Sava River Basin Management Plan

Background paper No.2

Groundwater bodies in the Sava River Basin

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1. Introduction

Groundwater in the Sava River Basin is of significant importance, mostly as a source of public water supply of population and industry, but also as a support for aquatic eco systems. According to the information collected for the purpose of preparation of the Sava RBMP, countries have identified 41 GWBs of basin wide importance. These GWBs are in the focus of the Sava RBMP and PoM.

Purpose of this Paper is to give an overview of delineation of GWBs in the Sava RB, methodologies for the assessment of groundwater chemical and quantitative status as well as results of status assessment. Since many gaps and uncertainties were identified concerning the current information on groundwater chemical and quantitative status, this fact pinpointed the need for establishment of groundwater monitoring or adaptation of the existing monitoring programmes to the WFD requirements set out in the Art. 8. Therefore, assessment of the existing national and basin wide groundwater monitoring networks with proposal for WFD compliant groundwater monitoring programme is also presented.

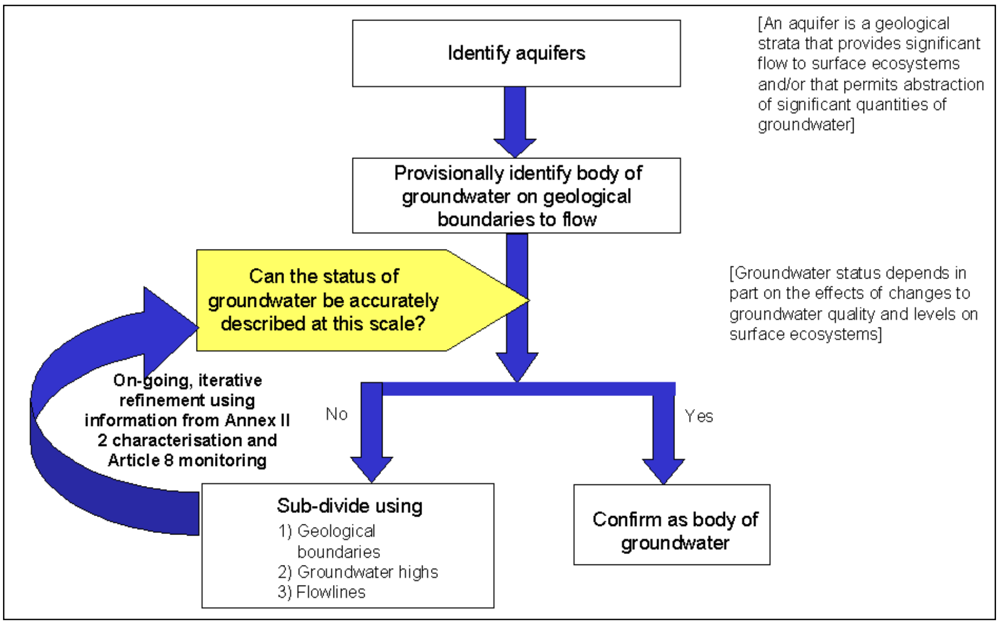
2. Delineation of GWBs

The diverse geological structure of the Sava River Basin comprises limestones, sandstones, gravel and permeable fluvial sediments, which are the main components of the aquifers of the important groundwater bodies. Different geological formations (with corresponding hydraulic properties of the aquifers), and the varying permeability of the overlying strata made groundwater bodies more or less protected from the anthropogenic influence.

To permit the accurate assessment of the groundwater status, countries have identified GWBs as coherent units in the river basin to which the environmental objectives must apply. Criteria for delineation of GWBs vary among the countries, reflecting different local geological and hydrogeological conditions and data availability on natural conditions and pressures. In general, hierarchical approach (groundwater ⇒ aquifer ⇒ groundwater body), recommended by CIS Guidance document on Identification of Water Bodies [1] was followed by all countries (Fig.1). The GWBs were generally delineated according to a combination of criteria including the geological type, borders of the surface catchment areas and present anthropogenic pressures.

[1] CIS Guidance Document no.2: *Identification of Water Bodies,* EC, Luxembourg, 2003.

Figure1: Summary of the suggested hierarchical approach to the identification of bodies of groundwater (Source: CIS Guidance Document no.2)



Delineation of groundwater bodies in *Slovenia* was based on significance of aquifers and aquifer systems, evaluation of anthropogenic pressures, significant flow between aquifers and aquifer systems and similar quality of groundwater[2].

Initial characterization of groundwater bodies in *Croatia* was carried out on the basis of geological and hydrogeological maps of different scales and numerous other published and unpublished studies. The basis for identification of the groundwater bodies included following elements: geological composition of the terrain, aquifer porosity, geochemical composition, hydrogeological characteristics, direction of the groundwater flow etc. Taking into account the potential groundwater uses and protection, the grouping of GWBs was carried out, for purposes to achieve the ecological goals, i.e. achievement of good groundwater status and establishment of surveillance monitoring.

In *Bosnia and Herzegovina*, for karstic aquifer type, definition of hydro-geological functions and characteristics of rock mass as well as designation of hydro-geological boundary of the basin (using tracer test where available) was used for delineation of GWBs. For non-karstic aquifers (intergranular porosity type), geological and hydrological (hydraulic) boundaries of the water bodies (in some cases using groundwater models) were the basis for delineation.

During the process of delineation of groundwater bodies in *Serbia* the principle criteria has been the geological characterization of the rock mass, hydrogeological boundaries as well as present quantitative pressures (groundwater use). On basis of the previously mentioned criteria, 44 groundwater bodies have been delineated in the Serbian part of Sava River Basin, out of which (based on defined criteria) 5 are of basin-wide importance.

Due to the late involvement of *Montenegro* in the process of WFD implementation, no delineation of groundwater bodies has been done. The Montenegrin portion of the Sava

[2] Pravilnik o določitvi vodnih teles podzemnih voda, (Ur. List Republike Slovenije st.63/2005).

River Basin is a mountainous region predominantly comprised of carbonate rock formations with incised river canyons, some of which are more than 1,000 m deep. Significant geomorphological characteristics of a major part of the area are extensive karst plains and overlying rock formations whose altitude can be more than 2,500 m. Karstic aquifers are predominantly elevated and deep aquifers with significant fragmentation of water bodies within them. In the scope of the preparation of Sava RBMP, the identification of GWBs in Montenegrin portion of Sava River Basin was done in a manner that groups of karstic water bodies in the river basins of Piva, Tara, Ćehotina and Lim were delineated. The boundaries of group of water bodies correspond to the boundaries of respective river basins.

On the scale of Sava River Basin (following the requirements of the Article 5 and Annex II of the WFD), in 2009 the SRBA Report was prepared, providing an overview of groundwater bodies of basin-wide importance. Criteria for identification of GWBs of basin-wide importance were established, defining them as:

- Transboundary and national GWBs important due to the size of the groundwater body (area >1,000 km^2) or
- If size smaller than 1,000 km^2, transboundary GWBs important due to other various criteria such as socio-economic importance; uses, impacts, pressures interaction with aquatic eco-system.

Since 2009 some countries have made changes in the delineation of GWBs. Furthermore, Montenegro joined the process of preparation of the Sava RBMP. According to information collected until November 2010, Sava countries have identified 41 GWBs of basin-wide importance, which are the subject of this RBMP (Table 1).

Table 1: Significant groundwater bodies in the Sava River Basin

No.	Country	GWB Name	Size (km^2)	Transboundary (Yes/No)
1	SI	Savska kotlina in Ljubljansko Barje	774.00	No
2	SI	Savinjska kotlina	109.00	No
3	SI	Krška kotlina	97.00	Yes
4	SI	Julijske Alpe v porečju Save	772.00	Yes
5	SI	Karavanke	414.00	Yes
6	SI	Kamniško-Savinjske Alpe	1,113.00	Yes
7	SI	Cerkljansko, Škofjeloško in Polhograjsko	850.00	No
8	SI	Posavsko hribovje do osrednje Sotle	1,792.00	No
9	SI	Spodnji del Savinje do Sotle	1,397.00	Yes
10	SI	Kraška Ljubljanica	1,307.00	No
11	SI	Dolenjski kras	3,355.00	No
12	HR	Sliv Sutle i Krapine	1,405.44	Yes
13	HR	Sliv Lonja - Ilova – Pakra	5,186.09	No
14	HR	Sliv Orljave	1,575.03	No
15	HR	Zagreb	987.52	Yes

No.	Country	GWB Name	Size (km²)	Transboundary (Yes/No)
16	HR	Lekenik – Lužani	3,444.26	Yes
17	HR	Istočna Slavonija - Sliv Save	3,328.12	Yes
18	HR	Žumberak - Somoborsko Gorje	443.30	Yes
19	HR	Kupa	2,870.29	No
20	HR	Una	540.57	Yes
21	HR	Kupa – krš	1,026.70	Yes
22	HR	Sliv Dobre	754.55	No
23	HR	Sliv Mrežnice	1,370.92	No
24	HR	Sliv Korane	1,244.71	Yes
25	HR	Una – krš	1,574.79	Yes
26	BA	Posavina II	1,350.00	No
27	BA	Romanija-Devetak-Sjemeč	2,050.00	No
28	BA	Treskavica-Zelengora-Lelija-Maglić	1,240.00	No
29	BA	Manjača-Čemernica-Vlašić	1,800.00	No
30	BA	Grmeč-Srnetica-Lunjevača-Vitorog	3,770.00	No
31	BA	Unac	1,720.00	No
32	BA	Plješevica	120.00	Yes
33	RS	Istočni Srem-OVK	1,593.65	No
34	RS	Mačva –OVK	763.41	No
35	RS	Zapadni Srem-pliocen	1,172.92	Yes
36	RS	Istočni Srem –pliocen	2,248.99	No
37	RS	Mačva-pliocen	1,577.53	No
38	ME	Sliv rijeke Pive *	1,500.00	Yes
39	ME	Sliv rijeke Tare *	2,000.00	Yes
40	ME	Sliv rijeke Ćehotine *	800.00	Yes
41	ME	Sliv rijeke Lim *	2,000.00	Yes

* In ME, karstic aquifers are predominantly elevated and deep, with significant fragmentation of water bodies within them. In the scope of the preparation of the Sava RBMP, the identification of GWBs in Mo n-tenegrin portion of the Sava RB was done in a manner that groups of karstic water bodies in the river ba-sins of Piva, Tara, Ćehotina and Lim were delineated. The boundaries of a group of water bodies corr e-spond to the boundaries of respective river basins.

