DIKTAS

Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System

Transboundary Diagnostic Analysis

December 2013

gef UNDP
UNESCO United Nations Educational, Scientific and Cultural Organization
International Hydrological Programme of UNESCO

Executive Summary

The Transboundary Diagnostic Analysis (TDA) described in this summary was conducted in the framework of a project 'Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System (DIKTAS). The DIKTAS project is a regional project that is aimed improving the management of karst groundwaters contained in the Dinaric Karst and shared by several countries in South-Eastern Europe. Karst is a special type of geologic environment that is formed when soluble rocks, such as limestone and dolomite, are corroded and dissolved by percolating water. Karst hydrogeology is characterised by the high permeability of preferential flow zones developed along fractures, faults and conduits, an almost total absence of permanent surface water, high infiltration rates and high velocities of groundwater.

Groundwaters of the Dinaric Karst System in South-Eastern Europe form some of the World's largest and most prolific karst aquifers which host many first magnitude springs. The system extends from North-East Italy through Slovenia, Croatia, Bosnia and Herzegovina, and Montenegro to Albania. Karst formations have also developed in carbonate rocks of the Dinaric mountain outcrop in Serbia, FYR Macedonia, and possibly in NW Greece. For the most part, this region is characterised by still pristine environments and a variety of unique geomorphological landforms. It also hosts numerous karst underground species, many of which are endemic such that some of the Dinaric karst localities are recognized as the most bio-diverse worldwide.

The DIKTAS Project started in 2010 and will continue until the end of 2014. The project was initiated by the aquifer-sharing states and is a full-size GEF regional project, implemented by UNDP and executed by UNESCO. The activities of the project focus on Albania, Bosnia and Herzegovina, Croatia and Montenegro. Several other countries and international organizations have also joined this challenging project and are providing valuable contributions to the realisation of its objectives. The DIKTAS project aims to improve the sustainable management of karst groundwater resources in the region through improvement of related knowledge and cooperation. As such, the project is the first ever attempt to globally introduce integrated management principles in a transboundary karst freshwater aquifer system of such magnitude.

The project is a collective effort to:

- facilitate the equitable and sustainable utilization of the transboundary water resources of the Dinaric Karst Aquifer System,
- protect the unique groundwater dependent ecosystems that characterize the Dinaric Karst region of the Balkan Peninsula.

At the global level, the project aims to focus the attention of the international community on the abundant but vulnerable water resources contained in karst aquifers.

The project's main outputs include the Transboundary Diagnostic Analysis, the establishment of cooperation mechanisms at national and regional level, and the adoption of a regional Strategic Action Plan (SAP) and corresponding National Action Plans (NAP) for each of the countries involved.

The TDA was conducted in the period 2011-2013 by the DIKTAS Project Team in accordance with the GEF guidelines provided in the TDA/SAP Training manual. The TDA is based on a substantial regional analysis that is required in order to fully understand the context of transboundary issues. The regional analysis was particularly important given the complexity of the karst environment and regime and the interconnectivity of karst aquifers. The regional analysis also enabled a delineation of transboundary aquifers (TBAs) shared by the project countries. The Project Team was organised in four working groups, reflecting the main issues of the regional analysis: a hydrogeological characterization; an environmental and socio-economical assessment; an assessment of the legal and institutional frameworks and policies; and a regional stakeholder analysis.

The regional analysis was followed by an in-depth analysis of the transboundary aquifer areas that focused on observed and potential issues of transboundary concern. The analysis was carried out in a systematic way that included climate, hydrology, hydrogeology, groundwater reserves and their utilization, groundwater quality and water resources protection. For each aquifer, the major issues of concern were determined and priority actions proposed.

The TDA shows that, based on the information made available to the Project Team, the state of groundwater in the DIKTAS project region is generally good in terms of both quantity and quality with a few exceptions and with a number of serious potential threats.

The main threat to the overall groundwater quality in the DIKTAS region is solid waste and wastewater disposal. There are hundreds of unregulated landfills and illegal dumping sites in the four project countries. The number of wastewater treatment plants is insufficient, with about half of the population not connected to this service. For the vulnerable karst environment of the Dinaric region, which has a very limited auto-purification capacity, this is the most serious current as well as (potential) future problem. To a lesser degree, karst groundwater resources in the region are also being contaminated by agricultural and industrial activities.

Currently no common legal framework and no common criteria exist for a) the delineation of water source sanitary protection zones, and b) setting cost-efficient measures for groundwater protection in the Dinaric Karst region. This was identified as the main issue of concern in the TBAs with centralized public water supply systems: Trebišnjica, Neretva, Cetina and Una.

There is a concern of some stakeholders about hydropower production in the region, especially in Bosnia and Herzegovina, including the impacts of hydrotechnical constructions in the TBA areas of Trebišnjica and Bilećko Lake (Bileća Reservoir). With the disintegration of Yugoslavia, this issue has obtained transboundary dimensions and has become very prominent. This holds for both already operational and planned hydrotechnical projects. The concern is not only environmental but also economic and political. The complexity of the karst environment, especially in terms of predictions (which were not a part of the TDA), further complicates the resolution of the identified concerns.

A major added value of the TDA can be seen in the collection and harmonisation of a large amount of data and information relevant for the assessment and management of karst groundwater resources in the region. This gathered information was not always complete and in some cases there were still significant information gaps. Nevertheless, the DIKTAS TDA was the first thorough regional groundwater analysis that covers Albania, Montenegro, Bosnia & Herzegovina and Croatia. The analysis included hydrogeological characterisation, as well as social, economic, legal and regulatory aspects of groundwater resources management in the region. Outputs of the TDA, including GIS materials such as thematic maps and databases, and quantitative hydrogeological analyses, form the basis for developing groundwater resources management models at both regional and local scales.

Stakeholder analysis revealed a pressing need for transparent, public sharing of knowledge, information and scientific data on the many unique characteristics of karst aquifers in the DIKTAS region. Stakeholders view DIKTAS as an opportunity for cooperation, networking and communication between government authorities, agencies, non-governmental organizations (NGOs) and other actors at transboundary level and, most importantly, for the harmonization of legal and karst aquifers management frameworks among the countries. Opportunities for participation in the decision-making process are also among the most widely anticipated outcomes of DIKTAS.

While the TDA has produced a fair assessment of groundwater resources in the region it also revealed limitations of knowledge on their actual state and trends in terms of quality and quantity. The main obstacle for this was a lack of monitoring data at both regional and local scales, such as in the vicinity of solid waste and wastewater disposal (treatment) sites, mines, intensive agriculture areas, and industrial facilities handling and generating hazardous materials. Therefore, a strong message resulting from the TDA is a request for improvement of the groundwater monitoring network throughout the region and the need to intensify capacity building in the public sector.

The TDA suggestions for priority actions in all the transboundary aquifer areas are:

- Establishment of a common groundwater monitoring program
- Harmonisation of criteria for delineation of source protection zones

A detailed inventory of non-point and point sources of pollution will be needed prior to the establishment of common groundwater monitoring programs. A proposal on common groundwater monitoring programs is currently being prepared in the framework of DIKTAS and will be an input to the Strategic Action Programme (SAP). Additional input for the SAP will be provided through three case studies to be conducted within the areas of three transboundary aquifers in the region. An extensive collection of DIKTAS project documents can be accessed via the DIKTAS portal at http://diktas.iwlearn.org.

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXES

Annex 1: DIKTAS Maps

1. Administrative Boundaries in the DIKTAS Region
2. Hydrogeological Map of the Dinaric Karst
3. Corine Land Cover Map
4. Water Resources Map
5. Dams and Reservoirs
6. Emerald Network Map
7. Karst Caves
8. Transboundary Aquifer Map
9. Monitoring Networks

Annex 2: Country Reports (a link to a digital version)

Annex 3: International Legal Instruments (a link to a digital version)

Annex 4: 4 Stakeholders and Public Participation Strategy (a link to a digital version)

ACRONYMS (a selection)

Agency of Environment and Forestry (of Albania)	AEF
Bosnia and Herzegovina	B&H
Groundwater Dependent Ecosystems	GDE
Groundwater bodies	GWBs
Hydro-electrical power plants	HPP
Hydrogeology Working Group	HGWG
International Sava River Basin Commission	ISRBC
Ministry of Environment, Forestry and Water Adm. (Albania)	MoEFWA
National Consultation Meetings	NCMs
National Water Council	NWC
Root cause analysis	RCA
State Ministry of Foreign Trade and Economic Relations	MOFTER
Strategic Action Programme	SAP
Strengths/Weaknesses/Opportunities/Threats	SWOT
Transboundary aquifer	TBA
Transboundary Diagnostic Analysis	TDA
United Nations Development Programme	UNDP
United Nations Educational, Scientific and Cultural Organization	UNESCO
Water Framework Directive	WFD

DIKTAS PROJECT TEAM

HYDROGEOLOGY

Arben Pambuku, Albania

Boban Jolovic, Bosnia and Herzegovina

Zeljko Pekas, Croatia

Dragan Radojevic, Montenegro

Zoran Stevanovic, International specialist

ENVIRONMENTAL AND SOCIO-ECONOMIC ANALYSIS

Suela Neziraj, Albania

Ognjen Čaldarović, Croatia

Dalibor Vrhovac, Bosnia and Herzegovina

Novak Cadjenovic, Montenegro

LEGAL AND INSTITUTIONAL FRAMEWORK AND POLICY

Bendis Boçari, Albania

Selma Cengic, Bosnia and Herzegovina

Zoran Nakic, Croatia

Maja Raicevic, Montenegro

Raya Marina Stephan, International specialist

STAKEHOLDER ANALYSIS

Erjola Keci, Albania

Alma Imamovic, Bosnia and Herzegovina

Marina Funduk, Croatia

Milica Lekic, Montenegro

Dimitris Faloutsos, GWP-Med

SUPPORT

Neno Kukuric, UNESCO/IGRAC, project coordinator

Neven Kresic, International specialist

Vedran Furtula, DIKTAS PCU

Anna Maria Papaioannou, GWP-Med

Zeljko Zubac, HET/DIKTAS PCU

PROJECT NATIONAL FOCAL POINTS

Viola Saliaga, Albania

Biljana Rajic, Bosnia and Herzegovina

Mirela Hahn, Croatia

Jelena Plamenac, Montenegro

1 Introduction

This document contains the results of the Transboundary Diagnostic Analysis (TDA) conducted in the framework of the project: Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System (DIKTAS). The DIKTAS project is about karst groundwaters.

DIKTAS is a full-size GEF (www.thegef.org) regional project, implemented by UNDP (www.undp.org) and executed by UNESCO-IHP (www.unesco.org/water/ihp). The activities of the project focus on Albania, Bosnia and Herzegovina, Croatia and Montenegro. Several other countries and international organizations have also joined this challenging project and are providing valuable contributions to the realisation of its objectives. The project is contributing to:

- equitable and sustainable utilization of the transboundary water resources of the Dinaric Karst Aquifer Systems
- protection of the unique groundwater dependent ecosystems that characterize the Dinaric Karst region of the Balkan Peninsula.

The core DIKTAS project partners are the four GEF fund-recipient countries of the Dinaric region, namely Albania, Bosnia and Herzegovina, Croatia and Montenegro. Several other countries (in the Dinaric region and beyond) and international organizations have also joined this challenging project.

Figure 1.1 The Spring Ombla, in the DIKTAS Project area

The Transboundary Diagnostic Analysis is, as well as a Cooperation Mechanism and a regional Strategic Action Plan (SAP), one of the main outputs of the project. The purpose of the TDA was to improve understanding of the groundwater resources in the project region and their environmental status in order to identify the issues of transboundary concern and their causes.

The TDA was conducted as a scientific and technical fact-finding analysis. It serves as the baseline for interventions and priority actions that are currently being specified within the SAP.

The approach to the DIKTAS TDA is described in Chapter 2 and it is characterised by a substantial regional analysis. This is because of the complexity of the karst environment and in particular of its regime and interconnectivity of karst aquifers. In this document, the results of the regional analysis are presented as follows:

- Chapter 3 - Regional hydrogeological characterization
- Chapter 4 - Regional environmental and socio-economical assessment
- Chapter 5 - Regional assessment of legal and institutional frameworks and policies
- Chapter 6 - Regional stakeholder analysis

After the regional analysis was completed, transboundary aquifers were delineated and an in-depth analysis of the transboundary aquifer areas was conducted (Chapter 7). This analysis was carried out thoroughly and in a structured way that included climate, hydrology, hydrogeology, groundwater reserves and their utilization, groundwater quality and protection. For each aquifer the major issues of concern are determined and priority actions suggested. Finally, the outcomes of the root cause analysis are summarised.

The information and data gaps addressed in Chapter 8 are about field data and related interpretations that are required for a proper assessment and management of groundwater resources in the project region. The gaps in policies and regulations specific to the karst environment and inadequate enforcement of legislation are discussed in chapters 5 and 7.

Chapter 9 contains the main conclusions and the pathway to the SAP analysis. Further information on on-going DIKTAS SAP activities can be found in the DIKTAS Work Plan for 2013.

This report has four annexes. Annex 1 includes a set of DIKTAS maps, among others the hydrogeological map of the Dinaric Karst region. The country regional reports of Albania, Bosnia and Herzegovina, Croatia and Montenegro need to be annexed to this document. However, since the reports are large (more than 100 pages each), only the cover pages and the links to electronic version of the reports are provided in Annex 2. Annex 3 contains a review of international legal instruments and Annex 4 contains the Stakeholders and Public Participation Strategy. Like Annex 2, only the links to these documents are provided.

2 Approach to the TDA in the DIKTAS Project

The TDA was conducted according to the GEF guidelines provided in the TDA/SAP Training manual. The TDA preparation started already at the Inception Workshop in November 2010 and the agreed preparation approach was included in the project plan for 2011.

In the DIKTAS Project Document the TDA is related to Component 1, with the purpose of improving the understanding of groundwater resources in the project region and their environmental status in order to identify issues of transboundary concern and their causes. The prepared TDA is the baseline for the interventions and priority actions that will be specified within the SAP. At the very outset of the project it was stressed that the TDA is a scientific and technical fact-finding analysis and it needs to lead to an objective assessment.

The first conclusion of the Project Team regarding the DIKTAS TDA approach was the need for a substantial regional analysis. In principle a regional analysis is always required in order to fully understand the context of transboundary issues. The reason for this substantial analysis was the complexity of the karst environment and in particular a regime and interconnectivity of karst aquifers. The regional analysis would also enable a delineation of transboundary aquifers among the project countries.

Accordingly, the Project Team was organised in four Working Groups (WGs), reflecting the main issues of the regional analysis:

- WG1 - Regional hydrogeological characterization
- WG2 - Regional environmental and socio-economical assessment
- WG3 - Regional assessment of legal and institutional frameworks and policies
- WG4 - Regional stakeholder analysis

Working Group 4 was also charged with information and communication activities in the project. The task of WG1 was the most extensive, because it included the harmonisation of the regional hydrogeological map. This would not have been possible without technical GIS/Database support organised within the Project Coordination Unit (PCU) in Trebinje, Bosnia and Herzegovina. The support included extensive geographical referencing and harmonisation as well as development of the DIKTAS database.

The environment and socio-economical analysis provided an overview of the environmental and socio-economic situation in the DIKTAS project countries. The hydrogeological characterisation is a basis for the groundwater assessment but it cannot be performed without information on observed pollution, the current state of nature resorts, population growth, economic strength, etc. WG2 strove to collect as much geographically referenced data as possible and to produce a series of thematic maps (some of which are presented in Annex 1). These maps, superimposed on the hydrogeological map, form the basis of the DIKTAS Management Map; this toolkit (under development) with predefined scenarios and visualisation functionalities is meant to support the decision-making process on groundwater-related issues in the region.

WG3's approach to the regional assessment of legal and institutional frameworks and policies was very systematic, including a regional Strengths/Weaknesses/Opportunities/Threats analysis

(SWOT). This analysis, for instance, clearly showed certain shortcomings in the formal adoption of the WFD and the GWD in national legislations. In addition, WG3 made a survey of the international legal instruments, summarised in Annex 3.

The regional analysis would not be complete without involvement of a wide cycle of stakeholders and the public. The approach for gathering and processing information on stakeholders included:

- Expert opinion and expert knowledge;
- A web-based survey;
- Workshops;
- Structured interviews

A detailed explanation of the used methodology is available in a comprehensive DIKTAS report 'Stakeholder Analysis' (2012), available via the DIKTAS portal http://diktas.iwlearn.org/. The analysis provided information on stakeholders, their perceptions with regard to the issues and problems - as well as their causes - related to the management of the Dinaric Karst Aquifer System and expectations and aspirations pertaining to the future of the transboundary karst aquifer management.

After the regional analysis was completed, the transboundary aquifers were delineated and an in-depth analysis of the transboundary aquifer areas was conducted. This analysis was concentrated around the observed and potential issues of transboundary concern. The analysis was carried out thoroughly and in a structured way that included climate, hydrology, hydrogeology, groundwater reserves and their utilization, and groundwater quality and protection. For each aquifer, the major issues of concern are determined and priority actions suggested (Chapter 7).

Regular Project Team meetings and meetings of the Working Groups were used to discuss reports, plans and the progress of on-going activities. Separate sessions were organised for brainstorming on issues of transboundary concern and on the root cause analysis. The DIKTAS web-based collaborative environment (Fig 2.1) was used on a daily basis. The progress results were summarised regularly in the DIKTAS Newsletters, also published via the DIKTAS portal.

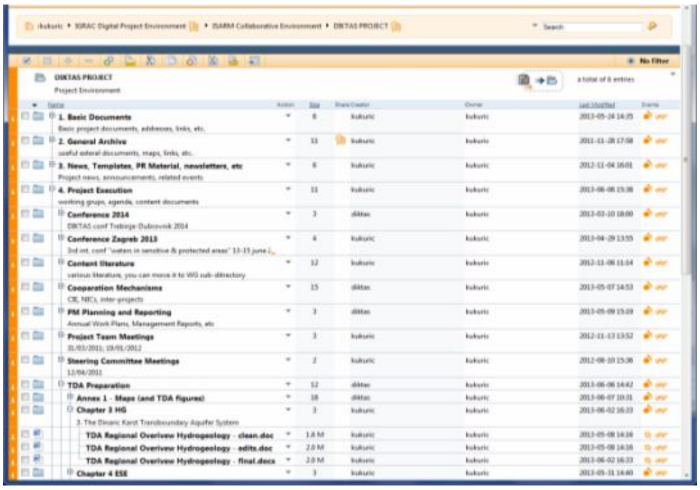


Figure 2.1 The DIKTAS Collaborative Environment

3 Regional Overview of the Hydrogeology of the Dinaric Karst

3.1 Historical summary and perspective

The Dinaric system (Dinarides) represents a geologically heterogeneous, south European orogenic belt of the Alpine mountain chain (Alpides) and is considered as a classic karst region worldwide. Not only was the term *karst* born in the area, but thanks to Jovan Cvijić, who performed most of his work in the Dinaric karst, a new scientific discipline - karstology - has been founded. 'His publication of Das Karstphänomen (1893) established that rock dissolution was the key process and that it created most types of dolines, "the diagnostic karst landforms". Germanicised as "karst", the Dinaric Kras thus became the type area for dissolutional landforms and aquifers; the regional name is now applied to modern and paleo dissolutional phenomena worldwide.' (Ford, 2005). Some local terms were accepted, and are still used, in international karst terminology (e.g. ponor, doline, uvala, and polje).

The main orientation of the Dinaric system is NW-SE, parallel to the Adriatic Sea. It is a long mountainous structure with numerous intermountain depressions including large karst poljes and valleys created by perennial or sinking streams. Most authors agree that the *Craso* area around Trieste-Monfalcone in Italy is the western boundary of the Dinarides; the question remains which parts of the Pindes and Hellenides, in Albania and Greece respectively, belong to the system. Although most professionals believe that only the Albanian Alps in the NW part of Albania belong to the Dinaric system, the members of the Hydrogeology Working Group (HGWG) of the DIKTAS project have agreed to extend the project boundary to the Vjosa River in Albania as the southern limit of the study area.

While the western boundary of the Dinaric system is clearly defined and represented by the Adriatic coast and numerous Croatian islands, the eastern boundary on the continent is less certain. However, since most published references agree that the tectonic graben of the Sava River represents the northern edge of the Dinarides, it is assumed that marginal parts of the Dinarides in Croatia and in Bosnia and Herzegovina (B&H) are located at an average distance of some 20-30 km south of the Sava River. The total surface area of the Dinaric system within the project countries is estimated at 110,500 km^2 as follows: 27,500 km^2 in Croatia, 45,400 km^2 in Bosnia and Herzegovina, 13,350 km^2 in Montenegro (where the entire country territory belongs to the Dinarides), and 24,250 km^2 in Albania. About 60% of the project area belongs to the Adriatic Sea basin, while 40% is in the Black Sea catchment (Figure 3.1).

In addition to four project countries, the Dinaric system extends to the territory of four other countries: Italy, Slovenia, Serbia and FYR of Macedonia, covering an additional 25,000 km^2 (these boundaries are shown on the DIKTAS Hydrogeological Map, in Annex 1 of the report).

Three out of the four project countries (with the exception of Albania) together with Slovenia, Serbia and FYR of Macedonia were parts of the former Yugoslavia between 1918 and 1991. During this period many common activities in the water sector, water management and infrastructure construction projects took place in the country. Following Cvijić's research, a large number of authors from Yugoslavia, Italy, and Albania contributed to the growing knowledge of the Dinarides in terms of its hydrology, geomorphology, geology, and hydrogeology, as well as its social and humanistic sciences. After WW II, the federal work on the Basic Geological Map of Yugoslavia, at a scale of 1:100,000 (with working sheets at 1:25,000), provided invaluable detailed geological information on the Dinaric karst (see the list of references in the basic reports of the hydrogeology working groups for each country which are provided as Annex 2 to this report).

Figure 3.1 The DIKTAS study area belongs to the Adriatic Sea and the Black Sea basins

Extensive and complex hydrogeological investigations throughout the Dinaric karst region in the former Yugoslavia were undertaken as part of large infrastructure projects including the construction of large and medium dams, development of well fields for water supply, and control and regulation of karst aquifers with drainage galleries and other engineering works. The large reclamation and hydropower systems were logical answers on increasing demands for water resources and energy. Modifications of water regime have had various impacts. They include hydrogeological, hydrological, ecological and social changes. In most instances, the impact has been positive and predictable (flood reduction, irrigation, water supply improvement, power production, infrastructure improvement, reduction of deforestation and many secondary benefits). However, some impacts have been negative and sometimes unpredictable: important cultural/historical monuments, natural resort areas and arable land were inundated; the survival of endemic species is endangered; the regime and quality of some aquifers and springs has been changed, etc. Therefore, keeping the balance between necessity for regional development and preservation of complex karst environment is the key issue for the region.

The results of hydrogeological investigations represent an important contribution to international hydrogeological science. Evidence of significant interest by the hydrogeology community in Dinaric karst is the book ‘Hydrogeology of the Dinaric Karst’ published by the

International Association of Hydrogeologists as Volume 4 of the book series 'International Contribution to Hydrogeology'.

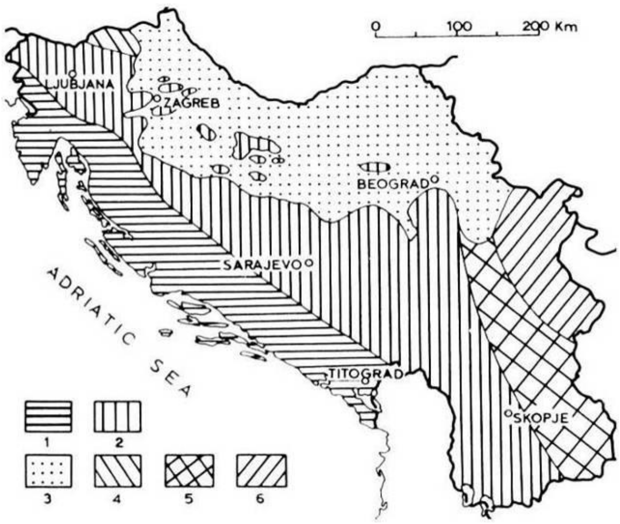
Due to its historical importance in the development of karst science, including its exemplary karst development with numerous geo-heritage sites, and abundant groundwater resources, an initiative has recently been taken to include the entire Dinaric region in UNESCO's list of World Heritage Sites.

3.2 Physiography

Classical karst terminology recognizes karst as a region consisting mainly of consolidated soluble carbonate rocks in which distinct surficial and subterranean landforms, caused by rock dissolution, have been developed. The term is applicable to any region made up of soluble rocks such as anhydrite, gypsum, and salt. In the case of the Dinarides, karstified rocks are predominantly limestones and dolomites of the Mesozoic age.

3.2.1 Geomorphologic characteristics

Cvijić in many of his works described and explained karstic features and water circulation oriented towards regional and local erosional bases (1893, 1900, 1918, 1960). He stated that there is no deeper or more complete karst development than in the karst of Herzegovina and Montenegro that is located between the lower Neretva River, Lake Skadar and the Adriatic Sea. In Albania, the best developed karst phenomena are in the Albanian Alps, and in the Mirdita and Ionian zones.



Legend:

1: Outer Dinaric units (Adriatic and high karst); 2: Inner Dinaric and south Alpine units; 3: Pannonian Basin; 4: Eastern Alps; 5: Serbian-Macedonian Belt; 6: Carpathian-Balkanides Belt.

Figure 3.2 Dinaric units in the major part of the DIKTAS project area

The development of the Dinaric karst was gradual, but with increasing volume and intensity. Herak (1972) stated that at the end of the Triassic or during the Lower Jurassic (old Cimmerian phase), the Triassic carbonate rocks were exposed at the land surface and subject to the impacts of freshwater circulation. The Laramian phase, between the Cretaceous and the Paleogene, is characterized by the uplifting of large landmasses, accompanied locally by intensive structural changes (Herak, 1972; Ćirić, 1984). Multiple disturbances caused movements of tectonic blocks and connection of the carbonate sediments from different stratigraphic horizons. Hence, for the first time in the geologic history of the region, there was a potential for more intensified groundwater circulation and widespread karstification (Herak, 1972). The subsidence of large areas triggered new transgressions and marine sedimentation of limestones, followed by the sedimentation of low-permeable flysch sediments.

Since the Oligocene, the Dinaric region has been continuously exposed to weathering, providing favourable conditions for intensified groundwater circulation and the development of karst features. The most distinct effects can be found in the areas of uplift and subsidence. The areas of subsidence include karst poljes where the water was active both before and after vertical tectonic movements. The Pleistocene started not only with climatic changes (glacial process, lowering of the sea level) but also with a new structural and morphologic evolution, especially in the Dinaric Mountains (Mijatović, 1996).

The Dinaric region contains all types of karst landforms including karren (lapies), dolines, pits (jamas), ponors (swallow holes, sinks), dry and blind valleys, caves and caverns as single forms, and uvalas, poljes and karst plains as larger complex forms (Roglić, 1965, 1972). Most of these features were developed in the Jurassic and Cretaceous limestones.

Overall, sinkholes (dolines) are the most frequent karst landform in the Dinaric karst. For example, sinkhole density in certain areas near Knin in Croatia reaches 150/km^2 (Šarin and Kostović-Donadini, 1981). The inner Dinaric zone comprises areas where there are no poljes, estavelles, or large ponors, but sinkholes (dolines) are frequent (Šarin, 1983).

Dry and blind valleys are numerous in the Dinaric karst (**Error! Reference source not found.**). nce hosting running surface streams, they gradually lost their hydrologic function as the surface water was diverted into the subsurface through ponors (sinks) and fractures in the underlying carbonates.

Figure 3.3 A small elongated depression – a former stream valley and now karst uvala used for crop cultivation (Mount Orjen, Montenegro and Bosnia and Herzegovina, photo Z.S.)

Though different in dimensions, karst uvalas are similar in shape to poljes and commonly dry the entire year. In contrast, karst poljes are characterized by very complicated hydrologic and hydrogeological functions. Some of them are lakes or swamps, the others periodically inundated or mostly dry. In general, karst poljes are heterogeneous with respect to geologic fabric, but a great abundance of non-carbonate rocks shows that their depressions were formed primarily by the impact of tectonic forces.

According to Milanović (2000), in the Dinaric karst region there are approximately 130 poljes. The total area of all these poljes is about 1,350 km^2. Drainage of the karst polje surface water is through ponors located both along the polje perimeter and at the polje floor within unconsolidated sediments or exposed carbonates. The ponors are frequently located in the polje areas nearest to the prevailing erosion base. The Adriatic and the Ionian Seas are regional erosional bases to which a cascade system of poljes is oriented (**Error! Reference source not ound.**). In the Nikšićko polje, about 880 ponors and estavelles were identified, 851 of which are located along its southern perimeter.

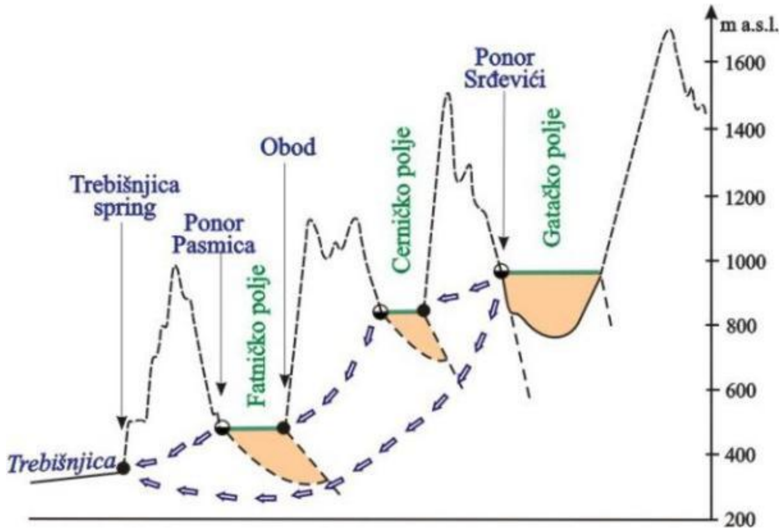


Figure 3.4 Cross section through the karstic poljes drained by the Trebišnjica Springs (now under the Bilećko reservoir) by P. Milanovic.

Poljes become flooded as soon as the sinking or drainage capacity of the ponors becomes lower than the inflow of water. Natural plugging of ponors may also lead to faster flooding and longer duration of floods. The size of karst poljes is highly variable: some are very small, with an area of 1-3 km^2, while the Livanjsko Polje (B&H), considered the world's largest karst polje, covers an area of 380 km^2, and together with Buško Blato, which morphologically may be considered its integral part, totals 433 km^2. Krešić (1988) listed some 15 potholes (pits, shafts) in the former Yugoslavia deeper than 400 m. Several much deeper potholes have recently been discovered including Lukina Jama-Trojama (-1392 m) and the Slovačka Jama (-1301) in the Velebit Mountain National Park. These jamas are among the deepest speleological phenomena in the World.

Some areas, such as Kameno More (the Stone Sea) and Mount Orjen above Risan (Kotor Bay, Montenegro), contain numerous deep vertical potholes. For example, within an area of only 8 km^2 more than 300 vertical shafts were registered (Milanović, 2005). Some of them have been speleologically investigated to depths of 200-350 m.

According to data obtained from Božičević (1966), potholes in the former Yugoslavia have been recorded and measured with a total depth of about 45 km (in Croatia over 25 km). Herak (1972) states that over 12,000 caves have been explored in the former Yugoslavia alone, more than 5,000 of which were in Croatia. More recent surveys show approximately 7,000 speleological objects in Croatia (Figure 3.5), many of which host spectacular cave formations and speleothems (Figure 3.6). Water is permanently or periodically present in approximately 25% of the Croatian caves.

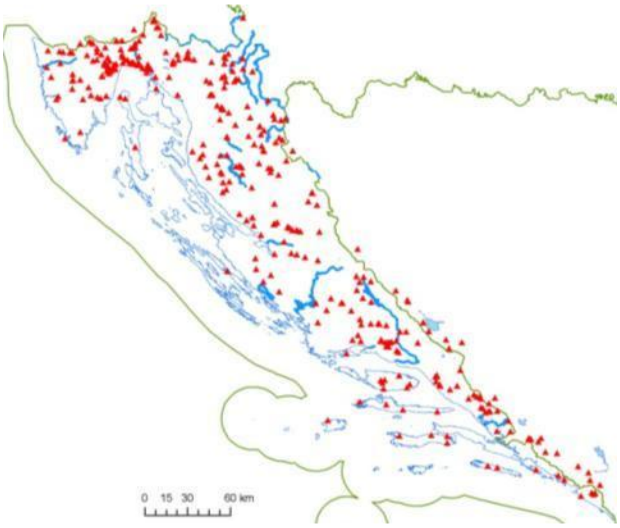


Figure 3.5 Distribution of caves and potholes in Croatia (after Pekaš, 2012; DIKTAS GIS DBase)

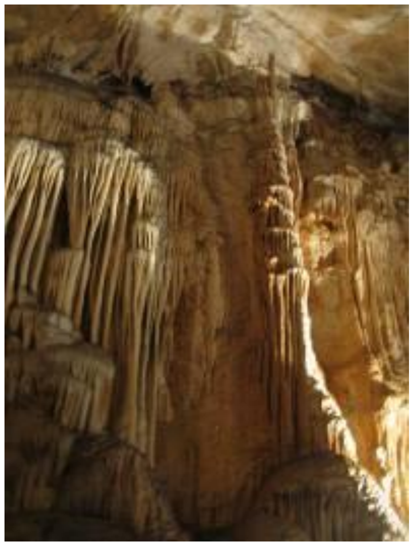


Figure 3.6 Speleo features from Cerovačke špilje – Donja špilja (Croatia, photo *Z.S.)*

3.2.2 Climate

The inland study area has a continental climate, while the Mediterranean climate prevails along the Adriatic coast. The main characteristics of the continental climate are long and cold winters and short and hot summers (annual air temperature varies between -20 ^{o}C and 40 ^{o}C). Annual precipitation varies between 700 mm in the northern and over 1,500 mm in the southern part which has the highest recorded annual rainfall in Europe. For example, average annual precipitation, from sea level up to an elevation of 1,800 m varies from 2,000 mm to more than 5,000 mm (Milanovic, 2005). Average annual rainfall at the Crkvice station (1,097 m asl, Mt. Orjen, Montenegro) is over 5,000 mm, and in some years it reaches 8,000 mm (Figure 3.7).

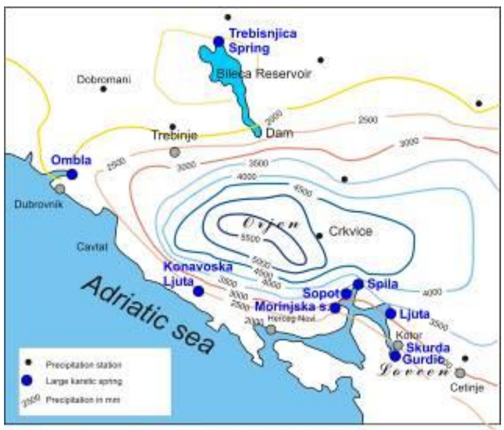


Figure 3.7 Map of isohyets in the Mount Orjen region and the major karstic springs (after Milanovic, 2005)

The distribution of precipitation is uneven during the year. Around 70% of rainfall regularly occurs during the wet season, between October and April. During the dry period of the year, discharge of coastal springs is reduced and many of them become brackish under the influence of seawater. Monthly rainfall can reach 300 mm, with an intensity of up to 4 mm/h.

Average air temperature in the study area varies between 12 and 13 ^{0}C. The Mediterranean climatic belt is characterized by high summer temperatures (daily maxima can be over 40 ^{0}C) and mild winters with significantly higher temperatures compared to the continental climate belt (Figure 3.8). Average air temperature in the Albanian Alps is around 7 ^{0}C. The temperatures are more affected by differences in elevation than by latitude or any other factors. Low temperatures in the Albanian highlands are caused by the continental air masses that control weather in the entire Balkans.

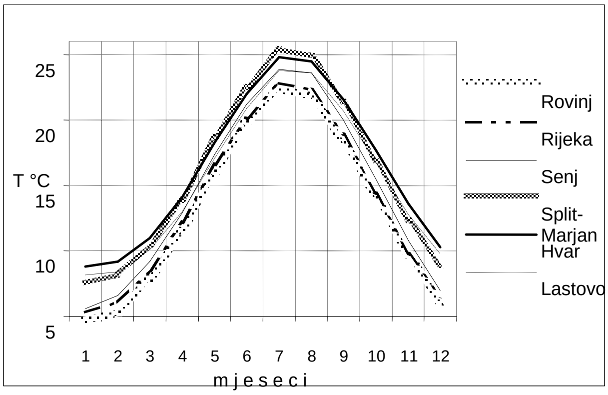


Figure 3.8 Average monthly (1-12) air temperatures at some climate stations on the Croatian coast and islands

Moderate air humidity is prevalent in most of the study area. Humidity is higher in the continental part and at higher altitudes compared to the coast and islands.

There are generally no systematic measurements of evapotranspiration from the plant cover and land surface. The assessment of evapotranspiration based on empirical formulae ranges from 500 - 650 mm in the continental part and 850 – 1,000 mm in the Mediterranean climate belt.

3.2.3 Hydrography and Hydrology

The spatial distribution of surface waters (rivers, lakes and transitional waters) and their interactions are determined primarily by morphology and geology. The total surface area of the Adriatic basin in the four countries is 65,545 km^2 while the Black Sea basin covers 44,865 km^2 of the project area (Table 3.1):

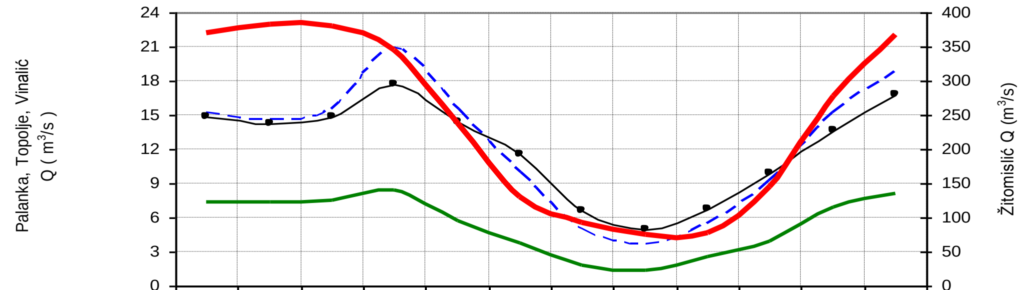
Table 3.1 Drainage areas of the Black and Adriatic seas in the DIKTAS project area

Project Area (km^2)	Croatia	B&H	Montenegro	Albania	Total
Black Sea	5,895	32,385	6,585	0	44,865

Adriatic Sea	21,550	12,990	6,760	24,245	65,545

In the Adriatic Sea basin, the density and length of surface streams are smaller, although there are significant groundwater flows through well developed karstic underground systems.

In the Croatian part of the Adriatic Sea basin, the Neretva River is the largest surface stream. It is shared with B&H where the Neretva drainage area is approximately 7,950 km^2. A significant sea influence is evident in the Lower Neretva delta. Intense mixing of saltwater and freshwater is also observed in Raša, Dragonja and Mirna in Istria and Riječina in the Kvarner Bay (northern Adriatic) as well as in Žrnovnica, Cetina, Jadro, and Ombla in Dalmatia (the central and southern Adriatic). Other large Croatian rivers flowing into the Adriatic are Lika, Zrmanja, Krka and Cetina (Figure 3.9).



m j e s e c i	1	2	3	4	5	6	7	8	9	10	11	12
ZRMANJA - Palanka	7,39	7,34	7,51	8,4	5,69	3,81	1,77	1,35	2,5	3,96	6,91	8,16
KRKA - Topolje most	14,9	14,2	14,9	17,7	14,4	11,6	6,65	4,96	6,73	9,87	13,7	16,8
CETINA - Vinalić	15,1	14,6	15,4	20,9	15,4	9,83	5,02	3,63	5,45	9,08	15,2	18,7
NERETVA - Žitomislić	370	382	379	346	238	129	92,5	74,1	76,9	145	278	368

Figure 3.9 Monthly average discharge of the main Croatian rivers in the Adriatic basin

The Una river basin, which belongs to the Black Sea catchment, is the western-most river basin in B&H's Dinaric karst. About 97.5% of the Una basin belongs to B&H and just about 2.5% (238 km^2) of the catchment is in Croatian territory.

