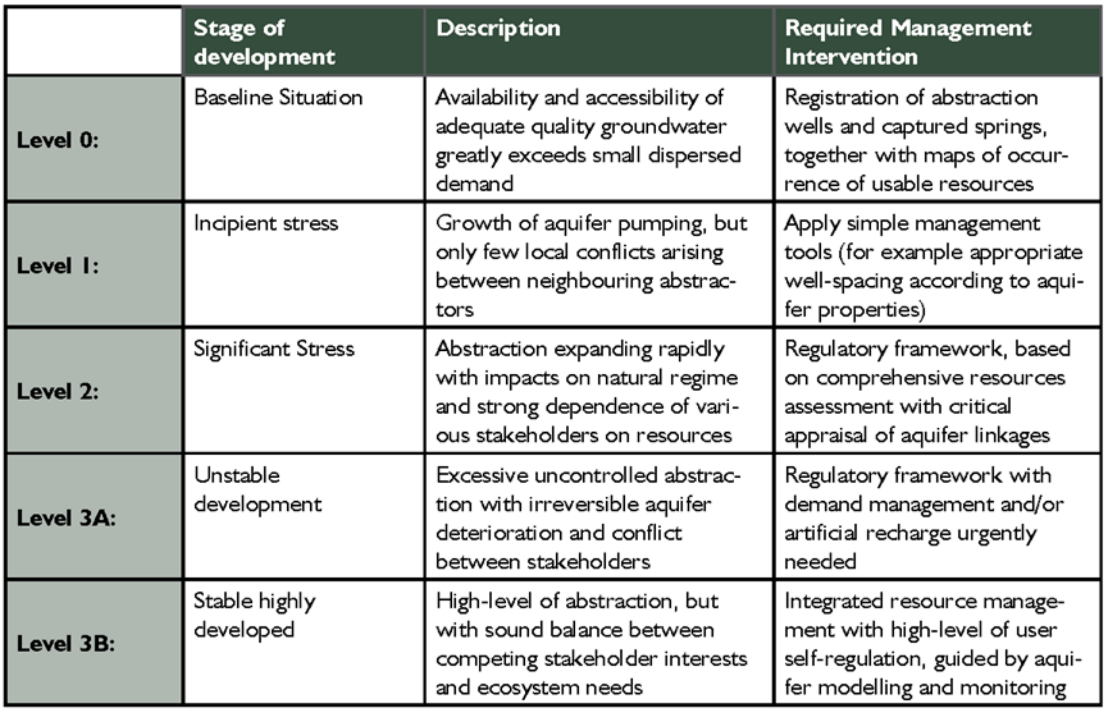


Figure 4. Levels of groundwater development (Cap-net, 2010).

Table 2. Levels of groundwater development and required management intervention (Cap-net, 2010).



	Stage of development	**Description**	**Required Management Intervention**
Level 0:	Baseline Situation	Availability and accessibility of adequate quality groundwater greatly exceeds small dispersed demand	Registration of abstraction wells and captured springs, together with maps of occurrence of usable resources
Level I:	Incipient stress	Growth of aquifer pumping, but only few local conflicts arising between neighbouring abstractors	Apply simple management tools (for example appropriate well-spacing according to aquifer properties)
Level 2:	Significant Stress	Abstraction expanding rapidly with impacts on natural regime and strong dependence of various stakeholders on resources	Regulatory framework, based on comprehensive resources assessment with critical appraisal of aquifer linkages
Level 3A:	Unstable development	Excessive uncontrolled abstraction with irreversible aquifer deterioration and conflict between stakeholders	Regulatory framework with demand management and/or artificial recharge urgently needed
Level 3B:	Stable highly developed	High-level of abstraction, but with sound balance between competing stakeholder interests and ecosystem needs	Integrated resource management with high-level of user self-regulation, guided by aquifer modelling and monitoring

The mandate of transboundary organization is not directly dependent from the stress on the system. The same levels of stress could be managed in different levels of management. However baseline situation or incipient stress probably wouldn't need higher level of management. On the other side, the unstable development stress wouldn't be manageable on the highest level until the adequate level of harmonization is reached in the process of Water management plan (Phases I to IV) in the lower levels of management. Anyhow, the system at the 3rd level of development stage (unstable / stable) would need management interventions adequate to the highest (3rd) level of management:

Baseline situation > incipient stress: 1st level management: focusing on the exchange of data and tasks mainly technical and execution

Incipient stress > significant stress > unstable development: 2nd level transboundary management: a consultative level without decisional power;

Unstable development > stable highly developed: 3rd level transboundary management: a decisional level.

Groundwater management interventions

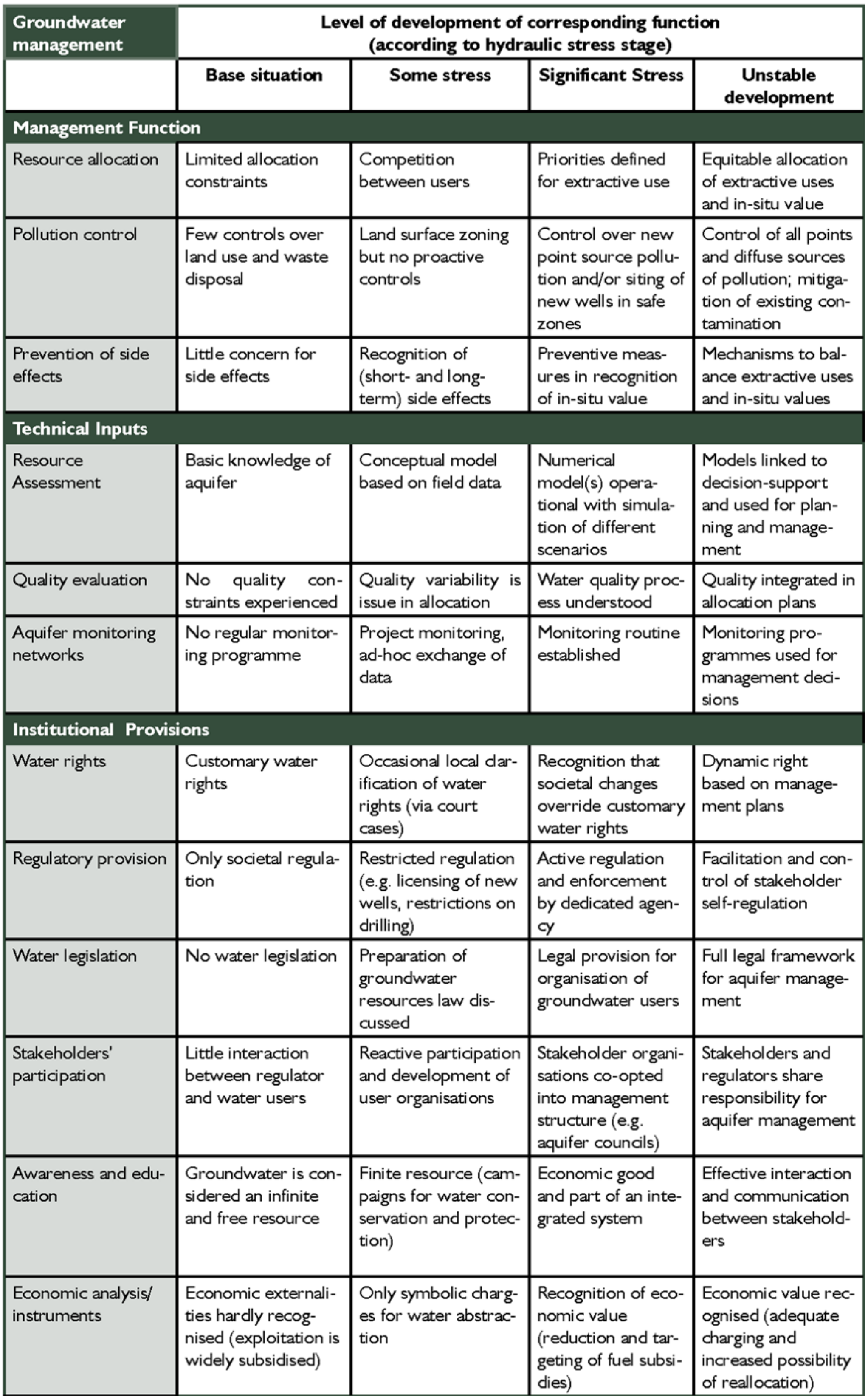
Groundwater management interventions described in column 4 (Table 2) follow the evolution of groundwater development. While accepted as a practical approach for implementing integrated groundwater management, it should not encourage purely reactive management approach. Preventive approaches are likely to be more cost-effective.

Groundwater management interventions can be grouped into three categories:

1. Management functions
2. Technical inputs
3. Institutional provisions

Table 3 illustrates the application of management systems according to the level of development and hydraulic stress of the aquifer.

Table 3. Levels of groundwater management functions and interventions necessary for given stage of resource development (Cap-net, 2010)



Groundwater management	**Level of development of corresponding function (according to hydraulic stress stage)**			
	Base situation	**Some stress**	**Significant Stress**	**Unstable development**
Management Function				
Resource allocation	Limited allocation constraints	Competition between users	Priorities defined for extractive use	Equitable allocation of extractive uses and in-situ value
Pollution control	Few controls over land use and waste disposal	Land surface zoning but no proactive controls	Control over new point source pollution and/or siting of new wells in safe zones	Control of all points and diffuse sources of pollution; mitigation of existing contamination
Prevention of side effects	Little concern for side effects	Recognition of (short- and long-term) side effects	Preventive measures in recognition of in-situ value	Mechanisms to balance extractive uses and in-situ values
Technical Inputs				
Resource Assessment	Basic knowledge of aquifer	Conceptual model based on field data	Numerical model(s) operational with simulation of different scenarios	Models linked to decision-support and used for planning and management
Quality evaluation	No quality constraints experienced	Quality variability is issue in allocation	Water quality process understood	Quality integrated in allocation plans
Aquifer monitoring networks	No regular monitoring programme	Project monitoring, ad-hoc exchange of data	Monitoring routine established	Monitoring programmes used for management decisions
Institutional Provisions				
Water rights	Customary water rights	Occasional local clarification of water rights (via court cases)	Recognition that societal changes override customary water rights	Dynamic right based on management plans
Regulatory provision	Only societal regulation	Restricted regulation (e.g. licensing of new wells, restrictions on drilling)	Active regulation and enforcement by dedicated agency	Facilitation and control of stakeholder self-regulation
Water legislation	No water legislation	Preparation of groundwater resources law discussed	Legal provision for organisation of groundwater users	Full legal framework for aquifer management
Stakeholders' participation	Little interaction between regulator and water users	Reactive participation and development of user organisations	Stakeholder organisations co-opted into management structure (e.g. aquifer councils)	Stakeholders and regulators share responsibility for aquifer management
Awareness and education	Groundwater is considered an infinite and free resource	Finite resource (campaigns for water conservation and protection)	Economic good and part of an integrated system	Effective interaction and communication between stakeholders
Economic analysis/ instruments	Economic externalities hardly recognised (exploitation is widely subsidised)	Only symbolic charges for water abstraction	Recognition of economic value (reduction and targeting of fuel subsidies)	Economic value recognised (adequate charging and increased possibility of reallocation)

1.4 References

Cap-net, 2010: Groundwater Management in IWRM. Training Manual

Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No. 26. Risk Assessment and the Use of Conceptual Models for Groundwater (2010).

Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No. 2. **Identification of water bodies (2003)**

Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance Document No. 3. **Analysis of Pressures and Impacts (2003)**

Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance Document No. 7. **Monitoring under the Water Framework Directive (2003)**

Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance Document No. 12. **The Role of Wetlands in the WFD.** (2003)

Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance Document No. 15. **Guidance on Groundwater Monitoring (2007)**

Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No. 16. **Groundwater in Drinking Water Protected Areas (2007)**

Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No. 17. **Preventing and Limiting Direct and Indirect Inputs (2007)**

Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No. 18. **Groundwater Status and Trend Assessment (2009)**

Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance No. 21. **Guidance for reporting under the WFD (2009)**

Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance No. 22. **Updated WISE GIS guidance (Nov'2008) (2009)**

Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No. 24. **River Basin Management in a Changing Climate (2009)**

GWP / INBO, 2012: The handbook for integrated water resources.

ICPDR ,2005: The Danube River Basin District. River basin characteristics, impact of human activities and economic analysis required under Article 5, Annex II and Annex III, and inventory of protected areas required under Article 6, Annex IV of the EU Water Framework Directive (2000/60/EC). Part A – Basin-wide overview, (WFD Roof Report 2004), 18 March 2005.

ICPDR, 2007: Summary Report to EU on monitoring programmes in the Danube River Basin District designed under Article 8 of the EU Water Framework Directive (2000/60/EC). Part II: Status report: Towards the development of groundwater monitoring in the Danube River Basin – Basin-wide overview, (WFD Roof Report 2007), 18 March 2007.

ICPDR, 2009: Danube River Basin Management Plan. Part A – Basin-wide overview.

ICPDR , 2010: Groundwater guidance.

UN/ECE Task Force on Monitoring & Assessment, 2000: Guidelines on Monitoring and Assessment of Transboundary Groundwaters. Work Programme 1996 – 1999. Lelystad, Netherlands. http://www.unece.org/env/water/publications/documents/guidelinesgroundwater.pdf

UN/ECE Task Force on Monitoring & Assessment,1999: Inventory of Transboundary Groundwaters. http://www.iwac-riza.org/downloads/task_force_vol1.pdf

UN/ECE Programme Area III Monitoring and Assessment: http://www.unece.org/env/water/cooperation/area423.htm

UN/ECE , 2011: Second Assessment of Transboundary Rivers, Lakes and Groundwaters" .
Document available at: http://live.unece.org/env/water/publications/pub.html

2 Overview of current state of groundwater management and monitoring

2.1 Current state of groundwater management in Slovenia

Current groundwater management is implemented by the Water Act (ZV-1: Official Gazette RS, No. 67/2002) and by the Decree on Danube and Adriatic Sea River Basins Management Plan (Official Gazette RS, No. 61/2011). The River basin management plan is implemented for the 1st management period 2009-2015 following the Water Framework Directive.

The management of geothermal resources is a complex task, with responsibility in Slovenia distributed between the government departments of water resources, energy and mineral resources. Although their action plans should work together to achieve the sustainable and effective development of geothermal resources, this is not currently the case. Implementation of the Water Framework Directive (WFD; European Commission, 2000) during the last ten years has increased the number of water rights granted for a variety of types of water use in Slovenia. However, the objective of attaining a good qualitative and quantitative status of thermal groundwater bodies appears to be endangered by discrepancies between current legislation and actions of users. A brief history of the evolution of this problem is described in the following paragraph.

All thermal water facilities were defined as socialised property before Slovenia's independence in 1991. After independence, a transition of the social-economic system from socialism to capitalism took place and public property became private. Between 1991 and 2002 (when the new Water Act according to the WFD was implemented), water rights were granted only as water permits on the basis of ownership of the water usage facilities, regardless of the status of the thermal resources. After 2002, all thermal water users were obliged to apply for concessions during the following two years. Existing permits of thermal water users were converted immediately into concessions, together with new applications of as-yet non-registered thermal water users. In 2006 processing of concessions for NE Slovenia took place. However, local hydrogeological conditions meant that individual treatment was not possible, while data required for the preparation of concession decrees was lacking. In addition, some legislative problems occurred. As a result the granting process almost stopped, with the fact that it is a discretionary right of the State not helpful. In 2007, the Geological Survey of Slovenia began a project of geothermal utilisation screening in the Mura-Zala basin in cooperation with the Ministry of the Environment and Spatial Planning. As time passed, the operation of the Mining Act (Official Gazette RS, No. 68/2008, 61/2010) and the renewed Water Act (Official Gazette RS, No. 57/2008) became quite harmonious, with activities associated with the granting process subsequently slowly increasing.

In Slovenia these unfavourable trends prohibiting the growth of geothermal energy and thermal water utilization are a direct consequence of a lack of systematically gathered and stored monitoring data, as geothermal aquifer exploitation is currently regulated by two ministries and legislations, as already discussed in the previous section. The Ministry of the Environment and Spatial Planning manages thermal water use via the Water Act (Official Gazette RS, No. 67/2002, 57/2008) and thermal water concessions. This type of use includes most thermal and thermomineral water users, which are predominantly thermal resorts and health centres that discharge waste water into the environment. The Ministry of the Economy manages mineral resources via the Mining Act (Official Gazette RS, No. 56/1999, 46/2004, 98/2004, 68/2008, 61/2010) and mineral concessions, as geothermal energy in Slovenia is currently administratively defined as a mineral resource. Thus the energy sector manages concessions for geothermal energy users who exploit only geothermal energy, including open doublet systems (i.e. water abstraction and reinjection). The unclear relationship between these two legislative bodies complicates the legal setting of concession decrees, with investors often applying for mining concessions, but failing to set up geothermal doublets. As a result only production wells are often drilled, with the associated reinjection well merely considered only in paper form and postponed to an unknown future date. This is unfortunately the case with the district heating system in Lendava and the greenhouse heating system in Dobrovnik. Nevertheless, production wells have been drilled in the same geothermal aquifers utilised by thermal water users and managed by much stricter obligations due to the Water Act. Before 2008 mining concession beneficiaries were not obliged to perform any production monitoring, but after 2008 the Mining Act (Official Gazette RS, No. 68/2008, 61/2010) and the Water Act (Official Gazette RS, No. 57/2008) were in principle coordinated. From then on, users with deep geothermal pumping-reinjection pairs of wells were obliged to follow both legislations (mutual responsibility). However, reporting to the water sector body does not take place in practice and in any case even the water sector requires only the establishment of production well monitoring. Moreover, the State is currently not interested in injection well performance data at all. It was finally decided that all users abstracting water from the same aquifer are to be processed under the same requirements and concessions granted simultaneously. The only currently remaining problem is a lack of precedent cases, which would stimulate the distribution of responsibility in this joint water concession granting procedure. We suggest that these shortfalls should be amended by Mining and Water legislation throughout the strategic document and technical regulations.

Besides this rather a political conflict, some discrepancies between users in NE Slovenia were also identified. At the beginning of spa resort development, abandoned oil and gas boreholes were used to utilise thermal water, with boreholes drilled primarily for geothermal purposes prevailing only from the late 1980’s. In the latter, users are also owners of the wells, while in the earlier examples this is not necessarily the case. This sometimes results in difficulties when applying for water concession, as no official agreement between well owner and user exists. Therefore, until well ownership and management issues are settled no concession application can be elaborated.

The third inconvenience is governed by the geological structure of NE Slovenia, positioned as it is on the western margin of the Pannonian basin, with the Mura-Zala basin extending in a SW-NE direction. An emphasis on the need for uniform treatment of existing and potential new users can be given now, as the same Tertiary aquifers are currently being exploited for different direct-use purposes throughout the entire area of the Mura-Zala basin. Overexploitation has already been identified as occurring in the Mura formation aquifer in Murska Sobota (Kralj and Kralj 2000, Kralj et al. 2009) and Radenci (Pezdič 2003).

2.1.1 Characterisation of groundwater bodies

The current management of groundwater in Europe is based on the principle of groundwater bodies (GWB). In Slovenia they were delineated and characterised according to WFD (European Union 2000) and Slovenian regulation in 2005 (Official Gazette RS, No. 63/2005). Groundwater body areas were delineated based on porosity and lithology boundaries, productivity and extent boundaries, catchment basin boundaries, flow lines, interstream boundaries, junctions with large affluent, recovering and potential use boundaries (water protection areas), tracer experiment results, as well as boundaries of significant pressures. The latest hydrogeological map (1:250,000) was used as the cartographic basis for delineation of groundwater bodies in Slovenia and elaborated upon using international recommendations and the standard legend proposed by the IAH (Struckmeier and Margat 1995).

However, at present, groundwater bodies in Slovenia are currently delineated only by surface boundaries (Prestor and Urbanc 2005) (Figure 5). The thermal water aquifers of the TRANSENERGY project area has been identified and characterised within six groundwater bodies (Slovene abbreviation is VTPodV): 4018 Goričko, 4016 Murska kotlina and 4017 Vzhodne Slovenske gorice in the Mura River basin and 3015 Zahodne Slovenske gorice, 3012 Dravska kotlina and 3014 Haloze in Dravinjske gorice in the Drava River basin. They have not been delineated yet in three dimensions, and have only been identified according to significant changes in stratification. Each of these GWB-s is stratified in set of different vertical layers, within characteristic aquifer according to their different properties (Figure 6, Figure **7**). From a site-specific view, all thermal water bodies are currently being delineated progressively as part of the actual water concession granting procedure for each individual user. Identified geothermal aquifer types in this region include geothermal aquifers in deeper Neogene sediments and Pre-Tertiary carbonate or metamorphic basement rocks, and aquifers in shallower Neogene sediments with fresh or thermal water.

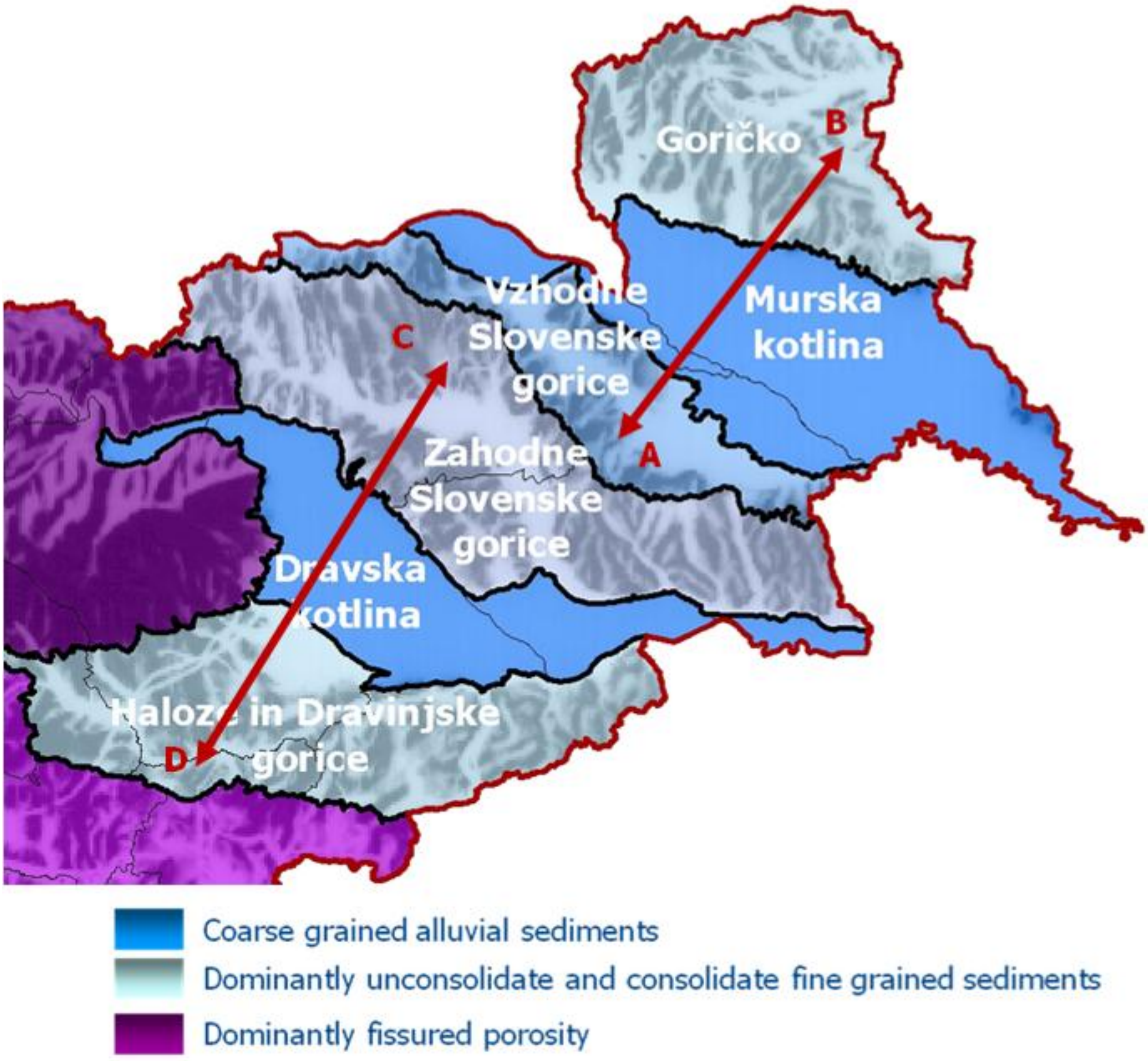


Figure 5. Delineation of Groundwater bodies (GWB) in Slovenia. For cross sections see Figs 6 and 7

According to the Rules on determining groundwater bodies (Official Gazette RS, No. 63/2005), the thermal groundwater reservoirs belong to the following aquifers from the initial unilateral characterization, status and risk assessment and program of measures (Table 4):

Table 4. Aquifers of geothermal water in NE Slovenia.

VTPodV 4018 Goričko	2nd aquifer	Thermal aquifers in deeper Tertiary layers and pre-Tertiary basement
VTPodV 4016 Murska kotlina	3rd aquifer	Thermal aquifers in deeper Tertiary layers and pre-Tertiary basement
VTPodV 4017 Vzhodne Slovenske gorice	3rd aquifer	Thermal aquifers in deeper Tertiary layers and pre-Tertiary basement
VTPodV 3015 Zahodne Slovenske gorice	3rd aquifer	Thermal aquifers in deeper Tertiary layers and pre-Tertiary basement

VTPodV 3012 Dravska kotlina	3rd aquifer	Thermal aquifers in deeper Tertiary layers and pre-Tertiary basement
VTPodV 3014 Haloze in Dravinjske gorice	1rd aquifer	Shallow and deep carbonate aquifers (include thermal)

The limit between thermal and non-thermal groundwater is actually not set in Slovenia. On the expert basis it is considered that thermal water is water that has the temperature higher than 4 °C above the average yearly air temperature of the location ($T_{thermal} > T_{air\ mean} + 4\ °C$). In the actual practice of exploitation permitting the thermal water has more than 20 °C and this is the limit when the exploitation has to be regulated by the concession.

Delineation of thermal aquifers has not been precisely performed yet. Nevertheless, the maps of the temperature field at different depths are showing that the temperature of 20 °C could be generally expected in the depths between of 100 m and 250 m below the surface, except in the region of deep intrusion of cold karstic water.

Tertiary layers represent the intergranular porosity type of aquifers composed of the thick basin fill sequences with thermal groundwater deeper than the isotherm 20 °C and are also in hydraulic connection with the overlying intergranular aquifers with colder water.

Pre-Tertiary basement represent fissured including karst porosity type of aquifers composed by fissured Paleozoic metamorphic rocks and also by fissured and karstified Mesozoic carbonate rocks. The groundwater in these layers has temperature over 30 °C and is recharged generally from the marginal uplands and from leakage from the overlaying Tertiary strata.

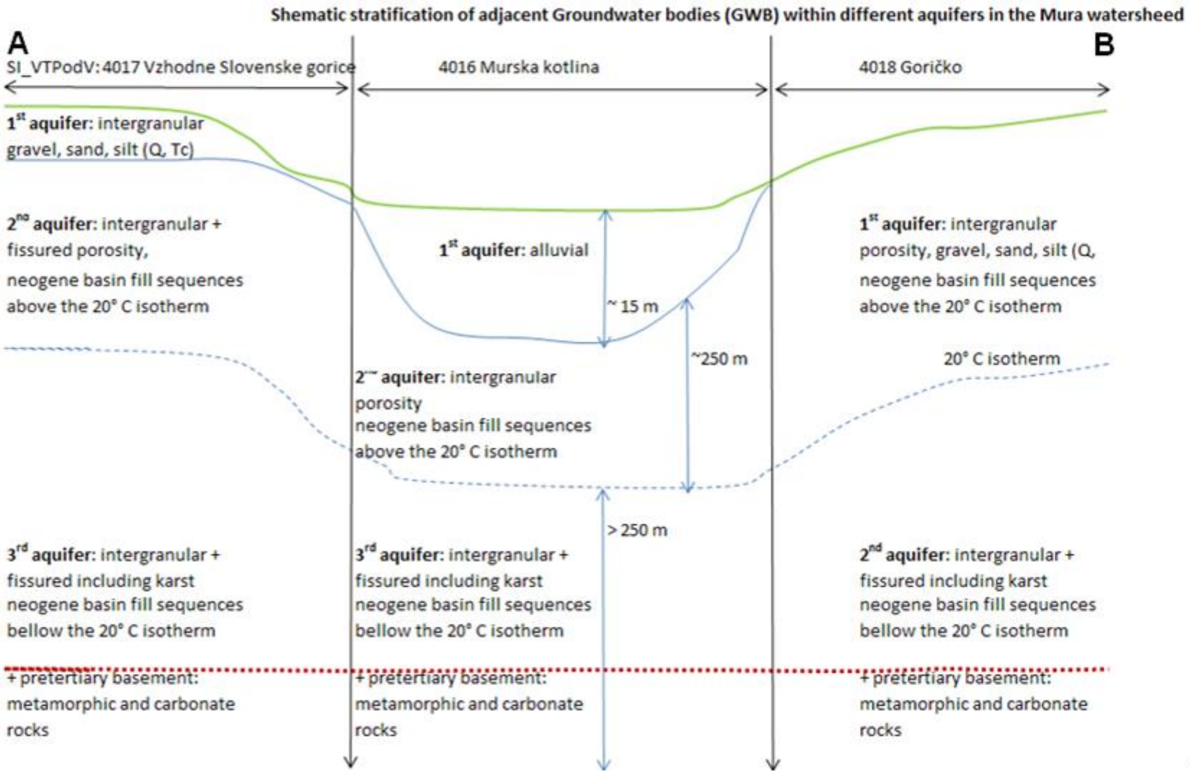


Figure 6. Schematic vertical stratification of groundwater bodies in Mura watershed (Slovenia) – (cross section A – B: Figure 5).

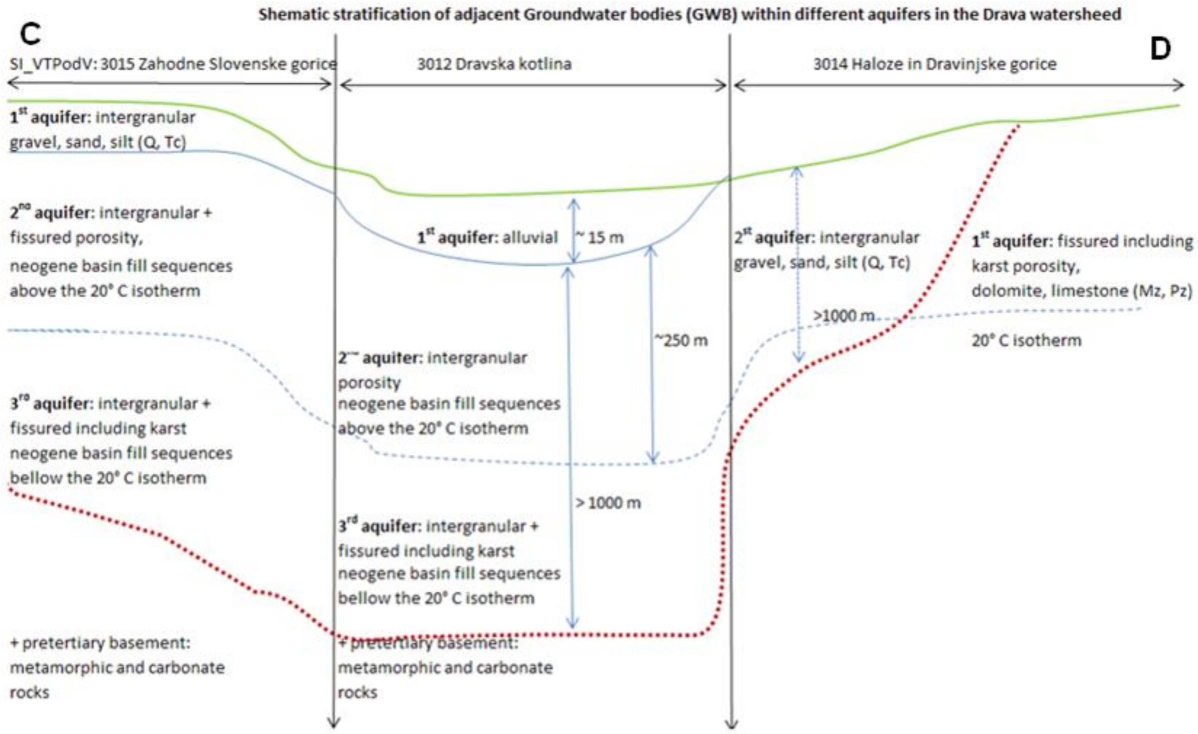


Figure 7. Schematic vertical stratification of groundwater bodies in Drava watershed (Slovenia) – (cross section C – D: Figure 5).

In the actual River Basin Management Plan (RBMP) of Slovenia 2009 - 2015 (Official Gazette RS, No. 61/2011, Decree on River basin management plans of Danube and Adriatic water districts) the status assessment, environmental objectives and supplementary and additional measures are given for all GWB-s. For all six presented groundwater bodies the very important supplementary measure which has to be fulfilled is written in the Article 8 of the RBMP: Water rights for new abstractions in Mura-Zala basin could be granted if the trend of water level is not decreasing. The water right for the existing abstractions depends on the trend of water level.

Table 5. Status assessment, environmental objectives and supplementary and additional measures from RBMP 2009 – 2015.

Groundwater body code	**Name of groundwater body**	**Classification** **(Status assessment)**		**Environmental objectives**	**Supplementary and additional measures**	
		Quantity status	**Chemical status**		till 2015	after 2015
VTPodV 4016	Murska kotlina (3rd aquifer)	Good with uncertainty*	Good	Good status / prevention of actual status deterioration	Article 8 (61/2011) / DUPPS8.6 / DDU25 / DDU26	

VTPodV 4017	Vzhodne Slovenske gorice (3rd aquifer)	Good	Good	Good status / prevention of actual status deterioration	Article 8 (61/2011) / DUPPS8.6 / DDU25 / DDU26	
VTPodV 4018	Goričko (2nd aquifer)	Good	Good	Good status / prevention of actual status deterioration	Article 8 (61/2011) / DUPPS8.6 / DDU25 / DDU26	
VTPodV 3015	Zahodne Slovenske gorice (3rd aquifer)	Good	Good	Good status / prevention of actual status deterioration	Article 8 (61/2011) / DUPPS8.6 / DDU25 / DDU26	
VTPodV 3012	Dravska kotlina (3rd aquifer)	Good	Good	Good status / prevention of actual status deterioration	Article 8 (61/2011) / DUPPS8.6 / DDU25 / DDU26	
VTPodV 3014	Haloze in Dravinjske gorice (1st aquifer)	Good	Good	Good status / prevention of actual status deterioration	Article 8 (61/2011) / DUPPS8.6 / DDU25 / DDU26	

**There are indications of local impacts between some wells of neighbouring abstractions that could cause the change of hydrogeological conditions and consequently eventual aggravation of the future exploitation conditions (Chapter 2.1.2.1 of RBMP text). There is also uncertainty because of actual scarcity of monitoring data (long term trends could not be evaluated), while there are indications of activations and interconnections of new layers in existing wells, increase of drawdowns in individual wells, increase of water demand and not efficient use (Chapter 2.4.2.3 of RBMP text). Environmental objectives probably could not be reached without supplementary measures (Chapter 4.1.2.2 of RBMP text).*

DUPPS = supplementary measures to prevent worsening or deterioration of actual status

DDU = other supplementary measures

Article 8 (61/2011): Water rights for new abstractions in Mura-Zala basin could be granted if the trend of water level is not decreasing. The water right for the existing abstractions depends on the trend of water level (Ur. l. 61/2011).

DUPPS 8.6: Change of the Rules on the content of application for acquiring water permit and on the content of application for acquiring groundwater research permit, where the depth and aquifer has to be defined. Activation of new layers has to be permitted through the research permit.

DDU 25: Elaboration of deep aquifers map.

DDU 26: Available thermal water reserves have to be assessed for the direct use of heat abstraction and tourism. Referential observation points have to be determined. Critical levels have to be defined and alert system established where the water demands could exceed available reserves.

The legislation and permitting procedures are already elaborated in report 3.3.1. Overview of EU, national and regional legislation. The discrepancy between ideal and actual status of water rights granting couldn't be higher. Among 14 active users of geothermal water which operate 28 wells only two have concession. Those are Terme Ptuj with water concession for the balneological use of boreholes P-1/73, P-2/88 and P3/05 (Anonymous, 2007) and Nafta Geoterm with mining concession for the use of geothermal energy source with pumping-reinjection doublet Le-2g/94 and Le-3g/08 (Anonymous, 2009). Among inactive users only Municipality of Destrnik has the water concession for the balneological use of well Jan-1/04 (Anonymous, 2008). In fact this is the task which still awaiting the responsible Ministry for the Environment and Spatial Planning to solve.

2.1.2 Structure and features of the monitoring systems

The groundwater monitoring systems in Slovenia rely on different reporting levels.

The top level is so called "national" groundwater monitoring for the characterization, status and risk assessment of groundwater bodies in Slovenia". This system is operated and evaluated by Environmental Agency of Slovenia (ARSO) under the umbrella of Ministry of the Environment and Spatial Planning of the Republic of Slovenia (MOP). This monitoring includes the *quantitative* monitoring systems, such as observing groundwater levels in karstic, fissured and intergranular porosity aquifers and spring discharge for the quantitative status assessment. This monitoring system also includes regular quality measurements for the chemical (*quality) status* assessment. The national River Basin Management Plan monitoring network was reported to the European Commission on March 22, 2007.

The sub-systems of the national monitoring system includes measurements and observations performed by water rights holders, subjects liable for the environmental impact monitoring and Public Health Institute of Republic of Slovenia.

Other monitoring sub-systems of quantitative and qualitative status of groundwater are performed by the individual municipal local governments and periodical surveys performed by government bodies, scientific institutes and other organizations.

Most data from the sub-system of the "national" groundwater monitoring" are also collected, managed and evaluated by ARSO. Only waterworks collect manage and distribute the observation data by themselves.

The actual "top level" national monitoring system in Slovenia does not include its "own" deep observation wells to monitor thermal groundwater status. The monitoring of thermal water should rely on the monitoring of water rights holders. Because actually the concessions of existing users are not yet granted, this monitoring is effectively not yet operational. The level of monitoring is significantly different from user to user and still not managed on an integrated way.

The recommendation for common monitoring system requirements for every individual concessionaire was already prepared. This recommendation has to be considered in the user's proposal of his monitoring design. The monitoring design has to be approved by Concession Provider and agreed by the concession contract.

Anyway, the monitoring system relying only on concessionaires' measurements and reports wouldn't be enough, especially if no observations wells which are not in the direct impact of neighbouring active abstraction wells are observed. For this reason some observation wells should be selected for the national monitoring that would serve to control the regional water level and water flow directions and the trend. Actually, an upgrade of national top level monitoring network is under preparation. This advanced network would include also deep thermal wells sufficiently far away from actual abstraction sites to monitor background and boundary conditions of the regional thermal water system. This kind of monitoring wells would be of extremely importance for transboundary management, especially, if the observation well would be designed and/or equipped and maintained in the cooperation by the neighbouring countries, using best practices examples and the most advanced technology.

A combined user's monitoring and national monitoring system would than enable the concession provider a more effective granting procedure:

Firstly, a unified and integrated operational monitoring programme must be established and upgraded by national surveillance monitoring. Secondly, application of the best available techniques is proposed. Stimulation of energy and balneology efficiency is needed, with recharge and reinjection conditions evaluated and applied where possible. Based on these key indicators, implementation of limited or full water concessions would then be granted. The proposed indicators would be checked annually on a regional level and proper measures taken to adjust water concessions if necessary. This continuous step-by-step approach should enable the implementation of adequate measures to meet the standards required for thermal groundwater bodies according to the EU Water Framework Directive.

2.2 Current state of groundwater management in Austria

The concerns of groundwater management are regulated by the Austrian federal water act (WRG 1959, BGBl 1959/215, last amendment 2011) and by the national water management plan[1] (NGP 2009). The national water management plan follows the Water Framework Directive and is implemented for the 1st management period from 2009 until 2015. Due to articles §§59, c to f (WRG 1959), the "Austrian federal water condition monitoring act[2]" is regulating groundwater monitoring in Austria.

The responsible authority for groundwater management is the Federal Ministry of Agriculture, Forestry, Environment and Water Management[3]. Depending on the maximum amount of water extraction the regional, state or federal authority is responsible for issuing water permit for each applicant. Considering boreholes with a depth greater than 300 meters, a drilling permit is needed from the Federal Ministry of Economic, Family and Youth[4].

The federal water act, federal water condition monitoring act and the NGP 2009 are governing monitoring procedures for subsurface water bodies in Austria. This also includes thermal water bodies. Until now only one observation point for thermal water monitoring has

---

[1] Nationaler Gewässerbewirtschaftungsplan 2009 (NGP 2009), WRG 1959, BGBl. I Nr. 123/2006

[2] Gewässerzustandsüberwachungsverordnung – GZÜV 2006, idF. BGBl. II Nr. 465/2010

[3] BMLFUW ("Lebensministerium")

[4] Bundesministerium für Wirtschaft, Familie und Jugend (BMWFJ)

been realized in the well Reichersberg 2 (Upper Austria), at the so called “Malm reservoir”, situated at the basement of the Molasse Basin. **Due to the intense costs associated to the installation of monitoring wells, further observation points of thermal waters will only be implemented at non successive or abandoned wells (personal note Samek, Lebensministerium). For that reason the Austrian monitoring strategy mainly focuses on data mandatorily reported by users.**

Until now, according to the national water management plan (NGP 2009) the only specified thermal water body is situated in Upper Austria at the above mentioned Jurassic Malm reservoir. At the same time, this thermal groundwater body is already regulated by a bilateral groundwater management procedure (**see Annex I**).

Up to now, no thermal groundwater bodies specified at the national water management plan (NGP 2009) are available for the Austrian parts of the Transenergy project area. Nor do harmonized management- and monitoring concepts exist from either a national or a transnational point of view. Even though mandatory reporting by individual users to the responsible authority is achieved, no public available summary reports on the conditions of the utilized thermal groundwater bodies exist so far.

2.2.1 Characterisation of groundwater bodies

In the following two different approaches have been applied in order to characterize the main thermal groundwater bodies with respect to the Austrian part of the project area:

i. Characterization according to the directive 2000/60/EC
ii. General characterization of thermal aquifers within the Austrian part of the project area

Ad i.) Directive 2000/60/EC groundwater bodies

In general in Austria two different types of classifications for the delineation of Directive 2000/60/EC groundwater bodies were used:

1. Based on the depth, shallow and deep groundwater bodies (or groups of them) were distinguished. The whole land is covered by shallow ones. Among the deep ones the only thermal one was described in Upper Austria. ***But so far there is no groundwater body with thermal water delineated within the Austrian area of Transenergy***
2. Furthermore among the shallow ones mainly fractured, porous and karst aquifer were distinguished.

Ad ii.) General characterization of the thermal aquifers in the Austrian part of the project region

The definition of thermal water mentioned in some Austrian guidelines for utilization and protection considers thermal water as water with a minimum outflow temperature of 20°C.
As mentioned above, in the frame of the application of Directive 2000/60/EC in Austria there is only one groundwater body with thermal water specified in the national groundwater

management plan (see also NGP 2009, water body listed as: GK100158), which represents the so called “Malm” aquifer situated in late Jurassic carbonates in the area between Bavaria and Upper Austria. However this aquifer is located outside of the Transenergy project area but serves as a best practice example for thermal water utilization in Austria (see Appendix I).

Nevertheless, in the Transenergy investigation area there are two regions of major importance for any further characterization of thermal waters, which are located in the Vienna Basin and in the Styrian Basin. Although specifications of thermal groundwater bodies are still missing at the national groundwater management plan (GNP 2009), significant geothermal utilizations are taking place since years in both regions.

Since an official specification of thermal groundwater bodies is missing for the Austrian part of the Transenergy project area, the following characterization of relevant thermal groundwater aquifers is based on the results of scientific studies.

Vienna Basin:

The characterization of thermal groundwater aquifers mainly follows the thesis of Wessely, 1983. In general two different types of hydrological systems exist in the Vienna Basin:

1. A hydrostatic system situated in the central part of the basin, which has no, or only minor contacts with the surface hydrology (recharge, discharge), stable temperature conditions and high mineralization.

This system seems to offer promising prerequisites but so far there are no geothermal usages in this area because of possible conflicts with hydrocarbon exploitation.

2. The second is an active hydrodynamic system in the southern part of the Vienna Basin, which is restricted to the border zones of the basin. It has a hydraulic connection to the surface where cool fresh waters of the alpine surface migrate downward underneath the Vienna basin (with Flyschzone and Greywacks as tight barriers leading them). The main stream moves along the middle and higher carbonate nappes towards the Leopoldsdorfer major fault system, which acts as a barrier towards the hydrostatic systems. After heating and mineralization of the infiltrated surface waters at lower section of the carbonate reservoir rocks, the discharge of thermal water is mainly associated to fault zones and basal conglomerates.

The active hydrodynamic system at the southern Vienna Basin is already used for balneological purposes and may be regarded as very sensitive to overexploitation due to limited recharge.

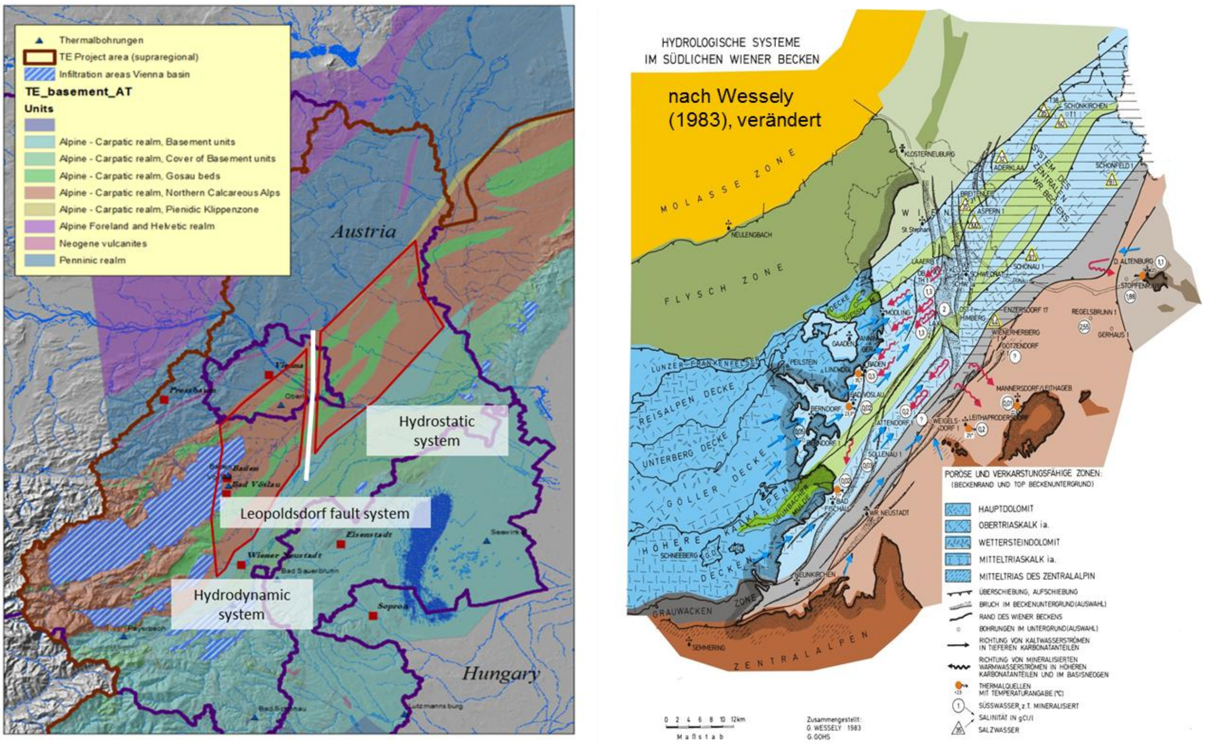


Figure 8. Left: infiltration areas feeding the hydrodynamic system. Right: scheme of water flow paths in southern Vienna basin (after Wessely 1983)

Figure 8 (left) shows the geological units of the Vienna basin basement and the infiltration areas feeding the hydrodynamic system in the southern part. Figure 8 (right) shows the hydrodynamic system in more detail with the fresh cold waters inflow from the outcropping Northern Alps (represented by the blue arrows). After their migration to greater depths the heated and mineralized waters ascend to the basin borders (red arrows).

Styrian basin:

The Styrian basin, an extensional basin of Miocene age, is a marginal sub-basin of the Pannonian Basin. It is separated in the subsurface as well as in some regions at the surface by the Burgenland swell. The basement is composed of high-grade metamorphic crystalline, anchimetamorphic palaeozoic phyllites and carbonates of the Austroalpine nappe complex.

During the project Transthermal (see Annex III) with the aim of an evaluation of geothermal potential in the border region between Austria and Slovenia (Goetzl et al., 2008) it was possible to outline some potential areas for geothermal usage. To estimate the geothermal potential in the basement the focus was set on the thermal water-bearing hard rock formations in the subsurface. Therefore these areas are mainly referring to the palaeozoic carbonate rocks (limestones and dolomites) of an important deep aquifer, which offers good prerequisites for geothermal energy usage.

Figure **9** shows the geological units of the Styrian basin basement characterized for areas of geothermal utilization potential (in yellow). This qualitative evaluation is mainly based on lithology and the depth of top formation (Goetzl et al., 2008).

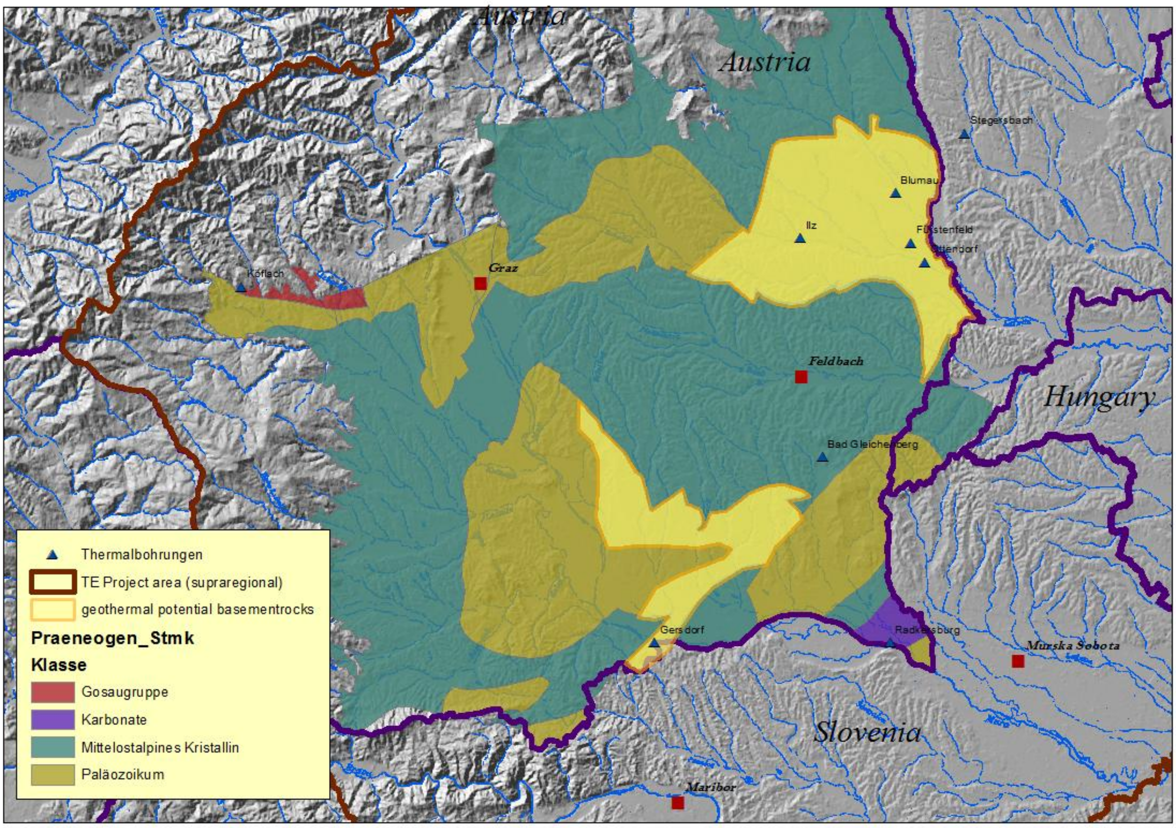


Figure 9. Qualitative geothermal potential map at the basement of the Styrian Basin (Goetzl et al., 2008)

The fillings of the Styrian basin consist of sediments from Carpatian to Pannonain age with a maximum thickness of 2,900 m. The thermal water bearing aquifers are located in Badenian and Sarmatian sands and sandstones. The spas Bad Blumau and Bad Waltersdorf are related to Paleozoic carbonate rocks (Goldbrunner, 2005). Figure **9** shows the geothermal potential in the Tertiary layers, which are based on the sediment thickness (light blue areas). There is further relevant thermal water aquifer in the area of Bad Radkersburg, which is related to Mesozoic carbonate rocks.