3. Groundwater status assessment methodologies

3.1 Slovenia

National monitoring programme

Environmental Agency of Slovenia in accordance with the 96. and 97.article of Law on Environmental Protection and the Regulation on the emission monitoring of groundwater each year prepares a program of monitoring groundwater quality. The basic elements of monitoring are the network of monitoring sites, sampling frequency and parameters analyzed. Monitoring of the quality of groundwater in Slovenia is done since 1987. It is consistent with the requirements of the Water Framework Directive and the Slovenian legal regulations. The national monitoring of groundwater quality includes 123 sampling points in 15 water bodies of groundwater. The network is denser in aquifers with intergranular porosity and alluvial aquifers, where the groundwater is intensively used and pollution exist. At each point sampling is done 2-3 times per year. The analysis is done for 130 to 165 chemical and physical parameters in the following categories:

Basic parameters (determined by the natural characteristics of groundwater due to increased levels of pollution):

- Temperature of water, conductivity, pH, dissolved oxygen, TOC, COD, ammonium, nitrate, nitrite, sulfate, chloride, fluoride, hydrogen carbonate, Na, K , Ca, Mg
- Block pollution parameters: mineral oils, detergents anionactive, polychlorinated biphenyls
- metals and metalloids: Mn, Fe, Al, As, B, Cu, Zn, Cd, Cr (VI-val. and total), Ni, Pb, Hg
- pesticides and their metabolites: triazine, organochlorine, organophosphate, phenoxy acetic acid derivatives, chloroacetanilidni, urea derivatives, amides
- volatile halogenated aliphatic hydrocarbons: Halogenated derivatives of methane, ethane and ethylene
- Aromatics: benzene and its methylated and chlorinated derivatives

The quality of groundwater bodies and determination of trend

The quality of groundwater under the Regulation on the groundwater quality standards for the groundwater bodies is defined by chemical status. Determination of risk that groundwater body will not achieve good chemical status by 2015 is based on long-term trends in growth or lowering of chemical parameters in groundwater. Chemical status of groundwater bodies for each year is determined on the basis of:

1. Statistically processed results of the comparison parameters of groundwater quality standards;

2. Effects of salt water intrusion into groundwater body;

3. Inconsistency of samples specified in the monitoring of drinking water from groundwater body;

4. Deterioration of surface water associated with groundwater, and damage to be correlated with terrestrial and aquatic ecosystems.

Conditions for good chemical status of groundwater body:

1. Arithmetic mean (AM) of all groundwater parameters at all measurement points lower or the same quality standards, and if the condition is not fulfilled: the representative of the aggregated value (AMSK) all groundwater parameters are lower or the same standard of quality.

2. On the basis of measurement there is no evidence of intrusion of salt water, meaning that the sodium and chloride ions are higher than natural background.

3. Samples of drinking water drawn from the groundwater body, comply with the requirements for drinking water (Drinking Water Rules).

4. Contaminants in groundwater do not impair the status of surface waters and correlated terrestrial and aquatic ecosystems, groundwater bodies and long-term trends.

Groundwater bodies which do not meet the above conditions have poor chemical status. Pollution, for which it was found poor chemical status, is identified by a location and the cause. At each sampling point, the arithmetic mean is compared with quality standards.

Groundwater is of adequate quality if the arithmetic mean for all parameters is less than or equal to quality standards.

For non-compliant drinking water samples collected from the taps, a source from which it is derived is determined.

Long-term trends in growth and reduction parameters for the groundwater body are determined by linear regression analysis of dependence AM_{SK} = f (t).

Remediation measures at the water source are imposed if the upward trend is observed and AM_{SK} reaches 75% of limit value.

3.2 Croatia

Assessment of status and risks for groundwater bodies from the standpoint of groundwater quality

For purposes of assessment of groundwater quality status and risk within groundwater bodies, in line with the requirements of the Water Framework Directive (2000/60/EC) and the Directive on the protection of groundwater against pollution and deterioration (2006/118/EC), the methodology for assessment was as follows:

- Based on the results of the national groundwater quality monitoring (period 2007-2008 for the Pannonian part and period 2000-2007 for karst area) obtained from Croatian Waters (Hrvatske vode), «reference indicator values» (from surveillance and, in some cases operational monitoring), i.e. average measured values were determined. Additionally, as supplemental information on groundwater quality, analyses of other institutions and companies were used.

- As the «threshold indicator value» i.e. «threshold value» of groundwater quality indicators, the Maximum Permitted Concentration (MPC) in drinking water was used. This approach is adopted due to the fact that: (1) utilization of groundwater is mostly linked for public water supply, (2) in most cases there are no long monitoring series for indicators and (3) based on the existing knowledge, there are no determined ecosystems which require better water quality than the existing one.

- For each identified groundwater body, analysis of loads and impacts of human activity on groundwater was conducted. Available sources of pollution are divided into groups of point and diffuse sources. Spatial distribution of space use was carried out by means of the CORINE land cover map. The ranking of agriculture impacts in the Pannonian part of Croatia was carried out on the basis of assessment of applied quantities of agrotechnical substances per agricultural surface unit. For this purpose, data on artificial fertilizer sale in individual counties were used.
- Within status and risk assessment for groundwater bodies, analysis was conducted of natural vulnerability for the entire area of Croatia. It was carried out by applying the SINTACS procedure (Pannonian part) and procedure adapted for the karst area, which belong to the group of globally accepted «point count» models.
- The status or risk assessment (which depends on available data) was calculated with regards to the values of individual indicators. For this purpose, the value over 75% of the threshold value of an indicator was a criterion. Additionally, surfaces in the Pannonian part of Croatia on which negative anthropogenic influences were registered in relation to the total surface of a groundwater body were also taken into account. In cases where it was over 30 %, it was assessed that the whole groundwater body was at risk.
- Analyses of groundwater quality in groundwater body Zagreb showed the high concentration of nitrates, although they didn't reach 75 % of MPC. But, because of very high vulnerability of aquifer and high pressures of point and diffuses sources of pollution, this GWB was classified as "possibly at risk".

Assessment of status and risks for groundwater bodies from the standpoint of quantity status (groundwater resources)

It is possible to define over-exploitation of groundwater, i.e. abstraction quantity exceeding renewable groundwater quantity through analysis of time series of groundwater levels, river levels, precipitation and abstraction quantities.

The analysis of abstraction impacts on the quantity status of groundwater was carried out based on the following data:

- Time series of data on groundwater levels in the period 1997 - 2008 (Pannonian part of Croatia),
- Time series of data on water levels of the Sava river in the period 1997 - 2008 (Pannonian part of Croatia),
- Time series of data on precipitation in the period 1997 - 2008,
- Exploitation quantities of groundwater on individual abstraction sites (according to issued concessions),
- Estimated renewal of groundwater resources,
- Hydrogeological models of aquifers.

Considering quantity status, groundwater bodies with poor status or at risk (which depends on available data) are groundwater bodies within which there is a registered trend of groundwater level decrease and groundwater level decrease is the consequence of large abstracted quantities reaching down to renewable groundwater reserves.

3.3 Bosnia and Herzegovina

At present no defined methodology for status/risk assessment exists in Bosnia and Herzegovina. Since groundwater is predominantly used for public water supply, for the *chemical status assessment* the criteria were drinking water quality, according to Rule on Drinking Water (Off. Gazette Federation Bosnia&Herzegovina no. 40/10) and Rule on sanitary property of drinking water (Off. Journal of the Republic of Srpska no. 44/03). Most of the data collected for the purpose of status assessment are from chemical and microbiology analysis, provided by waterworks. There is an ongoing preliminary characterisation of groundwater and in scope of this process a kind of methodology (based on WFD) will be developed.