Una, Vrbas, Bosna and Drina are the four major river basins of the inner part of the Dinarides in the territory of B&H. All of them are tributaries of the Sava River (Sana via Una) and belong to the Black Sea basin. Their flows are strongly influenced by distribution of the karstic rocks and show large variations throughout the hydrologic year.

The Trebišnjica River is the largest European sinking stream. Until construction of a large hydro-energy system Trebišnjica had regularly flooded the Popovo Polje. More than 500 ponors, estavellas and intermittent springs have been registered along the Popovo Polje (Milanović, 2006), while the total sinking capacity has been estimated at 300 m^3/s. The length of the Trebišnjica is 90 km, from the Bileća Springs (submerged) to the Ponikva ponor in the Popovo Polje. (Figure 3.10).

Figure 3.10 Channelled Trebišnjica riverbed in the Popovo Polje during the low water period (June 2011, photo ZEST)

The hydrograph of Montenegro is characterized by the existence of two watersheds: the Black Sea (52.5% of the territory) and the Adriatic (47.5%).

Lim, Ćehotina, Piva and Tara are four major rivers in the northern part of Montenegro. They are tributaries of the Drina and belong to the Black Sea basin. The Tara canyon is protected by UNESCO, while the Piva river flow is regulated by a large dam on the Piva (Figure 3.11).

With only 140.5 km of water course (of which 83 km is through the canyon), a catchment area of 1,853 km^2 and an average flow of 64 m^3/s, clear and wild River Tara flows through pristine nature.

The total area of the Adriatic watershed in Montenegro is 6,267 km^2. Morača with its tributaries Zeta, Cijevna, Rijeka Crnojevića and Orahovštica discharge into Lake Skadar, and from there the Bojana/Buna River flows towards the Adriatic Sea first crossing the Albanian territory and then making the border between the two countries further downstream (Hrvačević, 2004).

Figure 3.11 The artificial Lake Piva between the Piva dam and the planned upstream dam Loci (May 2012, photo ZS)

Lake Skadar (Shkodër, Skutari) is the largest lake on the Balkan Peninsula. Lake Skadar has had the status of a National Park since 1983, while it was included on the Ramsar list of internationally protected wetlands in 1995. It represents a real winter safe haven for European birds. Around 60% of the lake is in Montenegro, while 40% is in Albania.

The average altitude of the lake is 5 m, and the minimum and maximum depths are from 5-9 m to more than 60 m) respectively. The average surface area of the lake is 475 km^2. During the summer months this reduces to 370 km^2, while during the winter season it reaches 540 km^2. Lake Skadar has a peculiar water regime, with water level fluctuations of up to five meters. Noticeable oscillation of the water level of Lake Skadar results in the long term flooding of vast areas of Donja Zeta. The Morača River, with its two tributaries, Zeta and Cijevna/Cemi, contributes 62% of the lake's water. About 30% of this comes from many submerged karst springs called 'eyes'. The rest comes as direct runoff from the mountains or from rainfall. The Bojana/Buna and Drim/Drini rivers play an important role. The River Bojana/Buna flows from Lake Skadar (near the city of Shkodër) with an average yield of 320 m^3/s. Combined with the flow of the River Drim/Drini, the lake drains into the Adriatic Sea at an average rate of 682 m^3/s.

Lakes Crno, Plavsko and Biogradsko are also Montenegrin natural reserves, as typical glacial lakes. With the exception of Lake Plavsko, they are all located in national parks.

The largest rivers in Albania are the above mentioned Cemi, Buna, Drini and Black, as well as the White Drini, Semani and Vjosa. The average perennial flow of Albanian rivers is approximately 1,245 m^3/s. The annual discharge of all the streams in Albania reaching the sea is estimated at about 40 x 10^6 m^3/year.

Large seasonal differences in water regime are typical for this region. Although classical floods are not very common due to the large infiltration capacity of the karst, the ponors cannot always absorb runoff water from intensive rainfall, which causes regular flooding of many karst poljes. This is also the main reason why large projects to regulate river flows were initiated in all the countries in the region after WW II and many of these were implemented during the 1960s and 1970s. The idea to regulate flows is much older; the Klinje dam (Mušnica stream, B&H) was built in the period 1888-1896, while the hydro-electrical power plant (HPP) at Kraljevac (Cetina, Croatia) was erected in 1912. Today many streams are dammed (Figure 3.12) and their waters are utilized by hydro-electrical power plants.

Figure 3.12 The Mati River in Northern Albania (photo A.P.)

The major dams and reservoirs were built on the Cetina, Trebišnjica, Piva, Zeta, and Drini rivers.

The Cetina water system is run by the Croatian water authority although a considerable amount of water originates in the territory of B&H including catchments of the Kupres, Glamoč, Duvno, and Livno poljes, and Buško blato. Currently there are five HPPs on the Cetina River: Peruća, Orlovac, Đale, Zakučac (with the Prančevići reservoir) and Kraljevac. However, the largest storage reservoir, Buško Blato, is in B&H with a capacity of 831 x 10^6 m^3. This accumulates water to supply the Orlovac HPP (UNEP, 2000). Applying several calculation methods, the surface area of the entire watershed to its mouth on the Adriatic Sea is from 3,700 to 4,300 km^2 of which the topographic watershed encompasses about 1,300 km^2 and the subsurface watershed about 2,700 km^2 (Bonacci, 1987). The length of the Cetina River, from its source to its estuary, is 105 km, and its average flow is 118 m^3/s (UNEP, 2000).

The main structures of the Trebišnjica water system are the Bilećko Lake (i.e Bileća Reservoir) behind the Grančarevo dam, and the Gorica dam and reservoir downstream.[1] Active operating HPPs are Trebinje I (180 MW), Trebinje II (8MW), Čapljina (420 MW) and Plat (Dubrovnik, 210 MW). Although considerable works to solve water-tightness problems have been undertaken (the Grančarevo dam grout curtain surface is 64,000 m^2, after Milanović (2006)), leakages from one side have been detected. At Grančarevo dam site seepage is about 150 - 180 l/s. According to P. Milanovic, for a reservoir of the volume of 1.3 x 109 m3 in karst this seepage is negligible. In the case of the Gorica reservoir, the leakage has increased over time to about 5 m^3/s at the current time. (Cumulative) losses at the Grančarevo and Gorica dam sites are approximately 5-7% of the average river flows (of 74.3 m^3/s and 85.6 m^3/s respectively).

The number of artificial reservoirs in Montenegro is small in comparison with the hydropower potential. The total capacity of these reservoirs amounts to slightly more than 1 x 10^9 m^3 of water. With respect to the total amount of surface water (about 14 x 10^9 m^3/year) formed in the territory of Montenegro, this amounts to about 7% (Hrvačević, 2004). There are two reservoirs in the Black Sea basin: Piva on the River Piva and Otilovići on the River Ćehotina. The installed power is 360 GWh, with an average annual production of about 750 GWh, of which about 93% is peak power.

In the Adriatic basin, the reservoirs in the Nikšićko polje Krupac, Slano and Vrtac have been formed on the River Zeta, while the Liverovići dam controls the flow of the Gračanica River. Waters from the reservoirs are utilized by the HPP 'Perućica' which is designed for a flow of 80 m^3/s and power of 307 MW. The average production is 900 GWh/per year (Radojević, 2012). All the reservoirs in the Nikšićko Polje have been built in highly karstified rocks. Slano and Vrtac required intensive and expensive anti-infiltration works from the very beginning. The grout curtain along the southern rim of Slano is one of the longest in the worldIt has a length is 7011 m, depth 57 m and surface 396.122 m2.The current hydropower exploitation capacity of the main Albanian plants is 1,750 MW.

[1] A proper technical name for the reservoir behind the Grančarevo Dam is Bileća Reservoir. However, the country specialists of the DIKTAS Project Team decided to use colloquial name Bilećko Lake, also because of other-than-technical dimension of this project.

3.2.4 Land Cover and Land Use

Although Croatia is a country with a significant distribution of arable land, the coastal area and the islands are poor in terms of good quality soils. The most valuable agricultural areas are located in karst poljes and soils formed on flysch, marl and isolated alluvial deposits. Only locally (primarily in Istria) are there deeper soils of fertile *terra rossa*. In the interior of Croatia between the Sava and Kupa rivers, typical soils are loess and different types of hydromorphic soils. Different types of brown soils are present in the mountainous areas.

The most heavily populated is the north-western part of Croatia, where nearly 40% of the total population inhabits about 15% of the state's territory. Except along the coast, the population is sparse in the central part. The largest towns in the Croatian Dinaric karst are Split (175,000 inhabitants) and Rijeka (145,000).

Land cover in Bosnia and Herzegovina has been characterized by 33 out of 44 classes of the CORINE Land Cover nomenclature[2]. This project's analysis of the land cover database shows that more than 61.04% of B&H's territory is covered by forest and natural vegetation, while about 36.69% is occupied by arable land. In the southern part, the karstic area has sparse vegetation, and occasionally, for example in parts of Herzegovina, only bare rocks.

In the central part of the B&H Dinaric karst the largest towns are Sarajevo, Zenica, and Prijedor where more than 80% of the total population is located. In the south, large settlements are Mostar, Trebinje, Čapljina, Gacko, Bileća and Nevesinje.

The dominated land cover class in Montenegro is broad-leaved forest that occupies 26% of the total country territory. Almost 80% of Montenegro is covered by semi-natural and forest areas. Agricultural land occupies 16%, wetlands or water 3.4%, and developed areas only 1% of the national territory.
A detailed discussion on land use and land cover within the DIKTAS project area is provided in Annex 2, which contains separate country reports.

3.3 Geology

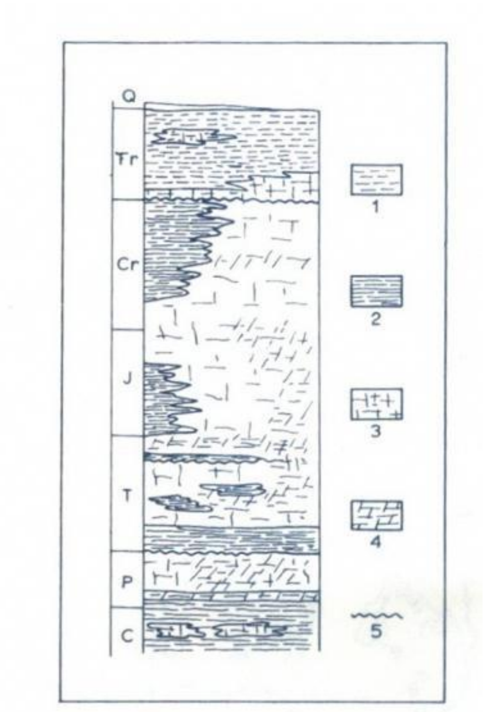
3.3.1 Stratigraphy and Tectonics

Throughout its early geologic history, the Dinaric region was part of the Mediterranean geosyncline (Tethys). It was not until the Late Paleozoic era that carbonate sediments were deposited in quantities favourable for karstification. The first sedimentation cycle represents the interval between the Upper Devonian and Middle Jurassic eras. In the inner Dinarides, marine sedimentation started mainly in the Upper Permian era and lasted until the end of the Lower Jurassic era. In the External Dinarides this cycle extended until the Upper Cretaceous).

There were a few distinct phases during the long sedimentation cycle that started (for a major part of the study area) in the Triassic and ended in the Paleogene era. At the end of the Upper

[2] Corine Land Cover is a programme initiated in the European Union in 1985. Corine means 'coordination of information on the environment'.

Cretaceous and during the Paleocene era, intensive uplifting and folding took place, during which most of the carbonate and flysch rocks were tectonized. After the Laramian tectonic phase, the next intensive movements occurred in the Helvetian phase (Eocene/Oligocene). All the main nappes along the Adriatic/Ionian Sea coastline can be related to this stage (Herak, 1972; Ćirić, 1984).



Legend:

1 = Tertiary clastic deposits; 2 = Palaeozoic and Mesozoic clastics; 3 = Limestones; 4 = Dolomites; 5 = Main unconformities; C = Carboniferous; P = Permian; T = Triassic; J = Jurassic; Cr = Cretaceous; Tr = Tertiary; Q = Quaternary.

Figure 3.13 Schematic lithostratigraphic column of the Dinaric region (Herak, 1972).

The Cretaceous sediments in the Dinaric region are almost entirely carbonates (limestones and dolomites) with the exception of Mount Durmitor in Montenegro, and northeast Herzegovina where Upper Cretaceous flysch has also developed (Bešić, 1972).

The main litho-stratigraphical formation members in the region are presented in Section 3.4.1 with the same classification used for the DIKTAS GIS maps and database.

The Dinarides are commonly divided into three major tectonic units: External, Central and Inner Dinarides. In addition these can be separated into several sub-units. This classification, proposed by the Croatian geologists (Herak, 1972), includes: A – Structural complex of the Adriatic carbonate platform (Adriatic) with the External Dinarides; D – Structural complex of the Dinaric carbonate platform (Dinaric) with the Central Dinarides; S – Structural complex of the Inner Dinarides (Supradinaric).

According to Herak (1972), two carbonate platforms existed in the area of the Dinaric Karst from the Late Triassic to the Eocene era - the Adriatic Carbonate Platform (Adriaticum) and the Dinaric Carbonate Platform (Dinaricum), separated by a persistent deep-water inter-platform (Epi-Adriaticum).

Herak (1972) divided the karst areas in Yugoslavia into three regions: (1) the Adriatic Insular and Coastal region, (2) the High Karst region (Central part), and (3) the Inner region. In his later works (1977) the name of the first region was shortened to the Adriatic belt.

The Inner Dinarides unit is often further divided into: (1) the Inner Dinarides Belt of Horsts and Rows, (2) the Inner Ophiolitic zone, and (3) the Inner Paleozoic zone.

The Albanian tectonic classification is relatively different in names and in structures. Nevertheless, units such as the Adriatic depression (Figure 3.14) and parts of the Ionian, Krasta-Cukali or Kruja zones belong to the External Dinarides, while the Mirdita unit could be interpreted as an extension of the Central ophiolitic zone of the Central Dinarides.

Figure 3.14 The contact zone between large tectonic zones – the Adriatic and Ionian (Dhermi, the Albanian coast, photo Z.S.)

The following geotectonic subunits are present in the External Dinarides of Montenegro from south to north (Figure 3.15): A) the Adriatic folds system, B) the Cukali zone, and C) the high karst zone.

A) In the Adriatic folds (part of the Adriatic-Ionian fold system), carbonate and flysch facies prevail. The carbonate facies consist of limestone, dolomite-limestone and in some places of dolomite of the Upper Cretaceous and Eocene age, while flysch facies consist of clay, marl, sandstone, breccias and conglomerates of the Eocene age.

B) Terrains in the Cukali zone are composed of several stratigraphic-lithologic members, starting with the Permian-Triassic up to the end of the Eocene era: flysch-clastic facies of the Lower Triassic; flysch facies of the Middle Triassic; volcanic rocks of the Middle Triassic; sediment-volcanic facies of the Middle Triassic; carbonate facies of the Triassic, Jura, Cretaceous and Paleogene, and flysch facies of the Paleogene era.

C) The majority of the territory of Montenegro belongs to the high karst zone (Figure 3.16). Its geology is very complex: Mesozoic limestone and dolomite prevail, but there are also spread-out non-karstic rocks such as Lower Paleozoic schist-argillaceous marl layers; Lower and Middle Triassic marl, sandstone and conglomerates as well as Middle Triassic porphyrite, quartzporphyrite, dacite and andesite. In addition, in two narrow zones across the entire territory of Montenegro from the southwest towards the southeast there are Upper Cretaceous-Paleogene flysch sediments represented by marl, argillite, sandstone, breccias and conglomerates.

Figure 3.15

Geotectonical units of Montenegro (A – Adriatic folds Paraauchtochton, B - Budva-Cukali zone, C – different subunits of High karst zone, and D - different subunits of the Durmitor tectonic zone (after Radulović & Radulovic 1997)

The Dinaric carbonate rock complex is the result of the Alpine orogenic phase with the most intensive tectonic movements during the Tertiary. Tectonic events resulted in a complex system of faults and fractures that acted as preferential flow paths in the karst aquifer system. Moreover, climatic conditions, particularly the successive wet and warm periods, significantly contributed to the karstification. The stream network, in most of the carbonate rock complex, was almost completely degraded, while only major streams such as the Cetina, Krka, Neretva, Zeta, and Vjosa had a perennial character. The folding and faulting continued during the Neogene era, while the formation of main depressions (poljes) as a result of intense faulting took place mainly during the Upper Pliocene – Pleistocene era. The regional faults also contributed to the deepening of the numerous karst poljes and creation of the current topography.

Figure 3.16 Karstified rocks of Mt. Sinjajevina in Montenegro (the high karst zone of the Central Dinarides, photo Z.S.)

3.4 Hydrogeology

3.4.1 Aquifer Systems

For the purpose of creating the Regional Hydrogeological Map of the Dinaric system in GIS (see Annex 1), 22 litho-stratigraphical members have been classified and attributed to different aquifer units. Some members of the same age were formed in different paleogeographic environments resulting in varying lithology as well as hydrogeological properties. Table 3.2 shows the classification of the 22 litho-stratigraphical members into the six aquifer units based on their hydrogeological characteristics,

Table 3.2 The main litho-stratigraphical members of the Dinaric Karst and their classification into the six aquifer units

Paleozoic rocks Pz – AT (aquitard),

Permian sandstones P - AT,

Permian-Triassic rocks P-T – FA (fissured aquifer),

Clastic rocks of Lower Triassic (Werfen facies) T 1 - AT,

Carbonate rocks of Middle Triassic T_2 - KA1 (highly productive karst aquifer),

Sediment-volcanic formations or flysch of Middle Triassic T_2 - AT,

Carbonate rocks of Upper Triassic T_3 - KA1,

Sediment-volcanic formation of Upper Triassic T_3 - AT,

Lower and Middle Jurassic carbonate rocks (limestones, dolomites) J_1, J_2 - KA1,

Upper Jurassic carbonate rocks J_3 - KA1,

Middle and Upper Jurassic ophiolite formation (diabase-cherts and serpentinites) J_3 - AT,

Lower Cretaceous carbonate rocks K_1 - KA1,

Upper Cretaceous carbonates K_2 – KA1,

Upper Cretaceous carbonate flysch (‘Durmitor facies’) K_2 – KA2 (karst aquifer of moderate productivity),

Paleocene and Eocene carbonates, Pc, $E_{1,2}$ – KA2,

Paleocene and Eocene flysch Pc, $E_{2,3}$ - AT,

Eocene - Oligocene flysch or undifferentiated sediments of major basins E-Ol - AT,

Volcanic and magmatic rocks of different age (dacites, andesites, granites, peridotites) – FA,

Mio-Pliocene sediments M, Pl – IA2 (intergranular aquifer of moderate productivity),

Quaternary (Pleistocene) terrace and deposits Qt – IA2,

Quaternary fluvio-glacial deposits Qf, gl - IA1 (highly productive intergranular aquifer),

Quaternary (recent) alluvium deposits Qal - IA1.

A karst aquifer (KA) is formed within a very thick (over 1,000 m) complex of limestones and dolomites (Figure 3.17). As a result of intensive karstification, carbonate rocks are characterized by well-developed surficial relief (morphological) karstic forms, but also by a network of highly permeable underground channels that act as preferential pathways of intensive groundwater circulation.

It is very difficult to estimate the overall effective porosity (considered also as a storage coefficient) of the karst aquifer because of the anisotropic and heterogeneous character of limestones and dolomites. Most references provide values in the range of 0.008-0.02, while locally it can be significantly higher.

Referring to the karstification base as an approximate depth to which the soluble rocks were exposed to the karstification process, Milanović (2005) noticed that in Mount Orjen the depth is between 350 and 400 m. Locally, in the wider area (Nikšićka Župa, Vilusi), deep boreholes have encountered karstified zones at depths of 500 m, and sometimes at depths exceeding 2,000 m. Milanović (2000) also stated that for the Dinaric region, the average depth of the base of karstification is not more than 250 m (Figure 3.18).

Figure 3.17 Highly fractured and folded Cretaceous limestones, KA1 unit (Mt. Durmitor, Montenegro, photo Z.S.)

Milanović (2000) concludes that in the surface zone of 0 - 10 m karstification is about 30 times greater than that at a depth of 300 m (Figure 3.19). When depths are greater than 300 m the index of karstification approaches its minimum value, slightly higher than zero. Deeper karstification is regularly associated with tectonic zones. According to Milanović, the zone with the most storage is the section of water table fluctuation.

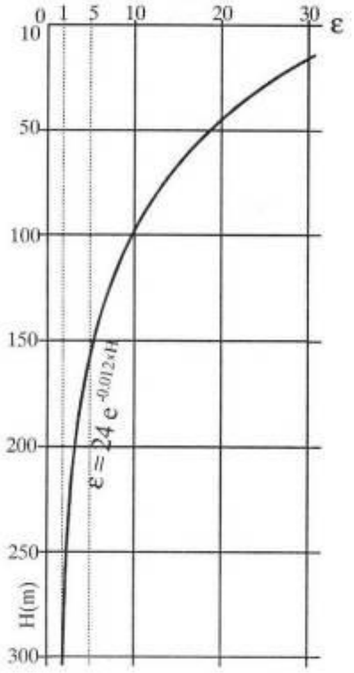


Figure 3.18 Generalized relationship between the karstification and the depth based on permeability tests in 146 boreholes in the Dinaric karst of eastern Herzegovina (after Milanović, 2000).

The recharge of a karst aquifer is from precipitation, sinking streams, and diffuse infiltration along some sections of perennial rivers.

In zones where highly karstified rocks are exposed to the surface most of the rainfall infiltrates into karstic aquifers (Figure 3.20). In rough terms, it can be estimated that the average infiltration rate is 60% of precipitation. Komatina (1983) noticed that for the River Cetina catchment area, more than 80% of the precipitation appears at the terminal water gauge controlled profile, while in the River Trebišnjica catchment area this percentage is even higher, reaching 90% as estimated from the data collected at the Arslanagića Most gauging station.

Effective infiltration in the Albanian karst is on average between 40 and 55% of rainfall (e.g. in the Albanian Alps 1,500-2,000 mm/year; in the Mali me Gropa area 1,100 mm/year). Several large springs are fed by waters infiltrated from large streams, such as the Poçem Spring from the Vjosa River (about 80%).

The main erosional base of the External Dinarides is the level of the Adriatic and Ionian Seas, while the local erosional base for numerous springs are the edges of karstic poljes or the contact of carbonate and non-carbonate rocks.

Some authors estimate that in the Dinaric region of ex-Yugoslavia there are 230 springs with a minimal discharge over 100 l/s, while about 100 springs have a minimal discharge of over 500 l/s.

Figure 3.19 Highly karstified rocks in the Karuč Spring catchment (Lake Skadar, Montenegro, photo Z.S.)

Figure 3.20 Estavelle Gornjepoljski Vir at the edge of the Nikšićko polje (Montenegro, photo Z.S.)

Milanović (2005) stated that only three huge springs along the Neretva Valley and Adriatic coast (Buna, Bunica and Ombla) and a few spring zones in the Kotor Bay (Orahovačka Ljuta, Spila, Sopot, Morinje Springs, Škurda and Gurdić) annually discharge more than 150 m^3/s, on average, into the Adriatic Sea directly or indirectly via the Neretva River. Approximately the same quantity of water is transported from the man-made reservoirs through the power plant canals and tunnels to the sea.

In the Vrbas River basin, the most important karst aquifers feed the River Pliva spring (Qmin=8 m^3/s) and the Janja River spring (Qmin =0.6 m^3/s). Characteristic flows of the River Sana springs are Q_{min}:Q_{av}:Q_{max}=2:8:50 m^3/s. Other large springs in the central part of B&H are the left and right springs of the River Ribnik (Q_{min}=1.3 m^3/s, Q_{av}=7.5 m^3/s), and the River Krka spring (Q_{min}=0.7 m^3/s).

Karst aquifers on the left bank of the River Neretva, in the Mostar region, discharge via very strong springs of the Buna and Bunica rivers (Q_{min}=5 m^3/s, catchment area about 1,100 km^2), the River Sabakova (Q_{min}=2 m^3/s) and the River Bregava (Q_{min}=>0.5 m^3/s, catchment area approximately 450 km^2).

Three capitals out of four in the project countries obtain their drinking water from the karstic aquifers. Sarajevo receives part of its water supply from the Vrelo Bosne springs in the Central Dinarides. The discharge of this group of springs that drain the rich Triassic aquifer of Mt. Igman is in the range of 1.4 – 24 m^3/s (Čičić & Skopljak, 2004). Currently, 0.4 m^3/s is an average discharge directly tapped at the springs while the Water Master Plan counts on roughly an additional 1 m^3/s to be used by the intake in the open river course located downstream (Kovačević & Lončarević, 2003).

The Albanian capital Tirana obtains its water in part from the source that drains the Triassic and Jurassic karstic aquifer of the Mali me Gropa plateau. Since WW II the two main springs, Selita (0.24 to 0.86 m^3/s) and Shemria (0.45 and 1.50 m^3/s), have been tapped for the city (Eftimi, 1971). Downstream from the third important spring, Buvilla, a large surface water reservoir has been constructed to drain the Mt. Dajti karst aquifer (Eftimi, 1998).

The Mareza spring (2.0–10.0 m^3/s) in the Skadar basin is the main source for the Montenegrin capital city of Podgorica. The group of typical ascending springs discharges at the 2 km-long point of contact between the Cretaceous limestone and limnoglacial sediments of the basin (Radulović, 2000).

Along the Adriatic and Ionian coast almost all the cities and tourist centres consume karstic groundwater (Stevanović, 2010a).

The Zvir group of springs were tapped at the end of the 19th century to supply water for Rijeka, the largest Croatian port. The discharge varies between 0.6 and 3.0 m^3/s (Biondic & Goatti, 1984).

The Jadro spring is the main source for Split's water supply . The average minimum discharges of Jadro during the recession period are 3–5 m^3/s, while maximum discharges are often over 50 m^3/s (Bonacci, 1987).

The Ombla spring (Figure 3.22) is the largest permanent karstic spring in the South Adriatic. It supplies the city of Dubrovnik.

Since the completion of the Trebišnjica HE system and the regulation of this biggest sinking river in Europe, the average discharge of Ombla has been reduced from 34 m^3/s to 24 m^3/s. However, the minimum discharge (2.3 m^3/s) has not been affected by the construction works (Milanović, 2006).

Figure 3.21 A karst spring near Tepelena (Albania, photo Z.S.)

Figure 3.22 The Ombla spring (source of the Rijeka, Dubrovačka, Croatia, photo Z.S.)

The best-known springs along the edges of the Boka Kotorska Bay in Montenegro are the Gurdić and Škurda springs near Kotor, the Ljuta spring at Orahovac, the Spila spring at Risan, the Morinj springs, the Opačica at Herceg Novi and the Plavda at Tivat. The Sopot near Risan (Figure 3.23) is the best known among the submarine springs. All these springs are characterized by a high variation in discharge due to a highly karstified catchment and extremely fast propagation of the rainfall. Some of these springs even dry out completely during summer (e.g. Sopot, Spila Risan), while after intensive rainfall or at the end of winter some of them can discharge over 100 m^3/s.

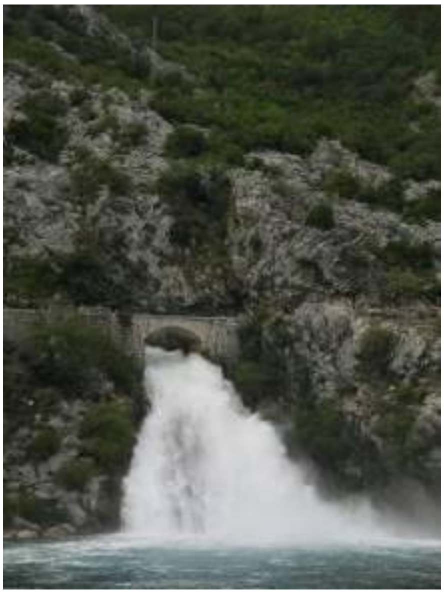


Figure 3.23 The Sopot spring near Risan (Montenegro) during peak flow discharge (September 2005, photo Z.S.)

At the farthest northwest edge of the Bjelopavlićka plain there is a very abundant periodical karst spring Perućica as well as two others, Glava Zete and Oboštičko oko. Their minimum yield is over 6 m^3/s and their maximum about 250 m^3/s of water (average about 55 m^3/s).

Along the edge of Lake Skadar there is a large number of sublacustrine springs (‘oka’ in Serbian, ‘eyes’ in English). The following are particularly noteworthy: Oko Matice, Golač, Kaludjerovo Oko and many other eyes along the edge of Malo Blato; Volač, Karuč, Bolje sestre (recently tapped for the regional water supply of the Montenegrin coastal area, Stevanović 2010b), Grab and others in the flooded valley of the River Crnojevića Rijeka.

In the Albanian karst there are roughly 110 springs with an average discharge exceeding 100 l/s. Of these, 17 have discharges exceeding 1,000 l/s (Eftimi, 2010). The majority of them are in the Dinaric part of the country (north from Vjosa). It is estimated that 2/3 of groundwater resources in the entire country are in karstic aquifers which provide more than 60% of the water consumed in Albania (Eftimi, 2010).

The karst water resources of coastal karst aquifers in the catchment of the Ionian Sea in Albania are estimated at about 15 to 20 m^3/s on average (after Eftimi, personal communication).

Komatina (1983) divided the large springs of the Yugoslav Dinaric karst into two groups. The first group of springs with a mean yield greater than 10 m^3/s includes Velika Ruda in the Grab —

Sinjsko Polje, Krupić and Bug in the Kovačevo Polje, the left spring of the River Pliva, Klokun in the Tihaljina river valley, the spring of the River Trebišnjica at Bileća, Ombla near Dubrovnik, Glava Zete, and Crno Vrelo in the Una river valley.

The second group of springs with mean yield between 5 and 10 m^3/s includes the Riječina River spring near Rijeka, the main spring of the River Gacka, the spring of the River Zrmanja, Veliki Praporac in the Neretva river valley, and Varvara in the Kovačevo Polje.

3.4.2 Groundwater Basins

The location of the water divide between the Adriatic/Ionian watershed, and the Black Sea in the Dinaric karst has been the subject of studies by numerous geologists, geomorphologists and hydrologists.

Komatina (1983) stated that according to geologic and hydrogeologic factors affecting the groundwater flow directions, the boundary between the Adriatic and Black Sea watersheds extends across Postojna, the Velika Kapela massif, along the edge of the Krbavsko Polje, the Staretina and Cincar mountains towards Bitovnja, and the Lelija and Golija mountains in Montenegro. Water from more than two thirds of the Dinaric karst territory gravitates to the Adriatic Sea. The River Sava catchment area, i.e. the catchment area of the Black Sea, spreads mainly over the northwest half of the karst belt (Figure 3.1), including the massifs of Grmeč and Plješevica and the terrains between the River Korana and the Slovenian karst (Ljubljansko Polje).

The main river basins in the Adriatic/Ionian catchment area are the Vjosa, Semani, Drini, Buna (Bojana), Zeta, Neretva, Trebišnjica, Bregava, Cetina, Krka, and Zrmanja. Other parts of the very extensive littoral terrain with islands drain directly to Adriatic or Ionian sea. The belt of this direct sea catchment area intrudes deeper inland behind the Boka Kotorska Bay, Trogir and Biograd and in the wider area of the Velebit massif and in the region of Istria.

Karst groundwater from the river basins of the Tara, Piva, Lim Ćehotina, Drina, Vrbas, Pliva, Sana, Una, and the upper course of the River Kupa gravitates to the Black Sea catchment area.

The parts of above river catchments can also be recognized as major groundwater basins within the DIKTAS study area, although their boundaries often do not coincide or could be variable throughout the hydrological year (Bonacci, 2008).

The DIKTAS project is focusing on transboundary aquifers (TBAs), examining current and potential issues of concern. The analysis of TBAs also provides an opportunity to test the applicability of outcomes of the regional analysis on a local scale, dealing with concrete issues of transboundary concern. In total, eight TBA have been selected for detailed analysis: Una, Krka, Cetina, Neretva, Trebišnjica (all shared by Croatia and B&H), Bilećko Lake, Piva (B&H and Montenegro) and Cijevna/Cemi (Montenegro and Albania).[3] Six of these TBAs belong to the Adriatic Sea catchment area and two (Una and Piva) are part of the Black Sea basin. The TBAs

[3] Introducing two TBAs in Eastern Herzegovina, namely Trebišnjica TBA and Bileća Lake TBA is arbitrary and done for the sole purpose of transboundary analysis. Both TBA belong to the regional karst aquifer system of Eastern Herzegovina. Perhaps TBA Popovo Polje would have been more suitable name for the TBA Trebišnjica.

comprise a total surface area of 12,000 km^2, which is approximately 10% of the entire study area. The surface area of the individual TBAs varies from 668 km^2 (Krka) to 3,455 km^2 (Cetina).

A delineation of the aquifer surface area was the first step in the hydrogeological analysis of each TBA. These areas usually comprise allogenic and autogenic zones of karst aquifer recharge. Further analysis included the characterization and development of conceptual models for each TBA. For example, in four out of the five TBAs shared between B&H and Croatia, groundwater flow is defined to be from B&H to Croatia, and only in one case (Una) is it vice versa (Figure 3.24).

Figure 3.24 Transboundary aquifers between Croatia and B&H (see Annex 1 for a larger map size)

3.4.2.1 Regional Groundwater Flow Directions

General groundwater flow directions in the Dinaric karst are relatively well understood. A large number of tracing tests were first conducted in the Slovenian karst (Ljubljansko polje) in the 1960s, followed by tests in Dalmatia and eastern Herzegovina during the 1970s, mainly for the purposes of dam and reservoir construction.

Komatina (1983) states that more than 650 localities were investigated in the Dinaric karst of the former Yugoslavia. In eastern Herzegovina alone 281 localities were subject to tracer tests, and in the catchment area of the Cetina River there were 99 such localities. Tracer tests were conducted in 77 localities in the Lake Skadar catchment area.

Milanović (2000) states that more than several hundred investigations have been performed in the Dinaric karst for the purposes of finding major flow paths of groundwater flow (Figure 3.25). By analysing data from these experiments, he concludes that the average flow velocity varies within a wide range from 0.002 to 55.2 cm/s, where the extreme values represent velocities that rarely occur.

The results of both historic and more recent investigations with various tracers have shown that the karst groundwater velocities vary with the season. During the dry season and low water table, groundwater flow in the karst system is characterized by relatively low velocities. In contrast, the groundwater velocities based on dye tracing tests conducted during the wet season are two to five times higher (Milanovic, 2004).

Figure 3.25 Connections between ponors and springs in the East Herzegovina region confirmed by dye tests

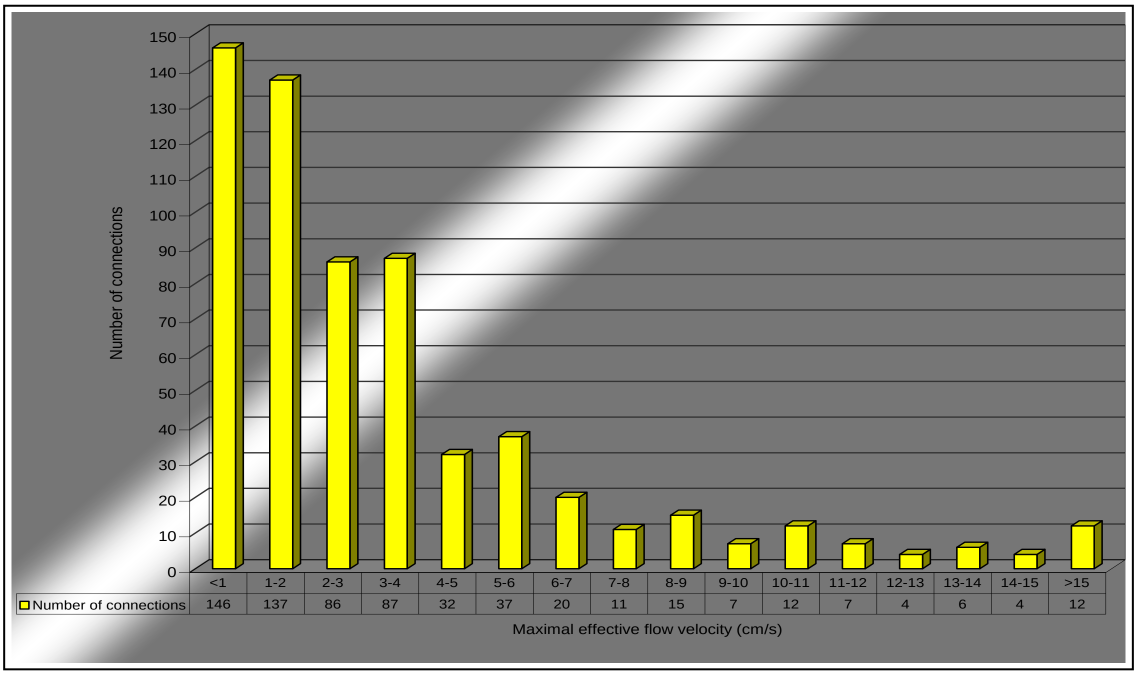


Figure 3.26 Frequency of maximal flow velocities based on 623 confirmed connections between ponors and springs in the Croatian karst (Pekaš, 2012)

Komatina (1983) cites works by Milanović and Magdalenić who found that, based on 380 conducted experiments, the virtual groundwater velocities in the Dinaric karst are as follows: in 70% of the cases from 0 to 5 cm/s; in 20% of the cases from 5 to 10 cm/s; and in 10% of the cases more than 10 cm/s. As illustrated in Figure 3.26, similar groundwater velocities have been observed in the Croatian karst as well.

Very high tracer velocities recorded at a large number of localities in the Dinaric karst are indicative of holokarst, or terrain with the most intense mature karstification and presence of extremely transmissive preferential flow paths in the underlying karst aquifer.

3.4.2.2 Groundwater bodies

As an important step towards implementation of the European Union Water Framework Directive (EU WFD) in all the four countries, some activities in the delineation and characterization of groundwater bodies (GWBs) were undertaken, but the results and achievements are different from country to country:

- Croatia: Characterization of GWBs completed; monitoring is taking place in accordance with the EU Water Framework Directive (Hrvatske Vode is the responsible institution).
- B&H: Characterization of GWBs is ongoing; no defined methodology for groundwater status/risk assessment.
- Montenegro: Characterization of GWBs in the Black Sea basin was carried out in 2005 under the International Commission for the Protection of the Danube River (ICPDR), but a new one is planned for the entire country; a methodology for the groundwater status/risk assessment has not yet been established.
- Albania: Preliminary characterization of GWB was performed within Consolidation of the Environmental Monitoring System in Albania (CEMSA) project. Currently, characterization is being undertaken by the Albanian Geological Survey (scale 1:200 000).

In the karst area of the Adriatic Sea basin of Croatia 101 GWBs were certified (Figure 3.27), while 28 additional GWBs were delineated in the Black Sea basin. All the larger islands were identified as separate GWBs.