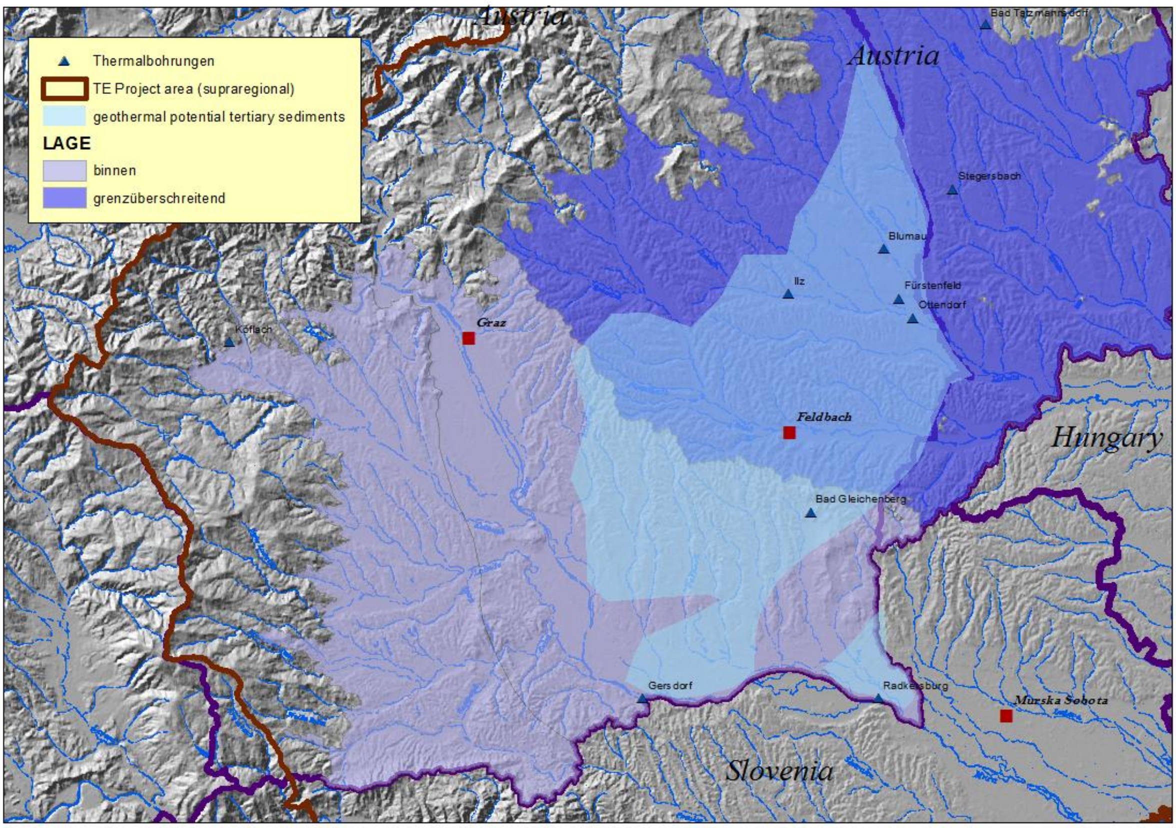


Figure 10. Groundwater bodies at Tertiary reservoirs within the Styrian Basin according to the NGP 2009, combined with qualitative geothermal potential maps of Tertiary basin fillings (Goetzl et al., 2008)

Figure **10** shows deep groundwater bodies of the Styrian basin (with depths from 30-80m), which are characterized by the national groundwater plan (NGP 2009) in combination with areas of hydrogeothermal potential in Tertiary basin fillings (Goetzl et al., 2008)

The fresh and saline waters interface varies greatly because most reservoirs are limited in space and are much dissected due to the fact that the carbonates are predominately karstified aquifers and, therefore, often have locally varying hydraulic attributes.

Table **6** finally summarizes relevant deep groundwater bodies as specified in the Austrian national groundwater management plan (GNP 2009). It has to be pointed out, that most of the below listed aquifers are not suitable for geothermal utilization due to shallow depths and therefore lowered temperatures. From these the GK100162, GK100168, GK100169, GK100171 and GK100193 are on the area of the project Transenergy.

Table 6. Deep groundwater bodies specified by the national groundwater management plan (GNP 2009)

Groundwater body code	***Groundwater body notation***
GK100157	Tertiärsande
GK100158	Thermalgrundwasser
GK100159	Enns
GK100160	Tertiärsande
GK100162	Donau Ost – Heideboden
GK100168	Steirisches u.

	Pannonisches Becken
GK100169	Oststeirisches Becken
GK100171	Weststeirisches Becken
GK100193	Rabnitzeinzugsgebiet

2.2.2 Structure and features of the monitoring systems

Currently two main types of monitoring systems are implemented in Austria:

i. National groundwater monitoring by Federal Ministry of Agriculture, Forestry, Environment and Water Management

ii. Individual monitoring by user regulated by national laws and individual permits.

Ad i.) <u>National groundwater monitoring by federal authorities</u>
Chapter 7 WRG 1959 as well as the third section of the federal act (GZÜV 2006) contain the handling of monitoring systems in Austria based on a nationwide standard.

It has to be pointed out, that the existing regulations mainly focus on near-surface groundwater bodies related to direct water supply.

In general there are three types of monitoring programs:

(1) General monitoring:
(2) Operational monitoring
(3) Investigative monitoring

(1) <u>General monitoring:</u>

General surveillance monitoring according to §59e WRG 1959 is aiming to systematically collect data in order to:

- Evaluate methods for the assessment of anthropogenic impacts on surface water and groundwater bodies.
- Enhance the efficiency of existing monitoring grids.
- Evaluate long-term changes of the natural condition according to groundwater bodies.
- Evaluate long-term changes due to human influences.

For the selection of observation points, it should be ensured that in particular those groundwater bodies are monitored, which:

- Have a risk of missing environmental targets in terms of the qualitative and the quantitative conditions of the specific groundwater body, or
- adjoin to the boundary of neighbouring countries (near- and trans-boundary monitoring).

In summary general monitoring is a basic survey in order to (i) achieve time-series to feed the Austrian monitoring database and (ii) evaluate and improve monitoring methods. General monitoring may be realized in terms of (a) reference date measurements, (b) continuous / frequent measurements for a limited observation period or (c) permanent monitoring as part of the national monitoring grid.

(2) Operational monitoring:

According to article §59f (WRG 1959) operational monitoring has to be applied for groundwater bodies, which:

- Do not meet quality standards or environmental goals.
- Are currently remediated in order to evaluate the applied measures.
- Are affected by bilateral obligations (near- and trans-boundary aquifers).
- Are relevant for public purposes (e.g. water supply).
- Are investigated for long-term changes due to anthropogenic impacts.

Operational monitoring may be seen as case-driven monitoring for a limited time period not affected by forthcoming danger. The setup of the monitoring concept has to ensure, that:

- The location of observation points is representative for the investigated groundwater body
- Chosen parameters to monitor are measured in adequate frequency and accuracy (e.g. to enable considering seasonal changes of parameters).

(3) Investigative monitoring:

According to article §59g (WRG 1959) investigative monitoring is necessary, if:

- Significant impacts on the quantitative and / or qualitative conditions are evident without proper knowledge about the reason.
- If surveillance monitoring shows that for a groundwater body won't meet the expected environmental targets and an operative monitoring has not been implemented yet. In that case clear focus is set on the investigation of possible causes for the observed negative influences.
- To assess the impacts of accidental contamination.
- Compression information for preparation measures programs.
- In the course of Environmental Impact Assessment procedures.
- In the course of permitting and licensing procedures.

According to article §59g (WRG 1959) there are no quality standards or further specifications concerning investigative monitoring.

According to article §59a (WRG 1959) all data collected by the above mentioned monitoring strategies have to be compiled into a federally governed database[5] (WISA), which intend to

---

[5] WISA-Wasser-Informationssystem Austria (http://wisa.lebensministerium.at/)

provide information about the qualitative and quantitative state as well as about existing impacts on surface waters as well as groundwater bodies in order to meet the goals of the Water Framework Directive 2000/60/EC. In this context the WISA information system acts as a web-based public dissemination tool of the federally governed Austrian groundwater management with emphasize on surface and groundwater. Thermal water resources are only treated marginally at WISA so far.

Competent authorities:

According to article §59i (1) WRG 1959 the state government is responsible for the organisation of monitoring programs. The collected data have to be reported to federal authorities (Federal Ministry of Agriculture and Forestry, Environmental and Water Management) and are used for water management plans.

According to §59i (2) WRG 1959 the Federal Ministry of Agriculture and Forestry, Environmental and Water Management is amongst others responsible for:

- Preparation of summarized reports including submitted data (§55o WRG 1959).
- Definition of general setups for monitoring programs describing the qualitative conditions of groundwater bodies including the specification of mandatory parameters, frequency, monitoring-periods and quality standards.
- Definition of general setups for monitoring programs describing the quantitative state of groundwater bodies in case of an existing active recharge (assessment of groundwater balances).

Federal water condition monitoring act – GZÜV 2006:

Monitoring of chemical and quantitative condition of groundwater is defined in the third part of the Austrian federal water condition monitoring act – GZÜV 2006. The articles §20 to §30 (GZÜV 2006) contain rules for:

- The placement of observation points for surveillance and operational monitoring.
- Setup of observation parameters.
- Duration and frequency of measurements.
- Applied methodologies.

As already mentioned before, federally governed monitoring of thermal aquifers according to the implementation of the Water Framework Directive is only of minor interest so far. Therefore in Austria until now only one federally governed observation point exists at the well Reichersberg 2 (Upper Austria), situated at the only thermal reservoir specified at the national groundwater management plan (NGP 2009)[6]. In the moment no further observation points for thermal groundwater bodies will be achieved, due to the fact, that drilling deep wells as well as the installations associated to observation points are very cost intensive.

Ad ii) Monitoring by users*:*

---

[6] Thermal groundwater body GK100158: Carbonates of the trans-boundary Upper Jurassic “Malm” reservoir (see also chapter 1.2.1)

As federally governed, standardized as well as centralized thermal water management has not been implemented yet in Austria, emphasize is set on individual monitoring by geothermal users. This predominately mandatory monitoring is regulated by individual permits.

The responsible water authority defines in the individual water permit parameters to monitor, as well as the frequency of measurements. These data have to be provided by the user to the governmental authority in terms of an annual report.

The Upper Austrian State Government publishes a report every 5 years containing monitored data from thermal water user. This report gives a good overview about water extraction, water level and possible changes in the aquifer.

Unfortunately, no similar reporting exists for the Austrian part of the Transenergy project area.

In general the received reservoir data are company secrets in Austria. However, according to article (§59a (3) and (4) WRG 1959) the competent federal authority is allowed to use monitoring data privately gained by users for updating the national groundwater management plan (NGP 2009).

2.2.2.1 Setup for qualitative and quantitative monitoring concept of the Austrian Water and Waste Management Association

Profound guidelines describing the practical realization of monitoring programs in order to protect thermal groundwater bodies are summarized at the guideline number 215 of the Austrian Water and Waste Management Association (see also OEWAV, 2010).

The most relevant guidelines concerning parameters to measure as well as the frequency of measurements related to the monitoring of thermal reservoirs are listed below in Table **7** and Table **8** (OEWAV, 2010):

Table 7. Setup for a qualitative monitoring concept according to OEWAV (2010), p. 49 (demonstrative listing).

Parameter	Unit	Accuracy	Frequency	
			Operational Monitoring	Observation Well
Subjective Evaluation (tarnish, smell ects.)	-	-	w	-
Spetctral absorption (436 nm, 254 nm)	-	-	w	-
Bacterial activity (36°C, 20°C)	N/ml	-	od	-
Dissolved organic carbonates	mg/l	-	m	a
Cumulated content of hydrocarbons	mg/l	-	m	a
H2S	mg/l	-	6m	a
H_2CO_3	mg/l	-	6m	a
Ca	mg/l	-	6m	a
Mg	mg/l	-	6m	a
Na	mg/l	-	6m	a
K	mg/l	-	6m	a

Fe	mg/l	-	6m	a
NH_4	mg/l	-	6m	a
Cl	mg/l	-	6m	a
F	mg/l	-	a	a
J	mg/l	-	a	a
Br	mg/l	-	a	a
H_2SO_4	mg/l	-	6m	a
Sulfide	mg/l	-	6m	a
Nitrate	mg/l	-	6m	a
Nitrite	mg/l	-	6m	a
HCO_3	mg/l	-	a	a
SiO_2	mg/l	-	6m	a
Quantitative gas-analyses	Vol%	-	a	a
^{13}C, ^{14}C	δ‰, $\%_{modern}$	-	a	5a
Deuterium, tritium, ^{18}O	δ‰, TE	-	6m	a
Outflow temperature (wellhead)	°C	0.1°C	log	w
Discharge temperature (surface drain)	°C	-	log	-
Temperature at re-injection well	°C	0.1°C	log	w
Conductance	µS/cm (25°C)	-	log	w
pH-value	-	-	log	w
Oxygen	mg/l	-	log	w
REDOX	mV	-	log	w
^{222}Ra	pCi/l	-	a	-

Annotation: log… data-logger (<1h), d.. daily, w.. weekly, 6m.. biannual, m.. monthly, a… annual, 5a.. every 5 years, od… on demand

Table 8. Setup for a quantitative monitoring concept according to OEWAV (2010), p. 51 (demonstrative listing).

Parameter	Unit	Accuracy	Frequency	
			Operational Monitoring	Observation Well
Wellhead pressure (dynamic)	bar	0.05bar	log	w
Hydraulic head	m	0.2m	d	w
Re-injection pressure	bar	-	log	w
Wellhead pressure (static)	bar, m	-	m	m
Yield (production rate)	l/s		log	-
Cumulative extraction	m^3	1 m^3	d	-
Yield (natural outflow)	l/s		-	w
Reinjection rate	l/s		log	-
Discharge rate (surface drain)	l/s		log	-
Wellhead temperature	°C	0.1°C	log	w
Re-injection temperature	°C	0.1°C	log	w

Annotation: log… data-logger (<1h), d.. daily, w.. weekly, 6m.. biannual, m.. monthly, a… annual, 5a.. every 5 years, od… on demand

2.3 Current state of groundwater management in Hungary

Proper management of thermal groudwater in Hungary is impeded by several facts. One is that the responsible authorities, decision-makers do not have a clear picture on the amount of abstracted thermal water and its heat content, as well as its utilization by different means. The different reports, expert opinions on these numbers differ from each other, sometimes even at a range of magnitude. A reason is that reporting on the thermal groundwater production is highly deficient, furthermore monitoring is also insufficient, therefore the country does not have an up-to-date and exact register on its thermal groundwater (and carried geothermal energy) resources. Based on the quantity status assessment of thermal groundwaters and modelling results, experts estimate much higher abstraction values than reported by the users. Regulations and licensing procedures of utilization of thermal groundwater are shared by the mining, energetic, environmental protection and water management sectors depending on the utilization aspect and depth. The legislation related to water management and environmental protection puts emphasis on achieving and maintaining the good status of groundwaters (quality and quantity), in line with the Water Framework Directive and prioritizes balneological utilization, consequently there are several discriminations regarding energetic utilization. This includes the higher allowed threshold value of contaminants (therefore less waste-water fine) of thermal waters released at the surface in case of balneological utilization, as well as multiple taxation of thermal groundwater abstracted for energetic purposes (water resource fee and mining royalty).

Although the status assessment of groundwater bodies in the frame of the River Basin Management Plans have been carried out at great details, the quality protection of thermal groundwater bodies still have some main issues. One hand the status assessments gave too high priorities to environmental aspects in some cases (e.g. the ecological water demand was set up that high, that an entire groundwater body may have got „poor quantity status” due to a locally unsatisfied water demand). This is mostly the case in some cold karstic groundwater bodies feeding deep thermal karstic reservoirs. On the other hand the so called „abstraction limit values” (Mi), which would quantify the maximum amount of abstractable thermal groundwater from a given groundwater body (or part of it) have not been determined yet (except for the surrounding of Lake Hévíz in the frame of a pilot project, see Annex I), which is strongly linked to the complex problem of re-injection in Hungary. As re-injection into porous reservoirs (from where the major part of thermal groundwater is abstracted for direct heat purposes) still raises a lot of technological and reservoir management concerns, only a few re-injection wells exist and operate. Although re-injection would be compulsory for the energetic users, the agricultural lobby was that strong, that they managed to achieve to get derogation from re-injection due to the lack of appropriate financial incentives. This does not promote the recovery of groundwater bodies at poor quantity status. Nevertheless it also has to be mentioned that the lack of re-injection from the energetic sector is not the solely reason for the poor quantity status of some thermal groundwater bodies. Excessive use for balneological purposes (abundant and fast growing number of thermal/wellness spas, energetic cascade systems with a spa as an end-user, therefore the entire system being not obliged for re-injection) also significantly contributes to the exhaustion of some reservoirs.

2.3.1 Characterisation of groundwater bodies

Regarding the general geology and hydrogeology of the Pannonian basin, groundwater bodies are classified into groundwater from intergranular and karstic aquifer types, groundwater of fractured mountainous areas. Groundwater with outflow temperature higher than 30°C is considered thermal (in that way the subdivision between cold and thermal is artificial and has no links to natural hydrogeological conditions). This threshold value is higher than in other Transenergy partner countries (Slovenia, Austria – 20 °C, Slovakia – 15 °C) due to the basin setting and resulting large amount of available thermal groundwater. The thermal karstic groundwater bodies are typically found within karstified basement Mesozoic rocks with lateral hydraulic connection to cold karstic groundwater bodies, which generally are recharged from the mountainous areas. The intergranular aquifers containing thermal groundwater bodies are composed of the thick Neogene basin fill sequences below the 30° C isotherm and are also in hydraulic connection with the overlying intergranular cold water aquifers (Figure 11). Due to these hydrodynamic connections the evaluation is also related to the connected cold karstic and intergranular groundwater bodies (Table 9). The cold shallow intergranular and fractured mountainous groundwater bodies are potential targets of open-loop heat pumps, but as this is not amongst the goals of the project, they are not discussed.

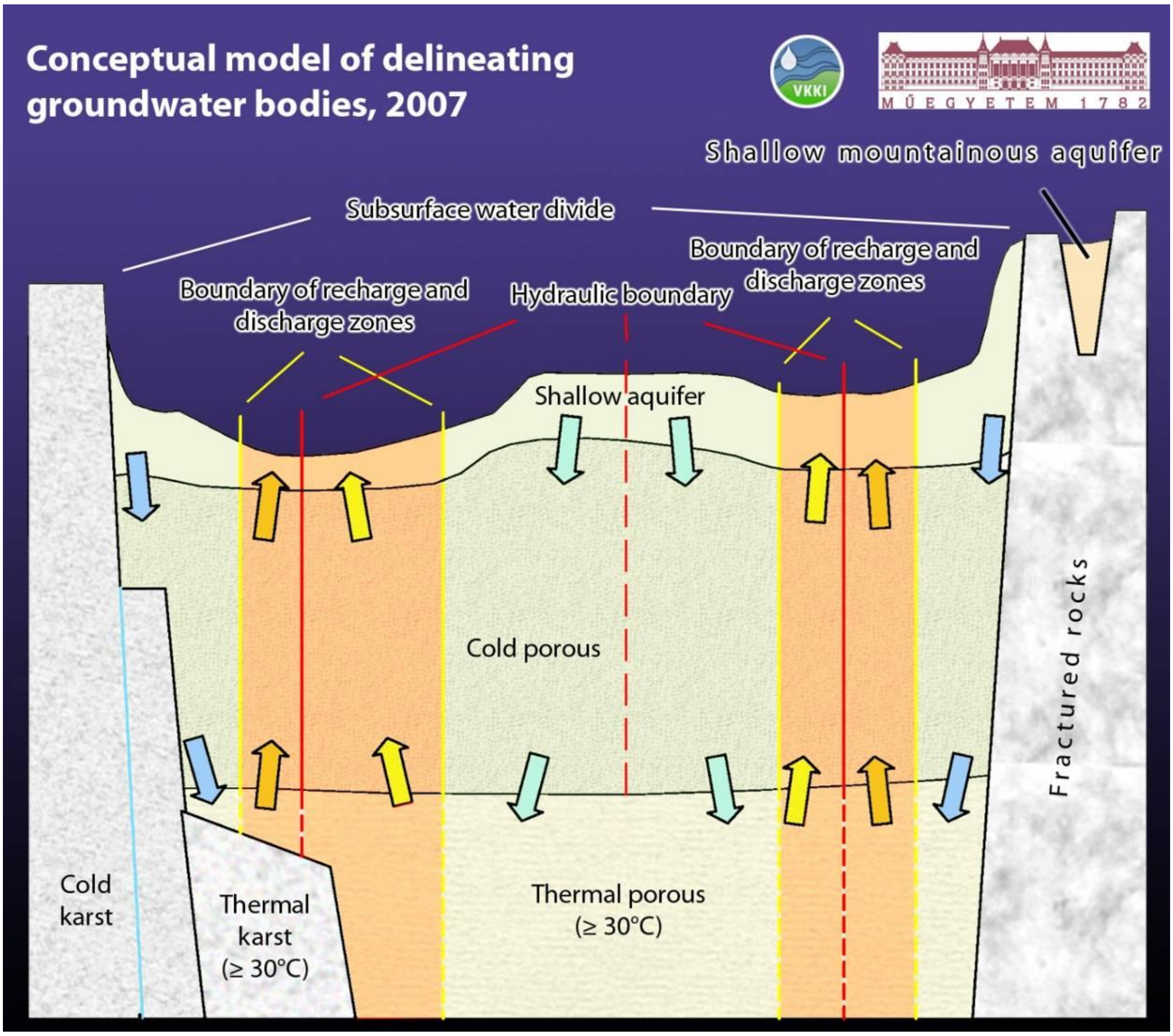


Figure 11. Classification of groundwater bodies in Hungary.

The Hungarian area of the Transenergy project overlaps with the recharge areas of some main rivers such as the Danube, Rába, Marcal, Mura and Zala rivers and some of their tributaries respectively, as well as the recharge areas of Lake Balaton, Fertő and Velence. These areas serve as planning sub-units for the River Basin Management Plans. Within these sub-units there are two intergranular thermal (pt_3.1. Délnyugat-Dunántúl and pt_1.1. Északnyugat-Dunántúl), six thermal karstic (kt_1.10 Sárvár, kt_1.11 Bük, kt_1.2 Észak-dunántúl, kt_1.4. Visegrád-Veresegyház, kt_1.7. Közép-dunántúl and kt_4.1. Nyugat-dunántúl), three cold karstic and ten intergranular cold groundwater bodies on the Transenergy area (Table 9, Figs. Figure 12, Figure 13, Figure 14). Regarding joint thermal groundwater management only the two thermal intergranular and the six thermal karstic groundwater bodies are relevant, however due to their recharge and the hydrodynamic connections, the above mentioned cold karstic and intergranular groundwater bodies have to be considered during assessment (modelling), too.

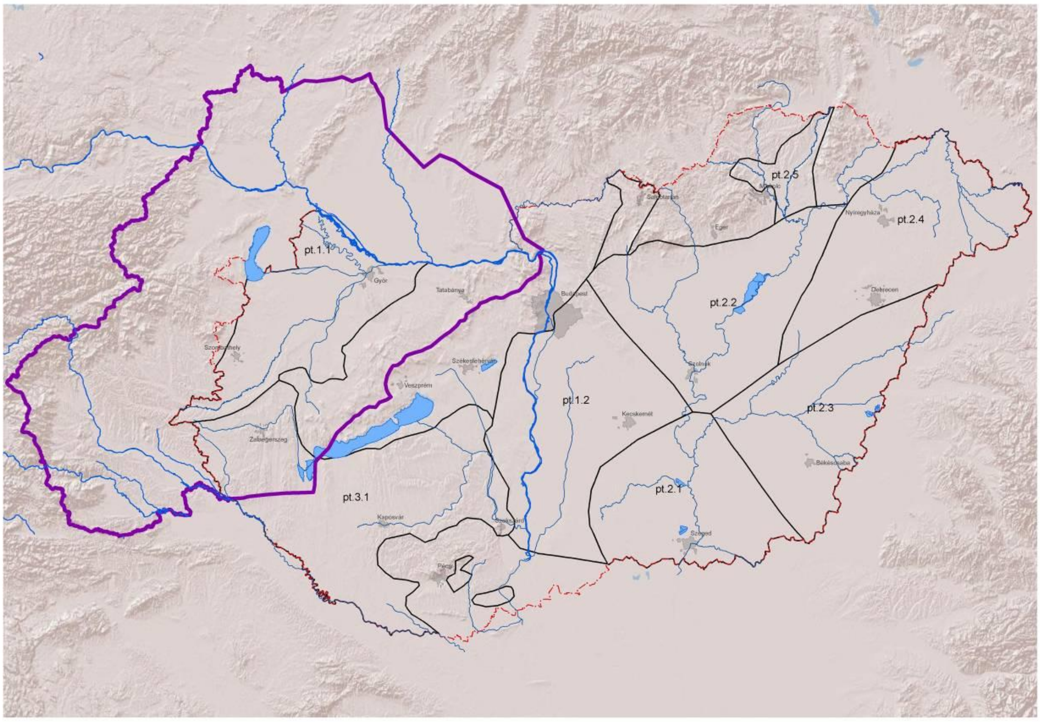


Figure 12. Intergranular thermal groundwater bodies of Hungary with the contour line (in purple) of the Transenergy project area.

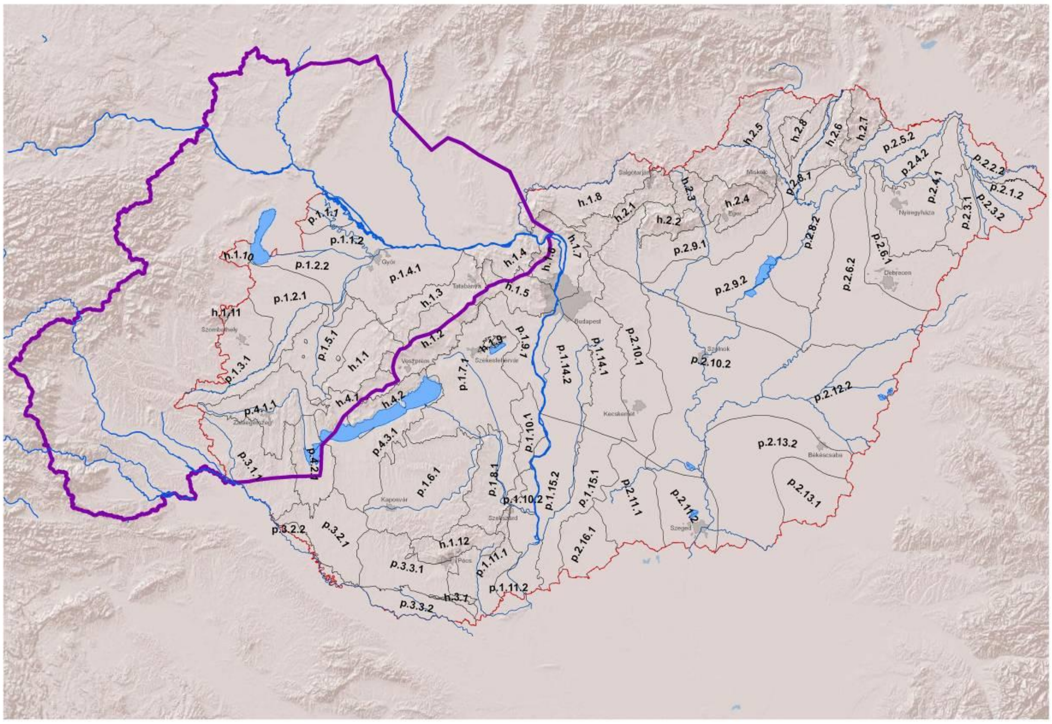


Figure 13. Intergranular (cold) groundwater bodies of Hungary with the contour line (in purple) of the Transenergy project area.

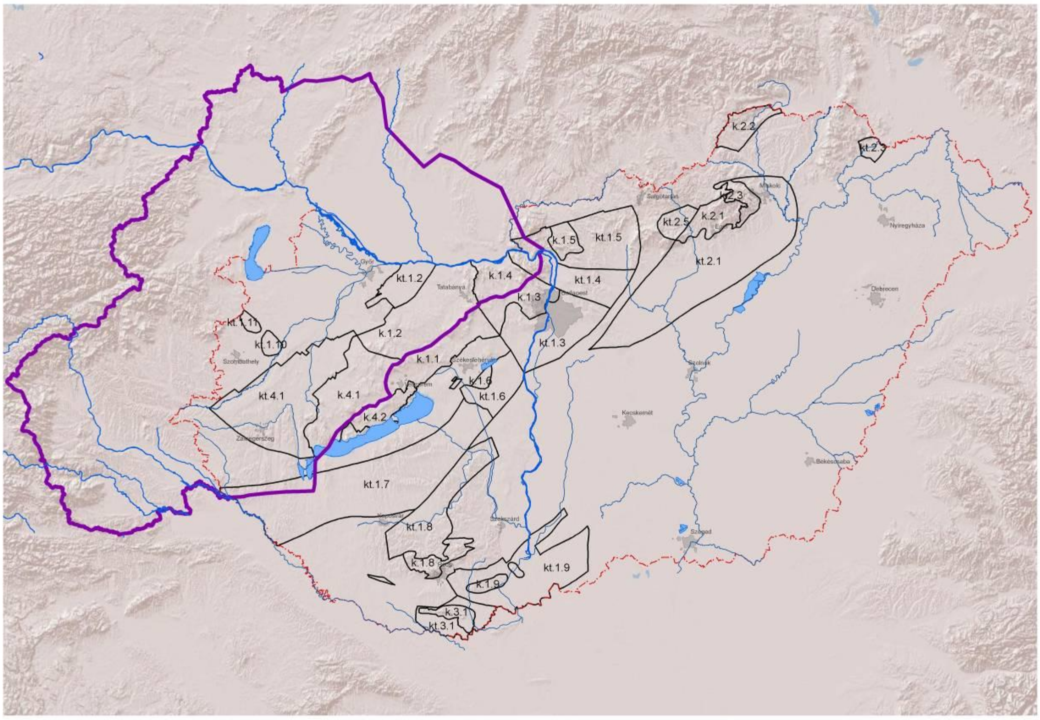


Figure 14. Cold (k) and thermal (kt) karstic groundwater bodies of Hungary with the contour line (in purple) of the Transenergy project area

Summary of environmental objectives

Table 9. Status assessment, environmental objectives and supplementary and additional measures for groundwater bodies on the Transenergy area from RBMP 2009 – 2015.

Groundwater body code	Name of groundwater body	Classification (Status assessment)		Environmental objectives	Supplementary and additional measures	
		Quantity status	Chemical status		till 2015	after 2015
AIQ517 pt_3.1.	Délnyugat-Dunántúl (intergranular thermal)	good	good	Maintaining the good status	-	KÁ4, FE1 / FE3 / FE4
AIQ569 pt_1.1.	Északnyugat-Dunántúl (intergranular thermal)	good	good	Maintaining the good status	-	KÁ4, FE1 / FE3 / FE4
AIQ599 kt_1.7.	Közép-dunántúl (karstic thermal)	good	good	Maintaining the good status	-	FE1 / FE3 / FE4
AIQ624 kt_4.1.	Nyugat-dunántúl (karstic thermal)	good	good	Maintaining the good status	-	FE1 / FE3 / FE4

AIQ660 kt_1.4	Visegrád-Veresegyháza (karstic thermal)	poor (water budget)	good	good status to be achieved by 2021	FE1 / FE3	FE4
AIQ564 kt_1.2	Észak-dunántúl (karstic thermal)	poor (water budget)	good	good status to be achieved by 2027	FE1	FE3 / FE4
AIQ639 kt_1.10	Sárvár (karstic thermal)	good	good	Maintaining the good status		FE1 / FE3
AIQ504 kt_1.11	Bük (karstic thermal)	good	good	Maintaining the good status		FE1 / FE3

During the preparation of the first River Basin Management Plans, the groundwater bodies were assessed by several tests regarding their quality and quantity, which gave valuable information on their future possible utilization. The methods applied were in accordance with the requirements of the Groundwater Directive of the WFD, and the guidelines on groundwater status and trend assessment, defined by WGC-2 EU working group (J. Grath, R. Ward, 2008). For thermal groundwater bodies quantity tests are important, as they characterize the current yield / pressure conditions of the aquifer and provide information where further abstractions have to be banned, or limited, which serves the basis for the regulation. An exemption for re-injection can be applied for those users, who abstract thermal water solely for energetic purposes from groundwater bodies of poor quantity status (according to the assessment in the River Basin Management Plans) till December 22, 2014, till June 30, 2015 for thermal waters users for energetic (direct heat) purposes in the agriculture sector and till December 22, 2020 in case thermal water is exploited from groundwater bodies of good quantity status (for details see legislation overview).

There are two major types of quantity tests. The drawdown test investigates if there is a significant drop in water level due to water abstraction. If this rate exceeds 0.1 m/year or more than 20% of the intergranular or karstic groundwater bodies, these groundwater bodies get a poor quantity status assessment. In case of shallow groundwater bodies the limit is 0.05 m/year. The second test is the so called water budget test, which investigates the proportion of water abstraction and available water resource. The available resource is the amount of recharge decreased by the water extraction plus the ecological water demand and the water transfer towards neighbouring groundwater bodies.

The other quantity tests are the surface water test, the groundwater dependent terrestrial ecosystem test and the saline or other intrusion test. In case of unsatisfactory results of either of these tests, the groundwater body get a poor status assessment and actions are phrased.

According to these tests both intergranular thermal groundwater bodies and four out of six thermal karstic groundwater bodies got good status assessment. Only kt_1.2 Észak-dunántúl and kt_1.4. Visegrád-Veresegyház thermal karstic groundwater bodies are in poor quantity status based on water budget tests (Table 9). The same good quantity status has been determined for all connected intergranular cold groundwater bodies, however all three associated cold karstic groundwater bodies are in poor quantity status due to the unsatisfactory result of the water budget test (k_1.2. Dunántúli-középhegység - Tatai- és Fényes- springs recharge area, k_1.4 Dunántúli-középhegység - Esztergomi- springs recharge area, and k_4.1. Dunántúli-középhegység - Hévízi-, Tapolcai-, Tapolcafő- springs recharge area). This raises concerns about the long-term supply of the linked thermal karstic groundwater bodies.

The River Basin Management Plan also provided data on the actual abstraction values and available water resources, which is summarized in Table 10. Data on the actual abstraction values and available water resources in m3/day.

Table 10. Data on the actual abstraction values and available water resources in m^3/day.

Groundwater body code	Name of groundwater body	Available water resource (m^3/day)	Direct abstraction (m^3/day)
AIQ517 pt_3.1.	Délnyugat-Dunántúl (intergranular thermal)	44500	8592
AIQ569 pt_1.1.	Északnyugat-Dunántúl (intergranular thermal)	23800	4697
AIQ599 kt_1.7.	Közép-dunántúl (karstic thermal)	?	524
AIQ624 kt_4.1.	Nyugat-dunántúl (karstic thermal)	11000	5646
AIQ660 kt_1.4	Visegrád-Veresegyháza (karstic thermal)	9380	15272
AIQ564 kt_1.2	Észak-dunántúl (karstic thermal)	26685	42815
AIQ639 kt_1.10	Sárvár (karstic thermal)	?	?
AIQ504 kt_1.11	Bük (karstic thermal)	?	1434

According to the Water Framework Directive, the River Basin Management Plan phrased basic, supplementary and additional measures, summarised in Table 9, as the following:

According to the present measures, the sustainable utilization of groundwater is supplemented by the national regulations (this is not discussed in the Water Framework Directive). The basic rules are set up in the Act LVII of 1995 on Water Management (order of priority of fulfilling the different water demands). The sufficient utilization of groundwater resources is promoted by the water fee (see legislation overview). The national legislation gives provisions on the achievement of good quantity status of groundwater bodies, and to reach this objective to determine the abstraction limit values (Mi) for each groundwater body (Governmental decrees 219/2004 (VII.21.) and 221/2004 (VII.21.)). However these values have not been determined yet, except for kt_4.1 (see short summary in Annex I, Lake Hévíz), although they would serve as a basis for issuing new water permits.

There is an increasing demand for the enhanced utilization of thermal groundwater, also as a renewable resource, therefore a stronger assert on ecological and water management rights would be required. Activities without permits exist, which endanger the good quality and chemical status of groundwaters, and cannot be terminated by the authorities at all times due to lack of their legislative and execution power.

Supplementary measures to be performed after 2015 for the intergranular and karstic thermal groundwater bodies (in case of kt_1.2 and kt_1.4 karstic thermal groundwater bodies in poor quantity status till 2015) are the following:

- Modification of water uses (FE1); Performer: user,
- Start licensing for water abstractions without permits, if necessary terminating them (FE3); Performer: user (control: authority),

- Re-injection of water abstracted for energetic utilization, development of re-injection technologies (FE4); Performer: user (control: authority).

In thermal intergranular groundwater bodies the above measures are supplemented by the measure of appropriate well technology, well reconstruction (KÁ4) which is performed by the water user and is controlled by the authority.

2.3.2 Structure and features of the monitoring systems

The groundwater monitoring system consists of two sub-systems in Hungary. One of them is the so called aerial monitoring that is under the auspices of the state and local governments and it is density and detail is proportional to the rate of the public interest.

The aerial monitoring system includes the following elements:

- monitoring systems continuously operated by governmental organizations under the auspices of the Minister of Rural Development (e.g. Regional Directorates for Environmental Protection and Water Management). These include the *quantitative* monitoring systems, such as observing unconfined and confined groundwater, karstic and thermal water pressures and water levels, spring monitoring systems, monitoring regarding the quantity and quality of surface waters related to groundwater bodies. These monitoring systems also include regular measurements regarding to the *quality*, and monitoring systems implemented for special observations of a certain area including strategic water reserves.

- other monitoring systems continuously operated by other state organizations (e.g. groundwater level monitoring system operated by the Geological Institute of Hungary (after April 1, 2012 the Geological and Geophysical Institute of Hungary), Soil Protection Information and Monitoring System operated by the plant and soil protection services, maintained by the Ministry of Rural Development)

- monitoring of quantitative and qualitative status of groundwater in the public administration area of the settlement performed by the municipal local governments

- periodical surveys performed by government bodies, scientific institutes and organizations and expedition surveys.

The other sub-system of the national monitoring system includes measurements and observations performed by *environmental users*. Measurements performed by waterworks, monitoring in connection with operation of industrial firms, waste deposition, and drinking water reserves, mineral- and medical water usage, and activities related to water resource protection are ranked under **the environmental impact monitoring.** According to a special regulation remediation monitoring systems in contaminated, permanently damaged areas and measurements performed in the surroundings of emission sources and polluted areas are also part of the environment impact monitoring.

For the assessment of the status of groundwater bodies, related to the provisions of the Water Framework Directive, all elements of aerial monitoring performed by the state, and environmental impact monitoring performed by the users are necessary. The monitoring assessing the status comprises not only the classical quantitative and qualitative observations, but data related to the use of the subsurface / groundwater aquifers whether they cover natural elements (e.g. groundwater dependant ecosystems), or man-made processes (e.g. sludge deposition).

However the reporting to the European Commission does not require all individual data, therefore representative monitoring stations were determined for groundwater bodies, transboundary aquifers and protected areas. The national monitoring report sent to the European Commission on March 22, 2007, altogether 3,500 monitoring stations and observations were listed, which officially form part of the **EU-WFD monitoring program**. The monitoring program of the River Basin Management Plans was also established on this document. The document is a legal obligation towards the EU for the performance of the monitoring program.

The EU-WFD monitoring program is performed by the 12 Regional Directorates for Environmental Protection and Water Management, the 10 Regional Inspectorates for Environment, Nature and Water, the Geological Institute of Hungary (after April 1, 2012 the Geological and Geophysical Institute of Hungary) and the selected users. The selected users (waterworks, spas, etc.) have to perform measurements on their own wells (except for those situations, when they were previously measured by the Inspectorates). Data collection and control is the task of National Institute for Environment.

2.3.3 Observations, data management

The various institutions try to face the challenges of the technical development when operating monitoring systems. Nowadays observations based on manual water level measurements are rare. Application of electrical water level register tools based on manometry is the most widespread, where it is possible to connect a remote transmitter unit to the electronic devices. In these cases extraction of the measured data from the register device does not require an on-spot reading. Measured data and the measurement circumstances are transmitted by GSM or GPRS. The operator can download the data directly from the trans-receiver centre, or from a protected web interface. Programming of the transmitter unit can happen from the data processing centre by remote transmission. Data processing is simplified and speeded up by remote transmission, and up-to-date information is available.

The accredited water sampling, immediate recording of the parameters measured on the spot and analysis of water samples in accredited laboratories are in essential in quality monitoring.

Both quantitative and qualitative measurements are performed by appropriate quality assurance. Verification, etalon for traceability, application of certified and calibrated measuring equipments and exact detailed documentation are the most important aspects. Gathering of control samples is a frequently used method during water sampling.

The measured data are recorded in a national database, where archiving and safe storage of data is ensured.

2.3.4 The Transenergy area WFD monitoring system

On the area of the pt_1.1. intergranular thermal groundwater body there are 8 monitoring wells, on pt_3.1 3 wells. All six thermal karstic groundwater bodies have monitoring wells, the largest number (18 wells) on the kt_4.1. (Nyugat-dunántúl). Currently there is no operative (chemical) monitoring on the project area. The reason of this is that operative monitoring program is compulsory only in those groundwater bodies which got a poor quality status assessment, or they are at risk. Thermal groundwater bodies do not fall in this category in Hungary. There are quantitative monitoring wells on the area of all thermal groundwater bodies, except for kt_1.11 (Bük).

In addition to the above mentioned monitoring wells, thermal water users provide data about their production wells according to the KvVM Ministerial Decree 101/2007(XII. 23.), which include yield, wellhead pressure or operational water level, temperature and water chemistry.

Figure 15 and Figure 16 show locations of the monitoring objects of the EU-WFD monitoring program in the Hungarian part of the Transenergy project area.

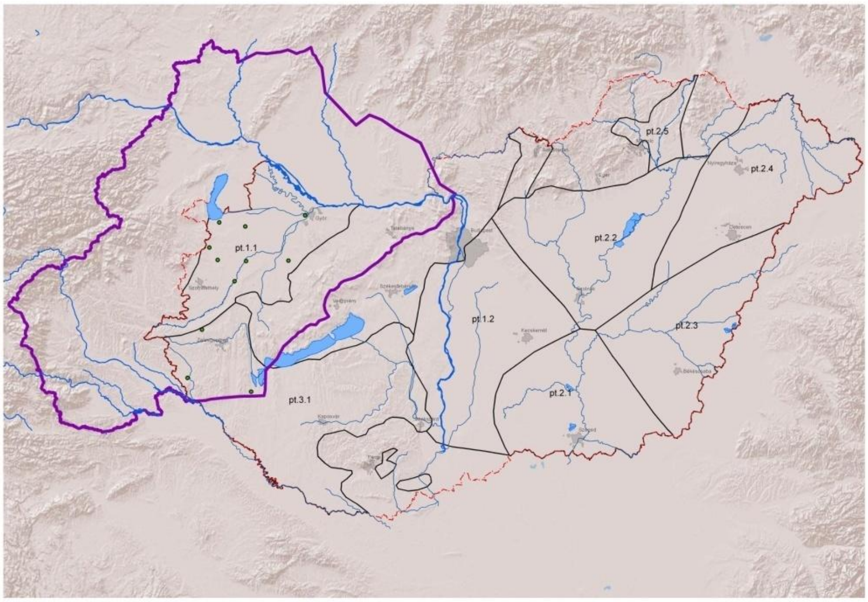


Figure 15. Locations of the monitoring objects of the EU-WFD monitoring program of the intergranular thermal groundwater bodies in the Hungarian part of the Transenergy project area

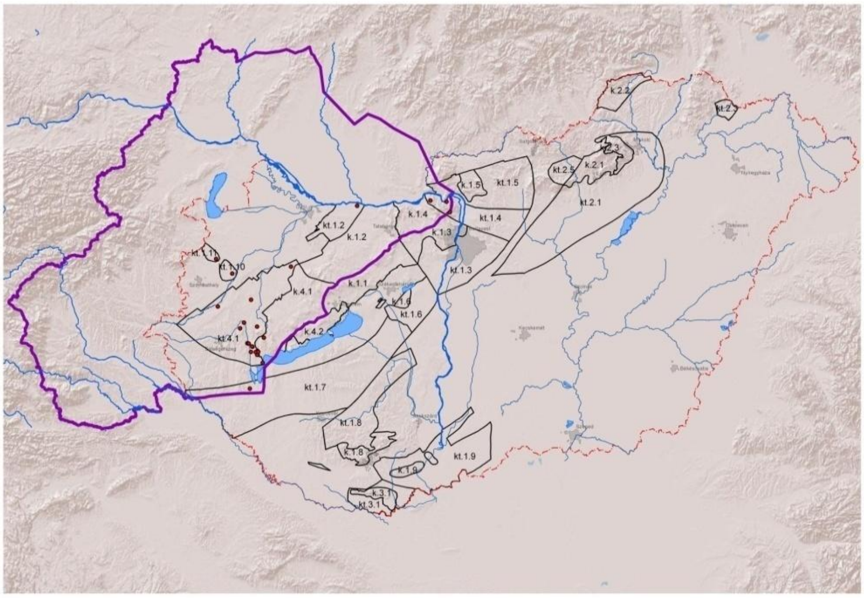


Figure 16. Locations of the monitoring objects of the EU-WFD monitoring program of the thermal karstic groundwater bodies in the Hungarian part of the Transenergy project area

2.4 Current state of groundwater management in Slovakia

The structure and content of planning documents have changed in response to the needs of different times. The first important document in water management (or water policy planning) is the National Water Management Plan (NWMP) approved by the Government of Czechoslovakia 8.1.1954. This was a baseline for water management plans in all sectors of national economy, as well as for basic water management measures in land use planning. NWMP was also one of the bases for the development of future plans for economic sectors that had demands on water resources, or otherwise influenced the water management. The NWMP contained (in general as the first document ever) the concept of water policy development (water management) in all its components.

The State Water Management Plan continued in 1975 and started Guiding Water Management Plan prepared for the Slovak Republic and in more detail elaborated by different hydrological basins (watersheds). This planning document has a similar content structure as NWMP. Guiding Water Management Plan has been in continuous development annually updated in so called Journal and every five years in Proceedings of NWMP.

As a result of social changes at the turn of the eighties and nineties it was considered that the Guiding Water Management Plan is out of date and unavailable (non-utilisable) in the future. Therefore development of new planning documents with new content structure, so called Hydro-Ecological Plans of river catchments (HEP) started in 1991.

The HEP purpose was to protect water quality and quantity, the sustainable and rational water use and water catchment plans (WCP) as the basis for management of economic activities where water is treated as a commodity. The basic land use planning unit for both planning documents (HEP and WCP) is the hydrological river basin (watershed). These planning documents were processed in five year cycles, which were completed in 1995 and 2000. They were summarized in strategic document titled "The General plan for protection and rational use of water" (the first edition - 1995, the second edition - 2001) (Ministry of the Environment of the Slovak Republic, Vodný Plán Slovenska, 2009).

The greatest changes in documents used for water management planning was connected with implementation of the Water Framework Directive ,which brought the most comprehensive set of objectives, instruments and obligations in the field of water policy, creating the basis for a common water policy in the EU.

Organizational Structure and Competences in Water Management

The water management sector is legally regulated by the Act No. 575/2001 Coll. on the organization of activities of the Government and the Central State Administration as amended in later regulations.

The Ministry of Environment of the Slovak Republic is a central body of the state administration responsible for development and protection of environment.

The Section of Water is under the Ministry of Environment and is within the competence of the State Secretary.

The Section of Water:

- is responsible for transposition and implementation of the EU water legislation;
- manages and controls the following institutions and organizations:
  - Water Research Institute (WRI),
  - Slovak Hydro-Meteorological Institute (SHMI),
  - Water inspection authorities,
  - Environmental authorities - in the field of water and fisheries,
  - Slovak Water Management Enterprise (SWME),
  - Water Management Construction Enterprise;
- cooperates with the following departments and organizations:
  - Ministry of Health – in the field of water protection,
  - Ministry of Agriculture and Rural Development – in the field of irrigation systems, drainage systems and aquaculture,
  - Ministry of Transport, Construction and Regional Development – in the field of inland navigation,
  - Ministry of Interior – activities related to flood protection (civil protection and integrated rescue system),
  - Regulatory Office for Network Industries.

The Section of Water comprises of the following departments:

- Department of National Water Administration,
- Department of Water Policy, and

- Department of River Basin Management and Flood Protection.

The Ministry of Environment coordinates and manages the activities of the Slovak Environmental Inspection, regional environmental authorities, local environmental authorities and municipalities in the field of water, public water supply and sewerage, fishery, and flood protection.

Other Organizations and Special Interest Communities:

- Slovak Environmental Agency, Banská Bystrica (SEA),
- State Geological Institute of Dionýz Štúr, Bratislava,
- Association of Employers in Water Management Sector in Slovakia,
- Slovak Fishery Union, Žilina Council, and
- Association of Water Companies.

Non-governmental organizations involved in stream and river basin restoration

At present, there are about 10 NGOs engaged in stream and river basin restoration in Slovakia, e. g. BROZ - Bratislava Regional Protection Association, EKOPOLIS Banská Bystrica, People and Water, Slatinka, Sosna, Muránka – noninvestment fund, Earth’s Friends - CEPA Banská Bystrica, Ipeľ Protection Union.

2.4.1 Characterisation of groundwater bodies

The basic prerequisite for the status assessment of groundwater is the definition of groundwater bodies - territorial units to which it is possible to develop the characterization of water, evaluate its condition and compare it with the desired environmental objectives.