As for the *quantitative status assessment*, groundwater levels and discharges are not monitored systematically on most of the groundwater sources. Therefore, for the *quantitative status assessment* approximate water balance is calculated (based on water balance studies, groundwater models etc.) in order to establish available water vs. exploited water ratio. Due to the significant size (i.e. capacity) of groundwater bodies and relatively small existing exploitation there is no quantitative risk on the scale of large groundwater bodies. On smaller groundwater bodies (which are the size of karstic spring catchment areas), there are cases of where even the total spring discharge is used, with no overflow.

3.4 Serbia

Chemical Risk Assessment

To assess the risk of failure to achieve good chemical status due to diffuse sources of pollution, a risk map was compiled based on natural characteristics and pollution susceptibility (vulnerability map), and on local facilities and activities which might contribute to pollution (land use map).

The following reference documents were used within the scope of the applied methodology: a groundwater pollution vulnerability map (draft) and a CORINE Landcover 2000 (CLC2000) land use map (showing potential impacts of diffuse sources of pollution within the territory of Serbia).

A 1:500,000 groundwater vulnerability map was developed[3] with the goal to classify and identify areas of different degrees of vulnerability. Identified areas/degrees of vulnerability were colour-coded to denote various vulnerability levels. This map provides a sound basis for the management of planning documents, such as the spatial plan for a certain area, as well as for the assessment of pollution risk. The groundwater

[3] Draft map was developed by the University of Belgrade/Faculty of Mining and Geology (Department of Hydrogeology), the Jaroslav Černi Institute, and the Geological Institute of Serbia, within the scope of the project "Development of Groundwater Monitoring in the Republic of Serbia", funded by the National Water Directorate and the Ministry of Environment and Spatial Planning.

vulnerability map was prepared applying a compilation method referred to as IZDAN; acronym stands for:

I Inclination (terrain slope) – infiltration;

Z Soil/top soil;

D Roof thickness – geological medium overlying the water-bearing layer;

A Aquifer – hydrogeological characteristics of the terrain;

N Groundwater level (or depth-to-groundwater).

Each of these layers contributed a certain "weight" to the draft vulnerability map As a result, the formula used to compile the draft vulnerability map based on natural factors was:

$$U = 1*I + 1.5*Z + 2*D + 3*A + 2*N$$

The draft vulnerability map reflects six groundwater vulnerability levels, as shown in Table 2.

Table 2: Vulnerability levels

	Vulnerability level	Vulnerability index
1.	Very high	75 - 90
2.	High	65 - 75
3.	Medium-high	55 - 65
4.	Medium	40 - 55
5.	Low	30 - 40
6.	Very low, or land devoid of groundwater	11 - 30

Land use was assessed following the CORINE Landcover 2000 (CLC2000), which addresses 43 soil types grouped into 15 categories and then divided into 5 general soil classes. The land use map of Serbia identifies 38 different types. With regard to chemical pollution risk assessment, these soil types have been divided into three risk categories:

- 0 No pollution risk,
- 1 Category I risk,
- 2 Category II risk.

Category I risk on the CLC2000 map refers to artificial surfaces, such as: urban fabric, industrial and commercial units, and mine, dump and construction sites.

Category II risk on the CLC2000 map refers to agricultural areas, forests, and semi-natural areas such as: arable land, permanent crops, pastures, heterogeneous agricultural areas, forests, scrub and/or herbaceous vegetation associations, open spaces with little or no vegetation, and inland wetlands.

Applying GIS software and tools, the above sources of information were used to draft a groundwater chemical pollution risk map. Certain transformations had to be made to adjust the compiled map to present needs. Layer "overlaps" resulted in 18 undefined risk classes. These 18 classes needed to be grouped and defined further. Several categories were integrated into a single category and final risk assessment classes were then defined. This resulted in five risk classes, as shown in Table 3.

Table 3: Predefined risk classes

RISK ASSESSMENT			CORINE		
			Risk 1 High risk	**Risk 2 Medium risk**	**Risk 0 No risk**
VULNERABILITY MAP	Very high		Very high risk	High risk	Low risk
	High		High risk	High risk	Low risk
	Medium-high		High risk	Medium risk	Low risk
	Medium		Medium risk	Medium risk	Low risk
	Low		Medium risk	Low risk	No risk
	Very low, or land generally devoid of groundwater		No risk	No risk	No risk

Quantitative Risk Assessment

Considering the risk of not achieving good quantitative status, groundwater bodies within which there is a registered trend of groundwater level decrease as a consequence of abstraction are considered to be at risk. For this purpose, data time series of registered groundwater levels were used only for shallow GWBs, since no organized monitoring of deep aquifers exists.

For groundwater bodies where no quantitative monitoring exists, the estimate of groundwater balance is calculated, using available data on precipitation, abstraction etc. Assessment of risk from non-achievement of the good quantitative status until 2015 was carried out based on the criteria that average GW abstraction over several years < 50% of groundwater recharge, no substance intrusion into the body caused by the change of GW streaming direction and associated surface ecosystems are not endangered by GW abstraction. In case one or more of these criteria is not fulfilled the GW body is "at risk".

3.5 Montenegro

Montenegro has not established methodology for groundwater status/risk assessment. Assessment of the risk not to achieve environmental objectives for groundwater set in the Article 4 of the WFD for groundwater bodies in the Montenegrin part of the Sava River Basin is based on the expert knowledge.

4. Results of the groundwater status assessment

4.1 Groundwater chemical status

Results of chemical status (or risk) assessment of GWBs is presented by four categories: two status categories-"good" and "poor", and two risk categories - "at risk" (or "possibly at risk") and "not at risk". A GWB is classified as being in poor status or "at risk", if following the nationally adopted status assessment methodologies, criteria for good chemical status are not fulfilled. In cases of insufficient data, GWBs have been classified as being "possibly at risk" until more detailed information is available.

In Table 4 are presented the results of chemical status and risk assessment of the GWBs in the Sava RB.

Table 4: Results of chemical status and risk assessment for the GWBs in the Sava River Basin

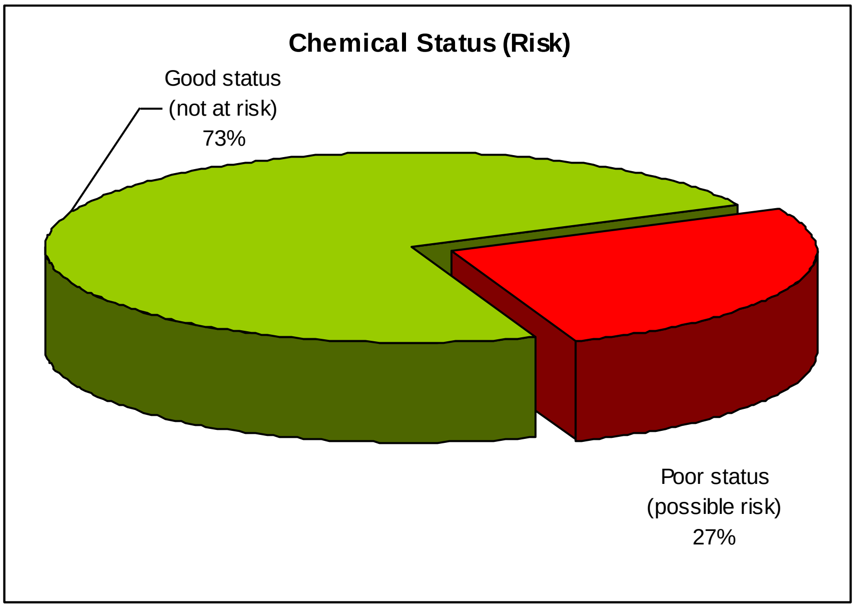
GW bodies		SI		HR		BA		RS		ME		Total Sava RB
		Nat.	Tran.	Nat.	Tran.	Nat..	Tran.	Nat.	Tran.	Nat.	Tran.	
Chemical status (risk)	Not at risk	-	-	4	5	-	-	2	1	-	4	16
	Good status	2	8	1	3	-	-	-	-	-	-	14
	At risk (or possibly at risk)	-	-	-	1	6	1	2	-	-	-	10
	Poor status	1	-	-	-	-	-	-	-	-	-	1

Results of status (risk) assessment concerning chemical status of groundwaters show that 11 GWBs (or almost 30%) are possibly "at risk" or have poor status and 30 GWBs are in good status (or not "at risk").

In cases where there was no status information available due to a lack of information (HR, RS, BA and ME), the information based on risk assessment is included. For the purpose of harmonized description of the status of GWBs, it was necessary to present the results of risk assessment as a status assessment with low confidence level. Confidence level is presented as high, medium or low, reflecting the confidence and precision of the results provided by the chemical monitoring programmes.

Results of the chemical status assessment of important GWBs in the Sava River Basin are presented on Figure 2 and in Annex 1.

Figure 2: Percentage of important GWBs in good/poor chemical status in the Sava RB



4.2 Groundwater quantitative status

As for the chemical status assessment, the results of quantitative status (or risk) assessment is presented by four categories: two status categories-"good" and "poor", and two risk categories- "at risk" (or "possibly at risk") and "not at risk". A GWB is classified as being in poor status or "at risk", if following the nationally adopted status assessment methodologies, criteria for good quantitative status are not fulfilled. In cases of insufficient data, GWBs have been classified as being 'possibly at risk' until more detailed information is available.