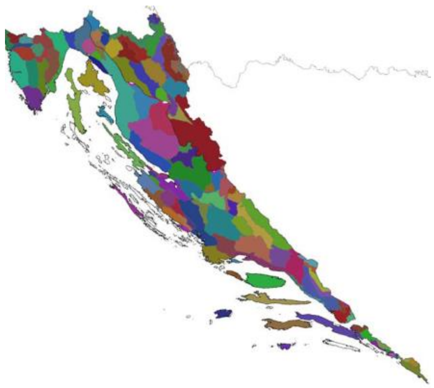


Figure 3.27 Groundwater bodies (GWBs) in the Croatian Dinaric karst

In B&H characterization of GWBs is under the jurisdiction of two entities. In 2008 the Contract between World Bank (WB), and Government of Croatia, Federation of B&H (FBH) and Republic of Srpska (RS), as well as Memorandum of understanding between B&H and Croatia have been signed. The Contract relates to the WB/GEF grant for common Project for B&H and Croatia "Managing of Neretva and Trebišnjica rivers". It started in 2010 and is planned to be completed in 2013. Project covers issues of water allocation, preservation of ecosystems and biodiversity, as well as reduction of pollution from sewerage systems in B&H's and Croatia's settlements and industries. One of the Project's components is the elaboration of Neretva – Trebišnjica river basin management Plan. Delineation of GWBs in the Trebišnjica and the Neretva river basins on the territory of Bosnia and Herzegovina (both the Republic of Srpska and the Federation of Bosnia and Herzegovina) and Republic of Croatia was performed as part of this project (carried out by Elektroprojekt Zagreb, Water Management Institute Bijeljina and others).

Characterisation of GWBs in the Sava River Basin, within a preparation of the Sava River Basin management plan, was carried out in 2011. In the FB&H, a characterisation report for Cetina and Krka River Basin (Adriatic Sea Basin) was performed in 2012.

In Albania, out of 60 identified GWBs, 18 are classified as 'carbonate' (Figure 3.28). Eftimi (2010) estimates that highly karstified rocks and productive karst aquifers crop out over an area of about 6,500 km^2 or ¼ of Albania's total surface area. Eftimi also stated that large karstic areas in the Ionian and Kruja zones and in the Adriatic basin are covered by flysch and molasses deposits.

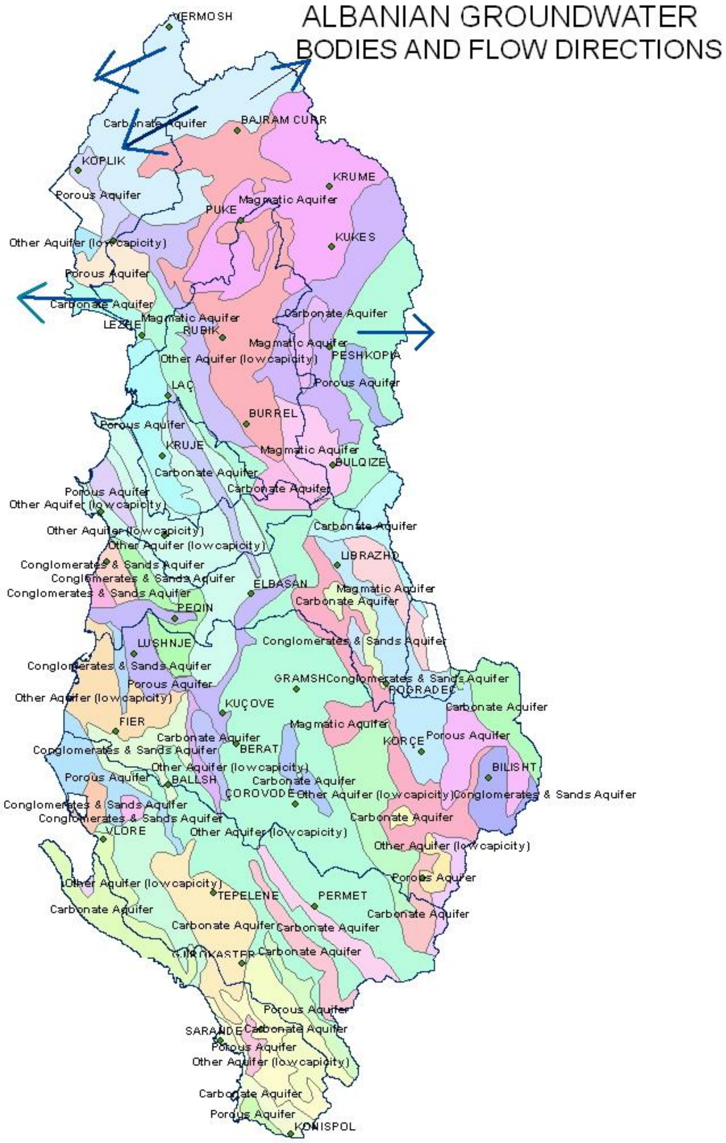


Figure 3.28 Groundwater bodies in Albania (after Pambuku, 2012)

3.4.2.3 Groundwater Regime and Balance

The water balance in Croatia is calculated based on the analysis of the average 30-year data for four river basins and/or groups of river basins and islands. The data used includes precipitation and air temperature records as well as data on water discharges for a 30-year period (1961-1990, Table 3.3).

Table 3.3 Water balance of major drainage basins in Croatia

Area	Surface	Precipitation	Evapo-transpiration	Discharge	Specific runoff
	km^2	mm	mm	m^3/s	$l/s/km^2$
Sava river basin	25.770	1.080	678	328	12,73
Drave andi Danube r. basin	9.362	782	621	48	5,13
Black Sea basin	**35.132**	**1.001**	**663**	**376**	**10,71**
Littoral-Istrian river basins	7.567	1.622	814	194	25,63
Dalmatian river basins	10.566	1.394	717	227	21,48
Islands	3.273	1.073	784	30	9,2
Adriatic Sea basin	**21.406**	**1.426**	**761**	**451**	**21,1**
Croatia	**56.538**	**1.162**	**700**	**827**	**14,6**

From the table it is evident that specific runoff in the Adriatic basin is much higher than in the Black Sea basin which is attributable primarily to the high infiltration rates over karst areas and subsequent subsurface (groundwater) flows that generate high specific groundwater runoff.

Similar results were obtained in B&H. The values of specific runoff are variable but regularly higher in the Adriatic basin. In the Trebišnjica river basin in a karstic area between the Popovo Polje and the Adriatic coastal zone the specific groundwater runoff ranges between 15 and 35 $l/s/km^2$.

In the Neretva river basin the following values were obtained: catchment area of the River Bregava 33.1 $l/s/km^2$, Jakešnica Spring 31 $l/s/km^2$, Nezdravica 19.30 $l/s/km^2$, and the Buna and Bunica springs 39 $l/s/km^2$. In the Una river basin the following values of specific groundwater runoff have been calculated: the catchment area of the Klokot spring 32.14 $l/s/km^2$, the Crno vrelo spring 9.5 $l/s/km^2$, and the Voloder spring 20.4 $l/s/km^2$. The specific groundwater runoff in the shared Cetina basin is 33 $l/s/km^2$.

Considering karstic groundwater resources, the Dinaric region is by far the richest in all of Europe. Some areas, such as southern Montenegro, are characterized by an average groundwater runoff of over 40 $l/s/km^2$.

Water budget elements calculated for the selected TBAs are presented in Chapter 7 of this report.

One of the main characteristics of karst aquifers in the external Dinarides zone is a large fluctuation of the water table and discharge of springs that very much depends on the amount of rainfall and its intensity. For instance, the water level can change by 312 m during a period of 183 days (example of the observation borehole Z-3 in the Nevesinjsko Polje). Milanovic (2006) noticed a quick reaction of the karstic aquifer in Eastern Herzegovina, within 10-15 hours of heavy rainfall. An increase of 90 m in only 10 hours (9 m/h) has also been recorded in this area. In the Cetina river basin the maximum recorded water table increase was 3.17 m/h (UNEP, 2000).

The main characteristic of karst springs is a very variable flow regime. The ratio between the minimum and the maximum discharge of large karst springs in the External Dinarides karst can be as high as 1:>1000 as in the case of some Kotor Bay springs. Other large springs such as Trebisnjica or Oko (tapped for Trebinje's water supply) also have highly variable discharge regimes with a ratio of 1:800 and 1:80 respectively. On the other hand, several very large springs such as Buna, Bunica, and Ombla do not regularly exceed 1:25 in an average hydrological year.

According to Šarin et al. (1983), variation in the karstic springs' discharge expressed by the ratio Qmax/Qmin is often larger than 100. For instance, the spring of the River Una - 197; the River Cetina spring — 100. In contrast, there are springs with a relatively more stable regime of discharge: the River Gacka spring — 3.1; the Varvara spring — 3.3; springs of the River Pliva — 4.4. As a rule, ascending contact springs have a more stable discharge throughout the hydrologic year compared to gravity springs.

Extremely high rainfalls and glaciations during the Quaternary era stimulated the karstification process and greatly influenced the current regime of karst waters in the area. The much deeper sea water level at that time (as much as 100 m during certain glaciation episodes) and steep groundwater gradients have additionally contributed to deeper groundwater circulation in the karstified Mesozoic rocks. Current evidence of this deep circulation is numerous submarine springs in the wide open Mediterranean littoral. Therefore, a general erosion base of karst groundwater discharge is situated between 100 and 150 m below the current sea level in the Mediterranean.

4 Environment and Socio-economic Analysis

This chapter provides an overview of the environmental and socio-economic situation in the DIKTAS project countries. The analysis showed the degree of similarity and regional interconnectivities. The countries share the same or similar geographic characteristics, the common or related history and similar trends. All these countries have their orientation to the Adriatic Sea, even Bosnia and Herzegovina, particularly through the delta of the River Neretva. Croatia and Bosnia and Herzegovina (and Montenegro to a limited extent) are also oriented to the River Sava that they share for several hundred kilometres. The region is abundant with pristine nature areas, which are often vulnerable and under threat. This threat is mostly from solid waste disposal and wastewater. Waste management in the region is still inadequate. One of the reasons for this is certainly the economic strength of the countries: Albania, Bosnia and Herzegovina and Montenegro are among the poorest countries in Europe and Croatia is also far below the average of the European Community. The countries are at various stages of the EU integration process.

Groundwater is used as a main source of drinking water in the region. The quality of the groundwater is in general good, although the monitoring is often sparse and irregular, and the enforcement of water protection zones is insufficient. In spite of a general abundance of water in the project region, some areas face severe shortages in water supply and availability during dry seasons; this is especially evident in coastal areas where demand increases substantially during the summer months. It is important to note that large quantities of water are used for production of electrical power. Related hydro-technical interventions in nature show, usually, favourable (economic) and less favourable (environmental) effects. On the other hand, the share of agricultural production and mining in economic activities is decreasing, indicating a relative decrease of potential pollutants.

The analysis was conducted during 2011 and 2012, and later updates were purposely not included.

4.1 Basic Country Information and Administrative Setup

The Republic of Albania is located in south-eastern Europe, stretching along the southern part of the Adriatic Sea. Albania covers a land territory of about 28,748 km^2, with a population of about 2.82 million (census 2011). Mountains and hills make up most of the country with relatively small plains along the coast. The country has a continental climate in its high altitude regions with cold winters and hot summers. The three largest and deepest tectonic lakes of the Balkan Peninsula are partly located in Albania, among them Lake Skadar/Shkodra that is part of the Dinaric Karst (Albanian Alps) in Albania.

Bosnia and Herzegovina (B&H) is located in the western part of the Balkan Peninsula, bordering the Republic of Croatia to the north, west and south, the Republic of Serbia to the east and the Republic of Montenegro to the southeast. The area of the country is 51,197 km^2, with a population of about 3.84 million (2011 estimate). The country is mostly mountainous, encompassing the central Dinaric Alps. The north-eastern parts of the country reach into the Pannonian basin, while to the west and south it borders Croatia, and only along a very limited section, reaches the Adriatic Sea. The country has in fact only 20 kilometres of coastline. B&H has mostly a continental climate, except its southern part where the Mediterranean climate prevails. The precipitation in the continental part ranges between 700 mm and 1400 mm, while the Mediterranean part (especially the eastern part of Herzegovina) has one of the highest amounts of precipitation in Europe.

Figure 4.1 Map of administrative boundaries in the DIKTAS region (see Annex 1 for a larger scale)

B&H is politically decentralized and comprises two governing entities, the Federation of Bosnia and Herzegovina and the Republic of Srpska, with the district of Brčko as a *de facto* third entity. The complex administrative structure results in a number of different institutions in charge of water management issues and exacerbates coordination on a national level. Unlike the central authority of B&H, the two entities (the Federation of B&H and the Republic of Srpska) and the district of Brčko have political, administrative and legal jurisdictions on water management and environmental protection in their own territories.

The Republic of Croatia, both a Central European and a Mediterranean country, is bounded by the Danube river basin to the north and by the Adriatic Sea to the south. About 4.29 million inhabitants live in its territory of 56,594 km^2, less than 50% of them in urban areas. Geomorphologically, Croatia can be differentiated in three units: the lower Pannonian and Peripannonian area in the north, the central mountainous area, and the Adriatic coastal area in the south. Both the central and the Adriatic coastal areas belong to the Dinaric Karst Aquifer

System. Groundwater flow is mostly towards the Adriatic, with minor sections draining to the River Sava. The coast consists of islands and of a narrow continental strip separated from the inland by high mountains. The coastline areas as well as the islands are usual tourist destinations, mostly in July and August. The pressures on all the systems are the highest in these months. In some cases the population of some places increases up to ten times due to the number of visitors.

Montenegro is a Mediterranean and a Dinaric country, covering a land area of 13,812 km^2 and with about 625,000 inhabitants (2011 census). It shares borders with Albania, Serbia, B&H and Croatia (it has only a 14 km wide coastal strip). Its relief, mostly mountainous, is dominated by the Dinaric mountain system, stretching parallel to the Adriatic coastline and with peaks above 2,500 m. The northern and central parts of Montenegro have high mountain ridges and plateaus, dissected by deep and narrow river valleys. Relatively large plains are present in its central part, and in the areas around Lake Skadar/Shkodra and the River Zeta. Approximately half of the territory belongs to the Sava river basin and the other half to the Adriatic Sea basin. The most important rivers of the Sava basin within Montenegro are the Piva, Tara, Ćehotina and Lim rivers. These rivers are tributaries of the River Drina and the Ibar is a tributary of the River Morava. The major river of the Adriatic Sea basin in Montenegro is the River Morača with its tributaries Zeta, Cijevna, Rijeka Crnojevića and Orahovštica. Morača flows into Lake Skadar/Shkodra, and from there to the Adriatic Sea through the River Bojana. Montenegro is rich in water resources.

Prior to the 1991-1995 war that ravaged the Dinaric region, the government of Yugoslavia directed the development of the Dinaric region towards mass tourism along the coastal areas, and stimulated agricultural production in the interior part of the region by construction of hydrotechnical infrastructure intended for flood protection, irrigation, water supply and hydropower production activities. Today, while the region is on a fast track for economic growth, spurred for some of the countries at least by the opening of EU accession discussions, countries are determined to move towards more sustainable development models and to deal with the main threats to the long term sustainability of the Dinaric Karst Aquifer System and their transboundary implications.

These threats include: (i) lack of harmonized multi-country policies regulating land use and physical planning throughout the karst region in view of the aquifer's high vulnerability to contamination; (ii) areas of potential future over-extraction, and lack of a conceptual framework for balancing the various demands on the resource which exhibits very strong seasonal and multi-annual variability; (iii) need to mitigate and/or prevent potentially negative impacts of infrastructure systems on the karst aquifer resources; (iv) potential impacts of global change (development, population growth, migration), including climate change (such as excessive variability in rainfall patterns, flooding etc.), and (v) lack of public participation in the Integrated Water Resources Management (IRMA) including both transboundary surface water and groundwater. Addressing these issues is therefore a strategic priority for the new independent states that emerged from the collapse of former Yugoslavia, as well as for Albania.

The countries are at various stages of the EU integration process. Croatia joined the EU on 1 July 2013; Montenegro is a candidate country whereas Albania and B&H are potential candidate countries. Their different statuses also mean differences in data availability, which made it necessary to compile data from different data sources for the DIKTAS project.

4.2 Economy, Population and Demography

4.2.1 Economy and economic trends

A snapshot analysis of the countries in south-east Europe, with data from 2010, is shown in Table 4.1 (in addition to the south-east European countries, selected countries are shown for comparison, namely Germany, Poland, and Greece. EU27 data is given as a benchmark). The region's heterogeneity is evident, as is its divergence from core Europe and, with the exception of Croatia, also from Central and Eastern Europe, represented here by the largest country, Poland. GDP per capita (at purchasing power parity) illustrates the countries' general level of development. Kosovo, Albania and Bosnia and Herzegovina are the poorest countries in the region, with income levels between 21 and 28 per cent of the EU27 average. Serbia, FYR of Macedonia and Montenegro represent middle-income countries, with shares between 35 and 42 per cent of the EU27 GDP per capita (when purchasing power differences are taken into account). Croatia, the most developed state in the region, has a relative income level comparable with Poland, with an income share of 62 per cent of the EU27 average. Monthly average remuneration per employee shows a wide variation. Here purchasing power differences were not taken into account and data show average wages in the national currency converted into the Euro at the market exchange rate (Montenegro and Kosovo use the Euro unilaterally). Albania has by far the lowest average wage level, at less than one tenth of the EU27 average. Serbia, Macedonia and Bosnia and Herzegovina have wage levels between one-seventh and one-fifth of the EU average. Montenegro has a wage level comparable to poorer CEE countries (some of the Baltic States), while Croatia has higher wage levels than Poland and most countries in Central and Eastern Europe. An important fact in the evaluation of the overall economic and social situation represents the fact that Croatia joined the European Union on 1 July 2013, which in the longer run could change its economic, political and social position. The overall perception of potential changes is positive.

Table 4.1 South-east Europe, facts and figures at a glance

Country	Population (end-year, million)	Real GDP change in %	GDP per capita at PPP (euros) 2010	Annual inflation rates (consumer prices)	Compensation per employee, monthly, euros
Albania	3.2	3.6	6 800	3.5	246
Bosnia and Herzegovina	3.8	0.7	6 500	2.1	622
Croatia	4.4	−1.2	15 100	1.1	1054
Kosovo	2.1	3.9 (a)	5 080 (c)	4.7 (b)	n.a.
Macedonia	2.1	1.8	8 600	1.6	491
Montenegro	0.6	2.5	10 200	0.5	715
Serbia	7.3	1.8	8 500	6.8	461
Germany	81.8	3.7	28 700	1.2	2910 (b)
Greece	10.8	−3.5	21 500	4.7	2300 (b)
Poland	38.1	4.0	15 300	2.7	883
EU-27	501	1.9	24 400	2.1	2776

Source: The Vienna Institute for International Economic Studies (2011).
(a) Data from the European Commission. (b) IMF – World Economic Outlook Database. (c) based on CIA Factbook 2012.

With the exception of Croatia, south-east Europe has been recovering from the crisis and shows more dynamic growth than the EU27. Inflation, an important indicator of economic stability, is generally moderate, although Serbia has higher values.

The main measure of economic development is GDP growth, especially relative to the EU27, if taking economic convergence into account. The figure gives an important message that, despite the region's economic and political instability in the first half of the decade and the effects of the 2008–2010 economic crisis, all the countries have managed a significant recovery. Serbia, Albania and Montenegro have achieved the most dynamic growth, nearly doubling their GDP per capita. Croatia moved almost in parallel with Poland, although starting at a somewhat higher level in 2000 and ending up slightly lower (but Poland has been the only country in the EU not to fall into recession during the crisis).

While Figure 4.2 is indicative of economic convergence, Table 4.3 shows domestic economic development, using real growth rates for GDP and industrial production in the national currency. Economic growth was highest in Albania, followed by Bosnia and Herzegovina and Croatia. Along the convergence, as shown in Figure 4.2, all the countries outpaced the EU27 and, with the exception of Croatia and FYR Macedonia, also Poland. The growth of industrial production was especially high in Albania and Bosnia and Herzegovina (both outpacing Poland), but rather moderate in Croatia, Serbia and Macedonia. Montenegro, on the other hand, suffered a contraction in industrial activity during the decade, even though it managed significant growth in the economy as a whole.

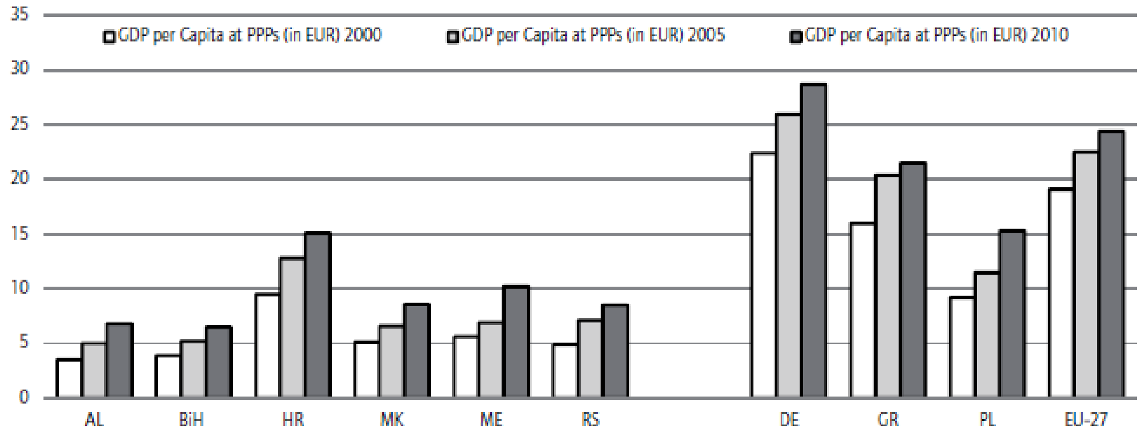


Figure 4.2 The measure of economic convergence: GDP per capita at PPP (Euros), 2000-2010. AL (Albania), BiH (Bosnia and Herzegovina), HR (Croatia), MK (FYR Macedonia), ME (Montenegro), RS (Serbia), DE (Germany), GR (Greece), PL (Poland), EU27 for the current EU (source: The Vienna Institute for International Studies, 2011)

The period of 1954 - 1984 was the period when some significant industrial facilities for the production of special steel, aluminium, aluminium oxide, bauxite, coal and sea salt were built, in addition to facilities for wood processing, metal processing, the leather and textile industry, the electric power production, the chemical industry, processing of agricultural products, and others. A decline in economic development in the 1990s resulted in very unfavourable conditions for industrial production that inevitably brought about a change in the direction of economic development. Contributions of the main economic activities to the GDP per country in 2011 are shown in Table 4.2.

Table 4.2 Contributions to GDP per sector (year 2011) in percentages (the World Bank, 2012)

Country	Agriculture	Industry (incl. construction)	Services
Albania	18.6	15.8	65.5
Bosnia and Herzegovina	8.8	26.19	65.04
Croatia	7.4	31.8	60.8
Montenegro	9.2	19.5	71.3

4.2.2 Population and demographic trends

Out of the four DIKTAS countries, Croatia has the biggest population with 4.29 million inhabitants (2011 census data), followed by Bosnia and Herzegovina (3.8 million; data from a 2011 estimate), Albania (2.8 million inhabitants; 2011 census) and Montenegro (625,000; 2011 census). The population density is the highest in Albania (98.5/km^2), and lowest in Montenegro (50/km^2), while Croatia and Bosnia and Herzegovina have an average population density of 75.8/km^2 and 75/km^2, respectively.

The population growth rate is low or negative for all four countries. The average age of the population in Albania is younger than in the other countries (Croatia, MNE and B&H). These demographic trends and migration are based on estimates and previous censuses. Croatia for example belongs to the 'older societies' due to the fact that the average age of the population is more than 45 years, almost every third marriage is broken, and the average number of children is 1.13 per family. In the country as a whole, the natural increase in the population is stagnant or even negative.

Across the region, there is a trend of migration from remote, rural areas towards urban areas and industrialized zones (Figure 4.3). Settlements are extremely dispersed, and some of the settlements in rural areas have been abandoned. This trend becomes visible in the TBA areas, most of which are rural. Due to tourism, population numbers may vary considerably across the year, with peaks in the summer season. Most tourist centres are situated along the coast (Croatia, Albania and Montenegro). Significant migration from one DIKTAS country to another is not registered.

Figure 4.3 The settlement of Velimlje in Montenegro. Once an important administrative centre of the DIKTAS TBA region, it is almost abandoned today.

4.3 Dams and Reservoirs

Hydropower plays a central role for energy production in all DIKTAS countries. Amounting to more than 90% of its energy production, Albania relies almost entirely on hydropower. The total number of dams for hydropower and electricity production total 42 in Albania, 13 in Bosnia and Herzegovina, 4 in Montenegro and 29 in Croatia. With more than 2,000 MW, Croatia has the highest installed capacity among the countries, while its share of hydropower to total energy production is the lowest among the DIKTAS countries (31%) (see Table 4.3). About 2/3 of the power plants are located in the DIKTAS karst area.

Table 4.3 Hydropower energy production in the DIKTAS countries (the World Bank, 2012)

Country	**Total installed capacity (MW)**	**% of total energy production from HPPs for each country per year**
Montenegro	658	62.2
Bosnia and Herzegovina	1125	42
Albania	1431.7	More than 90
Croatia	2076	31

A map of dams and reservoirs in the DIKTAS region is available in Annex 1.

4.4 Agriculture

Agricultural land occupies 24% of the Albanian territory (see Table 4.4). Agriculture is one of the most important sectors of the Albanian national economy. Agriculture provides an income for most of the population and serves as an employment safety net. Its contribution has been decreasing over the years and it is currently estimated at 17% of the GDP. The Albanian agricultural sector suffers from the small size of farms and the fragmentation of farm land, which is a barrier to production and marketing. The real mean growth rate of agricultural production during the last five years is estimated at about 4 per cent per year. Realization of agriculture production in 2010 as compared to 2009 was at 108%, led by fruit production (119%), crop production (113%) and livestock (102%).

In Bosnia and Herzegovina agricultural land occupies 47% of the territory. The contribution of agriculture to the GDP of Bosnia and Herzegovina has decreased from 14% to 8% over the past ten years. The most important crops are corn and wheat, while vegetables and fruit are also of significant importance.

Agricultural land in Croatia covers approximately 30% of the territory. Income generated from agriculture is ca. 15% of the total GDP, which was 10,394 Euros per capita in 2010. The role of agriculture is decreasing in the country in general, larger agricultural companies have been abandoned and in most cases agriculture is represented by small and medium-sized production units owned by one family with intensive production. The most common type of agriculture is maize and wheat (in 2010 2,068,000 tons of maize and 1,935,000 tons of wheat were grown) in the continental part of the country, and in the Dalmatian areas it is grapes, vegetables and fruit. Recently, some major agricultural companies have emerged and are organizing agricultural production for the region as a whole.

In Montenegro agricultural land occupies 516,404 ha or 38% of the total surface area (data for 2009). The agricultural sector in Montenegro represents 9% of GDP. During the period between 1992 and 2003 the annual growth in total production increased on average by 2.8%. The most important growth was achieved in crop production (annual growth rate of 4.7%), while livestock production showed significantly smaller rates of growth of 0.8%. Agriculture experienced a decrease in contribution to GDP from 11.3 % in 2005 to 9% in 2010.

The percentage of the agriculture sector in GDP in the participating countries varies from 8% to 18%. The percentage of land used for agriculture in Albania is lower than in other countries. However, the agricultural sector makes the highest contribution to GDP (more than 18%), compared with the other DIKTAS countries. It is important to mention that agricultural activities are decreasing, as well as the economic importance of agriculture at the regional level. Some of the reasons are cheaper food that is imported as well as the lack of intensive agricultural production in DIKTAS countries, lack of irrigation due to the small and scattered portions of agricultural land, and poor and non-selective organization of agricultural production.

Table 4.4 Agricultural production in DIKTAS Countries (the World Bank, 2012)

Country:	**Agricultural land (as % of total land)**	**GDP contribution in %**
Montenegro	38	9
Croatia	30	15
Bosnia and Herzegovina	47	8.8
Albania	24	18.6

4.5 Industries and Mining

Albania is a country with rich mineral resources. Mineral exploration and processing constitutes a key component of the Albanian economy, due to the traditional mining industry that has been a solid foundation of the country's economic sector and generated substantial revenues. The minerals mined and processed include chrome, copper, iron-nickel and coal. Since 1994 there has been a significant growth of the mining industry due to the transition from an economically centralized type of operation into one based on the free market.

In Bosnia and Herzegovina the mining industry, which was traditionally one of the most important, has slowed down significantly primarily due to the effects of the recent war as well as various consequences of country's economic and political situation. Currently, there are 29 active mines in the country with most extraction focused on coal, lignite and peat.

In addition to mining, other industries in B&H include manufacturing (production of food, beverages and tobacco, as well as of base metals and metal products), and the production and supply of electric power and heating. It should be noted that there is no heavy industry in the transboundary DIKTAS areas and there are no active mines reported.

In Croatia the main industries are shipyards that are located in the major cities along the coastline – in Pula, Rijeka, Zadar, Šibenik, Split and on some islands such as Ugljan and Mali Lošinj. Many shipyards are underperforming and quite a few of them are expected to be closed in the near future. Two major cement plants are located in Split and in Istria, and two oil refineries in Rijeka and on the Island of Krk. Large-scale production of chemical fertilizers is located in Kutina, and there is one major food production plant in Koprivnica. Small-scale industrial production is scattered throughout the country. Quarrying for construction materials is widespread including in the DIKTAS area. It should be noted that no data on heavy industry has been collected in the DIKTAS transboundary area and no active mines reported.

In Montenegro major industries are represented by iron works, the aluminium industry, the mining industry, the pharmaceutical industry and the food-processing industry. Most industrial facilities are operating at the moment with limited capacity (relative to the design capacity) or have been closed. As major industries often represent pollution threats, the Government has issued a list of '5 major industrial pollution hotspots in Montenegro' that comprise the following: the aluminium plant at Podgorica (hazardous waste dumpsite and red mud pond), Maljevac – the thermal power plant of Pljevlja, the Adriatic shipyard of Bijela, the steel plant in Niksic, and the Gradac flotation tailings pond.

It should be mentioned that there is a noticeable decrease in the role of heavy industry in the economies of all the four countries, although problems still exist with pollution in the form of PCBs, PAH, heavy metals, acids, fluoride, chlorine, lead, zinc, iron, copper and other metals. In B&H the traditional heavy industry that was located in the central portion of the country used large quantities of process water in the past, whereas in recent years there has been a clear decreasing trend in water use.

4.6 Tourism

Across the region, the tourism sector is expanding and providing an important source of income. In Albania, tourism is an important growing activity with a big impact on the economic and social development of the country. This sector of the economy accounts for 4.1 % of the national GDP and provides 160,000 jobs. According to the Bank of Albania, the tourist industry earned 170 million euro in 2007, making it a very important economic sector in the country. However, the sector is linked to the use of numerous natural resources and its recent development has been rather uncontrolled.

In Bosnia and Herzegovina the tourist industry contributes approximately 5% to the GDP of the country. Similarly to other countries involved in the DIKTAS project, the type of tourism is seasonal.

In Croatia, the tourist industry represents the most important asset of the country's economy. The average number of tourists is 3-4 million per year and this is expected to grow now Croatia has joined the EU. In relation to Croatia joining the EU, most people interviewed in the EU stated that the best qualities of Croatia are the sea, nature, good food and 'friendly people'. The total number of tourists/nights in 2010 was 56,416,379. However, the actual number of tourists is much higher because not all of them are registered and the 'visits' are measured only through the category of 'nights spent' in registered places of accommodation. Most tourists spend their holidays at the Adriatic coast or on the islands. The most popular destinations are the coastal cities of Dubrovnik, Zadar, Rijeka, Pula, and Split, as well as the national park areas.

In Montenegro direct revenue from tourism in the year 2011 has been predicted at 334 million Euro, which is 9.1 % of the overall GDP of the country. The economic importance of tourism is significant and the country is doing a lot to improve the conditions. Tourism is of a seasonal nature (summer months), and primarily in the coastal areas. The areas expected to be activated as tourist destinations are the mountains and rural countryside. It should be mentioned that Montenegro has 5 national parks, historic places and and monuments, and a lot of traditions and a way of life that are unique today. The highest pressures of all kinds (water, people, traffic, accommodation, etc.) are still at the rather narrow areas along the coast, while the mountainous part of the country is less visited with many pristine areas.

4.7 Solid Waste Disposal

The total amount of solid waste disposal in Albania is 455,866 ton/year (data for 2009), or approximately 150 kg/year/capita. The prefectures of Tirana, Fier, and Elbasan have the highest amount of solid waste in the country. Albania has very few recycling/reusing systems for waste and few engineered landfills for the disposal of waste. There is no system for the safe management of hazardous waste (neither domestic nor commercial). The main method for waste treatment is the construction of landfills although it should be noted that these landfills are not properly constructed or lined and therefore represent a potential source of contamination. Progress towards better waste management has been made in the construction of new landfills in some regions that comply with environmental standards. Additional landfills are under development. The increase in population and considerable migration of the population towards the developed cities in Albania have resulted in increased consumption and, therefore, increased volumes of municipal waste. There is no waste collection system in the DIKTAS transboundary area of Albania.

Based on the Waste Management Plan for B&H (for the years 2007-2012), there are 81 identified legal (regulated) landfills and 340 illegal ones in B&H. The total amount of solid waste in B&H is 666 kg/year/capita. There is no waste collection system in the DIKTAS transboundary areas of B&H that conforms to EU standards, and there is no regulated disposal or treatment of hazardous waste. Data on sanitary landfills and dumpsites for the entity Republic of Srpska is available at the website www.ekofondrs.org where a list of dumpsites and landfills exists with location, type and volume.

In Montenegro, approximately 297,430 tons of communal solid waste is disposed of every year, or 372 kg/year/capita. Although most municipalities have one or more dumpsites, only Podgorica, Bar and Ulcinj have two landfills built according to EU standards. There is no waste collection system in the DIKTAS transboundary areas of Montenegro. There is no treatment or regulated disposal of hazardous waste and industrial waste is usually poorly treated (or not at all) and dumped at locations in the vicinity of the production.

There are no complete statistics regarding the disposal of solid waste in Croatia. Based on the data which is accessible on the web pages of the agency that deals with the registration and permitting of solid waste sites (www.azo.hr), there are 9 dumpsites in the County of Zagreb, none of which is operated or closed according to applicable regulatory standards. In the area of Zagreb, the capital of Croatia, there are only 3 waste disposal sites, one of which is regulated and has been closed, and the other two are unregulated. A similar situation can be found in the vicinity of all the major cities in Croatia, as well as around smaller towns and settlements where mostly household waste is disposed of. In most cases, information on the solid waste disposal locations, waste content, waste processing and waste management is not available to the general public. Most solid waste disposal sites are not properly regulated or operated. Altogether, there are approximately 250 solid waste disposal sites with only a few that are regulated and built to the expected sanitary standards. The process of establishing, organizing and building of regional (on a county level) regulated landfills in Croatia is ongoing. It is expected that with Croatia's membership of the EU, these questions will be solved much quicker.

As in Croatia, the implementation of EU standards for solid waste and hazardous waste disposal, treatment and management in Albania, Montenegro, and B&H is considered a priority.

4.8 Wastewater Management

Wastewater treatment in the countries of the DIKTAS region is one of the most important issues and all the four countries are continuing efforts to improve the overall wastewater management in line with the EU Urban Waste Water Directive (UWWD) and Water Framework Directive (WFD) requirements. Most of the existing facilities were built in the late 1980s in states of the former Yugoslavia and do not meet current standards or needs. Sewage pipelines usually have a high percentage of leakage and a small percentage of wastewater is actually fully treated. In addition, a number of the existing Waste Water Treatment Plants (WWTPs) are not fully operational. Table 4.5 shows levels of the sewage service coverage with respect to the total population indicating a non-satisfactory status in all the countries. Sewage services are under the direct jurisdiction of local governments in municipalities, which own water utilities that also operate centralized sewage systems.

Service coverage is much less in rural than in urban areas and sanitation facilities in rural settlements are a major problem. Wastewater is discharged into improvised permeable septic pits, smaller adjacent surface streams or depressions in the terrain. Livestock waste typically ends up in small rivers, polluting these streams with organic content, ammonia and macro elements such as nitrogen and phosphorus, leading to eutrophication and long-term pollution of aquatic ecosystems. In karst terrains, sinkholes and surface streams are often used for disposal of wastewaters, leading to pollution of the whole hydrological system and endangering drinking water sources.

Table 4.5 Percentage of the total population with a sewage service

Country:	**Service coverage overall**	**Urban**	**Rural**	**Number of WWTPs**
Bosnia and Herzegovina	56%	72%	10%	15 in whole B&H; only 7 in function
Albania	64.6%	83%	10.9%	7
Montenegro	39%			2
Croatia	43 %	75-80%	12.7 %	109

Sources of data:

- (UNDP GoAL WaSH Programme Governance Advocacy and Leadership for Water: Sanitation and Hygiene: Volume 1 Bosnia and Herzegovina, 2009, UNDP, Vienna
- Ministry of Public Works and Transport of Republic of Albania, 2011, National water supply and sewerage sector strategy 2011-2017, Ministry of Public Works and Transport of Republic of Albania, Tirana, Albania
- Ministry of Agriculture, Forestry and Water Management of Montenegro, 2001, Water management master plan of Montenegro, Ministry of Agriculture, Forestry and Water Management, Podgorica 2001
- Ministry of Rural Development, Forestry and Water Management of Croatia, 2008, Water Management Strategy, Croatian Waters, Zagreb, Croatia)

4.9 Groundwater Quality

None of the countries in the DIKTAS project region currently has a complete and operational network for systematic regional monitoring of groundwater quality. Limited sporadic monitoring of groundwater quality is usually related to specific water supply and infrastructure projects, whereas continual water quality monitoring is concentrated solely on the water wells and springs used for the public drinking water supply. Consequently, a detailed assessment of the overall quality of the groundwater in the project region is not feasible. However, based on the available information, the quality of karst groundwater in the region is generally very good, and most of the time in line with the standards for drinking water quality without any pre-treatment needed.

Problems concerning chemical parameters of karst groundwater are very rare, and the main problems are turbidity (typically caused by the rapid infiltration of precipitation) and microbial contamination. Contamination with pathogens (bacteria, viruses and water-borne parasites) is mostly related to human activities, including inappropriate disposal of waste and wastewater. Sources of contamination such as untreated or poorly treated wastewater discharged from centralized systems, as well as from individual septic tanks are of particular concern in the sensitive karst areas and present a major threat to the groundwater quality in the region. These negative influences are magnified in more developed and urbanized parts of the Project area.

Another issue of concern is the proper establishment and enforcement of the source protection zones around springs and wells utilized for the public water supply. All countries have the necessary legislation in place but proper implementation is frequently missing which jeopardizes a generally good quality of groundwater at the source.

4.10 Surface Water Quality

A monitoring network of surface water quality has been developed on different scales in the DIKTAS region. Croatia has a systematic network of monitoring stations that measure surface water quality at more than 400 locations, while Montenegro has a network of more than 60 monitoring stations in place. Monitoring of the surface water in B&H was well developed before the 1990s, and constant effort has been provided to revitalize such a system since then. Albania has been also improving its monitoring system since 1990.

Different national classification of water quality exists among the countries. It is expected that all the countries will uniform their national classification system in accordance with the EU WFD in years to come as part of the national EU accession/approximation process.