The delineation of groundwater bodies followed the requirements of the Water Framework Directive 2000/60/EC. In Slovakia three layers of groundwater bodies were delineated (Figure 17):

- Upper layer (Figure 17 a) - Quaternary groundwater bodies
  - main quaternary basins and alluvial sediments of main rivers
  - 16 groundwater bodies
- Basic layer (Figure 17 b) - Pre-Quaternary groundwater bodies
  - 59 groundwater bodies
- Deep layer (Figure 17 c) - Groundwater - Geothermal bodies
  - 26 geothermal water bodies (> 15°C)

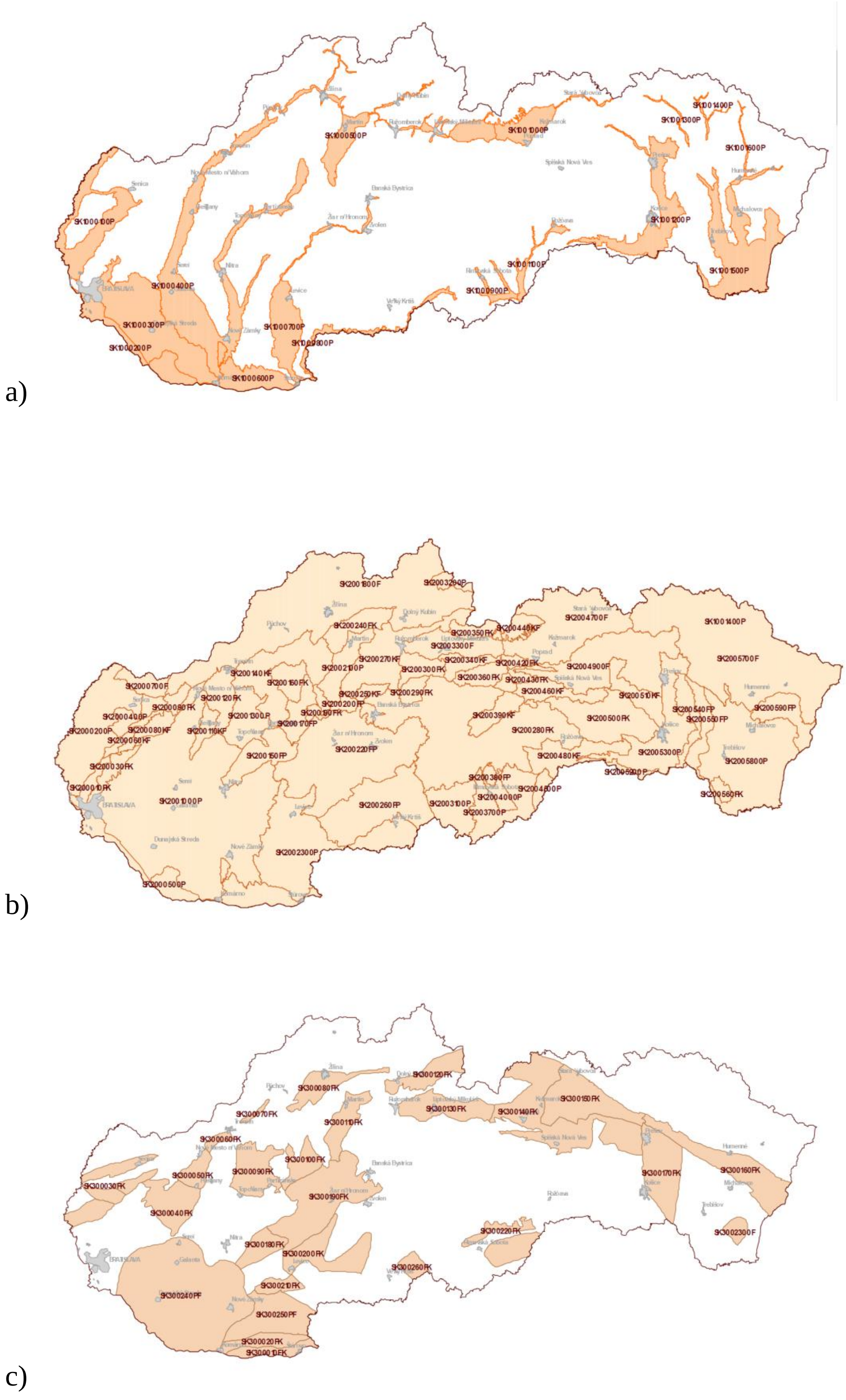


Figure 17. Delineation of groundwater bodies in Slovakia, a) Quaternary groundwater bodies; b) Pre-Quaternary groundwater bodies; c) - Geothermal groundwater bodies

Analysis of the geothermal water use in geothermal water bodies was prepared for purposes of the National Report (NR), which is prepared in accordance with the reporting requirements of the Water Framework Directive (Bartková et al., 2005).

In the south-western part of Slovakia, in the Transenergy project area, there are 6 geothermal groundwater bodies (Figure 18), which are situated in Neogene sands, sandstones, conglomerates and Triassic to Jurassic carbonates (Table 11). Status assessment, environmental objectives and supplementary and additional measures from River Basin Management Plan (RBMP) 2009 – 2015 are shown in Table 12 (Ministry of the Environment of the Slovak Republic, 2004, Report of the Slovak Republic processed for European Commission in line with Water Framework Directive, Article 3 and Annex I).

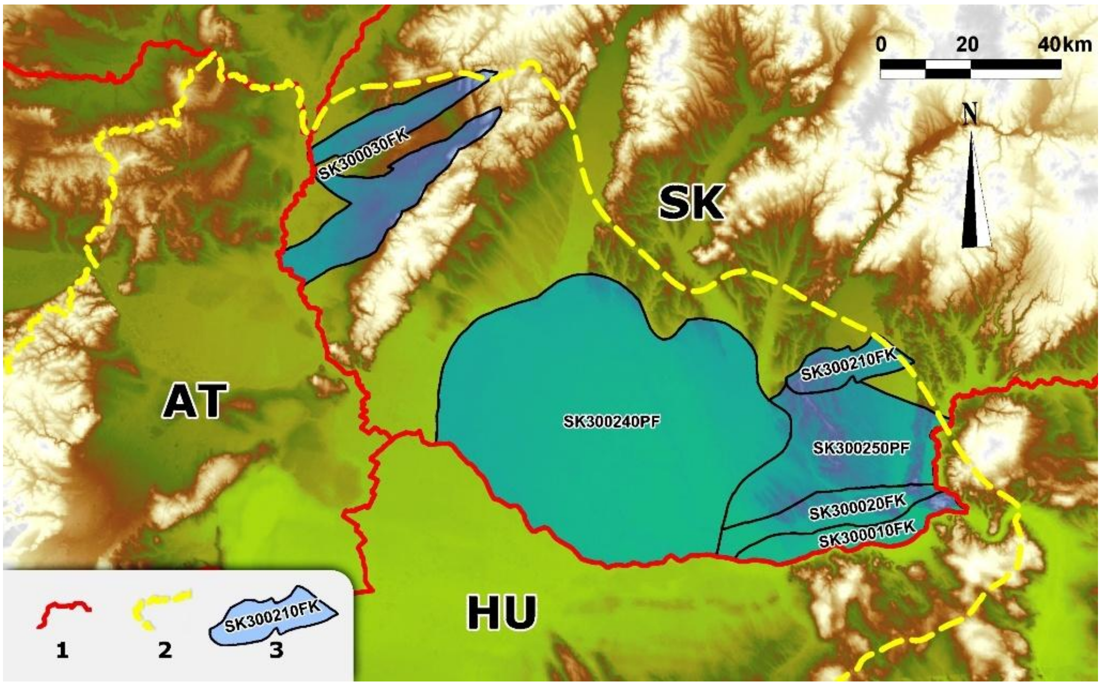


Figure 18. Delineation of geothermal groundwaters bodies in SW Slovakia (1 – state boundaries, 2 – Transenergy project area, 3 – geothermal groundwater body with groundwater body code)

Table 11. Geothermal groundwater bodies in SW Slovakia

Groundwater body code	Name of groundwater body	Aquifers of geothermal waters	Age of aquifer
SK300010FK	Komárno High Block	carbonates	Jurassic - Triassic
SK300020FK	Komárno Marginal Block	carbonates	Jurassic - Triassic
SK300030FK	Vienna Basin	carbonates	Jurassic - Triassic
SK300180PF	Dubník Depression	sands, sandstones and conglomerates	Neogene
SK300210FK	Levice Block	carbonates	Triassic
SK300240PF	Central Depression of the Danube Basin	sands, sandstones and conglomerates	Neogene

Table 12. Status assessment, environmental objectives and supplementary and additional measures from RBMP 2009 – 2015.

Groundwater body code	Name of groundwater body	Classification (Status assessment)		Environmental objectives	Supplementary and additional measures	
		Quantity status	Chemical status		till 2015	after 2015
SK300010FK	Komárno High Block	Good	**	in the evaluation process	***	

SK300020FK	Komárno Marginal Block	Good	**	in the evaluation process	***	
SK300030FK	Vienna Basin	*	**	in the evaluation process	***	
SK300180PF	Dubník Depression	*	**	in the evaluation process	***	
SK300210FK	Levice Block	Good	**	in the evaluation process	***	
SK300240PF	Central Depression of the Danube Basin	Good	**	in the evaluation process	***	

* Abstraction of geothermal water from the SK300030FK SK300180PF not realized until 2011.

** More accurate assessment not possible – based on the available data of geothermal water utilization (geothermal water abstraction records – Slovak Hydrometeorological Institute) and the absence of monitoring data on the geothermal waters.

*** The National Report in section 3.7.1 „The inadequacy of data and uncertainty in the risk assessment of groundwater bodies to achieve a good quantitative status by 2015“, states need to complete the database of geothermal resources and their exploitation and processing of geothermal water balance and the survey of geothermal units. Particular attention should be given to the selected cross-border services, which the assessment puts higher demands on the quantity and quality of the data. Quantitative monitoring is now performed only in geothermal structures used for medical purposes. Re-evaluation of geothermal potential of these structures (contemporary/up-to-date status) and the establishment of quantitative monitoring of geothermal structures are also required (Bartková et al., 2005)

2.4.1.1 Komárno block - Groundwater body code SK300010FK and SK300020FK

Located in the SE part of the Danube Basin, roughly between the towns of Komárno and Štúrovo. Komárno Block is a morphologically dissected structure of the Transdanubian Range. The geothermal waters are known from occurrence in natural springs (Patince, Virt, Obid) and wells. In structural–hydrogeothermal terms (Remšík et al., 1979; Remšík et al., 1992) it was divided into the Komárno High Block and the Komárno Marginal Block. In both structures the thermal waters are stored in Triassic limestones and dolomites of the pre-Tertiary, or pre-Cretaceous basement

2.4.1.2 Vienna Basin - Groundwater body code SK300030FK

A southern offshoot of the Slovak part of the Vienna Basin (Kröll & Wesselly, 1993) represents the westernmost part of the Danube region. The basement of the Neogene is composed mainly of Mesozoic limestones and dolomites forming the continuation of the Alps to the Malé Karpaty Mts envelope unit, located at depths between 500 and 1,000 m. Geothermal water is associated with the Triassic carbonates as well as overlying Eggenburgian clastics which form together a single hydrogeological unit. The structures occur at depth of 500 – 4,500 m and contain waters with reservoir temperature of about 40 – 140 °C.

2.4.1.3 Dubník Depression - Groundwater body code SK300180PF

This structure, located in the eastern part of Danube Basin, is filled mainly with the Miocene sediments underlain by crystalline schists and granitoids. The geothermal waters are stored in basal Badenian clastics (conglomerates, sandstones) at a depth between 1,000 and 2,000 m. The rate of exploitable geothermal energy using re-injection was assessed to be as much as 808 MW (Remšik & Fendek, 1995).

2.4.1.4 Levice block - Groundwater body code SK300210FK

Located in the north-eastern part of Danube Basin, this block, composed of Mesozoic rocks of the higher nappes of the Alps, is locally underlain by the remnants of the Mesozoic envelope of the crystalline complex (Fusán et al., 1979). Neogene sediments overlay the Mesozoic rocks. Most geothermal waters in the Mesozoic rocks (mainly Triassic dolomites, subordinately quartzites), as well as in the basal Badenian clastics, are heated to 70–80 °C (Remšík & Franko, 1983).

2.4.1.5 Central depression - Groundwater body code SK300240PF

The dish-like shape and brachysynclinal structure of this depression, located between the towns of Bratislava and Komárno/Komárom, is filled with Quaternary, Rumanian, Dacian, Pontian and Pannonian sediments. Quaternary and Rumanian sediments are represented by gravels and sands, while the other stages by alternations of clays and sandy clays with sands and sandstones. The topmost boundary of this geothermal water reservoir is at a depth of 1,000 m, while the bottom is represented by a relatively impermeable aquiclude (clay), which deepens from its periphery to its centre and reaches a depth of 3,400 m in the central part of the depression (Franko et al., 1984).

2.4.2 Structure and features of the monitoring systems

Environmental Monitoring - General Information

The concept of environmental monitoring on the territory of Slovakia and the concept of an integrated information system for the Environment (ISE SR) is approved by Resolution of the Government of the Slovak Republic no. 449 from May 26th, 1992. ISE SR is an interdepartmental information system operated by the Ministry of Environment. The implementation of the monitoring system is governed by Government Resolution no. 620 from September 7th, 1993. Based on these resolutions, projects for establishing the monitoring sub-systems were developed. The monitoring of the environment currently consists of 10 Partial Monitoring Systems. One of the environmental monitoring sub-systems is Partial Monitoring System – Water (http://www.shmu.sk).

Monitoring of the environment of the Slovak Republic is a systematic one, consistent across time and space. Monitoring is defined by observation of very specific characteristics of individual components of the environment (usually at points forming a monitoring network), which represent the monitored area and larger territorial unit. It provides objective information necessary for decision-making, management, control activities, scientific research and also for the public.

Partial Monitoring System – Water: aims, objectives and characteristics

Systematic identification and evaluation of the water occurrences and status of surface and groundwater in the Slovak Republic is a fundamental task of the State. It is essential for creating the concepts of sustainable development, the state administration and public information.

The Slovak Hydrometeorological Institute (SHMI), as the agency established by the Ministry of Environment, is responsible for the coordination and implementation of Partial Monitoring System - Water (PMS). Government Resolution no. 7/2000 and no. 664/2000 approved procedures for the implementation and funding of the comprehensive monitoring and information system (where PMS – Water is included).

Partial Monitoring System - Water currently consists of monitoring the following subsystems:

- 1 Quantitative indicators of surface water – in competence of SHMI
- 2 Quantitative indicators of groundwater – in competence of SHMI
- 3 Groundwater quality – in competence of SHMI
- 4 Surface water quality – in competence of SHMI
- 5 Thermal and mineral waters – in competence of Ministry of Health (Inspectorate of Spas and Springs)
- 6 Irrigation water – in competence of Ministry of Agriculture
- 7 Recreational water - in competence of Ministry of Health

The main objectives of the Partial Monitoring System - Water include in particular:

- knowing the current state of water systems in terms of quantity and quality and their distribution in space,
- trends of the characteristics of water systems and their protection and utilization projections,
- the fulfilment of international conventions and treaties,
- providing the necessary information for decision-making process of government, and
- public information and provide data and information on the status of water systems.

QUANTITATIVE INDICATORS OF GROUNDWATER - AIMS OF THE MONITORING SUBSYSTEM

The existence of a monitoring network and the knowledge of the groundwater are directly mentioned in the Constitution (Article 4), Government Decree no. 96/1953 and the Water Act. Monitoring activities of the Slovak Hydrometeorological Institute of the quantity of groundwater is a key part of environmental monitoring systems and integrated information system of the Slovak Republic (Government Resolution no. 449/1992, 620/1993, 357/1999, 7/2000 and part 31/2000).

The main objective of the monitoring subsystem is to provide quantitative indicators of groundwater (in springs and wells), to observe changes in yields, temperature, groundwater level regime (continuous or with weekly steps) for the purpose of processing reports, studies and expertise. It creates the preconditions for supporting the input data about the hydrological regime of groundwater to:

- the general public (information on the natural environment),
- the decision-making processes of state water management and environmental protection, and
- water management organizations and legal entities.

Partial structure of the database information system

Data on observation of objects were imported into an integrated information system in INGRES II. version 2.5 environment, till 2007. Since 2008, SHMI transferred to a new integrated information system based on Oracle (includes records of quality and quantity of surface and groundwater monitoring and water management). Currently, both information systems function and record data in parallel. Database is divided into a probe source.

The database contains basic information about the object (e.g., location, source name, object type, coordinates, depth of well, etc.). The updates of register/catalogue information are carried out according to the current needs, but at least annually.

The data imports to registers are recorded annually. The recorded data include yield of springs, piezometric levels, and groundwater temperature. Data are measured by automated instruments and/or weekly data from observers.

The database contains data from 1956, which are the basis for the evaluation of the groundwater regime in Slovakia, for the preparation of reports, expert opinions.

The network is designed in accordance with the Law of the State Hydrological Service and the State Meteorological Service no. 201/2009 Coll., Act no. 384/2009 Coll. amending and supplementing Law no. 364/2004 Coll. Water Act.

GROUNDWATER QUALITY - AIMS OF THE MONITORING SUBSYSTEM

The monitoring of groundwater quality (in competence of the Slovak Hydrometeorological Institute) incorporates:

- assessing the current state of groundwater in Slovakia,
- description of the quality trends,
- provide documentation to the Ministry of Environment and Water Management Authority and other entities for decision making, and
- supply the results of the research and expertise.

The need for groundwater quality monitoring is resulting from the current applicable national and EU legislation. The concept of groundwater quality monitoring is part of a comprehensive monitoring system of the Environment in accordance with Government Resolution no. 449/1992.

Partial structure of the data base information system

Data on observation of objects, the results of in situ measurements and laboratory analyses were imported into an integrated information system in INGRES II. version 2.5 environment, until 2007. Since 2008, SHMI transferred to a new integrated information system based on Oracle.

The database contains basic information about the object (e.g. object type, coordinates, depth of well, etc.), data determined on the ground in situ (water temperature, pH, conductivity, etc.), and the concentrations of determined parameters in the laboratory in range of Government Regulation 354/2006 Coll. establishing the requirements for water intended for human consumption and quality control of water intended for human consumption, effective from June 2006. Frequency of data storage is a once a year.

Archived data since 1982 are the basis for monitoring the development of groundwater in Slovakia, for the preparation of reports, expert opinions.

THERMAL AND MINERAL WATERS

Monitoring of the groundwater that have the status of "natural healing sources" and "natural mineral water" is methodically managed by the Inspectorate of Spas and Springs under the Ministry of Health based on § 4 Act 538/2005 Coll. on the natural healing waters, natural healing baths, spas and natural mineral waters.

Definition and responsibilities

The monitoring system of natural healing sources and natural mineral resources is a system through which the organization carries out monitoring of hydrogeological, chemical, physical, microbiological and biological indicators of natural healing sources, natural mineral resources, observation wells, observation objects and meteorological indicators within the territory specified in the water use permission.

The monitoring system of natural healing sources and natural mineral resources is a separate part of the environmental monitoring system.

Natural healing source and/or natural mineral resource user is required to establish and operate a monitoring system connected to central monitoring system of the Ministry of Health according to the conditions stated in the permit for water resource use, and provide continuous data to a database of the Ministry of Health, and run local information system.

The natural healing sources and natural mineral resources monitoring network

The Inspectorate of Spas and Springs under the Ministry of Health launched the ultimate operation of the monitoring system in early 2006. The Ministry of Health uses a central information system (CIS ISS) and at locations with the permission for the use of natural healing, natural or mineral resources local information systems (LIS ISS) are used.

In the whole area of Slovak Republic the monitoring network included a total of 40 sites, including 36 users with LIS ISS (with data transfer to CIS ISS) in 2010, where 162 objects were monitored. Most of the locations use LIS ISS with the transmission to the central database/information system (CIS ISS) of Ministry of Health. Figure 19 shows the locations of recognized natural healing and natural mineral waters in the Slovak Republic.

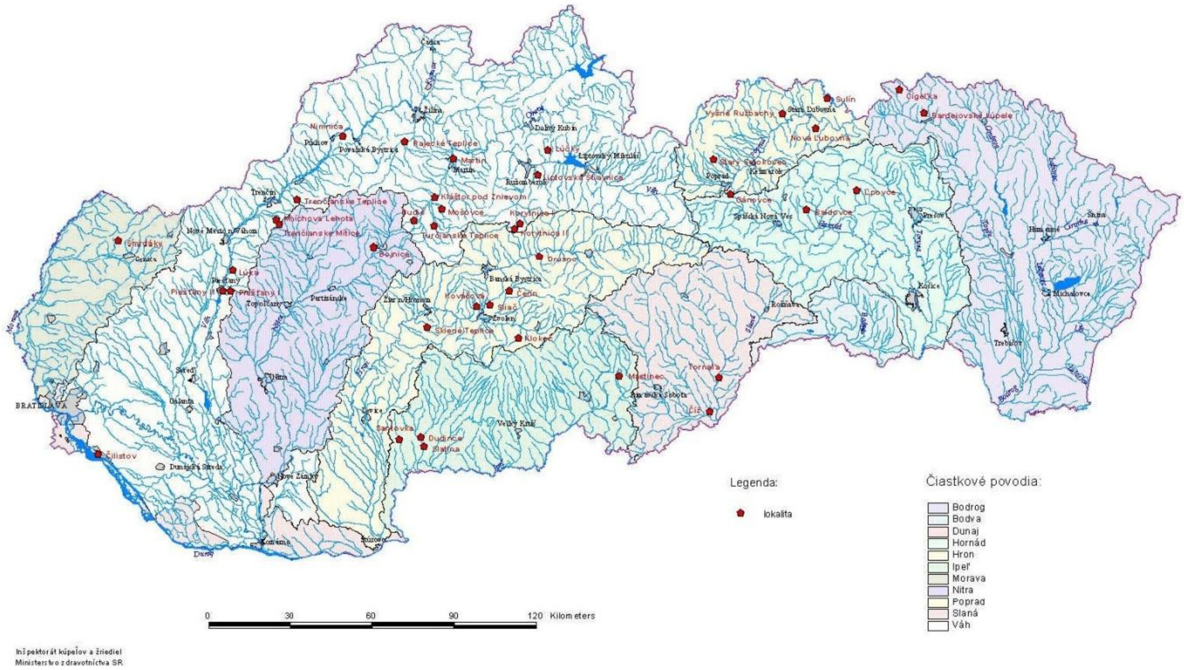


Figure 19. Locations of recognized natural healing and natural mineral waters in the Slovak Republic

Monitored parameters - indicators

The range of the monitored physical, chemical, and biological parameters (basic analysis or extended analysis of mineral water) are determined according to Decree 100/2006 Coll., establishing requirements for analysis of healing water and natural mineral water and balneology assessment.

Sampling and water analysis are carried out by accredited laboratories, which are entered in the list of State Committee for Spas under the Ministry of Health.

Range and frequency of monitoring indicators are site specific and are described in detail in the permissions for water exploitation (healing water exploitation) issued by the Ministry of Health.

Recording of data is carried out:

a) by water user/observer: manual measurement, respectively. Depreciation of the automatic measurement techniques - CO_2 content (mg/l), the content of HCO_3 (mg/l), H_2S content (mg/l), daily water consumption (m^3), hydrologic flow measurements on surface water/river - stage on the river - gauge (cm), meteorology - the daily precipitation (mm), temperature (° C), barometric pressure (kPa), depreciation of physical-chemical data, results of water analysis protocols.

b) by probe (automatic measuring equipment): recorded automatically at regular, intervals - water level (m), pressure on the well head (MPa), yield at source (l/s), state of the flow meter, water temperature (° C), pH, specific electrical conductivity (µS/cm).
In the area of the TRANSENERGY project only well FGČ-1 in Čilistov is monitored by the Inspectorate of Spas and Springs by the above mentioned methods. The monitoring is based on the Decree of Ministry of Health (06433/2006/IKŽ).

Range of indicators for monitoring that is reported to CIS ISS and frequency of the monitored parameters (for well FGČ-1 in Čilistov) is as follows:

Location :	Čilistov
Name of the source:	not defined
Technical data/Name of the well:	FGČ-1
Classification by Inspectorate of Spas and Springs:	natural healing source, exploited source
Type of exploitation:	pumping
Yield (l/s):	continuous measurement
Piezometric level (cm):	not defined
Water consumption (m^3):	measurement once per day
Pressure on the well head (kPa):	continuous measurement
Water temperature (°C):	continuous measurement
Electric conductivity (µS/cm):	continuous measurement
HCO_3 content (mg/l):	measurement once per day
CO_2 content (mg/l):	measurement once per day
H_2S content (mg/l):	not defined
Daily precipitation (mm):	measurement once per day
Stage on the river gauging station (cm):	measurement once per day
Air temperature (°C):	measurement once per day
Barometric/air pressure (kPa):	measurement once per day

Any other sources that are not declared as **“natural healing sources”** and **“natural mineral water”** are managed by the Regional Environmental Office under the Ministry of Environment.

The geothermal water user is (by the law 364/2004 - Water Act) required to pay for water use. That’s why geothermal water user is required to perform monitoring of the geothermal source. The conditions for monitoring (parameters to be measured and frequency of measurement) are stated in permission for water exploitation by Regional Environmental Office. The measured parameters include yield of source (well, spring), temperature of water, well head pressure. The permission can include the request for measurements of chemical components to assess the change in chemistry of the water. Based on the monitoring of the exploitation (yield, temperature, chemistry) the remedial action can be performed to protect the geothermal source.

This means the monitoring of the geothermal water is at the level of exploitation (mostly extracted amount and temperature) and is performed by the user.

Regional Environmental Office issues the permission for geothermal water disposal with stated conditions for monitoring of disposed water into surface recipient or reinjection. Conditions include measured parameters (usually temperature, TDS, basic chemical compounds) and frequency of measurements.

2.5 Concluding remarks on current groundwater management practices in Transenergy countries

From the overview of the current practices of groundwater management in Transenergy countries (chapters 2.1. to 2.4.) it can be concluded, that despite the fact that each country had to prepare and report its national river basin management plans according to the standards required by the Water Framework Directive, there are significant differences. Delineation of groundwater bodies, concepts for their classifications differ a lot from country to country, therefore a uniform evaluation based on groundwater body assessment cannot be prepared for the Transenergy project area. In *Slovenia* groundwater bodies are currently delineated only by surface boundaries and have not been delineated yet in three dimensions, and have only been identified according to significant changes in stratification. It has to be mentioned that in the frame of the T-JAM project (for description see Annex III) a recommendation was made to outline the Mura-Zala Transboundary Thermal Groundwater Body together with Hungary. In *Austria*, shallow and deep groundwater bodies were distinguished based on the depth. Most of the deep groundwater bodies are not suitable for geothermal utilization due to shallow depths and therefore lowered temperatures. Among the deep ones the only thermal one was described in Upper Austria, but so far there is no groundwater body with thermal water delineated within the Austrian part of the Transenergy project area either. Harmonized management- and monitoring concepts do not exist for thermal groundwater bodies from either a national or a transnational point of view. Even though mandatory reporting by individual users to the responsible authority is achieved, no publicly available summary reports on the conditions of the utilized thermal groundwater bodies exist so far. In *Hungary* the groundwater bodies are classified mostly according to the hydrodynamic situation into groundwater from intergranular and karstic aquifer types, and groundwater of fractured mountainous areas. Groundwater with outflow temperature higher than 30 °C is considered thermal (in that way the subdivision between cold and thermal is artificial and has no links to natural hydrogeological conditions). This threshold value is higher than in other Transenergy countries (Slovenia, Austria – 20 °C, Slovakia – 15 °C) due to the basin setting and resulting large amount of available thermal groundwater. In *Slovakia* three layers of groundwater bodies were delineated: the upper layer encompassing main Quaternary basins and alluvial sediments of main rivers, the Pre-Quaternary groundwater bodies, and the geothermal bodies (deep layer) with water temperature exceeding 15 °C.

It can be concluded that the monitoring systems in the countries are fairly complex, divided into different sub-systems, operated by different organizations, which are hard to overview even within a given country. Therefore the direct comparison of the monitoring systems, reporting procedures, data storage and service is practically not possible for the 4 countries. A lack of systematically gathered and stored monitoring data is a problem in all countries which may be one of the main reasons for the inefficient groundwater management systems.

Another important wrapping up statement is that the dual regulation of geothermal energy/thermal groundwater utilization (under ministries of “environment” and “energy” – for details see the report on legislation overview), as well as the resulting non-transparent management strategies (including licensing, monitoring, authority tasks, etc.) further hinder the growth of investments into the geothermal sector in the Transenergy countries.

It is obviously that the deep transboundary groundwater bodies are not harmonized between partners’ countries. Proposal for harmonisation of the deep transboundary groundwater bodies will be made on the pilot areas scale. For the characterisation of

transboundary geothermal aquifers we shall use the UNECE methodology and ICPDR template ''Draft initial characterisation (including risk information) of the transboundary GW-bodies of ICPDR basin-wide importance''. This should be the first step in the preparation of the international water management plan according the article 3 of WFD.

2.6 References

Anonymous, 2007: Decree on the concession for underground water use from wells P-1/73, P-2/88 and P-3/05 intended for activities in bathing areas and health resorts. Official Gazette of the Republic of Slovenia 119 (in Slovene). http://www.uradni-list.si/1/content?id=83991

Anonymous, 2008: Decree on the concession for underground water use from well of JAN-1/04 intended for activities in bathing areas and health resorts. Official Gazette of the Republic of Slovenia 104 (in Slovene). http://www.uradni-list.si/1/objava.jsp?urlid=2008104&stevilka=4424

Anonymous, 2009: Decree on mining rights for commercial exploitation of mineral resources in exploitation areas Lendava in the Municipality of Lendava, Premagovce in the Municipality of Krško, Rače 2 in the Municipality of Rače – Fram, Doline - enlargement in the Municipality of Sežana, Hren – enlargement in the Municipality of Vitanje, Skrbinjek in the Municipality of Poljčane, Šumet in the Municipality Solčava and Zadobova – enlargement in the Municipality of Celje. Official Gazette of the Republic of Slovenia 102 (in Slovene). http://www.uradni-list.si/1/content?id=83071

Bartková, E., Fatulová, E., Krechňák, L., Kollár, A., Kuníková, E., Hucko, P., Adámková, J., Makovinská, J., Borušovič, Š., Chriašteľ, R., Kullman, E., Vodný, J. 2005: Správa Slovenskej republiky o stave implementácie Rámcovej smernice o vode spracovaná pre Európsku komisiu v súlade s článkom 5, prílohy II a prílohy III a článkom 6, prílohy IV RSV. Ministerstvo životného prostredia SR, Výskumný ústav vodného hospodárstva, Slovenský hydrometeorologický ústav, Slovenský vodohospodársky podnik, š. p., s. 205

Franko, O., Remšík, A., Fendek, M. & Bodiš, D. 1984: Geotermálna energia centrálnej depresie Podunajskej panvy - prognózne zásoby (Geothermal energy in the central depression of the Danube Basin – prognostic of geothermal waters reserves). Čiastková záverečná správa. Geofond, Bratislava.

Fusán, O., Ibrmajer, J., Plančár, J., Slávik, J., Smišek, M. 1979: Geologická stavba podložia zakrytých oblastí južnej časti vnútorných Západných Karpát. (Geological setting of the basement in the buried region of the Inner West Carpathians). Zbor. geol. Vied, Západné Karpaty 15, 1–173.

Gál, R., Blaškovicová, L., Kullman,, E., Gavurník, J., Vancová, A., Kvapilová, L., Panák, D., Kosmálová, G., Píš, V., Valovicová, Z., 2008: Komplexný monitorovací systém životného prostredia územia Slovenskej Republiky, Čiastkový Monitorovací Systém – Voda, 2007, Slovenský hydrometeorologický ústav, Bratislava.

Goetzl, G., Lapanje, A. & Domberger, G., 2008: Transthermal – Geothermal potential of the border region between Austria and Slovenia – Evaluation of the geothermal potential based on a bilateral database and GIS-maps for the regions Carinthia, Styria and Northern Slovenia; INTERREG IIIA Austria-Slovenia”, Bilateral Final Report, Vienna-Graz-Klagenfurt-Ljubljana.

Goldbrunner, J., 2005: State, Possible Future Developments in and Barriers to the Exploration and Exploitation of Geothermal Energy in Austria – Country Update, Proceedings World Geothermal Congress, Antalya.

Kralj, P, Kralj, Po., 2000: Overexploitation of geothermal wells in Murska Sobota, northeastern Slovenia. In: Proceedings of the World Geothermal Congress 2000, IGA, Kjushu –Tohoku, pp. 837-842

Kralj, Po., Rychagov, S., Kralj, P., 2009: Changes in geothermal reservoir induced by exploitation: case studies from North-East Slovenia and South Kamchatka. In: Proceedings of the Applied Environmental Geochemistry – Anthropogenic impact on the human environment in the SE Europe, Geological survey of Slovenia, Ljubljana, pp. 71-76

Kröll, A. & Wesselly, G. 1993: Wiener Becken und angrenzende Gebiete, Strukturkarte. — Basis der tertiären Beckenfüllung. — Karte u. Erl. Geol. B. A., Wien.

Oesterreichischer Wasser- und Abfallwirtschaftsverband, 2010, OEWAV Regelblatt 215: Nutzung und Schutz von Thermalwasservorkommen, Wien.

Pezdič, J., 2003: Origin and migration of gases in the Pannonian sedimentary basin. In: Proceedings of the ICGG7, Freiberg, pp. 47-49

Prestor, J., Urbanc, J., 2005: Nacionalna baza hidrogeoloških podatkov za opredelitev teles podzemne vode Republike Slovenije. Report, Geological survey of Slovenia (in Slovene).

Remšík, A., Franko, O., Biely, A., Bodiš, D., Gazda, S., Gross, P., Kullmanová, A., Lukáčik, E., Samuel, O. 1979: Základný výskum geotermálnych zdrojov komárnanskej vysokej kryhy (Basic research of the geothermal springs of the Komarno high block.). Čiastková záverečná správa. Geofond, Bratislava

Remšík, A. & Franko, O. 1983: Geologický projekt výskumného geotermálneho reinjektázneho vrtu GRP–1 Podhájska. (Geological project of the GRP–1 Podhájska exploratory geothermal reinjecting well). Archív Geologický ústav Dionýza Štúra, Bratislava.

Remšík, A., Franko, O. & Bodiš, D. 1992: Geotermálne zdroje komárnanskej kryhy. (Geothermal springs of the Komarno block). Západné Karpaty, sér. hydrogeológia a inž. geológia. s. 159 - 199

Remšík, A. & Fendek, M. 1995: Geotermálna energia Slovenska so zreteľom na východoslovenský región (The geothermal energy of Slovakia with regard to the East Slovakian region). Konferencie-sympóziá-seminar, Zbornik referátov z konferencie III. Geologické dni Jána Slávika. Geologický ústav Dionýza Štúra, Bratislava. s.131–136.

Ministry of the Environment of the Slovak Republic, 2009: Vodný Plán Slovenska, Plán manažțmentu správneho územia povodia Dunaja, Plán manažmentu správneho územia povodia Visly 131 p.

Ministry of the Environment of the Slovak Republic, Water Research Institute, Slovak Hydrometeorological Institute, Slovak Environmental Agency, 2004: Report of the Slovak Republic processed for European Commission in line with Water Framework Directive, Article 3 and Annex I, 35 p

Struckmeier, W.F. Margat, J., 1995: Hydrogeological maps - A guide and a standard legend. IAH International Contribution to Hydrogeology 17.

Wessely, G., 1983: Zur Geologie und Hydrodynamik im südlichen Wiener Becken und seiner Randzone; Mitteilungen d. österreichischen geologischen Gesellschaft; Band 76, Wien.

Web-links

Groundwater
AT http://wisa.lebensministerium.at/
HU http://www.vizeink.hu/?module=ovgt100505
SI
http://www.arhiv.mop.gov.si/si/delovna_podrocja/voda/nacrt_upravljanja_voda_za_vodni_obmocji_donave_in_jadranskega_morja_2009_2015/nuv_besedilni_in_kartografski_del/
SLK http://www.shmu.sk/sk/?page=18

3 Principles of geothermal resource assessment

3.1 Introduction

Comprehensive and effective management of geothermal resources is an essential part of successful geothermal utilization. Geothermal systems are complex and their energy production potential is highly variable due to their composite internal structure, nature and properties which can only be observed indirectly. Successful management requires a proper understanding of the geothermal system involved (volume, geometry, temperature and pressure distribution as well as boundary conditions of the reservoir, properties of the reservoir rock, such as permeability, porosity, heat capacity and heat conductivity). This is primarily based on the data available at any stage of surface and subsurface exploration. However the most important data on a geothermal system's nature and properties are obtained through monitoring of the system's response to long-term production. Therefore careful monitoring of a geothermal reservoir during exploitation is an indispensable part of any successful management program. With proper management, operational problems can be held to a minimum (e.g. scaling, corrosion), over-exploitation can be avoided and production may be sustained for a long time, costs can be minimized and revenues maximized.

3.2 Reservoir vs. resource management

From a *viewpoint of reservoir* physics and reservoir engineering the key issue of geothermal resource management is to avoid over-exploitation, therefore it is focusing on modelling, monitoring and re-injection (e.g. Axelsson 2003, Axelsson and Stefánsson 2003, Axelsson et al. 2005). The purpose of geothermal *modelling* is to obtain information on the geothermal system for its proper understanding, as well as to predict response of the reservoir to future production and estimate production potential of the system. These can be simple analytical models, lumped parameter models and detailed numerical models. The most important data on the nature and properties of a geothermal system are obtained in the phase of operation through *monitoring* of the reservoir's response to long-term production, therefore monitoring is an essential part of successful management. *Re-injection* is an essential part of sustainable, environmental friendly geothermal utilization which makes possible to extract more thermal energy by providing artificial water recharge and provides safe waste-water disposal for environmental reasons.

The main objectives of a reservoir-oriented geothermal resource management are to (1) minimize the operation cost of a given geothermal reservoir, (2) to maximize the energy extraction from a given resource, (3) to ensure the security of continuous energy delivery, (4) to minimize environmental effects, (5) to avoid operational difficulties (e.g. scaling, corrosion). Accordingly most common management options include (1) changed production strategy, (2) application of injection, (3) drilling of additional wells, (4) changes in well-completion programs (e.g. casings), (5) lowering of down-hole pumps, (6) search for new production areas or drilling targets. Furthermore one of the most difficult aspects of reservoir management is to determine the most appropriate time-span of operation which is commonly matched with expected life-time of surface equipments (30-40 years).

However, in a broader aspect *geothermal resource management* refers to all stages of the life-cycle of a geothermal project (Figure 20) from the (1) identification of resources (reconnaissance study), (2) to carry out research programs to estimate the size of the resource and its preliminary potential (pre-feasibility study), (3) to confirm the resources by drilling complemented by further geo-scientific studies and modelling, environmental impact studies, leasing and permitting issues, elaboration of business models, etc. (feasibility study), (4) production (plant construction), (5) operation and (6) monitoring.

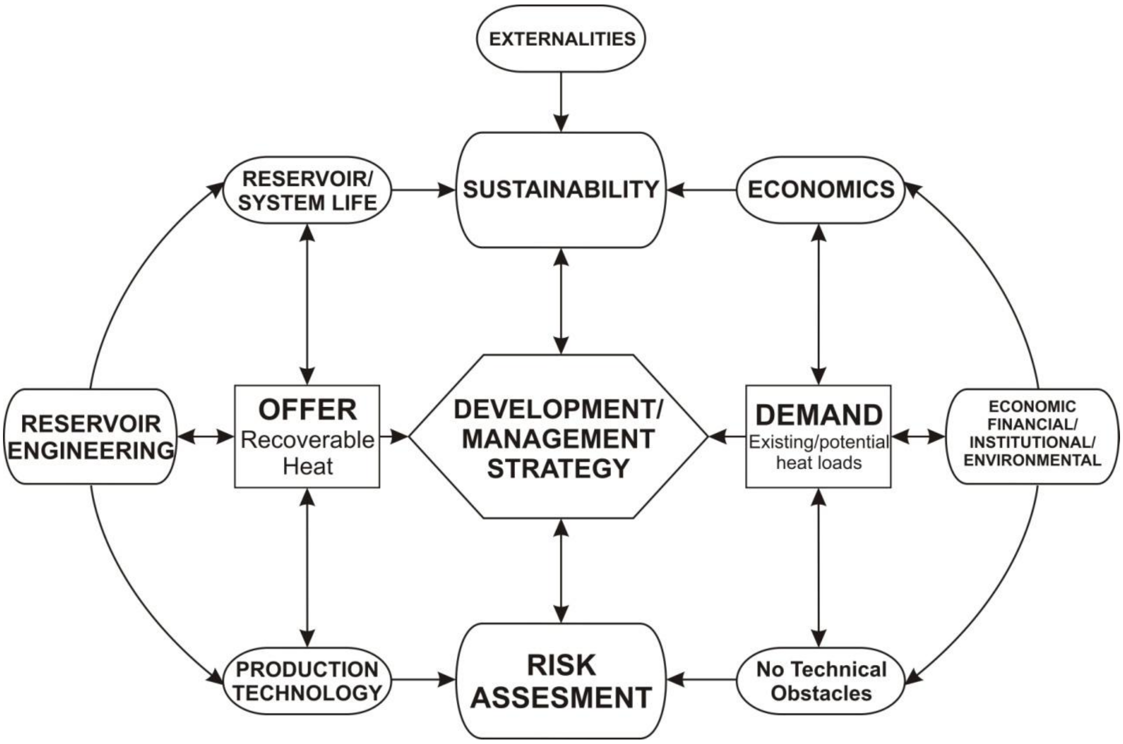


Figure 20. Components of geothermal resource management

The project Transenergy contributes to the identification and better understanding of the geothermal resources at the western part of the Pannonian basin and thus provides integrated geoscientific information for potential investors to carry on with subsequent phases (drilling, production, operation), therefore in the present report we focus on the management issues of the exploration stage and only briefly summarize considerations related to drilling, production, operation and monitoring.

Geothermal resources and reserves

Defining geothermal resources and reserves and their categories is a key issue in geothermal resource management as non-technical people often do not properly understand and interpret the large estimates of stored heat. The most widely accepted classification is provided by the Australian and Canadian geothermal reporting codes (AGRCC 2009, CGCC 2010). According to these codes the classification is as follows:

The *thermal energy in place* (PJ_{th}) or MW_{th}-years must not be described as geothermal resource.

Geothermal resource is the estimated recoverable thermal energy, i.e. a geothermal play which exists in such a form, quality and quantity that there are reasonable prospects for eventual economic extraction. The Reporting Code recognizes three levels of *geothermal resources: inferred, indicated and measured* based on the increasing level of geological knowledge and confidence of the assessment of probability of occurrence. These resource categories are usually estimated on the basis of geoscientific information. The “inferred” category covers situations where a geothermal play has been identified on the basis of limited and/or indirect measurements, extrapolations, but where data are insufficient for confidential interpretation of the resource. The “indicated” category covers that part of the geothermal resource, which existence has been demonstrated through direct measurements and assessments of volume of hot rock and fluids with sufficient indicators to characterize the temperature field, i.e. sufficient drilling information to allow confident interpretation of the geological framework and the continuity of thermal energy distribution and an initial evaluation of economic viability. The “measured” category is that part of the geothermal resource, which has been demonstrated to exist through direct measurements that indicate reservoir temperature, volume and well deliverability, so that recoverable thermal energy (PJ_{th}) or MW_{th}-years can be estimated with a high level of confidence and spacing is measurements is enough to confirm continuity.

Geothermal reserves are that portion of the indicated or measured geothermal resource, which is deemed to be economically recoverable considering both geothermal resource parameters and “modifying factors” which affect the likelihood of commercial delivery (e.g. production, economics, marketing, legal environment, land access, social and governmental factors, i.e. require input from a range of other disciplines), i.e. energy extraction may be economic and technically justified. Geothermal reserves have two categories: *probable and proven*, the proven geothermal reserve is the highest confidence category and refers to the economically recoverable part of the measured geothermal resource. The relationship between the different types of geothermal resources and reserves is shown on Figure 21.

It is important to note that neither geothermal resources nor geothermal reserves are precise calculations, therefore the Code suggests that final results should always be referred as “estimates” and not as “calculation”.

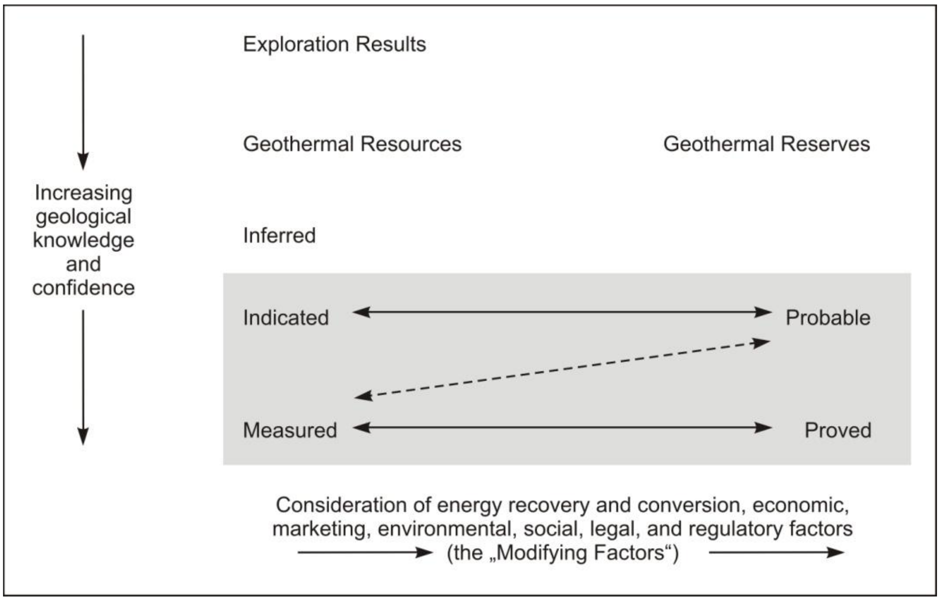


Figure 21. Relationship between different levels of geothermal resources and reserves (AGRCC 2009, CGCC 2010)

Geothermal resources and geothermal reserves must only be reported in units of *Recoverable Thermal Energy* i.e. as Petajoules (PJ_{th}) or $Megawatt_{thermal\text{-}years}$ (MW_{th}-years) relative to defined *Base* and *Cut-off Temperatures*. If the thermal energy is envisioned to be converted into electricity, then an estimate of the *Recoverable Electrical Energy* may additionally be stated using units of PJ_e or MW_e-years. In all cases the subscript ‘thermal’ / ‘th’ or ‘electrical’ / ‘e’ must be used to distinguish thermal from converted electricity energy. Furthermore all *recovery* and *conversion factors* used must be stated separately.

Geothermal resource assessment in Transenergy project will be accomplished by a 3 level approach, which is shown on Figure 22, and which in principle is line with the above described classification.

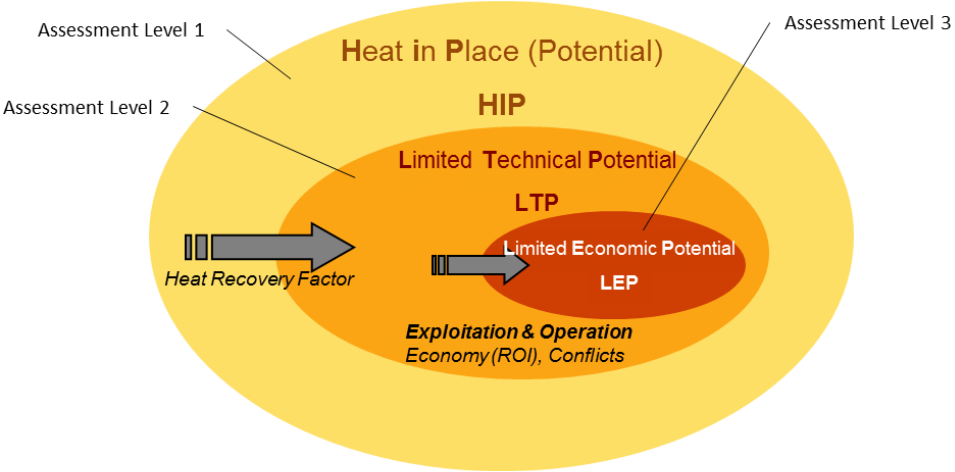


Figure 22. General scheme of the chosen geothermal resource assessment approach

The chosen approach is not conformable to general geothermal nomenclature (e.g. Hurter and Schellschmidt 2003), but in turn allows to quantify the theoretically available and technically or / and economically exploitable amount of energy based on already existing and calculated reservoir data considering hydrogeothermal use and is in line with the above described resource assessment protocols.

Level 1 covers the theoretically expectable, or available maximum and minimum potential in terms of the stored Heat in Place (energy amount stored in subsurface water). *Level 2* covers the technically extractable amount of heat and represents a part of Level 1. From a physical point of view, the governing time depending parameter is given by the so called Heat Recovery Factor, which limits the technically extractable amount of heat using a geothermal doublet, a multiplex, or a single well system. The other crucial aspect governing the so called "Limited Technical Potential" (LTP) is given by the actual state or degree of thermal exploitation. *Level 3* finally describes the economically feasible amount of extractable heat in the hydrogeothermal systems regarding the infrastructural and economical framework. This amount of heat is described by the term "Limited Economic Potential" (LEP). Level 1 assessment is provided for the supra-regional area, whereas level 2 (and potentially 3) assessment will be done for the pilot areas.

It has to be taken into account, that the quantification of geothermal potentials and resources has always been under consideration of specific utilization scenarios (e.g. electric power generation, industrial heating and district heating). Therefore the geothermal models also cover specific utilization schemes consisting of different levels of needed temperature levels and operational hours.

3.3 Renewable vs. sustainable utilization of geothermal resources

The terms renewable and sustainable are often mixed up, the former concerns the nature of a resource, and the latter applies to its utilization. However even the "renewable" character of geothermal energy can be further discussed (e.g. Rybach et al. 1999, Stefansson 2000, Rybach 2003, Rybach and Mongillo 2005, Axelsson et al 2005) and a special attention will be paid to this issue during the establishments of the geothermal models in Transenergy.

Even though geothermal resources are classified as *renewable* energy resources (i.e. "the energy removal from the resource is continuously replaced by more energy on time-scales similar to those required for energy removal and those typical of technological-societal systems"), such a classification may be an oversimplification. The ultimate source of geothermal energy is the immense heat stored within the Earth (about 10^{13} EJ) which is mainly produced by the decay of radioactive isotopes in the crust. This huge amount of heat is lost to the atmosphere via terrestrial heat flow of about 40 MW_t so it would theoretically exhaust in 10^9 years (Rybach and Mongillo 2006), i.e. rather geological than human time-scales.

Geothermal resources are a combination of an energy current (through heat convection and conduction) and stored energy. The renewability of these two aspects is quite different. The energy current can be considered as steady due to the immense amount of heat produced via radioactive decay (renewable, see above), while the stored energy is renewed relatively slowly, in particular the part renewed by heat conduction (Axelsson et al. 2005). Furthermore geothermal resources are commonly used by exploitation of fluids and extracting its heat content. In convective-driven hydrogeothermal systems the carrying medium of the heat is thermal groundwater. Its natural recharge cannot be considered "infinite", therefore its re-supply is a serious impeding factor in renewability of these systems.

Any balanced production of fluid/heat which does not produce more than the natural discharge can be considered as fully renewable (Stefansson 2000). Such examples include thermal springs in many parts of the world which discharge vast amount of heat (and fluid) to the surface for centuries without showing any signs of decline, presenting existing balance between surface discharge and fluid/heat recharge in the depth. However such production rates are not economical in many cases.

Utilization of geothermal resources involves mass and heat extraction from the given reservoir. In the natural state of a reservoir mass and heat transfer are driven by pressure variations, which are changed during artificial intervention (i.e. production). In addition to the rate of production, the energy supply of a geothermal system is predominantly determined by pressure decline due to exploitation. The pressure decline is determined by and the reservoir properties (size, rock permeability, recharge, etc.). The nature of such geothermal systems is such that the effect of "small" production can be maintained for a very long time (hundreds of years – renewable, see above), while the effect of "large" production is so great on the system, that it can't be maintained for long (Axelsson 2003).

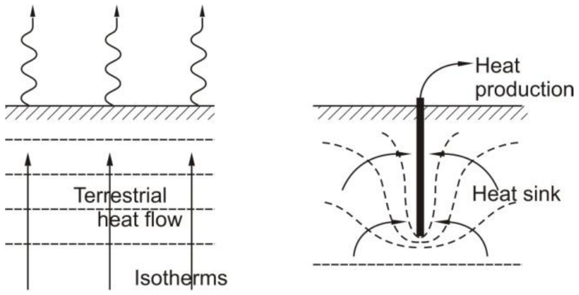
The term "*sustainable* development" has been defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987). Sustainabe utilization of geothermal energy has been discussed by several authors, including Axelsson and Stefansson (2003) and Axelsson et al (2002), Rybach (2003), Rybach and Mongillo (2006). According to these studies several decades of various experience show that by maintaining production below a certain limit, a geothermal system reaches a kind of balance, which can be maintained for a long time. Often the resources are produced with the main objective of a quick pay-back of the investment costs of exploration and equipment which results the reservoirs depletion.

Axellson et al (2001) attempted to define the term sustainable production of geothermal energy based on the assumption that for each geothermal system and for each mode of production there exists a level of maximum energy production (E_0), below which it is possible to maintain constant energy production from the system for a very long time (production period of 100-300 years). It applies to the total extractable energy which depends on the nature of the system and on the mode of production (e.g. spontaneous discharge, pumping, injection, periodic), but does not consider environmental aspects, economic issues, technological advances, utilization efficiency all of which may change in the future. The value of E_0 can be estimated on the basis of available data by modeling. Geothermal energy production below, or equal to E_0 is termed sustainable, while production greater than E_0 is termed excessive production. If energy production from a geothermal system is within the sustainable limit, it may be assumed that the stored energy is depleted relatively slowly and the energy content of the reservoir is renewed approximately the same rate as it is extracted.

Sustainable production can be reached in many resource types and utilization schemes, i.e. doublet systems in hydrogeothermal aquifers – Paris basin district-heating system (Ungemach and Antics 2006), low-enthalpy resources without reinjection – Laugarnes and Hamar geothermal fields, Iceland (Axelsson et al. 2005), high-enthalpy two-phase reservoirs – Wairakei-Tauhara geothermal system, New Zeland (O'Sullivan and Mannington 2005).