Based on the quantitative status (or risk) assessment, only three GWBs are possibly "at risk" not achieving good quantitative status, 38 GWBs are in good status or not "at risk" (Table 5).

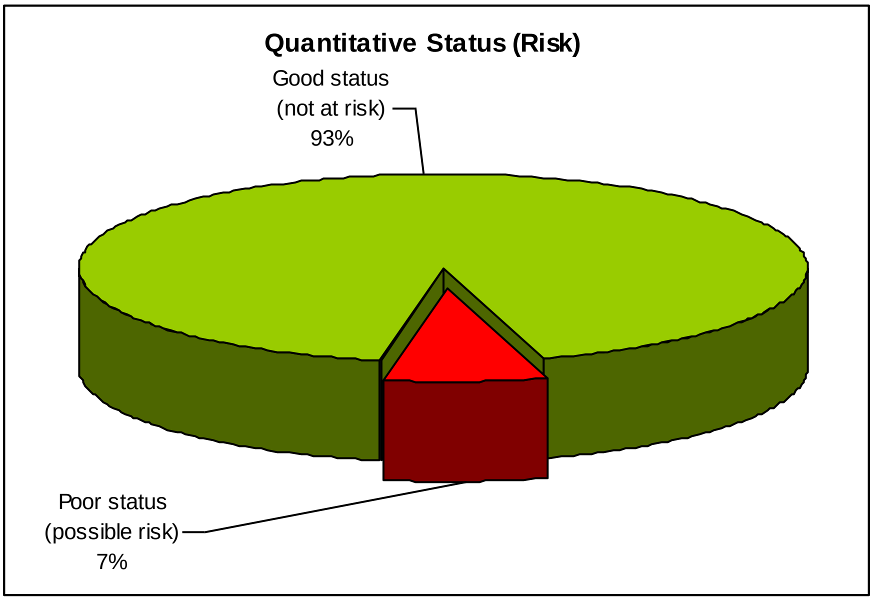
Table 5: Results of quantitative status and risk assessment for the GWBs in the Sava RB

GW bodies		SI		HR		BA		RS		ME		Total Sava RB
		Nat.	Tran.	Nat.	Tran.	Nat.	Tran.	Nat.	Tran.	Nat.	Tran.	
Quantitative status (risk)	Not at risk	-	-	3	5	6	1	2	1	-	4	22
	Good status	3	8	2	3	-	-	-	-	-	-	16
	At risk (or possibly at risk)	-	-	-	1	-	-	2	-	-	-	3
	Poor status	-	-	-	-	-	-	-	-	-	-	0

Where there were no information on status information available (HR, RS, BA and ME), risk assessment was used to present the status of GWBs. Similar as for the chemical status assessment the results of risk assessment for quantity were presented as a status assessment with low confidence level. Confidence level is presented as high, medium or low, reflecting the confidence and precision of the results provided by the quantitative monitoring programmes.

Results of the quantitative status assessment of important GWBs in the Sava River Basin are presented on Figure 3 and in Annex 1.

Figure 3: Percentage of important GWBs in good/poor quantitative status in the Sava RB



5. Groundwater monitoring in the Sava River Basin

Groundwater management is a part of the integrated management of all water resources, from a quantitative and qualitative perspective, focused on groundwater use, pressures and impacts. The role of groundwater monitoring in this management process is to provide reliable and timely information, pertinent to the basic elements of management.

Regardless of the different stages in the WFD implementation in Sava River Basin countries, there is a common need for adoption of existing national groundwater monitoring programmes with the requirements of the Art. 8 of the WFD, in order to establish a coherent and comprehensive overview of groundwater status.

The purpose of this chapter:

- To review the existing national and basin wide groundwater monitoring networks/programmes
- To analyze the limitations of existing national programmes and propose suggestions for improvement in line with Art.8 of WFD
- To define the basic elements of future WFD compliant groundwater monitoring programmes

5.1 Current monitoring programmes in the Sava River Basin

5.1.1 Basin wide monitoring networks

Danube TNMN

The development of the "Transnational Monitoring Network" (TNMN) of the ICPDR within the last 15 years was exclusively focussing on surface waters. Since 2000 and adoption of the WFD, revision of TNMN was under way, following the WFD implementation progress. In that manner, the transboundary groundwater management activities in the Danube River Basin District started in 2002, for the purpose preparation of Article V Report. 11 transboundary GW-bodies in the DRBD were identified as being of basin-wide importance, putting them in focus of WFD implementation activities of the ICPDR.

Monitoring of these selected GW-bodies was decided to be an integral part of the revised TNMN. The major objective of the revised TNMN is to provide an overview of the overall status and long-term changes of surface water and – where necessary – groundwater status in a basin-wide context with a particular attention paid to the trans-boundary pollution load. It should be emphasized that none of the 11 important GW bodies on Danube RB level identified for the 1st RBMP cycle lies within the Sava River Basin. However, the revision of the list of the important GW bodies is possible for the 2nd RBMP cycle so there is possibility that some of the important Sava RB GW bodies will be nominated also on the Danube basin-wide level.

The agreed six-year reporting cycle for groundwater, which is foreseen under the TNMN, is in line with the reporting requirements under the WFD. This will allow for making any relevant statement on significant changes of groundwater status for the GW bodies of basin-wide importance.

5.1.2 National monitoring networks

Slovenia

Groundwater monitoring programmes in Slovenia have been prepared on the basis of the requirements of Article 8 and Annex V of the WFD and GWD, as well as the relevant CIS guidance documents. For this purpose, a bylaw has been prepared (Pravilnik o monitoringu podzemnih voda, Uradni list RS, št. 31/09), defining types of programmes and principles for establishment of networks, monitoring frequencies and standards for groundwater sampling, transport and storage. Following requirements of WFD, in 2006 *Slovenia* established both quantitative and chemical (surveillance and operational) monitoring programmes. Monitoring network comprise different types of stations: drinking water wells, individual wells, automatic monitoring stations, springs etc. For karstic and fissured GWBs, monitoring of surface water flow (discharge) is used. Density of monitoring network is adjusted to hydrogeological homogeneity of aquifers.

For the monitoring of chemical and quantitative status of 11 groundwater bodies in Sava River Basin, there are approx. 70 monitoring stations. In period 2006-2008, on most GWBs, frequency of surveillance monitoring was 2-4/year covering all WFD core parameters (Oxygen, pH-value, Electrical conductivity, Nitrate, Ammonium and Temperature) as well as pollution parameters (mineral oils, PCBs, etc..), metals and metalloids, pesticides (organochlorine, triazine, organophosphate, etc..), volatile halogenated hydrocarbons (LHCH) and benzene and its derivatives.

Confidence level of groundwater chemical status assessment was defined by three scales: high, medium or low. High confidence level was assessed when the monitoring network represents hydrogeological characteristics of aquifers and the anthropogenic impacts, the data series are at least 2 years (5 years for polluted GWBs) long and monitoring sites are technically suitable. Criteria for medium confidence level are medium-representative monitoring networks, chemical datasets of water bodies at risk for at least 2 years. For low confidence level, one or more of the following criteria are valid: no available monitoring data, monitoring network is not representative related to hydro-geological characteristics of aquifers and the anthropogenic impacts and monitoring sites are technically less suitable.

Croatia

In Croatia, according to Croatian Law on Water ("Official Gazette ", no. 153/09), preparation of national annual monitoring program and monitoring of groundwater status is under responsibility of Croatian Waters. The ground-water monitoring in the Sava river basin is conducted on around 270 monitoring sites. The majority of monitoring sites are located on Zagreb aquifer, which is identified to be at risk. In general, monitoring plan is characterized by uneven coverage of the major aquifers, in terms of depth. Both in alluvial and karst aquifers, the monitoring network is related to wells and captured springs at abstraction sites, used for drinking water purposes. Groundwater monitoring results are published in the annual report on status of waters, which is submitted to the Ministry of Regional Development, Forestry and Water Management and Environ-mental Protection Agency.

Bosnia and Herzegovina

In *BA,* practically there is absence of systematic GW monitoring since early 1990's., except for groundwater sources used for drinking water supply, which are monitored and controlled by water supply companies and institutions responsible for public health. At 2005, systematic monitoring of groundwater in northern part of BiH has been established, on the territories of three municipalities (Bijeljina, Šamac and Modriča), on 33 sampling sites in total. Previously established monitoring on one GWB (local name "Semberija") in 2006 was ceased in 2008.

Serbia

The monitoring of groundwater resources in the Sava River Basin is performed at several levels:

- the national level (network of Hydrometeorological Service of Serbia-HMSS),
- a water supply source level (raw water networks) and
- level of other networks (such as in a portion of the riparian lands of the Sava River, which is within the backwater zone of the Iron Gate Dam).

HMSS Monitoring Network and Groundwater Monitoring Programmes were established under the previous Water Law (Official Gazette of the Republic of Serbia No. 46/91, 53/93, 67/93 and 48/94), in power until May 2010. It required that the HMSS monitor the groundwater regime only in the alluvial sediments and shallow aquifers of large water-bearing strata. A network of monitoring stations (total number in Serbia approx. 500) has been established for continuous monitoring of quantity and quality characteristics of surface water and groundwater regimes; the network is divided into monitoring areas corresponding to the basins of major rivers or large water-bearing strata within Quaternary sediments. Additionally, water quality is monitored at abstraction points and groundwater is occasionally tested under various projects. Systematic monitoring of Neogene and karstic aquifers was not established. The HMSS network distinguishes 3 types of stations: „Main hydrological stations“, „First level observation wells“ and „Second level observation wells“, different form the point of monitoring frequency and parameters observed. The principles of the HMSS present network design are:

• The HMSS monitors solely the first aquifer (mainly porous media).