The surface water quality in the Project region can generally be described as good to average (according to the EU WFD) in most cases. The quality of surface waters deteriorates immediately downstream of larger settlements and industrial pollution sites where the quality is below the European Union standards for water quality. Major threats for quality of the surface (and ground) water are identified as the very high percentage of untreated waste disposal and wastewater discharge (frequently directly to the recipient) as well as the number of untreated/unsecured industrial pollution hotspots, mainly from the heavy industries (mainly closed or only partly functioning) left after the transition period to open economy principles in the 1990s.

4.11 Water Use

All the DIKTAS countries are considered to have abundant groundwater resources at their disposal. However, during the summer period water shortages may occur, particularly in tourist areas along the coast.

Quantities of water use for different sectors correspond well with the level of economic development and structure of the countries' economies (e.g. Croatia uses a large percentage of the water for industrial needs, while Albania uses most water for irrigation and agriculture). Still, most water in the region is used for drinking water supply.

The main source for drinking water supply is groundwater basins, contributing as much as 90 % to the water supply (in Montenegro and Bosnia and Herzegovina 90 %, in Albania 70 %). Since most of the water supply in the DIKTAS region depends on groundwater sources, the protection of this resource is very important. Yet, water use per capita per day is very high in the region (in some places over 250 l/capita/day) which indicates that drinking water is usually being used in a non-economical way. This is probably due to the high percentage of water loss in water supply systems (from 30-70%) and the generally low price of drinking water on the market. Water supply companies are owned by the municipalities (despite some attempts to privatize this sector) and water is usually seen as a social category.

Table 4.6 Estimated quantities of water used for drinking water supply and industry (m^3/year), including irrigated areas (in hectares) in the DIKTAS region

Country	Drinking water supply	Industry	Irrigation
Albania	**260,400,000**		**80,000 ha**
B & H	**435,038,866** 261,542,143 in the Federation of Bosnia and Herzegovina 173,496,723 in the Republic of Srpska	**86,333,895** 59,147,760 in the Federation of B&H 27,186,135 in the Republic of Srpska	**3312 ha** 1,612 ha in the Federation B&H 1,700 ha in the Republic of Srpska
Croatia	**530,000,000**	**336,000,000**	**5,420 ha**
Montenegro	**109,403,000**	**54,998,000**	**1,800 ha**

Sources of data:

Croatia: Ministry of Rural Development, Forestry and Water Management of Croatia, 2008. Water management strategy, Croatian waters, Zagreb, Croatia;

Montenegro: Ministry of Agriculture, Forestry and Water Management of Montenegro, 2001. Water management master plan of Montenegro, Ministry of Agriculture, Forestry and Water Management, Podgorica, Montenegro;

Albania: EU Phare Programme, 1997. National Water Strategy for Albania, Tirana, Albania;

B&H: Ministry of Agriculture, Forestry and Water Management of F B&H, 2009. The Water Management Strategy of the Federation of Bosnia and Herzegovina, primordial report, Zavod za vodoprivredu Sarajevo i Zavod za vodoprivredu d.o.o Mostar, Sarajevo, B&H and Republic Directorate for Water of Republic of Srpska, 2007. The Framework Plan of Water Management Development of the Republic of Srpska, Bijeljina, Republic of Srpska, B&H.

Most water supply systems in the urban areas are regularly monitored for quality, while rural water supply systems sometimes are not subject to any system of quality control. The percentage of the total population connected to the public supply system varies from 48 % (the Republic Srpska in Bosnia and Herzegovina) to 80 % (in Croatia), with significant discrepancies between rural and urban areas.

Water quantities used for industry and irrigation are significant, but those numbers rapidly decreased from the 1990s, due to the economic and political situation in the region. Larger amounts of water are used for irrigation only in Albania while in the rest of the countries it is almost insignificant. Still, these countries have plans to repair/improve their irrigation systems in the near future (Croatia by up to 160,000 ha and Albania up to 35,000 ha), which will lead to higher water demand from this sector.

It is important to note that large quantities of water are used for producing electrical power, and that this is a significant contributor to the countries' economies. Albania gains 83 % of all electricity from hydropower plants, Montenegro 75 %, Bosnia and Herzegovina 60% and Croatia 54 %.

Despite a general abundance of groundwater in the region, some areas of the DIKTAS project countries face severe shortages in water supply and availability during dry seasons, especially in coastal and remote areas (e.g. Herceg Novi in Montenegro, the Adriatic islands in Croatia, and Mati Basain aquifer in Albania.)

Floods are frequent in the project region due to the natural conditions, dam regime and shortage of funds for flood protection (e.g. Split, Rijeka and Šibenik in Croatia are prone to the floods , the same holds for the Skadar-Shkodra region in Montenegro and Albania).

A map of water resources in the DIKTAS area is provided in Annex 1 of this report.

4.12 Protected Areas and Groundwater Dependent Ecosystems

Protected areas in each country are established in accordance with the respective national legislation. Therefore, categories of protected areas vary in the region and the number of protected areas cannot be considered as an absolute indicator for comparison (this number varies from 11 in Bosnia and Herzegovina and up to 802 in Albania). The percentage of protected surface to the total area of the country is for: Albania 12.4 %, Montenegro 9.04 %, Croatia 9 % and Bosnia and Herzegovina 0.5 %.

Figure 4.4 The proteus anguinus (proteus) is an endemic amphibian species found in the DIKTAS project region (IUCN conservation status: threatened). It is the only cave-dwelling chordate found in Europe.

None of the protected areas (or categories) in any country is solely related to the groundwater dependent ecosystems. This is despite the fact that the karstic area of all the countries is very rich in biodiversity with many species and habitats of European and global importance for protection. By establishing the Emerald network (a regional project of the Council of Europe) some pioneering steps have been taken in order to identify and map some of the important EU habitats and species on a regional scale.

Natural wetlands are dispersed over the region and are considered to be areas of high ecological value. Many of them are Ramsar sites and are severely threatened by water use (such as for hydropower) and land-based sources of pollution and drainage.

Table 4.7 List of Wetlands of International Importance in the DIKTAS region

	Name of the site	Date of designation	Location	ha	coordinates
Albania					
	Butrint	28/03/03	Vlora	13,500	39°50’N 020°00’E
	Karavasta Lagoon	29/11/95	Lushnja	20,000	41º00’N 019º30’E
	Lake Shkodra and River Buna	02/02/06	Malesia e Madhe, Shkodra	49,562	42°03’N 019°29’E
B&H					
	Bardaca Wetlands	02/02/07	Republic of Srpska Entity	3,500	45°06’N 017°27’E
	Hutovo Blato	24/09/01		7,411	43°03’N 017°37’E
	Livanjsko Polje)	11/04/08	Hercegbosanska canton	5,537,400	19º17’N 022º54’E
Croatia					
	Crna Mlaka (Crna Mlaka Fishponds)	18/01/93	Zagreb County	756	45º36’40”N 015º44’09”E
	Neretva River Delta	18/01/93	Dubrovnik-Neretva County	12,742	43°01’40”N 017°34’25”E
	Lonjsko polje and Mokro polje including Krapje Đol	18/01/93	Sisak-Moslavina, Brod-Posavina	51,218	45°21’43”N 016°15’02”E
	Nature Park Kopacki rit	18/01/93	Baranja	23,894	45º40’N 018º54’E
	Vransko Lake	02/02/13	Zadar, Sibenik-Knin	5,748	43°53’27”N 015°35’20”E
Montenegro					
	Skadarsko Jezero	15/12/95	Bar, Podgorica Municipalities	20,000	42º12’N 019º17’E
	Tivat Saline (Tivatska solila)	30/01/13	Tivat Municipality	150	42°23’37”N 018°42’55”E

In Albania a massive operation (during a previous regime) has been implemented to drain large wetlands along the coast to provide agricultural land. The Neretva Delta in Croatia and Hutovo Blato in Bosnia and Herzegovina are suffering from heavy loads of pollution. Beside these, in Croatia 29 areas has been enumerated and described as areas depending on groundwater resources (based on the N2000 network), while similar data for the rest of the countries is missing (development of N2000 is in progress in the other countries). It is most likely that some of the important groundwater dependent species and habitats are spread across the karstic region, but additional institutional capacity building and investigations are necessary for other countries in order to be able to properly identify GDEs as highly valuable and vulnerable areas and implement appropriate protection measures.

Detailed maps of the protected areas and the Emerald network in the DIKTAS area are included in Annex 1.

4.13 Significant Caves

There are a number of caves in the DIKTAS region, but most of them are not commercially utilized or known to the wider public. A map of the important caves is provided in Annex 1. Generally, the caves are equally dispersed throughout the DIKTAS region and in high numbers. Only a limited number of caves is protected (mostly in the category of natural monuments). The project failed to find systematized data on speleological objects from the official institutions; therefore the data has been collected with help and records of various speleological societies. Higher institutional attention (and management) of sensitive karstic morphological features is strongly needed as they represent unique (eco) systems of geological and biological importance and valuable parts of groundwater depended ecosystems.

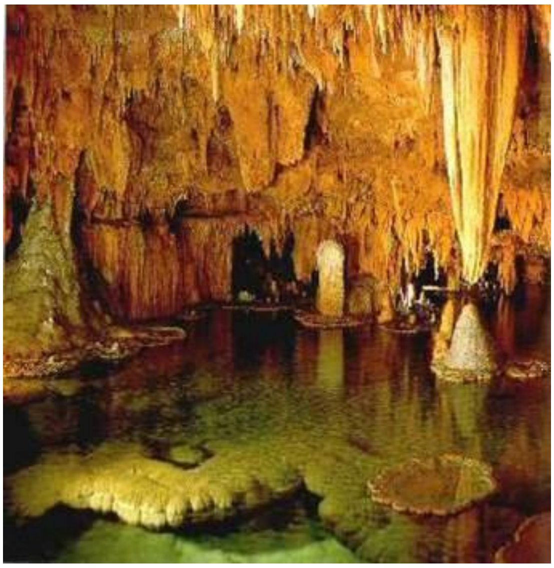


Figure 4.5 Vjetrenica Cave in Popovo Polje (Bosnia and Herzegovina)

4.14 Conclusions

This short presentation of the major features of the countries included in the DIKTAS project shows that many situations are similar but some of them are unique to a certain country. Nevertheless, taken altogether, these countries represent very important sources of clean water, protected and unprotected nature, specific local economies, habits, traditions and future prospects. Each of the countries has many possibilities for development based on the wise exploitation of natural resources. All of the countries are famous due to their tourist potential and tourism is and most probably will be one of the major sources of economic growth in the years to come. Hence, the future development of the DIKTAS countries must take in account the following:

- Nature 'as itself', protected and saved from excessive use as well as for commercialization
- Respect for the values of nature, natural resources and human potential
- Respect for the transboundary aspects of the natural resources, especially for the karstic areas that are at the core of our investigation and that represent a specific natural phenomena as well as a relation with the nature of local population
- Respect for the simple and 'taken for granted', but at the same time very important, fact that water represents the source of life and that karstic areas are specific 'bases' for life not only for the local population in karstic areas, but for the wider population as well
- Respect for the natural environment that support all the activities in it.

Based on the available and processed data, the major conclusions concerning the future use of the karst areas in the DIKTAS countries include the following:

- Since tourism represents one of the major industries in the DIKTAS countries, measures concerning the carrying capacity of the environment must be taken into account, especially in nature parks and national parks. An excessive number of tourists will not only degrade the basic phenomenon, but will also produce a negative impact in general and will – in the longer run – prevent visits to these special places;
- The respect for the existing situation that is marked by the values of the natural environment must be taken into account as a primary element of assessment of any kind of future investments, changes and plans. Once the primary value–phenomenon is endangered and/or destroyed, then the whole phenomenon is in question, taking into consideration its resources, the quantities of water and the like;
- The karst areas that have been studied in the DIKTAS project represent a unique natural phenomena in which a special combination of the 'natural life' of the population that is naturally combined with rhythms of nature, or 'natural factors' that determine the overall situation.
- If any plans for future development of these areas change these 'natural rhythms', the results could be a disaster. So, for the DIKTAS areas, the only future will be a harmonized and balanced development based on respect for the natural cycles and situations. And that is precisely the result of the DIKTAS project up until now.

5 Legal and Institutional Framework and Policy

One of the goals of the DIKTAS project is to establish cooperation among the countries. One of the steps in building cooperation for the transboundary Dinaric Karst Aquifer System is to understand the legal and institutional setting for water and groundwater management in the four involved countries and to identify the applied principles, common approaches and areas of concern in view of sustainable management of the transboundary water resources. Transboundary water resources are primarily managed at the national level, and it is at this level that all decisions are finally applied (even when adopted by a transboundary joint institution); hence the existing settings in the countries should be known. Harmonization of the policy, legal, and institutional frameworks is another step to ensure that the four countries are applying common principles, to be agreed upon. International cooperation on water resources of the DIKTAS countries, formalized by inter-state agreements, is another important element for consideration. The existing frameworks can be instrumental for DIKTAS countries in terms of experience, lessons learnt, principles applied in transboundary water management, and possible cooperation. The following chapter describes the policy, legal and institutional framework in the DIKTAS countries, with a focus on the challenges, as well as international cooperation.

5.1 Institutions Involved in Management of Water Resources

5.1.1 Water Management Administrative Framework

In all four countries water issues are covered by various ministries and institutions at different administrative levels. Those that are fully and directly responsible for water management are described below.

Albania

The Ministry of Environment, Forestry and Water Administration (MoEFWA), including relevant Directorates; six River Basin Councils and respective six River Basin Agencies; an inter-institutional body (National Water Council - NWC).

Bosnia and Herzegovina

Two Ministries at the State (B&H) level - Ministry of Foreign Trade and Economic Relations (MoFTER) and Ministry of Transport and Communications; Ministries of Agriculture, Water Management and Forestry of the two Entities (FB&H and RS) and Ministries of energy, mining and industry of the two Entities (FB&H and RS); two Water Agencies in FB&H: one for the watershed area of Sava River and one for the watershed area of Adriatic sea; Public Institution "Waters of Srpska" in RS, founded in January 2013, including departments for Water Management of River Basin Sava and for Water Management of River Basin Trebisnjica;
ten Cantonal Ministries in FB&H, dealing with Water issues; Governmental departments of Brčko District for for Agriculture, Forestry and Water Management and for Utilities.

Croatia

The Ministry of Agriculture (with various Directorates); national water agency 'Croatian Waters'.

Montenegro

The Ministry of Agriculture and Rural Development; Directorate for Water; Water Council.

Water law enforcement in the DIKTAS project countries is the responsibility of the inspectors from the River Basin Agencies, line ministries inspectorate, or independent inspectorates (as in B&H). Generally, the level of law enforcement in all four countries is not sufficient. By the adoption of the Water Laws in all four countries, the key provisions of the European Water Framework Directive (WFD) have been transposed into their legislation including designation of authorities for water management and identification of the river basin districts. The countries are making significant efforts to develop a wide range of secondary legislation, but they are not yet completed.

Coordination and clear division of responsibilities among the institutions at the different administrative levels, central/entity level and the local/cantonal level have not been properly defined within water laws in Albania and B&H.

Strengthening of the administrative capacities in B&H at the State level, and improving coordination between the Entities, is crucial for implementing B&H obligations originating from different international agreements. In this context the Ministry of Foreign Trade and Economic Relations (MOFTER) plays a key role. In B&H, water issues are not sufficiently addressed within other sectoral legislations due to lack of intersectoral coordination during preparation of policies, legislation, and strategic documents.

5.1.2 River Basin Management Institutions

Pursuant to the actual Water Laws/Acts in all four countries, water management is carried out at the river basin level. Water Management Plans and programs of measures are to be adopted by the Government, at the proposal of the relevant Ministry of Water. Currently, only Croatia has developed a draft River Basin Management Plan for the Danube river basin district and the Adriatic basin district. Its final adoption is expected soon. In the other countries, the river basin management plans are in the process of development. In Bosnia and Herzegovina, a characterization report has been prepared only for the Adriatic Sea basin, and a preliminary flood risk assessment has been prepared both for the Danube/Sava and the Adriatic Sea basin. Although all four countries have assigned institutional responsibilities for the implementation of the EU water acts, it is apparent that the overall process is moving slowly. Professional staff of the responsible authorities needs to be trained on the application of the transposing legislation, particularly on understanding the river basin management issues such as characterization of water bodies, establishment of reference conditions, analysis of human impacts, application of the *combined approach* principle, and development of river basin management plans and programme of measures. Additionally, the Albanian and Montenegrin water management institutions are not sufficiently staffed.

5.1.3 Surface Water and Groundwater Monitoring

Surface water and groundwater monitoring is embedded in the legislation and/or water strategies of all four countries. It has been carried out at different levels of detail in different countries, mostly by water agencies, hydro-meteorological institutes or geological surveys (in the case of groundwater monitoring), as well as by research institutes contracted by the water ministries.

In all four countries there are significant gaps in implementing the surface water, and particularly the groundwater, monitoring. The main obstacles to full implementation of the monitoring are as follows:

- The EU legislation regarding monitoring is not fully or properly adopted by the national legislation;
- Water monitoring does not include all the river basins;
- The institutions in charge are not accredited yet and there is a lack of monitoring equipment;
- There are overlapping institutional responsibilities.

5.2 Institutions Involved in Environmental Protection

Environmental protection in all four countries is covered by different ministries, agencies and institutions. There is a general overlapping of responsibilities and lack of coordination at different or same administrative levels between the institutions listed below.

Albania

The Ministry of Environment, Forestry and Water Administration (MoEFWA) including relevant Directorates; Albanian Agency of Environment and Forestry (AEF); an inter–institutional body, National Water Council (NWC).

Bosnia and Herzegovina

The State Ministry of Foreign Trade and Economic Relations (M0FTER); ministry responsible for the environment in each entity (B&H and RS); 10 cantonal Ministries for the Environment in B&H; environmental funds in each entity; Environmental Inter-Entity Body.

Croatia

The Ministry of Environmental and Nature Protection; Ministry of the Maritime Affairs, Transport and Infrastructure; Ministry of Agriculture; Environmental Protection Agency, The State Institute for Nature Protection.

Montenegro

The Environment Protection Agency; Ministry of Sustainable Development and Tourism.

5.3 Legislation and Regulations

5.3.1 National Water Strategies

Croatia, Albania and B&H (B&H and RS) have Water Management Strategies, and Montenegro has a comparable Water Basis Document.

The concept of management and water protection in Croatia is determined by the national Water Management Strategy, a long-term planning document which sets out the vision, mission, goals and tasks of state policy in water management, including groundwater management. The Strategy is harmonized with the requirements set out in the EU Water Framework Directive and the Groundwater Directive. It should be emphasized that the Strategy for the first time clearly defines strategic groundwater reserves of the Republic of Croatia as resources that are of national importance. The Strategy defines the need to adequately determine the rational use and protection of strategic reserves of groundwater and to include it in physical plans and physical planning documents.

In B&H the documents related to water management are prepared and adopted by the two state entities, Federation of Bosnia and Herzegovina (FB&H) and Republic of Srpska (RS). Water Management Strategy of FB&H represents a planning document which sets out the vision, goals and measures of policy in water management, including groundwater management, and defines different strategic and operational goals with respect to different aspects of water management. Draft RS Strategy of integrated Water management up to 2024 was prepared in 2012 in the RS and is currently in the adoption phase. The document "Framework Plan for Development of Water Management" from 2006 was the base for this Strategy. Draft RS Strategy of integrated Water management is a planning document which defines the model of strategic management planning, objectives and criteria for integrated water protection as well as principals of integrated water protection, particularly important for selection of strategic orientations. It defines directions, priorities and measures with respect to water usage and protection.

Montenegro has not yet adopted its National Water Management Strategy. A planning document that is especially important for long-term and sustainable water management is the Water Basis from 2001. This document contains a description of the current state of the water balance and water management facilities by areas, and the requirements for maintaining the water balance and development which ensure that the most optimum and expedient technical, economic and ecological solutions for an integral management of water resources are being used. The document also addresses protection from the harmful effects of water, and the protection of water resources from pollution and overuse.

In Albania, the National Strategy for Water Management addresses issues such as: supply of drinking water for development of tourism including raising standards of water quality and quantity; strengthening of measures for wastewater treatment and solid waste management; preservation of the quality and quantity of agricultural water; defining the standards for urban and industrial water discharges; protection of the riverbed through a system of permits and regulations for the extraction of sand and gravel.

5.3.2 Groundwater

There are on-going efforts in all four DIKTAS countries for inclusion of the fundamental principles, objectives and measures from the EU Groundwater Directive in their national legislation. All the DIKTAS countries have established a system for regulation of groundwater abstraction and delineation of sanitary protection zones. However, they are all lacking regulations specific to groundwater in karst areas.

From the institutional point of view, the implementation of water protection measures within sanitary protection zones and the implementation of the Rulebook on Sanitary Protection Zones are weak in all DIKTAS countries.

From a legal point of view the areas (water bodies) intended for the abstraction of drinking water are not properly defined in legislative documents in any of the DIKTAS countries.

In all the DIKTAS countries governmental and ministerial decisions on sanitary protection zones are not fully in compliance with the existing national legislation and regulations on water and groundwater management.

There is a lack of consideration of groundwater dependent ecosystems in the national legislation in all the DIKTAS countries.

Croatia has a well-established system for regulation of groundwater abstraction. However, decisions on zones of sanitary protection around well fields and springs are still not harmonized with the existing regulations, particularly with the Rulebook on Conditions for Establishing Sanitary Protection Zones.

In Bosnia and Herzegovina, a FB&H document entitled ‘Water Management Strategy’ was drafted according to the requirements of the Water Law. In RS the ‘Integral Water Management Strategy’ was drafted in 2012 according to the RS Water Law that is currently expected to be adopted by the National Assembly of RS. The Integral Water Management Strategy of RS elaborates the groundwater resources , their quality, and it also contains measures related to development of the Program of the works of monitoring of the groundwater quality in the area of RS as well as performance of the groundwater quality monitoring. Water laws of both entities contain provisions related to the classification and status of groundwater bodies.

Although the adoption of EU legislation in B&H has progressed significantly in the last few years, there is still a lack of water quality and quantity monitoring, particularly for groundwater. The existing system of protection of the well fields and springs is not satisfactory. The situation is similar in RS. In both entities, the regulations for delineation of the sanitary protection zones and the protective measures for water sources that are used or planned to be used for the drinking water supply do not differentiate between non-karst and karst areas.

Adoption of the EU Water Framework Directive 2000/60/EC in Montenegro is progressing slowly. There is overlapping of competences in the area of monitoring of water and groundwater, and in tracking of pollutants. There is a lack of integrated information systems for data management. Montenegro does not have an organized network for groundwater monitoring which is currently limited to quality of water from private wells. The legislation in Montenegro provides provisions for regulation of groundwater abstraction.

In Albania, some of the requirements of the EU Water Framework Directive have not yet been adopted in the existing ‘Law on Water Reserves’. The groundwater reserves that are used for drinking water are identified and protected in the current legislation including urban spatial plans at national and municipal level. However, although Albania has a system for regulation of groundwater abstraction, the water bodies intended for the abstraction of drinking water have not been properly defined in legislative documents.

The water-monitoring program does not cover all the river basins. The methodology, indicators and data assessment for water monitoring are not at contemporary standards. The institutions in charge of water monitoring are not yet accredited and there is a lack of a common database system based on the harmonized methodology for both water quantity and quality aspects.

Strategic reserves of groundwater in Albania are not legally defined in the current law and the groundwater protection areas are not clearly defined in spatial planning documents.

5.3.3 Environmental Principles

In the four DIKTAS countries the ‘polluter pays’ principle and the principle of ‘recovery of the costs’ are promoted and embedded in the current respective legislations. However, they are not fully implemented in either the national regulations or in water management practices. Regulation on the assessment of impacts of water management practices on the environment is harmonized with the Environmental Impact Assessment Directive in all the DIKTAS countries.

5.4 Law Enforcement

All the DIKTAS countries are applying the principles, goals and measures of water protection in accordance with the EU Water Framework Directive (WFD). The water management and protection in the DIKTAS region is carried out through implementation of the Law on Waters, as the framework piece of legislation, and through relevant by-laws. Furthermore, this subject matter is regulated by other laws from the area of environmental protection. However, the main shortcoming of this legislative framework is the underdeveloped system of by-laws and insufficient implementation of the present legislation including implementation of the Rulebook on Sanitary Protection Zones.

Supervision over the implementation of the Law on Waters and relevant regulations is carried out by water inspectors, who can order administrative measures and lodge requests for initiating a misdemeanour procedure and bring criminal charges, aiming to sanction legal entities and persons who are found to be in breach of substantive law provisions.

The existing environment and water regulations include administrative sanctions such as penalties for non-compliance with environmental permit requirements or non-compliance fees, but the ratio of collection has been very low.

The following obstacles are recognized in all the DIKTAS countries regarding law enforcement:

- Lack of human resources and financial means for fulfilling policy requirements at the DIKTAS level.

- Poor performance of law enforcement with regard to application of water management principles.
- Low level of implementation of water protection measures within the sanitary protection zones.
- Weak implementation of the Rulebook on Sanitary Protection Zones.

5.5 Water and Environmental Sector Financing

The legal framework in the water and environment sectors in the DIKTAS region has created a necessary basis for implementation of economic instruments: fees for protection and use of waters and other natural resources, and fees for environmental pollution. These fees are paid in line with the 'user pays', 'polluter pays' and 'cost recovery' principles described earlier. However, the principle of full cost recovery has only been partially implemented in the four countries. In addition, there are no legal or policy documents in any of these countries that adequately define and prescribe the integration of environmental and resource costs into development of pricing policies.

Due to the lack of clear development strategies, programs and plans for water management, the DIKTAS region cannot be considered as an example of successful implementation of the core principles of sustainable development. In the absence of appropriate charges for pollution and use of natural resources, the existing national financial resources are not sufficient to cope with the accumulated problems. Due to their small budgets, local communities rely upon the assistance of state and international donors. At the same time, it appears that funds collected from charging special water fees are not used to invest in the water and environmental sectors.

5.6 International Cooperation

The DIKTAS countries have a wide experience with international cooperation on transboundary waters. The countries are party to a multilateral framework convention, and have bilateral and multilateral agreements at the inter-ministerial level covering transboundary water issues.

5.6.1 Multilateral Framework Conventions

Albania, B&H and Croatia are party to the *Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992)* under the auspices of the UN Economic Commission for Europe (known as the UNECE Convention), and Montenegro is in the preparation phase for its ratification. The Convention applies to all the transboundary waters. It is guided by the equitable and reasonable use principle, the precautionary principle, and sustainable development. It obliges parties to prevent, control and reduce water pollution from point and non-point sources. The Convention also includes provisions for monitoring, research and development, consultation, warning and alarm systems, mutual assistance, institutional arrangements, and the exchange and protection of information, as well as public access to information.

Under this Convention, draft model provisions on transboundary groundwater were prepared as a guiding tool for countries sharing groundwater. These draft model provisions are based on the draft articles on the law of transboundary aquifers annexed to Resolution 63/124 of the UN General Assembly (UN GA), December 2009, *(see Annex 3 of TDA)*. In this Resolution (confirmed by Resolution 66/104 (2011)), the UN GA "Encourages the States concerned to make appropriate bilateral or regional arrangements for the proper management of their transboundary aquifers, taking into account the provisions of these draft articles'". While a Resolution of the UN GA is non-binding, it represents the only global instruments on transboundary aquifers. It is available as a reference and as guidelines for States. The main principles included in the draft articles annexed to the Resolution are: Equitable and reasonable use, No harm rule, General obligation to cooperate, Regular exchange of data and information, Bilateral and regional agreements and arrangements, Protection and preservation of ecosystems, Recharge and discharge zones, Prevention, reduction and control of pollution, Monitoring, Management.

Albania, B&H, and Croatia are also party to the *Protocol on Water and Health* (1999), adopted under the previous Convention. Montenegro is in the preparation phase for its ratification. The main goal of the Protocol is to protect human health and well being by better water management, including the protection of water ecosystems, and by preventing, controlling and reducing water-related diseases. Its objective is to attain an adequate supply of safe drinking water and adequate sanitation for everyone by effectively protecting water used as a source of drinking water.

5.6.2 Bilateral/Multilateral Agreements

Croatia, B&H and Montenegro are parties to the *Convention on Co-operation for the Protection and Sustainable Use of the River Danube (Danube River Protection Convention,* 1994). The Convention represents an overall legal instrument for cooperation and transboundary water management in the Danube river basin. Its main objective is to ensure that surface waters and groundwater within the Danube river basin are managed and used sustainably and equitably.

Croatia and B&H along with Slovenia and Serbia are party to the *Framework agreement on the Sava river basin* (signed in 2002, enforced in 2004). The Commission was established in 2005. The vision of the International Sava River Basin Commission (ISRBC) is transboundary cooperation for sustainable development of the region and includes water resources management issues such as:

Sustainability, protection, and improvement of water quality, water quantity and aquatic ecosystems;

Protection against the harmful effects of water (due to floods, ice, droughts, and accidents);

Development activities such as navigation, hydropower, water supply, irrigation, recreation and tourism, and other aspects of water use.

The DIKTAS countries are also Party to inter-State agreements including at least one other DIKTAS country, some extending beyond the DIKTAS region.

Some are specific to a transboundary water body such as the agreement between Albania and Montenegro (14 December 2010) which covers Basin of Skadar (Shkodra) Lake, Drini and Buna rivers.

The Government of the Republic of Croatia and the Government of Bosnia and Herzegovina signed an agreement on Water Management Relations (Dubrovnik, July, 1996). It relates to the water management activities at the water streams which present the mutual state border between Croatia and Bosnia and Herzegovina or at the water streams and groundwater bodies which are crossed by the borders. This Agreement is also relevant for all areas of interest for improvement of water management of B&H and Croatia.

In the frame of the Agreement on water management relations between Republic Croatia (RC) and Bosnia and Herzegovina (B&H), Commission for water management of RC and B&H was established, consisting of representatives from Republic Croatia and B&H, including both B&H's entities (FB&H and RS), as well as two sub-commissions: for Adriatic catchment area and for Black See catchment area, also consisting of representatives from Republic Croatia and B&H. The agreement between Croatia and Montenegro (2007) establishes a permanent joint commission for water management.

The DIKTAS countries (Albania, B&H, Croatia and Monte Negro), as a parties to the Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention, 1976), are the part of the Strategic Partnership for the Mediterranean Sea Large Marine Ecosystem (MedPartnership). It is the collective effort of leading organizations (regional, international, non governmental, etc.) and countries sharing the Mediterranean Sea towards the protection of the marine and coastal environment of the Mediterranean. The MedPartnership is being led by UNEP/MAP and the World Bank and is financially supported by the Global Environment Facility (GEF), and other donors, including the EU and all participating countries.

5.6.3 Agreements at the DIKTAS Regional Level

One of the expected results of the DIKTAS project is that, through the joint work, the four participating countries will soon reach a level of mutual trust and shared understanding of the aquifer system and of its transboundary nature sufficient to enable them to commit to a cooperation mechanism for an improved management of the shared groundwater resource. Despite the existence of numerous agreements, any such mechanism at the level of the whole karst aquifer system is lacking at present in the region. A consultative and information exchange (CIE) body of the four countries could be a first step towards a systematic commitment to joint management. Such a body could undertake the development of a better mutual understanding of the unique properties and functions of the Dinaric Karst Aquifer System, and to adopt policies for its joint management, based on a regional consultative and management mechanism. Without such a consultative body, the States will continue developing this shared resource on a unilateral basis without any coordinated policy. The consultative body would be in a position to develop and define a program of measures on the basis of application of economic criteria (cost effectiveness) and principles of 'combined approach' and 'best environmental practice'.

5.7 Challenges to Water Resources Governance

Challenges to water resources governance in the DIKTAS region are manifold and include the harmonization of the water sector with other sectors, implementation of the IWRM principles in groundwater governance, capacity building for public administration, and strengthening the role of public participation in making decisions.

5.7.1 Harmonization with Other Sectors

Water Management Strategies in Croatia, Bosnia and Herzegovina (B&H and RS) and Albania and *Water Basis* in Montenegro are long-term planning documents that set out the vision, mission, goals and tasks of policy in water management. These water policy documents are only partly harmonized with other sectoral strategies, which were adopted years ago and are now obsolete.

Sectoral policy documents, such as energy development strategies, strategies of industrial development, and territorial development strategies imply the existence and consumption of water as a resource. However, on the one hand these sectoral strategies have not been harmonized with each other, and on the other hand they rarely estimate real demand for water and water pollution potential of sectoral activities, which may threaten the implementation of the water protection measures both on national as well as on regional (transboundary) levels.

5.7.2 Improvement of Groundwater Governance

One of the most challenging topics related to groundwater governance in the region is the establishment of a regional cooperation with a joint body in the DIKTAS countries in order to ensure effective transboundary groundwater management.

The attention of the water governance bodies has to be turned to the management of water demand by measures such as water pricing mechanisms, reduction of water losses, water reuse and recycling, increasing the efficiency of domestic, agricultural and industrial water uses, and water saving campaigns supported by public education.

A program of measures at the DIKTAS level should be defined on the basis of application of economic criteria (cost effectiveness) and principles of ‘combined approach’ and ‘best environmental practice’. This is particularly important when applying measures to prevent the introduction of hazardous substances or measures to restrict the introduction of priority substances and other pollutants. The principle of cost recovery should be redefined in existing national water legislations as a goal to be achieved in the future. Specifically, it means that water pricing policies need to be based on the assessment of costs and benefits of water use and have to consider both the financial costs of providing services as well as environmental and resource costs. Implementation of water pricing policies means a combination of pricing and metering, in order to provide adequate incentives for using water efficiently and to change users’ behaviour.

It is essential that measures at the transboundary level are implemented within a timeframe which is realistic and acceptable for the countries. This requires transboundary agreements on the measures to be taken, political commitment to their enforcement, and sustained cooperation to monitor their effectiveness. A joint program of measures should stimulate the rational use of water resources and should make distinction between users with regard to pollution, not with regard to the economic sector (thus applying the ‘polluter pays’ principle).

Of particular importance for DIKTAS might be recommendations for integrating environmental principles in hydropower sectoral development activities. The key challenge is how to bring the key players from the energy and water sector on board in order to achieve a joint understanding of challenges. For this purpose, the outcome of the ICPDR activity might be used, including a status report on hydropower in the Danube region and guiding principles on hydropower development in the Danube region.

Policy and legal mechanisms at the DIKTAS level should be implemented to ensure application of measures to prevent or limit input of pollutants into groundwater from point or diffuse sources, such as industrial agglomeration, deposition of air pollutants, or wastewater (sewage) discharges. On the one hand this requires promoting investment in the field of wastewater collection and treatment for large and small agglomerations and on the other hand it requires the introduction of provisions for remediation of contaminated soil and water in national and regional legal documents.

In all countries the legal transposition of the WFD and the GWD was already implemented or is underway. The regional Strength/Weaknesses/Opportunities/Threats (SWOT) analysis, provided during TDA preparation phase, clearly showed certain shortcomings in the formal adoption of the WFD and the GWD in national legislations. For example, the areas (water bodies) intended for the abstraction of drinking water (drinking water protected areas) need to be properly defined in legislation *(see WFD, Article 7. „Waters used for the abstraction of drinking water")* and in principle, be distinguished from sanitary protection zones around well fields and springs. However, in national legislations there is no clearly defined relationship between groundwater bodies which are intended for the abstraction of drinking water (drinking water protected areas) and sanitary protection zones which are determined to focus protection measures within drinking water protected areas. Drinking water protected areas need to be defined based on Article 7. of WFD, but defining of sanitary protection zones is only optional. *(see WFD, Article 7).*

Another key challenge for water governance in the region is adaptation to climate change impacts and mitigation of changes in land use on transboundary groundwater resources. Adaptation and mitigation mechanisms and establishment of adequate supervision system(s) under these processes should be reflected in national legislations and transboundary agreements. The goal is to reduce the uncertainty in predictions of groundwater quality and quantity status determination and to enhance the conceptual understanding of the karstic aquifer system and its interactions with receptors, terrestrial and aquatic ecosystems.

A revision of monitoring programmes, in accordance with the WFD, is needed in order to ensure comparability and continuity with historical data from national monitoring programmes, which has great value in relation to the assessment of climate change impacts, the effects of land use change, water quality trends, and the beneficial impacts of programmes of measures.

5.7.3 Public Participation and Capacity Building

Capacity building for public administration and strengthening the role of public participation in taking decisions are an absolute 'must' in order to improve the existing state and practice of transboundary water management in the DIKTAS countries.

There is a general consensus that the lack of human resources can significantly slow down the implementation of IWRM principles in the region. Therefore, an efficient education system for the public administration working on both surface water and groundwater management issues needs to be developed in cooperation with all interested stakeholders.

Experience from the Sava River Commission shows that a number of activities are needed to broaden the platform of stakeholders, to include not only the governmental and NGO sectors (which have already been involved to a great extent), but also the academic and business sectors, and to involve these sectors in the process of the implementation of international agreement documents. Activities that might be launched in this regard are manifold and include the establishment of the Dinaric Karst Aquifer System Water Partnership, which may be foreseen as a platform of stakeholders for better policy/science interfacing. This Partnership would provide *ad hoc* and permanent mechanisms for the involvement of the interested stakeholders. It would also ensure better communication between decision makers and legislators and scientists working on national or international scientific or professional karst groundwater projects. This joint platform would enable a better transfer of the results of scientific investigations to target groups, namely the legislators, the decision makers and those working on the implementation of IWRM principles in the region. It should also make it possible for the decision-makers and legislators at all levels of decision-making to formulate the needs for future scientific investigations of the Dinaric Karst Aquifer System.

Finally, a series of meetings and workshops could help in integrating the scientific and professional community in the activities related to transboundary groundwater management. This includes training courses on karst hydrogeology suitable for decision makers and water legislators. International symposia could be an efficient way to introduce scientific advances to working professionals, decision makers, and investigators. Notes published in newspapers, on the Internet, TV and radio may be suitable for providing information for the general public on key aspects of karst groundwater resources protection.

5.8 Summary of Findings

The regional SWOT analysis enabled the identification of the fundamental causes of environmental problems and threats in the Dinaric Karst Aquifer System. The main challenges to effective groundwater management at the regional level are related to: harmonization of the water sector with other sectors, implementation of the IWRM principles in groundwater governance, capacity building in the public sector and increase of public participation in decision-making. The main shortcoming of this legislative framework is the underdeveloped system of by-laws and insufficient implementation of the present legislation.

To effectively tackle problems related to the protection and sustainable use of vulnerable transboundary water resources in the Dinaric karst region, the attention of the water authorities needs to be turned to the management of water demand, implementing measures such as water pricing mechanisms, reduction of water losses, water reuse and recycling, increasing the efficiency of domestic, agricultural and industrial water uses and water-saving campaigns supported by educational and awareness-raising activities. A program of measures at the transboundary level should be implemented within a timeframe that is realistic and acceptable for the countries and defined on the basis of application of economic criteria (cost effectiveness) and principles of a 'combined approach' and 'best environmental practice'. This requires transboundary agreements on the measures to be taken, political commitment to their enforcement, and sustained cooperation to monitor their effectiveness. A consultative and information exchange (CIE) body of the four countries could be the first step towards a systematic commitment to joint management. Such a body could undertake the development of a better mutual understanding of the unique properties and functions of the Dinaric Karst Aquifer System, and to adopt policies for its joint management, based on a regional consultative and management mechanism.

To improve the existing state and practice of transboundary water management in the countries, there is a strong need for capacity building of the public administration and to strengthen the role of public participation in taking decisions. A Dinaric Karst Aquifer System Water Partnership could be established, as a platform of stakeholders for better policy/science interfacing. It would improve communication among scientists, legislators, decision makers and those working in the implementation of IWRM principles in the region.