Regeneration of geothermal resources after exploitation is a process operating on various time-scales, depending on the size and characteristics of the reservoir, the rate of production. Model results show that recovery driven by pressure and temperature re-supply shows asymptotic character being strong at the start, than slowing down subsequently. Practical replenishment (95%) occurs generally on time-scales of the same order as the life-time of the geothermal production system (Rybach and Mongillo 2006), however some experiences show that it might be much slower. The production of geothermal energy creates a hydraulic

/heat sink in the reservoir which leads to temperature and pressure gradients generating fluid/heat inflow towards the well, or opposite processes after the cessation of production to re-establish the natural state (Rybach et al. 2000) (Figure 23). A theoretical modeling on the recovery cycle of a hypothetical lower permeability two-phase reservoir showed that the pressure recovery occurred much faster than the temperature re-establishment, both showing asymptotic behaviour (fast recovery at the beginning, decreased subsequently) (Pritchett 1998).



The terrestrial heat flow is lost to the atmosphere

The heat sink captures the heat flow

Figure 23. Principles of geothermal heat extraction and production (Rybach and Mongillio 2006)

Long-term production from geothermal resources should be limited to sustainable levels, however short periods of extreme production may rapidly establish pressure and temperature sinks and encouraging greater flows of heat recharge from much larger heat/fluid recharge areas (Rybach and Mongillo 2006).

Geothermal heat/fluid extraction is often described as "heat mining" which is an absolutely wrong terminology and should be avoided in all cases. When a mineral resource is mined, it will gone forever, while the geothermal resource (both heat and fluid) will be replenished some time, i.e. geothermal energy cannot be defined in physical terms as a mineral resource (Rybach and Mongillo 2006). This incorrect analogy also leads to legal problems and obstacles

3.4 Over-exploitation and re-injection

Reservoir pressure is one of the most important parameters in geothermal utilization. When geothermal systems are over-exploited, production has to be dramatically reduced. Although pressure depletion can be beneficiary to some reservoirs by locally stimulating increased hot water recharge to the created heat/fluid sink (see above) at the beginning, if new pressure equilibrium is not established before the pressure drops too much, the well production rates may become uneconomic. Over-exploitation generally occurs because of the poor understanding of the system which makes reliable modeling impossible, therefore the system answers inadequately to long-term production. The second main reason is that many users utilize the same system without common management and control. This is especially important in transboundary resources, where neighboring countries lack harmonized management strategies. This is the key issue of Transenergy project, too.

Reinjection is an integral part of efficient, sustainable and environmentally friendly geothermal operation, as it (1) provides disposal of waste-water (environmental reasons), (2) supports the reservoir pressure, and (3) enhances the production capacity by adding to natural recharge (exploitation, reservoir management reasons).

As the thermal water reserves are limited (to an extent of their natural recharge from infiltrating meteoric waters), production can be increased/maintained without significant drop in the pressure only by re-injecting the cooled water back to the same reservoir, where it warms up at the depth, and thus makes possible the repeated exploitation of the heat-content stored in the rock matrix. Consequently the utilization of geothermal energy from hydrogeothermal systems can be considered as only “partly renewable” (the energy carrier medium, i.e. groundwater is not unlimited, while the heat content of the rock matrix is “unrestricted”, due to the immense heat content of the Earth).

In addition to maintain reservoir pressures, the other major aspect of re-injection is the protection of surface aquifers and ecosystems. The used thermal waters of high temperature and organic matter content released into rivers or lakes are increasing the heat and pollution load of surface waters and the geological environment. The temperature higher than that of the environment promotes the development of organic materials, the intensive growth of plants and the silting of the channels. Due to the higher temperature hydrobiological processes accelerate and may endanger the biological equilibrium of surface ecosystems. The high salt content of thermal waters also loads the ecosystem and surface waters and may lead to the salinization of the soil.

Injection of heat-depleted brines into clastic sedimentary reservoirs has been used for a long-time in the hydrocarbon industry (enhanced oil recovery) and also to some extent in the geothermal sector (Ungemach 2003). Geothermal re-injection started in Ahuachapan, El Salvador in 1969, The Geysers, California in 1970 and in Larderello, Italy in 1974. However the major difference is, that improving the production of depleting hydrocarbon fields by re-injecting fluids does not require long-term sustainability, while with geothermal fields, this is a key issue.

The water injected into geothermal reservoirs includes waste-water and condenser-water from power plants, return-water from direct use, groundwater, surface water, or even sewage water. Operational problems include cooling of production wells (thermal break-through caused by cold water injection), scaling in surface equipments and injection wells (geothermal fluids are in equilibrium with rocks and reservoir conditions, therefore separated fluids may become supersaturated on the surface) and an increased investment and operation cost. Cooling due to re-injection can be minimized by locating injection wells far away from production wells, however the benefit from re-injection can be maximalized by locating injection wells close to production wells. Tracer tests (injecting a chemical tracer into the hydrogeological system and monitoring its recovery through time and various observation points) is one of the most important tools in finding a proper balance in locating the re-injection well and study connections between the injection and production wells (Axelsson 2003). However tracer tests provide information only on the volume of flow paths connecting the injection and production wells, the thermal decline is determined by the surface area involved and the heat transfer from reservoir rock to the flow path, which can be assessed by coupled numerical heat and transport models.

Successful re-injection projects mostly operate in fractures, carbonate systems (e.g. Shahe filed, Beijing, China − Axelsson et al. 2002; Paris basin, France − Boisdet et al. 1990, Axelsson and Gunnlaugsson 2000), however it is a more complex procedure into clastic (sandstone) reservoirs, as the necessary injection pressure can substantially increase within a relatively short time. The most common is the plugging of screens (perforation) in the well and pore throats of the reservoir formation. The permeability may decrease due to clay swelling, pore-space blocking by fine particles, or precipitation of dissolved solids due to the mixing of injected and formation water. The precise mechanisms which determine injectivity are site specific and processes are not entirely understood yet. Therefore existing and well operating technologies in one place cannot be directly adopted to another site and no uniform policy, standardized know-how is available which would guarantee the success of a re-injection project. Processes can be better understood based on local experiments including theoretical analyses, numerical simulations, laboratory and in-situ experiments.

Experts in Hungary have attempted to re-inject into the Upper Pannonian sandstone reservoirs for more than 30 years, so the country has long-term experience in facing re-injection problems. Although thermal water from several hundred wells are used for direct heat utilization only about 20 re-injection wells exist in the country, which shows that the direct use of water without re-injection is unfortunately a current standard.

The extensive abstraction of thermal water, especially from porous aquifers resulted in drop of hydraulic heads in many places in Hungary, mostly on the Great Hungarian Plain. This trend was clearly proved during the preparation of the River Basin Management Plans related to the Hungarian implementation of the Water Framework Directive, where the groundwater bodies were assessed from a quantitative and qualitative point of view. The quantity status of groundwater bodies was investigated by several methods. Based on the so-called decline test (which investigated whether noticeable drop in the hydraulic potential occurred due to water abstraction) the major part of the Great Hungarian Plain was qualified as being in poor status, where the drop of potential exceeded 0.1 m/year (Gondárné and Simonffy 2009). This area clearly coincides with the area of most extensive utilization for agriculture purposes where re-injecting wells are missing.

The main lessons learned from local re-injection experiments carried out in Hódmezővásárhely, Szeged and Szentes areas (SE-Hungary) (Szanyi and Kovács 2010, Bálint et al. 2010, Barcza et al. 2011) are that long-term sustainable injection is possible, but instead of ad hoc approaches, scientifically sound solutions must be found were the right selection of the injection well (location and depth), specially designed and completed well in technical terms, good hydraulic performance, very slow transient performance process (pressure, temperature, flow rate) are needed. Special investigations are needed as early as the drilling phase to determine permeability, conductivity, rock-mechanical, pressure, geothermal properties of the reservoir as well as hydrogeochemistry of the formation fluids.

The main reason for the initial failure of re-injection was that users tried to transform existing abstraction wells into re-injection wells, not paying attention to micro-filtration prior to re-injection. After many unsuccessful attempts, Aquaplus Ltd. constructed the first well specially designed for re-injection which is operating economically and which has the following main characteristics:

- installation of filter-pipe instead of posterior perforation
- gravel packing in the filter area
- cautious starting and stopping to avoid sudden pressure impact that can cause sand-filling of the wells

The question of re-injection in general, and recommendations for the increase of geothermal doublets in the Transenergy project area to promte the enhanced and sustainable utilization of geothermal energy will be in the focus during the hydrogeological and geothermal modeling, as well as in the final recommendations to be phrased at the end of the project.

3.5 Monitoring of geothermal systems

The most important data on the nature and properties of a geothermal system are obtained in the phase of operation through monitoring of the reservoir's response to long-term production, therefore are essential part of successful management. Monitoring the physical changes in a geothermal reservoir involves measurements of (1) mass and heat transport, (2) pressure, and (3) energy content (temperature in most situations). As these measurements must be done at high temperatures and pressures in most cases, in practice this is highly complicated (Axelsson 2003, Axelsson and Gunnlaugsson 2000). Measurements are generally limited to a few boreholes. Methods of monitoring as well as monitoring frequency may vary in different geothermal systems. Conventional geothermal monitoring programs cover the following direct observations:

- Mass discharge history of production wells
- Enthalpy or temperature of fluid produced
- Wellhead pressure (water level) of production wells
- Chemical content of water and steam produced
- Injection rate histories of injection wells
- Temperature of injected water
- Wellhead pressure (water level) of injection wells
- Reservoir pressure (water level) in observation wells
- Reservoir temperature through temperature logs in observation wells
- Well status through caliper logs, injectivity tests and other methods

Monitoring programs have to be specifically designed for each geothermal reservoir because of their individual characteristics. Monitoring program s may be revised as time progresses, which may apply for monitoring frequency of different parameters.

In addition indirect monitoring of changes occurring at the depth through various surface observations and measurements may apply for high-temperature fields. These are mostly surface geophysical measurements, such as topographic measurements, micro-gravity survey, electrical resistivity surveys, ground-temperature and heat-flow measurements, micro-seismic monitoring, self-potential surveys. These methods are infrequently used in low-enthalpy fields, because their physical changes during exploitation are not that great and rarely have surface manifestations, furthermore these measurements are rather costly, therefore they are not applicable to Transenergy project area.

3.6 Environmental aspects

Despite the well-known advantages (e.g. an energy resource nearly indefinite delivering heat and power 24 hours a day throughout the year available all over the world, zero-to very low CO_2 emission, relatively small footprint for surface facilities, etc.) geothermal energy production also has some impact on the environment, which degree depends on the technology used (Rybach 2003). In power generation the environmental effects include changes to landscape, land use, emissions to the atmosphere (gas, fluids, although considerably lower carbon-dioxide emission compared to the burning of fossil fuels), emissions to surface and subsurface waters (e.g. waste heat), noise, land subsidence, seismicity, production of solid waste. Environmental impacts of direct use are the same as with power generation, its degree is proportional to its scale. As re-injection becomes more frequent, induced seismicity has also become an issue. Re-injection of large volumes of spent geothermal fluids under pressure changes the pore-pressure conditions and the local stress-field. Induced seismicity is especially relevant for engineered geothermal systems (EGS), where artificial reservoirs are created by hydraulic fracturing.

Environmental aspects for some recommended utilization schemes in the Transenergy project area will be discussed in details in the feasibility study to be prepared in WP6.

3.7 Energy efficiency

Cascade use is a favorable option, when the resource is utilized in steps of decreasing temperature: industrial applications, space heating, agricultural use, balneology, fish-farming, ice-melting. Such good examples already exist in the Transenergy project area (Rman et al. 2011) and additional recommendations for such utilization schemes will be elaborated.

Furthermore thermal efficiency (η_i) should be increased in all existing and planned utilizations. Thermal efficiency is the ratio between used and available annual heat energy:

$$\eta_i = E_{used\ i} : E_{available\, i} \qquad (1),$$

Used annual heat energy ($E_{used\ i}$) Eq. 2:

$$E_{used i} = V_{aa} \cdot 4.18 \frac{kJ}{kgK} (T_{wellhead} - T_{outlet}) \qquad (2),$$

V_{aa} - average annual quantity of abstracted thermal water,

($T_{wellhead}$ – T_{outlet}) – temperature difference between abstraction (wellhead) and outlet (discharge).

Available annual heat energy ($E_{available\ i}$) Eq. 3:

$$E_{available i} = V_{aa} \cdot 4.18 \frac{kJ}{kgK} (T_{wellhead} - T_{location}) \qquad (3),$$

($T_{wellhead}$ – $T_{location}$) - temperature difference between abstraction (wellhead) and yearly average air temperature of the location, e.g. 12° C.

If the volumes of abstracted and waste water are the same ($V_{aa} = V_{ww}$) then the thermal efficiency is calculated by Eq. 4:

$$\eta_i = \frac{T_{wellhead} - T_{outlet}}{T_{wellhead} - T_{location}} \qquad (4),$$

where $T_{wellhead}$ and T_{outlet} correspond to the aforementioned parameters.

If the volume of abstracted thermal water is partly reinjected, then thermal efficiency is calculated by Eq. 5:

$$\eta = \frac{V_{aa}(T_{wellhead} - T_{outlet})}{V_{aa}(T_{wellhead} - T_{outlet}) + V_{ww}(T_{outlet} - T_{location})} \qquad (5),$$

If all abstracted water is re-injected then the thermal efficiency $\eta = 1$ is 100 %.

Equations show that the cooling of waste water and re-injection are the two major factors increasing thermal efficiency which will be greatly promoted in the Transenergy project as well.

3.8 Requirements of public reporting of exploration results and geothermal resource and reserve assessment as a key of successful geothermal resource management

The Geothermal Reporting Codes of the Australian Geothermal Energy Association (AGEA) and the Canadian Geothermal Energy Association (CanGEA) (AGRCC 2009, CGCC 2010) aimed to produce and maintain a methodology and provide a minimum, mandatory set of requirements for public reporting of exploration results and the assessment of geothermal resources and reserves to inform existing and potential investors, their advisors, as well as governmental geo-scientific agencies. The codes give provisions on the entire life-cycle of a geothermal project, applicable also in other countries, therefore they became internationally accepted. The Geothermal Reporting Codes are relevant to all forms of geothermal energy (including naturally permeable aquifers, engineered geothermal systems and both magmatic and non-magmatic heat sources) and all forms of end-use applications of geothermal energy (including both electricity generation and direct use projects) except for ground source heat pumps operating at low source temperatures.

The Code provides a detailed list of parameters which have to be assessed during various phases of a geothermal project such as the following:

Pre-drilling exploration technical data: geological maps and interpretations, data location and spacing, evidence for past/present rock-water interaction, hydrology, sampling techniques, analytical techniques, temperature measurements and geothermometry (nature and quality of techniques used), temperature gradient, thermal conductivity (K), heat flow, heat generation determination, geophysical techniques, data integrity and verification.

Tenement, environmental and infrastructure data: permit and land tenure status (ownerships, royalties, historical sites, national parks, etc.), terrain, geotechnical issues and access (geotechnical and geohazard which could affect future drilling), environmental issues (e.g. water requirement), land-use issues (potential conflicts affecting future drilling), infrastructure (e.g. water supply, transmission lines for electricity), exploration by other parties.

Subsurface and well-discharge data: drilling data (technical specifications of drilling), sample recovery (e.g. cuttings, core, fluid, sampling intervals), geological log (qualitative vs. quantitative logs, lithology, paleontology, mineralogy, fluid inclusions, vitrinite reflectance, etc.), downhole temperature pressure and flow logs (types and quality of measurements), other downhole logging, aquifers (location of permeable zones), depth of reservoir, injection tests, multi-well tests, well-discharge testing.

Naturally convective systems and hot sedimentary aquifer resource parameters: flow-rate (well-tests: individual vs. interference, duration, depth, etc), pressure data, recharge, water saturation and enthalpy, reservoir fluid chemistry (scaling, gas content and acidity), reservoir properties (rock types, porosity, permeability, anisotropy, etc), conceptual model on the nature of the system (integrated geo-hydrogeological reservoir model including analogies used and key-assumptions made, interpretation of physico-chemical reservoir processes), numerical modeling (model structure, key parameters, boundaries and relationship to conceptual model, results of nature-state modeling, history matching and forecast runs), data interpolation/extrapolation.

Estimation and reporting of geothermal resources: expected use (nature of anticipated exploitation), data integrity (source and reliability of relevant data, data validation), data interpretation (certainty of interpretation of geological, geophysical and geochemical data), well deliverability (pumping or self-discharging wells, expected power requirement for production or injection wells), estimation and modeling techniques (e.g. previous production records), cut-off parameters (cut-off temperatures, flow rates, quality parameters), recovery factors, conversion efficiency (heat into electricity), dimensions (expressed as surface area and depth below, reservoir geometry), geothermal resource life, classification (into confidence categories), third party involvement, audits or reviews, accuracy/confidence (sensitivity analysis, probabilistic analysis, scenario trees, discussion of factors which could affect the relative accuracy and confidence of the estimate).

Estimation and reporting of geothermal reserves: description of geothermal resource for conversion to a geothermal reserve, plant when related to electricity generation (technology to be used, expected capacity, etc.), environmental and land-use factors (third party development, emissions to air or water, subsidence, effects on groundwater and ecosystems, changes in surface heat flow, induced hydrothermal eruptions, seismicity, effect on tourism bathing and other land use, etc.), costs and revenue factors (project capital and operating costs, revenue, royalties), market assessment (market capacity vs. price), other (effects of any natural risk, infrastructure, legal, social or governmental factors), classification (into confidence categories), audits or reviews, accuracy/confidence (sensitivity analysis, probabilistic analysis, scenario trees, discussion of factors which could affect the relative accuracy and confidence of the estimate).

Additional factors: existing developments: production data (past total heat and fluid extraction and reinjection, pressure, temperature, enthalpy and chemical historical trends, assessments on heat and fluid recharge), reservoir monitoring (surface and downhole pressure and temperature, fluid flow and enthalpy measurements, tracer tests well output tests, thermal activity and heat-flow monitoring, ground deformation, microgravity, environmental monitoring), production history, numerical modeling (simulation modeling with history matching for credibility, scenario models), future development scenarios.

Transenergy project – by its nature and goals – cannot and will not cover all the above listed aspects, especially those ones which are related to drilling, tenement and infrastructure data, developments, however tries to cover as many of the above listed criteria related to exploration data and naturally convective systems and hot sedimentary aquifer resource parameters as possible (available).

3.9 Utilization schemes as Transenergy targets

Transenergy focuses on the utilization of naturally heated subsurface waters (above 20 °C) (*Hydrogeothermal Utilization*). There are two main hydrogeothermal utilization concepts: (a) *single well thermal water extraction* – typically for balneological purposes, where re-injection is not possible due to contamination and (b) *geothermal doublets* (reinjection of used thermal water into the same reservoir after energetic utilization). A single well thermal water extraction with subsequent disposal of utilized thermal water to a surface discharge is not sustainable if the amount of abstracted water exceeds the amount that is naturally re-supplied through recharge, as it leads to decrease of pressure and yield in the reservoir. The doublet concept – in theory – keeps the mass- and the pressure balance equalized. Nevertheless, a temperature change in time at the water extraction site (production well) may occur due to the thermal breakthrough of injected cooled water via the injection well.

In general, there are 5 different technical utilization schemes with specified production (θ_{out}) and injection temperature levels (θ_{in}), operational hours:

1. General (reference scheme): $\theta_{out} > 30°C$; $\theta_{in} = 25°C$; year-round operational hours [single-well; doublet, multiplex].

2. Pure Electric Power Generation considering ORC schemes: $\theta_{out} > 90°C$; $\theta_{in} = 70°C$; specified operational hours [doublet, multiplex].

3. Combined Electric Power Generation and Local Heating Scheme: $\theta_{out} > 90°C$; $\theta_{in} = 30°C$; specified operational hours for power generation and heating [doublet, multiplex].

4. Combined Heating and Balneological Scheme: $\theta_{out} > 50°C$; $\theta_{in} = 20°C$; specified operational hours for heating and year-round mass extraction for balneological use [doublet, single-well in terms of a mass deficit at the injection well].

5. Pure Balneological Use: $\theta_{out} > 30°C$; $\theta_{in} = 20°C$ (at a surface discharge) year-round operational hours [single-well]

Regarding the present utilization schemes (Rman 2011), and the overall geological, hydrogeological and geothermal conditions of the Transenergy project area, all above listed utilization schemes are potential and will be investigated. As high reservoir temperatures (> 90°C) are not common and poorly known in the area, pure and combined electric power generation has less potential.

3.10 References

Australian Geothermal Reporting Code Committee (AGRCC) 2009: Australian Code for reporting of exploration results, geothermal resources and geothermal reserves. 2nd edition

Axelsson, G. 2003: Essence of geothermal resource management. − IGC Short Course. The United Nations University, Geothermal Training Programme, September 2003, Reykjavík, Iceland

Axelsson, G., Gunnlaugsson, E. 2000: Long-term monitoring of high- and low-enthalpy fieldsunder exploitation. − World Geothermal Congress, Short Course 2000, Kokonoe, Kyushu, Japan, May 2000, 226 pp.

Axelsson, G., Gunnlaugsson, E., Steingrimsson, B., Palmason, G., Armannson? H., Tulinius, H., Flovenz, O.G., Bjornsson, S., Stefánsson, V. 2001: Sustainable production of geothermal energy: suggested definition. − IGA News Quarterly 43 January-March 2001, 1-2.

Axelsson, G., Stefánsson, V., Xu, Y. 2002: Sustainable management of geothermal resources. − Proceedings of the International Symposium of Geothermal and the 2008 Olympics in Beijing. Beijing, October 2002, p. 277-283.

Axelsson, G., Stefánsson, V. 2003: Sustainable management of geothermal resources. − International Geothermal Conference, Reykjavík, September 2003. Abstracts, p. 40-48.

Axelsson, G., Stefánsson, V., Björnsson, G., Liu, J. 2005: Sustainable management of geothermal resources and utilization for 100-300 years. − Proceedings, World Geothermal Congress 2005, Antalya, Turkey, 24-29 April, 2005

Barcza, M., Bálint, A., Kiss, S., Szanyi, J., Kovács, B. (2011). A Szentes térségi hévíztározó képződmények hidrodinamikai viszonyai szivattyú tesztek kiértékelése alapján. − A Miskolci Egyetem Közleménye, A sorozat, Bányászat, vol. 81, p. 245-254

Bálint, A., Barcza, M., Szanyi, J., Kovács, B., Kóbor, B., Medgyes, T. (2010). Investigation of thermal water injection into porous aquifers. − 1st Knowbridge Conference on Renewables. September 27-28, 2010. Miskolc, Hungary. Abstracts

Boisdet, A., Ferrandes, R., Fouillac, C., Jaudin, F., Lemale, J., Menjoz, A., Rojas, J. 1990: Current state of exploitation of low-enthalpy geothermal energy in France. − Geothermal Resources Council, Transactions 14, p. 55-61.

Canadian Geothermal Code Committee (CGCC) 2010: The Canadian geothermal code for public reporting of exploration results, geothermal resources and geothermal reserves

Gondárné Sőregi K., Simonffy Z. (2009). Felszín alatti vizek mennyiségi állapotának meghatározása. − Zárótanulmány a „Vízgyűjtő-gazdálkodási tervek készítése” c. KEOP-2.5.0. projekt keretében. Kézirat, 47 pp.

Hurter, S., Schellschmidt R., 2003: Atlas of Geothermal Resources in Europe; Geothermics, 32, p. 779 – 787, Elsevier.

O’Sullivan, M., Mannington, W. 2005: Renewability of the Wairakei-Tauhra geothermal resource. − Proceedings World Geothermal Congress 2005

Pritchett, J.W. 1998: Modelling post-abandonment electrical capacity recovery for a two-phase geothermal reservoir. − Geothermal Resources Council transactions v. 22, p. 521-528

Rman, N., 2011: Database of users and database of current and potential utilization parameters – Transenergy project report, 39 p. http://transenergy-eu.geologie.ac.at

Rybach, L., Mégel, T., Eugster, W.J. 2000: At what time-scale are geothermal resources renewable? − Proceedings, World Geothermal Congress Japan, p. 867-873

Rybach, L. 2003: Geothermal energy: sustainability and the environment. − Geothermics v. 32, p. 463-470.

Rybach, L., Mongillo, M. 2006: Geothermal sustainability – a review with identified research needs. − GRC Transactions vol. 30, p. 1083-1090.

Stefansson, V. 2000: The renewability of geothermal energy. − Proceedings, World Geothermal Congress Japan, p. 883-888.

Szanyi, J., Kovács, B. (2010). Utilization of geothermal systems in South-East Hungary. − *Geothermics,* vol. 39, p. 357-364

Ungemach, P. (2003): Reinjection of cooled geothermal brines into sandstone reservoirs. − *European Geothermal Conference* 32, Abstracts 743.

Ungemach, P.M., Antics, M. 2006:Geothermal reservoir management. a 30 year practice in the Paris basin. − ENGINE Launching Conference, Orléans, France

4 National Renewable Energy Action Plans

4.1 Introduction

EU Directive on Promotion of Renewable Energy Sources (Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC) establishes a common framework for the promotion of energy from renewable sources. It sets mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy, and for the share of energy from renewable sources in transport. The overall EU target is to double the share of renewables to 12 % by year 2010 in the gross energy consumption and in particular to achieve a 22.1% indicative share of electricity produced from renewable energy sources.

It also lays down rules relating to statistical transfers between Member States, joint projects between Member States and with third countries, guarantees of origin, administrative procedures, information and training, and access to the electricity grid for energy from renewable sources.

The Directive prescribes the adoption of the national renewable energy action plan (NREAP) for each Member State. These plans are prepared in accordance with the template published by the Commission; provide detailed roadmaps of how each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption. The NREAPs submitted to the Commission were evaluated in 2011 by EGEC In the following we summarize the NREAP-s main conclusions regarding deep geothermal energy, as well as EGEC's final remarks for Austria, Hungary, Slovakia and Slovenia regarding deep geothermal.

4.2 National Renewable Energy Action Plan - AUSTRIA (2011)

Austria must increase its share of renewable energy in gross final consumption of energy to 34 % by 2020. In the 2005 base year this share was 24.4 %, in 2008 it has already reached 29.0 %. These targets can be reached by a 13 % reduction of final energy consumption and an increase of 18% in the volume of renewable energy (388 PJ).

Austria has already 2 geothermal power plants and one ORC plant with low temperature at 80 °C, one of the best examples in continental conditions (Altheim). The NREAP does not propose a target for electricity in 2020. The feed-in tariff for geothermal is low (7.5 €cent/kWh) and much less than for other RES. There are no measures to develop geothermal electricity unless the potential is important and the Austrian Energy agencies are not promoting this technology.

There are some incentives for deep geothermal (District Heating) and Geothermal Heat Pumps; but no ambitious targets for the future.

For deep heating & cooling, Austria proposes a steady growth (+2 ktoe/y) from 19 to 40 ktoe. 20.2 ktoe was produced in 2010 (845 TJ/y) and in the near future new deep geothermal projects can be expected in the Vienna Basin.

In summary, some measures for developing geothermal heating in Austria are proposed, but not the relevant targets.

4.3 National Renewable Energy Action Plan – HUNGARY (2011)

The goal to be achieved by 2020 for the utilization of renewable energy resources is 14,65% of the total energy demand in Hungary (120,56 PJ) by 2020, from which the share of geothermal energy will be 14%. In the 2005 base year the share of renewables was 4,3%. Table 13 shows the amount of geothermal energy production regarding both electricity and heat during the past years, as well as the probable utilization in the future. It seems that heat production has to be tripled in the next 10 years to reach the 15 PJ object value. The electricity object value to be produced by geothermal energy seems to be highly ambitious for the present.

Table 13. Share of geothermal energy

Share of geothermal energy	2005	2008	2010	2015	2020
in electricity production (GWh)	0	0	0	29	410
in heat production (PJ)	3.63	4	4.23	6.15	14.95

The conventional geothermal potential for electricity production is low (e.g. binary ORC, or Kalina) but quite high for future EGS systems, however this is mostly relevant for SE-Hungary (outside of Transenergy area). Hungary proposes to have a first geothermal electrical plant in 2013 (4 MWe capacity producing 29 GWh and operating 7,250 hours/year), a second one in 2016 (8 MWe for 57 GWh, operating 7,125 h/y) and 57 MWe from 2018 (210 GWh, operating only 3,684 h/y).

Hungary has a legal framework for deep geothermal with support measures:

- Mining Act, Water management Act, Electricity Act and the Act for environmental protection;
- Renewable energy and a geothermal legislation are under preparation (notably for new geothermal energy concessions);
- There is a feed-in tariff and regulated takeover price of the produced electricity from renewable energy. The price is subsidized and fixed. There are three price levels; the weighted average is ~ HUF28/kWh (around 10 €cent/kWh);
- The promotion of renewables is also supported from EU sources through the Environmental and Energy Operative Program.

The country has high potential for low- and medium enthalpy geothermal, suitable for direct uses. For deep heating & cooling systems, Hungary proposes a growth from 101 ktoe in 2010 to 357 ktoe by 2020. The objective is to develop all geothermal applications: for balneology, agriculture, bathing, district heating (new and retrofitting) etc.

The Hungarian NREAP emphasizes that in accordance with sustainable resource management, special attention must be paid to re-injection to preserve geothermal assets. There is significant potential in increasing the role of geothermal energy in heat supply, which is already at this time a widespread method of heating in certain areas (e.g. in horticulture) in Hungary. In addition to the direct costs of the construction of wells and re-injection (which would not be necessary in all cases), the most important limiting factor in the case of geothermal energy is the provision of funding.

The Hungarian NREAP suggests a challenging development for geothermal, but the potential is much higher. Firstly, the geothermal statistics must be verified and then targets could be recalculated.

4.4 National Renewable Energy Action Plan – SLOVAKIA (2011)

Slovakia must increase its share of renewable energy in gross final consumption of energy to 14 % by 2020, compared to the 6.7 % in 2005.

Slovakia plans to have installed its first geothermal power plant of 4 MWe in 2012 but no more projects afterwards. The production from 2012 will be 28 GWh (availability = 7,000 h/y) and increasing to 29 GWh in 2019 and 30 GWh in 2020, with the same capacity of 4 MWe (availability improved to 7,250 h/y and to 7,500 h/y).

This forecast is rather peculiar because if the first plant is successful, many more projects will be developed. The potential for geothermal power in Slovakia is large, with low temperature power plants and EGS. Some projects have already been initiated: Geoterm, a joint venture of local players and the Ministry of the Economy expect a plant of 8-9MW, for a cost of EUR 30 million, to be installed in the eastern part of the country in the Košice basin (outside of Transenergy area).

There are no specific support measures for geothermal (some incentives mentioned in the plan are not detailed), or any indication about the deep geothermal regulations and the simplification of procedures.

Slovakia is ambitious for developing geothermal direct uses: increase by 300% the production from 3 ktoe in 2010 to 90 ktoe by 2020, with a growth from 2013 of +10 ktoe each year.

It is difficult to evaluate this growth rate because the support measures on geothermal heating and cooling are not described. Flanking measures should also be adopted: renovate and build new district heating, develop cascade uses, simplify procedures, promote the technology, etc.

Statistical data of current utilization in Slovakia are also largely controversial.

4.5 National Renewable Energy Action Plan - SLOVENIA (2011)

In 2005 the share of renewable energy sources (RES) in final overall energy consumption in Slovenia was 16.2 %, which must be increased to 25 % by 2020 (57.43 PJ). Estimated total contribution of geothermal energy (cca. 6%) to the binding targets for 2020 is shown in Table 14.

Table 14. Share of geothermal energy

Share of geothermal energy	2008	2010	2015	2020
in electricity production (GWh)	0	0	0	0
in heat production (PJ)	0.92	1.11	2.48	3.42

The NREAP provides substantial information about measures for developing geothermal energy in Slovenia, which has a big potential, mostly in NE-Slovenia in the Transenergy project area.

The guaranteed purchase price for geothermal electricity is 15.25 €cent/kWh. However, no geothermal power plants are installed and the plan does not forecast any production! Production of electricity from geothermal energy is planned between 2020 and 2030 and would provide only 0.65 PJ of energy by 2030 (Source: NEP - Draft proposal for a National Energy Programme by 2030). It means that other support measures are needed, such as increased awareness amongst decision-makers and the public, or establishing risk insurance. There are several support measures for geothermal heating and cooling; Slovenia aims at promoting systems of district heating using geothermal energy.

A range of measures to promote renewable energy sources is already being implemented as part of the adopted programme documents, especially under the Operational Programme for Developing Environmental and Transport Infrastructure 2007-2013 (OP DETI), the Operational Programme for Reducing Greenhouse Gas Emissions up to 2012 (OP RGGE), the Action Plan for Green Public Procurement (AP GPP) and National Renewable Energy Action Plan 2010 – 2020 (ANOVE).

A support scheme for generating heat from RES for heating is also proposed with an introduction of a system of feed-in incentives. It will be completed by a proposal for an obligatory share of RES in district heating systems and the establishment of a spatial planning of district heating and CHP geothermal plants.

A new version of the Mining Act should allow a clarification of the regulations about deep and shallow geothermal. The proposed new version of the Mining Act will regulate in detail the exploitation of geothermal energy sources, such that it may be pursued only in a closed system with a geocollector or by exploitation with reinjection. Slovenia indicates that between 2010 and 2020, 10 million Euros should be invested for building new geothermal district heating (GDH) systems. Yet Slovenia proposes just a small increase from 18 ktoe in 2010 to 20 ktoe in 2020.

According to EGEC this is not aligning with the support measures proposed. The capital costs for a geothermal district heating is ca. 1 Mio € /MWth. So 10 new MWth should be installed in Slovenia according to the NREAP. It represents 45 GWh (a GDH typically runs 4,500 h/y) so 4 ktoe. Moreover, there is already 18.45 ktoe (772 TJ/y) produced and the district heating in Benedikt will start operating soon (14.4 TJ/y so 0.34 ktoe). Therefore EGEC suggests updating this target.

In 2012 National governments are submitting their Progress Report to the European Commission. So far only 15 member states have accomplished this duty and only two-three of those reports are available in English (Luca Angelino, EGEC, personal communication).

4.6 References

http://ec.europa.eu/energy/renewables/transparency_platform/action_plan_en.htm.

http://egec.info/wp-content/uploads/2011/03/NREAP-Evaluation-August-2011.pdf.

5 Benchmarking / indicators of sustainability of thermal groundwater management

5.1 Aim of benchmarking

Association for protection of Lake Leman (L'association pour la sauvegarde du Léman - ASL) effectuated from 1980 numerous actions intended to achieving and maintaining good water status of Lac Léman river basin. These actions and theirs' results conducted the association to initiate a wide research in 2002. The aim of the research was to offer to the region a tool to evaluate and to support decision making that would allow them to manage the water resources in the respect of sustainable development principles. Lemano region is appertaining to two countries (France and Suisse), three regions and 600 communities (Lachavanne, J-B., Juge, R., 2009). What has Lac Léman in common with transboundary thermal aquifers?

"Transenergy" transboundary thermal aquifers are extending across the states' and other administrative borders. They are situated in rather different economic and social environments and also natural conditions. Although the same energy objectives and environmental goals are followed in those environments, the actual management efforts could be more or less successful and efficiency could be variable. It is thus very important to reveal the strong and weak points of the actual management and take the resolved steps to improvement.

Sustainability is reached when there is a favourable efficiency of resources exploitation and the real expenses are not postponed to the next generation. Where to focus the further efforts to reach short and long term sustainability?

Based on our study of transboundary thermal aquifers and during preparation of recommendation for transboundary thermal water management, we find certain important indicators that could be observed to reveal the actual sustainability of transboundary thermal water management. We tried to use the "Lemano" idea and method and define 10 crucial indicators that would enable us to do a kind of benchmarking, i.e. to follow and compare the sustainability of management:

1) Monitoring status.
2) Best available technology.
3) Energy efficiency.
4) Faktor uporabe polne zmogljivosti.
5) Balneological efficiency.
6) Reinjection rate.
7) Recharge of thermal aquifers.
8) Overexploitation.
9) Quality of discharged waste thermal water.
10) Public awareness.

Proposed indicators are described in following chapter.

5.2 Indicators

Monitoring status

The first and most important key indicator is mandatory, unified and integrated operational monitoring. This should be implemented by the user and should consist of continuous recording of groundwater level or wellhead pressure, water temperature, yield and chemical composition or conductivity (Axelsson and Gunnlaugsson 2000). The latter can be checked by annual chemical analysis, but only if variation of chemical composition is not monitored. Chemical sampling and interpretation of trends should follow the Groundwater Daughter Directive (European Union 2006). Where reinjection takes place, the required measurements should also be performed at the reinjection well. Monitoring results should be interpreted annually by users and also on a regional basis. This data should eventually be combined with results derived from the newly established national surveillance monitoring of deep geothermal aquifers. It is proposed that this should become an obligation for both users and the state since the data obtained in terms of actually used thermal water, changes in aquifers and regional evaluation of available thermal water quantities will be used to assist in the distribution of hydrogeologically acceptable thermal water concessions. In order to monitor changes occurring in aquifers, systematic build-up tests are recommended although different approaches can be taken. In the transboundary Lower Bayern - Upper Austrian Molasse basin (Büttner et al. 2002), wells are shut down every Tuesday at 4 pm for 15 minutes, wich is followed by recovered wellhead pressure or groundwater levels measurement. Weekly values are averaged to monthly values and graphical trends observed. The alternative possibility is to measure the difference in water level 15 minutes before and after the well is closed. Vižintin et al. (2008) proposed that build-up tests should be undertaken annually, with producing wells shut down for 6 hours. Whichever approach is agreed upon and used, its continuous execution and interpretation is essential.

Table 15. Monitoring status

Monitoring status	**Points**
Sporadic observations	0
Operational monitoring: Continuous measurements of discharge, piezometric level, temperature and regular water analysis (defined in the concession contract)	5
Yearly report of monitoring results submitted by concessionaire and approved by granting authority	3
Surveillance monitoring in non exploited observation well: Regular measurements of piezometric level	1
Surveillance monitoring in non exploited observation well: Temporarily sampling of groundwater for chemical / isotopic analysis for global changes identification	1

Where:
I_{MON} = monitoring indicator
P_i = points of abstraction well i)
N_{tot} = total number of all abstraction wells

Table 16. Monitoring indicator

I_{MON}	Results	
	Descriptive	Points [%]
> 8	Very good	100
6 - 8	Good	75
4 - 6	Medium	50
2 - 4	Bad	25
< 2	Very bad	0

Best available technology use

Encouragement of the use of best available technology (BAT) is proposed, as this will have a direct impact on decreasing the need for thermal water, increasing usage efficiency, mitigation of potential system failures, as well as diminishing environmental pollution. Appropriately managed geothermal wells should give answer on following questions:

Table 17. Best available technology use.

BAT use	Response	Points
Well-maintained wellheads which are isolated and protected from unfavourable weather conditions and unauthorised persons	Yes	0
	No	1
Materials installed in and above the well should be inert for aggressive water/gas mixtures and higher temperatures, while calcite scaling problems could be effectively mitigated by injecting inhibitors	Yes	0
	No	1
Installation should avoid areas of gas or water leaks and include the placement of a water release valve before the degassing unit at the wellhead.	Yes	0
	No	1
Abstracted water is precisely and continuously following the water demand. If pumping is required computer-managed frequency pumps are recommended.	Yes	0
	No	1
The exploitation system from well to emitted waste water area should be based on the principles of cascade use, with both computerised and individual phases controlled as much as possible. This can be achieved through the establishment of automatic and precise monitoring.	Yes	0
	No	1
Supporting technical, lithological, hydrogeological and chemical documentation should be well-kept and regularly updated.	Yes	0
	No	1
Specific yield of wells is not decreasing	Yes	0
	No	1
Indeks I	Sum	

$$\bar{} \qquad \frac{}{}$$

Where,
$\bar{I}_{BAT}$ = indicator of BAT use on the respective area
I_i = Indicator I for source i
Q_i = annual abstraction rate of source i (m^3/a)

Table 18. Indicator of BAT use.

$\bar{I}_{BAT}$ [points]	Result	
	Descriptive	Points [%]
0	Very good	100
1	Good	75
2	Medium	50
3	Bad	25
> 3	Very bad	0

Thermal efficiency

Though only rare users cool thermal water near to the mean annual air temperature (12 °C), this should be followed by others. Higher therma efficiency should lead to a reduction in the total amount of abstracted thermal water, as well as lower thermal and chemical pollution of the surface streams into which waste water is emitted. To indicate good thermal efficiency, a value of at least 70% usage of available energy should be reached, with most wells already achieving levels of around 65%. This would mean that if wellhead thermal water temperature is 60 °C, waste water should have a maximum temperature of 26.4 °C before being emitted to the environment, while if wellhead water temperature is 40 °C, emitted wastewater temperature should be below 20.4 °C.

Increment of thermal efficiency

Increase of the thermal efficiency facilitates development of additional new water abstractions and better conditions for existing abstraction installations.

Thermal efficiency has to be increased step by step from 30 % towards 70 % and even more.

Adequate rate of thermal efficiency increments have to be foreseen and set up on mutual agreement to promote the BAT as priority instead of abstraction increment.

Thermal efficiency (η_i) is the ratio between used and available annual heat energy:

$$\eta_i = E_{used\ i} : E_{available\,i} \qquad (4),$$

Used annual heat energy ($E_{used\ i}$) Eq. 2:

$$E_{used\,i} = V_{aa} \cdot 4.18 \frac{kJ}{kgK} (T_{wellhead} - T_{outlet}) \qquad (5),$$

V_{aa} - average annual quantity of abstracted thermal water,

($T_{wellhead} - T_{outlet}$) - temperature difference between abstraction (wellhead) and outlet (discharge).

Available annual heat energy ($E_{available\ i}$) Eq. 3:

$$E_{available\,i} = V_{aa} \cdot 4.18 \frac{kJ}{kgK} (T_{wellhead} - T_{location}) \qquad (6),$$

$(T_{wellhead} - \mathrm{T}_{\mathrm{location}})$ - temperature difference between abstraction (wellhead) and yearly average air temperature of the location, e.g. 12° C.

If the volumes of abstracted and waste water are the same ($\mathrm{V}_{\mathrm{aa}} = V_{ww}$) then the thermal efficiency is calculated by Eq. 4:

$$\eta_i = \frac{T_{wellhead} - T_{outlet}}{T_{wellhead} - T_{location}} \qquad (4),$$

where $T_{wellhead}$ and T_{outlet} correspond to the aforementioned parameters.

If the volume of abstracted thermal water is partly reinjected, then thermal efficiency is calculated by Eq. 5:

$$\eta = \frac{V_{aa}(T_{wellhead} - T_{outlet})}{V_{aa}(T_{wellhead} - T_{outlet}) + V_{ww}(T_{outlet} - T_{location})} \qquad (5),$$

If all abstracted water is re-injected then the thermal efficiency $\eta = 1$ is 100 %.

Where,
TE = indicator of thermal efficiency on the respective area
η_i = thermal efficiency for abstraction point i
Q_i = annual abstraction rate of source i (m^3/a)

Table 19. Indicator of thermal efficiency.

TE [%]	Result	
	Descriptive	Points [%]
> 70	Very good	100
60 - 70	Good	75
40 - 60	Medium	50
30 - 40	Bad	25
< 30	Very bad	0

Utilization efficiency indicator (capacity factor)

Where:
F_u = utilization efficiency indicator [%]
$Q_{a\,i}$ = average anual abstraction of source i [m^3/s]
$Q_{cap\,i}$ = installed capacity of source i [m^3/s] (water right quantity)

Table 20. Utilization efficiency indicator.

F_u [%]	Results	
	Descriptive	Points [%]
> 30	Very good	100
25 - 30	Good	75
20 - 25	Medium	50
15 - 20	Bad	25
< 15	Very bad	0

Balneological efficiency

The only indicator of balneological efficiency that can be derived based on reported water use data is the volume of available pure thermal water used in the filling of swimming pools. A value of 10 m3 per bather per day, which is the limit above which pool water does not need to be disinfected (Anonymous 2003, 2006), should not be exceeded by anyone who uses thermal water for balneological purposes.

Reinjection rate

Where a closed thermal water exploitation system is used, all water can be returned into the aquifer - although probably more than one reinjection well will be required. In open systems only non-treated thermal water can be returned into the aquifer and as a consequence, fewer reinjection wells will be needed. Secondly, reinjection wells represent a large investment cost, which is from a user's point of view not currently feasible as exploitation problems are not yet severe. Indeed, even though reinjection is already a legal requirement it currently takes place at rare sites. However, we believe that due to the positive effect on aquifer hydraulic conditions and environmental pollution mitigation, reinjection should be required for all users utilising non-treated thermal water. Limited period of time should be given to current users for reinjection well implementation, while new users should establish the necessary system before starting production. This of course should be based on numerical simulation of aquifer capacities and cost-benefit analyses, but poor economic conditions should not be used as an excuse to release.

= indicator of ratio between reinjected and abstracted annual volume of water for heat abstraction [%]
Q_{abs} = abstracted volume of water for heat abstraction [m^3/a]
Q_{reinj} = reinjected volume of water recharging the exploited thermal water for heat abstraction [m^3/a]

Table 21. Indicator of ratio between reinjected and abstracted annual volume of water for heat abstraction.

[%]	Result

	Descriptive	Points [%]
> 60	Very good	100
$40 < \quad \leq 60$	Good	75
$20 < \quad \leq 40$	Medium	50
$0 < \quad \leq 20$	Bad	25
	Very bad	0

Recharge of thermal aquifers – status of water balance assessment

The need for reinjection is partly conditioned by the natural recharge of thermal aquifers. Estimation of the latter is heavily dependent on the quality and availability of regional hydrogeological data. More accurate estimates should be obtained when a national surveillance monitoring programme is implemented by the Slovene Environmental Agency (ARSO), which should combine and interpret data from users' operational monitoring as well as from its own deep monitoring wells. These can take the form of newly drilled geothermal monitoring wells at optimum locations, although a scenario involving a combination of existing and redrilled abandoned oil and gas boreholes is much more feasible.

Annual data should be analysed every 3-5 years, since in this period the quantity and quality of aquifer trends should probably become more evident (Goldbrunner et al. 2007). Until a regional numerical model of the basin is established, this monitoring scheme and analysis should represent a sufficient tool for the supervision and adjustment of granted concessions if necessary.

As soon as sufficient regional monitoring data for the basin is available, a nationally managed regional numerical model of flow and heat transfer should be established for geothermal aquifers in the Mura-Zala basin. Results obtained from the performed simulations should enable the accurate estimation of available thermal water reserves in individual aquifers, which will furthermore represent an expert basis for the redistribution of water concessions. As such, the model should be integrated and continuously re-evaluated in order to manage geothermal aquifers in a sustainable way. National guidelines for geothermal wells should also be prepared, in which uniform instructions for the construction, operation and closing of a geothermal well will be discussed, as outlined by Büttner et al. (2002).

Table 22. Status of water balance assessment.

Status of water balance assessment	**Points**
Not assessed	0
Critical level point is defined (not based upon measurements on the location but from other available data / locations)	0,25
Critical level point is defined (based upon average yearly minimum level value from previous years on the location)	0,5
Critical level point is defined, Renewable and available volume of water is assessed + Critical point of abstraction is defined - Study made on the base of old / regional data and knolewdge	0,75
Renewable and available volume of water is assessed + Critical point of abstraction is defined and critical level point is defined - Study made and updated on the base of actual measurement	1

Where,

I_{wba} = indicator of water balance assessment status
points = number of points regarding the status water balance assessment
E_{tot} = total number of points on the basin level (all users)

Table 23. Indicator of water balance assessment status

I_{wba} [%]	Results	
	Descriptive	Points [%]
> 95	Very good	100
75 - 95	Good	75
50 - 75	Medium	50
25 - 50	Bad	25
< 25	Very bad	0

Overexploitation

Table 24. Indicators of overexploitation.

Overexploitation	Response	Points
Significant decreasing of piezometric level showing that new equilibrium could not be reached	Yes	1
	No	0
Decreasing suitability of water quality or temperature caused by the abstraction	Yes	1
	No	0
Decreasing of groundwater availability	Yes	1
	No	0
Impact on dependent ecosystems is significant	Yes	1
	No	0
Soil subsidence caused by the abstraction	Yes	1
	No	0
Indeks I	Sum	

Where,
$\bar{I}_{OE}$ = indicator of overexploitation on the respective area
I_i = Indicator I for source i
Q_i = annual abstraction rate of source i (m^3/a)

Table 25. Indicator of overexploitation.

$\bar{I}_{OE}$ [points]	Result	
	Descriptive	Points [%]
0	Very good	100
1	Good	75
2	Medium	50
3	Bad	25
> 3	Very bad	0

Quality of discharged waste thermal water

Number of samples (%) which provide normatives for discharged water.

Where,
I_{Qual_disc} = Indicator - share of positive samples [%]
$Smp_{positive}$ = number of positive samples per year
Smp_{tot} = total number of samples per year

Where,
= Indicator of suitability of discharged water [%]
Q_i = annual discharge of waste water of source i (m^3/a)

Table 26. Indicator of suitability of discharged water.

I_{Qual_disc} [%]	Result	
	Descriptive	Points [%]
> 95	Very good	100
90 - 95	Good	75
80 - 90	Medium	50
70 - 80	Bad	25
< 70	Very bad	0

Public awareness - accessibility of reliable information

Table 27. Accessibility of reliable information

Information about	Points
Monitoring	1
BAT use	1
Quantity status (overexploitation)	3
Quality status of waste water	3
Energy efficiency	2

Where:
I_{inf} = information indicator
P_i = number of points of abstraction site i
N_{tot} = total number of abstraction sites

Table 28. Information indicator

I_{inf}	Results	
	Descriptive	Points [%]
> 8	Very good	100
6 - 8	Good	75
4 - 6	Medium	50
2 - 4	Bad	25
< 2	Very bad	0

5.3 Conclusion

Benchmarking is comparison analysis between different management entities. According the results of activities in previous T-JAM project and actually in Transenergy project we developed ten indicators to compare the actual stage of the thermal groundwater management sustainability. Data for evaluation of these indicators should be available through the obligations set up in concession acts, reporting obligations from Water Framework Directive & Directive On The Promotion Of The Use Of Energy From Renewable Sources and also following the EGEC recommendations for geothermal resources management.

All data are not free accessible, especially for individual wells and users. Nevertheless, benchmarking is performed on the level of legal entity that should have available data from the monitoring and reporting obligations. Each individual user can than compare his own data on the level of legal entity and take his own decisions to improvements and contribution to the legal entity success.
Presentation of results is also made on the level of certain legal entity. Very simple presentation of results could be used or also some more illustrative.

Presentation of results

Table 29. Presentation of results

		Very bad	Bad	Medium	Good	Very good
1	Monitoring status	🟨	🟨	🟨		
2	Best available technology	🟩	🟩	🟩	🟩	
3	Energy efficiency	🟥				
4	Faktor uporabe polne zmogljivosti	🟧	🟧			
5	Balneological efficiency	🟦	🟦	🟦	🟦	🟦
6	Reinjection rate	🟨	🟨	🟨		
7	Recharge of thermal aquifers	🟩	🟩	🟩	🟩	
8	Overexploitation	🟩	🟩	🟩	🟩	
9	Quality of discharged waste thermal water	🟦	🟦	🟦	🟦	🟦
10	Public awareness	🟧	🟧			

5.4 References

Anonymous, 2007: Decree on the concession for underground water use from wells P-1/73, P-2/88 and P-3/05 intended for activities in bathing areas and health resorts. Official Gazette of the Republic of Slovenia 119 (in Slovene). http://www.uradni-list.si/1/content?id=83991

Anonymous, 2008: Decree on the concession for underground water use from well of JAN-1/04 intended for activities in bathing areas and health resorts. Official Gazette of the Republic of Slovenia 104 (in Slovene). http://www.uradni-list.si/1/objava.jsp?urlid=2008104&stevilka=4424

Anonymous, 2009: Decree on mining rights for commercial exploitation of mineral resources in exploitation areas Lendava in the Municipality of Lendava, Premagovce in the Municipality of Krško, Rače 2 in the Municipality of Rače – Fram, Doline - enlargement in the Municipality of Sežana, Hren – enlargement in the Municipality of Vitanje, Skrbinjek in the Municipality of Poljčane, Šumet in the Municipality Solčava and Zadobova – enlargement in the Municipality of Celje. Official Gazette of the Republic of Slovenia 102 (in Slovene). http://www.uradni-list.si/1/content?id=83071

Axelsson, G., Gunnlaugsson, E., 2000: Course on long-term monitoring of high- and low-enthalpy fields under exploitation. World Geothermal Congress Short Courses 2000, IGA, Kokonoe-Kyushu.