• The groundwater monitoring network is spatially related to the wider river catchment areas.

• All observation wells are located in such a way as to prevent any influences through groundwater abstraction.

• The design of the monitoring network is not oriented at the land use.

• Abstraction wells and springs are generally not included in the governmental network.

As for nearly all chemical monitoring points in Serbia (in Sava River Basin approx. number 20), where water is sampled for chemical analyses of groundwater, the monitoring frequency is once per year. About 50 different parameters are analyzed on a regular basis. These parameters include the main cations (i.e., Na^+, K^+, Ca^{2+} and Mg^{2+}), the main anions (Cl^-, SO_4^{2-} and HCO^{3-}), and the three nitrogen components (NH_4-N, NO_2-N and NO_3-N), which are major indicators of agricultural impact on shallow aquifers. The redox-sensitive parameters, iron and manganese, are part of the monitoring program, as well as the heavy metals Zn, Cu, Cr, Pb, Cd, Hg, Ni and As. Furthermore, measurements for groundwater contamination originating with certainty from non-geogenic sources are also included. Some prominent pesticides, like Lindane, Atrazine, Simazine, Propazine, Aldrin, Endrin, and Methoxychlor, and other organic chemical components like PCB’s (potential anthropogenic contaminants), are also covered by this program. As far as chemical analysis is concerned, all major components - other than lightly volatile halogenated hydrocarbons (typical point-source related substances - defining the groundwater quality according to the EU WFD or the EU GWD), are covered by the regular groundwater quality monitoring program. Groundwater monitoring results are published annually in HMSS Annual Reports.

In 2010 two important legislative acts for future development of groundwater monitoring programmes were adopted: Law on Water (“Official Gazette of the Republic of Serbia” no. 30/2010) and Law on Meteorological and Hydrological Activities (“Official Gazette of the Republic of Serbia” no. 88/2010). Most important activities which lie ahead are those concerning preparation of bylaws, covering issues of GWB delineation and establishment of GW quality threshold values and status assessment methodology in general, institutional building and improvement of financial framework.

Montenegro

No information on groundwater monitoring in *Montenegro* was available.

Table 6: Parameters and frequency of surveillance monitoring programmes in the Sava RB

		Chemical parameters with frequency								Quantity parameters		
Country	GWB Name	Oxygen	pH-value	El. conductivity	Nitrate	Ammonium	Temperature	Further parameters, e.g. major ions	Operational monitoring	GW levels/well head pressure	Spring discharge	Extraction (not obligatory)
SI	Cerkljansko, Škofjeloško in Polhograjsko hribovje	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years		no			
SI	Dolenjski kras	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years		no		X	
SI	Julijske Alpe v porecju Save	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years		no		X	
SI	Kamniško-Savinjske Alpe	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years		no		X	
SI	Karavanke	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years		no		X	
SI	Kraška Ljubljanica	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years		no		X	
SI	Krška kotlina	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years		no	X		
SI	Posavsko hribovje do osrednje Sotle	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years		no	X	X	
SI	Savinjska kotlina	1/a	1/a	1/a	1/a	1/a	1/a		yes	X		
SI	Savska kotlina in Ljubljansko Barje	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years		no	X	X	
SI	Spodnji del Savinje do Sotle	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years	twice/six years		no	X	X	
HR	Sliv Sutle i Krapine	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a		X		X
HR	Sliv Lonja-Ilova-Pakra	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a		X		X
HR	Sliv Orljave	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a		X		X
HR	Zagreb	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a	X	X		X
HR	Lekenik - Lužani	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a		X		X
HR	Istočna Slavonija - sliv Save	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a		X		X
HR	Žumberak-Samoborsko gorje	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a				X
HR	Kupa	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a		X		X
HR	Una	occasionally	occasionally	occasionally	occasionally	occasionally	occasionally					X
HR	Kupa-krš	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a				X	X
HR	Sliv Dobre	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a					X
HR	Sliv Mrežnice	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a					X
HR	Sliv Korane	>1/a	>1/a	>1/a	>1/a	>1/a	>1/a					X
HR	Una-krš	occasionally	occasionally	occasionally	occasionally	occasionally	occasionally				X	X
RS	Istocni Srem-OVK	1/a	1/a	1/a	1/a	1/a	1/a	1/a	no	X		X
RS	Macva-OVK	1/a	1/a	1/a	1/a	1/a	1/a	1/a	no	X		X
RS	Zapadni Srem-pliocen	1/a	1/a	1/a	1/a	1/a	1/a	1/a	no			X
RS	Istocni Srem-pliocen	1/a	1/a	1/a	1/a	1/a	1/a	1/a	no			X
RS	Macva-pliocen	1/a	1/a?	1/a	1/a	1/a	1/a	1/a	no			

Remarks:	
1/a	Frequency once per year
>1/a	Frequency more than 1 per year
1/na	Frequency once per n years
X	Parameter is measured
NA	Not available information

5.2 Groundwater monitoring according to the requirements of WFD

According to the WFD, the primary focus of groundwater monitoring is the body of groundwater as a whole; however, monitoring also supports overall river basin district management and aids in the achievement of respective environmental objectives. Article 8 of the WFD requires the establishment of groundwater monitoring programs, which must produce information to determine if environmental objectives set out in Article 4 have been met; the information additionally allows for an assessment of: the qualitative status of groundwater, the chemical status of groundwater, significant long-term trends under natural conditions, and trends of groundwater bodies which result from human activity. These might have to be supplemented by additional monitoring programs to meet requirements relating to protected areas (e.g. protected areas of drinking water supplies), and to support the validation of characterization and risk assessment procedures stipulated in Article 5.

The WFD requires the establishment of four groundwater monitoring programs:

- Monitoring of quantitative status;
- Monitoring of chemical status (surveillance and operational); and,
- Monitoring of protected areas for drinking water supplies (DWPAs).

A *quantitative monitoring* network is set up to supplement and validate characterization and risk assessment procedures (Article 5), with respect to the risk of failing to meet good quantitative status objectives for all groundwater bodies or groups of such bodies. Based on Annex V, Section 2 of the WFD, member states are required to establish and maintain a quantitative status monitoring network whose density of representative monitoring sites is adequate to support the assessment of groundwater levels for each groundwater body or group of groundwater bodies. Such assessments must take into account short-term and long-term recharge variation, especially with respect to groundwater bodies that are at risk and groundwater bodies which extend across the border(s) of two or more states. The groundwater level regime is a parameter which is monitored because it indicates any disproportion between water abstraction and recharge; as such, it can be used to assess the quantitative status of a groundwater body. The frequency of groundwater level monitoring needs to be such, that it produces an adequate amount of data which are representative from a quantitative status perspective, keeping in mind long-term and short-term variations in recharge levels.

Chemical status monitoring is comprised of two types of monitoring conducted during the period covered by a river basin management plan: *surveillance monitoring* and *operational monitoring*.

Surveillance monitoring has multiple objectives; its main objective is the supplementation and validation of procedures relating to the characterization and assessment of the risk of failing to meet good chemical status objectives for groundwater. In essence, the outcomes of surveillance monitoring show whether and for which groundwater quality parameters there is a risk of failing to achieve WFD quality standards by the year 2015. This type of monitoring also produces data which are used to assess long-term trends in the concentration of various substances in groundwater, resulting from natural processes (conditions) and/or human activity.

According to the WFD, surveillance monitoring should be conducted at least once during the period covered by the plan, although the specific time is not stipulated.

When surveillance monitoring finds chemical quality parameters to be in excess of prescribed levels or to have a significant upward trend in concentration, such parameters become the object of further, detailed or *operational monitoring*. An *operational monitoring* program is established for groundwater bodies which are at risk of failing to meet the objectives set out in Article 4, in order to:

(a) identify the status of all groundwater bodies, or groups of groundwater bodies, which are found to be “at risk”, and,

(b) establish the presence of significant and sustained upward trends in pollutant concentrations.

Operational monitoring should be conducted between two surveillance monitoring cycles.

According to CIS DG GW 1 Monitoring Guidance document (2006), monitoring information is to be used for:

- Establishing the chemical and quantitative status of groundwater bodes (and assessing available groundwater resources);
- Use as input information in further characterizations of groundwater bodies;
- Validating risk assessments according to Article 5;
- Estimating the direction and rate of flow in groundwater bodies that cross member state boundaries;
- Use in the development of a program of measures;
- Assessing the effectiveness of the program of measures;
- Proving compliance with objectives relating to protected areas for drinking water supplies and other protected areas;
- Characterization of the natural quality of groundwater, including natural trends; and,
- Establishing the presence of anthropogenically-induced trends in the concentrations of pollutants, and assessing how to reverse such tends.