6 Stakeholder Analysis

The analysis of stakeholders identified different actors that could influence/affect or be influenced/affected by the Project, as well as the management of the karst aquifers in the Dinaric karst region. It also provided insight into stakeholders:

- Their characteristics and positions;
- Their perceptions with regard to the issues and problems - as well as their causes - related to the management of the Dinaric Karst Aquifer System;
- Their expectations and aspirations pertaining to the future of the transboundary karst aquifers management.

This information was used for the revision of the Stakeholders and Public Participation Strategy and the preparation of the TDA. Furthermore it will be used in support of the preparation of the Shared Vision.

Representatives of a wide spectrum of stakeholder groups participated in the activities which led to this analysis, from water management-related ministries, regional authorities and research, groups associated with tourism, NGOs working with nature and ecosystems, and the private sector, industries and hydropower. In general, there has been a good representation of stakeholder groups except the ones in the tourist sector and in agriculture and animal husbandry, the latter being really under-represented and consequently not identified in the analysis. The water management-related institutions - perceived by the stakeholders as the most influential actors in the field of karst aquifers management - were those best represented.

The basic methods for gathering and processing information for this stakeholder analysis include:

- Expert opinion and expert knowledge (provided by international and national experts);
- A web-based survey;
- Workshops;
- Structured interviews.

Information collected from interviewees and workshop participants represents their perceptions and views and has been used as such in conjunction with background research and expert knowledge (for more detailed information refer to '*Stakeholder Analysis*', DIKTAS Stakeholders Public Participation and Communication Facility, August 2012).

6.1 Categorization of Stakeholders

The identified stakeholders include a very wide range of actors, from primary users (farmers' associations, municipalities, hydropower), to secondary stakeholders (ministries relevant to management of the water resources, and research institutes) of various influence and importance to the project development. Most primary stakeholders are characterised as having a high level of interest.

The majority of the identified stakeholders are supportive towards DIKTAS and other similar initiatives. The project will consult with the stakeholders who, although not influential, have major interests in groundwater management, and gain their support. This is also recommended since stakeholders such as NGOs and farmers associations can become very vocal if they feel their interests are undermined. Furthermore, large sections of the media have been identified as stakeholders, some of whom are attributed with high influence, although mostly at national level; the DIKTAS will take this under consideration when implementing project promotion activities.

Water Management-Related Ministries, Regional Authorities and Research Institutes

This group of stakeholders is perceived as having a major interest and in most cases considerable influence on the management of the karst aquifers throughout the region. The project will seek to actively engage such stakeholders in meaningful participation.

Agriculture and Animal Husbandry

This analysis, to a degree, failed to identify some of the primary users in agriculture and animal husbandry stakeholders at the regional level, mostly because they remain small in size and underrepresented and are not organised at an institutional level. However, this group presents a contradiction between the importance and influence of individual, local and regional stakeholders, which have low representation and little influence, and their sector's representative institutions at a central level which are important stakeholders at the transboundary level. Furthermore, although there are lots of small-scale agricultural units in Croatia, due to historical reasons farmers' cooperatives are not popular among Croatian farmers. The Croatian Agricultural Chamber, although officially the representative of the agricultural producers' interests at the national level, is not supported by many farmers and is at conflict with other farmers' associations. In recent years new farmers' associations and producers' groups and organisations and other similar organisations have been created throughout the region, and the DIKTAS Project will make a concentrated effort to identify and engage the groups and associations relevant to the transboundary karst areas. This is all the more important since agriculture was identified by the key stakeholders as a developmental option for the region.

Tourism

Tourism-related primary stakeholders at regional or local levels are generally underrepresented. The tourism sector is estimated to have a low level of influence regardless of the degree of interest at stake. In some cases (Montenegro) the tourism-related ministry is considered to have significant influence, whereas organisations such as the National Tourism Organisation are considered not to have significant influence. In other cases (B&H), tourism is regarded as having low levels of interest in karst aquifer management. However, since sustainable tourism is the foremost proposed development option for the area, their current and potential impact on the water resources will be taken under consideration.

NGOs, Nature and the Ecosystem

Despite the existence of many environmental NGOs in the wider region, and while most are estimated to have high levels of interest, the majority are characterised as having little influence. The majority of the identified NGOs are believed to be supportive towards DIKTAS and other similar initiatives and it is highly advisable to actively engage them in order to maintain their support.

However, unlike in other project countries, the analysis in Croatia reveals that the stakeholders consider the ecosystem as an important user of the karst aquifer and groundwater resources; in this regard it is treated in the same way as other users, such as hydropower, households and agriculture. In particular, national parks and NGOs are identified as stakeholders of high levels of interest and importance to the project. What is more, they are considered stakeholders of high levels of influence. The vast majority of them are considered to be supportive of the DIKTAS project objectives, and the project will aim to maintain this support and engage the stakeholders in meaningful participation in the project activities.

Private Sector, Hydropower, Industries

The private sector and especially industries are believed to have a neutral or negative attitude towards the project's aims and objectives, while in some cases they are considered to be opponents. In addition, the industrial sector has been identified as one of the main pressures on the resource, while some industries have been criticised for their contribution to the environmental pressures on the water bodies and groundwater in the region, either through pollution or water use.

Hydropower in particular is a sector that requires special attention, since it is one of the most important industries of the region, exerting significant pressure on the management of groundwater. Taking into account the possible impact it can have on the quantity and quality of groundwater resources, the project will aim to raise awareness regarding the vulnerability of the resource and try to win the sector's support. Having once gained the support of the hydropower sector and the private sector, they will be involved further in the project.

6.2 Stakeholder Involvement in DIKTAS

The majority of the key stakeholders are interested in participating in the stakeholder engagement activities proposed by DIKTAS and in contributing to the project's outcomes and efforts for shared karst aquifers' management. They are also eager to participate in the preparation and implementation of management plans, project activities and proposed solutions. The key stakeholders in the region represent a good source of information and in all the countries they are willing to contribute expertise and information and, to a reasonable degree, human resources in order to participate in karst aquifer management.

Figure 6.1 Stakeholders during a DIKTAS workshop

The majority of the key stakeholders interviewed in the framework of the Stakeholder Analysis wish to participate in the DIKTAS project implementation. Being consulted on the TDA/SAP preparation process is the most preferred form of participation, followed by being involved in and contributing to the project activities, and lastly to contributing information related to their domain/business for the better management of karst aquifers.

Table 6.1 Preferred form of participation in the DIKTAS activities

What is the preferred form of participation in DIKTAS' activities?	Responses
Contribute information related to my domain/business to be used through DIKTAS for the sustainable management of the transboundary karst aquifers	29
Consulted on the preparation of the document that analyses the aquifers' systems state/on the transboundary problems and issues. Consulted regarding the identification of policy, legal and institutional reforms and investments needed to address the problems?	43
Involved in and contribute to the implementation of the project activities	40

Additionally, stakeholders wish to participate in the management of the transboundary karst aquifers, through consultation on the proposed decisions and measures at the transboundary, national and regional levels. The major constraints to their participation are the economic cost of such an involvement and the workload. Lack of training/education seems to be a considerable constraint as well.

Table 6.2 Preferred form of participation in transboundary karst aquifer management

What is the preferred form of participation in the management of the transboundary karst aquifers?	Responses	International/ transboundary	National	Regional	Local
Informed about decisions and measures	42	18	24	22	16
Consulted on proposed decisions and measures	56	22	28	26	15
Involved in decision making	41	19	26	18	10
Involved in implementation of decisions	36	16	18	16	10

In order for stakeholders to participate meaningfully in the management of the transboundary aquifers, they would mostly need financial support, but also opportunities for information exchange with other stakeholders. Training, education and/or more human resources are also viewed as important in facilitating participation.

Financial support is considered very important or important for stakeholders to overcome constraints and to participate meaningfully in the management of the transboundary aquifers.

Furthermore, opportunities for information exchange are also valued as an important means of support for participation. The latter gives an additional value to the communication and information activities and the efforts of DIKTAS to engage stakeholders, and indicates the vital role the project could play in the wider field of groundwater management in the area as a platform for information exchange.

Table 6.3 Support for participation in the management of the transboundary karst aquifers

What kind of support would you need to overcome these constraints and participate/ be involved?	Not Important	Slightly important	Quite important	Important	Very important
Financial support	0	4	17	22	22
Training/education and/or more human resources	0	1	18	20	13
Opportunities for information exchange with other stakeholders (e.g. conferences, meetings)	0	2	13	26	17
Legal advice	2	3	14	13	4
Access to information	1	1	11	13	19

The Stakeholder, Public Participation and Communication Facility implemented a number of activities within the first year of implementation of the Project.

Information provision

The DIKTAS Project Brochure and leaflet were prepared. The brochure was distributed at the 6th GEF Biennial International Waters Conference, in Dubrovnik, Croatia, 17-20 October 2011, while both the brochure and leaflets were distributed during the National Consultation Meetings in the Project countries (see below). Additionally, an Information Note was prepared in the national languages of the Project countries as well as in English and used in all the documents prepared by the Project.

Electronic means of information provision and communication were used for reaching a wide audience. The project website was updated in appearance and content; there is continuous effort to publicize its existence among the Project's stakeholders. Two issues of the DIKTAS newsletter containing the developments from all the DIKTAS workgroups, news from project activities and other groundwater management-related news, were published and circulated to the DIKTAS stakeholders in December 2011 and June 2012 and uploaded to the project website.

Communication and consultation activities

A web-based survey aiming to collect initial information to be used in the preparation of the stakeholders' analysis and the TDA, but also to inform on the objectives and activities of the project, was conducted between December 2011 and May 2012. The survey was conducted in the national languages.

Four National Consultation Meetings (NCMs) were organised, one in each of the four Project countries, between 28 February and 8 March 2012. The participants in the NCMs included targeted representatives of national and local stakeholders including national, regional and local authorities, important economic sectors (such as energy), research/scientific institutions, private sector and NGOs. The NCMs served multiple purposes: to identify the stakeholders to participate in the Project and investigate their characteristics i.e. their interest, influence, importance and perceived attitude towards the Project; and to consult with stakeholders regarding their views on the significant issues and pressures on karst aquifers, the causes and the impacts of these issues, in order to provide input in the preparation of the TDA. Furthermore, the NCMs were used as an opportunity to inform stakeholders about the DIKTAS project objectives, activities and developments and to raise awareness regarding karst aquifers.

Additionally, semi-structured interviews were conducted in all the Project countries between 24 April and 13 July 2012 to collect information for the preparation of the Stakeholders Analysis and the TDA. In total, ninety-one (91) out of 100 planned key stakeholders were interviewed. The interviews also contributed to enhancing the participation process: they facilitated the provision of information about the aim, objectives and activities of the project as well as attaining the interviewees' interest in being involved in the activities.

Two capacity-building workshops on specific aspects of policy and technical issues related to sustainable management of karst aquifers/integrated water resources management have been organized.

Involvement in the decision-making

The Project countries have been participating in the preparation and implementation of the Project's activities through their representatives in the Steering Committee as well as through the representatives of the focal ministries. A number of related meetings have taken place in this initial phase of the Project.

6.3 Perceived Transboundary Issues

Some of the perceived issues, such as pollution, are common in all the four Project countries. Unsustainable/insufficient wastewater management and solid waste management - especially inappropriate landfills - are recognised as the most important causes in this regard by stakeholders from all sides of the borders. Pollution from industry and agriculture is also indicated.

There is a general agreement on the need for more research as well as information and scientific knowledge exchange. Knowledge of the karst aquifers' characteristics, borders, use and condition is considered incomplete. Lack of awareness is also identified as a cause of many issues, while information and education is prescribed as a means for improvement of water resources management. Lack of cooperation of stakeholders, institutions and initiatives at all levels is stipulated; agreements, joint bodies etc. are proposed. Inadequate implementation and enforcement of legislation is indicated. The harmonisation of national legislations among neighbouring countries and complete transposition of the EU Directives is proposed. Most of all, stakeholders from all the countries stipulate the need for improvement in the overall management of water resources, combining all of the above-mentioned issues.

When comparing results in pairs of countries sharing aquifers some further conclusions can be derived. Stakeholders in Albania and Montenegro agree that the main issue is that of surface water and groundwater pollution. However, stakeholders in Albania attribute pollution issues primarily to the unsustainable/insufficient municipal solid waste management, while stakeholders in Montenegro point towards unsustainable/insufficient municipal wastewater management as the main culprit. Both sides recognise the issue of industrial pollution (having a transboundary effect), the need for enhanced water resources management, and the need for more research and information exchange.

Accordingly, stakeholders from B&H agree with those from Croatia that pollution is the main issue including toxic substances, organic and bacteriological pollution of groundwater and surface waters. The two sides cite different causes; the former attributes pollution mainly to shortcomings in municipal solid waste management and the latter to municipal wastewater management practices. Another significant issue that is pointed out by both sides is the over-abstraction of water resources; they relate this to the production of hydropower and the subsequent impacts on water flows and dependent ecosystems downstream. Stakeholders from both countries highlight the need for cross-border cooperation and coordination on resources management, research and monitoring. Finally, the harmonisation of legislation and the adoption and implementation of the EU Water Framework Directive is proposed by stakeholders from both countries.

Regarding the stakeholders from B&H and Montenegro, their views diverge on the nature and sources of pollution; the former report toxic substances as the main pollution-related problem followed by organic and lastly bacteriological pollution. In Montenegro nitrate and phosphate pollution is perceived as the most important problem, followed by organic pollution and lastly toxic substance pollution. The need for better water quality monitoring of the Bilećko Lake is agreed by stakeholders from both countries. The need for more research and information, adoption of EU legislation and regulations, integrated management and cooperation of all states sharing the resource is acknowledged by everyone.

6.3.1 Surface Water and Groundwater Contamination

The main issue identified by stakeholders is surface water and groundwater pollution, and more specifically toxic substances, organic and bacteriological pollution, as well as nitrate and phosphate pollution.

Pollution due to unsustainable/insufficient wastewater management is an issue rated as one of the top priorities; it is believed to affect equally both surface water and groundwater. It is one of the most mentioned pressures in all the methods employed, the on-line survey, interviews and National Consultation Meetings. Households are recognised as the main users exerting pressure on karst aquifers and the problem is thought to originate mostly from domestic wastewater and exacerbated by urbanisation and unsustainable tourism development.

Unsustainable/insufficient solid waste management is identified as one of the most important pollution-related issues. Municipalities/households, illegal landfills, industry, construction (aggregates) and tourism-related activities are specified as the main sources. The latter calls for special attention since tourism is the activity quoted most often by the key stakeholders for future development in the area. In some cases the failure of landfills to meet basic sanitary and technological conditions is pointed out, resulting in infiltration of toxic substances to groundwater. Unsustainable waste management is believed to impact more groundwater than surface waters, causing toxic substance pollution.

The use of agrochemicals is thought to impact groundwater quality. Unsustainable agricultural practices, and most noticeably livestock waste management and use of agrochemicals, are indicated as the major contributors to nitrate and phosphate pollution. Agriculture is recognized as one of the main uses in terms of pressure exerted on water resources (at the same level as households). On the other hand, sustainable agriculture is an activity proposed by many stakeholders as a development option for the region, calling for more attention to this issue.

Pollution from industry/manufacturing, mines and construction is considered another significant issue contributing to the decline of the quality of both surface water and groundwater resources.

6.3.2 Surface Water and Groundwater Availability

The decline of groundwater levels and the respective effects on groundwater flows is indicated as significant in many cases; water abstraction for domestic use and drinking water, irrigation and the production of hydropower are pointed out as the causes.

Over-exploitation and over-abstraction for household use and irrigation of crops is reported throughout the region and it is believed to adversely influence groundwater levels. Lack of awareness, absence of a set abstraction regime for drinking water supply, irrigation of agricultural land and a failure to implement and enforce protective legislation are thought to be among the causes.

However, the decline of groundwater levels is mostly associated by stakeholders with the use of the resource for the production of energy. Construction and operation of dams for electricity production is one of the issues mentioned in conjunction with the issue of groundwater over-abstraction, the disturbance of the water balance and the hydrologic regime. Hydropower production is thought of as the second most important user in terms of pressure exerted on groundwater resources, affecting water-dependent ecosystems as well as disturbing the water flow regime.

The degradation of the traditional water management infrastructure in rural areas such as the rain water-collecting reservoirs used for agriculture was also mentioned as an issue in one of the National Consultation Meetings.

Another issue which was mentioned mostly as an issue in Albania related to quantitative, availability and management issues of flooding, thought to be caused by deforestation and degradation of the vegetation cover; the latter has resulted in erosion that is believed to affect the permeability of soil layers above the aquifers.

6.3.3 Impacts of Surface Water and Groundwater Withdrawals

The main impacts of water withdrawals reported mostly regard the negative impacts on the health and biodiversity in the water-dependent ecosystems. Reduction of groundwater flows is reported downstream affecting ecosystems, such as Malostonski Zaljev and Malo More – Uvala Bistrina (the bays), springs, and wetlands. Furthermore, agricultural production in the Popovo Polje is also believed to be affected by water scarcity exacerbated by the exploitation of water resources. Finally, saltwater intrusion through the aquifers of the River Neretva to the Dračevo in Čapljina Municipality is reported by stakeholders in B&H, believed to be linked to the reduction in groundwater flow.

6.3.4 Areas of Special Concern

6.3.4.1 Transboundary Areas of Special Concern

Albania and Montenegro

Stakeholders from Albania and Montenegro both report pollution and the need for protection measures as prevailing issues in the River Cemi/Cijevna area.

Bosnia and Herzegovina and Montenegro

The management of Bilećko Lake is mentioned by stakeholders from both countries. Interviewees from both countries indicated that water supply and water use issues affect the lake.

Stakeholders from both countries agree on the impact of water use on the resources of the aquifers in Trebišnjica and the dependent ecosystems. Stakeholders from B&H point towards the use of the resource for hydropower production as the main pressure. The concentration of industrial polluters in the area is also pointed out by stakeholders interviewed in Montenegro.

Bosnia and Herzegovina and Croatia

According to stakeholders from B&H, attention should be given to the quality, quantity, use and protection of the sources of transboundary karst groundwater for the source and catchment area of Klokot Privilica, which is located in the Municipality of Bihać in Bosnia, for lakes Plitvice and Udbina in Croatia and for the sources Ostrovica and Toplica which are also used for drinking water. Additionally, it is reported by Croatian interviewees that settlements near lakes Korenica and Plitvice need to be connected to wastewater treatment plants through an improved connection network.

Another noteworthy point cited by both sides is the Popovo Polje. Stakeholders from B&H mention floods and scarcity of water resources, to such a degree that one stakeholder commented that agriculture production in Popovo Polje was completely destroyed due to lack of water resources. Stakeholders from Croatia report pollution originating from the Popovo Polje reaching the area of Dubrovnik.

The third point of great concern reported by both countries refers to the transboundary basin of the Neretva and Trebišnjica, where, according to stakeholders from B&H, there is a need for river basin management plans. The major issue reported in both countries is the reduction of groundwater flows. According to stakeholders from B&H, the use of the resource for the production of electricity is creating the problem, while stakeholders from Croatia cite that the reduction in groundwater flows is evident downstream and is having negative impacts on ecosystems, such as Malostonski Zaljev and Malo More – Uvala Bistrina, or areas where the groundwater is returning to the natural state (springs, wetlands, etc.). Furthermore, saltwater is reported by stakeholders in B&H to be intruding through the aquifers of the Neretva River to the Dračevo in the Municipality of Čapljina.

6.3.4.2 Areas of Special Concern in the Participating Countries

Albania

The stakeholders indicated several areas where specific issues manifest:

- The KAP-Aluminium Processing Plant in Montenegro is believed to impact both Lake Skadar (Shkodra) and the aquifers in the area.
- It is commented that in the areas surrounding Lake Shkodra and the Buna and Drini rivers, the vegetation has been reduced resulting in increased erosion.
- The possible exploitation of the River Morača waters in Montenegro for generating electricity has been commented on in the interviews as a potential source of disturbance of the hydrological regime in the area affecting the aquifers, in addition to Lake Shkodra.
- The 'Nenshkodra area', the area of Lake Shkodra and the River Buna were mentioned as areas impacted by flooding.
- It is pointed out as an issue, that water resources in Vermosh and Puka are yet to be exploited.

Finally, the key stakeholders interviewed drew the attention to the protection and management of the following water bodies:

- Lake Skadar (Shkodra)
- The River Cemi
- The River Valbone
- The River Shales
- The River Theth
- The River Drini with its water catchments
- Water resources in Aplin, in the area of Rrjoll of Malesi e Madhe.
- Shegan Eye in the Vermosh area.

Bosnia and Herzegovina

Several issues were indicated by stakeholders as manifesting in a number of areas:

- The management of Lake Bileća is insufficient.
- Attention should be paid with regards to the quality, quantity, use and protection of the:

- (catchment areas) sources of Klokot, Privilica, Toplica, Ostrovica and several other smaller springs, which are used by the Municipality of Bihać for drinking water supply.
- Lakes Plitvice and Udbina in Croatia.
- There is concern that in Hutovo Blato and delta of the River Neretva, hydro-power production company(ies) do not respect the 'biological minimum flow'.
- Saltwater upconing has been observed in Dračevo in the Municipality of Čapljina.
- There have been flooding incidents in Mostar and the Popov Polje.
- The 'Upper Horizons' project can significantly disturb the water regime in the area affecting both surface water and groundwater. [4]
- Point and diffuse sources of pollution exert pressure on the groundwater resources in the Una river basin.

Croatia

In addition to the general feedback on issues from the interviewed key stakeholders, several geographic specific issues were indicated, in some cases providing detailed information.

- Settlements near lakes Korenica and Plitvice need to be connected to wastewater treatment plants.
- According to one interviewee, an issue of transboundary importance is the effect that the operation of the refinery in Bosanski Brod in B&H has on groundwater resources. The suggestion is for the refinery to modernise its operation to meet the environmental standards and to acquire an environmental permit.
- One interviewee indicated that the area of Mount Trgovska Gora (Una River) is still a location earmarked in the Physical Planning Program of Croatia for the disposal of nuclear waste (low and medium radioactive waste) from the Krško nuclear power plant in Slovenia; according to the interviewee the geological conditions in this area are not suitable for the construction of such a disposal site.
- The hydro power plants planned to be constructed on the River Trebišnjica in B&H will have an impact on Croatia. The proposal is for the two countries to prepare jointly an environmental impact assessment.
- Pollution from the Popovo Polje occasionally reaches the area of Dubrovnik.
- There are evident changes in groundwater flows in the Neretva River basin area attributed to the construction of reservoirs in neighbouring countries.
- The reduction of the flow of groundwater is reported by another interviewee to have a negative impact on some ecosystems, such as 'Malostonski zaljev' and 'Malo More – Uvala Bistrina'. The same interviewee quotes these areas together with the estuary of the River Ljuta, the estuary of the River Ombla, and the coastal sea waters, as areas where efforts should be focused on preserving and protecting the economy and the ecological systems. Finally the stakeholder quotes findings of the Institute of Oceanography and Fisheries, Laboratory of Dubrovnik, which has detected heavy metals in fish near the island of Daksa, in the waters under the direct influence of the river Ombla and in transboundary groundwater flows.

[4] According to P. Milanovic, in most instances this impact will be positive, offering irrigation, flood reduction, water supply improvement, power production, infrastructure improvement, increasing of Bregava River minimal flow and many secondary benefits including positive influence on the critical minimal inflow into the Hutovo Blato Nature Park.

- Abstractions of water for domestic consumption and irrigation in the city of Šibenik and its county exert pressure on the River Krka.
- The River Krka is also quoted as the direct recipient of wastewater discharges from inadequate infrastructure and industrial facilities in Knin and Drniš.

Montenegro

Several issues were indicated by stakeholders as manifested in a number of areas:

- Water use from the aquifers in the Trebišnjica river basin by Montenegro and B&H.
- Concentration of industrial polluters in the Trebišnjica river basin.
- Water pollution in the Cetinjsko Polje has an impact on the quality of water that leaves the Obod pit (note: this is not a transboundary problem).
- In Zeta there is abstraction of large amounts of water for irrigation. Pollution from industrial and municipal waste is also reported. Monitoring is thought to be far from sufficient.
- Pollution is cited as an issue in the Cijevna River.
- Bilećko Lake is reported to be affected by water uses in the area.

6.3.5 Expectations from DIKTAS

Most key stakeholders expect to see an increased production of reliable scientific research and knowledge on karst aquifers, the updating of methods in research, and the use and protection of the resources as outcomes of the DIKTAS project. They consider the project as an opportunity to improve the management of water resources through the implementation of the project findings, and the promotion of sustainable management proposals, practices and mechanisms.

Stakeholders view DIKTAS as an opportunity for the cooperation, networking and communication between the different actors and stakeholders at the transboundary level and the harmonization of karst aquifers management frameworks among the countries. Opportunities for participation in the decision-making process are also among the next most expected outcomes. They see the project as a platform for professionals from aquifer-sharing states, to share knowledge and information.

Finally, many key stakeholders would like to see the issue of karst aquifers and the management of the resource gaining more publicity aided by the knowledge, information and data volume produced by DIKTAS and the raising of the public's awareness regarding the issues related to the resource.

6.4 Summary of Findings

Overall, all the stakeholder groups are in favour of the DIKTAS project and its envisaged outcomes contributing to the sustainable management of karst aquifers in the region. The industrial sector has been identified as one of the main sectors in terms of pressures exerted on the resource and along with the private sector these are the two areas to have a neutral or negative attitude towards DIKTAS' aims and objectives. Hydropower in particular is regarded as one of the most important economic activities in the region and the second most important user in terms of exerting pressure on groundwater. It is perceived to cause significant impacts on the quantity and quality of the resource. The majority of NGOs have high levels of interest but little influence and are believed to be supportive towards DIKTAS. Sustainable tourism is regarded as the foremost proposed development option for the area with the agriculture development coming second; the identified groups in the above sectors should be more engaged in karst aquifer-related actions.

Some of the perceived transboundary issues, such as pollution, are common in all the four project countries. Unsustainable and insufficient wastewater and solid waste management – especially inappropriate landfills – are recognized as the most important pressure in this regard. Pollution from industry and agriculture is also indicated as significant. It was clearly shown that there is a need for more information and education for water resources management as well as more research and scientific knowledge exchange among stakeholders. Lack of cooperation among stakeholders, institutions and initiatives at all levels is noted. The development of joint bodies and agreements is proposed. Inadequate implementation and enforcement of legislation is believed to be an issue. The harmonization of national legislations among neighbouring countries and the completion of the transposition of the EU Directives are thought to be of importance. Stakeholders from all the countries stipulate the need for improvement in the overall management of water resources, combining in this all of the above mentioned issues. When comparing results in pairs of countries sharing aquifers, some further conclusions can be derived; these are described in detail in Table 6.4 below.

Table 6.4 Summary of findings

<table>
<tr><th>Stakeholders findings</th><th>Albania</th><th>Montenegro</th><th>Bosnia and Herzegovina</th><th>Croatia</th></tr>
<tr><td>Impact</td><td colspan="4">Pollution on surface waters and groundwater</td></tr>
<tr><td>State</td><td>Not specific</td><td>Nitrate and phosphate, organics and toxic substances</td><td colspan="2">Toxic substances, organic and bacteriological pollution</td></tr>
<tr><td>Cause 1</td><td>Unsustainable/ insufficient municipal solid waste management</td><td>Unsustainable/insufficient municipal waste water management</td><td>Shortcomings in municipal solid waste management</td><td>Shortcomings in municipal waste water management</td></tr>
<tr><td>Cause 2</td><td colspan="2">Industrial pollution</td><td colspan="2">Over abstraction of water resources due to production of hydropower</td></tr>
<tr><td rowspan="2">Necessary Measures Accompanying the addressing of main causes</td><td colspan="2">Enhanced water resources management, research and info exchange</td><td colspan="2">Cross border cooperation and coordination on resources management, research and monitoring. Harmonization of legislation and the adoption and implementation of the EU Water Framework Directive</td></tr>
<tr><td></td><td colspan="2">Better management of the Bileća/ Bilećko Lake</td><td></td></tr>
</table>

The majority of the key stakeholders are interested in participating in the stakeholder engagement activities proposed by DIKTAS and to contribute to the project’s outcomes and efforts for shared karst aquifer management. They are also eager to participate in the preparation and implementation of management plans, project activities and proposed solutions. The key stakeholders in the region represent a good source of information and in all the countries they are willing to contribute expertise and information and, to a reasonable degree, human resources in order to participate in karst aquifer management.

7 Priority Transboundary Challenges and Problems

This chapter contains the results of an elaborated analysis of important transboundary aquifers in the project region. There are in total eight distinct TBAs between the project countries, most of them named after the related rivers: Una, Cetina, Kupa, Beretva, Trebišnjica, Bilećko Lake, Piva and Cemi/Cijevna. The TBAs are shown on the Transboundary Aquifer Map (Annex 1.8). [5]The aquifers of Kupa and Piva are, according to the Project Team hydrogeologists from related countries, too local. Nevertheless, some data about the Piva aquifer is given below, as provided by the national experts. [6]

The results of the analysis for the seven TBAs are presented below (Sections 7.1-7.7). The analysis was carried out thoroughly and in a structured way that considered Climate and Hydrology, Hydrogeology, Groundwater Reserves and Their Utilization and Groundwater Quality and Protection. For each aquifer Major Issues of Concern are determined and Proposed Actions suggested. This chapter closes with a brief Root Cause Analysis and summary of Priority Actions.

7.1 The Transboundary Aquifer Una

The Transboundary Aquifer (TBA) Una is shared by Croatia and B&H (Figure 7.1). The information available from various government agencies in the two countries used for the assessment of its general characteristics includes (1) long-term climate record by the hydro-meteorological institutes of B&H and Croatia; (2) basic geological map, on the scale 1:100,000, completed when the two countries were part of the former Yugoslavia (sheets Bihać and Udbina); (3) detailed geologic maps on larger scales produced for various other purposes; and (4) data on numerous tracing tests performed as part of regional hydrogeological studies.

Hydrological data on karst springs, although outdated as it was collected mainly before 1992, is still being used in all relevant documents (such as in the Water Management Strategies). This data needs to be updated and re-analysed in light of the new land-use practices as well as various issues related to climate change.

Data on groundwater utilization for the industry and other major uses including public water supply is mostly accurate, but the data collection on water consumption in rural areas and the groundwater quality in general needs to be improved. There has been an increasing focus on

---

[5] Introducing two TBAs in Eastern Herzegovina, namely Trebišnjica TBA and Bileća Lake TBA is arbitrary and done for the sole purpose of transboundary analysis. Both TBA belong to the regional karst aquifer system of Eastern Herzegovina. Perhaps TBA Popovo Polje would have been more suitable name for the TBA Trebišnjica.

[6] The methodology for delineation of transboundary aquifers was based on two basic guidelines:

- Each transboundary aquifer belongs to one of the main transboundary river basins or lakes, defined in accordance to WFD.
- Transboundary aquifer covers all transboundary recharge area of all indentified karst springs (within a particular transboundary river basin or lake).

Anyway, due to complexity of karst and limited data availability the estimated boundaries are approximate in their nature.

delineation of sanitary protection zones for major sources of drinking water in recent years; however, a legal framework for establishing such zones at the transboundary level is still missing.

The estimated total area of the TBA at Una is 1,773 km^2 of which 77.8 % (1,379 km^2) is karst terrain. The Croatian portion of the TBA is 1,605 km^2 (of which 77.5 %, or 1,245 km^2 is in karst), and the B&H portion is 168 km^2 (80 % or 134 km^2 in karst).

The TBA at Una belongs mostly to the Una river basin, and a smaller part to the Korana river basin (tributary of the River Kupa). The average flow of the River Una near Bihać is 90 m^3/s.

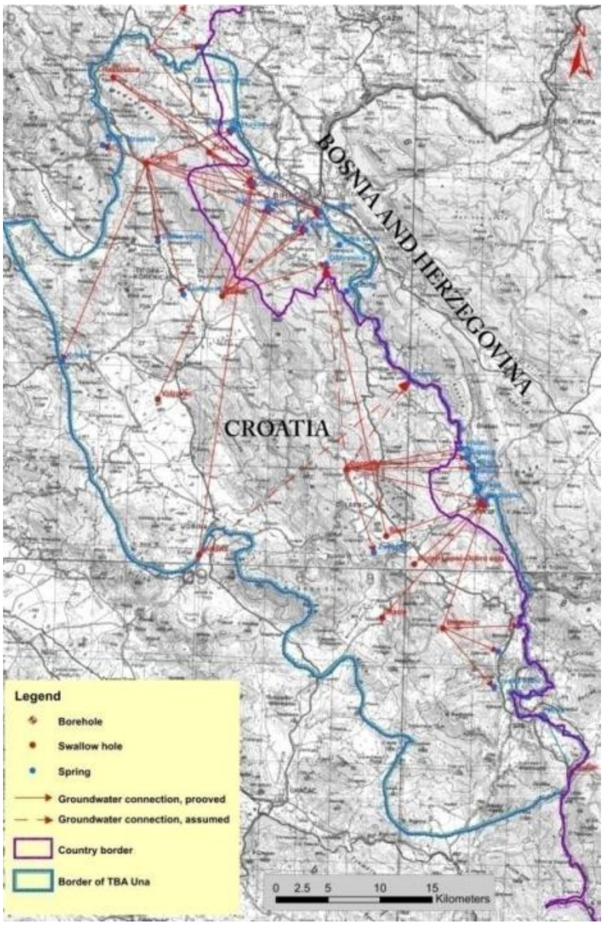


Figure 7.1 The transboundary aquifer at Una shared by Croatia and B&H with groundwater connections

The largest portion of the TBA Una, or 654 km^2, belongs to the catchment area of Klokot 1 and 2 springs (Kupusović, 2004). The Ostrovica spring drains approximately 200 km^2 (Slišković, 1973), whereas the rest is drained by smaller springs including Dobrenica, Privilica, Ilijića Springs, Žegar, Toplica, Crnoć, Đakulin, etc.

7.1.1 Climate and Hydrology

Long-term climate data series (more than 30 years of observations) were used for the aquifer water balance estimation (this data is available from the hydrometeorological institutes of B&H and Croatia). The average precipitation for the B&H and the Croatian portions of the TBA is 1,350 mm/year and 1,460 mm/year respectively. The average air temperature for B&H (station Bihać) is 10.5 °C.

Average sinking rates of major sinking streams which, in addition to large karst springs, represent the most important hydrologic features of the TBA, are given in Table 7.1. The combined average sinking rate of the five Croatian sinking streams is approximately 6.32 m^3/s. In comparison, the average combined discharge rate of karst springs in B&H, which are partially fed by some of these sinking streams, is 27.10 m^3/s. A detailed review of the springs and their characteristic discharge rates is provided in the following section.

Table 7.1 Average sinking rates of the major Croatian sinking streams in the TBA at Una

Sinking River	Country	Average sinking rate (m^3/s)
Korenička rijeka	Croatia	1.500
Prijeboj	Croatia	0.150
Krbava	Croatia	1.650
Krbavica	Croatia	0.175
Korana	Croatia	2.840

7.1.2 Hydrogeology

The TBA Una is formed primarily within limestones of the Mesozoic age, with a smaller contribution of areas underlain by the Jurassic and Triassic limestones. All the limestones are intensely fractured and faulted and have a high infiltration capacity at the land surface that allows for rapid aquifer recharge by precipitation and sinking streams. The majority of the aquifer recharge zone is located in Croatia.

The groundwater flow directions are exclusively from Croatia to B&H as identified by numerous dye tracing tests which traversed the boundary between the two countries (**Error! Reference ource not found.**).

The groundwater flow velocities range from 0.11 cm/s and 0.22 cm/s(from the swallow hole Prijeboj to Privilica and Žegar Springs) up to 14.64 cm/sec (from the swallow hole in Donji Lapac to Ostrovica Spring). The most common groundwater velocities are between 1 and 4 cm/sec. The minimum, average and maximum flows of the main karst springs are shown in Table 7.3.

Other smaller springs in B&H include Toplica-Klisa, Ilijića vrelo, Panjak, Bistrica, Žegar, Đakulin-Loskun, Crnoć-Nebljuši and Draga Springs.

In Croatia there are Koreničko, Čuić, Krčevine, Krbavica, Udbina, Joševica, Mala Nateka, Velika Nateka and Una Springs. Combined minimum discharge of these springs in Croatia is approximately 0.68 m^3/s (Figure 7.2)

Table 7.2 Results of dye tracing tests traversing the boundary between Croatia and B&H.

Swallow hole	Date of tracing test	Connection with spring	Distance: ponor - spring (km)	Virtual GW velocity (cm/s)	Type of GW connection	Hydrological conditions
Jaruga, Krbavsko	25.6.1969	Klokot 1	23	3.65	Strong	Average
Prijeboj	16.9.1982.	Klokot 1	12	3.47	Strong	Dry
		Klokot 2	12	1.74	Medium	
		Žegar	16.5	0.22	Weak	
		Privilica	18.6	0.11	Weak	
		Arkovac	10.3	1.08	Medium	
		Brišovac	10.3	1.00	Medium	
Korenica	23.5.1968.	Klokot 1	11	3.47	Strong	Average
		Klokot 2	11	3.47	Strong	
		Privilica	12	2.78	Strong	
		Dobrenica	12	2.78	Strong	
		Ilijića vrelo	10	1.97	Medium	
		Pećina	10	1.97	Medium	
Piezometer PB-1 (D. Grad)	25.9.2007.	Klokot	16	1.13	Weak	Dry
Rastovača	21.4.2005	Klokot	17.5	1.14	Medium	Average
Bare	21.31972.	Ostrovica	26	2.61	Strong	Medium
		Dobrenica	26	2.61	Strong	
Dnopolje	3.7.1984.	Ostrovica	13.7	14.64	Strong	Dry
		Toplica	11.6	12.39	Strong	
		Klisa	11.8	1.69	Weak	
Mazin	26.03.1973.	Ostrovica	14	1.61	Strong	Average
Brezovac	15.06.1989.	Ostrovica	13.1	1.89	Strong	Average

Table 7.3 Characteristic flows of major karst springs in the TBA Una.

Spring	Country	$Q_{min}/Q_{aver}/Q_{max}$ (m^3/s)	discharge observation period or reference
Klokot 1 and 2	B&H	2.3/14/70	IX 1978 – VII 1981
Ostrovica	B&H	0.79/3.71/12	Slišković[7]
Privilica	B&H	0.05/-/2	Miošić[8]
Dobrenica	B&H	0.23/0.61/5	Miošić[3]
Crnoć	B&H	1.2/-/2	Miošić[3]
Đakulin	B&H	0.75/-/16	Miošić[3]

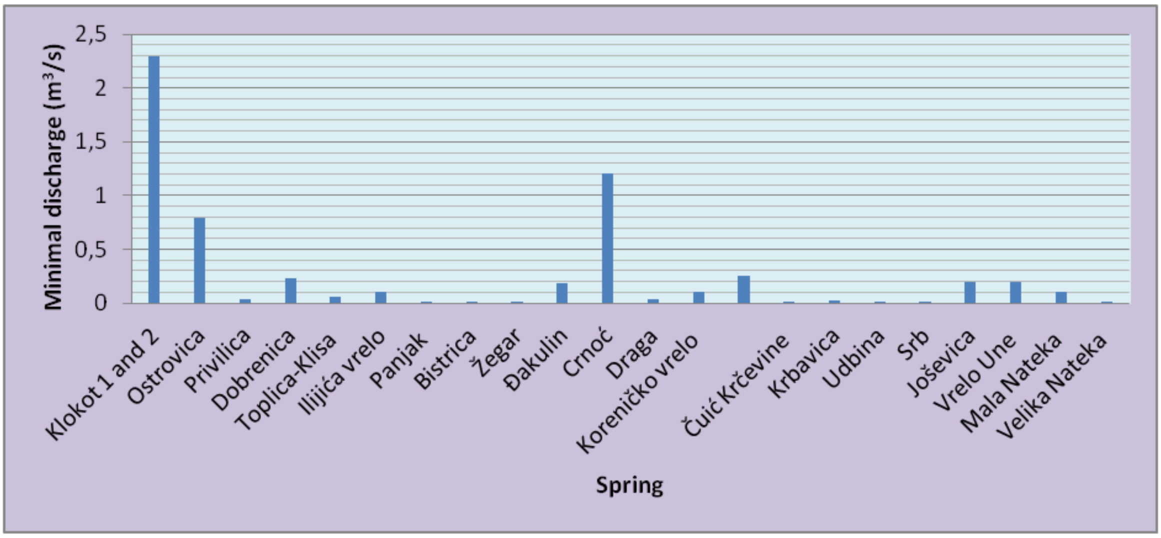


Figure 7.2 Minimal discharge of springs within the Transboundary Aquifer Una

Discharge of the karst springs is characterised by highly variable flows. The ratio between maximum and minimum spring discharge ranges from 4 (the Dobrenica Spring) to more than 350 (the Una Spring). There is no regular groundwater monitoring except for the water quality monitoring of tapped springs conducted by water utilities, and an occasional groundwater quality monitoring conducted by the Sava Water Agency from Sarajevo.