Büttner, W., Kneidinger, C., Roth, K. et al., 2002: Grundsatzpapiere zur Thermalwassernutzung im niederbayerisch – oberösterreichischen Molassebecken. Ständigen Gewässerkommission nach dem Regensburger Vertrag (in German)

De Stefano, L., 2010: International initiatives for water policy assessment: a review. Water Resource Management 24: 2449-2466

Goldbrunner, J., Shirbaz, A., Heiss, H.P., 2007: Wasserwirtschaftliche Bewertung der Thermalwassernutzungen in Oberösterreich. Berichtszeitraum 2000-2005, Wasserwirtschaft (in German).

Kralj, P, Kralj, Po., 2000: Overexploitation of geothermal wells in Murska Sobota, northeastern Slovenia. In: Proceedings of the World Geothermal Congress 2000, IGA, Kjushu –Tohoku, pp. 837-842

Kralj, Po., Rychagov, S., Kralj, P., 2009: Changes in geothermal reservoir induced by exploitation: case studies from North-East Slovenia and South Kamchatka. In: Proceedings of the Applied Environmental Geochemistry – Anthropogenic impact on the human environment in the SE Europe, Geological survey of Slovenia, Ljubljana, pp. 71-76

Lachavanne, J-B., Juge, R., 2009: LEMANO, pour une gestion durable de l'eau. Lemaniques, revue de L'association pour la sauvegarde du Léman. Numéro 72, Juin 2009.

Pezdič, J., 2003: Origin and migration of gases in the Pannonian sedimentary basin. In: Proceedings of the ICGG7, Freiberg, pp. 47-49

Prestor, J., Urbanc, J., 2005: Nacionalna baza hidrogeoloških podatkov za opredelitev teles podzemne vode Republike Slovenije. Report, Geological survey of Slovenia (in Slovene)

Struckmeier, W.F. Margat, J., 1995: Hydrogeological maps - A guide and a standard legend. IAH International Contribution to Hydrogeology 17.

Vižintin, G., Vukelič, Ž., Vulić, M., 2008: Monitoring the geothermal potential of deep tertiary aquifers in North-East Slovenia using old abandoned oil and gas wells. In: Proceedings of the 2nd International Symposium Mining Energetic 08, Tara, pp. 39-52.

6 Conclusions

The sustainable management of hydrogeothermal resources is two-folded: one one hand it has to follow the priciples of groundwater management with a clear environmental protection focus, on the other hand those of geothermal resource assessment which final goal is rather oriented towards exploitation and utilization of the geothermal energy (and henceforward its carrying medium). Therefore thesese two fields have sometimes competing nature, however supplement each other on many areas. The transboundary character of hydrogeothermal reservoirs is another factor that requires harmonized management strategies in both aspects.
Transboundary geothermal groundwater management is part of integrated water resources management. It should follow the principles given by Water convention, EU Water Framework Directive, Danube river basin management plan (ICPDR) and the recommendations of UNECE transboundary groundwater assessment tool as well as should incorporate even the IWRM principles. In addition to the environmental goals, it also has to follow the aims of sustainable utilization of renewable energy resources. Awareness of all these principles and goals would significantly reduce the data exchange and reporting procedures efforts.

The level of transboundary groundwater management and the mandate of the organizations responsible for its performance dominantly depend on the significance of the transboundary groundwater flow. To a reliable assessment of this significance, mainly four phases of management plan preparations should be followed by neighbouring countries (Chapter 1.3).

The most important issue in establishing transboundary management is to reveal the stage of development of the thermal groundwater resources and what are the needed management interventions. Conceptual models are strongly recommendable tool to exchange the information and refinements of the assessment.

Geological and hydrogeological knowledge of the system is the indispensable and mutual coordinated expert activities significantly facilitate management planning processes.

In work package WP 6 we will prepare the recommendations for transboundary managements of selected pilot areas within the Transenergy project area using the results from WP 5 (modelling results) and the methodology from this report. **We will follow template ‘’Draft initial characterisation (including risk information) of the transboundary GW-bodies of ICPDR basin-wide importance’’ for characterisation of transboundary geothermal aquifers. This approach is also in accordance with the article 3 of WFD.**

While in transboundary groundwater management, the above mentioned international frameworks provide a good basis for harmonized work, in the field of geothermal energy utilization not such clear standards are set up. The National Renewable Energy Action Plans provide a framework for the national target numbers, but their execution (performance of actual projects through investment) is mostly done by the private sector, therefore the management role of the state is fairly limited (e.g. providing legal framework like concessional system, or financial incentives such as feed-in tariff, risk insurances, etc). The companies perfoming the different geothermal projects generally follow well-accepted protocols, mosty adapted from the hydrocarbon industry, but rarely link their activity to a wider national framework, not even mentionning cross-border concepts. This may only become an issues, when investment conditions are more adventageous in the neighbouring country (e.g easier licensing procedure, more favourable financial incentives) resulting the exploitation of the transboundary geothermal reservoir “on the other side”. Heat in Place (HIP) will be calculated for the whole Transenergy project area, Limited Technical Potential” (LTP) assessment will be done for the pilot areas.

In the chapter 5 we introduce the concept of benchmarking to follow and compare the sustainability of management in transboundary aquifers. Benchmarking indicators of management sustainability is absolutely necessary tool to control the effectiveness of transboundary management and to foresee the needed and on-time management interventions. **In the frame of Transenergy project we will represent benchmarking on the case of Mura – Zala basin between SI and HU on the level of bilateral Mura Commission, which could be then the demonstration case.**

The links between the energetic utilization aspects (e.g. in the frame of a concession) and the protection of the environment have already raised a lot of concerns (e.g. competing water uses, competing sectors like hydrocarbon and CCS, interactions resulting from different utilization aspects affecting the same reservoir, problems of re-injection, outline of protection zones from where thermal groundwater/geothermal energy can be exploited, firmly based assessment and monitoring of quality and quantity status of geothermal aquifers, etc.). There are no general and universal answers and solutions for these questions, and have to be addressed at site specific level. Therefore these concrete recommendations for the selected pilot areas will be given at the end of the project.

ANNEX I

Good practice example for thermal water management

They did it, they are doing it, could we do it too?

1 Lake Hévíz (HU)

Hydrogeological setting

Lake Hévíz with its 4.4 ha area is Europe's largest thermal karstwater lake in the western foreland of the Keszthely Mountains, which has been used for balneological purposes since the 18th century (Fig. 1 & 2). The lake is fed by cold and warm karstic springs, water temperature in the summer is 33-35 °C, in winter 24-26 °C. In 1972 divers discovered the springs feeding the lake at a depth of 38.5 meter below the water surface, which discharged with a yield of 30-40,000 l/min. However this sub-aqueous conduit is just the entrance of a larger cave hall of 14-17 m width. At the eastern wall of this hall „cold" water of 26.3 °C, while at the western wall "warm" water of 41 °C discharge and mix with each other feeding the lake with water of cca. 38 °C (Fig. 3).

Figure 1. Lake Hévíz

Figure 2. Lake Hévíz

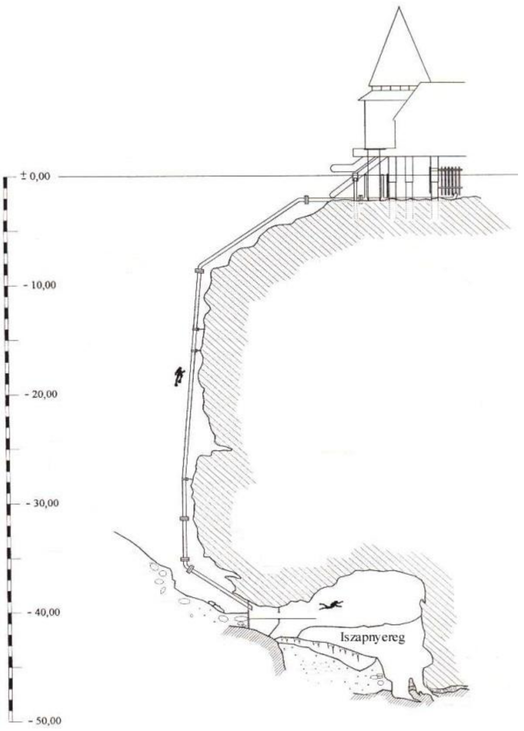


Figure 3. Vertical cross section of Lake Hévíz showing the sub-aqueous cave where springs feeding the lake discharge

^{14}C isotope measurements revealed that the age (i.e. subsurface travel time since its infiltration) of the “cold” water is 5-7,000 years, while that of the warm component is 10-12,000 years, but it has to be mentioned, that these ages are not fully exact, because of the intensive mixing of the waters outside the spring also.

Regarding the hydrogeological setting, Lake Hévíz is found at the border of the thermal karstic groundwater body kt_4.1. (Western-Transdanubian, or in Hungarian Nyugat Dunántúl) and cold karstic groundwater body k.4.1. (Transdanubian Central Range) (Fig. 7). The Nyugat-dunántúl thermal karstic groundwater body represents the SW-ern continuation of the Transdanubian Central Range unit in the deep subsurface. The surface of the karstic Mesozoic rocks outcropping in the Keszthely Mountains is downfaulted to the basement, where they can be as deep as 3,500 m below the surface. The main karstic aquifers of the thermal groundwater body are the Upper Triassic and Upper Cretaceous carbonates, which get their recharge from the cold karts of the Transdanubian Central Range (cold karstic groundwater body k.4.1.), via mixed gravity- and geothermal (density)-driven flow systems.

The infiltrating meteoric water flows towards the marginal discharge areas of the Keszthely Mountains in a shallow depth. The karst water flowing in bigger depths towards the SW and W reaches a tectonic zone in the Nagylengyel area, and rises in one or some long vertical tectonic zones with good permeability (so called “heat chimney”), then it is forced back towards the E and SE, and after a long flow path it discharges into the Lake Hévíz (Fig. 4).

The linked flow system of the fractured, karstified rocks and the covering clastic strata is represented by the W-ern and N-ern surroundings of the Lake Hévíz, where karstified and fractured Triassic rocks are directly overlained by Pannonian aquifers. Mixing of the waters with different chemical characters contributes to the special chemical composition of thermal groundwater in Lake Hévíz and nearby. This mixing also causes karstic corrosion which resulted in the enhanced permeability of rocks in the W-ern, NW-ern surroundings of Lake

Hévíz, which fosters further enhanced mixing of different groundwaters with different temperature and chemical characters.

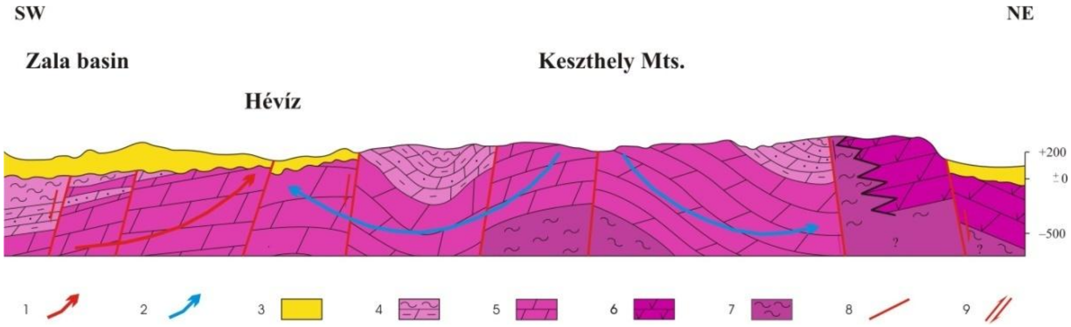


Figure 4. Groundwater flow system in the surroundings of Hévíz

The annual heat discharge of the spring-lake can be estimated, from water discharge and the outflowing temperature (T_2 = 37.95 ºC) The mean annual surface temperature is T_1 = 10.5 ºC, so ΔT = 27.45 ºC. The discharge of the lake is 400 l/s, so the total heat discharge is 46 MW. Considering that groundwater circulating on the covered basement collected heat from 60 mW/m^2 heat flux, one can estimate a 770 km^2 of heat-collecting area in the Zala basin.

The discharge rate of the springs feeding Lake Hévíz before the 1960-ies was over 500 l/s, but the huge karst water abstraction at the nearby bauxite mine at Nyírád decreased this value to approximately 300 l/s (1970-1990). After the mining activities finished some regeneration has occurred and the discharge has stabilized at 390-420 l/s.

Water management recommendations

In Hungarian legislation *Governmental Decree 219/2004 (VII.21.) on the protection of groundwaters* introduces the term „abstraction limit value” (“Mi”, in thousands m^3/year). According to article 9, in order to achieve the good quality status, water abstraction cannot exceed the abstraction limit value (“Mi”). According to the *Governmental Decree 221/2004 (VII.21.) on certain rules of river basin management*, the abstraction limit value (“Mi”) should be determined for the different parts of the groundwater body ensuring that abstractions do not endanger to achieve the environmental objectives, do not cause permanent drop in the groundwater table / hydraulic head and do not result the mixture of other surface or subsurface waters causing unfavorable changes in quality. However “Mi” values have not been determined during river basin management plans. Lake Hévíz study stands for a good example, where based on local studies requirements were provided for the quantitative protection of thermal groundwaters.

A research program was performed between 2005-2009 to provide recommendations for the regional water management problems in the South-Bakony–Zala Basin region, focusing on Lake Hévíz. The program was financed by a consortium of the thermal water users of the region. The aim of the program was the review of existing utilizations and to study the possibility of new utilizations without any effect on the yield of the spring of Lake Hévíz, or unfavorably effects in existing utilizations. The study was based on a regional hydrogeological model incorporating all geological hydrogeological and hydrodynamical evaluation of reliable data of the targeted region.

The developed hydrogeological model made it possible to quantify the available amount of groundwater (water budget) and heat, its hydrogeochemical character, helped in the refinement of the boundaries of groundwater bodies; contributed to the determination of the protected zones, thus served as a basis for groundwater management decisions and recommendations, such as the share of available groundwater resources, limitation for further use, etc. Furthermore a detailed survey contributed to the identification of the sources of contaminations.

Based on the results of the research program, a proposal was elaborated by the Geological Institute of Hungary (MÁFI) - who was a key partner in the research program -, by the West –Transdanubian Inspectorate for Environment, Nature and Water and by the West – Transdanubian Directorate for Environmental Protection and Water Management.

According to status assessment performed in the River Basin Management Plan, the kt.4.1. thermal groundwater body is in good quantity status, with an available water resource of 5,354 m^3/day, while the connected cold karstic groundwater body k.4.1. is in poor quantity status, where the rate of water deficit is -14,536 m^3/day. The two groundwater bodies are in strong hydrodynamic connection, the k.4.1. cold karstic groundwater body supplies about 46,000 m^3/day to the kt.4.1. thermal groundwater body. Based on this water budget, it was concluded that an expansion of further utilization (increased abstraction of thermal water) is possible on the area of the thermal groundwater body kt.4.1. (Nyugat-Dunántúl). However the maintenance of the water-level and yield of springs of Lake Hévíz require an aerial differentiation within the thermal karstic groundwater body which has an overall 5 354 m^3/day available water resource. The recommendation for this areal differentiation outlined 3 zones with different abstraction limitations such as the following:

Inner zone: this is the direct recharge zone of the lake, where the Triassic karstic, and the overlying Sarmathian and Pannonian clastic reservoirs forming a connected hydraulic system have good conductivity. This is the zone of intensive mixing of warm, lukewarm and cold waters, which feed the “cold” and “warm” springs of the lake at its bottom (see above). .

The border of this zone can be outlined by the kartswater-level isoline of 114,5 m Bf, which has to be determined from the groundwater table of thermal-water observation wells from 2008 year data. Fig. 5 shows the variation of this isoline in years 1991, 1999, 2005 and 2008.

Within this zone neither further water abstractions can be allowed, nor the present allowed amount can be increased. This means that the abstraction limit value (“Mi”) for this zone is equal with the amount of water permitted in the water licenses, which is 2,853 m^3/day (33 l/s).

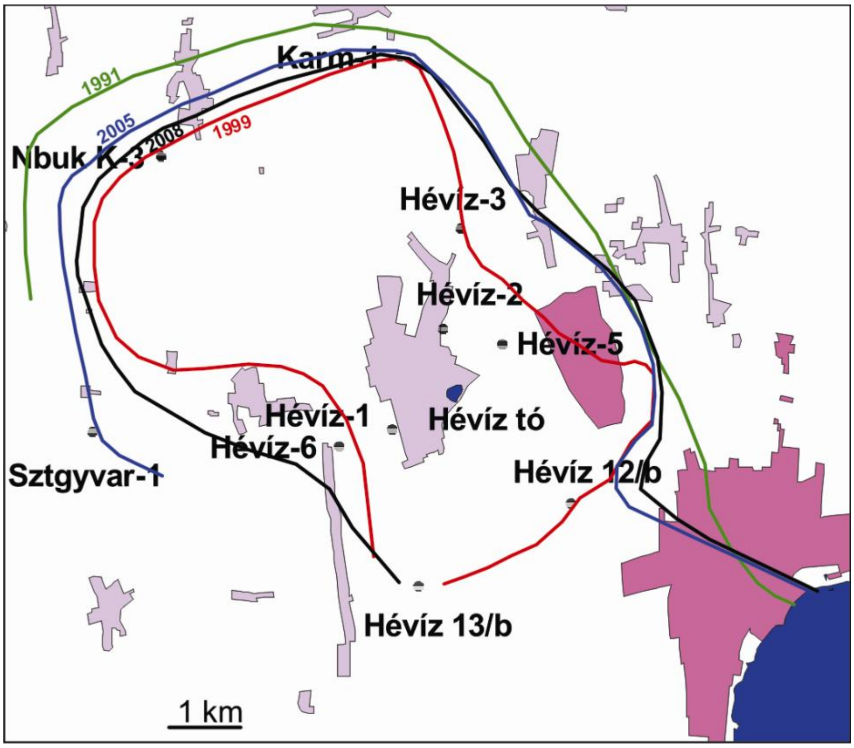


Figure 5. Variation of isolines of karstic groundwater level 114,5 m Bf around Lake Hévíz in years 1991, 1999, 2005 and 2008.

Within the inner zone, transfer of permitted amount of exploitable water among the users is not allowed. The ratio of present water abstraction should not be changed either to avoid alterations in the flow paths. If such changes are required, they should be only minor and based on local studies.

In case the yield of springs of Lake Hévíz decrease below 390 1/s (33,696 m^3/day) in two following years, than the total amount of permitted exploitable (abstractable) water should be decreased by 10%, till the lake springs re-establish their discharge of 390 1/s

From the groundwater-level observation wells within this zone (where water level is proportional to the discharge of the Lake springs) data of Hévíz-6 well are recommended to be available through the internet for the stakeholders.

Water users in the inner zone are obliged to equip their wells with devices measuring water level and yield by remote sensors and supply these data.

These actions are necessary, because water users nearby the lake (balneological and medicinal) require stable water composition and temperature. Any further changes in water abstraction may modify the flow paths, chemical composition and temperature of this sensitive system. Discharge of the lake springs and karstwater level in the observation wells of this inner zone show only minor fluctuations showing the natural variations in recharge. In accordance with the model results, it shows that the lake discharge may increase (assuming unchanged present abstraction values) only in case of increase in natural recharge. In case natural recharge further diminishes (i.e. gradually decreasing annual precipitation) temporary reductions in current utilization may be necessary to avoid drops in lake discharge.

Zone A: The outline of this zone was determined in the above cited research program and is shown on Fig. 6.

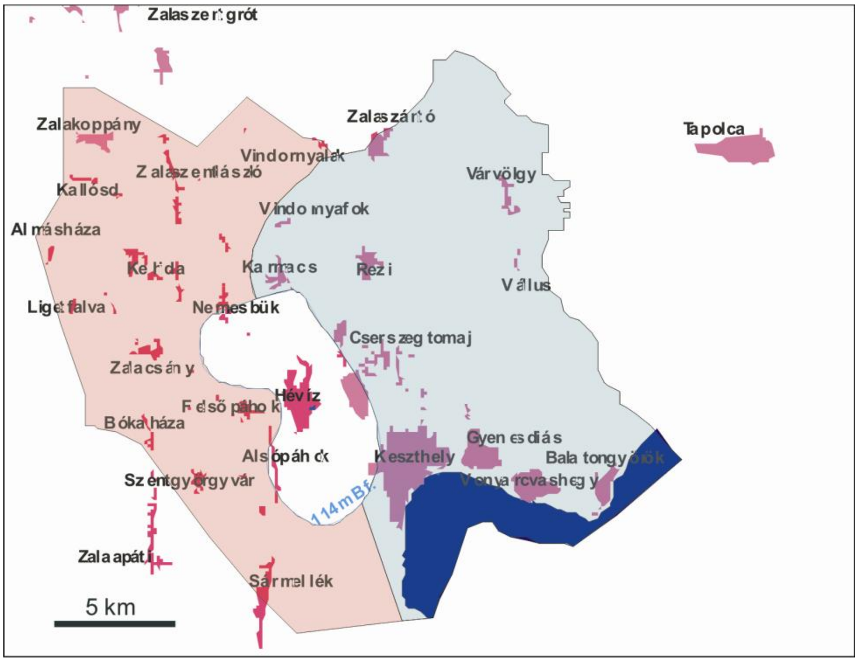


Figure 6. Outline of zone A

Within this zone the aim is to license such new developments, which require relatively little amount of thermal groundwater, but do not have direct effect on the lake's water budget, thus the load of the inner zone can be diminished.

Within the zone the maximum permitted amount of new water abstraction is 50 m^3/day, in case of already existing balneological (medicinal) objects 100 m^3/day, both based on individual impact assessment, proving that the abstraction has no effect on the quality, temperature and quantity of groundwaters of the inner zone. For this zone the total abstraction limit value ("Mi") is the amount of water permitted in the water licenses plus 200 m^3/day.

As this zone encompasses the supply are of the warm water component of the lake, individual impact assessments should include heat transport models, too.

Water users in the zone A are obliged to equip their wells with devices measuring water level and yield by remote sensors and supply these data.

Zone B: Its area is equal with the thermal karstic groundwater body kt. 4.1. (Fig. 7).

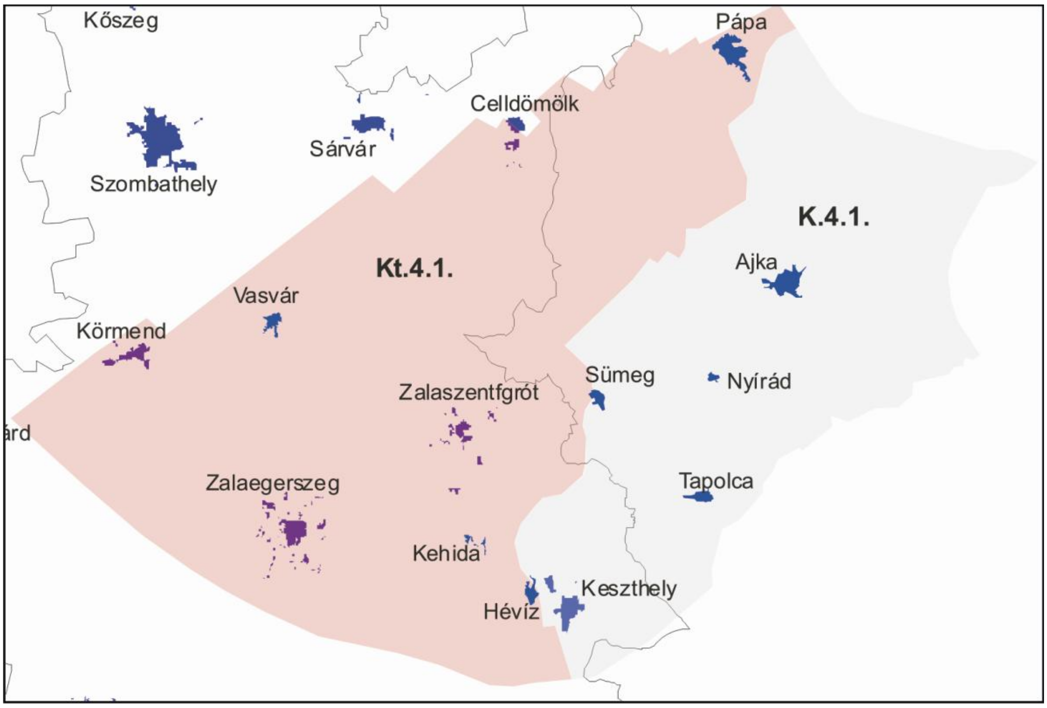


Figure 7. Outline of zone B

In zone B new developments with minor to medium water demand can be licensed.

Water abstraction up to max. 200 m^3/day can be licensed without impact assessment, if the nearest groundwater abstraction is beyond 3 km. Water abstraction exceeding 200 m^3/day, and cases where water abstraction together with other exploitation within 5 km exceed 200 m^3/day can be licensed only on the basis of individual impact assessment. Furthermore, individual impact assessment is required for water abstraction above 100 m^3/day in the 2 km border zone of ”zone A”. Individual impact assessments have to prove that the abstraction has no effect on the quality, temperature and quantity of groundwaters of the inner zone and zone A. In zone B the abstraction limit value (“Mi”) is 3,600 m^3/day.

As this area is further away from Lake Hévíz, water abstraction in this zone has little effect on the lake. Although for the thermal karstic groundwater body kt.4.1. has an overall 5,354 m^3/day available water resource was determined in the river basin management plan, the recommended 3,600 m^3/day reflects a cautious approach.

In zone B water abstraction up to 50 m^3/day can be licensed without impact assessment.

Groundwater level monitoring in the surroundings of Lake Hévíz

Sustainable groundwater management can be done only with strict controls. The most effective tool for this is groundwater monitoring. The water level monitoring system developed in the frame of the Lake Hévíz program included the establishment of a monitoring system equipped with GSM tools, which can measure the water temperature, too. The water levels in some monitoring objects are correlated with the discharge of the lake, serving as a transparent instrument of the actual state of the quantity status. The daily transmission of the measured data by GSM, there monthly evaluation and displaying them on the internet are part of the management “good practice”. There is a plan to spread on-line the measured data to the public in the local pubs, as an “agora” of the community of the inhabitants and the tourists as well.

2 *Malm-aquifer in the border region of Bavaria-Upper Austria (D-AUT)*

Introduction

The existence of a significant thermal water resource in the late Jurassic carbonates (so called "Malm-aquifer"), located at the area between Regensburg und Linz, led to an intensive use on both sides of the border. In 1996 the cumulated net extraction of thermal water was about 70 l/s, which equated to a degree of exploitation degree of about 25 % of all available hydrothermal resources (Goldbrunner et al., 2007, p.6/78). In this context measurements in the central part of the reservoir (around the area of Bad Fuessing) already showed some pressure decrease in the range of 30 meters with a downward trend.

Because of the fact, that hydrogeothermal utilization, especially for balneological purposes, exhibits an enormous economic factor at this trans-boundary region, the implementation of a bilateral groundwater management concept showed to be inevitable.

On December 1st, 1987 in Regensburg, Bavaria an international contract between Germany, Austria and the European Community was signed which regulates the cooperation of the German and Austrian water management authorities in the intake area of the river Danube. This treaty concerns also the thermal aquifer in the Bavarian-Upper Austrian border region. The water commission installed by the Regensburg treaty initialized the numeric modeling activities in order to improve the water management in this special region.

Development of 2D and 3D reservoir models

In the years 1984 to 1989 a research and development plan named "Hydrogeothermische Energiebilanz und Grundwasserhaushalt des Malmkarstes im süddeutschen Molassebecken" was formed, funded by the German Federal Ministry for Economy and Technology[7] (EXPERTENGRUPPE „THERMALWASSSER", 2002). Investigations carried out in the context of this plan showed a cumulated thermal water flow rate of 1.5 m³/s for the so called Malm aquifer system in southern Germany. This moderate flow rate in combination with already recorded pressure decrease at existing thermal wells caused the permanent water commission (according to the bilateral "Regensburger Vertrag" between Austria and Germany) to propose further detailed research. In April 1992 a bilateral ad hoc Expert group "Tiefenwasser" was founded and instructed to develop a hydrological model for the Molasse basin, which was built up by the geotechnical bureau Prof. Dr. Schuler/Dr. Ingo Gödecke in Augsburg (under technical and organizational supervision by the "ad hoc expert group"). The aim of this model was to serve as basis for further water resource assessment. This first hydrogeological model was based on the acquisition and analysis of already existing data (geological, tectonic, hydrogeological, hydrochemical, isotope-hydrological, geothermal and hydrological) and was used to outline the boarder of the Thermal water balancing area of the Lower-Bavarian-Upper Austrian Molasse basin.

The achieved results of the first flow model served as basis for a numerical 2D- hydrological thermal water flow model, developed between 1995-1998 (DETAILMODELL)

---

[7] Former known as: Ministry of Research and Technology – "Bundesministerium für Forschung und Technologie (BMFT).

(EXPERTENGRUPPE „THERMALWASSSER“, 2002, p.9/30), which finally allowed to balance the flow rate and picture the flow rate ratio for the Malm aquifer.

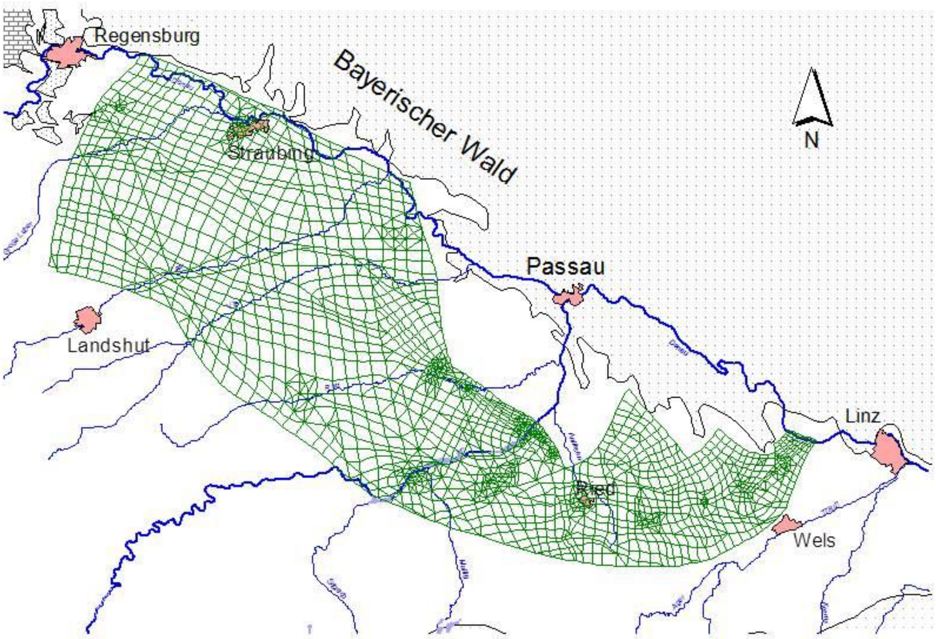


Figure 8. Numerical 2D- groundwater flow model (DETAILMODELL 1998) (Bundesministeriums für Land- und Forstwirtschaft des Landes Oberösterreich und des Bayer. Landesamtes für Wasserwirtschaft, 1999)

As a consequence of the project each future usage of the reservoir for energetic purposes required a system of dublets (extraction and reinjection of thermal water). After the installation of the first dublets systems, the pressure conditions in the central region of the reservoir could already be improved. Measured values of the net extraction in 2002 were around 40 l/s, which is a decrease of around 30 l/s compared to the measurements in 1996 (Goldbrunner et al., 2007, p. 9/78).

Because of the extent of the research area and due to the strongly varying data density the model could not provide a sufficient accuracy of the effects on future extractions for the whole reservoir. Furthermore the increase in geothermal utilizations of the thermal waters raised thermal- hydraulic issues. In order to expand the knowledge concerning the handling and implementation of geothermal usages and for further development of the aquifer model a workshop especially for sustainable utilization of the reservoir was held in Munich 2002, named: “*Grundsatzfragen zur nachhaltigen Nutzung der Geothermie im Malmkarst des niederbayrisch-oberösterreichischen Molassebeckens unter wasserwirtschaftlichen Gesichtspunkten*”.

The following crucial scientific questions have been elaborated during this workshop:

- Investigation of the effects of temperature decrease due to re-injection on the reservoir conditions (pressure, hydraulic conductivity and storage coefficient, water quality and gas content)
- Regional scale assessment of temperature decrease in the reservoir due enhanced re-injection of used thermal waters (spatial and temporal mapping of temperature fronts).
- Sensitivity studies on the impact of variable reinjection temperatures on the temperature regime of the reservoir

- Sensitivity study on the impact of different geothermal operational methods (e.g. single well use, dublet use) at different sites within the project area

Because of the increased demand of geothermal utilization in the Malm aquifer it became necessary to develop basic principles and procedures to protect thermal water resources and to maintain, as far as possible, the natural hydrological and geothermal conditions in terms of a sustainable joint water management.

The complexity of the questions which arose at the international Workshop in Munich 2002 called for further analysis based on a numerical, 3-dimensional, coupled thermal-hydraulic model. Thus in 2005 the Bavarian State Office for Environmental Protection (LfU) in association with the Austrian Federal Ministry of Agriculture and Forestry, Environment and Water and the responsible authority in Upper Austria launched the project: "*Grundsatzuntersuchungen zu thermischen Auswirkungen von Thermalwassernutzungen im zentralen, grenznahen Bereich des niederbayrisch-oberösterreichischen Molassebeckens*" (acronym: **TAT** - Thermische Auswirkungen von Thermalwassernutzungen - Thermal consequences of thermal water utilizations).

As part of this project a scientific study group ("ARGE TAT") was established, consisting of the expert-companies "Geoteam GmbH" (AUT), "Hydroconsult GmbH" (GER) and Geowatt AG (SUI) with an external advising board called "Thermalwasser" for the technical and professional supervision (achieved within the scope of the study Interreg IIIA, co-financed by the European Union).

The final report about the results and the 3-D model developed during the project was given at 2007 (Goldbrunner et al., 2007). The main aim of the project was a better understanding of the basic thermal-hydraulic relations and to provide references for the development of further management strategies, plus an estimation of the heat supply and the degree of regeneration for the extracted heat quantity of the reservoir.

The underlying hydrogeological model (DETAILMODELL 1998), has been updated with latest scientific findings and perceptions of the area. Thus it was possible to map the surface structure, spatial position and outline of the following three distinctive stratigraphic layers:

- Top crystalline basement
- Top Malm
- Top Eocene

(EXPERTENGRUPPE „THERMALWASSSER“, 2008, p.10/30)

The elaborated structural maps and additional geological and hydrochemical data give information about the thickness of the most important hydrostratigraphic units above the crystalline basement, which represent the layers of the 3D-model and are listed below:

- Crystalline basement: Assuming no flow rate at greater depths than 5,000 below sea-level. This elevation level serves as base of the model.
- Jurassic Malm: The layer is divided by rock characteristics and therefore by hydraulic characteristics in two main types of facies:
    1. Deeper Malm (less karstic, marl-rich, layered limestones, thickness of at least 50 m, low permeability)

2. Upper Malm (carstified sequence of limestones in reef- or mass-facies, thickness of about 200 m, very permeable) ➔ **main thermal aquifer**

- Cretaceous Cenoman: Thickness is estimated between 20-30 m, permeable and hydraulically coupled to the Upper Malm Aquifer).
- Upper Cretaceous/Eocene: The boundary between Upper Cretaceous and Tertiary is not visible in seismic measurements. The silty-clayey deposits of the Eocene layers are only slightly permeable. But because they are not very thick (50 m) they are combined in the hydrological model with the a few hundred meters thick layers of the Upper-Cretaceous. The Santon/Campan sands of the Upper Cretaceous are not mentioned as hydrostratigraphical units but the hydrological model respects them as a distinct layer with better hydraulic conductivity.
- Tertiary: Up till 30 m below surface, slightly permeable
- Quaternary: Upper limit of model surface.

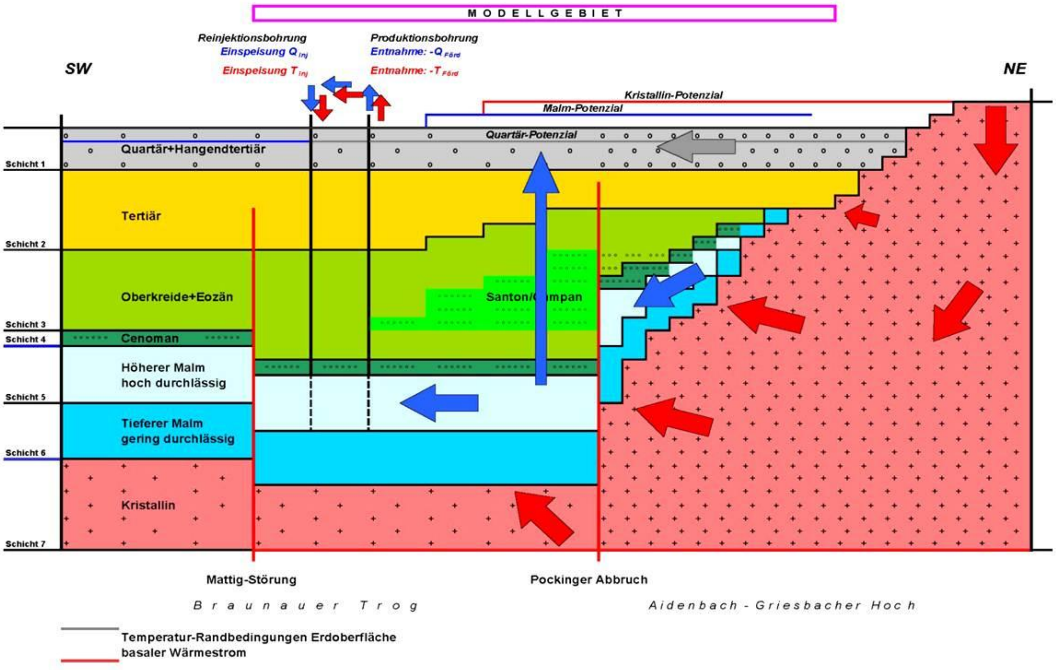


Figure 9. Conceptual model of the 2D- groundwater model (DETAILMODELL 1998) picturing the inflow by red arrows and the extraction by blue arrows (Bundesministeriums für Land- und Forstwirtschaft des Landes Oberösterreich und des Bayer. Landesamtes für Wasserwirtschaft, 1999)

To minimize the required computing effort the numerical thermal-hydraulic modeling was divided in to work-packages, which aimed to establish a **regional 3D model** as well as a **local-scale 3D-model**.

The **3D- regional model** is based on DETAILMODELL 1998 and vertically separated in the layers mentioned above (with further separation of Deeper and Upper Malm). It was used to calculate the effect of different hydraulic and thermal rocks characteristics. Therefore the 3-D model was calibrated in 3 different ways (EXPERTENGRUPPE „THERMALWASSSER“, 2008, p.18/30):

1. Stationary hydraulic calibration: hydraulic potential with different hydraulic conductivities

2. In-stationary hydraulic calibration: hydraulic potential as function of time-dependent boundary conditions (represented by extraction and re-injection)
3. Stationary thermal calibration: stationary temperature field with different heat conductivities of the rocks and different hydraulic conductivities of the aquifers

Although the regional model offered a good approximation to the calculated potential relationships in the DETAILMODELL 1998, steady-state calculations for small periods of time clearly showed that the hydraulic characteristics of the aquifer are no longer stationary due to intense thermal water extraction. Therefore a time-depending simulation was required, which lead to improved conclusions about the hydraulic conductivities. The effect of temperature on the hydraulic conductivity was investigated in an additional sensitivity study.

The thermal calibration was based on measured temperature data of the Upper Malm, an estimated boundary condition for the surface of 10°C and different heat conductivity values at the base of the model. The effect of advective thermal processes on the temperature regime was realized during an additional sensitivity study by further varying the hydraulic conductivities.

The **3D- local model** covered a representative section within the regional model to calculate case studies for different utilizations scenarios (geothermal as well as balneological) of the Malm aquifer. **39 virtual case-studies** have been investigated to gain further information concerning the effect of the well position and spacing of wells (dublets as well as different utilizations) on pressure and temperature characteristics of the aquifer.

The following factors were examined in the context of the local model:

- Flow rate (amount of extraction and re-injection per time)
- Temperature of re-injected fluid
- Operational method (yearly or seasonal)
- Spacing between extraction and re-injection well
- Location of faults relative to extraction- and re-injection wells
- Re-injection upstream of extraction well

The implementation of an additional sensitivity study provided further information about the effects of variations of the so called reservoir related system-factors (thermal conductivity, porosity and hydraulic conductivity of the matrix and the faults) on the pressure and temperature behaviour.

The calculated effects of different operational methods on pressure and temperature behaviour in the wells and the outline of drawdown cones could be mapped for each case-study and are provided in final report (EXPERTENGRUPPE „THERMALWASSSER“, 2008, p.21/30).

Outcome and conclusions of the project TAT: (EXPERTENGRUPPE „THERMALWASSSER“, 2008, p.26/30)

- Possible estimation of the effect of discharge and reinjection temperature on pressure and temperature behaviour at different sites within the project area

- Lower impact of the reinjection temperature on the temperature front propagation (reservoir cooling) than expected so far
- The productivity of geothermal wells in terms of dublet systems is more sensitive to the amount of extractable (circulable) thermal water than to the temperature level of the utilized waters from an economical point of view.
- According to calculations the available heat in place can be used in a geothermal sense for a long time.
- The extracted energy during the lifetime of a dublet-system exceeds the naturally regenerated amount of energy (without an estimation of the necessary period for an entire heat recharge by conductive and advective heat-transport).
- Doublets can operate for decades without any significant impact on local pressure and temperature behaviour, whereas the effect of changes in pressure is generally more spacious than in temperature.
- The magnitude of several reservoir related so called “system-factors” affecting the hydraulic and thermal behaviour could only be estimated.

<u>The actually existing model doesn’t provide reliable information on:</u>

- The estimation of lifetime for individual dublets under consideration of mutual influences by neighbouring utilizations

Furthermore the achieved results and derived conclusions concerning the impact of different operational systems on the temperature and pressure conditions may also not be transferable to the whole Molasse basin or to other reservoir systems in Austria.

Because of licensing reasons the actually available 3D thermal water flow model is only allowed to be used at the Bavarian State Office for Water Management in Munich, the Federal Ministry of Agriculture, Forestry, Environment and Water Management in Vienna, at the government of Upper Austria in Linz and at the Institute for Hydraulics, Hydrology and Water Management of the TU Vienna.

However there is still need for improvement because some utilisations are not implemented correctly and thus are showing different hydraulic connections in reality than in the calculated results (personal note M. Samek, Lebensministerium), January 2012). The continuous implementation of new hydrological and qualitative data derived during the installations of new usages of the reservoir helps to constantly update the model.

Concept of the water management

In the area of the Lower Bavarian – Upper Austrian Molasse Basin the thermal water is extracted for balneology and geothermal use. The objective is to regulate thermal water use of the reservoir on a technically coordinated basis and according to uniform criteria and usage. Uppermost water management policies target the comprehensive protection of the resources quantitatively and qualitatively as well as to preserve the natural pressure conditions. The management strategies worked out during the development of the 3D-thermal-hydraulic groundwater model are based on a mutual exchange of all relevant information and data. Because of differing legal regulations and administrative structures of the involved countries it was also necessary to elaborate uniform guideline papers which regulate a comprehensive monitoring systems and data reporting to the authorities. To further ensure a sustainable utilization the application, maintenance and further development of the groundwater model is of major importance (Samek, 2011).

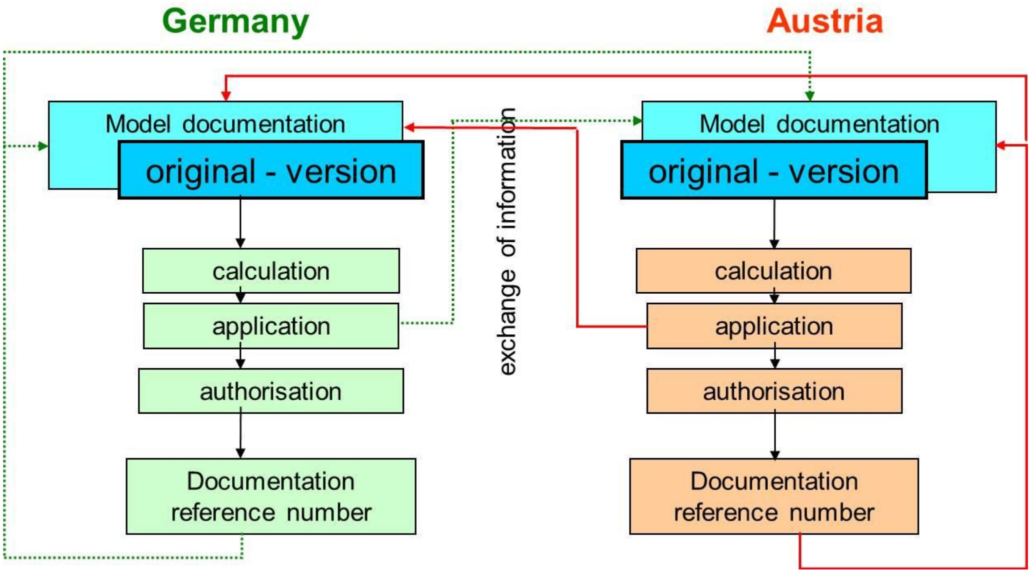


Figure 10. Flow chart of the stated model application (Samek, 2011)

A sustainable utilization of the Malm aquifer:

- Must be based on the extent of natural groundwater recharge
- Should not lead to pressure and temperature reductions with more than minor adverse effects on existing utilizations
- Should preserve the chemical composition of the utilized thermal waters by inhibiting the inflow of highly mineralized waters due to intense reduction of pressure in the reservoir.

(Goldbrunner et al., 2007, p.6/78)

Current monitoring concept

The spas and geothermal plants using the Malm reservoir have to fulfil an evidence program that was compiled by the competent authorities of both involved countries.

The evidence program combines the acquisition, storage and analysis of the relevant operating data of each usage. Type and extent of the required program are regulated by the responsible authorities in the water rights permit. In Bavaria the responsible authority is represented by the mining authority whereas in Austria the water rights department of the state government of Upper Austria is concerned with these issues.

Official procedures for obtaining the water rights are differing due to the legal situation in the countries, but within the scope of the permanent water-commission according to the bilateral “Regensburg” contract it was agreed on a coordinated procedure.

The evidence program also orders to present the measured data in terms of an annual report to the responsible water authority. So far there are no basic templates for this kind of reporting. Nevertheless they should include the graphical analyses and record tables of the measured data. Since 2005, every 5 years summary reports based on the annual reporting comprising all utilizations are published by responsible authorities. They intend to provide a public evidence of the realization of the mandatory monitoring program by the user.

Reporting requires aquifer and well related data (like pressure, temperature or conductivity of the fluid) as well as operational data of the facility (e.g. temperature range and spread of the heating facility, working hours). These monitoring data serve as verification of the allotted amount of extraction and provide some documentation of the operating procedure.

Actual permitting procedure for new utilizations

If a new user applies for a water permit concerning the production and / or the re-injection of thermal water in the Lower Bavarian – Upper Austrian Molasse Basin the agreement prescribes, that the other party (Bavaria in case of an Austrian application) is notified immediately. New numerical calculations based on the numerical 3D-model, which aim to update the thermal water flow model, have to be executed under accordance of the involved two states based on the same initial data and the same principles applied.

By the use of numerical modelling it has to be proven, that the applied extraction- and injection permits do not negatively influence neither the temperature- nor the pressure regime at existing users at the Malm reservoir. These calculations require the application of the 3D-thermal flow model with stationary boundary conditions (Goldbrunner et al., 2007, p.17/78).

Hence the simulations have to provide the following groundwater potential maps (Goldbrunner et al., 2007, p.21f/78):

- the allotted annual extraction and reinjection rates
- the allotted and submitted annual extraction and reinjection rates
- a balance map of the extracted and re-injected water amounts (allotted as well as submitted)
- the actual extracted and re-injected amounts
- the actual and the allotted extraction and re-injection data of the previous year
- balance map of the actual and allotted annual amounts and the actual data of the previous year

According to Goldbrunner et al. (2007, p. 46-66) the following general requirement demands for applied geothermal utilizations, as listed below, have to be met for:

- The drilling of the explorative well
- The execution of hydraulic tests
- The operation of thermal water utilization – heating purpose
- The operation of thermal water utilization – balneological purpose
- Shut-down of abandoned wells.

These demands, listed in catalogues, are provided by both countries in a uniform way. They contain a list of documents needed for the application at the permitting authority, which intend to ensure a sustainable utilization of the thermal water by applying state of the art technology. The explorative documentation includes amongst others (Goldbrunner et al., 2007, p. 31-44):

- Technical reports: location, geology, hydrogeology, the used drilling method, type of geophysical tests, the type of hydraulic tests and the monitoring during the tests, the amount of extraction and reinjection, temperature and discharge as well as a description of the technical installation and the operating data)
- Plans: of the explorative wells, the hydraulic tests and operational system of thermal water utilization (site map, geological profile, completing borehole),
- Numerical model calculation: to provide the required groundwater potential maps

It has to be pointed out, that explorative permits have to base on the above described numerical simulation of the applied utilization for an operational period of 50 years (EXPERTENGRUPPE „THERMALWASSSER“, 2008, p.20/30). After receiving the water rights the project reaches the next phase - the well drilling.

Any new drilling requires special data acquisition as well as an intensive test program, which also intends to amend the data background of the numerical model.

The following table gives an overview about the necessary tasks during and recently after the drilling:

Table 1. Required measurements during prospection (Goldbrunner et al., 2007, p. 251/276)

Task	*Description*
geological interpretation of the drilling profile	In combination with samples of the drilling cuts and the well loggings
drilling parameters	Documentation of • progress • type and amount of flush fluid • circulation loss • chemical & physical parameters
geophysical well logging	• resistivity measurements (2 penetration depths) • self potential • caliber log (4-arm-caliber) • gamma-ray log • deviation measurements (dip and orientation) • temperature log and maximum temperature • compensated neutron log • BHC sonic log • cement-bond log (in cased well)
pressure and temperature measurements	measurement depth (top malmian reservoir))
positioning	

hydrological tests	• Huge pumping test (Estimation of water yield) • Short-term pumping test /discharge • Long-term pumping test /discharge • Doublet-system: pumping and reinjection test
Hydrochemical analyses, isotopes	• First hydrochemical analysis • Isotope chemistry • pH value and conductivity

The initial hydraulic well-tests reflect the conditions of the undisturbed aquifer, therefore an exact data acquisition of flow rate, drawdown, pressure level and temperature is important to define the extractable amount of water (irrespective of any aimed reinjection).

The outcomes of these tests decide about the following steps of the project. If they show the well to be sufficiently productive, the re-injection well of the geothermal dublet is allowed to be drilled. Also the final setup of the well-completion and the final technical layout of the permanent monitoring system are based on these results.

The well-tests have to be carried out in a way that enables hydraulic evaluation, which necessitates constant extraction flow, exact entry of quantities, record of pressure level including profound drilling and testing reports. During the extraction-phase temperature and hydrochemical parameters, conductivity as well as the pH value have to be recorded too.

The hydraulic analysis should consist of:

- raw-data data concerning pumping and pressure-equalizing phase in terms of tables and plots
- evaluation of the data with regard to permeability and storage coefficient

User related monitoring program

The following tables present the *continuous and periodic hydrological measurements* as well as the *continuous and periodic qualitative measurements* required by the evidence program.

Table 2. Required continuous measurements at current usages (Goldbrunner et al., 2007, p. 244-245/276)

Parameter	*Interval*	*Accuracy*
Flow rate Q [l/s]	15 min	0.1 l/s
○ operating pressure [bar] or ○ Water level during operation [m]	15 min	0.1 bar or 0,1-1 m
Flow temperature T [°C]	15 min	0,1 °C
Elec. Conductivity Lf [µS/cm]	15 min	1 µS/cm
Water meter (total extraction)	Once a day	1 m³, weekly manual check

Table 3. Required periodic measurements at current usages (Goldbrunner et al., 2007, p. 245/276)

parameter	*interval*
Closing pressure **or** Static water level	Closing pressure and temperature trend: every Tuesday 16:00 there is a production stopp followed by pressure and temperature measurements within a 15 min interval in 5 sec increments
Hydrochemical analysis	Basic observation: every 5 years Repeated observation: annually

Authority governed monitoring program

Despite of a user related mandatory monitoring setup, there also exist a couple of governmentally owned monitoring wells to serve as observation of the pressure in the Malm aquifer (Goldbrunner et al., 2007, p. 250/276). For this purpose already existing wells were adopted and equipped with monitoring systems. In Bavaria they are part of the Bavarian national monitoring network for Groundwater level. According to Goldbrunner et al., 2007 in Bavaria the following monitoring are actually installed:

- Haimhausen II (since 1990, depth: 1,453m)
- Altdorf Tiefbrunnen (since 2002; depth: 796m)
- Bohrung Köfering (since 2005)

In Austria there is only one monitoring well, namely

- Reichersberg 2

Suggestions for an expansion of the measurement network of monitoring wells in Austria according to Goldbrunner et al. (2007) contain the wells:

- Raab Thermal 1
- Marginally used domestic wells located in the discharge area (Eferding basin)

Summary and conclusions

Within the scope of a more than 10-year collaboration of the expert group “Thermalwasser” it was shown that the regular mutual exchange of information and experiences is an essential factor for a successful management of a trans-boundary thermal water body. Only a joint water management of both involved countries Germany and Austria, based on bilateral agreements, may lead to a sustainable use of the reservoir.