The WFD requires surveillance monitoring during each planning cycle and requires operational monitoring during periods which are not covered by surveillance monitoring. The WFD does not specify the minimum duration or frequency of surveillance monitoring. Operational monitoring, however, must be conducted at least once a year, during the interval between surveillance monitoring cycles.

Member states are required to implement surveillance monitoring in such a manner as to allow for adequate validation of risk assessments stipulated in Article 5, and to allow for collection of data for trend assessments. The scope of operational monitoring must be broad enough to allow for the identification of the status of bodies which are at risk, and of any significant and sustained upward trend in pollutant concentration.

According to Article 7 of the WFD, all groundwater bodies currently used for the abstraction of drinking water (or those which will be used for such abstraction in the future) and which provide more than 100 m^3/day (≈1.15 l/s), are subject to monitoring and control. As a result, special monitoring programs become necessary to assess potential impacts on *Drinking Water Protected Areas (DWPAs).*

This need for a special monitoring program for protected areas should not be interpreted as an obligation to establish a special network of monitoring sites; existing monitoring sites used for the other programs should be utilized to the maximum extent and monitored parameters should be adapted to meet the new requirements.

5.3 Basis of the future WFD compliant ISRBC Groundwater Monitoring Programmes

Future ISRBC GW monitoring network will be based on the existing national monitoring networks, assuming that most of the necessary information for basin wide level assessment will be obtained with minimum adjustments of existing monitoring programmes which are (or will be) WFD compliant. Existing national monitoring programmes are in some cases still under adaptation to the requirements of Article 8 WFD. The assessment of WFD compliance of existing monitoring programmes is the first step in the process of preparation of ISRBC GW monitoring.

5.3.1 Identified gaps in national groundwater monitoring networks and programmes and recommendations for further development

Establishment of monitoring programmes based on WFD principles is a prerequisite for reliable GW status assessment. Present absence of information on GW quantity and quality parameters resulted in low confidence of GW body status assessment, in many cases allowing only the assessment risk of not achieving environmental goals stated in Art. 4 of WFD. Since the future ISRBC GW monitoring network will be based on the national monitoring networks, the first task was to identify general weaknesses of the existing networks and programmes and to propose recommendations for improvement in line with the future needs.

Based on the information collected, major identified gaps in groundwater monitoring in Sava countries for different aspects are:

Legal and organizational aspect:

- Legal background for groundwater monitoring does not exist in all countries
- Ambiguous responsibilities of different state institutions concerning the monitoring, data flow
- Results of monitoring for other different purposes (drinking water production, GW protection, …) are often not used for the purpose of status assessment → no data flow

Concept of establishment of monitoring networks:

- Locations of monitoring sites (stations) mostly based on local hydrogeological settings and not on the conceptual model (understanding of the groundwater system), existing pressures (quantitative and chemical), vulnerability of aquifer and land use
- Unequal spatial distribution of monitoring sites → does not represent overall status of GW body

- Large areas not covered with any kind of monitoring
- Abstraction wells and springs are generally not included in the monitoring network

Concept of monitoring programmes (parameters and frequency):

- Measurement frequency and parameters are often not in accordance with existing pressures and possibility of entering the underground media
- List of analyzed chemical parameters is not reviewed and adjusted periodically
- Monitoring parameters are usually not focused on pressures affecting the overall state of the groundwater body

General recommendations for the development of groundwater monitoring:

- Establishment of legal background for groundwater monitoring (where it does not exist), with clearly defined objective, scope, types of monitoring, monitoring parameters, monitoring frequency, applied standards, responsible institutions
- Systematic integration of water supply companies (and other water users) into the national wide groundwater monitoring system by a legal solution; groundwater monitoring must also be the task of water users such as public and industrial water suppliers, using groundwater for drinking and process water purposes.
- The network should have a balanced spatial density which considers the conceptual understanding of the natural characteristics and of the pollution risks of the groundwater body, to help focusing monitoring activities in areas where significant pressures combined with higher vulnerability exist. This approach requires preparation of land use maps and vulnerability maps.
- List of monitoring parameters should be adjusted to the WFD requirements, Annex V (core parameters: oxygen content, pH value, conductivity, nitrate, ammonium + parameters which put GW body at risk of failing to achieve good chemical status. 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.
- The number of monitoring stations and sampling frequency should be proportional to the complexity of status assessment of the groundwater body and presence of upward pollution trends
- Local scale pollution processes which do not affect the overall state of the groundwater body should be the target of different monitoring activities run by the appropriate competent authorities (e.g. local authority etc.) responsible for the relevant legal provisions.

5.3.2 Objectives and scopes of future WFD compliant groundwater monitoring networks and programmes

The major objective of the ISRBC groundwater monitoring programmes is to provide an overview of the overall status and long-term changes in groundwater bodies of basin-wide importance. For Sava River Basin, criteria for identification of groundwater bodies of basin-wide importance were defined as follows:

- Transboundary and national GWBs important due to the size of the groundwater body (area >1,000 km^2) or
- If size smaller than 1,000 km^2, transboundary GWBs important due to other various criteria such as socio-economic importance; uses, impacts, pressures interaction with aquatic eco-system.

According to information collected, 41 GWBs were identified as of basin wide importance.

Compared to the criteria for TNMN (only transboundary GWBs area>4,000 km^2), the adopted criteria for Sava RB sets higher resolution and more comprehensive overview of groundwater status, focusing not only on transboundary issues. At this point, within the scope of TNMN, there are no groundwater bodies which lie within Sava RB, so the ISRBC groundwater monitoring programme practically will be the only programme covering ground waters in this part of Danube RBD.

ISRBC monitoring will be focused on both national and transboundary groundwater bodies. While for national GW bodies countries have different criteria for the design of monitoring networks (mainly based on already existing national monitoring programmes), for transboundary GW bodies there are specific provisions of the WFD. Main focus in the future bilateral activities of Sava countries sharing the same aquifers should be:

- Development of conceptual models of GW bodies
- Achievement of harmonised monitoring networks
- Establishing of criteria for the selection of parameters

5.4 Description of the WFD compliant Groundwater monitoring programmes in the Sava River Basin

5.4.1 Groundwater Quantitative Monitoring

Objective

Main objective of quantitative monitoring is to validate characterization and risk assessment of failing to meet good quantitative status. Such assessments must take into account short-term and long-term recharge variation, especially with respect to groundwater bodies that are at risk and groundwater bodies which extend across the border(s) of two or more states. The groundwater level regime is a parameter which is monitored because it indicates any disproportion between water abstraction and recharge; as such, it can be used to assess the quantitative status of a groundwater body. For transboundary GW bodies, additional objective is to estimate the direction and rate of groundwater flow across the Member State boundary.

Selection of monitoring sites and parameters

The monitoring network shall be designed so as to provide a reliable assessment of the quantitative status of all groundwater bodies or groups of bodies including assessment of the available groundwater resource. The choice of where to monitor will depend on what is needed to test the conceptual model and the predictions it provides. In principle, the more spatially variable the groundwater flow system or the pressures on it, the greater the density of monitoring points that will be required to provide the data needed to make suitably confident assessments of the status of a groundwater body, or group of bodies.

Selection of monitoring sites also depends on the parameters which should be observed (measured). Although WFD requires only monitoring of GW levels (in boreholes and wells), recommendation is that other parameters should be monitored for the purposes of quantitative assessment of groundwater[4] :

- Spring flows
- Flow characteristics and/or stage levels of surface water courses during drought periods
- Stage levels in significant groundwater dependent wetlands and lakes.
- Water abstraction

Spring flows or even base-flows in rivers are more appropriate, especially in large parts of Interior Dinarides, with karstificated limestones of the mountain massifs and karst areas.

Monitoring frequency

The most appropriate monitoring frequency will depend on the understanding of the groundwater system and the nature of the pressures on the system. The frequency chosen should allow short-term and long-term level variations within the groundwater body to be detected. For example, for formations in which the natural temporal variability of groundwater level is high or in which the response to pressures is rapid, more frequent monitoring will be required than will be the case for bodies of groundwater that are relatively unresponsive to short-term variations in precipitation or pressures. Where monitoring is designed to pick up seasonal or annual variations, the timing of monitoring should be standardised from year to year.

5.4.2 Groundwater Surveillance Monitoring

Objective

Surveillance monitoring shall be carried out in order to:

- supplement and validate the risk assessment carried out for 2009 SRBA Report
- provide information for use in the assessment of long term trends both as a result of changes in natural conditions and through anthropogenic activity

For transboundary GW bodies, according to Annex V 2.4 of WFD, additional objective for surveillance monitoring is to provide sufficient monitoring sites to be monitored for those parameters, which are relevant for the protection of all uses supported by the groundwater flow. Beside these basic objectives, results of the surveillance monitoring

[4] Common Implementation Strategy for the Water Framework Directive: Groundwater Monitoring-Technical report on groundwater monitoring as discussed at the workshop of 25th June 2004, Brussels, 25th June 2004

will be used for design the monitoring programmes of current and subsequent river basin management plans.

Selection of monitoring sites and parameters

Surveillance monitoring should be carried out on identified important groundwater bodies in the Sava RB in order to provide an assessment of the overall chemical status. The selection of monitoring sites process should be based on three main factors:

- the conceptual model (hydrological, hydrogeological and hydrochemical characteristics of the body, different types of land uses, receptor sensitivity),
- risk assessment and the level of confidence in the assessment,
- practical considerations relating to the suitability of individual sampling points.