---

7 Groundwater flows connection and water supply in holokarst of Lika and Bihać region, Croatia and Bosnia and Herzegovina, Federal institute for geology, Sarajevo, 2008

8 Groundwater flows connections and water supply in holocarst of Lika and Bihać region, Croatia and Bosnia and Herzegovina, Herald Geological 37, Geological Institute of the Federation of B&H, Sarajevo, 2008

7.1.3 Groundwater Reserves and Their Utilization

The estimation of groundwater reserves within the TBA Una is performed in accordance with a water balance calculation methodology proposed by the Working Group Hydrogeology. The review of the methodology is provided in Chapter 3.

The available average reserves of groundwater in the TBA Una are about 34 m^3/s. The minimum recorded discharge of springs is assumed to correspond to the minimum ecologically acceptable flow. This value for the springs in Croatia is 0.86 m^3/sec and in B&H it is 4.95 m^3/sec, with a total of 5.81 m^3/sec (Table 7.4). The tapped amount of groundwater used for water supply in B&H is 0.52 m^3/sec and about 0.165 m^3/sec in Croatia, with a total of 0.685 m^3/sec. This includes industry and inhabitants connected to centralized water supply systems, as well as one smaller autonomous waterworks (the Bihać brewery). It is estimated that approximately 35-40% of the inhabitants in the area are not served by these systems and instead obtain drinking water from smaller local (rural) waterworks, individual wells or smaller tapped springs (e.g. Goginovac, Klenovac, and Žbukovac in B&H).

Table 7.4 Available and tapped (utilized for public water supply) groundwater reserves in the TBA at Una

$Q_{average}$ (m^3/s)	Tapped groundwater (m^3/s)	Ratio $Q_{available}/Q_{tapped}$ (%)	Q_{min} (m^3/s)	Tapped groundwater (m^3/s)	Ratio Q_{min}/Q_{tapped} (%)
34	0.685	2	5.81	0.685	11

The total amount of tapped groundwater within the TBA at Una (0.685 m^3/sec) represents about 2% of the combined average discharge, and about 11% of the combined minimum discharge of springs.

Unfortunately, no data was provided about groundwater consumption in the TBA at Una for uses other than public water supply.

7.1.4 Groundwater Quality and Protection

Generally, the chemical quality of karst groundwater in the TBA Una is good and does not require treatment according to current drinking water standards and regulations.

The main springs in the Bihać area in B&H (Klokot, Privilica, Ostrovica and Toplica) have occasionally exceeded drinking water standards for ammonia, NO_2 and HPO_4 in the past, whereas during the last few years the results of physical and chemical analyses of all tapped springs in the Bihać region have conformed to drinking water standards (the analyses are performed by the Public Health Institute in Bihać).

According to Džankić (2006)[9], the presence of microorganisms in each spring as an indicator of faecal pollution does not point to anthropogenic sources. However, numerous inadequate septic tanks in the catchment areas of the tapped karst springs, in both Croatia and B&H, indicate a possibility of microbiological contamination from these sources (Miošić, 2008)[10].

The problem of persistent organic pollutants (POPs) such as PCBs, explored during the EU project APOPSBAL, is reported in the Project Summary Report for some locations near springs and requires further investigation. This includes the presence of seven key PCBs in the sediments of the fishpond at Klokot 2 Spring near Bihać.

Sanitary protection zones of all major springs in B&H have been defined by appropriate studies, but there are no common bilateral criteria or law mechanisms yet for their full implementation and enforcement. Bilateral cooperation between B&H and Croatia were initiated regarding this issue (see Chapter 7.1.6. - *2. Absence of common criteria for delineation of the sanitary protection zones).*

7.1.5 Major Issues of Concern

The following major issues of concern in the TBA Una have been identified by the DIKTAS project team:

- Possible microbiological contamination of karst springs in the Bihać region (B&H) from both the Croatian and B&H sections of the TBA, because there is a lack of wastewater treatment;
- Possible contamination of karst springs in the Bihać region (B&H) with POPs, in particular by spills of PCBs from destroyed military installations including Željava Airport in the boundary area, and Udbina which is located in Croatia;
- Absence of a comprehensive groundwater monitoring program, including a necessary bilateral agreement;
- Absence of reliable data on groundwater consumption in rural areas without a centralized water supply;
- Lack of harmonised policy/regulation or common guidelines on hydrological and other technical criteria for delineation of transboundary water source protection zones and protection of karst springs used for public water supply.
- Lack of legal /regulatory frameworks for establishment and law enforcement in transboundary sanitary protection zones;
- Lack of a database on non-point and point sources of surface water and groundwater contamination (landfills, septic tanks, quarries, wastewater discharges, and others);
- No wastewater treatment (or inadequate wastewater treatment) in the area of concern which may impact the quality of groundwater used as a source of potable water;
- It should also be mentioned that in the TBAs there are also villages, towns and larger cities that are near the TBA areas that have impacts on the TBAs concerning socioeconomic and environmental issues. They are called 'Zones Of Impact' (ZOI) and a

[9] Study of anthropogenic pollution after the war and establishing the measures for protection of the Plitvice National Park and Bihać region at the border area of Croatia and Bosnia and Herzegovina, Final Report, 2003

[10] Groundwater flows connections and water supply in holokarst of the Lika and Bihać region, Croatia and Bosnia and Herzegovina, Herald Geological 37, Federal institute for geology, Sarajevo, 2008

total number of 12 was found. The largest is the city of Split (178,192 inhabitants according to the last census in 2011) and the smallest settlement is Gruda with 731 inhabitants. It is clear that larger cities have many impacts on the TBAs in various ways no matter how distant they are from them. Small cities depend on and gravitate to the TBAs. The total population in the ZOIs is 419,249 and it is clear that almost half a million inhabitants represent a important factor in projecting pressures on the TBAs as well as different environmental impacts and economic demands.
- The total number of inhabitants in the TBAs and in the ZOI is 505,142. As we can see, most of the population falls in the ZOI areas due to the fact that in ZOI areas larger cities are located along the coastline, while the TBAs have less inhabitants because of the bigger distance from the coastline, not yet developed tourism, and a karst environment that represent more difficult conditions for everyday life.
- It should be mentioned that the TBAs represent 'points of development' – in many cases, especially, for example, the TBAs at Krka and Una, where Parks of Nature (national parks) are located. A recent visit to the Park of Nature at Una discovered that in one season (currently only the second year of operation) the park had approximately 15,000 visitors. It is clear that the declaration of a certain area as 'a national park' brings a lot of visitors, gives employment opportunities for the local population and – in the longer run – changes the economic situation of the wider area. This is especially important due to the stagnant or/and negative demographic trends in Croatia. Many demographers in Croatia are even projecting the extinction of several hundred villages (or more) nationally that contain very small populations, usually below 100 inhabitants, meaning that in some cases in these remote villages there are only a few (older) inhabitants depending on the help of their relatives, family members or social services.

7.1.6 Proposed Activities

Priority activities proposed for addressing some of the major issues of concern listed in the previous section include:

- Establishment of a common groundwater monitoring program;
- Improvement of wastewater treatment (or inadequate waste water treatment) in the area of concern because it may impact on the quality of groundwater used as a source of potable water in the Bihać region (B&H);
- Harmonisation of hydrological and other technical criteria for delineation of water source protection zones;
- Definition of legal /regulatory frameworks for establishment and law enforcement in transboundary sanitary protection zones;
- Making alternative projections concerning the future water demands depending on the socio-economic issues emphasized earlier – i.e. the number of permanent inhabitants that is stagnant or even negative, the increase of the number of visitors to the Parks of Nature and national parks with an emphasis on the changeable nature of these pressures (peaks mostly in July and August), the potential that national parks and Parks of Nature offer in employment possibilities for locals, etc.

In continuation, relevant legal and policy responses for some of the above issues of concern in this TBA – Una, are proposed below:

1. No waste water treatment or inadequate waste water treatment in the area of concern which may impact the quality of groundwater used as source of the potable water

Water Laws in Republic of Croatia (RH) and Bosnia and Herzegovina (B&H) give the framework to limit or forbid the discharge of the wastewater into surface water or groundwater. Particularly, B&H Water laws (Federation of Bosnia and Herzegovina, FBH and Republic of Srpska, RS) stipulate that it is forbidden to discharge the wastewater into a natural lake, pond, swamps and other natural water reservoirs, which have permanent or temporary inflow or outflow into / out of surface water or groundwater. Also, waste water discharge directly into groundwater is prohibited. Croatian Water Law regulates the prohibition of discharge of pollutants into waters and prohibits other actions and behaviors that can cause pollution of the aquatic environment and the environment in general.

One of the operational goals of the FB&H Water management Strategy related to water protection is to decrease the pollution load from urban and industrial waste water systems and corresponding measures will include increasing of population coverage with public waste water system and construction of WWTP. Draft RS Strategy of integrated Water management up to 2024, put special emphasis on construction of sewage systems and waste water treatment Plants (WWTP) for agglomerations with population 5000 or more, i.e. on increasing the population coverage with the public waste water systems. This should also be applied for the smaller agglomerations, if proved to be necessary due to e.g. water source protection, protection of natural values e.t.c.. Strategy also put special emphasis on construction of WWTPs for bigger towns in RS but also for the settlements which affect accumulations and ecosystems.

In RH, according to the Croatian Water Management Strategy (WMS), the strategic goal of water protection is an intensive construction, repair, and reconstruction of urban wastewater sewerage and treatment systems, which threaten groundwater quality. The Water Management Strategy stipulates that the management of point pollution sources in the economy is based on respecting national and international standards for releasing wastewater in the environment. In that, particular emphasis is given to the Waste Water Management Plan, which has to be made by an economic subject. This management plan has to include the list of measures and activities in the case of exceptional and sudden pollutions.

So, both countries have sound legal framework for regulating waste water treatment, which enables that common criteria and conditions in transboundary areas are set for:

- regulating emissions from technological wastewater, before discharging into the construction of public sewage system or septic tanks,
- regulating emissions from the purified or non-purified wastewater discharged into the water;
- temporary permission of discharges above the prescribed amount and the emission threshold values (national or international);
- collection, treatment and discharge of urban waste water;
- exceptionally allowed discharges of pollutants into groundwater.

2. Absence of common criteria for delineation of the sanitary protection zones

In B&H sanitary protection zones are regulated by sub-laws (in FBF and RS). In FBH it is the "Regulation on the determination of conditions for determining the zones of the sanitary protection and protection measures for the sources used for public water supply. («Official Gazette F B&H», 2012). In RS it is the "Regulation on the protection measures, method of determining the sanitary protection zones, areas where water sources and water management structures exist, and areas where water is used by humans" («Official Gazette RS», No. 7/03). In RH the "Rulebook on conditions for establishing sanitary protection zones" ("Official Gazette of Croatia", No. 66/11) exists.

Although regulations in both countries define the protection of ground water in karstic areas and groundwater protection in countries is realized in accordance with the Decision on Spring Protection, there are many differences in: criteria for delineation of the sanitary protection zones and in criteria for setting the groundwater protection measures in particular zones.

In relation to the differences in methodology for delineation of sanitary protection zones in countries, it is quite clear that in cases when catchment areas of springs cross the state boundary there is a need to harmonize this methodology between countries. The solution might be that countries agree on applying one common rulebook or guidance, which will prescribe the common criteria for delineation of the sanitary protection zones.

In that regard, the concrete actions were made in 2010, when working group for elaboration of guidelines for defining water protection zones in karst areas, established by sub-commissions for Adriatic catchment area and Black See catchment area (see Chapter 5.6.2), has elaborated the "Proposal for the protection system and investigation methods for protection of karst aquifers located in the bordering areas of B&H and Croatia" ("the Proposal").

This Proposal includes, among other, the part of a Rulebook (Agreement) on determination of sanitary protection zones of the water sources located in the bordering areas of Croatia and B&H.

In December 2010 the meeting of the Commission for water management of Republic Croatia and Bosnia and Herzegovina was held. Some of the outcomes (conclusions) of the meeting were the following:

- Financial means have to be ensured for harmonising water sources protection for two springs (one in each Country) with "the Proposal".
- The Commission supports the application submission for EU funding of the projects for protection of karst water sources and other projects in the field of cross border cooperation in water management.
- The Commission considers that the following water sources in B&H and Croatia are the most feasible for the application for funding: spring Klokot in B&H and spring(s) Šimića Vrelo or Vukovića Vrelo in Croatia.

In relation to measures set in sanitary protection zones, it turned out that in practice, in both countries, many decisions on spring protection are unenforceable, in terms of ensuring cost-efficient protection measures in zones of sanitary protection. There is a strong need to define criteria how to select the most acceptable combination of economic measures for the protection and remediation of ground water, which would be based, inter alia, on the valuing of groundwater resources and assessment of environmental and resources costs in the catchment areas of springs.

Accordingly, the above mentioned Proposal have to be updated, in order to have the relationship with the Water Framework Directive and the Directive on the protection of groundwater against pollution and deterioration. It may include the possibility of application of economic criteria and the most acceptable combination of basic and supplementary measures in the sanitary protection zones. Measures to prevent the introduction of hazardous substances or measures to restrict the introduction of priority substances and other pollutants, taking into account the principle of "combined approach" and "best environmental practice", have to be properly defined in decisions on the zones of sanitary protection. Where possible, measures to prevent or limit input of pollutants from diffuse sources, such as agriculture, industrial agglomeration, and deposition of air pollutants or permeable sewage network should be taken into account. Furthermore, the possibility of exemptions from the application of measures to prevent or limit the entry of substances into groundwater should be foreseen, such as in cases of permitted discharges of small quantities of substances into groundwater (soil), which should be defined in accordance with the provisions of the WFD (e.g. for scientific investigations), as well as in cases where the input of pollutants are result of accidents or exceptional circumstances of natural cause.

3. Absence of common criteria for setting cost-efficient groundwater protection measures in transboundary areas in cases of development of industry or agriculture that may affect groundwater quality

For the TBA, an elaboration of basic and supplementary measures in specific rulebook or guidance is recommended, primarily through the identification of specific instruments of environmental protection (water) to address identified problems, such as various regulatory and economic instruments and institutional mechanisms. There is a need to adopt management plans for the lower order units within TBA, which would define the measures and activities specific to each sub-catchment area or even lower units, which could integrate on the level of the RBMPs.

According to the Water Framework Directive, for purposes of calculating the rate of cost recovery the economic costs need to be estimated, which include the financial costs (capital costs, operating and maintenance costs) and external environmental and water resources costs. Currently, principle of cost recovery is not fully implemented nor in HR and B&H regulations nor in water management practice as well. General principle of the application of the charges (fees) for the use and protection of water, in the way defined by the national Water Acts, is necessary to expand, taking into account the environmental and resources costs.

Specifically, there is a need to define the economic value of groundwater, especially in terms of evaluating the different functions of a (ground)water and groundwater dependent system environment. Hence, it may be necessary to carry out investigation of the economic costs in the

TBA to arrive at the first estimate of total economic costs, which will include estimated environmental and resource costs. Furthermore, there is a need to elaborate remediation measures of already present pollution in the underground.

There might be a need to estimate the possibility to establish more stringent threshold values in the relation to quality standards that are already prescribed in national regulations or EU regulations. If applicable, in identifying and testing the methodology for determining threshold values, it might be option to take into account the economic criteria which would indicate how the change of groundwater quality standard values affects the costs of implementing measures.

According to the WFD and GWD (and CIS guidelines: European Commission (2007): Guidance on Groundwater in Drinking Water Protected Areas, Guidance Document No 16. Technical Report - 2007 - 010. ISBN 978-92-79-06201-8. European Communities, Luxembourg; European Commission (2007) Guidance on groundwater monitoring, Guidance No. 15: Groundwater monitoring, ISBN 92-79-04558-X, European Communities, Luxembourg), monitoring of groundwater (parameter selection, location and sampling frequency) must be based primarily on the conceptual understanding of aquifer systems (including the definition of natural geological, hydrogeological features, and characteristics of (anthropogenic) pressures and the behaviour of pollution in the aquifer systems), within which the monitoring is carried out. In principle, these criteria should be followed in implementing the groundwater monitoring in TBA area.

Regarding future development in the region, for certain industrial activities (operation) with possible detrimental impacts on groundwater quality, a prior assessment of environmental impact (including the effects on the aquatic environment) may be provided, in order to ensure the realization of the precautionary principle in the early stages of planning the project.

7.2 The Transboundary Aquifer Trebišnjica

The Transboundary Aquifer (TBA) at Trebišnjica is shared by Croatia and B&H (Figure 7.3). The information available from various government agencies in the two countries used for the assessment of its general characteristics includes (1) long-term climate records by the hydro-meteorological Institutes of B&H and Croatia; (2) a basic geological map (scale 1:100,000) completed when the two countries were part of the former Yugoslavia (sheets Trebinje, Dubrovnik, Ston, and Kotor); (3) detailed geologic and hydrogeological maps at larger scales produced for various other purposes including design and construction of the hydropower system at Trebišnjica; and (4) data on numerous tracing tests performed as part of regional and local hydrogeological studies for different components of the hydropower system at Trebišnjica.

The data on groundwater utilization for industry and other major users including public water supply is mostly accurate.

There has been an increasing focus on delineation of sanitary protection zones for major sources of drinking water in recent years; however, a legal framework for establishing such zones at the transboundary level is still missing.

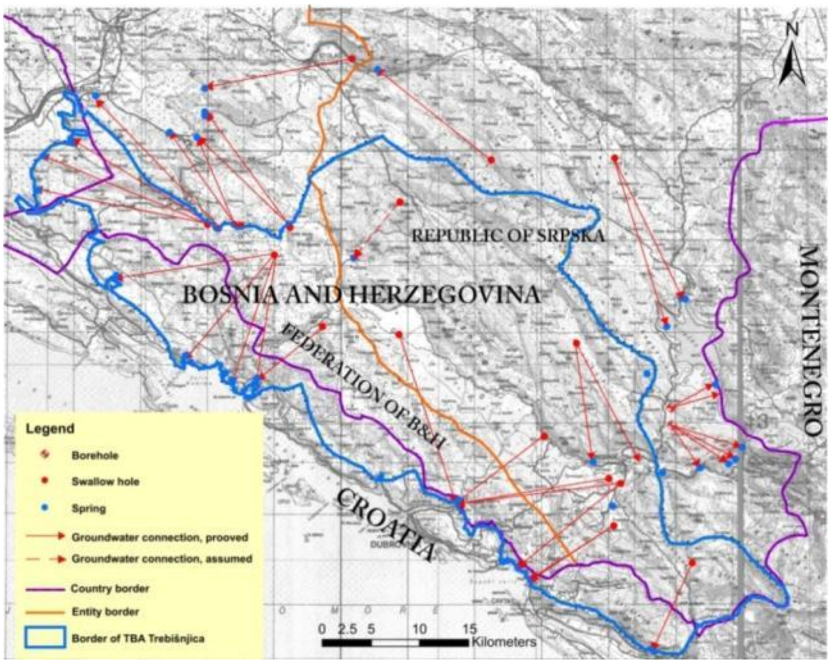


Figure 7.3 The Transboundary Aquifer at Trebišnjica shared by Croatia and B&H

The estimated total area of the TBA at Trebišnjica is 1,674 km^2 of which 77.8% (1,379 km^2) is karst terrain. The Croatian portion of the TBA is 340 km^2 (of which 92.6%, or 315 km^2 is in karst), and the B&H portion is 1,334 km^2 (90.7% or 1,210 km^2 in karst).

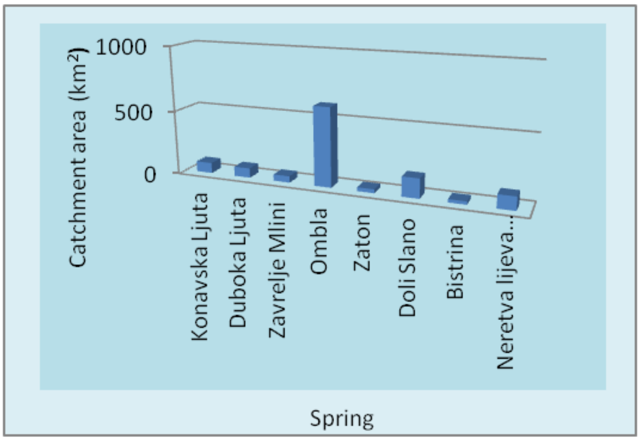


Figure 7.4. Catchment areas of major karst springs within the TBA at Trebišnjica

The TBA at Trebišnjica belongs to the direct Adriatic Sea basin as there are no major permanent surface streams flowing into the Adriatic Sea. Drainage areas of the major karst springs are: the Ombla spring 610 km^2; the Doli-Slano spring 243 km^2; the Konavska Ljuta 138 km^2; and springs on the left side of the River Neretva 156 km^2 (Slišković, 2012). The rest of the TBA at Trebišnjica belongs to the catchment areas of the following springs: Bistrina, Zaton, Zavrelje and Duboka Ljuta (Figure 7.4).

7.2.1 Climate and Hydrology

The average precipitation in the TBA area used for the water balance calculation is 1,900 mm/year. It is based on the precipitation maps developed by the hydro-meteorological institutes in Croatia and B&H. The average annual air temperature is about 16 °C.

Hydrological data on karst springs is of varying length and accuracy and needs to be updated and re-analysed in light of the new land use practices, as well as various issues related to climate change. A notable exception is the Ombla spring utilized for public water supply by the city of Dubrovnik. The spring's discharge rate and water quality parameters have been regularly monitored for decades.

The most important hydrological records are on the spring discharges in Croatia. The minimum spring discharges are presented in Table 7.5.

Table 7.5 Minimum discharge of major karst springs in the TBA at Trebišnjica

Spring	Country	Minimum discharge (m^3/s)
Konavska ljuta	Croatia	0.12
Duboka ljuta	Croatia	0.18
Zavrelje	Croatia	0.03
Ombla	Croatia	3.00
Zaton	Croatia	0.03
Spring on the left side of the River Neretva	Croatia	0.25

The most important surface stream is the River Trebišnjica. Downstream of Trebinje the river channel is covered with concrete and the aquifer recharge by water losses from what used to be the largest sinking stream in Europe is now all but eliminated. Notably, some of the former ponors (swallow holes) such as Doljašnica and Morašnica had a capacity of several m^3/s.

Before construction of the Gorica Dam and Reservoir, and of the hydro-technical tunnel for the hydroelectric power plant (HPP) Dubrovnik 1 (the tunnel intake is located upstream of the town of Trebinje), the average flow at the dam site was 88.5 m^3/s. Since the system completion the average flow through Trebinje is about 8.5 m^3/s and the remaining 80 m^3/s is diverted via the tunnel.

7.2.2 Hydrogeology

The TBA at Trebišnjica is formed primarily within limestones of the Jurassic and Cretaceous age, with a smaller contribution of areas underlain by the Triassic limestones and dolomites. All the limestones are intensely fractured and faulted and have a large infiltration capacity at the land surface that allows for rapid percolation of precipitation, the main mechanism of aquifer recharge. To a smaller degree the aquifer is also recharged by sinking streams as in the case of water losses from the Gorica Reservoir on the Trebišnjica River just upstream of Trebinje, and an occasional sinking of the Trebišnjica River in the swallow zone Pridvorički krak near Trebinje. Water losses have also been recorded along the hydro-technical tunnel for the hydro-power plant Dubrovnik.

Approximately 80% of the aquifer recharge zone is located in B&H. The groundwater flow directions are exclusively from B&H to Croatia as identified by numerous dye tracing tests performed by the mid 1980s. Table 7.6 shows the results of some of these tests for illustration purposes.

Table 7.6 Results of the dye tracing test crossing the state border between B&H and Croatia

Swallow hole	Date	Connection with spring	Distance	Virtual velocity of tracer (cm/s)
Geljev most	16.8.1956	Ombla	16.5	2.08
Kočela - Trebišnjica,	28.2.1972	Ombla	11.3	1.89
Poljice - Mlinica	25.2.1952	Ombla	18.0	6.7
Pridvorci	29.7.1956	Ombla	16.25	3.2
Pridvorci	28.3.196?	Ombla	16.25	6.45
		Zavrelje	12.7	5.78
Bitomišlje - Češljari	1.2.1972	Slano	8.7	0.98
Trap - Mokro polje	2.2.1972	Robinzon	11.0	4.7
Trnje – Mokro polje	25.2.1957	Robinzon	10.7	3.15
Bravenik - Zubci	3.12.1971	Konavoska ljuta	10.0	0.53
Provalija	23.3.1962	Budimska vrulja	-	-
Provalija	20.6.1958	Doli	16.6	1.5

The flow velocities range from 0.53 cm/sec (Bravenik-Konavoska ljuta) to 6.7 cm/sec (from the swallow hole Poljice to the Ombla spring). The most common groundwater velocities are in the range of 1-5 cm/sec.

Table 7.7 Characteristic flow rates of the major karst springs in the TBA at Trebišnjica.

Spring	Country	$Q_{min}/Q_{aver}/Q_{max}$ (m^3/s)
Konavska ljuta	Croatia	0.12/30.00
Duboka ljuta	Croatia	0.18/10.40

Zavrelje	Croatia	0.03/15.00
Ombla	Croatia	3.00/138.0
Zaton	Croatia	0.03/9.10

Discharge of the karst springs is characterised by highly variable flows. The characteristic flows of major karst springs are given in Table 7.7. The ratio between maximum and minimum spring discharge ranges from 45 (the Ombla spring) to more than 500 (the Zavrelje spring; see Figure 7.5).

There is regular monitoring of water quality performed by the Croatian water utilities at all the springs tapped for water supply, and an occasional groundwater quality monitoring within the national monitoring program in Croatia.

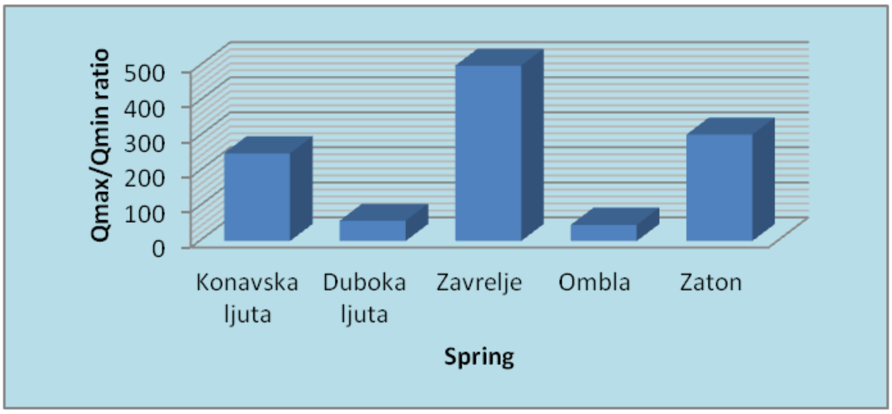


Figure 7.4 Ratio between maximum (Q_{max}) and minimum (Q_{min}) discharge of the major karst springs in the TBA at Trebišnjica

7.2.3 Groundwater Reserves and Their Utilization

Estimation of groundwater reserves within the TBA at Trebišnjica is performed in accordance with a water balance calculation methodology proposed by the Working Group Hydrogeology. The review of the methodology is provided in Chapter 3.

The available reserves of groundwater are about 25.4 m^3/s. The minimum recorded discharge of springs is assumed to correspond to the minimum ecologically acceptable flow. This value for the springs in Croatia is 5.20 m^3/sec (Table 7.8).

The tapped amount of groundwater for water supply in Croatia is currently 0.385 m^3/sec which represents only about 1.5% of the estimated available groundwater reserves and 7.4% of the combined minimal discharge of karst springs. The approved concession contracts are for the total of 2 m^3/sec, based on the projected significant increase in water usage in this important tourist area. This represents 39% of the available reserves.

Table 7.8 Available and tapped (utilized for public water supply) groundwater reserves in the TBA at Trebišnjica

$Q_{available}$ (m^3/s)	Tapped GW (m^3/s)	Ratio Q_{avail}/Q_{tapped} (%)	Q_{min} (m^3/s)	Tapped GW (m^3/s)	Ratio Q_{min}/Q_{tapped} (%)
25.4	0.385 (2*)	1.52 (7.9*)	5.20	0.385 (2*)	7.4 (38.5*)

*Permitted by concession contracts

Hydro-system Trebišnjica

The Eastern Herzegovina is one of the most karstified regions worldwide. Sinking rivers, underground flows, temporary flooded karst poljes and lack of arable land are the main properties of region. The main flows Trebišnjica, Zalomka and Bregava are sinking rivers. Only agricultural land Dubrave area and karst poljes (about 24,690 hectares), are surrounded by desertous bare rock. In natural conditions a large portion of this land is temporarily flooded with limited possibility to be cultivated. Sowing and harvest are not determined by man, but by water. Since time immemorial, the people of this region have had to cope with two kinds of misfortune: flood and drought. For centuries people have emigrated from this region in searching of a better life. The population density per km2 varies from 29 to 21. The only natural resource of importance for the regional socio-economic development is water. However, distribution of precipitation is uneven during the year. Outflow toward the erosion bases (Adriatic Sea and Neretva valley) occurred only through the huge underground karst channels. In natural conditions only about 145 m3/s, of a total 367 m3/s, of annual precipitation, can be controlled at the surface. Appropriate modification of surface and groundwater regime was a key, and only, requirement for regional economic development. Successful solutions require serious and complex investigations and close cooperation of a wide spectrum of scientists and engineers.

It was clear that this can be done only by constructing of an integral "Reclamation and Hydropower System in Eastern Herzegovina" (document accepted 1960). From the very beginning project was strongly supported by people from all Eastern Herzegovina communities and government. Trebišnjica River, the largest sinking river in Europe constitutes the backbone of entire project. It is one of the most complex projects situated in any karst region of the world. Seven dams, six reservoirs, six tunnels and four channels provide variety of uses of the water, which flows from an elevation of 1000 m a.s.l. to the sea level. All structures are situated in Herzegovina except Power Plant Dubrovnik (Croatia) and 18% of Bileća Reservoir (Montenegro). The most important structures are the Grančarevo Dam (123 m high) and Bileća Reservoir (1.28 bill. m3). All structures have been designed in such a manner that can be used for: food production, water supply, flood reduction, hydropower production, industry, fish farming, recreation, prevention of deforestation and number of secondary benefits. Once completed the System enables irrigation of about 240 km2 of arable land and average annual hydropower output of 856.2 GWh. Such modification of water regime provokes some environmental impacts. An important issue was how to keep the balance between the necessity for development of

Eastern Herzegovina and preservation of complex karst environment, including important cultural and historical monuments and natural rarities. The majority of impacts are foreseen and mitigated by appropriate designs. Some of impacts were unpredictable, however its influence is negligible comparing by positive impacts.

From the very beginning of this major project, one of the crucial questions was a possible impact to the water regime at springs along the sea coast and Neretva valley, including some specific issues (operation of a commercial oyster and mollusc farm, cooling of sea water and similar). To avoid possible conflicts, and to provide the sustainable and peaceful management of transboundary waters the designers undertook a series of long-lasting and complex investigation programs with close cooperation of a wide spectrum of scientist and engineers: geologists, hydrologists, chemists, civil engineers, biologists, archaeologists, seismologists and others. For instance, before started construction of the System, 120 springs along the sea coast and the left bank of the Neretva River were catalogued (1960) and many of them selected for monitoring.

The large part of Hydro-System Trebišnjica is already for many years operational. After long years of pending, the construction of the project's final stage, so-called “Upper Horizons”, is currently under realisation. The Hydro-System Trebišnjica has become the internationally recognised paradigm for water resources development in karst areas as a key requirement for regional socio-economic development.

7.2.4 Groundwater Quality and Protection

Generally, the chemical quality of karst groundwater in the TBA at Trebišnjica is good and does not require treatment according to current drinking water regulations. [11]

An occasional increase in microbiological contaminants is successfully addressed by water treatment with chlorination. Such increases are commonly related to naturally occurring turbidity caused by a more intense rainfall. Naturally occurring saltwater intrusion is register at some springs such as Bistrina and Doli-Slano, and aquifer overexploitation has been indicated as a possible cause of saltwater intrusion at Doli-Slano (Slišković, 2012)[12].

Sanitary protection zones of some springs, such as the Ombla spring utilized for water supply for the city of Dubrovnik, have been defined by appropriate studies, but there are no common bilateral criteria or law mechanisms yet for their full implementation and enforcement. Bilateral

---

[11] The first hydrobiological analysis of water, taken from 39 localities in Eastern Herzegovina, has been done alreay in 1956. Resolving water resources conflict issues between the Trebišnjica Multipurpose Hydrosystem and spring consumers along a 100 km length of Adriatic Sea coast in Croatia and along 50 km of the Neretva River valley (Croatia and BiH) an inventory of springs and monitoring program began in 1960, means 8 years before the first power plants were operational. A total of 120 springs that could potentially be affected by construction were catalogued. Initially, 46 springs were selected for permanent monitoring and equipped with gauge stations. After two years, the number of monitoring springs was reduced to 26 and permanently monitored. In 1975 started systematic water sampling (twice per year) at the area of eastern Herzegovina and at 1983 was founded Laboratory for water quality as part of the Trebišnjica Multipurpose Hydrosystem. (P. Milanovic)

[12] Trebišnjica-Neretva river basin management plan, interim report, Elektroprojekt Zagreb and Water management Institute Bijeljina, Zagreb, 2011

cooperation between B&H and Croatia were initiated regarding this issue. (see Chapter 7.1.6. - *2. Absence of common criteria for delineation of the sanitary protection zones).*

7.2.5 Major Issues of Concern

The following major issues of concern in the TBA Trebišnjica have been identified by the DIKTAS project team.

- Absence of a comprehensive groundwater monitoring program, including a necessary bilateral agreement;
- Lack of harmonised policy/regulation or common guidelines on hydrological and other technical criteria for delineation of transboundary water source protection zones and protection of karst springs used for public water supply in Croatia.
- Lack of legal /regulatory frameworks for establishment and law enforcement in transboundary sanitary protection zones; (used for public water supply in Croatia.)
- Lack of a database on non-point and point sources of surface water and groundwater contamination (landfills, septic tanks, quarries, wastewater discharges, and others).
- Lack of precise statistics on the economic activities in the catchment area that are dependent on the water reserves in Croatia. Agricultural activities are mostly concentrated in the Konavle municipality where the fields are used mostly for vineyards and growing vegetables.
- It should be calculated that the need for water will be increasing due to development of tourism in this area in the Croatian part of the catchment area. Also, the fact that sanitary outflow is mostly unregulated (usually septic tanks that allow discharge in the ground) should be taken into account.

Besides the above-mentioned problems, the planned project 'HPP Dabar' which foresees construction of a hydro-power plant (HPP) in the upper part of the Trebišnjica catchment is considered as an issue of concern by some stakeholders. There are discussions that it might influence the water regime in the TBAs at Neretva and Trebišnjica, affecting surface and groundwater, as well as water economy and biodiversity of the lower part of the River Neretva and a coastal part of the Adriatic Sea in Croatia.

The planned project is located in RS territory, so RS has elaborated the Environmental Impact Assessment study of HPP at the River Trebišnjica and issued an environmental permit, but an agreement at the inter-entity level (B&H and RS) on this issue has not yet been reached. Also, the communication between B&H and Croatia has not resulted in any concrete conclusions regarding this issue.

It is expected that some of the above issues of concern will be elaborated by B&H's and Croatia's on-going common project 'Managing of Neretva and Trebišnjica rivers' (see Chapter 3.4.2.2.) which will result, among other, in the Neretva and Trebišnjica river basin management plans.

7.2.6 Proposed Activities

Priority activities proposed for addressing some of the major issues of concern listed in the previous section include:

- Establishment of a common groundwater monitoring program;

- Introduction of efficient waste management in the region;
- Harmonisation of hydrological and other technical criteria for delineation of water source protection zones;
- Definition of legal /regulatory frameworks for establishment and law enforcement in transboundary sanitary protection zones;
- Inventory of non-point and point sources of pollution (landfills, septic tanks, quarries, wastewater discharges, and others);
- Establishment of regulations between the countries which will set up regulatory frameworks concerning the discharge of wastewaters into the land stressing the importance of a unified policy for, for example, 'sewerage policy' (i.e. the law and regulations that every septic tank should be properly treated when full through the usual practice).

Legal and policy responses for some of the above issues of concern in this TBA – Trebišnjica, were already described within Chapter 7.1.6., under points 2 and 3 *(2.Absence of common criteria for delineation of the sanitary protection zones and 3.Absence of common criteria for setting cost-efficient measures for groundwater protection in karst areas*). Consequently, those responses apply to this TBA – Trebišnjica, as well. However, in this TBA, the absence of efficient waste management is also considered as an issue of concern , so the following relevant legal and policy response is presented as following:

- Absence of efficient waste management in the region and lack of relevant data on potential landfills impact on groundwater

One of the operational goals of the Water management Strategy in B&H is related to water protection is to decrease pollution of surface and ground waters from dumping sites and measures will include removal of dumping sites and construction of environmentally sound landfills.

In Croatia, the management of waste is carried out on all levels of administration (national, regional, local) and in all economic areas. According to the Plan of Waste Management in the Republic of Croatia for the period 2007-2015, the reconstruction of black points and waste dumps is planned and building of the Centres for Waste Management, according to European standards, is progressing.

The real problems in the management of transboundary aquifers in TBA can be expected in the future, due to eventual economic growth in the region. Karst groundwaters in TBA, which are extremely sensitive to any contamination from the surface, have to be comprehensively analyzed to determine possible contamination which originates by illegal dumping or inadequate waste management practice (e.g. landfills). It has to be ensured by agreed (e.g. legal or economic) instruments (approved by countries) that contaminated groundwater in transboundary aquifers will be cleaned up in cases of proven contamination by these sources of contamination.

7.3 The Transboundary Aquifer Neretva

The Transboundary Aquifer at Neretva in the basin of the Neretva River's right bank is shared by Croatia and B&H (Figure 7.5).