To ensure the sustainable use of the Malm aquifer, the users have to monitor and report their measured data once a year to the authorities. To map the general tendency of the reservoir every 5 years an additional report (compiled by the responsible authority) serves as survey for the realization of the required evidence program.

In addition to the user related mandatory monitoring there are a few monitoring wells installed and maintained by the competent authorities to independently log the pressure and temperature conditions (with prospects of an expansion of the measurement network).

Already during the development of the numerical 2D- groundwater model the requirement of using dublet-systems was stated in order to preserve, as far as possible, the natural temperature and pressure conditions of the reservoir. Since the implementation of these joint measures the hydrothermal conditions of the aquifer, which already were affected by overexploitation, could slightly regenerate.

The requirement of modelling the latest 3D- hydrothermal model in both involved countries leads to an ongoing improvement of the reservoir model. It also serves as measure to ensure that the implementation of a newly supplied utilization with a lifetime of 50 years does not lead to negative effects on already allotted systems.

The policy paper on the evidence program is revised at the moment (anticipated publication in May 2012) due to some objections to the required measures of the program listed below:

- The obligatory weekly measurement of the closing pressure at 16:15 on each Tuesday by the user causes large efforts due to the entire shut-down of the pumping cycle.
- Another point of criticism is the short measurements intervals, which lead to a huge amount of data and at the same time handicap their evaluation. For hydrological issues not the short-term but the long-term behaviour is significant and therefore there is a demand for the adjustment of the measurement increment to the requested analysis.
- The required hydrochemical analyses are carried out conform to standardized investigation criteria without regard to differing water- and gas analysis which would necessitate an adaptation to local conditions.

Outlook on future improvements of the water management concept

The planned improvement of the measures will most likely consist of an integration of the suggestions made by the project TAT and the associated expert group “Thermalwasser” (personal note: M. Samek, Lebensminsiterium, January 2012), which are based on the experience gained by the evaluation of the 5-year reports. Especially with regard to data comparability uniform procedures will be necessary in future.

In the following there is an overview of the main recommendations for future enhancement of the thermal water management concept according to Goldbrunner et al. (2007):

- When delivering the data in the context of a report a binding description of the data acquisition (used measuring device, location, etc.) would be favourable
- Carrying out additional hydrological tests in ongoing thermal water usages (so called operating tests) would expand the knowledge about the effects on the aquifer. Preconditions are a defined time-frame, a fixed flow rate and the consent of the surrounding users as their production may be affected.
- Annual reports should include a text section with the processing of the obligations dictated by the regulatory authorities, plus a description of special occurrences, the current usage situation, data presentation and analysis

- Balneological usages should provide additional information about attendance figures.
- The most important operating data should be summarized in tabular.
- Measured hydrochemical parameters require graphical (annual hydrograph) and integrated presentation.

References

BUNDESMINISTERIUMS FÜR LAND- UND FORSTWIRTSCHAFT DES LANDES OBERÖSTERREICH UND DES BAYER. LANDESAMTES FÜR WASSERWIRTSCHAFT, 1999, Thermalwasservorkommen im niederbayerisch-oberösterreichischen Molassebecken – Hydrogeologisches Modell und Thermalwasser-Strömungsmodell - Kurzbericht; Wien, November 1999

EXPERTENGRUPPE „TIEFENWASSER" IM AUFTRAG DER STÄNDIGEN GEWÄSSERKOMMISSION NACH DEM „REGENSBURGER VERTRAG", 2002, Grundsatzpapiere zur Thermalwassernutzung im niederbayerisch-oberösterreichischen Molassebecken, März 2002

EXPERTENGRUPPE „THERMALWASSSER" IM AUFTRAG DER STÄNDIGEN KOMMISSION NACH DEM „REGENSBURGER VERTRAG", 2008, Thermalwasservorkommen im niederbayerisch-oberösterreichischen Molassebechen – Grundsatzuntersuchung zu thermischen Auswirkungen von Thermalwassernutzungen; Kurzbericht;; Dezember 2008

GOLDBRUNNER, J. (ED.), 2007, TAT – Thermische Auswirkungen von Thermalwassernutzungen im oberösterreichisch-niederbayerischen Innviertel; Endbericht; ARGE „Thermische Auswirkungen von Thermalwassernutzungen" (Bearbeitung: Univ.-Prof.Dr. J. Goldbrunner, Mag. M. Gold, Mag. H.P. Heiss, Mag. A. Shirbaz [Geoteam], Dr. B. Huber [Hydroconsult], Univ.-Prof.Dr. T. Kohl, Dr. C. Baujard [Geowatt AG]; 25.6.2007

SAMEK M. (ED.), 2011, Austrian – German Cooperation in managing a transboundary groundwater body, Power-Point Presentation at the 5th Hydrogeological Slovenian colloquium IAH, Ljubljana 2011

3 *Waiwera water management and allocation plan (NZL)*

Introduction

Waiwera is a small settlement, built on local geothermal water source, situated 50 km north of Auckland. The geothermal field at Waiwera is a small low temperature fracture related system. Geothermal waters, heated by the natural geothermal gradient, rise along faults in the greywacke rocks from depths in excess of 1,200 m. The geothermal water is stored in Waitemata Aquifer at depths of between about 50–400 m (ARWB, 1980; ARC, 1991). Maximum bore production temperature at the centre of the Waiwera field is 53 °C and groundwater pressures in the field stand below the water table in the overlying cold sand aquifer (Crane, 1999). Geothermal water is characterised by concentrations of boron, lithium and fluoride significantly greater than for non-geothermal fresh groundwater, also naturally high sodium and chloride concentrations occurs there.

Problem (1960's-1970's)

Waiwera is an example of random development of limit and delicate resource without any prior knowledge about its limitations. It had been subjected to a gradual increase in water use until early 1970's, when this gradual trend accelerated due to increased use for several purposes including swimming pools, baths saunas and toilet facilities and home and water heating. In 1975 the Waiwera residents express their concern about thermal water level decline to Auckland Regional Water Board (AWB). There was little scientific information available at that time to provide an understanding of the thermal water (availability, quality, temperature and use). ARWB initiated the study designed to assist in the protection, allocation and management of the resource. The findings of the study and preliminary management plan was documented in the report ''Waiwera water resource survey – preliminary Water allocation / management plan'' (Auckland Regional Water Board, 1980).

Resource assessment (1977-80)

The working group began collecting historian data on water level, temperature borehole logs and with establishing of monitoring network for measuring water level trends. In the second phase the pumping test was conducted to provide information on aquifer characteristic. In the last phase they expand the data collection to include temperature and conductivity profiling, water chemistry analyses and study of tidal and barometric effects on water levels.

The natural springs at the beach were initially used by Maoris (Waiwera means hot water). European utilisation goes back to 1863 when the first hotel was build. Subsequent development means drilling more boreholes and more deep boreholes. Fist problem with the ceasing of artesian flow was observed in the 1950's, by the year 1969 only periodical natural flow was noted. In the 1970's rapid decline of water levels occurred. The natural springs on the beach were drying up before 1978.

Resource Assessment conclusions were (ARWB, 1980):

a) The thermal water resource is limited in extend and confined to the vicinity of town centre. The temperature of thermal water was between 35 and 49 °C. The hottest temperatures occur in the centre of a field, and generally increase with depth. The shallow boreholes at the edge of field had cooled to an unusable temperature.

b) The groundwater level was also dropping with the rate of 0.3 m/annually from 1977-1979.

c) Temperature and conductivity measurement showed intrusion of cold water from inland and saltwater from the seaside.

The schematic representation of the conceptual model of the Waiwera thermal water resource and its changes are presented in figure 11. The evaluating team also noticed several utilisation problems, among them for us two are interesting, waste thermal water disposal to the sewerage system and waste thermal water discharge to the storm water drainage system. Both could produce problems by increasing water temperature and salinity and thus creating good growing condition for the bacteriological, algal and amoebic contaminants.

The ARWB found out in 1980 that ‘’existing management practices, inefficient boreholes will prevent any further exploitation of the resource in the near future. In fact there is an urgent need to decrease existing uses through more carefully utilisation and an acceptance that, at least until the resource is stabilised to a satisfactory level and temperature lower operating temperature will have to be accepted.’’

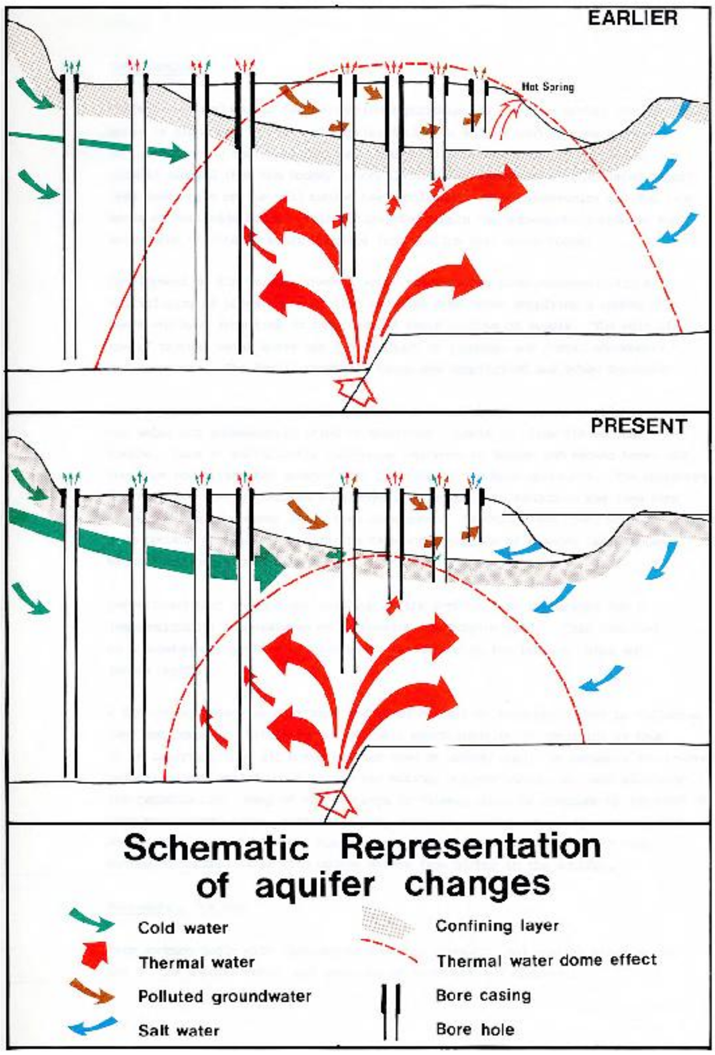


Figure 11. Schematic representation of groundwater pumping induced changes in the Waiwera geothermal aquifer (ARWB, 1980).

Management and allocation plan (1980)

The study identified that the resource is over-exploited. Immediate corrective action was proposed: to pump less and at lower rate to enable thermal water level to recover and to establish hydrostatic barrier to the intruding salt water. The ARWB implement the **management and allocation plan** that attempts to improve the situation and perhaps reinstate the resource close to its earlier known level of availability.

Proposed actions consist of:

1 Remediation

  1.1 Backfilling and sealing of unused boreholes

  1.2 Minimum standard of bore construction

  1.3 Conservation in utilisation (pipe lagging, wind breaks, pool covers, time control switches and thermostats).

  1.4 Water treatment

  1. 5 Waste thermal water disposal (reducing the temperature and mineral content of emitted waters)

2 Priorities of Use (public hot pools, commercial hot pools, communal pools, private polls, other uses)

3 Allocation of the resources (the total extraction should be reduced. No allocation should be made to new users and allocations to existing facilities should be restricted to recreational use only. Extending the allocation or expanding the uses is possibly only if after a period of time the remedial works and allocations as outlined here allowed water temperatures and pressures to recover satisfactory).

4 Monitoring

  4.1Measuring water extraction (regular monitoring of water use enhances awareness of the resource and promotes conservation which leads to a reduction in consumption)

  4.2 Monitoring water temperature

    4.2.1 Maximum production temperature measurement (after two our of pumping and on regular basis)

    4.2.2 Measurement of thermal efficiency (how the water from the borehole is heating up after starting pumping)

    4.2.3 Temperature profile of water column (ascertaining the position and shape of the temperature gradient in each borehole on annual level

  4.3 Monitoring chemistry

    4.3.1 Routine chloride analyses (twice a year)

    4.3.2 Detailed chemical analyses (if the increase of chloride is observed in routine analysis)

    4.3.3 Deep well conductivity profiles

  4.4 Water level monitoring (drilling a new monitoring borehole and applying of automatic instruments measurement)

The authors prepared also objectives and policies which would provide a suitable basis for managing the Waiwera thermal water resource (are in the course with the existing legislation or should be promoted in the new legislation):

Objection 1 to rectify damage caused by past and exiting means of extraction and to protect the aquifer against further damage

Objection 2 to allow the resource to recover to previous conditions of temperature and pressure

Objection 3 to continue the monitoring the resource so that changes in aquifer behaviour and quality may be quickly recognized

Objection 4 to promote conservation of the water resource and it wise and efficient use

Table 4. Abstractions from Waiwera geothermal resource.

	1980	Proposed allocation plan (1980)	Current allocation plan (2012)	2002	2004/05	2005/06	2006/07	2008	2009	2010	2011
	m^3/d	m^3/d	m^3/d	m^3/d	m^3/d	m^3/d	m^3/d	m^3/d	m^3/d	m^3/d	m^3/d
Public	1090	1000									
Commerc.	348	225									
Commun.	842	210									
Private	417	130									
Totals	2697	1565	2338	1277	1249	1156	1271	1058	1031	1249	978

Implementation of the Water management and allocation plan (1980 - present)

The ARC maintains a geothermal groundwater-monitoring site at Waiwera beachfront (6457041). The bore, drilled in 1980, is 407 m deep and water levels are monitored automatically. In 1996 a shallow cold geothermal water bore was drilled adjacent to the hot geothermal bore. This site was established as part of the ARC long-term groundwater-quality baseline-monitoring programme. Water levels are measured coincident with water quality sampling (ARC,2002). Groundwater pressures in the coastal geothermal aquifer have fluctuated significantly over the last 100 years. Prior to development geothermal groundwater levels stood over 5 m amsl. In the 1970's hot springs on the beach ceased to flow and by the 1980's water levels had fallen to 1m below sea level (Fig. 11). At this time conditions existed for saline water to enter the aquifer at the coastal margin and at the landward margin. In 1979 monitoring of geothermal water quality in beachfront bores indicated up to 3.5 % of the bore water was of seawater origin. Geothermal groundwater levels rose through the late 1980's then declined for several years before beginning to trend up again since 1994. In 1998 a new deep bore was drilled by the Waiwera Thermal Pools and most of their water requirements were taken from this bore rather than the existing 3 production bores. The upward trending water levels in the ARC monitoring bore supports the assertion that bore location, construction and amount of pumping have a large effect on the ARC monitoring bore water levels (Chapman, 1998; Crane, 1999).

The ARC management objectives for the Waiwera geothermal field are to maintain aquifer water levels sufficient to avoid cold groundwater or seawater intrusion, to prevent reduction in aquifer temperatures, to avoid long-term decline in aquifer water levels and to seek restoration of geothermal springs on Waiwera Beach (Crane, 1999).

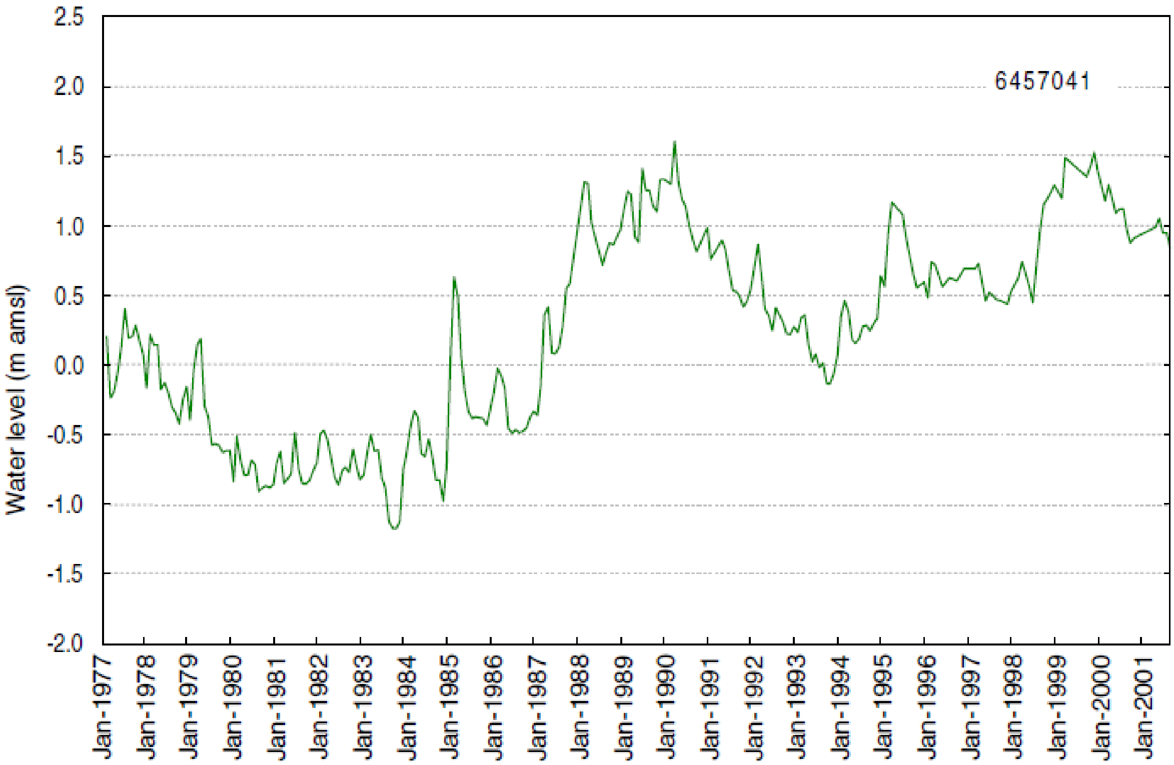


Figure 12. Groundwater level record at Waiwera geothermal (6457041) monitoring bore.

The management regime to achieve this is to maintain a mean groundwater level in the ARC deep geothermal groundwater monitoring bore No. 74 (6457041) **of at least 0.5 m amsl**. This minimum ground water level was set by the Proposed Auckland Regional Plan: Air, Land and Water (PARP:ALW). This will ensure that the water level in the geothermal aquifer at the coastal margin will remain on average 0.2 m amsl and hence avoid cold seawater intrusion (ARWB, 1986, ARC, 1991). Location and bore construction are almost as important as the quantity abstracted from a bore when assessing whether there will be an effect on the resource. Therefore a single value for aquifer availability, based on recharge to the aquifer as a whole is not appropriate.

In 2001 there were 48 geothermal groundwater consents that were collectively allocated 466,105 m3/year or an average of 1,277 m3/day. The largest average daily allocation, 850 m3/day, was the public pools complex Zentrum Holdings Ltd (Waiwera Thermal Resort). Other large allocations at Waiwera include the proposed hotel development Waiwera Resorts Ltd for 120 m3/day, Waiwera Spa Apartments Body Corporate 60 m3/day and the Caravan Park site redevelopment Waiwera Ltd for 50 m3/day. Eight smaller allocations are for motels, private apartments, holiday complexes and large private pools totalling 117 m3/day and the remaining 33 small private pool allocations total 78 m3/day.

In the period June 2004-May 2005 groundwater levels in the aquifer were lower than average and the mean groundwater level during this period was 0.45 m (Fig. 12). This is below the PARP: ALW management water level of 0.5 m averaged over 12 months. Most geothermal groundwater taken from the geothermal field is allocated to several users for pool use. During 2004/2005 water use records show that water use was within allocation with the exception of one consent, where water use exceeded both daily and maximum annual allocations. Groundwater levels have risen since May 2005 to above the management level. Consent renewals for 6 consent holders at Waiwera were being processed in 2006 and the abstraction and overuse by one consent holder was addressed though that process.

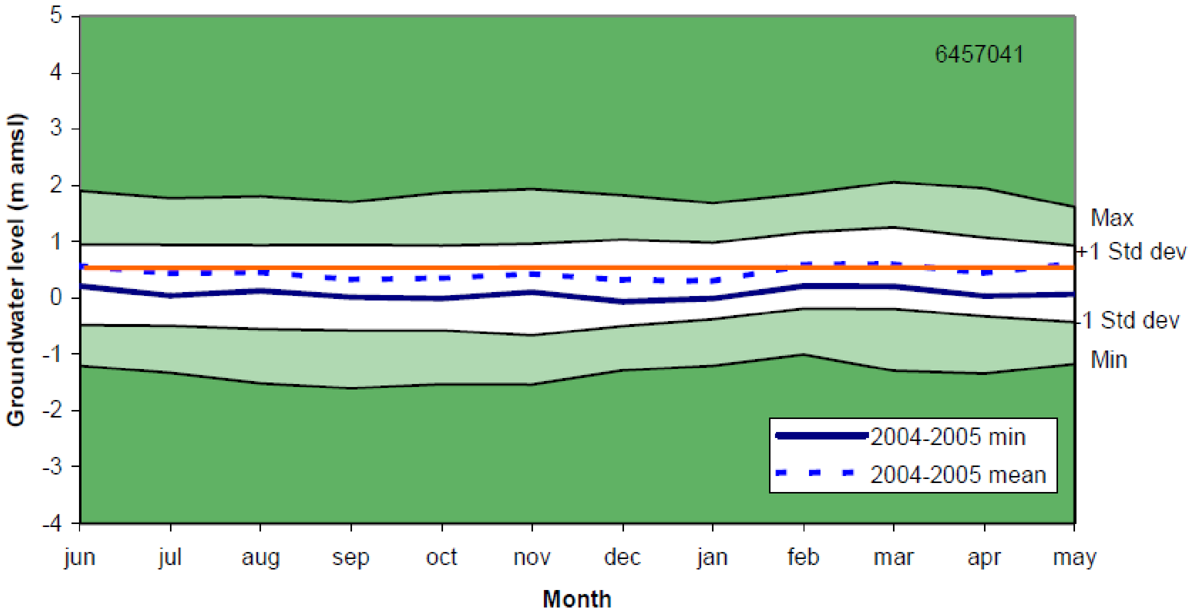


Figure 13. 2004 – 2005 Groundwater envelope for Waiwera geothermal bore 6457041. The orange line indicates the target groundwater management level of 0.5m amsl

The average groundwater level for June 2005 to May 2006 was 0.6 m amsl. The water allocation and usage has remained the same as last year for the high use management aquifer. The consent holders that extract water from the aquifer use the water for public and private pools.

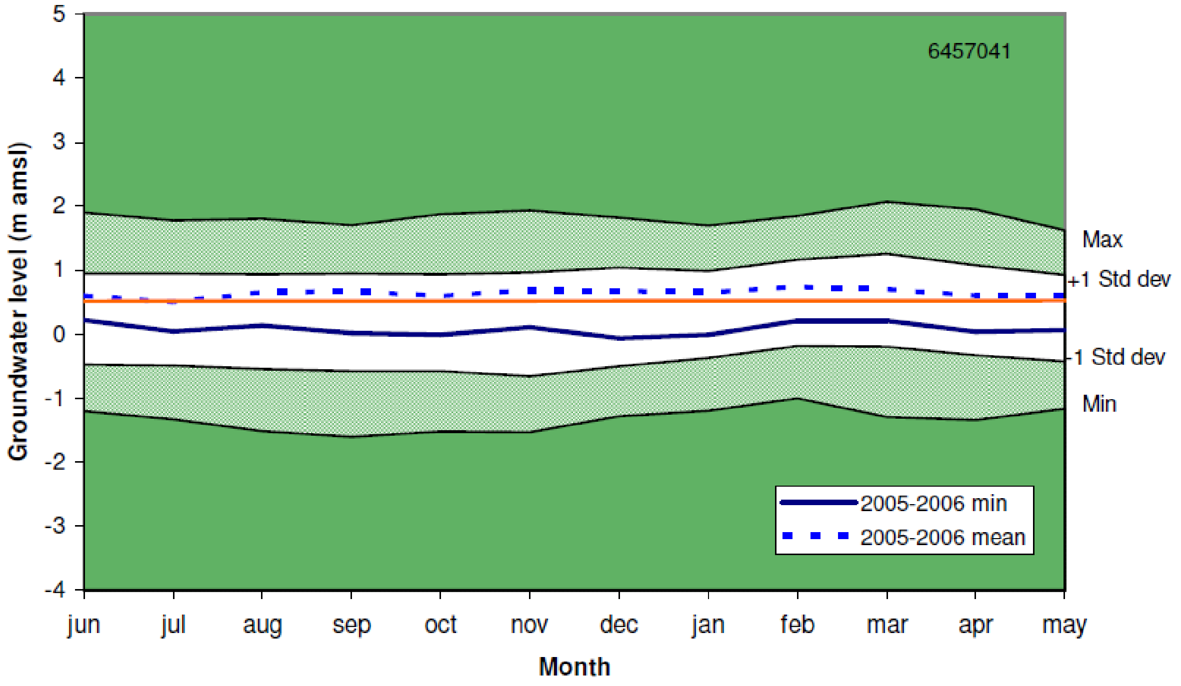


Figure 14. 2005 – 2006 Groundwater envelope for Waiwera geothermal aquifer bore 6457041.

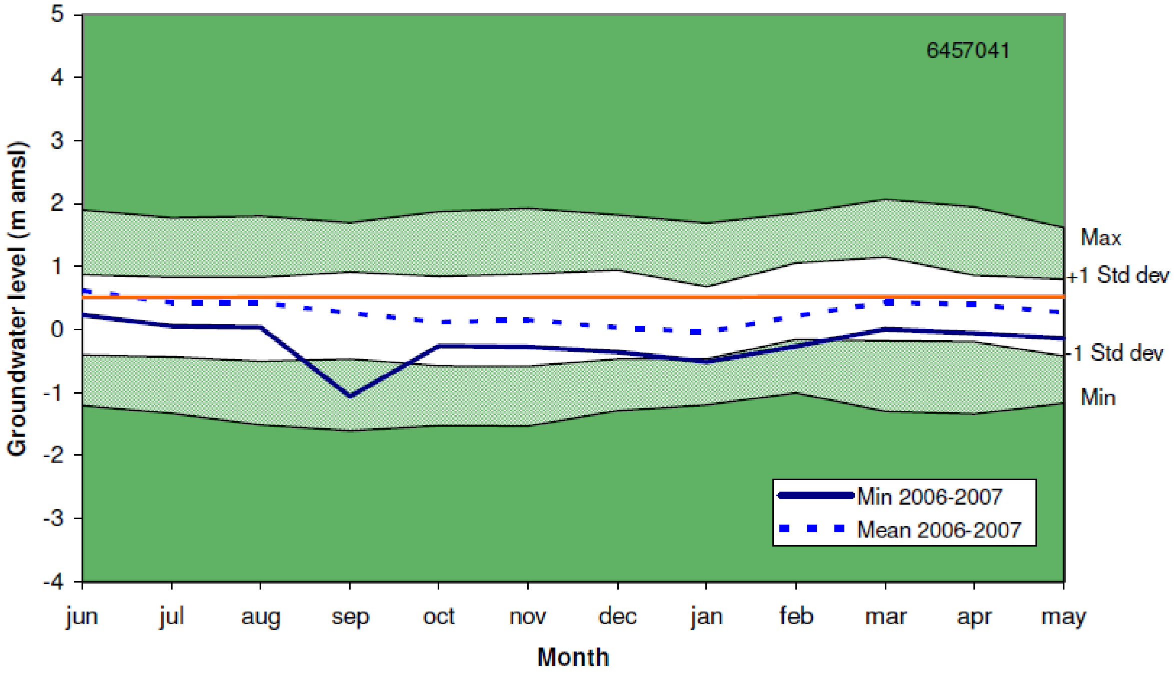


Figure 15. 2006 – 2007 Groundwater envelope for Waiwera geothermal aquifer bore 6457041.

The average groundwater level for June 2006 to May 2007 was 0.277 m amsl. This is well below the management level for the aquifer. The total water allocation was the same as the previous year and use was up. This is some concern as the mean water level has been below the management point of 0.5 amsl. These points are indicative of conditions permitting saltwater and cold freshwater entering the geothermal aquifer.

The Waiwera geothermal aquifer was under extreme stress during the 2006-2007 hydrological year. The mean levels recorded were well below the management level of 0.5m amsl, the level only exceed this management in June 2006. From the data supplied by consent holders it can be seen that total use was less than allocation, this is some concern for the management of the aquifer, as the allocated volumes may be greater than the aquifer can maintain.

The information about Waiwera geothermal water management for years 2008-2011 was provided to us directly from Auckland Regional Council (ARC, 2012). They delivered us the water level data from Beachfront deep bore No. 74 (6457041) and the water temperature data from Thermal pools old and new production bores. There is a trend of decreasing use in recent years, which is considerably lower than allocation (see also Table 4). The water level in the monitoring borehole 6457041 increased (Figure 16) and is firmly above the management level of 0.5 m a.s.l. The increase in water level is in concordance with the lower use. The lower use might be a consequence of higher water temperature of water captured with new bore in the Thermal pools (Figure 17). Recently there is noticed also a decline in water temperature, especially in the main bore, probably due to smaller yield and consequently higher thermal loss.

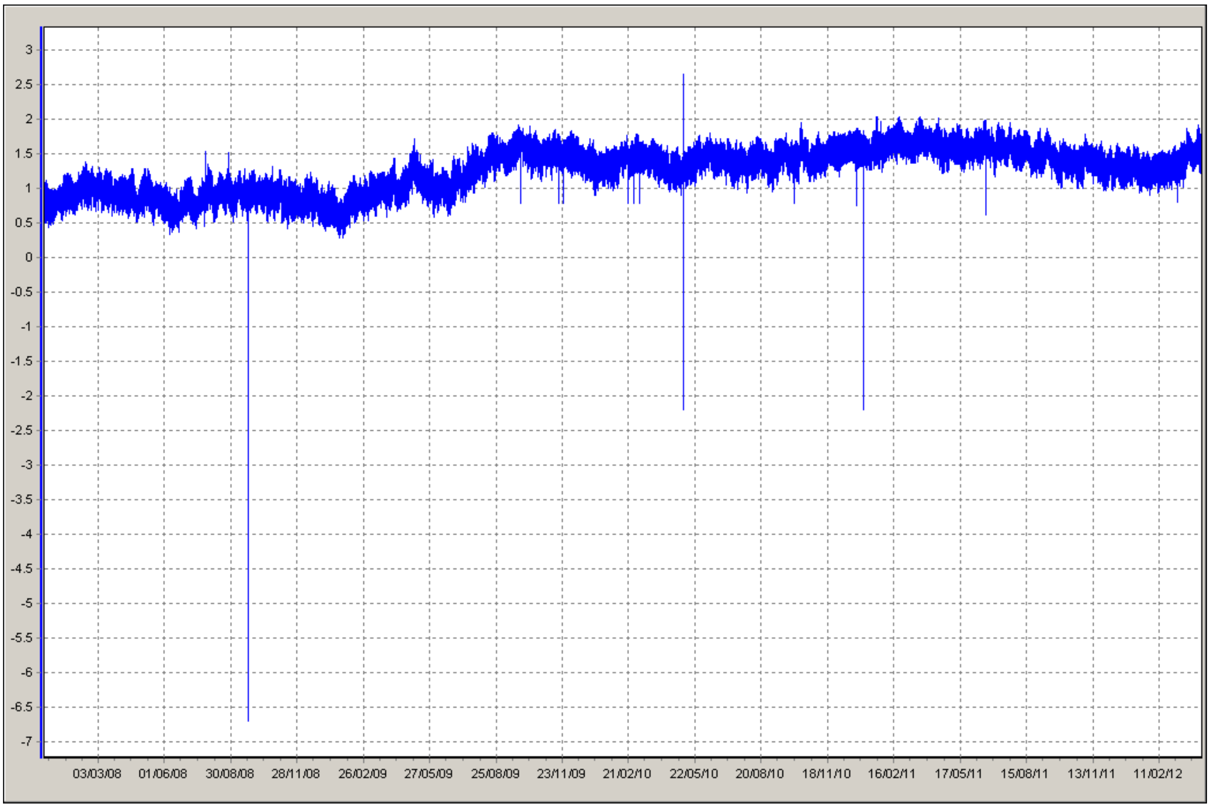


Figure 16. 2008 – 2011 Groundwater level measurements in Waiwera geothermal aquifer bore 6457041.

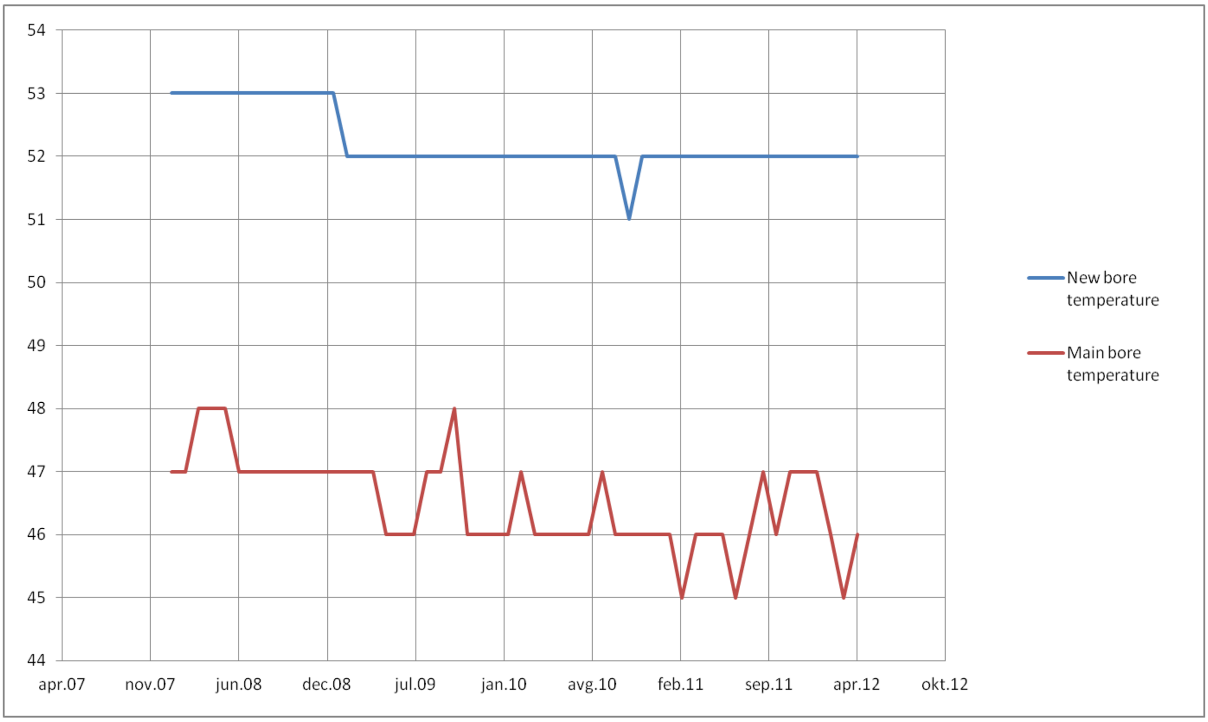


Figure 17. Monthly measuremens of water temperautre from producion bores at Thermal pools in Waiwera

References

ARC, 1991: Draft Waiwera geothermal groundwater resource statement and allocation plan.

ARC TP 112.

ARC, 2002: Auckland Water Resource Quantity Statement 2002. ARC TP 171.

ARC, 2006: Auckland Water Resource Quantity Statement 2004/05. ARC TP 300.

ARC, 2007: Auckland Water Resource Quantity Statement 2005/06. ARC TP 323.

ARC, 2008: State of the Environment Monitoring Auckland Water Quantity Statement, 2006/07: ARC TR 2008/011.

ARC, 2012: Official Information Request No. 9000115651.

ARWB, 1980: Waiwera water resource survey: preliminary water allocation/Management plan.

ARWB, 1986: Waiwera thermal groundwater allocation and management plan 1986.

Chapman, M.G, 1998: Investigation of the dynamics of the Waiwera geothermal groundwater system, New Zealand. Unpublished M.Sc thesis, University of Waikato.

Crane, S. G., 1999: He Kaupapa Tiaki i nga Wai Puia: draft Waiwera geothermal groundwater water resource assessment report. Auckland Regional Council.

The Proposed Auckland Regional Plan: Air, Land and Water (PARP:ALW).

ANNEX II

Measurement experience

1. *Measurement of pressure, temperature and yield in deep boreholes – experience from company Geological Survey of Slovenia*

On-line pressure and temperature measurements – Near wellhead approach

For the measure of pressure and temperature in the boreholes the company Geological Survey of Slovenia currently uses electronic measurement devices manufactured by ELTRATEC Ltd. from Sv. Jurij ob Ščavnici (Slovenia). The probe with sensors is lowered into the borehole, and is connected to the surface with the special measuring cable, which ensures probe power charge and distribution of measured data to the surface data logger of GRS 301 and GRS 310 type. Where the opportunity exist the data loggers are powered through the transformer and rectifier to the electrical network, otherwise they use 12 V batteries.

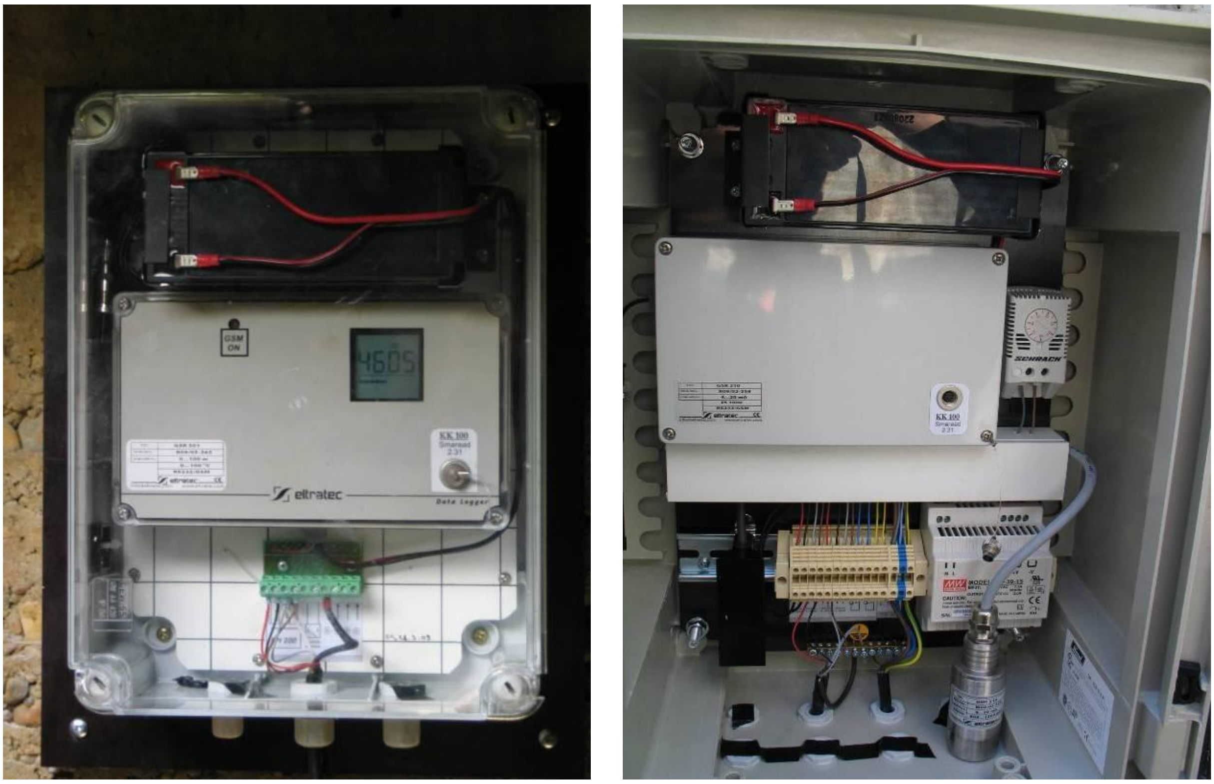
The measurements are carried out with measurement probes type PPI 200 in which the Siemens pressure and temperature sensors are installed. All probes used for thermal water monitoring have the measuring scale of pressure from 0 – 10 bars, and temperature from 0 – 100 °C. The probes are installed in the borehole to the depth of 50 m bellow the wellhead.

The electronic data loggers of type GSR 301 (1 counting channel, 2 analogue and 2 digital channels) and of type GSR 310 (6 counting and 6 analogue channels) are mounted on the wellheads. All data loggers are equipped with GSM/GPRS modem from producer Telit. Data from loggers are transmitted via modem to the Geological Survey of Slovenia server daily and stored in the data base. Such transfer allows regular inspection of each measurement location and fast reaction in the occasion of possible damage or interference with the measurement equipment. The software allows the setting of alarms (send SMS to selected number) on failure of preset parameters, e.g. power failure, low groundwater level in the case of the implementation of pumping tests, protection of the pump, sensor failure, etc..) During the reporting time of the measurement stations (data loggers) also on-line connection to the logger and remote update of the default parameters is possible, e.g. sampling frequency, change of the phone numbers or time reporting, etc.).

From the beginning of measurements in the thermal wells in NE Slovenia since 2009 up to now, some weaknesses and errors were registered during set up and performance of measurements. In cooperation with equipment manufacturers we tried to eliminate or at least to reduce those weaknesses to acceptable levels. At the start the problem has occurred primarily with probes that were installed in production boreholes, since in these wells quite extreme conditions appeared, such as high temperature (50 - 60 °C) and fast and large fluctuations in groundwater levels (rapid change of pressure) caused by special pumping regime. Due to these factors individual sensors malfunctioned. The probe producer was required to find solutions, especially in the probe sealing and the differential stretching of individual components that make up the measuring probe. The frequency of damage has been reduced to an acceptable level. In the case of probe malfunction, alarm is activated. Spare probes are prepared at the producer storehouse, so the reacting time for the probe replacement is measured in days. Because the malfunctioned probe is installed in the maximum depth of 50 m below wellhead, no special expensive service for replacement is needed.

The second types of problems are related to the data transfer. Proximity of frequency inverters for the control of submersible pumps due to strong electromagnetic fields prevents the transmission of GSM signal. All data loggers had to be installed outside the radiation area of frequency converters. The electricity needed for the data loggers in those conditions must be provided by the cable, which is beyond the influence of frequency regulators.

Figure 1. Data logger GRS 301 (on the left-hand side) and data logger GSR 310 (on the right-hand side).



Thermal water flow measurements

Thermal water flow measurements on production wells are implemented through the flow meter. In some wells (SOB-2, P-1 and P-2) flow measurements are performed using a flow gauge with vane and "reed" sampler, which is linked to the data logger. The data logger record the current flow, the cumulative flow rate is read directly from the flow gauge or calculated in the data logger. We use the flow gauge from manufacturer MeineckeMeters.com (C/O Cross Instrumentation, BlvdConyers Autumn 1621, Georgia 30012, USA) in combination with Sensus Metering System.

Figure 2. Flow meter on SOB-2 well.

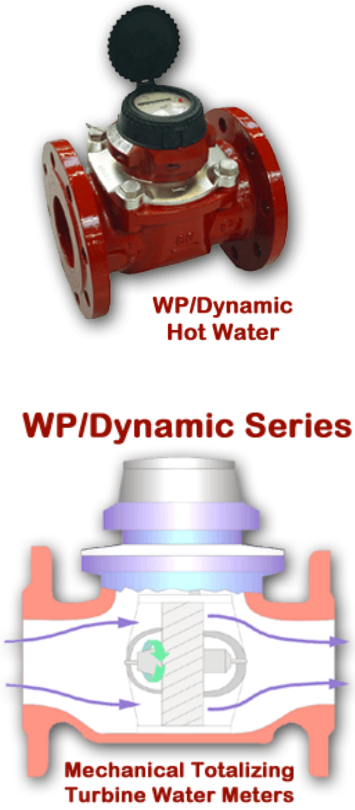


Figure 3. Vane flow meters.

This type of flow meter is suitable for low-mineralized thermal water with a low content of dissolved gases. In highly mineralized water deposition of minerals on the turbine and housing leads consequently to the variations in flow measurement accuracy. In waters with high content of dissolved gases (e.g. CO2), these flow meters can only be used behind degassing containers. Flow measurements with this type of flow gauge in water with high scaling potential are practically useless. In such cases rapid wear of mechanical parts of the measuring instrument and frequent breakdowns are expected.

For flow measurements in water with high scaling potential also electromagnetic (inductive) flow meter in combination with different transmitter (e.g., MA, 5000) are used. Such flow meters are used in Terme 3000 and Vivat Spa in Moravske Toplice.

Figure 4. Induction flow meters with transmitters.

These gauges are mainly used for the measurement of large flows. Accuracy of measurement value is within ± 0.4%. These meters are most often mounted on outflow pipes in the thermal water source, before the split pipelines to different customers. Compact flow meters described as inductive or as the turbine type (with vane) are mounted on the pipelines leading to individual consumers. Only in Terme 3000 spa about 300 flow meters are installed.

Difficulties by flow measuring with inductive flow gauges for thermal non-mineralized water are practically not observed, but in high mineralized thermal water and water with high content of dissolved gases similar problems are observed as in the turbine gauges. Flow meters must be installed after degassing reservoir, so flow measurement data is within the error tolerances. Since inductive gauges have no rotating mechanical parts, there are no frequent failures. Inductive gauges have output 4 to 20 mA and the possibility of connection to the data logger.

2. *Measurement of pressure, temperature and yield in deep boreholes – experience from company HGEM d.o.o.*

(provided by doc. Goran Vižintin, Ph.D, and Ivan Supovec)

In the scope of project we asked the company HGEM, d.o.o. which has knowledge about measuring in the region (Slovenia) to provide us their experience with the measurement of pressure, temperature and yield in deep boreholes.

Pressure and temperature measurements with the probe of the type »Diver« - Production layer approach

The company HGEM currently use probes manufactured by DMS Ltd. from Golnik (Slovenia). The probes are "Diver" type and are composed of the sensors (pressure, temperature), memory works (logger) and batteries. So far they used probes that withstand 200 bar of nominal pressure and temperature of 110 °C, while the majority of measurements were carried out at the temperature range of 70-90 °C and at depths ranging from 1,400 to 1,800 m. Based on experience gained with the use of this type of probes, the below description is made. It is very important that the measuring devices are adequately protected by additional casing; otherwise the measuring devices are usually damaged, which can also result in a partial loss of measurements.

It is necessary to implement pressure measurements in the centre of the "production" layer! In our opinion the best way to install the probe is into an additional stainless steel casing, which provides better protection, and it should hang on a stainless steel cable profile. Given the reliability of such probes is best to install two probes. At the moment it is possible to make probes that are resistible to temperatures more than 170 °C, depending on the battery. The price of such probes is very high. Probes manufactured by DMS d.o.o. withstand up to 105/110 °C. We consider that 3 probes per borehole are necessary in order to perform an adequate monitoring, two probes for measurement as aforementioned and one probe on spare. Our colleagues from abroad came to the same conclusion even for probes within a significantly higher price range as the ones that are manufactured by DMS. In addition, it is necessary to ensure regular lifting of the probes from borehole. In our opinion it is necessary to lift the probes at least once a month (if we want to be sure). Before each lowering of the probe it is necessary to replace it with a spare and keep this cycle of changes in each lift. Given the battery lifespan and the difficult conditions, in which probes are located, it is necessary to ensure regular service of each probe at least once a year, if needed the probe should be re-calibrated or even replaced (for example if the casing is damaged). Particular attention should be paid to the lifting and lowering of the probes, which should be done slowly and carefully enough not to induce any damage. We believe that the maximum rate of lifting should not exceed 0.2-0.5 m/s. This means that the lifting of the probes from deep borehole could take several hours (3 to 4 hours). At higher rates the casing could be heavily damaged.

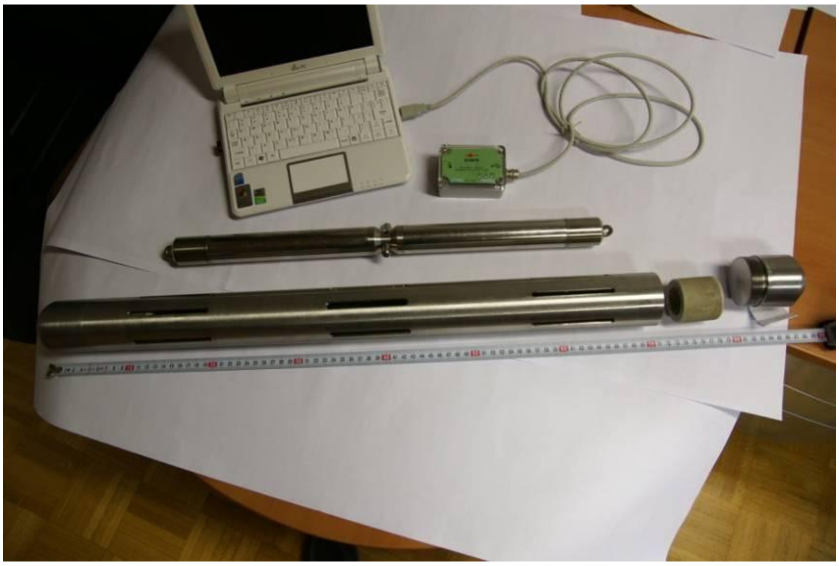


Figure 5. The ‘’Diver’’ probe with additional stainless steel casing

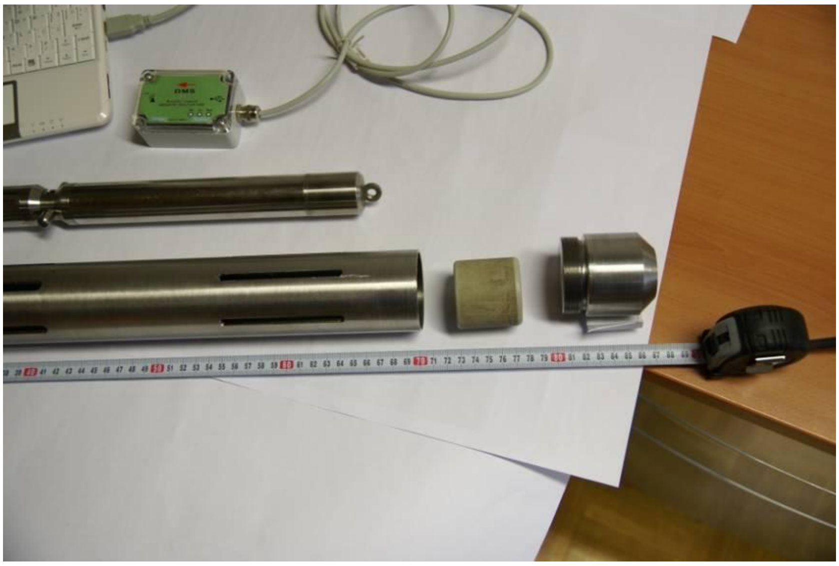


Figure 6. The ‘’Diver’’ probe with additional stainless steel casing - detail

It is known that worldwide for the on-line pressure and temperature measurements commonly used systems are those, where the sensors are lowered into the borehole and are connected to the surface with a special measuring cable, which also ensures the system power charge. It is a classic 4-20 mA measurement loop, which can operate at depths of 2-3 km, specific models can withstand up to 1,000 bar of pressure and temperatures of 150-170 °C. The main advantage of this system is that sensitive electronics is not needed in the borehole itself, except the sensors. On the other hand the main disadvantage is that the connecting cable is much expensive in comparison to the much cheaper steel cable with ‘’Diver’’ type of probe.

This type of system, although with a different type of cable, is still used in the Velenje coal mine, where multi-level piezometers are installed (up to 5 sensors arranged in depth, maximum depth 610 m). A different type of cable is used for this purpose, which is totally inert to its surroundings, but it is not suitable for higher temperatures (max. 50 °C). Pressure sensors withstand the nominal pressure up to 100 bar. Some of them have been operating for more than 15 years.