Monitoring sites should be chosen based on the possibilities to monitor the potential impacts of identified pressures. Selected sites should be representative with regard to continuity of measurements, for the purpose of trend assessment, therefore missing of two or more subsequent values should be avoided for trend assessment.

These specific considerations regarding the suitability of individual groundwater sampling points (monitoring stations) require local knowledge and experience of national experts who are involved in monitoring process on state level. Based on their expertise, sufficient number of appropriate monitoring sites will be selected for surveillance monitoring. For transboundary GW bodies, the selection of monitoring sites should be bilaterally agreed.

Selection of monitoring parameters

According to Annex V, 2.4.2 of WFD the following core set of determinants must be monitored on all GW bodies:

- dissolved oxygen,
- pH-value,
- electrical conductivity,
- nitrate,
- ammonium,

As for the transboundary groundwater bodies, beside the core set of parameters they shall also be monitored for those parameters which are relevant for the protection of all of the uses supported by the groundwater flow.

ICPDR GW TG recommended that within TNMN temperature and a set of major (trace) ions should also be monitored. These parameters are not formally requested by the WFD but may be helpful to validate the Article 5 risk assessment and the conceptual models. Selective determinants (e.g. heavy metals and relevant basic radio nuclides) would be needed for assessing natural background concentrations.[5]

[5] CIS Guidance Document No. 15: Groundwater Monitoring. (2007).

Sampling frequency

For groundwater surveillance monitoring there isn't required minimum frequency. Sampling frequency should be in accordance with the natural conditions of the GW body, meaning that it should be based on the conceptual model and, in particular, the characteristics of the aquifer and its susceptibility to pollution pressures.

Since in most of the Sava countries monitoring programmes are in different stages of adaptation to WFD standards, sampling frequency will be decided from case to case. One proposal for setting sampling frequencies depending on aquifer properties (porosity type, depth to GW, type of cover layer, recharge) is presented in Table 7.

Table 7: German guidance on monitoring frequencies in relation to aquifer properties

Scenarios	Frequencies					
	Monthly	Quarterly	Half yearly	Yearly	2 Years	5 Years
Shallow groundwater (depth to table ≤ 3 m), unconfined porous aquifer	(x)	X	X	(x)		
Deep groundwater (depth to table ≥ 10 m), unconfined porous aquifer				(x)	X	X
Shallow ground-water (depth to table ≤ 3 m), unconfined fractured aquifer	(x)	X	X	(x)		
Deep groundwater (depth to table ≥ 10 m), unconfined fractured aquifer		(x)	X	X		
Karst aquifer (without more or less impermeable cover)	X	X	X			
Karst aquifer (with more or less impermeable cover)	(x)	X	X	(x)		
Confined groundwater (with more or less impermeable cover with thickness < 2 m)				X	X	(x)
Confined groundwater (with more or less impermeable cover with thickness > 2 m)				(x)	X	X
High rate of recharge		(x)	X	X		
Trend assessment			X	X		
Season-dependent human activities		(x)	X	(x)		

Note: X indicates the most likely frequency. (x) indicates the range of frequencies depending on the particular circumstances. The frequencies suggested may not be relevant for trend assessment.

The table does not address monitoring frequencies in relation to behaviour of pollutants in the underground, which also has to be considered when the sampling frequency has to be determined.

5.4.3 Operational monitoring

The design of operational monitoring is based on WFD Annex V, 2.4.3. and will be carried out at the national level.

Objective

Operational monitoring shall be undertaken in the periods between surveillance monitoring programmes in order to:

- establish the chemical status of all groundwater bodies or groups of bodies determined as being at risk,
- establish the presence of any long term anthropogenically induced upward trend in the concentration of any pollutant.

Selection of monitoring sites

Operational monitoring shall be carried out for all those groundwater bodies or groups of bodies of basin wide importance which on the basis of both the impact assessment carried out in accordance with Annex II and surveillance monitoring are identified as being at risk of failing to meet objectives under Article 4. The selection of monitoring sites shall also reflect an assessment of how representative monitoring data from that site is of the quality of the relevant groundwater body or bodies.

Selection of quality elements

Where the risk assessments indicate a risk of failing to achieve WFD objectives, in addition to the core parameters, selective determinants will need to be monitored at specific locations, or across GW bodies.

The selection of parameters depends on the results of the risk assessment, the characterisation of a GW body, considering existing water quality data and local expert knowledge. The chemical monitoring sites must be reviewed on a regular basis to ensure that they provide representative information and data on groundwater quality and fully support the risk assessment process.

Sampling frequency

WFD requires that operational monitoring shall be carried out at a frequency sufficient to detect the impacts of relevant pressures, but at a minimum of once per annum. Sampling for operational monitoring must be continued until the GW body is determined with adequate confidence, to be no longer at poor status or at risk of being at poor status and there is adequate data to demonstrate a reversal of trends.

Sampling frequency and sample timing at each monitoring location will be defined case-by-case, because of the specific considerations, such as: position regarding the pressure, seasonal effects, land use management patterns etc. The details of implementing operational monitoring are a national task.

5.5 Cost estimate for establishing of groundwater monitoring programmes

Cost estimation for the establishment of GW chemical surveillance and operational monitoring programmes was calculated for Bosnia& Herzegovina and Montenegro, because at present no GW monitoring exists in these parts of Sava RB.

5.5.1. Monitoring network

Estimation for the number of stations was based on several assumptions, concerning density and type of monitoring stations and percentage of stations from existing waterworks which can be used.

Proposed density of monitoring stations is related to the size of GWBs, presented in Table 8.

Table 8: Proposed density of GW surveillance monitoring stations

Size of GWBs (km²)	Density of mon. stations
1-300	1/75 km² (min 3 stations)*
301-1000	1/100 km²
>1000	1/150 km²

*Minimum number of stations is based on recommendations from the CIS Guidance Document No. 15: Guidance on Groundwater Monitoring, EC2007.

Proposed number of GW monitoring stations was based on the number and size of reported GWBs and types of aquifer (intergranular or karstic/fissured). In case of BA, total area of GWBs is approx. 40% of the BA portion of the Sava RB. Since the principle of the area wide protection of all groundwater must be implemented according to GWD, the monitoring should also cover the whole territory. Therefore, the proposed number of groundwater monitoring stations covers not only reported GWBs, but the whole territory of the Sava RB in BA (Table 9).

Table 9: Proposed density of GW surveillance monitoring stations

Proposed number of monitoring stations	BA	ME
Number of GWBs in the Sava RB	19	4
Number of GWBs (intergranular aquifers)	8	0
Number of GWBs (karstic/fissured aquifers)	11	4
Total area of GWBs (km²)	15,144*	6,300
Area of GWBs (intergranular aquifers) (km²)	5,132	0
Area of GWBs (karstic/fissured aquifers) (km²)	10,012	6300
No. of monitoring stations for surveillance monitoring	125** (320***)	46
No. of monitoring stations for operational monitoring******	25** (90***)	10
Total number of monitoring stations	150** (410***)	56

* Total area of all reported GWBs in the Sava RB in BA covers only 40% of the territory
** Proposed number of monitoring stations for the reported GWBs in BA
*** Proposed number of monitoring stations for the whole territory of Sava RB in BA
****Number of additional stations for operational monitoring approx. 20% of surveillance monitoring

Cost estimation for establishment of GW surveillance monitoring stations was calculated for two cases (Table 10):

A) Monitoring network consists only of newly established monitoring stations

B) Monitoring network consists of newly established monitoring stations (~70%) and existing monitoring stations (~30%) (waterworks, industry, other users).

Table 10: Cost estimation for establishment of GW surveillance monitoring stations

Cost of establishment of monitoring network	BA	ME
A) Cost of surveillance monitoring network (€)	1,350,000	250,000
B) Cost of surveillance monitoring network-incl. existing mon. stations (€)	950,000	200,000
Cost of operational monitoring network (€)	250,000	50,000
A) Total cost of monitoring network (€)	1,600,000	300,000
B) Total cost of monitoring network- incl. existing mon. stations (€)	1,200,000	250,000

5.5.2. Monitoring programmes

Surveillance Monitoring

For 6 year RBMP period:

<u>Year 1 (2 samples/ year)</u>

Parameters:

- main cations and anions (i.e., Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and HCO^{3-}),
- nitrogen components (NH_4, NO_2 and NO_3)
- Redox-sensitive parameters (Fe, Mn,), pH, conductivity, dissolved oxygen
- heavy metals (Zn, Cu, Cr, Pb, Cd, Hg, Ni, As)
- pesticides (Lindane, Atrazine, Simazine, Propazine, Aldrin, Endrin, and Methoxychlor, and other organic chemical components like PCB's)
- other potential anthropogenic contaminants

<u>Year 2-6 (1 sample/year)</u>

- short list of parameters for (main cations and anions, nitrogen components) for monitoring of natural trends

Operational Monitoring

<u>Year 2-6 (4 samples/year)</u>

- Major ions
- List of parameters putting GWB at risk or in poor status

Table 11: Cost estimation of monitoring programmes (for 6 year RBMP period)

Cost of monitoring programmes	No. of stations	Year 1	Year 2-6	BA
Cost of surv. monitoring programmes (€)	320	640,000	480,000	1,120,000
Cost of operational monitoring programmes (€)	90		1,080,000	1,080,000
Total cost of monitoring programmes (€)				2,200,000

Cost of monitoring programmes	No. of stations	Year 1	Year 2-6	ME
Cost of surv. monitoring programmes (€)	46	92,000	69,000	161,000
Cost of operational monitoring programmes (€)	10		120,000	120,000
Total cost of monitoring programmes (€)				281,000

5.6 Conclusions

Reliable information on quantitative and chemical status of groundwater bodies is crucial for effective groundwater management in the Sava River Basin. This requires the establishment of an appropriate monitoring system, which must be complex enough to encompass all relevant aquifers and their characteristics as well as present quantitative and chemical pressures. Purpose of this document is to review the existing groundwater monitoring networks and compare them to the requirements of the WFD, toward establishment of the future monitoring programmes in the Sava River Basin.