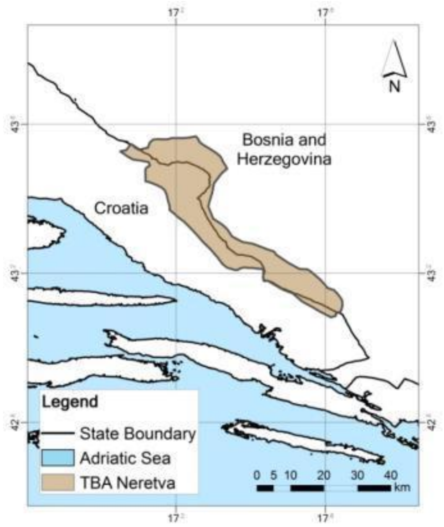


Figure 7.5 The Transboundary Aquifer at Neretva shared by Croatia and B&H

The boundaries of the aquifer are relatively well defined based on data from regional investigations that have been conducted for a number of years in this area, as well as numerous data from detailed investigations carried out for different purposes. The basic geological data and structural-tectonic relations are shown on the Basic Geological Map of Former Yugoslavia (sheets Imotski, Ploče and Metković) at the scale 1:100,000. Climate elements for this area are defined on the basis of long-term measurements carried out by the Meteorological and Hydrological Services of Croatia and B&H covering the entire area in both countries. The spatial distribution of the meteorological stations fully satisfies the needs for definition of average values of basic climate elements. There are, however, some problems related to analyses of climate elements for longer time periods and determination of potential indications of climate changes due to a lack of data for some meteorological stations in the period from 1990 to 2000 as a consequence of war and post-war events in parts of Croatia and B&H.

The majority of data on spring yields is from the period before 1990. This data generally consists of minimum and maximum spring discharge based on estimates made during different investigation works and a relatively small number of occasional measurements at springs. The majority of spring yield estimates were made based on watercourse discharge measurements in the vicinity of the springs. In the post-war period, measurements have been carried out at a relatively small number of springs.

There is no monitoring of groundwater level fluctuations in the area of this transboundary aquifer and only two springs in the territory of Croatia are included in the national groundwater quality monitoring network.

There is reliable data on water use for public water supply of the population and a part of industry. Data for technological water consumption unrelated to public water supply is somewhat less reliable due to the fact that not all users are registered.

There are no accurate records on the water use for agricultural purposes.

The estimated surface of the TBA at Neretva is 638 km^2, of which 354 km^2 (55.5 %) is located in B&H and 284 km^2 in Croatia.

The total surface of the karstic part of the terrain in both countries equals 523 km^2 (81.97 %). In the territory of B&H the karst covers 83.61 % of its surface (296 km^2), and in Croatia 79.93 % (227 km^2).

With respect to large karst springs, the north-western part of the TBA belongs to the basin of the spring Opačac near the town of Imotski, while the south-eastern part belongs to the basin of the Prud spring (source of the River Norin) near the town of Metković.

7.3.1 Climate and Hydrology

The values of basic climate parameters for precipitation and temperature for both countries are the official data of the meteorological and hydrological services of Croatia and B&H, and are based on long-term records.

The average precipitation values used for the calculation of the water balance are based on the measurement period from 1961 to 1991, and equal 1,500 mm/year for B&H and 1,600 mm/year for Croatia.

The average annual temperature in the part of the TBA that belongs to Bosnia and Herzegovina is not known whereas in the Croatian part it is 13.6 ^{0}C.

The River Vrljika plays a very important role in the TBA water balance because it drains not only the main springs in the north-western part of the Imotsko-bekijsko polje, but also numerous smaller springs on the northern edge of the polje, after which it sinks in the polje's south-eastern part.

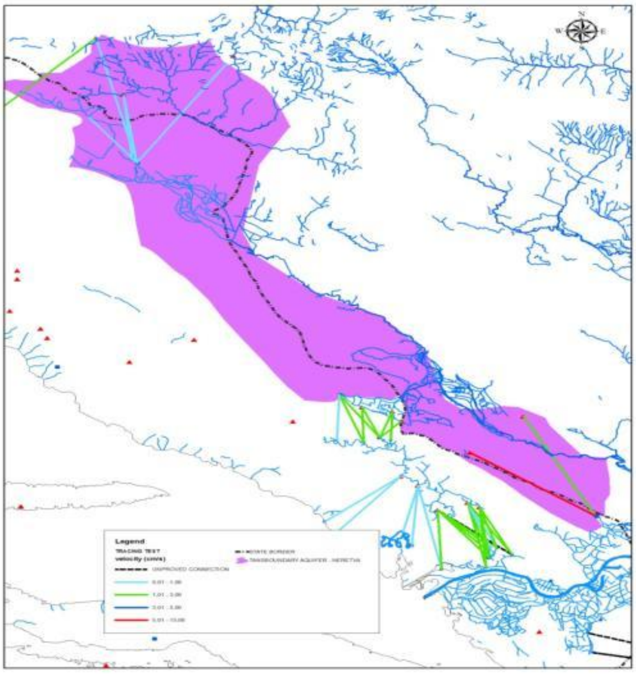


Figure 7.6 Tracing tests within the TBA at Neretva

A small amount of this water reappears on the northern edge of the Vrgoračko Polje and eventually ends in the Baćinska Lakes, whereas the majority of water reappears in the Tihaljina River after travelling several kilometres in the subsurface. In the Ljubuško polje, after the confluences with its tributaries, the Tihaljina forms the River Trebižat, a tributary of the River

Neretva. A part of the Trebižat water sinks in the territory of B&H along the stretch from the south-eastern edge of Ljubuško polje to the waterfall at Kravica, and reappears in the Croatian territory at the Prud Spring, where it forms the River Norin - a tributary of the Neretva.

7.3.2 Hydrogeology

In the recharge area of karst springs in the northern part of Imotsko Polje, the TBA is formed predominantly within limestones, thoroughly karstified deposits of the Cretaceous age. The aquifer outcrops at about 80 % of the land surface area while the rest is built from impermeable flysch deposits of the Eocene age and poorly permeable deposits of the Miocene age overlying the Cretaceous limestones. The thickness of these deposits is relatively small and does not present a barrier to karst groundwater flow. The general direction of groundwater flow in this area is along the neotectonically active fault and fissure systems, from B&H to Croatia.

Water from the north-western part of the Imotsko Polje flows as surface water (the River Vrljika and its tributaries) to directly beyond the border between Croatia and B&H, where it sinks. After about 3.5 km, this water reappears as the River Tihaljina, which, after flowing into the Ljubuško Polje and being joined by its tributaries, forms the watercourse Trebižat. In this part of the basin, groundwater mostly flows parallel to the structures in the northwest-southeast direction.

After the Ljubuško Polje, a part of the Trebižat water sinks along the river bed stretch to the waterfall at Kravica and flows, perpendicular to the main geologic structures, towards the Prud spring (source of the River Norin, which is a tributary of the River Neretva). The water from the area south of the Ljubuško polje flows parallel to the geologic structure in the south-east direction towards the Prud spring.

The directions and velocities of groundwater flow are determined based on tracing tests that were implemented as part of various projects. In general, the velocities of groundwater in the north-western part of the TBA are lower (< 1 cm/s) than those in the south-eastern part of the aquifer.

A special characteristic of the TBA at Neretva is the fact that velocities of groundwater flowing in the direction perpendicular to the geologic structures are significantly lower than those in the direction parallel to the direction of the structures, which has to be taken into consideration when planning and implementing groundwater protection measures.

The measurements of spring yields in the area of the TBA at Neretva are carried out at two main springs (see Table 7.9): the Opačac spring (source of the River Vrljika in Imotsko Polje), and the Prud spring (source of the River Norin).

Table 7.9 Characteristic flows of the major karst springs in the TBA at Neretva

Spring	Country	$Q_{min}/Q_{aver}/Q_{max}$ (m^3/s)
Opačac	Croatia	1.2/8.38/28
Prud	Croatia	2.47/6/11

Measurements at other numerous springs are not carried out, and data on estimated minimum spring discharges is unreliable.

The discharge regime of all springs is typically karstic, with a large difference between spring yields in dry and wet periods. This difference is only slightly smaller for the Prud spring, which is due to the fact that the majority of its recharge comes from the water sinking in the riverbed of the River Trebižat.

There is no organized monitoring of groundwater level fluctuations in the area of this TBA, whereas the water quality is monitored only at the Opačac and Prud springs as a part of the national water quality monitoring.

7.3.3 Groundwater Reserves and Their Utilization

The available groundwater reserves are approximately 11 m^3/s. The ecologically acceptable minimum flow is taken as the minimum spring discharge. Its combined value for the TBA springs is a total of 3.82 m^3/s.

The tapped amount of groundwater for water supply in Croatia is 0.43 m^3/s (Table 7.9). This represents about 2% of the groundwater reserves considering the combined average spring discharge of all springs, and about 11% of the combined minimum spring discharges. The maximum permitted amount under the current concession contracts is 0.63 m^3/s. There is no registered use of tapped groundwater in B&H.

Table 7.10 Available and tapped (utilized for public water supply) groundwater reserves in the TBA at Neretva

Q_{aver} (m^3/s)	Tapped groundwater (m^3/s)	Ratio Q_{avail}/Q_{tapped}	Q_{min} (m^3/s)	Tapped groundwater (m^3/s)	Ratio Q_{min}/Q_{tapped} (%
11	0.43	3.9	3.82	0.43	11.25

The data on the use of tapped water refers to public water supply, which includes water supply of households and water utilized by industry. Groundwater is abstracted from the Opačac spring (0.2 m^3/s, concession contract 0.25 m^3/s) and the Prud spring (0.23 m^3/s, concession contract 0.38 m^3/s). The water from the Opačac spring is the mainstay for the water supply system of Imotska krajina, roughly the area within the TBA, where no significant increase in water demand is expected in the future. The Prud spring is the only abstraction site of the regional water supply pipeline Neretva-Pelješac-Korčula-Lastovo-Mljet (Figure 7.8), which serves areas outside the TBA. In the Neretva River delta no significant increase in water demand is expected in the future, while in the areas of the Pelješac peninsula and of the islands of Korčula, Lastovo and Mljet, where tourism is being intensively developed, significant increases in water demand are expected, likely above the quantities permitted by current concessions.

In the area of the TBA at Neretva, water is neither used nor planned to be used for hydropower generation.

In the areas of the Imotsko polje and the Ljubuško polje, very small quantities of water are used for irrigation, mostly by individual farmers. There are plans for construction of irrigation systems in both poljes. In the area of the Neretva delta, the existing irrigation and its planned extension are based on the use of water from the River Neretva and irrigation canals.

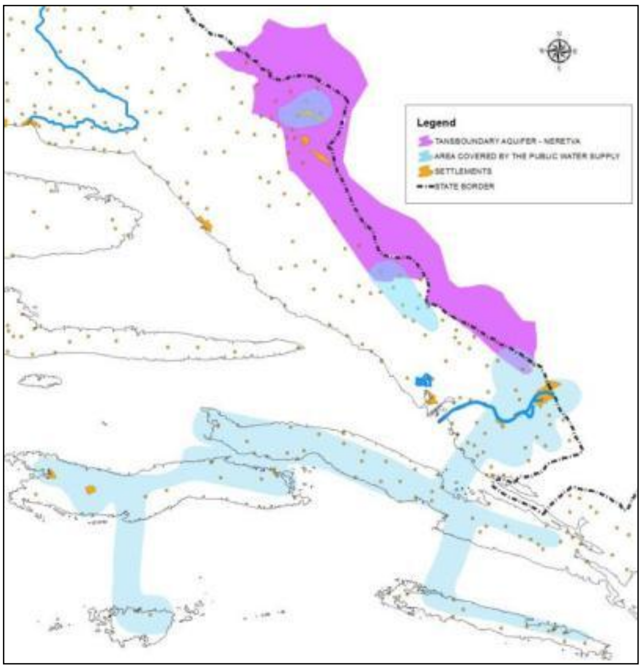


Figure 7.7 Areas (in blue) served by public water supply systems

7.3.4 Groundwater Quality and Protection

Groundwater quality in the area of the TBA at Neretva is very good, while its chemical composition fulfils the criteria for safe drinking water. The only exception is the Prud spring, with a continuing presence of elevated sulphate concentrations that occurs naturally.

Microbiological pollution occurs, as is typical in karst, during intense rain periods, particularly if preceded by longer dry periods.

Studies with proposals for delineation of sanitary protection zones of the abstraction sites Opačac and Prud have been completed; however, decisions on the protection zones and protection measures have been adopted and implemented only in the territory of Croatia.

In the framework of bilateral cooperation between B&H and Croatia in the area of water management, concrete cooperation in the field of groundwater protection, which would include a joint definition and proclamation of protection zones for drinking water abstraction sites, has been initiated (see Chapter 7.1.6. - *2. Absence of common criteria for delineation of the sanitary protection zones).*

7.3.5 Major Issues of Concern

The following major issues of concern in the TBA at Neretva have been identified by the DIKTAS project team:

- There is a possibility of contamination of the Prud spring by nitrates, pesticides and phosphates as a result of agriculture activities in the Ljubuško polje.
- There is a possibility of contamination of the Prud spring due to the inadequate wastewater collection and treatment system of the town of Ljubuški.
- Lack of harmonised policy/regulation or common guidelines on hydrological and other technical criteria for delineation of transboundary water source protection zones and protection of karst springs used for public water supply.
- Lack of legal /regulatory frameworks for establishment and law enforcement in transboundary sanitary protection zones;
- In the Neretva delta area, use of many or illegal types of pesticides and fertilizers is usual practice, according to rumours but no evidences are found. Nevertheless, more extensive control is recomended. Illegal or semi-legal practices of the 'use' of the whole region that is often called 'a little California' due to its potential is actually endangering the area in the long run. Biodiversity has been endangered in the whole delta area that is registered as a Ramsar site, due to salinization (the sea enters the Neretva estuary region and comes close to the city of Metković, ca. 20 km upstream), excessive use of land for agriculture, etc.

7.3.6 Proposed Activities

Priority activities proposed for addressing some of the major issues of concern listed in the previous section include

- Establishment of a common groundwater monitoring program;
- Harmonisation of hydrological and other technical criteria for delineation of water source protection zones;
- Definition of legal /regulatory frameworks for establishment and law enforcement in transboundary sanitary protection zones;
- Fostering better control of the current agricultural and similar practices;
- Opening up alternative types of development that will be based more on tourism, short-term visits and on local attractions (e.g. photo safaris, bird watching, experience with small streams, local vegetation and animals, local cuisine, etc.).

Legal and policy responses for some of the above issues of concern in this TBA - Neretva were already described within Chapter 7.1.6., under points 1, 2 and 3 (1. *No waste water treatment or inadequate waste water treatment) in the area of concern which may impact the quality of groundwater used as source of the potable water,* 2. *Absence of common criteria for delineation of the sanitary protection zones 3. Absence of common criteria for setting cost-efficient measures for groundwater protection in karst areas*) and within Chapter 7.2.6. uder point 4 *(Absence of efficient waste management in the region and lack of relevant data on potential landfills impact on groundwater)*. Consequently, those responses apply to this TBA – Neretva as well.

In addition to the elaboration made in Chapter 7.2.6. regarding responses to the issue of absence of efficient waste management, for this TBA – Neretva specifically, it should be stressed that current problems are connected with the impacts of the four larger settlements and smaller settlements in the region due to the outdated facilities with inadequate wastewater treatment and uncontrolled solid waste deposits. Due to the fact that this TBA is characterized by the high aquifer vulnerability and significant potential impacts from uncontrolled waste dumping, the cost-efficient measures may be envisaged to assure adequate groundwater quality.

7.4 The Transboundary Aquifer at Cetina

The Transboundary Aquifer at Cetina is intersected by the international border between B&H and Croatia (Figure 7.8). It includes a major part of the Cetina river basin and belongs to the Adriatic basin.

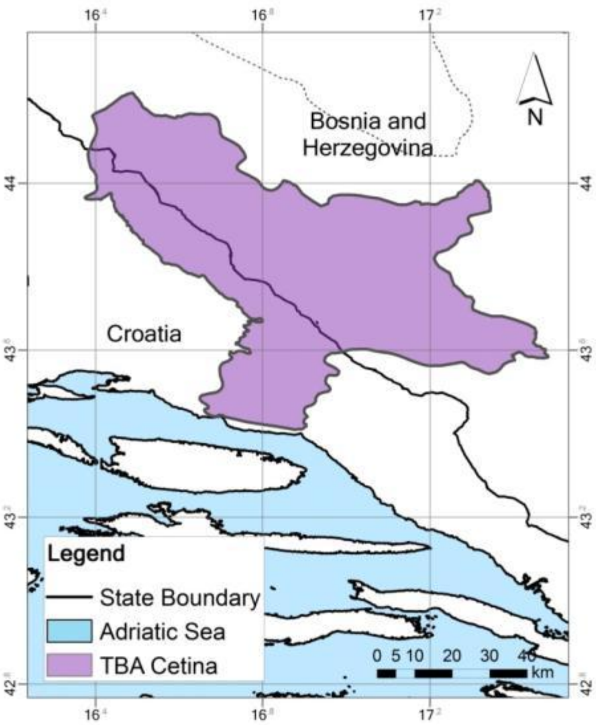


Figure 7.8 The Transboundary Aquifer at Cetina shared by Croatia and B&H

The boundaries of the aquifer are relatively well defined based on data from regional investigations which have been conducted for a number of years, and numerous data from detailed investigations carried out for the purposes of utilization of waters of the Cetina river basin for power generation. The basic geological data and structural-tectonic relations are shown on the Basic Geological Map of Former Yugoslavia (sheets Imotski, Ploče and Metković) at the scale of 1:100,000.

There is reliable data on water use for public water supply of the population and a part of industry. Data for technological water consumption unrelated to public water supply are somewhat less reliable due to the fact that not all the users are registered.

There are no accurate records on the water use for agricultural purposes.

The estimated surface of the TBA at Cetina is 3,454 km^2, of which 2,462 km^2 (71.3 %) are located in B&H and 992 km^2 in Croatia.

The total surface of the karstic part of the terrain in both countries is 2,519 km^2 (72.93 %). In the territory of B&H the karst covers 63.65 % of its surface (1,567 km^2), and in Croatia 95.97 % (952 km^2).

7.4.1 Climate and Hydrology

Climate elements for this area are defined on the basis of long-term measurements carried out by the meteorological and hydrological services of Croatia and B&H covering the entire area in both countries. The spatial distribution of the meteorological stations fully satisfies the needs for definition of average values of basic climate elements. There are, however, some problems related to analyses of climate elements for longer time periods and determination of potential indications of climate changes due to a lack of data for some meteorological stations in the period from 1990 to 2000 as a consequence of war and post-war events in parts of Croatia and B&H.

The average precipitation values used for the calculation of the water balance are based on the measurement period from 1961 to 1991, and are 1,250 mm/year for B&H and 1,580 mm/year for Croatia.

The average annual temperature in the part of the TBA that belongs to B&H is not known whereas in the Croatian part it is 11.8 ^{0}C.

7.4.2 Hydrogeology

Very complex hydrogeological relations in the TBA at Cetina are caused by the spatial position of permeable carbonate deposits and impermeable deposits of the Neogene age. The TBA at Cetina can be generally divided into two portions: (1) the entire part of the TBA in B&H including an area from the Cetina source to the southern end of the Sinjsko polje in Croatia where both permeable and impermeable deposits are present, and (2) the portion south of the Sinjsko polje in Croatia which is built entirely from carbonate deposits.

Most of the groundwater is located in the northern, larger part of the TBA at Cetina and flows from the morphologically highest terrain towards the lowest erosion base in the Sinjsko Polje. Along its flow path, the groundwater encounters barriers built of Neogene deposits in several places where it flows out to the surface, and then flows over impermeable deposits as surface water and again sinks at the edges of the polje. Some of the water bypasses the barriers and flows out at springs on the north-eastern edge of the Sinjsko polje. There are five levels at which groundwater flows to the surface, and these are the following karst poljes: the Kupreško polje – about 1,125 m above sea level (a.s.l.), the Šuičko polje – about 915 m a.s.l., the Glamočko polje and the Duvanjsko polje – about 860 m a.s.l., the Livanjsko Polje and Buško Blato – about 700 m a.s.l. and the Sinjsko polje – about 300 m a.s.l.

In the southern part, the River Cetina flows as a ‘hanging’ river, with groundwater flowing below it in the direction of the Adriatic Sea and coming to the surface on contact with permeable carbonate deposits and impermeable flysch deposits.

The TBA at Cetina is built mostly within limestones, but also for a minor part within dolomites of the predominantly Cretaceous and some of the Jurassic age.

The limestones are mostly well fragmented and karstified, directly exposed at the land surface or with a very thin cover, thus facilitating very high infiltration of precipitation.

The aquifer is recharged in two ways – through concentrated sinking of water in sinkholes and through dispersed infiltration of precipitation. Very frequently, the same water appears at springs with different elevations. The majority of the TBA at the Cetina recharge zone is located in the territory of B&H.

The conceptual model of groundwater flow in the TBA at Cetina is defined on the basis of hydrogeological characteristics of the terrain and the results of numerous tracer tests. Tracings were carried out over a long time period by application of different tracers and different methods of detecting tracer appearance. This resulted in a relatively large number of unreliable and illogical connections that were used by different authors to define the boundaries of the Cetina river basin. Within the DIKTAS project, an analysis of all the conducted tracer tests was carried out (Figure 7.9) and used to define the boundaries of the TBA at Cetina.

The conceptual flow model for the area of groundwater discharge at the Sinjsko Polje level, from the Cetina spring to the southern edge of the Sinjsko polje, is relatively well defined. The zone of the Cetina spring is recharged by way of direct groundwater inflows from the territory of B&H. The situation in the remaining area is much more complex. Groundwater from the highest parts of the terrain and the southern part of the Kupreško polje (1,125 m a.s.l.) sinks along the southern edge of the polje and reappears in the Šuičko polje (915 m a.s.l.). After a short flow, the River Šuica sinks and then reappears in the Duvanjsko polje (860 m a.s.l.). After flowing through the field, where it also collects water from the surrounding areas, it sinks and reappears in the southern part of the Livanjsko polje, the Buško blato (700 m a.s.l.). The water from the southern part of the Glamočko polje (860 m a.s.l.) sinks in the southern part of the field and reappears in the central part of the Livanjsko polje.

In the southern part of the Livanjsko polje, the Buško blato, a reservoir with a capacity of 831×10^6 m^3 was constructed, in which the water from the southern part of the field is collected and transported through hydrotechnical tunnels to the hydroelectric power plant Orlovac located at the edge of the Sinjsko polje (about 300 m a.s.l.). Long-term analyses of water inflow into the reservoir at Buško blato have revealed an average annual loss of 10 m^3/s from the reservoir, which flows underground towards springs on the left bank of the River Cetina and towards the southern part of the TBA. The remaining water from the Livanjsko polje sinks in numerous sinkholes in the western part of the polje and reappears at many springs on the left bank of the River Cetina.

In the area south of the Sinjsko polje, the Cetina flows as a 'hanging' river, where the main transport of water occurs below the river bed. This groundwater generally flows in the direction of the Adriatic Sea and discharges at the contact of carbonate and flysch deposits. The tracing of the edge of the reservoir at Prančević revealed that a part of this water flows towards the Jadro spring near Split.

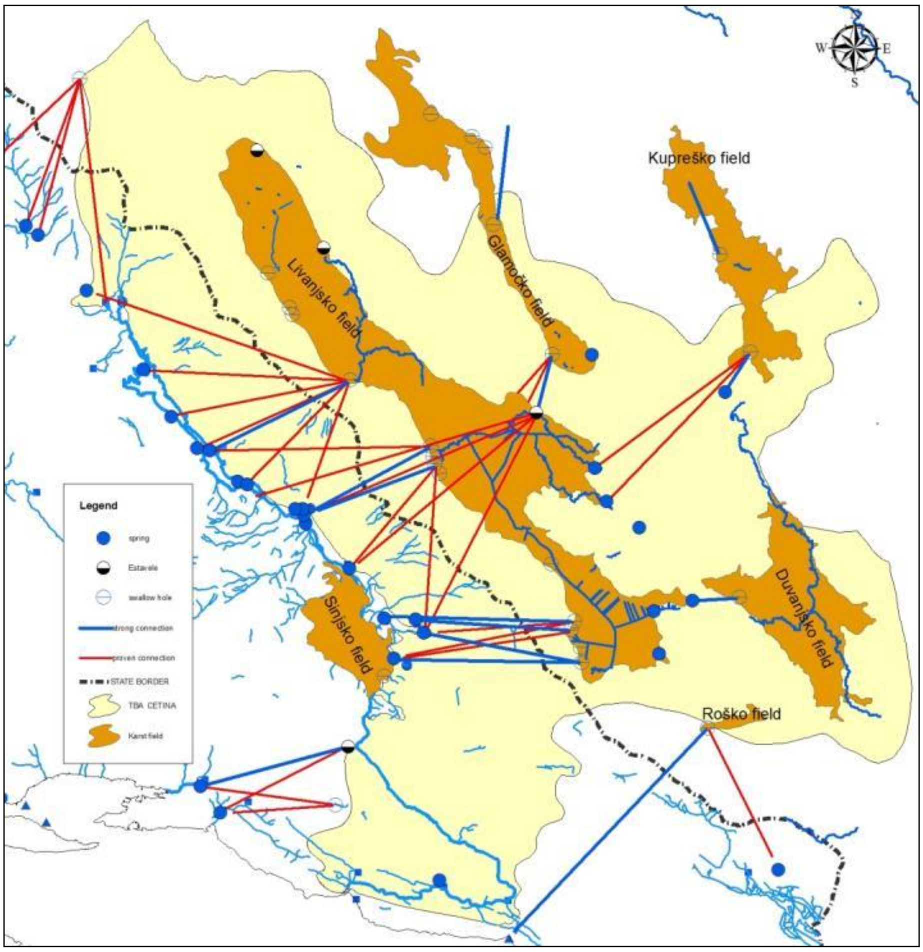


Figure 7.9 Tracing tests within the TBA at Cetina

Groundwater flow directions within the TBA at Cetina are exclusively from B&H to Croatia.

The minimum, average and maximum discharge rates of the main springs are shown in Table 7.11.

The majority of data on spring yields is from the period before 1990. This data generally consists of minimum and maximum spring yields estimated during different investigative work and of a relatively small number of occasional measurements at the springs. The majority of spring yield estimates were made based on watercourse discharge measurements in the vicinity of the springs. In the post-war period, measurements have been carried out at a very small number of springs. Only three springs in the territory of Croatia are included in the national groundwater quality monitoring network.

Spring discharges are characterized by a non-uniform regime. The relation between maximum and minimum discharges at springs in B&H range from 10.5 (Sturba) to > 1,000 (Ričina), and in Croatia from 8.8 (Ovrlja) to more than 750 (Veliki Rumin).

Table 7.11 Characteristic flows of the major karst springs in the TBA at Cetina

Spring	Country	$Q_{min}/Q_{aver}/Q_{max}$ (m^3/s)
Duman	B&H	0.600/3.60/24.13
Žabljak	B&H	0.140/2.06/4.96
Sturba	B&H	0.9/4.48/9.50
V. Stržanj	B&H	0.11/2.29/-
M. Stržanj	B&H	
Volarica	B&H	
Ostrožac	B&H	0.04/0.21/-
Ričina	B&H	0/9/>60
Mali Rumin	Croatia	0.05/3.43/9
Veliki Rumin	Croatia	0.1/17.4/75
Ovrlja	Croatia	0.6/1.66/5.3
Mala Ruda	Croatia	0.2/3.1./17.2
Velika Ruda	Croatia	5/18.17/44
Grab	Croatia	1.3/5.22/25
Malin	Croatia	>0.01/-/-
Kosinac	Croatia	>0.10/-/-
Krenica	Croatia	>0.10/-/-
Studenac	Croatia	>0.10/-/-
Šilovka	Croatia	>0.10/-/-
Peruća	Croatia	>0.10/-/-
Dabar	Croatia	>0.10/-/-
Kreševo	Croatia	>0.10/-/-
Dragović	Croatia	>0.10/-/-
Preočko vrelo	Croatia	>0.10/-/-
Pećina	Croatia	>0.10/-/-
Vukovića vrelo	Croatia	>0.10/-/-
Milaševo vrelo	Croatia	>0.10/-/-
Suhi Rumin	Croatia	>0.10/-/-

In the area of the TBA at Cetina there is no organized monitoring of groundwater level fluctuations. Spring yields and water quality are measured only at those springs that are tapped for water supply. Groundwater quality in Croatia is monitored as part of the national monitoring at the springs Vukovića vrelo, Šilovka and Mala Ruda.

7.4.3 Groundwater Reserves and Their Utilization

The assessment of groundwater reserves within the TBA at Cetina was attempted by application of the water balance calculation methodology proposed by the DIKTAS Working Group 1 but this failed. The primary reason was the lack of data on the discharge regime of a large number of springs on the left bank of the Cetina River in Croatia. An additional problem was the failure to obtain data on the Buško blato Reservoir's water levels and water discharges from the reservoir through the hydrotechnical tunnels. The attempt at indirect monitoring of discharge by way of the monitoring of discharges of the River Cetina was not possible since the inflows from the right bank of the Cetina do not belong to the TBA at Cetina, and the reservoirs, primarily Peruća, directly influence the discharge of the Cetina River as well.

In general, the available groundwater reserves within the TBA at Cetina are very large in comparison to the current needs. The tapped amount of groundwater for water supply in B&H is 0.2 m^3/sec and about 0.27 m^3/sec (without tapped surface water from Cetina) in Croatia. The data on the utilization of tapped water relates to public water supply, which includes water supply to households and industry.

In addition to the public water supply within the boundaries of the TBA, which is not expected to increase significantly in the future, the water from the River Cetina is also tapped for water supply of the town of Makarska and the surrounding coastal areas including the islands of Brač and Hvar. As these are areas in which tourism is being intensely developed, a significant increase in water demand is expected in the future.

In the area of the TBA at Cetina, water is intensely used for hydropower generation, and virtually all potential water is utilized to its maximum. There are no plans for additional utilization of water for this purpose.

Relatively very little water is utilized for irrigation. The only significant irrigation is implemented in the Sinjsko polje on a surface of only 313 ha. Plans and irrigation projects for a significantly larger area are being developed.

7.4.4 Groundwater Quality and Protection

The groundwater quality in the area of the TBA at Cetina is very good and its chemical composition fulfils the criteria for safe drinking water. Microbiological pollution occurs at most springs, as is typical in the karst, during intense rain periods, particularly if preceded by longer dry periods.

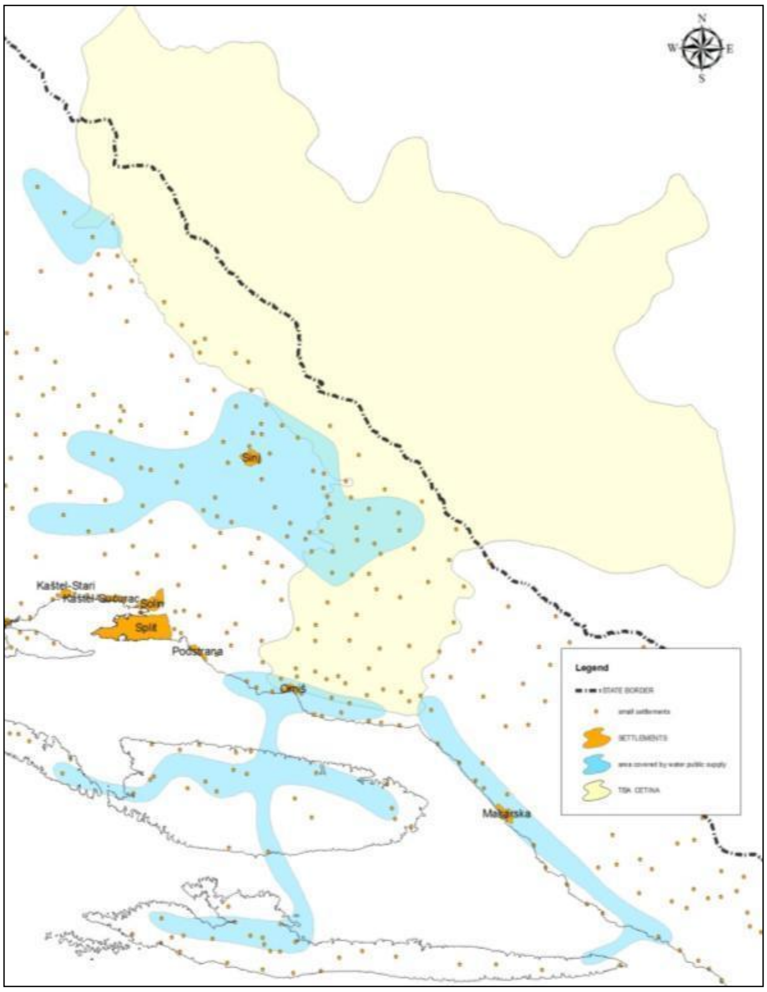


Figure 7.10 Areas (in blue) served by public water supply systems

Studies with proposals for sanitary protection zones at the abstraction sites used for public water supply in Croatia were developed according to the old, now invalid legislation. These old decisions on the protection zones and planned protection measures were adopted and implemented only in the territory of Croatia.

In the framework of bilateral cooperation between B&H and Croatia in the area of water management, concrete cooperation in the field of groundwater protection, which would include a joint definition and proclamation of protection zones for drinking water abstraction sites, has been initiated. (see Chapter 7.1.6. - *2. Absence of common criteria for delineation of the sanitary protection zones).*

7.4.5 Major Issues of Concern

The following major issues of concern in the TBA at Cetina have been identified by the DIKTAS project team:

- Implementation of protection measures only in the territory of Croatia, without its extension to include the territory of B&H, cannot ensure good water quality in the long term. At present, the situation is only satisfactory due to the current poor development of the areas in B&H. The delineation of sanitary protection zones for all sources of drinking water used for public water supply, in the territory of both countries, must be conducted in accordance of the new regulations.

- Lack of harmonised policy/regulation or common guidelines on hydrological and other technical criteria for delineation of transboundary water source protection zones and protection of karst springs used for public water supply.
- Lack of legal /regulatory frameworks for establishment and law enforcement in transboundary sanitary protection zones;
- There is a possibility of water pollution at the springs in Croatia due to inadequate wastewater collection and treatment systems of settlements in B&H.
- There are plans for developing large open pit coal mines in Duvanjsko and Livanjsko poljes that could have negative consequences for water quality in the entire downstream area.
- It should be also taken into account that economic, mostly agriculture activities in this TBA are based on 'natural changes' of water levels in the karst fields where usually relatively small villages are located. So, the whole 'local economy' is based on the long-term experiences of local residents on how to utilize the water and land resources. Water that comes into the fields from time to time and that goes again into many karst holes is a sign and a source of agricultural economic activities. Due to the – on the one hand – abundance of water and on the other hand, 'no water at all', it is difficult to predict and orient economic activities that in most of its dimensions remain out of control.
- One of the major threats bearing in mind the way people live in these karst field areas is the collection and treatment of sewage water that is in most cases discharged into the ground from septic tanks.

7.4.6 Proposed Activities

The priority activities proposed for addressing some of the major issues of concern listed in the previous section include:

- Establishment of a common groundwater monitoring program;
- Harmonisation of hydrological and other technical criteria for delineation of water source protection zones;
- Definition of legal /regulatory frameworks for establishment and law enforcement in transboundary sanitary protection zones;
- A precise analysis of the ways in which people use natural resources such as water and land in their everyday way of life. Based on this, a plan should be made for more sound utilization of these resources trying to minimize the negative effects such as pollution etc. it should be taken into account that the way of life in these areas is deeply rooted in habits and therefore potential changes will not be easy to introduce without the cooperation of the local population.

Legal and policy responses for some of the above issues of concern in this TBA – Cetina, were already described within Chapter 7.1.6., under points 1, 2 and 3 (*1. No waste water treatment or inadequate waste water treatment in the area of concern which may impact the quality of groundwater used as source of the potable water,* 2. *Absence of common criteria for delineation of the sanitary protection zones, 3. Absence of common criteria for setting cost-efficient* *measures for groundwater protection in karst areas).* Consequently, those responses apply to this TBA – Cetina as wel.

In addition to the elaboration made in Chapter 7.1.6. regarding responses to the issue of absence of common criteria for setting cost-efficient measures for groundwater protection in karst areas, for this TBA – Cetina specifically, it should be stressed that for the parts of the catchment areas of Cetina and Krka located in FB&H, the characterisation report was elaborated, in accordance to the Article V of WFD. This report presents the base for the elaboration of the RBMP.

7.5 The Transboundary Aquifer at Bilećko Lake

The Transboundary Aquifer at Bilećko Lake is shared by Montenegro and B&H (Figure 7.11).

The following information which was available from government agencies in the two countries was used for the assessment of its general characteristics: (1) long-term climate records by the hydro-meteorological institutes of B&H and Montenegro; (2) Basic Geological Map (scale 1:100,000) completed when the two countries were part of the former Yugoslavia; (3) detailed geological and hydrogeological maps at larger scales produced for various other purposes including the design and construction of the hydropower system at Trebišnjica; and (4) data on numerous tracing tests performed as part of regional and local hydrogeological studies for different components of the hydropower system at Trebišnjica.

In general, the availability of data is uneven for the two countries. For the TDA portion in B&H there is an abundance of data on tracer tests, groundwater levels at numerous monitoring wells, spring discharge characteristics, and groundwater quality, whereas such data is virtually non-existent for the Montenegro portion.

Data on groundwater utilization for the industry and other major users including public water supply are in general complete.

The estimated total area of the TBA at Bilećko Lake is 1,652 km^2 of which 82 % (1,354 km^2) is karst terrain. The Montenegro portion of the TBA is 595 km^2 (of which 92.4 %, or 550 km^2 is in karst), and the B&H portion is 1,059 km^2 (76.1 % or 806 km^2 in karst).

The TBA at Bilećko Lake belongs to the direct Adriatic Sea drainage basin as there are no permanent surface streams flowing to the Adriatic Sea. Two larger surface streams in the western portion of the TBA, a highly karstified terrain of Banjani, are the Nudoljska River (Sušica) that flows into Reservoir Gorica. The hydrologic and hydrogeologic drainage basins in the TBA have not yet been identified due to a very deep karstification and lack of data.

7.5.1 Climate and Hydrology

The average precipitation in the TBA area used for the water balance calculation is 1,700 mm/year. This is based on the precipitation models developed by the hydro-meteorological institutes in B&H and Montenegro. The average annual air temperature is about 9 °C.

The most important hydrological records are on spring discharges for which the characteristic values are provided in Table 7.12.

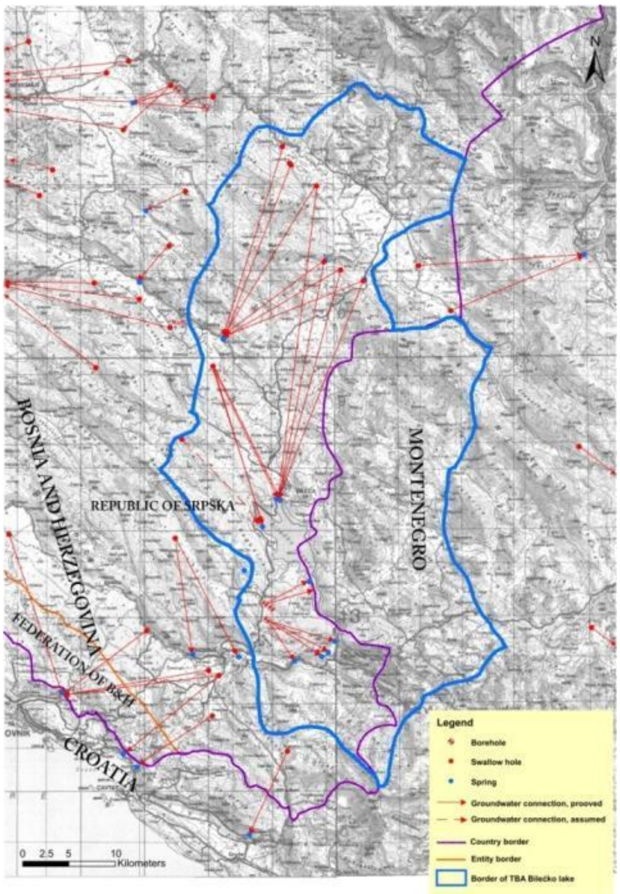


Figure 7.11 The Transboundary Aquifer at Bilećko Lake shared by Montenegro and B&H

As indicated earlier, the western parts of the TDA that belong to Montenegro are almost without surface streams. The most important stream is the River Nudolska; its topographic drainage area is approximately 10% of the Montenegro portion of the TBA. The rest of the TDA drains via the subsurface directly to Bilećko Lake or to the River Trebišnjica.