Thermal water flow measurements

In a system where water cannot be returned back into the aquifer, the best method for measurement is with a flow profile (triangular, square), where the water level is measured with a pressure sensor that is installed in a sufficiently large measurement pool. The sensor can be on-line or memory.

In a closed system the induction meter was proved as the most suitable, which should be designed for flow measurements that are expected in the system (measurements should be performed in the most favourable measurement range of the sensors)! Particular attention should be paid on gas content and their composition, since they can cause several problems during measurements.

The experiences of HGEM are based on Endress+Houser induction flowmeter, which is relatively insensitive to damage, as well as to the presence of gas. It is important that the measuring device is properly installed and that it is operating within the optimal measurement range.

The similar experience were gather from Velenje coal mine, where measurements in several production wells have been performed using the same sensors. A relatively high content of methane and CO_2 was detected in the water and the manual measurements were consistent with the automatic measurements. Besides the current display of flow and total flow amount (totaliser), this type of measurement devices have output for 4-20 mA measuring loop, which requires only passive flowmeter as the voltage is provided by the measuring device itself. In this way the on-line flow monitoring is possible or it is also possible to install the memory module for measurements.

HGEM Company states that for the pressure measurement is important that the measurements are performed directly in the production layer, where the separation of gas and associated changes in density and pressure of water do not take place yet. The incontinent factors of thermal and gas lift are also absent in this case.

In the world market (as was shown on Berlin fair) there is a number of different induction flowmeters that have battery power supply and data logger, which is even more favourable for measuring because a constant voltage of 220 V is not needed as in the case of the Endress+Houser flowmeters.

ANNEX III

Former transboundary projects in the region

Project presentations and lessons learnt

1. *DANREG (Danube Region Environmental Geology Program)*

Introduction

In 1989 a bilateral agreement was signed by the Geological Institute of Hungary (MÁFI) and the Geological Survey of the Slovak Republic (SGUDS) concerning joint geological research of the border zone on both sides of the Danube aiming at the joint production of harmonized maps. In 1990 the Geological Survey of Austria (GBA) joined as a third partner. The trilateral research program became one of the formal projects of the Earth Science Committee of the Central Europe Initiative (CEI).

The basic aim of DANREG was to arrange the geological and geophysical data of the border zone (about 20,000 km^2 area) of the three partner countries (Fig. 1) in a unified framework and to make their uniform interpretation assisting the decision makers dealing with the management of the region, including the three capitals: Budapest, Bratislava and Vienna. In such way DANREG can be considered as one of the major fore-runners of the Transenergy project.

Different thematic maps were compiled using GIS techniques (Integraph and ArcInfo) at 1:100 000, 1:200 000 and 1:500 000 scales and cross sections. The maps and their explanatory texts were published in the Jahrbuch 1999-2000 of Geological Survey of Austria (Császár 2000).

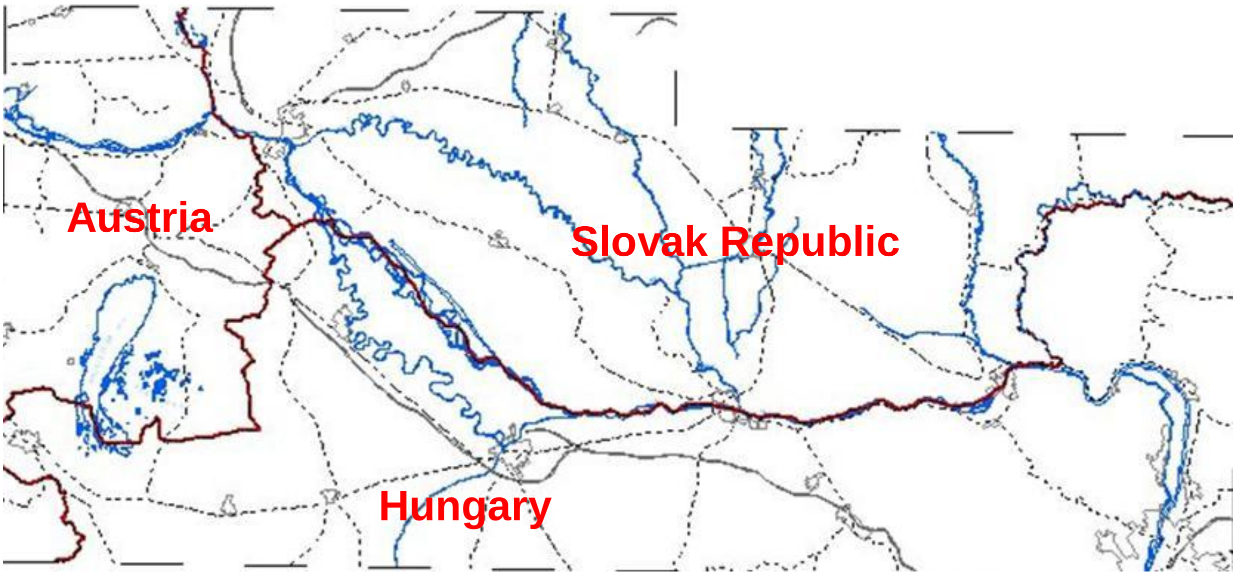


Figure 1. The DANREG area

DANREG maps

In the frame of DANREG, the following maps were edited with uniform legends:

- Surface geological map (1:100 000)
- Map of genetic types and thickness of Quarternary sediments (1:200 000)
- Lithofacies and thickness map of Pontian and the Pliocene (1:200 000)
- Lithofacies and thickness map of the Pannonian (1:200 000)
- Map of the Pre-Tertiary basement (1:200 000)
- Tectonic map (1:200 000)
- Neotectonic map (1:200 000)
- Hydrogeological map (1:200 000)
- Engineering geological map (1:200 000)
- **Geothermal potential map (1:200 000)**
- Geological cross-sections (1:200 000)
- Bouguer anomaly map (1:200 000)
- Stripped gravity anomaly map (1:500 000)
- Magnetic ΔT anomaly map (1:500 000)
- Gravity lineament map (1:500 000)
- Results of the magnetotelluric measurements (1:500 000)
- Contour map of the Pre-Tertiary basements (1:500 000)
- Contour map of the Pannonian basement (1:500 000)
- Thickness of the Quarternary sediments (1:500 000)
- Apparent resistivity map AB=200 m (1:500 000)
- Map of environmental geohazards (1:100 000)

2. *Geothermal potential map*

The geothermal potential map (Fig. 2) has a very simple legend showing the expectable water temperatures by drilling to impermeable rocks (mainly crystalline rocks) in a maximum depth of the basin bottom by different colors (blue=cold, variations of violet=mixing moderate temperature, red=hot).

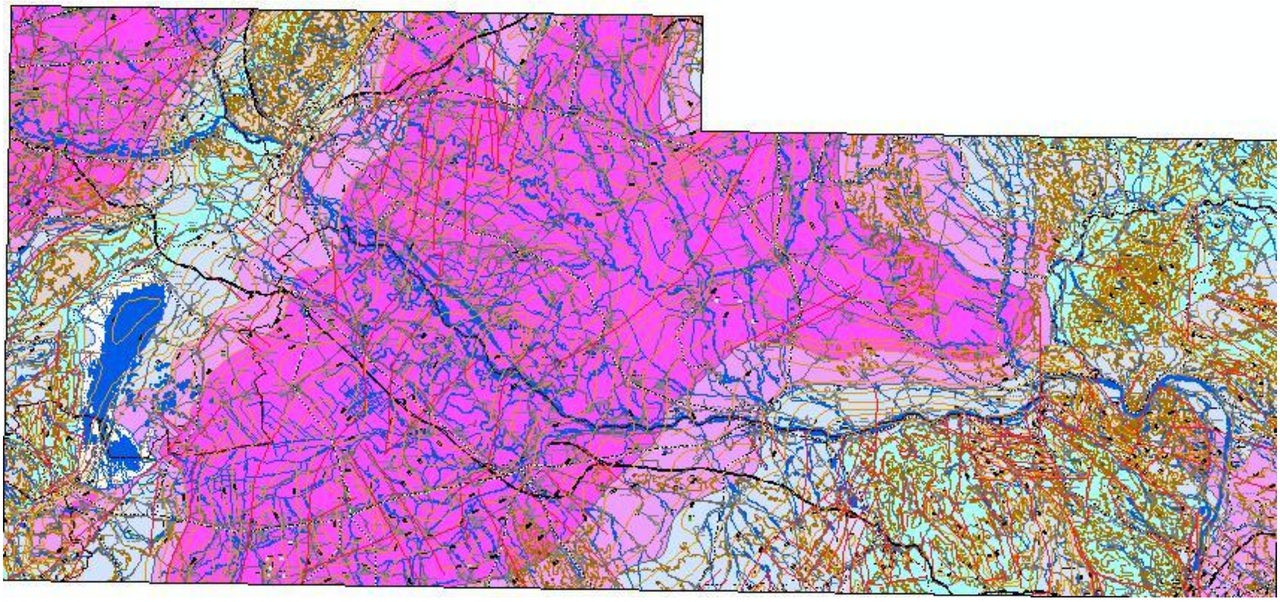


Figure 2. Geothermal potential map of the DANREG region

The explanatory notes (Kollmann and Rotár-Szalkai 2000) give a summary description about the hydrogeothermal setting of the main structural units and their sub-units: Danube basin (Central depression, Komárno block, Dubník depression, Levice block); North- and South-Vienna basin; Pannonian basin (Kisalföld basin, NE region of the Transdanubian Range, Northern Hungarian Paleogene basin). The descriptions included the type, structure and short characterization of the main thermal water aquifers, the chemical character of the thermal waters, and their potentiometric conditions.

DANREG as a pioneer project in transboundary geoscientific research provided a good example how to overcome problems of creating a new, uniform projection system for maps from different national coordinate systems used in the partner countries, as well as a GIS system, how to construct harmonized thematic maps and provide their uniform synthesis. Of course this was all done at the technical level available at the late 1990's (GIS still in its infancy) and at the level of geological knowledge of that time. Although some of the DANREG maps are applied geological ones (e.g. engineering geology, hydrogeology), still the main program was rather a "basic research"-type one.

References

Császár, G.(ed) 2000: Danube Region Environmental Geology programme. DANREG Explanatory Notes. − Jahrbuch 1999-2000 Band 142/4. Geologische Bundesanstalt, p. 411-607

Kollmann, W.F.H., Rotár-Szalkai, Á. 2000: Geothermal potential map. In: Császár, G.(ed) 2000: Danube Region Environmental Geology programme. DANREG Explanatory Notes. − Jahrbuch 1999-2000 Band 142/4. Geologische Bundesanstalt, p. 535-544.

3. TRANSTHERMAL („The geothermal Potential of the Eastern Alps“ Geothermal potential of the border region between Austria and Slovenia – Evaluation of the geothermal potential based on a bilateral database and GIS – maps for the regions of Carinthia, Styria and Northern Slovenia)

Introduction

The aim of the Community Initiative INTERREG IIIA AUSTRIA – SLOVENIA 2000 – 2006 study TRANSTHERMAL was to collect geothermal-relevant metadata and characteristics from the border region Austria-Slovenia and to combine them in a transnational database. Based on these results geothermal maps of the investigation area were compiled and provided in terms of GIS-applications. By a digital geothermal atlas (web application in the Carinthia atlas) the gained expertises of the TRANSTHERMAL-project will be published for a sustainable and economically reasonable use of natural thermal water in the border region between Austria and Slovenia. Scientific part of project was conducted by GBA, Joanneum Research Forschungsgesellschaft mbH from Graz and GeoZS. Executing Organizations were Amt der Kärntner Landesregierung, Abt. 15 Umwelt from Klagenfurt, Amt der Steiermärkischen Landesregierung, Abt. 19A Wasserwirtschaftliche Planung und Siedlungswasserwirtschaft from Graz and RRA Koroška d.o.o. from Dravograd.

For the first time comprehensive datasets

The border region between Austria, Slovenia and Hungary represents one of the most important balneological and geothermal utilization areas in Central Europe. The substantial use of natural thermal springs in spas in the area of south-eastern Styria, southern Burgenland, north-eastern Slovenia and south-western Hungary has become an essential driving force of the economic development within the last decade.

Considering the constantly high prices of fossil fuels and the cumulative public awareness-raising concerning the application of environment-neutral, alternative energy sources, the energy utilization of geothermal energy for heating and electricity production is of increasing interest. First demonstration plants are already working in south-eastern Styria (Blumau, Waltersdorf). Albeit from the advantages the geothermal potential in the eastern area of the border region Austria-Slovenia and the economical interests linked to it harbour also risks:

- The intensive use of natural thermal water horizons can lead to overstraining and a loss of efficiency. This is particularly problematic, if cross-border aquifer-systems (like in the area of Bad Radkersburg) are existent and there is no integrative, trans-border aquifer-planning.
- Economically successful examples of geothermal use (basically spas) prompt municipalities and investors to make exploration plans in areas of low utilization potential, which in many cases prove uneconomical later on. Behind the lack of knowledge of the geothermal basic conditions and combined with exaggerated expectations there consequently waits economic disprofit.

Although over the last 20 years quite a number of geothermal studies mostly limited to local scale were carried out in the border region between Austria and Slovenia, thitherto there were no data from the whole region.

Investigation area border region Carinthia – Styria - Slovenia

The investigation area is situated in the border region of Austria and Slovenia and contains the northern part of Slovenia, the eastern part of Carinthia and the southern part of Styria.

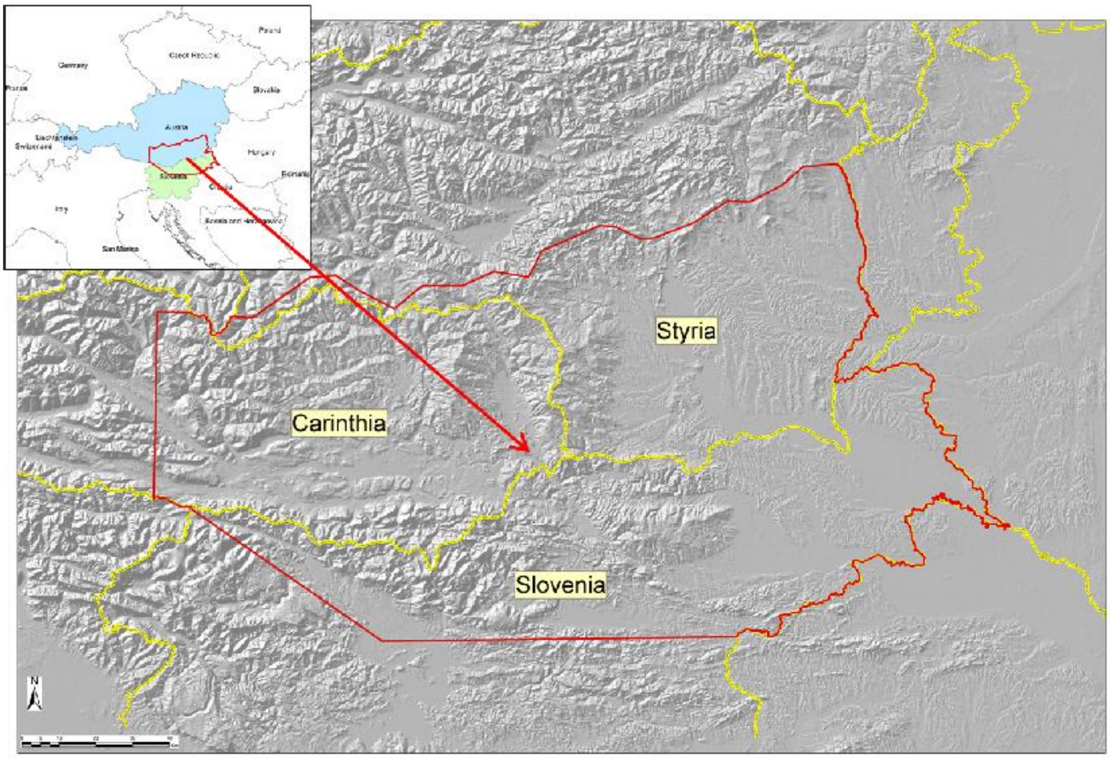


Figure 3. Compendium of the situation of the investigations area in the marginal region.

The boundary of the investigation area runs along the southern edge of the Save-valley from Rateče to Kranj and after that in an eastward direction to the national border of Croatia close to Rogaška Slatina. The western boundary of the investigation area in Austria is running longitudionally to a direct North-South line in the west of Villach, the northern boundary follows the frontier of Carinthia and Styria and proceeds in the eastern part up to the styrian-burgenlandian frontier, whereas the eastern boundary runs along the direction of the styrian-burgenlandian frontier to the south.

The western part of the project area is both on the Slovenian and on the Austrian side characterised by mountain ranges (Karawanken, Steiner Alps and small parts of the Julian Alps) and intra-mountainous basins (f. e. Ljubljana basin, Klagenfurter basin and Lavanttal). The eastern respectively south-eastern part of the project area however is affected by the basin scenery of the outbound Pannonian basin. According to the hydro-geological and morphological premises in the western part of the common project area are shallow ground, partly natural discharging subthermal springs and temperate thermal springs (Bad Kleinkirchheim, Warmbad Villach, Bad Weißenbach) observed. In the area of the Pannonian basin however the temperature of the basin waters, which are used via deep borehole for balneological and energy purposes, range from moderate to highly tempered (f. ex. Bad Blumau, Bad Waltersdorf, Rogaška Slatina).

Analysis of the geothermal utilization potential in various depths

Within the bounds of the project TRANSTHERMAL it was tried to analyse and represent the geothermal service capacity of the investigation area. In doing so only the deep geothermal potential with a focus on natural thermal water (hydrothermal potential) were included.

Based on a transnational representation of the geological basic parameters and on merged processing of the geologic data-basis (geologic maps and profiles) an analysis of the geothermal potential was carried out. The specification of the geothermal potential in terms of prospective utilization possibilities required despite of the analysis of the geothermal boundary conditions also a report about the situation of the current use (spas, heating, electricity production) and the already available aquifer key data (e.g. capacity, water temperature, chemism). The main focus was furthermore put on increasing rock temperature with depth (heat flow density, rock temperatures at different depths) dependent upon the region, the more so as the geothermal gradient (increase of temperature with depth) represents an important factor for economic efficiency (control of the drilling charges) concerning utilization of geothermal resources.

The handling of shallow ground geothermal power plants (e.g. groundwater heat pumps, geothermal energy collectors) is only depending indirectly on the lithological build-up of the subsurface. Hydrological boundary conditions, in particular conflicts with water management, play a non-negligible role. It was tried to accommodate the handling of shallow ground geothermal energy plants within a temperature distribution map in the depth of 250 m below surface.

The geothermal potential without water extraction from the subsurface (Hot Dry Rock Technology) is not yet realisable at the current moment. The prospective efficiency of this sort of plants is predominantly depending on the exploitation depth of hot rocks (controlling the drilling costs). To accommodate however this prospective utilization potential, various depth temperature maps for a range of depth up to 4,000 m below surface were compiled in the course of the project TRANSTHERMAL.

Representation of the geothermal subsurface conditions

All essential basis-data for the evaluation of the geothermal utilization potential during the project TRANSTHERMAL were archived in a multilingual project data base and were linked to the GIS-software ArcGIS 9.2 for spatial visualization.

Based on borehole temperatures the thermal subsurface conditions (geothermic gradient, terrestrial heat flow density) have been processed by means of common correction- and modelling methods. The geothermal potential was according to the geological-lithological subsurface conditions structured into a geothermal potential of solid rocks (basement) as well as into a potential of the sedimentary basement fill. By superposition of these two geothermal „part-potentials“ a geothermal „total potential“ was derived, which exhibits areas with advantageous geothermal subsurface conditions.

By the superposition and combination of various geological information and geothermal subsurface characteristics as well as by inclusion of already existing boreholes and thermal water utilizations a comprehensible cartography was developed. This combination of methods made an efficient project management and representation of the results possible.

Product geothermal atlas

A broad cartography, summarised to a digital geothermal atlas for the investigated region, was the main achievement of the project TRANSTHERMAL. In the frame of TRANSTHERMAL, the following maps were edited with uniform legends:

- Geological map, scale 1:200.000,
- Overview of tectonic units, scale 1:300.000,
- Geological cross sections, scale 1:200.000 & 1:50.000,
- Preneogene basement rock, scale 1:300.000,
- Relief of the pretertiary basement / Hard rock relief,
- Thickness of Tertiary sediments,
- Deep wells and natural thermal springs,
- Recent use of thermal water,
- Water temperatures at deep wells and natural thermal water,
- Hydrochemical water types,
- Geothermal wells, thermal and subthermal springs: yield classes,
- Temperature distribution maps in depths of 250, 500, 1000, 1500, 2000, 2500, 3000, 4000 m and surface heat flow density maps,
- Geothermal potential: Tertiary sediments (Neogene / Paleogene),
- Geothermal potential (Pretertiary basement),
- Total geothermal potential: Sediment and basement.

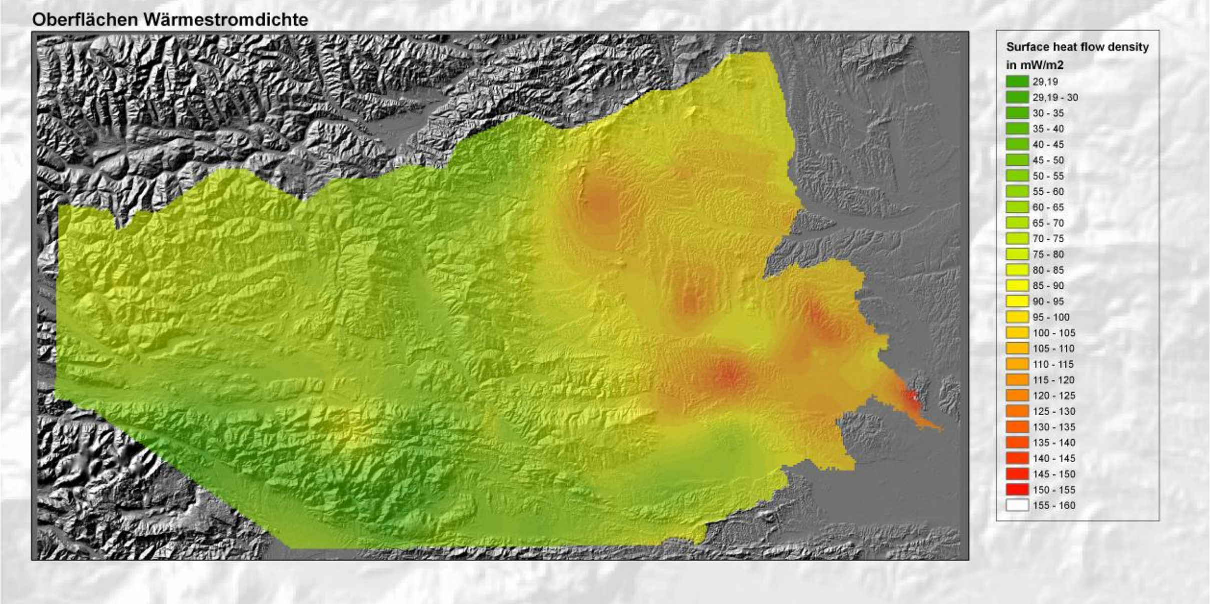


Figure 4. Distribution of the surface heat flow density in the transnational project area as an important element of the thermal potential (abstract of attachment 12).

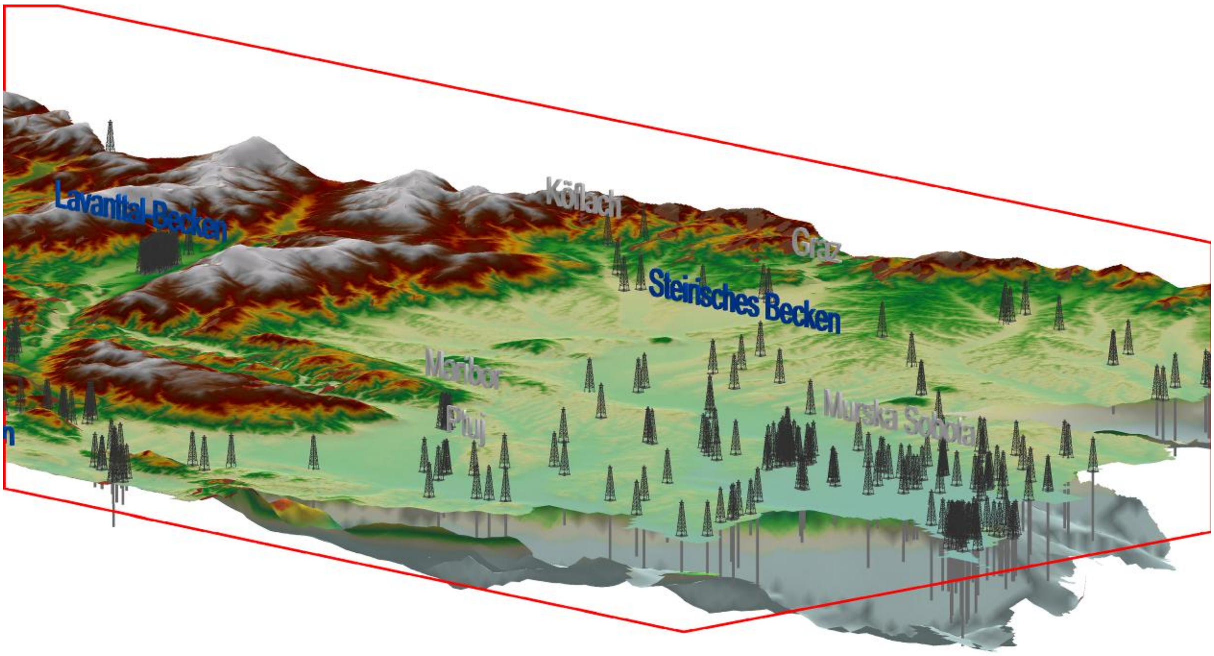


Figure 5. 3D-View of the Pannonian basin in the southeast of the project area with a display of existing deep boreholes

Regionally varying exploration risks and development costs

Geothermal utilzation areas are situated preferentially in the basin regions of the south-eastern part of the project area due to a favourable geothermic gradient matched with favourable hydrological-lithological subsurface conditions as observed.

In the areas outside of the sedimentary basins the geothermal potential can often be described insufficiently because there is only sparse subsurface information (lack of boreholes). In principle geothermal utilization possibilities in terms of natural thermal waters extraction can’t be excluded in these areas. Prosperous economic examples are represented by the spas of Bad Kleinkirchheim (Carinthia) and Bad Bleiberg (Carinthia). The exploration risk in these areas is heightened in comparison to the basin areas and the thermal potential is estimated to be reduced because of increased thickness of the crust.

Conversely it has to be kept in mind that in areas with already accounted, increased geothermal potential only an exploration borehole can ratify or discard the a-priori predicted conditions. Insecurities of the prognosis, which rely on the heterogenic geological subsurface conditions, can only be reduced by means of adequate detailed investigations (hydro-geological preliminary study, geophysical measurements). This will finally lead to an accurate estimation of the development risk.

Furthermore it has to be paid attention to zones within the project area, which as a result of already existing intensive thermal water utilization allow additional exploration only in limited extent. Areas with high exploitation level especially exist in eastern part of the project area at the Styrian Slovenian border (Radkersburg).

Albeit the geological finding risk of natural thermal waters the regionally varying increase of temperature with depth represents another crucial economical limitation criterion. Drilling costs are a non-negligible part of the total exploitation costs of geothermal ressources, which in turn depend basically on the drilling depth. Because of the increased effort concerning the drilling procedure (increased drilling diameter, rigs with high heave capacity, rig-safety) the drilling costs are escalating significantly with exploitation depth. By looking at the distribution of the different depths to gain for example a rock temperature of 90 °C (factual lower limit of the geothermal electricity production via ORC-method) expectable reservoir depths vary between 1,700 to 2,200 meters below surface in the area of the Styrian and Slovenian basin and between 3,000 and 3,500 m below surface in the region of Carinthia and northwest Slovenia. Converting the prognosticated drilling depths into drilling costs, the additional expenses for this area resulting just from the increasing drilling depth and regardless of the additional geological finding risk are estimated about 250 % to 300 % in comparison to the south-eastern part of the project area.

References

Bäk, R., Budkovič, T., Domberger, G., Götzl, G., Kumelj, Š., Lapanje, A., Liparski, P., Poltnig, W., Rajver, D., 2007: Geotermalni viri severne in severovzhodne Slovenije / Geothermal resources of northern and north-eastern Slovenia. Geološki zavod Slovenije in RRA Koroška, regionalna razvojna agencija za Koroško, Ljubljana, Dravograd.

Bäk, R., Budkovič, T., Domberger, G., Götzl, G., Hribernik, K., Kumelj, Š., Lapanje, A., Liparski, P., Poltnig, W., Rajver, D., Rman, N., 2008: TRANSTHERMAL : geothermal potential of the border region between Austria and Slovenia - evaluation of the geothermal potential based on a bilateral database and GIS -maps for the regions of Carinthia, Styria and northern Slovenia : INTERREG IIIA Austria - Slovenia : bilateral final report (Austria / Slovenia); G. Goetzl, A. Lapanje,. (editors): Geologische Bundesanstalt, Joanneum Research, Geološki zavod Slovenije. Vienna, Graz, Ljubljana. http://www.geo-zs.si/UserFiles/677/File/portal_pdf/Porocilo(1)(1).pdf

4. Environmental State and Sustainable Management of Hungarian–Slovakian Transboundary Groundwater Bodies (ENWAT project)

Introduction

Groundwater bodies along the Hungarian–Slovakian border form interconnected systems, which supply both countries with drinking water. Also surface waters, rivers and wetland ecosystems are depending on the underlying groundwater.

The ENWAT project running in the frame of the INTERRGEG III/A Hungary-Slovakia-Ukraine Neighborhood Program between 2006 and 2008 aimed to prepare a joint Hungarian–Slovakian water management plan for three selected groundwater bodies: Ipoly /Ipel valley, Aggtelek-Slovak karst and Bodrog basin (Fig. 6) (Brezsnyánszky et al. 2008a, b). The main partners were the Geological Institute of Hungary (MÁFI) and Štátny geologický ústav Dionýza Štúra (ŠGÚDŠ) – Slovak Geological Survey. Project results were used by the Permanent Slovakian-Hungarian Water Management Committee. During the preparation of river basin management plans project outcomes were also considered during defining different threshold values.

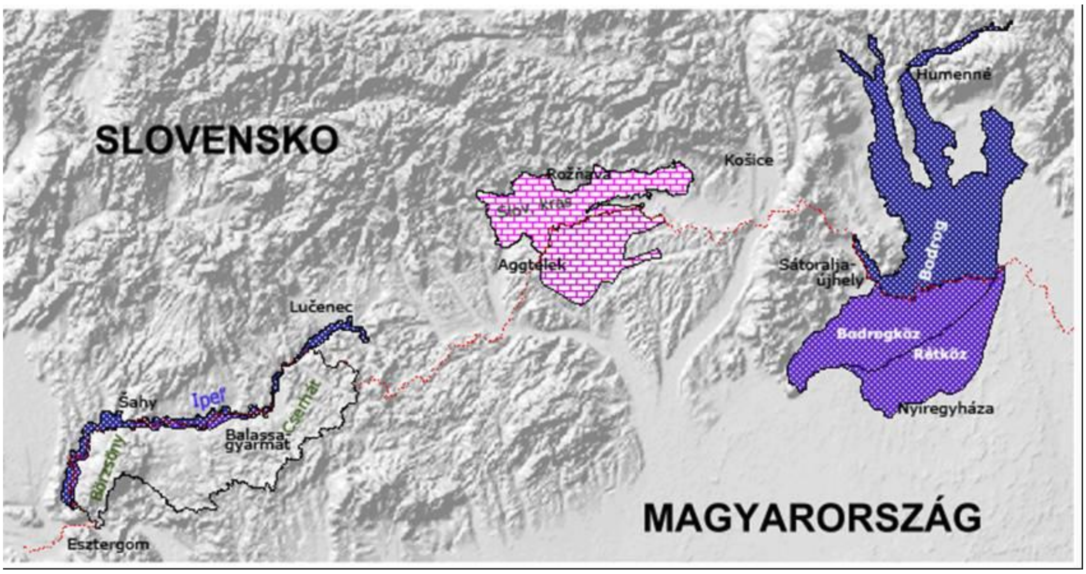


Figure 6. Studied transboundary aquifers of the ENWAT project

The work was based on joined GIS databases, hydrogeochemical evaluations and hydrogeological models, as well as screening of local needs, cost aspects and best practices. The project was providing information on the quality and quantity of (mainly shallow) aquifers in order to make healthy drinking water supply available, raise awareness of contaminations and pollutants deriving mainly from agriculture, offer a firm environmental assessment for major constructions, as well as training the local people on rationale water use and restoring groundwater-dependent ecosystems (Leveinen et al. 2010).

Status, threats and proposed measures for the three selected groundwater bodies

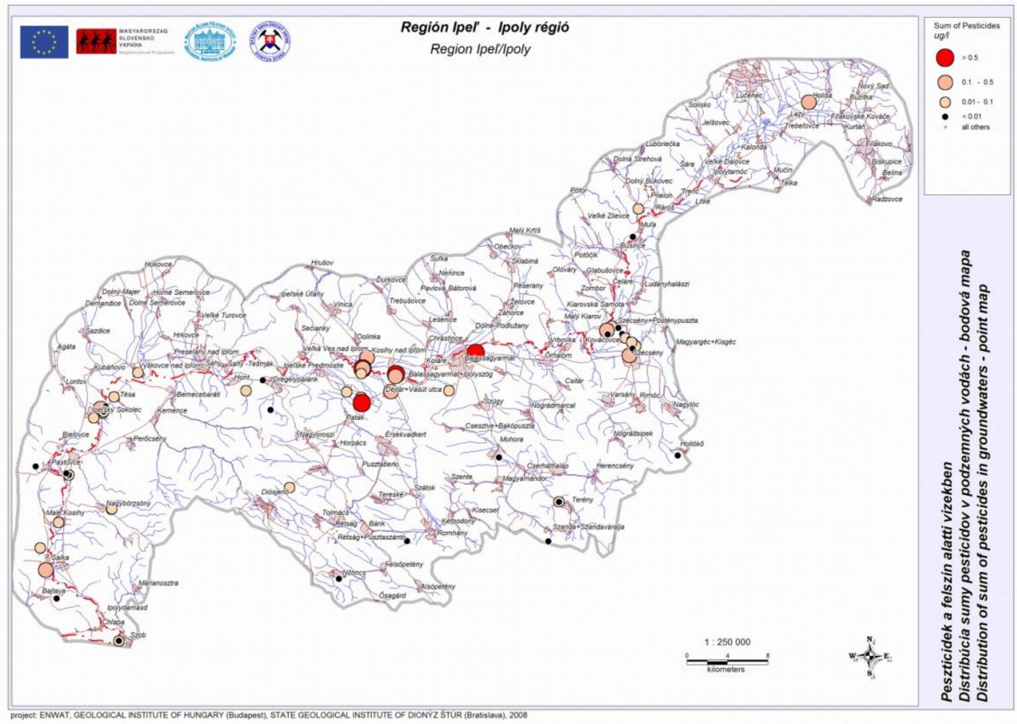
The three selected groundwater bodies have different geological-hydrogeological setting and environmental/utilization problems (Pethő et al. 2010, Szőcs et al. 2010). In the Ipoly/Ipel' valley and Bodrog basin aquifers are mostly found in the Quaternary alluvium, on the Aggtelek-Sloval karst groundwater bodies are in Mesozoic carbonates.

Ipoly/Ipel valley

Recent state. Total groundwater abstraction in 2002 was calculated 101,106 m^3/day. Although the water production is sustainable some parts of the groundwater bodies have poor chemical status. Locally high *pesticide* concentrations are found in both surface water and in groundwater samples along the Ipoly Valley (Fig. 7). Past use of pesticides has been intensive in Slovakia (25 kg/ha in 1997) and less in Hungary (2.8 kg/ha in1994-1996). *Nitrates* have also a substantial impact on the shallow parts (0-20 m) of the groundwater systems.

Threats. 63 obsolete stocks of pesticides were mapped in the Ipoly River catchments area. Depending on the thickness and properties of soil, migration of pesticides to groundwater can take up to tens of years. Pesticides in unsaturated soils can be released by erosion and climate change may increase this risk. Large-scale stock farming can worsen nitrate pollution of groundwater and associated surface waters.

Proposed measures. Pesticide pollution in subsurface and in surface waters should be assessed in detail followed by remediation actions. A public awareness campaign on the pesticides should be organized targeting particularly owners of orchards and local farmers and people at the agricultural parts of the settlements.



project: ENWAT, GEOLOGICAL INSTITUTE OF HUNGARY (Budapest), STATE GEOLOGICAL INSTITUTE OF DIONÝZ ŠTÚR (Bratislava), 2008

Figure 7. Distribution of pesticides in groundwaters in the Ipel valley

Aggtelek - Slovak karst region

Recent state. Chemical status can be considered good. Total groundwater abstraction in 2002 was 33,747 m^3/day. The water budget is maintained by the water abstraction mainly from springs (Fig. 8).

Threats. Climate change may increase extreme hydrological events. In the worst scenario, higher and more rapid flood peaks will set pressures to water channels by erosion while drought periods damage the ecology of the karst areas and ecoturism. A significant treat in this poorest part of Slovakia and Hungary is the uncontrolled land use and building on flood-prone areas.

Proposed measures. Rehabilitation and creation of wetlands provides water storages and prevention of basal erosion in flow channels as well as the cost-efficient measures including use of constructed wetlands as local waste water treatment systems to reduce local nitrate problems and eutrophication of surface water.

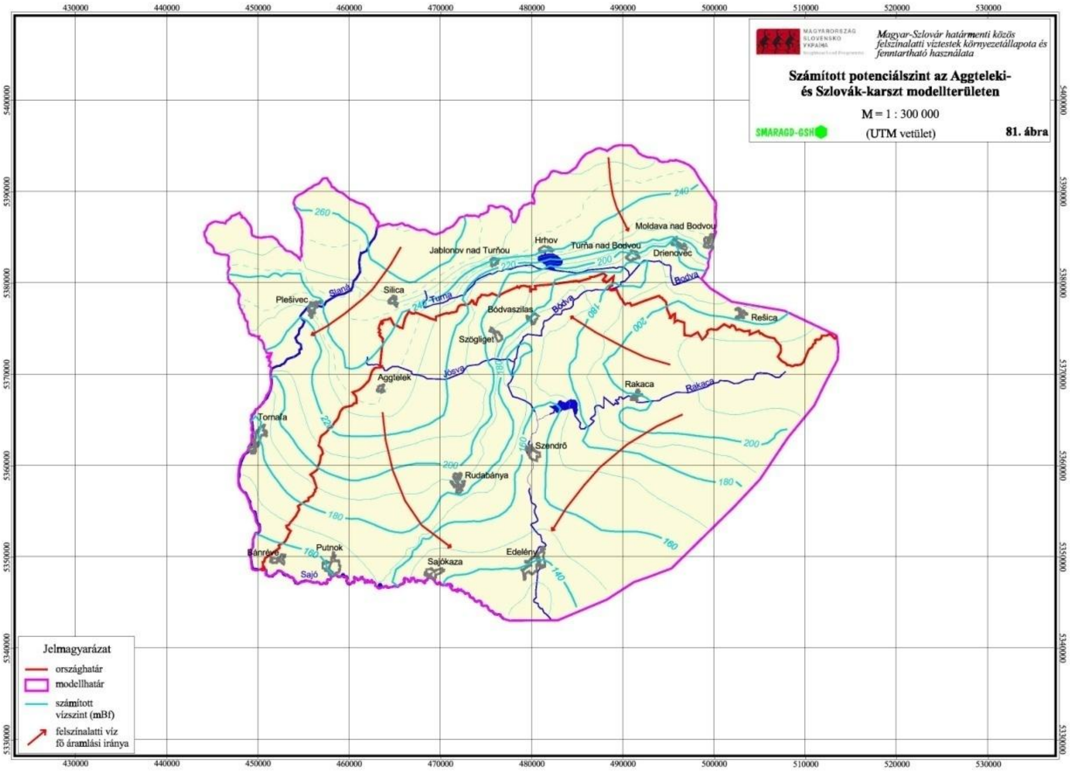


Figure 8. Measured hydraulic head in the Aggtelek and Slovak karts area

Bodrog region

Recent state Total groundwater abstraction rates in 2002 was 61,442 m^3/day. The drainage basin is in a state of equilibrium but the chemical status of groundwater is strongly affected by human activities. In Slovakia, average concentrations of *nitrates* exceed 50 mg/l in 0-20 m depths (Fig. 9). In spite of lower average concentrations in Hungary data includes high measured nitrate concentrations particularly in association with potential pollution sources such as rural settlements, and dump sites. Highest values of some components in Hungarian part of the study area exceed the quality standard several to couple of hundred times. The main anthropogenic components with significantly increased concentrations include NO_3^-, NH_4^+, NO_2^-, Cl^-, SO_4^{2-}, Fe^{3+}, Mn^{2+}, TDS, COD_{Mn}.

Threats. The salt contents in shallow groundwater can increase critically because of the increasing evaporation due to climate change (warming).

Proposed measures. Due to good denitrification and biodegradation potential of organic materials, the cost-efficient use of constructed wetlands suggested as local waste water treatment method. It is possible that most of the anthropogenic pollution can be attenuated so that the good qualitative status and environmental objectives in general can be attained. Improved agricultural practices should reduce nitrate pollution. Due to the relatively high TDS and Cl^- concentrations in shallow groundwater the future management of water resources should pay attention to the potential impacts of increasing evaporation in a warming climate.

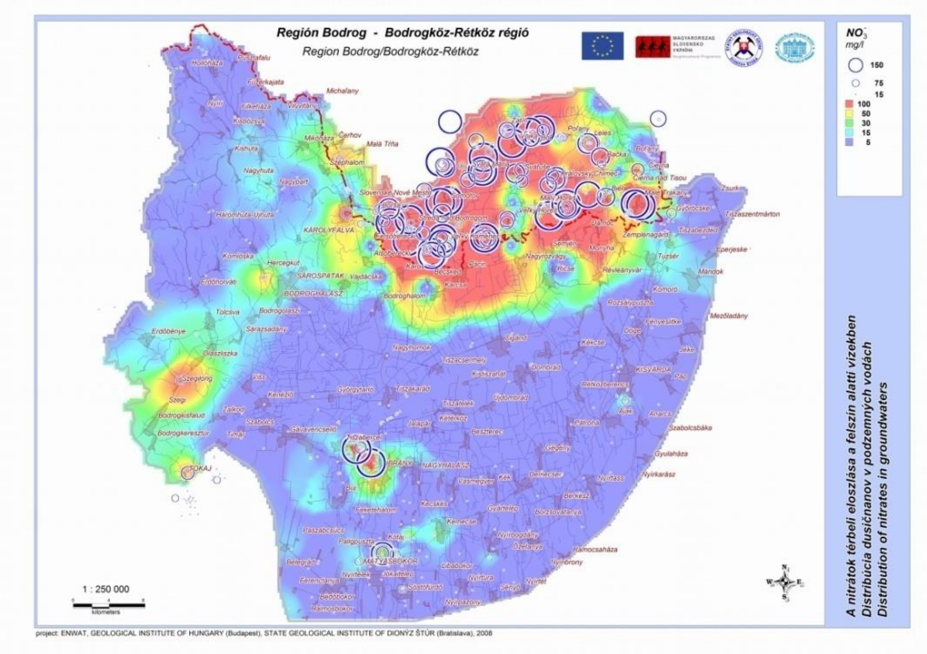


Figure 9. Distribution of nitrates in groundwater in the Bodrog region

As a summary it can be concluded that the ENWAT project served as a good example in establishing joint harmonized water management plan and recommendations for transboundary aquifers. Although it was not dealing with thermal groundwaters, but focus was rather on water quality of shallow aquifers, methodology (e.g. joint databases, hydrogeological modelling) served as a good example for similar work, such as e.g. Transenergy.

References

Brezsnyánszky K., Gaál G., Szőcs T., Tóth Gy., Bartha A,. Turczi G., Halmai J., Horváth I., Gál N., Gál B., Havas, G., Vikor Zs., Maigut V., Gyalog L., Nádor A., Kuti L., Malik, P., Kordik, J., Michalko, J., Bodiš, D., Švasta, J., Slaninka, I., Rapant, S., Bottlik, F., Maglay, J., Marcin, D., Cernak, R., Vrana, K., Kaija, J., Leveinen, J.,-.Ács V., Gondár, K., Kun É., Pethő, S., Sőregi K., Székvölgyi K. (készítette); Jerabek Cs., Katona G., Lajtos S., Muráti J., Pálfy É., Sásdi L., Tihanyiné Szép E. (közreműködött) 2008a: Zárójelentés Magyar-Szlovák határmenti közös felszínalatti víztestek környezetállapota és fenntartható használata. — Kézirat. Magyar Bányászati, Földtani és Geofizikai Adattár, Budapest, T: 21778.

Brezsnyánszky, K., Malik, P., Gaál, G., Szőcs, T., Tóth, Gy., Bartha, A., Havas, G., Kordik, J., Michalko, J., Bodiš, D., Švasta, J., Slaninka, I., Leveinen, J., Kaija, J., Gondár-Sőregi, K., Gondár, K., Kun, É., Pethő, S., Ács, V. 2008b: ENWAT: Hungarian-Slovakian transboundary groundwater bodies. — European Geologist 26, (Dec 2008), pp. 37–41.

Leveinen, J., Kaija, J., Savolainen, H. 2010: Water management of three Slovakian-Hungarian transboundary groundwater bodies. — A Magyar Állami Földtani Intézet Évi Jelentése a 2008. évről, pp. 129–134

Pethő, S., Ács, V., Gondár, K., Gondár-Sőregi, K., Kun, É., Svasta, J., Tóth, Gy. 2010: The function of the numerical hydraulic modeling in the case of the determination of the environmental status of transboundary groundwater bodies. — A Magyar Állami Földtani Intézet Évi Jelentése a 2008. évről, pp. 135–154.

Szőcs, T., Kordik, J., Horváth, I., Tóth, Gy., Bartha, A., Slaninka, I., Rapant, S., Bodiš, D., Novák, B., Repková, R. 2010: Hydrogeochemical evaluation of three transboundary groundwater bodies int he Ipoly/Ipel’ Valley, Aggtelek–Slovak Karst and Bodrog Basin of Hungary and Slovakia. —– A Magyar Állami Földtani Intézet Évi Jelentése a 2008. évről, pp. 167–186.

5. Screening of the geothermal utilization, evaluation of the thermal groundwater bodies and preparation of the joint aquifer management plan in the Mura-Zala basin (T-JAM)

Introduction

The T-JAM project (**T**hermal **J**oint **A**quifer **M**anagement, full title: Screening of geothermal utilization, evaluation of thermal groundwater bodies and preparation of joint aquifer management plan in the Mura-Zala basin) was running in the frame of the Slovenia-Hungary Operational Programme 2007-2013. The project's duration was from Sept. 1 2009 to Oct. 31 2011. Partners were Razvojna Agencija Sinergija (lead partner), Geological Survey of Slovenia (Geo-ZS), Geological Institute of Hungary (MÁFI), West Hungarian Environmental Protection and Water Managament Directorate (NYUDUVIZIG), Lokalna Energetska Agencija za Pomurje (LEA)

The final goal of the T-JAM project was to establish a common, harmonized thermal water management strategy for the area of the Mura-Zala basin (Fig. 10), which promotes the sustainable utilization of thermal groundwater body (divided by the Slovenian-Hungarian border but officially not delineated yet) and geothermal energy in the region.

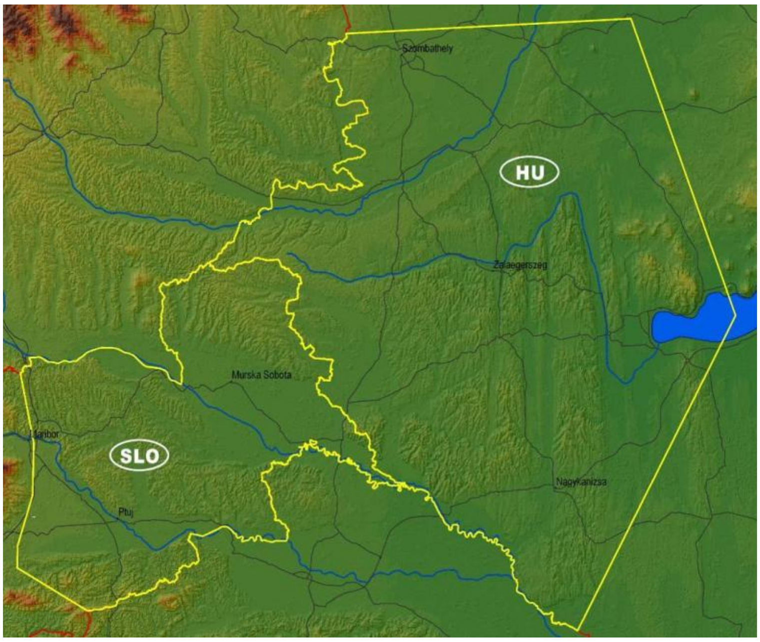


Figure 10. The T-JAM project area encompasses Pomurje, Podravje regions in Slovenia, Vas and Zala counties

The project intended to contribute to the solution of the problem of sustainable use of natural resources shared by neighbouring countries. The main carrying medium of geothermal energy is thermal groundwater, which flows along regional flow paths determined by geological structures independently of state borders. Possible negative effects (depression, decrease in yield and temperature) due to (over)exploitation in a given country may arise in the neighbouring country leading to political-economical tensions. Thus only a joint, cross-border, harmonized management strategy can lead to the sustainable utilization of hydrogeothermal resources.

Vast amount of scientific data on geothermal water management issues was gathered, evaluated and interpreted which allowed the common understanding of the cross-border groundwater flow system. All important knowledge for the characterisation of the joint hydrogeothermal system between NE-Slovenia and SW-Hungary were gained during the project and presented in separate reports (joint database, geological model, hydrogeological model, geothermal model, hydrogeochemical model and numerical flow model, utilization aspects). On the basis of their results the cross-border thermal water flow was identified and a common thermal groundwater body (Mura-Zala) was delineated for which recommendations for transboundary management and monitoring were phrased. All reports – including the recommendations for joint groundwater management are available at the project website: www.t-jam.eu

The project partners believe that implementation of the proposed joint management recommendations based on a firm geoscientific basis makes possible to achieve good status of the Mura-Zala transboundary thermal groundwater body according to the Water Framework Directive. Based on the project results the Permanent Slovenian-Hungary Water Management Commission could proceed to establish and perform joint management actions.

Delineation and characterization of Transboundary Thermal Groundater Body (TTGWB) Mura-Zala

Based on the geological extent of the major thermal aquifer system, and considering the major recharge and discharge areas, as well as the potential impact areas Transboundary Thermal Groundwater Body (TTGWB) Mura-Zala was delineated (Fig. 11). In the Hungarian part the vicinity of Lake Hévíz was also included, because it is the only groundwater dependent ecosystem of the project area, furthermore it is closely connected to the investigated thermal groundwater flow system. In the Hungarian part, where it was possible, the border of the intergranular thermal groundwater bodies, delineated for the EU Water Framework Directive, River Basin Management Plan (pt_3.1.and pt_1.1.) were followed. In Slovenia, the TTGWB Mura-Zala was delineated by the Slovenian - Croatian state border on the south, on the north by the Slovenian - Austrian state border, on the northwest by the pinching out of the Mura formation (major thermal groundwater aquifer) and on the west by the surface water divide between Mura and Drava rivers.

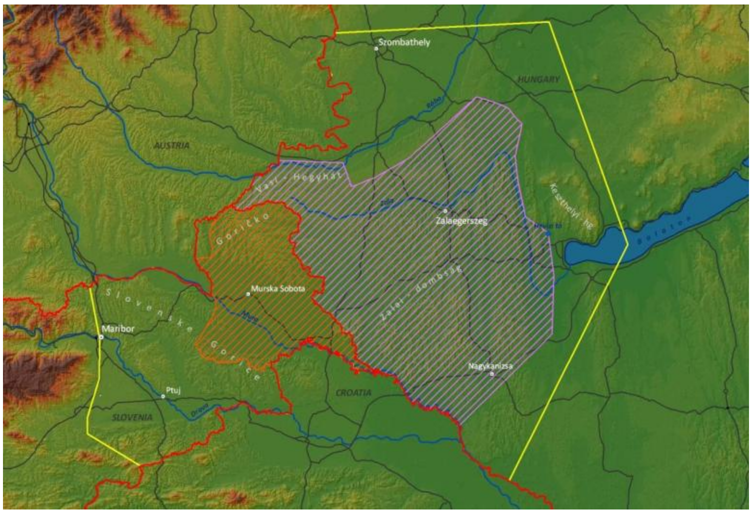


Figure 11. Areal extent of Transboundary Thermal Groundwater Body Mura-Zala.