The future ISRBC Groundwater Monitoring Programmes comprise following activities:

- Quantitative Monitoring, with main objective of quantitative monitoring to validate characterization and risk assessment of failing to meet good quantitative status.
- Surveillance Monitoring, with role to supplement and validate the risk assessment carried out for 2009 SRBA Report and provide information for use in the assessment of long term trends
- Operational Monitoring, established to determine chemical status of all groundwater bodies assessed as being at risk and to determine the presence of any long term anthropogenic induced upward trend of any pollutant.

It is foreseen that future ISRBC GW monitoring network will be based on the existing national monitoring networks, and that the necessary information from basin wide perspective will be obtained with minimum adjustments of existing monitoring programmes, assuming that these programmes are (or will be) WFD compliant.

Annex 1

List of delineated groundwater bodies and status assessment

No.	Country	GWB name	Code	Transboundary (Y/N)	Size [km²]	Main use	Overlying strata [m]	Risk		Status		Exemptions (Art4.4 i Art4.5)
								Quality	Quantity	Quality	Quantity	
1	SI (11)	Savska kotlina in Ljubljansko Barje	VTPodV_1001	N	774	DRW, IND		-	-	good	good	n/a
2		Savinjska kotlina	VTPodV_1002	N	109	DRW, IND		at risk	-	poor	good	n/a
3		Krška kotlina	VTPodV_1003	Y	97	DRW, IND		-	-	good	good	n/a
4		Julijske Alpe v porečju Save	VTPodV_1004	Y	772	DRW, IND		-	-	good	good	n/a
5		Karavanke	VTPodV_1005	Y	414	DRW, IND		-	-	good	good	n/a
6		Kamniško-Savinjske Alpe	VTPodV_1006	Y	1,113	DRW, IND		-	-	good	good	n/a
7		Cerkljansko, Škofjeloško in Polhograjsko	VTPodV_1007	N	850	DRW, IND		-	-	good	good	n/a
8		Posavsko hribovje do osrednje Sotle	VTPodV_1008	Y	1,792	DRW, IND		-	-	good	good	n/a
9		Spodnji del Savinje do Sotle	VTPodV_1009	Y	1,397	DRW, IND		-	-	good	good	n/a
10		Kraška Ljubljanica	VTPodV_1010	Y	1,307	DRW, IND		-	-	good	good	n/a
11		Dolenjski kras	VTPodV_1011	Y	3,355	DRW, IND		-	-	good	good	n/a

No.	Country	GWB name	Code	Transboundary (Y/N)	Size [km²]	Main use	Overlying strata [m]	Risk		Status		Exemptions (Art4.4 i Art4.5)
								Quality	Quantity	Quality	Quantity	
12	HR (14)	Sliv Sutle i Krapine	DSGIKCPV_24	Y	1,405.44	DRW, IND	0-600	No	No	-	-	No
13		Zagreb	DSGIKCPV_27	Y	987.52	DRW, IND	0-20	Poss	Poss	-	-	-
14		Lekenik - Lužani	DSGIKCPV_28	Y	3,444.26	DRW, IND	5-80		No	good		No
15		Istočna Slavonija - Sliv Save	DSGIKCPV_29	Y	3,328.12	DRW, IND	5-50		No	good		No
16		Kupa-krš	DSGIKCPV_13	Y	1,026.70	DRW, IND				good	good	No
17		Sliv Korane	DSGIKCPV_16	Y	1,244.71	DRW		No	No	good	good	No
18		Una-krš	DSGIKCPV_17	Y	1,574.79	DRW, IND		No	No	probably good	good	No
19		Sliv Lonja - Ilova - Pakra	DSGNKCPV_25	N	5,186.09	DRW, IND	7-60	No	No	-	-	No
20		Sliv Orljave	DSGNKCPV_26	N	1,575.03	DRW, IND	2-13	No	No	-	-	No
21		Žumberak - Somoborsko Gorje	DSGIKCPV_30	Y	443.30	DRW		No	No	-	-	No
22		Kupa	DSGNKCPV_31	N	2,870.29	DRW, IND	2-45	No	No	-	-	No
23		Una	DSGIKCPV_32	Y	540.57	DRW	5-20	No	No	-	-	No
24		Sliv Dobre	DSGNKCPV_14	N	754.55	DRW, IND		No	No	good	good	No
25		Sliv Mrežnice	DSGNKCPV_15	N	1,370.92	DRW, IND		No	No	good	good	No

No.	Country	GWB name	Code	Transboundary (Y/N)	Size [km²]	Main use	Overlying strata [m]	Risk		Status		Exemptions (Art4.4 i Art4.5)
								Quality	Quantity	Quality	Quantity	
26	BA (7)	Plješevica	BA_UNA_2	Y	120	DRW		Poss	No	-	-	No
27		Posavina II	BAGW_SAV_2	N	1,350	DRW,IND	5-10	Poss	No	-	-	No
28		Romanija-Devetak-Sjemeč	BAGW_BO_DRN_1	N	2,050	DRW	<2	Poss	No	-	-	No
29		Treskavica-Zelengora-Lelija-Maglić	BAGW_DRN_1	N	1,240	DRW	<2	Poss	No	-	-	No
30		Manjača-Čemernica-Vlašić	GW_VRB_1	N	1,800	DRW	<2	Poss	No	-	-	No
31		Grmeč-Srnetica-Lunjevača-Vitorog	BAGW_VRB_UNA_1	N	3,770	DRW	<2	Poss	No	-	-	No
32		Unac	BA_UNAC_UNA_1	N	1,720	DRW		Poss	No	-	-	No
33	RS (5)	Istočni Srem - OVK	RS_SA_GW_I_2	N	1,593.65	DRW, IND, IRR	2-50	Poss	No	-	-	n/a
34		Mačva - OVK	RS_SA_GW_I_3	N	763.41	DRW, IND, IRR	1-22	Poss	No	-	-	n/a
35		Zapadni Srem - pliocen	RS_SA_GW_I_6	Y	1,172.92	DRW, IND, IRR	5-90	No	Poss	-	-	n/a
36		Istočni Srem - pliocen	RS_SA_GW_I_7	N	2,248.99	DRW, IND, IRR	20-90	No	Poss	-	-	n/a
37		Mačva - pliocen	RS_SA_GW_I_8	N	1,577.53	DRW, IND, IRR	50-190	No	No	-	-	n/a

No.	Country	GWB name	Code	Transboundary (Y/N)	Size [km^2]	Main use	Overlying strata [m]	Risk		Status		Exemptions (Art4.4 i Art4.5)
								Quality	Quantity	Quality	Quantity	
38	ME (4)	Sliv rijeke Pive	n/a	Y	1,500	CAL		No	No	-	-	n/a
39		Sliv rijeke Tare	n/a	Y	2,000	DRW		No	No	-	-	n/a
40		Sliv rijeke Ćehotine	n/a	Y	800	IND		No	No	-	-	n/a
41		Sliv rijeke Lim	n/a	Y	2,000	DRW		No	No	-	-	n/a

Legend:

Aquifer characterisation, aquifer type: P = porous, K = karst, F = fissured (combinations are possible)

Main use: DRW = drinking water, AGR = agriculture, IRR = irrigation, IND = industry, SPA = balneology CAL = caloric energy, OTH = other

GWB NAME: Name of the important groundwater body

COUNTRY CODE: Member State Code which is a unique identifier.

Transboundary GWB: Yes/No

Total size (km^2): Whole area of the groundwater body covering all countries concerned (just in case of the transboundary groundwater body)

National size (km^2): Country indicates the size on the national territory

Aquifer characterisation, aquifer type: P = porous, K = karst, F = fissured (combinations are possible)

Confined: Yes, No or Yes/No

Main use: DRW = drinking water, AGR = agriculture, IRR = irrigation, IND = industry, SPA = balneology CAL = caloric energy, OTH = other

Overlying strata (m): Range of thickness of overlaying strata in metres.

Risk: Indicates whether a groundwater body is at risk of failing good status. Quantitative (Yes, No, Poss), Chemical (Yes, No, Poss)

Status: Assessment of GWB status. Quantitative (Good, Poor, Unknown), Chemical (God, Poor, Unknown)

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