The Transboundary Thermal Groundwater body Mura-Zala is a distinct groundwater body within the intergranular aquifer composed of the thick Neogene basin fill sequences. The aquifer is built up of Upper Miocene (Pannonian / Pontian) delta front, delta plain and alluvial plain sand-silt series of the Mura, Újfalu (and partly Zagyva) Formations. The top boundary of TTGWB Mura-Zala was delineated at a depth of -500 m below the surface, (majority of the thermal water wells are screened below this level). Some areas, where thermal waters (> 30 °C) are above the 500 m deep isobath, were also included (e.g. vicinity of Lake Hévíz, where thermal groundwater contributes by mixing to the discharge of the thermal karst spring). The bottom border of TTGWB Mura-Zala was delineated approximately at a depth of -2,200 m, where the thermal water aquifer is underlain by the clayey aquitard-aquiclude complex of the Upper Miocene Lendava and Algyő Formations. The surface area of TTGWB Mura-Zala is 4,974 km^2 (Slovenia 1,151 km^2 and Hungary 3,823 km^2), the shared state border length is 108.35 km.

TTGWB Mura-Zala is not hydrodinamicaly confined except at the bottom. It is opened to the neighbouring cold and thermal intergranular groundwater bodies, from where it gets its recharge. Open boundaries also cross the state borders (HU-SI, HU-CR, SI-CR, HU-AT). (Fig. 12).

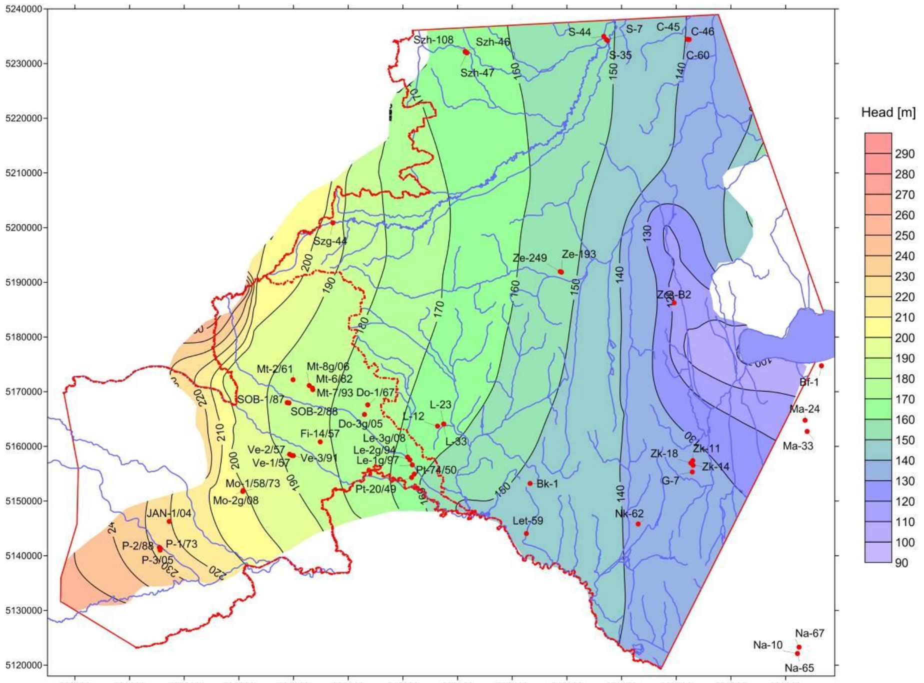


Figure 12. Computed head for the Mura / Újfalu system – natural, (pre-exploited) state. It clearly shows that the major thermal groundwater flows through the SLO-HU (and also AT and CRO) borders. The main direction is from west to east.

The thermal water stored in TTGWB Mura-Zala is of meteoric origin, based on the modelled travel times of a water particle (roughly equivalent to the age of infiltration) the majority of the thermal groundwater might have been be recharged into the flow system before the last ice-age, most probably in the Riss-Würm interglacial period (between 93,000-132,000 years before present). Thermal water is alkaline, mostly of Na-HCO_3 type. Outflow temperature is in the range of 30 to 70 °C. The water is reduced, as redox potential varies from -300 to -150 mV. The total dissolved solid content of groundwater increases with depth, from about 300 to about 4,000 mg/l.

Management framework

The main identified pressure on TTGWB Mura-Zala is the abstraction of thermal water by 13 users situated on Slovenian part and 29 users on Hungarian part (Fig. 13). Total average flow rate of the abstraction is 227 kg/s, including abstraction from the thermal karst (55 % SI and 45 % HU). Abstraction rate of thermal groundwater at maximum operation is 891 kg/s (33 % SI and 67 % HU).

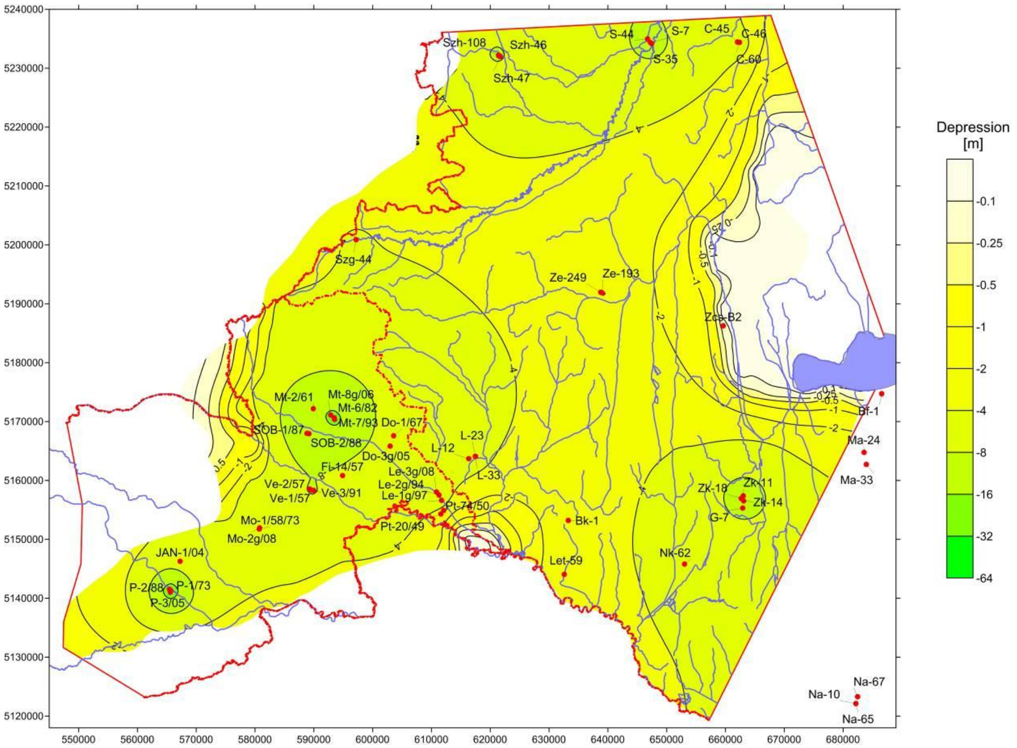


Figure 13. Depressions for the 6th thermal aquifer layer (Upper Miocene Pliocene delta front sediments of the Mura and Újfalu Formations) with thermal water abstractions both on the HU and SLO sides.

Along the border the computed depression is between 5-7 m meters, and it reflects the joint effect of the solely thermal water production in both countries. The depressions are smaller in grade and areal extent compared to that one, when the effects of the cold and thermal water abstraction were modelled together, clearly showing that the cold and thermal water reservoirs form a joint system and interactions exist.

During the numerical hydrogeological modelling three cases were investigated: the pre-exploited state, the present productions, and extreme version, with 5 times higher thermal water productions in both countries. Results showed that the pre-exploited balance between Slovenia and Hungary was strongly positive for Hungary: 5,137 m^3/day (59.5 l/s) water surplus from Slovenia. At the present productions decreased somewhat this value to 4,330 m^3/day (50.1 l/s). The extreme production scenario would cause much stronger change: only 649 m^3/day (7.5 l/s) would remain the surplus from Slovenia.

In the project both environmental and energetic objectives were phrased for both sides of the Transboundary Thermal Groundwater Body Mura-Zala. The environmental objective is to maintain the good status, i.e. prevention of actual status deterioration. This objective will be achieved by maintaining the long term positive water balance, i.e. the abstraction should not stop or redirect the recharge surplus from Slovenian to Hungarian side. This means that regional abstraction should not approximate to 5 times higher thermal water productions in both countries. If we take into consideration that the available reserves wouldn't be endangered if the abstraction doesn't exceed 70 % of the renewable volume of groundwater, the increment factor should not be more than 3.5. The critical point of 3.5 factor of abstraction increment should be lowered in the cases where significant negative long term trends of piezometric levels would be observed, or intrusions would occur, i.e. significant long term negative trends in thermal water quality, quantity, or temperature.

Regarding objectives related to the enhanced utilization of renewable energy, the envisaged increment factor of geothermal energy for heat production in both countries is approximately 3.7 for the period 2008 – 2020 according to national NREAP-s. Future increase of actual thermal water abstraction rate by a factor below 3.5 would theoretically enable to fulfil these targets. However, the priority related to energetic objectives should be to increase thermal efficiency. The temperature of discharged thermal waste water should be lowered as much as possible and reinjection should be promoted. Best available technologies (BAT) of water abstraction should be disseminated and required.

Proposed measures

Based on the main identified issues of joint thermal groundwater management, some specific measures were elaborated by the T-JAM project. These are the following:

Water rights granting

Water right for individual well should define the screened depth of the planned water production. In the permitting procedure it should be defined whether the production section of the well is entirely or partly situated in the Mura – Újfalu/Zagyva aquifer below 30° C isotherm or below 500 m depth.

Activation of new aquifer layers in the existing well should be reported, whether this activation could affect the Mura – Újfalu/Zagyva aquifer below 30° C isotherm or below 500 m depth.

Water rights for new or additional abstraction in Mura-Zala basin could be granted depending on the trend of water level taking into account the critical level point and critical point of abstraction:

Critical water level point

In case of decreasing trend in the thermal water level, the recommended critical point is 30 meters below the original pre-exploited potential. This value should be determined by regional transient hydrogeological model calibrated by the water level of monitoring wells further away from the production sites.

Critical point of abstraction

The suggested critical point of 3.5 factor of abstraction increment is valid for the border region, in 20 km for both (Slovenian and Hungarian) directions from the border.

In order to achieve a harmonized and evenly distributed abstraction system on the TTGWB Mura-Zala it has to be taken into account that the Hungarian side is 3.3 times higher than the Slovenian one, while the present productions are roughly the same.

The suggested 3.5 increment factor is based on the Slovenian thermal water extractions, mainly valid for the Slovenian part and for the border region on the Hungarian part. Detailed investigations are needed on the Hungarian side of the TTGWB Mura-Zala further than 20 km from the border.

Reduced areas for further developments of abstractions

10-15 km zones around the major production sites should be delineated as “reduced area” for further developments of abstractions:

- within these zones the maximum allowable abstraction rate should be determined („Mi” concept) and/or

- representative water level monitoring point (not too close to the centre of production well field) should be constructed and the critical level should be determined using a transient model.

The abstraction limit value or “Mi” concept could be adapted from the Hungarian Governmental Decree No. 219/2004 (VII. 21.) on the protection of groundwater.

Developments of abstractions outside of “reduced areas” should be evaluated by the impact assessment (risk analysis) by the help of the regional flow model.

Future research for electricity production from geothermal energy

Efficient operation of geothermal power plant relies on big discharge which causes the regional depression of piezometric head and large possible impact on cross border thermal water flow. In the exploration permitting process the impact of geothermal power plant wells on TTGWB Mura-Zala should be assessed from quality and quantity aspect. In the case of unfavourable results, where exploitation for electricity production would not be feasible, the exploration well could be eventually used for direct geothermal heat.

Maintenance of common knowledge platform

Geological maps and regional hydrogeological model of the Mura – Újfalu/Zagyva aquifer and maps of the 30 °C isotherm should be updated from the common transboundary database regularly - at least once in a 6 years period.

Available thermal water balance and critical level and abstraction points have to be updated at least every 6 years, regarding the contemporary monitoring data.

Information exchange

Information of intended abstraction increment has to be yearly exchanged between both sides. Information about intended drilling activities to Mura – Újfalu/Zagyva aquifer in the 20 km border area on each side has to be exchanged during procedure of exploration permitting. Geothermal energy productions from TTGWB Mura-Zala have to be reported yearly. Monitoring data has to be regularly exchanged. Common management and monitoring have to be approved by the permanent bilateral Slovenian – Hungarian water management commission. The accessibility of data from different monitoring networks has to be set up. It has to be also defined which data will be exchanged, what will be the format, and the time intervals, and which data will have free access, restricted access or no access.

Promotion of best available technologies (BAT)

Best available technologies (re-injection, increase of thermal efficiency) are proposed instead of increasing thermal water extraction to enhance thermal energy production.

Recommendations for joint monitoring

One of the key elements of the recommendations on common thermal groundwater management is the establishment of a joint groundwater monitoring system. The goal of a monitoring system in general is to foster realization of the environmental goals of the WFD, to ensure information about natural and man-induced processes and their trends. Monitoring has to support the periodical status assessments and the elaboration of the necessary action programmes. The monitoring system has to give information about the cross-border effects of human interventions in the transboundary groundwater bodies.

The WFD regards the aquatic environment continuous, so the monitoring has to be suitable to depict the water transfer among groundwater bodies, the connection between groundwater and surface water bodies and between groundwater bodies and related surface ecosystems. All this can be achieved with integration of observation locations set up for different purposes that contributes to a cost-effective operation.

The cross-border joint monitoring system has to be set up using mainly the existing objects. The most important elements of the system are the currently used monitoring wells. The existing national monitoring stations contain only a few number observation points targeting thermal water bodies, so data supply and periodical reviews deriving from the regular measurements of the operating wells become significantly important.

Comparison and joint evaluation of the monitoring measurements is possible on the basis of harmonised methods of processing and interpretation. This requires observations performed with the same method on the basis of a harmonized legislation.

During setting up the recommendations for a common monitoring network for the TTGWB Mura-Zala, all above considerations were taken into account. Because of the great depth of the Mura – Újfalu/ Zagyva aquifer, instead of creating a new monitoring network system, T-JAM project recommend to include existing monitoring, or non-operating thermal wells. These monitoring sites should be evenly distributed on the area taking into account the water flow direction and area of the highest utilisation and potential. Thus 17 observation wells were selected according to the aerial proportion, 5 observation wells from Slovenian part and 12 from Hungarian part of TTGWB Mura-Zala (Fig. 14). In the border area between Lendava and Lenti a common construction and operation of one representative monitoring well was proposed, because this area is of highest geothermal potential and the main flow of thermal groundwater is expect to cross the border from Slovenia towards Hungary here. This observation well would provide regional hydraulic head measurement and also quality of cross-border thermal water flow.

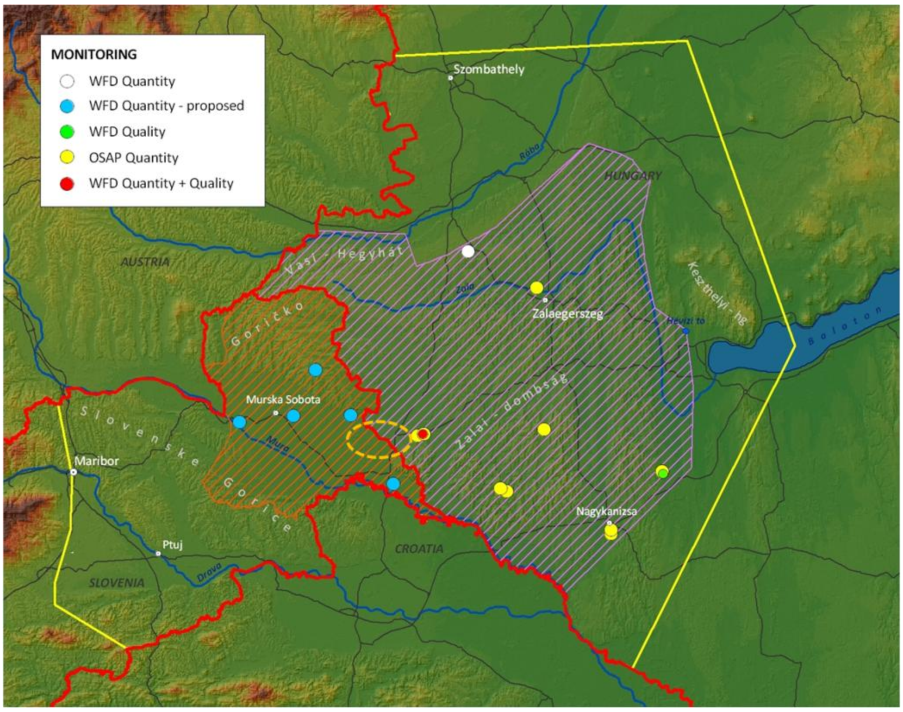


Figure 14. Proposed joint TTGWB Mura – Zala monitoring network.

ANNEX IV

Templates for description of transboundary groundwater body

1 Second Assessment of Transboundary Rivers, Lakes and Groundwaters under the UNECE Water Convention DATASHEET

Information in this datasheet is key input to the second Assessment of Transboundary Rivers, Lakes and Groundwaters under UNECE's Convention on the Protection and Use of Transboundary Watercourses and International Lakes. To ensure 1) that the information and data on the state and management of shared basins and aquifers are correct and 2) that the assessment reflects the views and priorities of the countries concerned, review of the draft information below by experts nominated by the countries is essential.

To facilitate the work of national experts the secretariat of the Water Convention has pre-filled datasheets on transboundary surface and groundwaters waters in Eastern and Central Europe on the basis of available official information in English, in particular the first Assessment, UNECE's Environmental Performance Reviews and official information that the countries have agreed to be used for this purpose.

The Working Group on Monitoring and Assessment was invited in its 10th meeting in Bratislava (10-11 June 2009) to provide its comments on the draft datasheet(s). The datasheet was revised in the light of the comments provided and used for the preparation of the second Assessment of transboundary rivers, lakes and groundwaters, mainly to clarify further what is expected.

When reviewing the datasheet and elaborating on the information, please take note of the following:

- Please be brief and clear.
- Provision of details for sections indicated by the Secretariat for information lacking or being deficient should be prioritized.
- Even though it is desirable to have all the parts filled in, please indicate the reason if any points have to be left blank, for example, because of the issue or factor being insignificant in the case of this particular basin or aquifer (or groundwater body), or because of there is simply not information available.
- The main interest in the information requested is in the transboundary dimension, for example in the case of measures taken or monitoring, but it is important to distinguish activities that are transboundary but also their linkage to the national framework. Information on the national arrangements is particularly relevant if no transboundary work or exchange is YET in place.
- Concerning groundwater: The objective is to collect technical information on transboundary groundwaters[8] and therefore the related input should not be limited by

---

[8] The physical scope of the UNECE Water Convention expressly encompasses "ground waters" (Art. 1, para. 1)

definitions of political or legal nature such as “groundwater body” in the sense of EU’s Water Framework Directive. Due to the Assessment’s technical nature and the regional scope, we would appreciate as priority input on transboundary aquifers. If this is not possible — for example due to the set up of data collection — information on groundwater bodies can also be provided, even though this makes it less comparable to the rest of the region. In such a case, the secretariat would be grateful if this could be mentioned clearly and if an explanation of the delineation criteria used could kindly be provided. If no transboundary groundwater body has been agreed upon and defined by the countries concerned, this will be clearly mentioned in the Assessment, should the countries so wish.

- Inclusion of tables, maps and graphs is very welcome when these illustrate for example the distribution of pressures within a basin or change in water quantity or quality over time. The latter is of particular interest if it can be linked to developments such as aggravated impacts or measures taken to protect the watercourses.

Part I: Draft datasheet for a river basin and groundwaters located within that basin

RIVER BASIN ______

The information already included in the present datasheet is based on the first Assessment of Transboundary Rivers, Lakes and Groundwaters in the UNECE region as well ….

Please amend and complete the information provided and include narrative description, as needed, in the tables below.

I. DESCRIPTION OF THE BASIN

Please indicate whether you have available high resolution maps of relevance for the basin that could be used for the assessment (e.g. groundwater resources, water bodies, land use, flood risk/vulnerability): _________

____

A. Introduction
The basin of the river ____________ is shared by ___ *[insert countries]* __________. The river has its source in _________ and discharges to _____________ *[please give final recipient such another river, a lake or the sea]*. The basin has a pronounced _____________ *[insert as appropriate: mountain, lowland,...]* character with an average elevation of about ______ m a.s.l. Major transboundary tributaries include: ________________________ *[More details on the major transboundary tributaries should preferably be given in separates datasheets.]* Transboundary and not-transboundary aquifers (or groundwater bodies) in the basin *[More details on these aquifers should preferably be given in separate datasheets.]*

B. Countries sharing the river basin Please provide only information regarding your own country's part of the basin.		
The area of the river basin in the country:	Country	Area in the country in km^2
Number of inhabitants and population density in the river basin in the country (persons/km^2, please indicate the source and year of the information):		

C. Land use/land cover *(% of the basin as well as additional information on different areas) Please provide only information regarding your own country's part of the basin. Use of European Corine (2000) landcover classification (or the respective categories) is encouraged, if possible (in the classification below agricultural land is split into cropland and grassland).*
Waterbodies (watercourses, lakes, reservoirs/ponds)
Forests:
Cropland (what % of the cropland area is irrigated):
Grassland:
Urban/industrial areas:
Surfaces with little or no vegetation
Wetlands/peatlands:
Protected areas (RAMSAR sites, NATURA 2000, etc):
Other forms of land use:
What are the trends and projected changes in land use in the basin due to drivers such as industrial/urban development, agriculture policies, demographic change, climate change, etc:

II. HYDROLOGY AND HYDROGEOLOGY

Please indicate the period of evaluation/observation for the parameters.

A. General information

Please provide information on water resources in the basin (surface waters and groundwaters). Please indicate, whether information relates to the national part of the river basin or the entire basin.

Water resources

Surface water resources: ____ m^3/year (average for the years ____ to ____)

Please separate 1) run-off generated internally from precipitation on the country's territory within the part of the basin that is the country's territory, as well as 2) incoming water from adjacent basin country/countries

Groundwater resources: ____ m^3/year (average for the years ____ to ____)

Groundwater resources are defined here as annual groundwater recharge derived from precipitation falling on the country's territory within the river basin concerned, plus entering external groundwater flow. Please distinguish these, if possible. Please remember that external groundwater flow may also originate from outside the basin.

Total water resources: ____ m^3/year (average for the years ____ to ____)

Total water resources per capita in the basin: ____ m^3/year/capita (average for the years ____ to ____)

B. Discharge characteristics

Please add more tables, if you have more gauging stations and in particular include data from gauging stations at the border.

For heavily regulated rivers and rivers in semi-arid and arid regions, please fill in the table under C below.

Gauging station (name and km reading e.g. from the mouth of the river or another fixed point): ________________

Discharge characteristics	Discharge	Period of time or date
Q_{av}	___ m^3/s	
Q_{max}	___ m^3/s	
Q_{min}	___ m^3/s	

Please provide some explanatory information of the data provided above, including information on the level of flow regulation.

C. Discharge characteristics for heavily regulated rivers and rivers in arid and semi-arid regions *(Please add more tables, if you have more gauging stations)*

Discharge characteristics of the _____ River at the gauging station ____

Q_{av}	____ m^3/s	Average for: ____
Mean monthly values:		
October: ____ m^3/s	November: ____ m^3/s	December: ____ m^3/s
January: ____ m^3/s	February: ____ m^3/s	March: ____ m^3/s
April: ____ m^3/s	May: ____ m^3/s	June: ____ m^3/s

July: ____ m^3/s	August: ____ m^3/s	September: ____ m^3/s

Please provide some explanatory information for the data provided above.

D. Additional information on groundwaters

Please provide information for each transboundary aquifer(or groundwater body; please specify which definition applies) in the basin

Aquifer/groundwater body.. Shared with countries............................

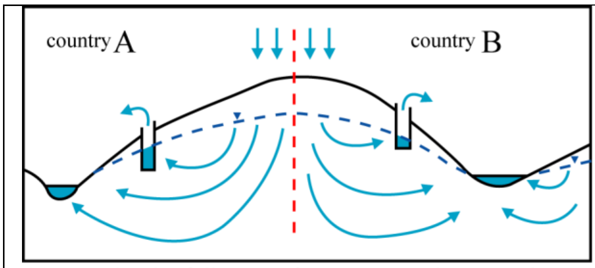
General characteristics of the aquifer/aquifer body in your country

a) Predominant lithology or lithologies..
b) Stratigraphy and age ....
c) Thickness: mean (m)............ maximum (m).............. d) Areal extent (km^2)...........................…
e) Dominant groundwater flow direction: from.. .... to .... *(countries)*
f) Link with surface water systems: strong ☐ medium ☐ weak ☐

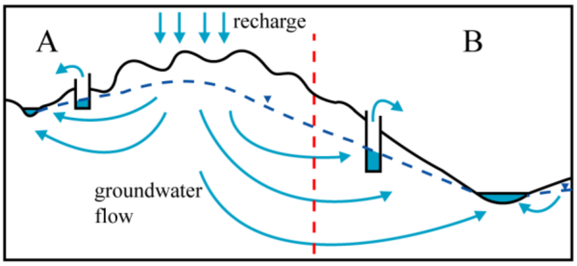
Provide indicate whether you have available a clear map of the transboundary aquifer, including its boundaries and adequate geographical reference (coordinates, projection type and projection parameters) (e.g. a GIS-file)

Brief description of the transboundary aquifer

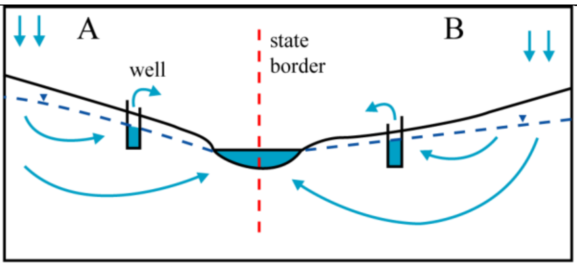
Please look at the four simplified pictures of groundwater systems below and indicate in the boxes which of them most closely characterizes your transboundary aquifer. If none of the four, then please provide a conceptual sketch of your transboundary aquifer in the blank box below.



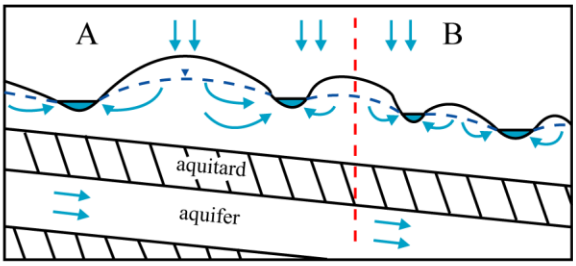
(1) state border follows surface water catchment and groundwater divide, little transboundary groundwater flow.



(2) Surface water and groundwater divides separate from state border, recharge in one country, discharge in adjacent.



(3) state border follows major river or lake, alluvial aquifer connected to river, little transboundary flow.



(4) Large deep aquifer, recharged far from border, not connected to local surface water and groundwater.

(5) Your conceptual sketch of your transboundary aquifer.

Please tick: Example 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

E. Interaction between surface water and groundwater in the basin

Please provide an integrated overview on the interaction between surface waters and the groundwaters in your own country's part of the basin; please consider both transboundary as well as non-transboundary aquifers in the basin. Please mention also if there are aquifers which are not connected to the rivers (for example coastal aquifers discharging directly to the sea).

F. Projected climate change impacts on hydrology

- Projected impacts of climate change on precipitation (rain and snow) including on seasonality
- Projected impacts of climate change on river discharge (including extreme events frequency and extent and impacts on yearly distribution of discharge)
- Projected impacts of climate change on groundwater level
- Projected impacts on water use (e.g. through increased irrigation)
- Projected impacts on groundwater quality
- Projected indirect or secondary impacts, for example on land use and agriculture

III. ANNUAL WATER WITHDRAWAL BY SECTOR

General Information

Please indicate, whether information relates to the national part of the river basin or the entire basin.

Current situation in [insert year]

Mean annual total renewable water resources in the basin (as in section II A above, the sum of surface water and groundwater resources):

Total withdrawal	Agriculture	Domestic	Industry	Energy	Other
____ m^3/year	___ %	___ %	___ %	___ %	___ %

Prospects for [insert year]

Mean annual total renewable water resources in the basin:

Total withdrawal	Agriculture	Domestic	Industry	Energy[9]	Other
____ m^3/year	___ %	___ %	___ %	___ %	___ %

---

[9] Please include only consumptive water use related to energy generation in the calculation of percentage, but please quote also the non-consumptive diversion of water, which occurs related to e.g hydropower generation.

Prospects for [insert year] Mean annual total renewable water resources in the basin:					
Total withdrawal	Agriculture	Domestic)	Industry	Energy	Other
____ m^3/year	___ %	___ %	___ %	___ %	___ %

IV. SPECIFIC USES AND FUNCTIONS OF TRANSBOUNDARY GROUNDWATERS IN THE BASIN

Provide information only for transboundary groundwaters in the basin and for the part of the aquifer/groundwater body in your country

Do transboundary groundwaters have specific uses and functions

No ☐ Why not? Irrelevant groundwater resource ☐
(no demand for groundwater)
Problems with groundwater ☐
(if so, indicate these in section V)

or:

Yes ☐ Uses ☐ Groundwater as % of total water use ....

Other functions: Support of ecosystems ☐
Support of agriculture ☐
(directly from shallow water table)
Preventing land subsidence ☐
Maintaining baseflow and springs ☐
Seasonal heat storage ☐
Any other function ☐
(please specify)....................................

V. MAIN PRESSURES AND PROBLEMS IN THE BASIN

Please indicate under the Narrative description, to which part of the basin the information relates to.

Types of issues/influences or activities exerting pressure	**Narrative description of related problems**	**Relative importance of the influence in the basin (1 - local and moderate, 2 - local but severe, 3 - widespread but moderate, 4 - widespread and severe)**
Geochemical processes or other natural pressure factors		
Natural water flow in the basin (extreme events, seasonality)		
Hydromorphological changes		
Agriculture and animal production		
Forestry		
Mining and quarrying		
Industry and manufacturing		
Electricity generation (e.g. hydropower, thermal power, nuclear power stations)		
Sewerage (e.g. untreated/insufficiently treated urban wastewater)		
Waste management (e.g. controlled and un-controlled dump sites)		
Transportation (road, pipelines)		
Navigation		
Storage (including tailing dams for mining and industrial wastes)		
Industrial accidents		
Discharges (permitted and illegal) from industries		
Groundwater abstraction (please specify for which use)		
Surface water withdrawal (please specify for which use)		
Recreation and tourism		
Other (specify)		

VI. STATUS AND TRANSBOUNDARY IMPACTS

Please provide brief statements and indicate the relative importance, in particular specify whether there are transboundary impacts.
Please indicate whether information relates to the national part of the river basin or the entire basin.

If some factors are a concern in the case of either surface water or groundwater in particular, please indicate this.

A. Most significant factors affecting surface water and groundwater resources , both in terms of quantity and quality, their relative importance for the basin including impacts on human health and the environment

Factors	**Relative importance for the basin [ranked as 1) local and moderate, 2) local but severe, 3) widespread but moderate, 4) widespread and severe] and impacts on human health and the environment**	**Implemented measures** *(this will complement information in section VII)*
(a)Water quantity and quality, including loss of biodiversity		
Natural/ background pollution		
Pollution from municipal wastewater (e.g. BOD, COD, nitrogen, phosphorus)		
Pollution from agriculture (e.g. nitrogen, phosphorus, pesticides)		
Pollution from industrial wastewater (BOD, COD, heavy metals, hydrocarbons)		
Thermal pollution		
Viruses and bacteria from lack/inefficiency of wastewater treatment facilities		
Radioactive substances		
Decline of groundwater levels (or piezometric levels), reduced baseflow and springflow of groundwaters		
Sea water intrusion in groundwaters		
Salt water upconing		
Groundwater pollution		
Land subsidence		
Flooding		
Scarcity and droughts		
Salinization		
Erosion/accumulation of sediments		
Suspended sediments, mud flow		
Eutrophication/Nutrification		
Loss of biodiversity in surface waters and water-related ecosystems		

Factors	**Relative importance for the basin [ranked as 1) local and moderate, 2) local but severe, 3) widespread but moderate, 4) widespread and severe] and impacts on human health and the environment**	**Implemented measures** *(this will complement information in section VII)*
Other (specify)		
(b) Environment, including water-related ecosystems (For selected basins this part will include an assessment of (transboundary) Ramsar sites in the basin.		
(c) Additional specific effects of climate change		

(d) Additional information on water-quality determinands and/or water-quality classification

Please add tables and/or graphs, containing for information/data on water-quality determinands and/or water-quality classification, for a certain number of years. Inclusion of graphs is particularly interesting if a trend over at least a few years can be seen, for example either the quality having gotten worse because of development or better thanks to measures that have been taken. Please indicate the time period for which the information is presented. Trends over time – covering in particular the recent years – are of special interest. Also, adding new data to continue what was presented in the first Assessment is very welcome.

B. Most significant impacts of surface water and groundwater resources availability (quantity and quality) on social development and key sectors of economy, the relative importance of the impacts for the basin and relevant measures

Social and economic aspects	**Relative importance of the impacts for the basin and the economy and social development [ranked as 1) insignificant, 2) limited, 3) moderate, 4) significant]**	**Implemented measures** *(this will complement information in section VII)*
Population displacement		
Impacts on industrial activities (e.g. mining, manufacturing)		
Impacts on occupation		
Impacts on electricity generation (e.g. hydropower, thermal power, nuclear power stations)		
Increased pumping lifts or costs for groundwater abstraction		
Impacts on physical infrastructures		

Social and economic aspects	**Relative importance of the impacts for the basin and the economy and social development [ranked as 1) insignificant, 2) limited, 3) moderate, 4) significant]**	**Implemented measures** *(this will complement information in section VII)*
Impacts on hydrotechnical constructions		
Impacts on navigation		
Impacts on costs related to supply of drinking water		
Forestry		
Impacts on soil quality and agriculture		
Tour operator activities/ Tourism		
Others: [specify]		

VII. RESPONSE MEASURES

Please describe the current approach to the management of transboundary waters (both surface and groundwaters), the measures which have been implemented, the existing gaps and the measures which are planned or foreseen to address these gaps. Please also include measures that are addressing water related sectors such as agriculture, energy and industry. In the case of agreements, please clarify 1) whether it covers both surface and groundwater, and 2) the geographical scope, that is, whether it covers the catchment or only a certain part of it. Please give also the title of the agreements, as well as date of signing and entering into force. For national laws, giving the year is sufficient.

(a) Legal and policy frameworks

Implemented measures:

- Bi- and multilateral transboundary agreements (scope, key provisions)

- National laws/regulations

- National strategies

- Integration of water management issues in the instruments related to other sectors, such as agriculture, energy and industry

- Other

Gaps in the legal and policy frameworks:

In transboundary agreements (scope, key provisions), national laws/regulations, national strategies, other sectoral policies, etc.

Foreseen measures to address these gaps *(indicate the expected implementation date):*

In transboundary agreements (scope, key provisions), national laws/regulations, national strategies, other sectoral policies, etc.

(b) Institutional framework

Implemented measures:

- Joint bodies on transboundary waters (mandate, composition and main activities)

- River basin organizations and councils

- Institutional arrangements to support inter-departmental and cross sectoral cooperation that also address water management

- Other institutional arrangements

Gaps in the institutional frameworks at the national and transboundary levels:

Foreseen measures to address these gaps *(indicate the expected implementation date):*

(c) Non structural management instruments

Implemented measures:

- Permit and licensing systems and their enforcement

- IWRM basin plans

- Conjunctive management of surface waters and groundwaters

- Water safety plans

-Recently agreed transboundary actions

- Water demand management measures or measures to increase water efficiency, including consumer metering and cutting distribution leakage losses and irrigation efficiency

-Measures to adapt to climate change

- Integration of water management issues in the instruments related to other sectors, such as agriculture, energy and industry

-Vulnerability mapping for land use planning

-Good agricultural practices

- Establishment of protection zones for drinking water supply

- Other management instruments

Gaps in the implemented management measures:

Foreseen measures to address these gaps *(indicate the expected implementation date)*

(d) Structural/technological measures

Implemented measures:

-Construction of dams, reservoirs

- Constructions of waste water treatment plants

-Decommissioning of dams and reservoirs

-Wastewater reuse or artificial recharge

- Efficient irrigation measures

- Other structural/technological measures

Gaps in the implemented structural/technological measures:

Foreseen measures to address these gaps *(indicate the expected implementation date)*

(e) Monitoring of transboundary waters (at the national and transboundary levels; both surface water and groundwater, please distinguish)

Implemented measures:

- Monitoring/data collection (extent of the network/number of monitoring stations, observation frequency) and exchange

-Joint monitoring programmes and pilot projects (scope, arrangements)

- Data management (including databases, information systems, quality assurance), assessment and reporting

-Funding (please specify what is covered from state budget and what from project funding)

-Others

Gaps in the monitoring of transboundary waters (at the national and transboundary levels):

Foreseen measures to address these gaps *(indicate the expected implementation date):*

(f) Financing and investments

Implemented measures:

- Use of economic instruments (charges and fees, incentives, payments for ecosystem services, etc)

- Financing and investments related to the IWRM (from national budget/international projects)

- Specific financial measures for transboundary actions

- Others

Gaps in financing and investments:

Foreseen measures to address these gaps *(indicate the expected implementation date):*

(g) Involvement of stakeholders

Implemented measures:

- Awareness-raising and education

- Public participation

- Private sector involvement

- Other aspects

Gaps in the involvement of stakeholders:

Foreseen measures to address these gaps *(indicate the expected implementation date):*

(h) Additional measures related specifically to adaptation to climate change and its impact on water resources and water dependent sectors (at the national and transboundary levels)

Implemented measures:

- Development of scenarios:

- Vulnerability assessment for the basin, for specific sectors

- Development of measures to increase resilience

- Development and implementation of prevention and preparedness measures

- Other aspects

Gaps in adaptation to climate change of the water and related sectors:

Foreseen measures to address these gaps *(indicate the expected implementation date):*

VII. FUTURE TRENDS

Please provide narrative description of the foreseeable trends on the status, possibly including scenarios on water quality and water quantity; taking into account drivers of change such as economic development, climate change, etc.

VIII. SUGGESTION FOR DECISION(S) TO BE TAKEN BY THE MEETING OF THE PARTIES TO THE UNECE WATER CONVENTION AND/OR ITS PROTOCOLS

IX. SUPPORTING INFORMATION

Useful links and publications (for example national water resources management plans of the country, documentation related to reporting on the implementation of the EU Water Framework Directive where applicable, national reports on climate change (e.g. for UNFCCC) and relevant project documentation, especially in case such material is focused on transboundary rivers, lakes or groundwaters):	
Annexes: Figures, maps (e.g. land cover/land use, distribution of diversions and dams or pressure factors, location of transboundary aquifers or groundwater bodies) and tables	
Contact information of the expert(s) who filled in this datasheet	
Name(s)	
Institution(s)	
Telephone and fax numbers	
E-mail addresses	

For any question on how to fill in the datasheet, please contact the secretariat of the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes at:

E-mail: water.convention@unece.org
Tel: +41 22 917 2463 or 2376

2 Draft initial characterisation (including risk information) of the transboundary GW-bodies of ICPDR basin-wide importance

GIS Templates

The respective GIS templates relevant for GW issues were elaborated by the GIS Expert Group:

GWBody
GWBodyAggr
GWStn

The templates are available for download at http://www.danubegis.org (after login) under "Template Tools" and they are attached in a separate file (Draft-Guidance-V2_2010-10-29_Annex2.xls):

The detailed content of the templates is explained in the related code lists.

The templates need(ed) to be submitted to DANUBIS by the national GIS experts in close cooperation with the groundwater experts (GW TG members) who are mainly responsible for the groundwater related content.

Templates MS Word and MS Excel based

The following tables were developed and discussed within the GW TG and used for the collection and exchange of information and data between the member countries and the ICPDR.

template description									info for database	
attribute name	**field name**	**field type***		**description of the attribute**	**values and codelists**	**obligation****	**obligation date according to WFD*****	**example values**	**key_to_field**	**linked_table**
DatabaseInternalKey	DANUBEID	double	10,0	Unique identifier for features in data set	automatic value	automatic value				
MetadataID	META_ID	string	24	Link to Metadata	"GWBody_" & ISO3166_CD Domain & RBDCode Domain	m		GWBody_AT1000	META_ID	Metadata
CountryCode	COUNTRY	string	2	Country Code	ISO3166_CD Domain	m		AT		
AreaKM2	AREAKM2	double	9,2	Area in square kilometers (in case of transboundary GWB size of national portion)		m				
Name	NAME	string	100	Locally used name of the Gwbody		m				
EuropeanGWBCode	EUCD_GWB	string	24	International code for a GW body	ISO3166_CD Domain & [MSCD_GWB]	m		ATGK100158		
MSGWBCode	MSCD_GWB	string	22	National code for a GW body		m		GK100158		
EcoRegionCode	ECOREG_CD	string	2	Ecoregion to which a waterbody belongs	EcoReg Domain	m			ECOREG_CD	Ecoreg
InsertedWhen	INS_WHEN	date		Moment of insertion in the database	DD/MM/YYYY	m				
InsertedBy	INS_BY	string	15	Acronym of operator		m				
Transboundary	TRANSBOUND	string	1	Does the groundwater body cross a country border	YNUnknown Domain	o				
EuropeantransboundaryGWBCode	EUCD_TGWB	string	24	Internationally agreed code for a transboundary GW body		c for (TRANSBOUND=Y and O_PART_B=A)		1 = Deep Groundwater Body - Thermal water AT/DE		

template description									**info for database**	
attribute name	**field name**	**field type***		**description of the attribute**	**values and codelists**	**obligation****	**obligation date according to WFD*****	**example values**	**key_to_field**	**linked_table**
EuropeanAGWBCode	EUCD_AGWB	string	24	International code for an aggregated GW body	ISO3166_CD Domain & [EUCD_TGWB]	c for (TRANSBOUND=Y and O_PART_B=A)		AT1		
GroupOfGWB	EUCD_GROUP	string	24	International code for a Group of GWBodies		o				
OutOfRBD	OUT_OF_RBD	string	1	Indicator if any part of GW falls outside RBD	YNUnknown Domain	m				
FinalDesignation	FINAL	string	1	Final or preliminary identification of GWB	Designation Domain	m				
EuropeanRBCode	EUCD_RB	string	24	Code of the parent riverbasin		c for international/bilateral subbasin activities			EUCD_RB	RivBasin
StatusYear	STATUS_YR	string	4	Year of reporting of waterbody characterisation		m				
Latitude	LATITUDE	double	8,5	Latitude (decimal degree) in ETRS89 that represents Gwbody		m		48,20154		
Longitude	LONGITUDE	double	8,5	Longitude (decimal degree) in ETRS89 that represents Gwbody		m		16,39586		
Horizon	HORIZON	integer	2	Unique identifier for the horizon where separate, overlying bodies exist. 0 in case that only one main horizon exists. The uppermost horizon starts with 1, the lower the horizon the greater the number		m				
Capacity	CAPACITY	double	10,3	Capacity of WB in m³		o				

template description									info for database	
attribute name	**field name**	**field type***		**description of the attribute**	**values and codelists**	**obligation****	**obligation date according to WFD*****	**example values**	**key_to_field**	**linked_table**
Indicatorfor LayeredGWB	LAYERED	string	1	Indicator for groundwater bodies with deeper relevant layers 0 = no deeper layers 1 = deeper aquifer layers		o				
GWStatusDate	GWSTAT_DAT	date		Date for which this GW status assessment is valid	DD/MM/YYYY	m				
QuantitativeStatus	QUANT_STAT	string	1	WFD Annex V 2.2	Status Domain	m	2009			
ConfidenceLevelQuantitativeStatus	CONF_QUANT	string	1		Conf_Level Domain	o	DRBMP 2009			
ChemicalStatus	CHEM_STAT	string	1	WFD Annex V 2.3	ChemStatus Domain	m	2009			
ConfidenceLevelChemicalStatus	CONF_CHEM	string	1		Conf_Level Domain	o	DRBMP 2009			
ExemptArt4.4	EXEMPT_4	string	1	Usage of extended deadline (2021/2027)	YNUnknown Domain	m	DRBMP 2009			
ExemptArt4.5	EXEMPT_5	string	1	Usage of less stringent objectives (2021/2027)	YNUnknown Domain	m	DRBMP 2009			
RiskDate	RISK_DATE	date		date for the risk assessment	DD/MM/YYYY	c if risk assessment given				
RiskTotal	RISK_TOTAL	integer	1	Risk for waterbody	Risk Domain	o				
RiskChemicalStatus	RISK_CHEM	integer	1	Risk category associated with the Chemical Status	Risk Domain	c if Chemical Status = unknown				
RiskQuantitativeStatus	RISK_QUANT	integer	1	Risk category associated with the Quanitative Status	Risk Domain	c if QuantitativeStatus = unknown				
SWBAssociation	SWB_ASSOC	string	1	Is the waterbody dynamically linked to any surfacewater(s)	YNUnknown Domain	o				

template description									info for database	
attribute name	field name	field type*		description of the attribute	values and codelists	obligation**	obligation date according to WFD***	example values	key_to_field	linked_table
ProtectedAreaAssociation	PA_ASSOC	string	1	Is the waterbody dynamically linked to any protected area(s)	YNUnknown Domain	o				
ReasonPointSourcePollution	RSN_P_POL	string	1	Is waterbody not in good status or at risk as a result of point source pollution	YNUnknown Domain	c if not in good status or at risk				
ReasonDiffusePollution	RSN_D_POL	string	1	Is waterbody not in good status or at risk as a result of diffuse pollution	YNUnknown Domain	c if not in good status or at risk				
ReasonWaterAbstraction	RSN_ABSTR	string	1	Is waterbody not in good status or at risk as a result of water abstraction	YNUnknown Domain	c if not in good status or at risk				
ReasonWaterRecharge	RSN_RECHAR	string	1	Is waterbody not in good status or at risk as a result of water recharge	YNUnknown Domain	c if not in good status or at risk				
ReasonSaltWaterFlowIntrusion	RSN_INTRUS	string	1	Is waterbody not in good status or at risk as a result of salt water intrusion	YNUnknown Domain	c if not in good status or at risk				
PollutantTrend	POLL_TREND	string	1	WFD Annex V 2.4 not defined	Trend Domain	m	2009			
OnlyPartB	O_PART_B	string	4	indication for data that is only used for part B (national or sub-basin), this data will not be represented in Part A overview-maps	O_Part_B Domain	m		Bsub = data that is only used on sub-basin-level, A = Part A data (i.e. it is both part A and part B data)		
OutOfSubUnit	OUT_OF_SUN	string	1	Indicator if any part of GW falls outside a Sub-Unit	YNUnknown Domain	o				
EuropeanSubUnitCode	EUCD_SUNIT	string	24	Unique code for a sub-unit at EU level		o		AT4	EUCD_Sunit	SubUnit

template description									info for database	
attribute name	field name	field type*		description of the attribute	values and codelists	obligation**	obligation date according to WFD***	example values	key_to_field	linked_table
EuropeanRBDCode	EUCD_RBD	string	24	Unique code for a river basin district	ISO3166_CD Domain & [MSCD_RBD]	m		AT1000	EUCD_RBD	RBD
GWBSizeClass	GWB_SIZE	string	2	sizeclass of the whole GWB (in case tranboundary: sum of the size of all parts)	SizeGWB domain	m		L		

Same template structure as GWBody

For this dataset: EUCD_GWB = EUCD_AGWB

template description									info for database	
attribute name	field name	field type*		description of the attribute	values and codelists	obligation**	obligation date according to WFD***	example values	key_to_field	linked_table
DatabaseInternalKey	DANUBEID	double	10,0	Unique identifier for features in data set	automatic value	automatic value				
MetadataID	META_ID	string	24	Link to Metadata	"GWstn_" & ISO3166_CD Domain & RBDCode Domain	m		GWStn_AT 1000	META_ID	Metadata
CountryCode	COUNTRY	string	2	Country Code	ISO3166_CD Domain	m		AT		
EuropeanGWStCode	EUCD_GWST	string	24	International code for the GW station	ISO3166_CD Domain & [MSCD_GWSt]	m		ATPG40006 22		
MSGWStCode	MSCD_GWST	string	22	National code for the GW station		m		PG4000622		
Name	NAME	string	100	Locally used name of the GW Station		o				
EuropeanGWBCode	EUCD_GWB	string	24	Unique code of parent GW Body		m		ATGK10015 8	EUCD_GWB	GWBody

template description									info for database	
attribute name	**field name**	**field type***		**description of the attribute**	**values and codelists**	**obligation****	**obligation date according to WFD*****	**example values**	**key_to_field**	**linked_table**
EuropeanAGWBCode	EUCD_AGWB	string	24	Unique code of parent aggregated GW Body		m		AT1	EUCD_AGWB	GWBodyAggr
Quantity	QUANTUM	string	1	Monitoring station of the groundwater level monitoring network for the quantitative status	YNUnknownDomain	m		Y		
Operational	CH_OPERAT	string	1	Monitoring Station of the chemical network for operational monitoring	YNUnknownDomain	m		N		
Surveillance	CH_SURVEIL	string	1	Monitoring Station of the chemical network for surveillance monitoring	YNUnknownDomain	m		Y		
ScreenRangeUpperLimit	SCREEN_UPP	single	6,1	Depth of the upper end of the screen		c for WELL_O_SPR = well				
ScreenRangeLowerLimit	SCREEN_LOW	single	6,1	Depth of the lower end of the screen		c for WELL_O_SPR = well				
Depth	DEPTH	integer	1	Depth in classes	DepthGWSamplingDomain	c for WELL_O_SPR = well				
WellOrSpring	WELL_O_SPR	string	6	Is the site a well or spring	WellSpring Domain	m		well		
OnlyMonitoring	MONITOR	string	1	Site is used for monitoring of groundwaterstatus only	YNUnknownDomain	m				
DrinkingWaterAbstraction	DRINKWATER	string	1	Site is used for drinking water abstraction	YNUnknownDomain	m				
IndustrialSupply	INDU_SUPPL	string	1	Site is used for industrial supply	YNUnknownDomain	m				
Irrigation	IRRIGATION	string	1	Site is used for irrigation	YNUnknownDomain	m				
OtherSupply	OTHE_SUPPL	string	1	Site is used for other purposes	YNUnknownDomain	m				

template description									info for database	
attribute name	**field name**	**field type***		**description of the attribute**	**values and codelists**	**obligation****	**obligation date according to WFD*****	**example values**	**key_to_field**	**linked_table**
Longitude	LONGITUDE	double	8,5	Longitude (decimal degree) in ETRS89 that represents EUCD_GWST		m		16,39586		
Latitude	LATITUDE	double	8,5	Latitude (decimal degree) in ETRS89 that represents EUCD_GWST		m		48,20154		
Part of Monitoring Network	PART_O_NET	string	100	Is the site part of other international monitoring networks (e.g. EIONET-water)? Codes for intaernational networks separated by comma	InternatNet Domain	m		A = EIONET		
InsertedWhen	INS_WHEN	date		Moment of insertion in the database	DD/MM/YYYY	m		1.4.2006		
InsertedBy	INS_BY	string	15	Acronym of operator		m		scheidleder		
OnlyPartB	O_PART_B	string	4	indication for data that is only used for part B (national or sub-basin), this data will not be represented in Part A overview-maps	O_Part_B Domain	m		Bsub = data that is only used on sub-basin-level, A = Part A data (i.e. it is both part A and part B data)		
RiverBasin	EUCD_RB	string	24	Unique code at EU level for a river basin		c for international/bilateral subbasin activities			EUCD_RB	RivBasin
EuropeanSubUnitCode	EUCD_SUNIT	string	24	Unique code for a sub-unit at EU level		o		AT4	EUCD_Sunit	SubUnit
EuropeanRBDCode	EUCD_RBD	string	24	Unique code for a river basin district	ISO3166_CD Domain & [MSCD_RBD]	m		AT1000		