Table 7.12 Characteristic flows of the major karst springs in the TBA at Bilećko Lake

Spring	Country	Min/average/max discharge (m^3/s)
Zaslapnica	Montenegro	0.1/1.6/-
Račevina	Montenegro	0.025/0.1/-
Dejanova pećina	B&H	
Nikšićka vrela	B&H	Three submerged springs 2.0/42/>800
Čepelica	B&H	
Oko	B&H	Submerged spring 0.5/3.75/40

7.5.2 Hydrogeology

The TBA at Bilećko Lake is formed primarily within limestones of the Jurassic and Cretaceous ages, with a smaller contribution of areas underlain by Triassic limestones and dolomites. All the limestones are intensely fractured and faulted and have a large infiltration capacity at the land surface that allows for rapid percolation of precipitation, the main mechanism of aquifer recharge.

Numerous dye tracing tests within the B&H portion of the TDA, primarily for the purposes of design and construction of the hydropower system at Trebišnjica, were performed in the mid 1980s. Table 7.13 shows the results of some of these tests for illustration purposes.

The groundwater flow velocities range from 1.13 cm/sec up to 11.27 cm/sec and are frequently higher than 5 cm/sec.

Discharge of the karst springs is characterised by highly variable flows. The ratio between maximum and minimum spring discharge is as high as 400 (the Čepelica spring).

Table 7.13 Results of dye tracing tests between major swallow holes and karst springs in the TBA at Bilećko Lake

Swallow hole	Date of tracer test	Spring where tracer occurred	Virtual velocity (cm/s)
'C' Fatničko field	02.04.1964	Veliki Suhavić Trebišnjica springs	7.15 8.24
Ključ, Cernica field	29.11.1961	Trebišnjica springs	11.27
Srđevići, Gacko field	31.08.1958	Trebišnjica springs	1.13
Srđevići, Gacko field	19.10.1964	Trebišnjica springs	7.53

7.5.3 Groundwater Reserves and Their Utilization

Available reserves of groundwater are about 44.72 m^3/s. Minimal discharge of springs is taken as the ecological minimal acceptable flow.

Water demand for water supply in Montenegro is currently 0.01 m^3 /s and in B&H 0.24 m^3/s, with a total of 0.25 m^3/s.

Approximately 35,000 inhabitants of Herceg Novi are supplied from Bilećko Lake with a capacity of about 350 l/s.

7.5.4 Groundwater Quality and Protection

Generally, the chemical quality of groundwater is good and does not need additional treatment regarding regulations pertaining to drinking water.

A systematic sampling and analyses of physical and chemical water quality parameters have not been performed on the Montenegrin portion of the TBA. Nevertheless, since this area is very sparsely populated (the total number of inhabitants is 2,293) and in the absence of any industry, it is concluded that there is no significant pressure on the groundwater quality.

7.5.5 Socio-Economical and Environmental Situation

Bilećko Lake is a artificial reservoir, about 18 km-long, covering surface area of circa 27 km2. The lake is used for the purpose of electric power production as well as for drinking water supply.

On the Montenegrin side, the TBA at Bilećko Lake is located in the north-west of the municipality of Nikšić. In this part, it stretches from the settlements of Velimlje, Grahovo and the border of the TBA at Piva to the state border between Montenegro and Bosnia and Herzegovina. On the Montenegrin side, the total population in the TBA area Bilećko Lake is 2,293 inhabitants divided into 30 settlements. These settlements are very remote from administrative centres. The average age of the inhabitants in the TBA is 44.4 years which indicates a demographically extremely old population, e.g. in the settlement at Klenak, 48 % of the total population is older than 60 years. Cattle breeding is usually the main source of income for households in the TBA while traditional agriculture usually contributes an additional source of income. There is no water supply system in any of the settlements i Montenegro (and groundwater is very scarce). Drinking water supply is individual with the help of mobile water tanks (from the city of Niksic), individual rain collection systems (*bistjerne*) and water wells.

Figure 7.12: Water scarcity in the TBA area: a water reservoir for cattle *bistijerna*, a mobile water tank and another *bistijerna* along the road in Pocekovici (photo: Novak Cadjenovic).

The area of TBA Bilećko Lake in Monetegro is remote with a small population, unfavourable demographic conditions and a low economy and personal income rate. Migration and de-population is notable and has been a stable trend for the last 50 years.

A very important fact for Montenegro about water use from the TBA at Bilećko Lake is the actual use of water from Bilećko Lake for drinking water supply for the coastal city of Herceg Novi (Montenegro) and production of hydropower for the Republic of Srpska in Bosnia and Herzegovina (HE Trebinje I and HE Trebinje II, HE Dubrovnik) and Croatia (HE Plat). Bilećko Lake (i.e. Reservoir Bileća) is partly (ca 18%) located at the teritory of Montenegro. Water from Bilećko Lake is firstly used by the HE Trebinje I (nominal power 3x60 MW) and then transported through 16.6 km long (6 m in diameter) hydraulic tunnel to the Plat in Croatia (the Trebisnjica-Plat system). In Plat, water is used by the hydro power plant at Dubrovnik (nominal power 2x108 MW) and then transferred (to be used as drinking water) to the city of Herceg Novi on the Montenegrin coast through 32 km long pipeline (the Plat- Herceg Novi system, constructed in 1980). Around 70 % of the drinking water for over 35,000 inhabitants of Herceg Novi is supplied from Bilećko Lake (around 350 l/s) while the rest is supplied from the underground accumulation at Opacica in Zelenika in Montenegrin territory.

The current price that the Municipality of Herceg Novi is paying to the communal company of Konavle in Croatia for water transfer via the Plat-Herceg Novi system is fixed at 25,000 Euro/month (according to the bilateral agreement from 2011).

According to Montenegro, the high water transfer price, and the fact that the Municipality of Herceg Novi is occasionally left without a drinking water supply (e.g. during maintenance works in the hydro power plant system at Trebišnjica) raises the question of fair use of the system built in the ex-Yugoslavia Several times Montenegro claimed rights to benefit from hydro-power produced by the system at Trebišnjica). Since the negotiations have not yet produced any results in this regard, Montenegro has developed plans for construction of a new hydro electric plant at Boka in Risan, Boka-Kotorska Bay in order to utilise water from Bilećko Lake for its own hydropower production and water supply. [13] It is not likely that any of the TBA area is suffering from significant pollution from waste or wastewater. Individual septic tanks exist as a potential treat but are not considered as a major concern, since the TBA areas have a very small population. The main limiting factor for development of the TBA areas is seen as the lack of drinking water that can serve everyday needs and be used to add to the household economy by improving traditional agriculture and animal husbandry.

In the TBA there are no protected areas. However, on the border of the TBA area (in Grahovo) there is an arboretum of national importance under state protection. The locality has been protected since 2000 as a unique horticultural area with 127 species of trees.

[13] These paragraphs reflect the Montenegrin view on water utilisation of Bileća Reservoir. The issues like cost/benefit sharing of power production or a water transfer price are not a subject of this project. Nevertheless, they are related to transboundary groundwaters and need to be mentioned in the TDA report (N.Kukurić, project coordinator).

Nearby, in the area near Velika Osecina, a habitat of the endemic amphibian Triturus vulgaris has been registered. This rare species has been registered in other karst water pits in Montenegro (e.g. the Kovacevica water pit).

7.5.6 Major Issues of Concern

The following major issues of concern in the TBA of Bilećko Lake have been identified by the DIKTAS project team.

- Absence of a comprehensive groundwater monitoring program, including a necessary bilateral agreement;
- Lack of a database on non-point and point sources of surface water and groundwater contamination (landfills, septic tanks, quarries, wastewater discharges, and others);
- The concern of Montenegro is that Montenegro currently does not benefit from the hydropower generated by using water from the Bilećko Lake, though a substantial part of the Lake's catchment area is in Montenegrin territory;
- Water from Bilećko Lake is used for the water supply of the Herceg Novi municipality. The concern of Montenegro is that that Montenegro pays a high price to the communal company of Konavle in Croatia for transfer of water to Herceg Novi .
- Lack of data related to the Groundwater Dependent Ecosystems in this area.

7.5.7 Proposed Activities

Priority activities proposed for addressing some of the major issues of concern listed in the previous section include:

- Establishment of a common groundwater monitoring program.
- Harmonisation of hydrogeological criteria for delineation of source protection zones as the basis for policy harmonisation and protection of karst springs used for public water supply.
- Inventory of non-point and point sources of pollution (landfills, septic tanks, quarries, wastewater discharges, and others).

7.6 The Transboundary Aquifer at Cemi/Cijevna

The Transboundary Aquifer at the Cemi/Cijevna River is shared by Albania and Montenegro (Fig. 7.12).

Information provided here is based on different sources such as the Albanian Geological Survey, Environmental Ministry of Albania, former institute of hydrometeorology and papers published on various websites. The information is related to:

- Climate and hydrology registered by the former Hydro-Meteorological Institute (today the IGJEUM - Institute for Geo-science, Energy, Water and Environment);
- Hydrogeological data registered by the Albanian Geological Survey over a long period;
- The new Geological Map of Albania (scale 1:200 000) published in 2003;
- Detailed geological and hydrogeological maps at scales of 1:50,000 and 1: 25,000;

- Different hydrogeological studies for drinking water supply in urban and rural areas;
- Different scientific published papers.

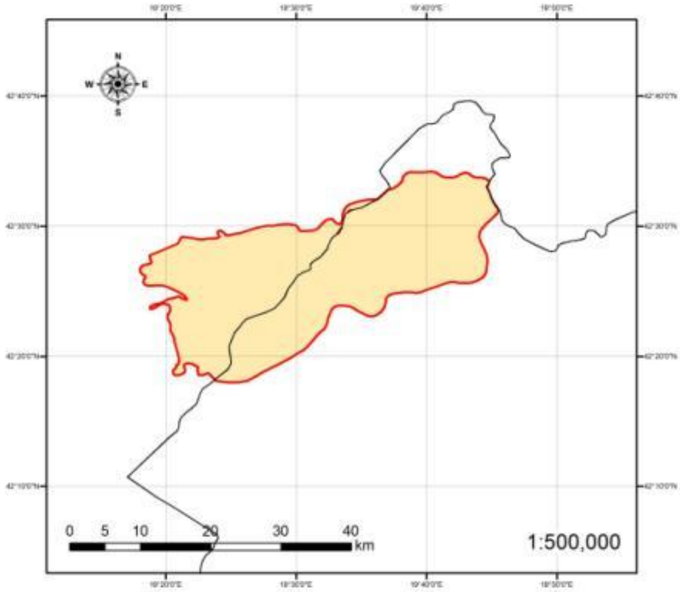


Figure 7.13: The Transboundary Aquifer at the Cemi/Cijevna River shared by Albania and Montenegro

There is no abundant information about the wells, spring discharge characteristics, or groundwater quality because of the lack of a regular monitoring system in the TDA zone. Data on groundwater utilization for the industry and other major users including public water supply is mostly accurate.

The Cemi river basin extends across two states, Albania and Montenegro. From the geographical point of view it is located on the west side of Bjeshkët e Namuna, while from the hydrological point of view its basin is part of the Lake Shkodra basin and together it and the Buna river basin belong to the Adriatic Sea.

The Cemi is one of the main rivers that run through the Albanian Alps. It runs along the northwest of the Alps. It has a total length of 62.2 km. Its basin covers an area of 368 km^2, and 238 km^2 of its basin and 30.8 km of its length are within the territory of the Republic of Albania. The average altitude of the Cemi River is 1,237 m above sea level. The Cemi is composed of two branches: the Cemi of Selca and the Cemi of Vukli. The Cemi of Selca is 22.5 km long and the Cemi of Vukli is 17.9 km long. The Cemi of Selca is the northern branch and it begins in the springs of Koprishti and goes up to the Holes of Selca. Its valley has the features of a canyon, with very steep crests, significant slopes and many small waterfalls. The Cemi of Vukli is the southern branch of the Cemi and it begins in the spring of Vukli (in Lluga). After it comes in flysch, in the upper part of its stream it enters the ridge of Golishti and Dubina, where it forms narrow valleys with very steep crests and waterfalls. Both branches of the Cemi join each other in Tamara. The Cemi then runs in a south-westerly direction through a typical V-shaped valley. It goes through the limestone blocks of Mizhdrakuli and Kapezdroja and near Grabomi, where it leaves Albanian territory. Cemi brings 25.5 m^3/sec water. The drainage system belongs to the Moraça River, which discharges its waters in Lake Shkodra. The Cemi river basin is a part of the Albanian Alps and therefore it is understandable that it flows in karst formations. From a hydrogeological point of view the drainage zone and the glacial depositions near the villages of Tamara and Kopliku, the latter near Lake Shkodra, belong to Lake Shkodra. These drainage systems are verified by the hydrodynamic levels and chemical water analyses performed in the past and some new observations from the last 10 years.

7.6.1 Climate and Hydrology

From a climate point of view, the River Cemi basin is mountainous-Mediterranean, with cold winters and cool summers. The average temperatures are 14 °C in the Cemi's basin and 5 °C in the mountains. The coldest month of the year is January with average temperatures of 0 °C in the Cemi's basin, and -8 °C in the mountains. The hottest month of the year is July with average temperatures of 18-20 °C in the Cemi's basin, and 12 °C in the mountains. The annual rainfall in the Cemi's basin is 2,308 mm, and 2,500-3,500 in the mountains. The average number of rainy days is about 140. The driest month is August; the average rainfall is 78.9 mm in the Cemi's basin, and 150 mm in the mountains.

The average snow thickness is 25-50 cm in the Cemi basin, and more than 150 cm in the mountains. Snow lies on the ground for 20-60 days a year in the Cemi basin, and 140 days a year in the mountains.

It rains 120 days annually in the Cemi basin, and 140 days in the mountains. The Cemi basin has 2,200 sunny hours a year. Regarding the local winds, Murlan, ice-wind (dry and cold), sirocco and south-wind (warm and wet) as well as mountain and valley winds occur in the area.

Table 7.14 Characteristics of the major karst springs in the TBA of the Cemi River

X	Y	Z	Yield Q	Ca	Mg	Na	HCo3	SO4	Cl	Tm	Dr	Th	T	Name_of_spring
4711600	4389690	1100	12	0.034	0.008	0.006	0.140	0.010	0.007	0.207	0.13	6.86	6.00	Kroi Krinet
4711250	4387250	700	400	0.030	0.003	0.010	0.109	0.012	0.003	0.173	0.09	5.06	5.30	Selce Vrela
4710660	4384400	800	100	0	0	0	0	0	0	0	0	0	6.00	Selce Kelmend
4709500	4386500	625	200	0.033	0.007	0.002	0.128	0.008	0.003	0.183	0.112	6.3	9.20	Selce Jasanova
4706050	4389870	600	500	0.036	0.002	0.007	0.122	0.008	0.005	0.181	0.118	5.63	6.30	Spring Vukel
4705400	4382450	400	150	0	0	0	0	0	0	0	0	0	9.50	Tamare Kelmend
4704070	4381900	250	5	0	0	0	0	0	0	0	0	0	0	Spring Tamare
4702950	4387250	600	40	0	0	0	0	0	0	0	0	0	7.00	Kosnice Vukel
4701550	**4387800**	**625**	**500**	**0.033**	**0.003**	**0.004**	**0.103**	**0.017**	**0.003**	**0.166**	**0.102**	**5.49**	**5.20**	**Kosnice Vukel**
4701300	**4379900**	**450**	**100**	**0.035**	**0.005**	**0.018**	**0.144**	**0.006**	**0.008**	**0.219**	**0.138**	**5.48**	**9.80**	**Broje Kelmend**

7.6.2 Hydrogeology

The water-bearing complex of Cretaceous (Cr) is composed from various carbonatic and dolomitic deposits. The depositions of this complex expanded in almost all the north western and northern part of the region and composes the Albanian Northern Alps. They form a big structure, a big anticlinoria, containing a lot of anticlines and syncline structures. Beginning from the lower zone toward the higher zone (SW-NE) there are a lot of anticlines and anticlines as well as the synclines at Brushtullit and Vuklit;

The TBA at the Cemi River is formed primarily within limestones of the Cretaceous age, with a smaller number of areas underlain by Triassic limestones and dolomitesThere are also some small quaternary depositions near the Cemi valley. The karst is very fractured and the filtration coefficient is high, about 0.6-0.7. The coefficient of the runoff has increased during the last 20 years because of the changes in land use and forests.

Discharge of the karst springs is characterised by highly variable flows. The ratio between maximum and minimum spring discharge is high: the ratio in percentages for the natural springs varies by approximately 85% between the minimum and maximum. In Albania there is no data related to the trace test.

7.6.3 Groundwater Reserves and Their Utilization

The available reserves of groundwater are about 32.46 m^3/s. The minimal discharge of the springs is calculated as 85% of spring depletion. Minimal discharge for the natural spring is about 269 l/s, maximal discharge is 1,792 l/s and the average is 1,030 l/s.

Demand for water supply in Albania is currently 0.0013 m^3/s with a total of 0.43 m^3/s. Approximately 6,000 inhabitants of the Kelmendi Commune are supplied by the natural springs of the Cemi basin with a minimum capacity of about 269 l/s. The water is used for drinking water and agricultural purposes.

7.6.4 Groundwater Quality and Protection

Water in the Cemi River, especially in the upstream, near the village of Dinosha, is of very good quality as it emerges from the mountainous areas that are uninhabitable and normally lack people which means that the area is pristine. Water from the River Cemi has been used for drinking since ancient times, proved by the remains of an old Roman water supply in the village of Dinosha which used to supply drinking water to the old Dolcean location.

Water from the Cemi River is clean but parameters for phenol, detergents and ammonia have tended to change for the worse in the village of Targaj. Sh. coli bacteria is sometimes present. One can speak for the content of nitrite, phenol, total content of Ex bacteria coli germs and faeces. The River Cemi is a clean river whose water is drinkable without needing to be filtered. However, in summer periods of a lower water level and higher water temperature, the water quality decreases due to extensive washing in the river by local population. According to the analysis of clean water (which is used by the local population), there is a significant increase in the parameter values related to quality of the water.

Generally, the chemical quality of groundwater is good and does not need any additional treatment regarding regulations pertain to drinking water during the year. A systematic sampling and analyses of physical and chemical water quality parameters have not been performed on the Albanian side of the TBA. Nevertheless, since this area is very sparsely populated (the total number of inhabitants is approximately 6,000 instead of 15,000) and due to the lack of any industry, it is concluded that there is no significant pressure on the groundwater quality. However, there is some temporary pollution caused by quarries, marbles and abandoned mines, as well as from pesticides and sewages.

7.6.5 Socio-Economical and Environmental Situation

The TBA at Cijevna is situated along the valley of the River Cijevna along the Montenegrin - Albanian state border. The total coverage of the area in Montenegro is 235.54 km^2 and the population of this part is 1,475 inhabitants. The Montenegrin part has a small population with no extensive industries and with poor infrastructure. Settlements in this TBA have a high rate of depopulation (nearly 10 % per year). The population in this TBA has an average age of 39 (the population is on the border between demographically old and demographically very old).

Main sources of income for the population of the TBA at Cijevna are small-scale (traditional) agriculture and social welfare or employment in the industries/administration which is situated outside the TBA (in Podgorica, Tuzi).

Agriculture is limited by the scarce agricultural areas available and the mountain climate. Cattle breeding is usually the main source of income for households in the TBA that is sometimes combined with income from traditional agriculture or occasionally collection of medicinal herbs.

There is water scarcity registered at the one part of the TDA where water wells, direct water supply from Cijevna River and mobile water tanks are frequently used.

According to limited measurements, the quality of the water in the upstream of the Cijevna River is in the A1, S, I category which is the highest quality category in national legislation (corresponding to the category 'good' in the EU WFD).

However, occasionally (especially after a rainy spring season), elevated levels of HPK and phosphates has been registered by the Trgaja monitoring station as well as elevated levels of PAH, phenols and pesticides. This pollution is probably related to the untreated hazardous waste dumping site of an aluminium factory in Podgorica and pesticides and fertilizers runoff from large agricultural properties belonging to a company "13 Jul" in Podgorica. Both of these polluters are outside the TBA. No industries are registered in the Montenegrin part of the TBA.

Since this area has a small population and no extensive agriculture, we can assume that only the wastewater and solid waste produced from households can be considered as potential polluters of underground water.

The canyon of the Cijevna River has been identified as a important site for nature protection. Despite the fact that the Cijevna River is not legally protected, the area has been recognized as one of the 32 Emerald sites in Montenegro (Number 16: the Cijevna River Canyon), because it is an important area for plant conservation (IUCN Important Plant Areas - IPA programme) and a site of international importance for bird habitation (IBA). Altogether seven habitat types from Resolution 4 and thirty-six species from Resolution 6 of the Bern Convention exist in this area.

7.6.6 Major Issues of Concern

The following major issues of concern in the TBA at Cemi/Cijevna have been identified by the Albanian project team:

- Lack of a regular monitoring system for natural springs;
- Lack of a sewage system in almost all the settlements in the TDA zone;
- A high degree of vulnerability of the karst aquifers because of the lack of vegetative cover and forests;
- Lack of sanitary zones;
- Water exploitation and discharge without permits or control by the authorities;
- Lack of an appropriate drinking water system (water pipelines are local and amortized).

In the TDA area an infrastructure of water utilities has been created but only for some main communities. The drinking water supply system is based on natural springs without any costs during exploitation. Pumping stations for drinking water supply are not preferred because the cost of energy and maintenance. So, in general, the villages are not connected to main pipelines but they work locally, independently of the state or the water utilities. They take their water from local sources and use it as for drinking as well for industry or other activities.

The main threats are related to water quality and their non-uniform distribution in the TDA area. The recharge zone is located at the considerable heights, in very vulnerable zones, where animals, sewage and other technological remains from the mines can pollute the water. Another treath is the lack of controlled landfills, sewage treatment and necessary infrastructure for polluted water discharge.

The use of fertilizers is uncontrolled and washing water is not discharged into a regular drainage system . The fertilizers just drain into the nearest hydrographical network such as the Cemi River which flows to Lake Shkodra. Additionally, the polluted water drains into the underground karst system.

7.6.7 Proposed Activities

Priority activities proposed for addressing some of the major issues of concern listed in the previous section include:

- Establishment of a common groundwater monitoring program with the same standards as Montenegro;
- Identification of the permanent and local sources of pollution in Albania and Montenegro and their influence in these countries;
- Harmonisation of hydrogeological criteria for delineation of source protection zones as the basis for policy harmonisation and protection of karst springs used for public water supply and other public needs;
- Development of a pilot project in this TBA zone;
- Future systematic investigation of potential GDE characteristics and proposal of special protection measures for possible joint management plan of the Cijevna River as a joint Natura 2000 site.

7.7 The Transboundary Aquifer at Piva

This transboundary flows from B&H to Montenegro, within the aquifer, as proved using a dye test. Surface waters of the south-eastern part of the Gatačko field sink in two dominant swallow holes: the Dobreljska pećina and Bogotovo groblje. Water appears in the big karst spring at Piva in the territory of Montenegro, submerged by a reservoir for the HPP Peruća. In the south this transboundary aquifer borders with the transboundary aquifer at Bilećko Lake.

In the territory of B&H this aquifer covers only about 80 km^2. There are only small villages with a few hundred inhabitants and the use of groundwater in this area of B&H is pointless.

The rest of the transboundary aquifer, about 230 km^2, belongs to the territory of Montenegro The same conclusion, regarding water use, can be drawn for the territory of Montenegro as well. The reason is because only about one thousand people live within the whole area of the transboundary aquifers.

A tracing test provided in the early 1960s proved a connection between the eastern part of the Gatačko field (the Republic of Srpksa, and Bosnia and Herzegovina) with the big karst spring at Piva (in Montenegro, today submerged by the Peruća Reservoir).

The results of this test show a significantly worse connection between swallow holes and springs than in the neighbouring Bilećko Lake TBA. Namely, the registered fictive groundwater velocities are among the lowest in Eastern Herzegovina (Table 7.15).

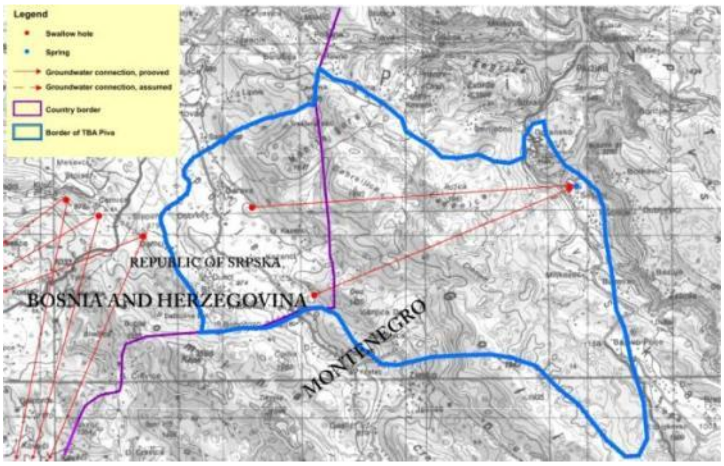


Figure 7.14: The Transboundary Aquifer at Bilećko Lake shared by Montenegro and B&H

The results of this test show a significantly worse connection between swallow holes and springs than in the neighbouring Bilećko Lake TBA. Namely, the registered fictive groundwater velocities are among the lowest in Eastern Herzegovina (Table 7.15).

The main use of waters is for hydro-energy production in Montenegro (HPP Peruća).

Table 7.15: Groundwater connections and velocities from the eastern part of the Gatačko field to the submerged Piva springs

No	Swallow hole	Date of test	Spring	Distance (km)	Fictive groundwater velocity (cm/s)
1	Bobotovo groblje	26.05.1964	Piva	16.4	0.54
2	Dobreljska cave	15.04.1963	Piva	18.1	1.19

There is no issue of concern about this transboundary aquifer.

7.8 Root Cause Analysis and Priority Actions

In general, root cause analysis (RCA) is a method that tries to solve problems by identifying and correcting the root causes of events, as opposed to simply addressing their symptoms. By focusing correction on root causes, problem recurrence can be prevented. GEF has adopted a RCA as a standard part of the TDA where Immediate, Underlying and Root causes are distinguished. The analysis is not simple, also because it involves various sectors, such as agriculture, fisheries and aquaculture, urbanisation, industry/mining, energy production, transport/ infrastructure, tourism, leisure and recreation and defence. In addition, sectors often interact; they can share root causes and may affect each other. Finally, what makes the root cause analysis even more complex is the transboundary character of the problems. Nevertheless, environmental problems need to be dealt with at their roots, independent of sectoral and geographical boundaries.

Basically all the sectors listed above have an impact on the state of groundwater resources in the Dinaric Region. Agriculture and energy production play a prominent role here because of diffuse pollution and changes in environmental flow, respectively. On the other hand, disposal of liquid and solid waste is the main threat to water quality in the region, being directly related to urbanisation and industry. Additionally, tourism puts a significant pressure on water resources, particularly in coastal areas during the summer months.

In the transboundary aquifers in the DIKTAS project region, there are a few observed problems and many more potential problems. For instance, microbiological contamination was observed in the karst springs in the TBA at Una but in the other TBAs pollution is mentioned as a potential threat (e.g. the TBA at Neretva).

Although there are some indications available, the immediate cause of the microbiological pollution in the TBA at Una has not been assessed, due to lack of monitoring. It is very likely that the problem is of a technical nature, related to lack of waste (water) treatment. Immediate (or primary) causes of some potential problems can be easily named (but not assessed, being potential). For instance, large open pit coal mines in the Duvanjsko and Livanjsko poljes could have negative consequences for water quality in the entire downstream area of Neretva. The coal mines would then be an immediate cause of water quality deterioration if the plans for their development are materialised and pollution is observed. An even more general example also comes from the TBA at Neretva where there is a possibility of water pollution at the springs in Croatia due to inadequate wastewater collection and treatment systems of settlements in B&H. Clearly, inadequate wastewater treatment would be the (potential) immediate cause, whereas underlying causes should be sought in a broader socio-economical perspective (see below).

A similar situation applies to the impact of hydropower production plants where immediate causes could be related to hydrotechnical interventions in the environment but the underlying and root causes reach much further than dams, tunnels and reservoirs. Here a distinction should also be made between current and potential causes, the latter being related to planned hydrotechnical constructions or those in the early stage of development. It is not a purpose of this TDA to make any predictions of the impact of hydrotechnical objects regarding the environment. It is understood that dedicated (inter)state commissions have been set up to deal with this issue. Nevertheless, it can be stated that hydrotechnical interventions in the environment clearly have an additional weight in an international context (compared with a national one). In general, hydrotechnical constructions bring positive (mostly economic) impacts, but often some less favourable (environmental) impacts as well. That was most likely the case with the hydropower plants constructed or planned in the former Federal Republic of Yugoslavia. With the splitting up of Yugoslavia, the question of the impact of hydrotechnical constructions has received international attention and has become a very topical issue. This holds for both already operational and planned hydrotechnical constructions. Following the GEF classification, the underlying cause related to hydropower production plants is increased sectoral development. The main root cause of increased attention (and tension) around operational and planned hydrotechnical constructions is the political change in the region (transformation of a federal state into independent states), although social changes and development biases play a role as well.

Looking at the DIKTAS project region as a whole, the main potential threat to groundwater by far is pollution from waste and wastewater (as the immediate cause). Croatia has 109 wastewater treatment plants (WWTP), covering 43% of the population which is insufficient. The situation in the other project countries is much worse: Bosnia and Herzegovina has only 15 (7 operational) WWTP, Albania 7 in total and Montenegro only 2. For the vulnerable karst environment of the Dinaric region (with a very limited auto-purification capacity) these are very disturbing figures. The underlying cause of this situation could be associated with the GEF category of 'resource uses and practices' and particularly waste discharge. The main root cause is clearly poverty (this is the poorest region in Europe) although an unregulated and overrepresented market economy and low environmental values are also a significant cause.

8 Information and Data Gaps

Information and data gaps addressed in this chapter are about field data and related interpretations that are required for a proper assessment and management of groundwater resources in the project region. The gaps in policies and regulations specific to karst environment (e.g. with respect to delineation of sanitary protection zones, inadequate legal framework which would enable establishment and law enforcement in transboumdary sanitary protection zones and inadequate enforcement of legislation (e.g. with respect to waste and wastewater treatment and disposal) are not elaborated here (see chapters 5 and 7).

Some data on groundwater quality monitoring was collected during the TDA preparation, although not sufficient to provide a precise picture of the state of the groundwater monitoring network in the project region. Nevertheless, it seems that none of the countries in the DIKTAS project region currently has a complete and operational network for systematic regional monitoring of groundwater quality. Limited sporadic monitoring of groundwater quality is usually related to specific water supply and infrastructure projects, whereas a continual water quality monitoring is concentrated solely on the water wells and springs used for public drinking water supply. Consequently, a detailed assessment of the overall quality of the groundwater in the project region is not feasible.

Even less is known about the state of the groundwater quantity-monitoring network. The monitoring of groundwater levels seems to be non-existent for large parts of the region. It does not come as a surprise that a major recommendation by the DIKTAS Project team for priority action is the establishment of a common groundwater monitoring program.

As a part of the Sava River Basin Management Plan, a background paper has been prepared on Groundwater Bodies in the Sava River Basin (version 2, 2011). This valuable document provides an overview of groundwater monitoring in the Sava River basin. It appears that there has been virtually no systematic groundwater monitoring in Bosnia and Herzegovina since the early 1990s; the exception is groundwater sources used for drinking water supply, which are monitored and controlled by water supply companies and institutions responsible for public health. Similar conclusion is valid for Trebišnjica and Neretva river basins, based on the Trebišnjica Neretva River Basin Management plan. No data was available from Montenegro.

The data on groundwater monitoring in the Dinaric region is difficult to obtain in most of the countries. Anyway, regular groundwater observations seem to be very sporadic, except around abstraction wells or captivated springs. In most cases, water agencies are responsible for groundwater observations. Actual monitoring is often carried out by water supply companies and hydropower production companies; they need groundwater data for monitoring and optimising the production.

Locations of 15 groundwater-monitoring wells in the project region in Bosnia and Herzegovina and 37 in Albania are shown on the map below (Figure 8.1). About 30 wells in Croatia, 14 in Bosnia and Herzegovina and 5 in Montenegro are not on the map because their coordinates are still unknown. Annex 1 contains a map showing the same groundwater monitoring network but then together with the precipitation and surface water monitoring networks in the DIKTAS project area.

Not only is the number of observation wells in the region limited, this refers also on their characteristics and the operational status. Moreover, the purpose of the monitoring network is to record groundwater change and use the records to assess state of the resources. At this stage there is very little known about the historical records in the DIKTAS project area.

One of the on-going tasks of the DIKTAS Project Team is to define the environmental status indicators and to suggest their targets and a related joint monitoring program. There is still an understanding that sufficient information on the existing monitoring (including historical records) will be collected/made available to allow a proper judgement on the current state of the monitoring, its reliability and representativeness. Only then can the (content) basis of the joint monitoring program be established.

Groundwater monitoring of a karst environment is very complex and there are no specific guidelines for design and/or optimisation of monitoring the network in a karst. Groundwater monitoring for general reference purposes (IGRAC 2006, http://www.un-igrac.org/publications/331 and EU Water Framework Directive provide some guiding principles.

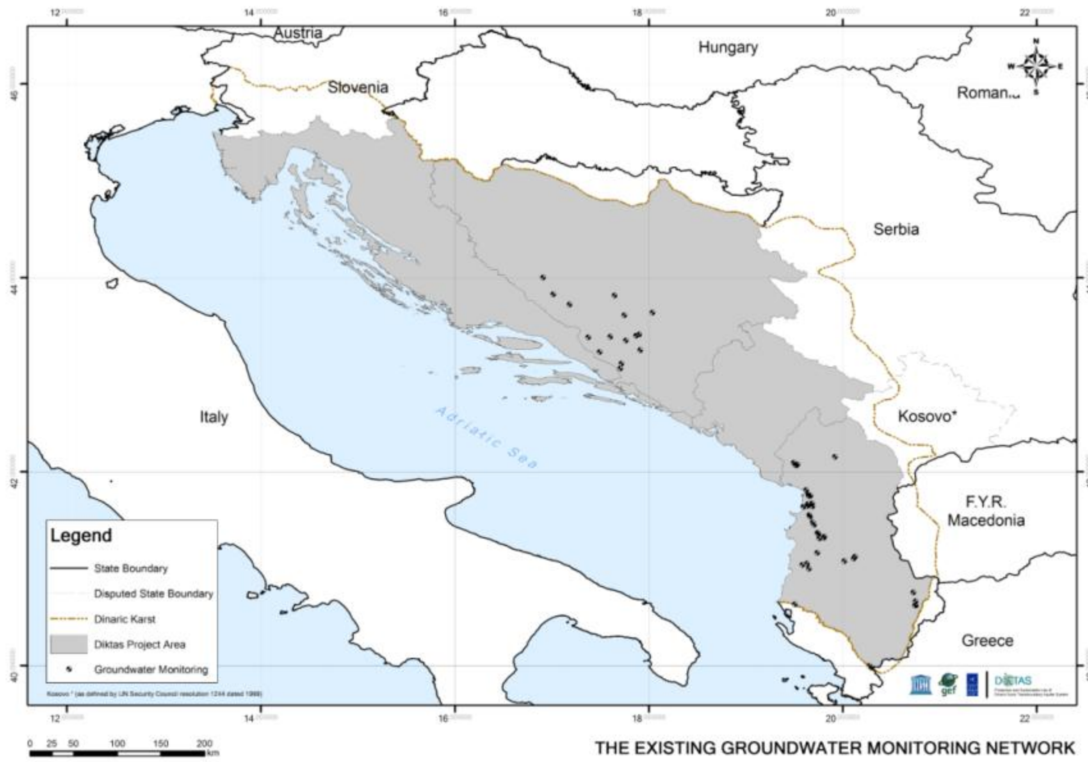


Figure 8.1 Locations of some of the groundwater monitoring wells in the DIKTAS region (see also Annex 1)

The parameters to be measured need to provide information for regular assessment of spatial and temporal variability of environmental status indicators. Spatial density and sampling frequency of observations in karst cannot be designed in the same way as for an intergranular environment, due to variability of the hydrogeological matrix (i.e. absence of a representative elementary volume) and the dynamics of the groundwater flow (i.e. presence of nested drainage systems).

The costs of establishing a monitoring network and a monitoring programme need to be taken into account as well. The document on Groundwater Bodies in the Sava River Basin mentioned above gives an estimation of the required investments per country, covering only the Sava River catchment area. For example, the establishment of so-called surveillance monitoring stations in Bosnia and Herzegovina would cost 1.2 - 1.6 million Euros. The cost of a six-year monitoring programme for B&H is estimated at 2.2 million Euros. Bearing in mind the economic strength of the countries in the DIKTAS region, these are very large investments. Therefore, the necessity of filling information and data gaps needs to be expressed in convincing terms and the monitoring programme should contain a proper balance of reliability (of the monitoring) and feasibility (of the programme realisation). The DIKTAS monitoring programme will be elaborated in a separate report and stressed in the Strategic Action Programme (SAP).

9 Conclusions and Pathway to the SAP

The Transboundary Diagnostic Analysis (TDA) showed that, based on the information made available to the project team, the state of groundwater in the DIKTAS project region is generally good in terms of both quantity and quality with a few exceptions and with a number of serious potential threats. The main threat to the overall groundwater quality in the DIKTAS region is solid waste and wastewater disposal. There are hundreds of unregulated landfills and illegal dumping sites in the four project countries. The number of wastewater treatment plants is insufficient, with about half of the population not connected to this service. For the vulnerable karst environment of the Dinaric region, which has a very limited auto-purification capacity, this is the most serious current as well as potential future problem. To a lesser degree, karst groundwater resources in the region are also contaminated by agricultural and industrial activities.

There is a significant concern of some stakeholders about hydropower production in the region, especially in Bosnia & Herzegovina, including the impacts of hydrotechnical constructions in the TBA areas of Trebišnjica and Bilećko Lake. With the disintegration of Yugoslavia, this issue has obtained transboundary dimensions and has become very prominent. This holds for both already operational and planned hydrotechnical projects. The concern is not only environmental but also economic and political. The complexity of the karst environment, especially in terms of predictions (which were not a part of the TDA), further complicates the resolution of the identified concerns. This also confirms that the optimal strategy of water resources development in Dinaric karst area is a key requirement for regional socio-economic development.

A major added value of the TDA can be seen in the collection and harmonisation of a large amount of data and information relevant for the assessment and management of karst groundwater resources in the region. This gathered information was not always complete and in some cases there were still significant information gaps. Nevertheless, the DIKTAS TDA was the first thorough regional groundwater analysis that covered Albania, Montenegro, Bosnia and Herzegovina and Croatia. The analysis included hydrogeological characterisation, as well as social, economic, legal and regulatory aspects of the groundwater resources management in the region. Outputs of the TDA, including GIS materials such as thematic maps and databases, and quantitative hydrogeologic analyses, form the basis for developing groundwater resources management models at both regional and local scales.

While the TDA has produced a fair assessment of groundwater resources in the region it also revealed limitations of knowledge on their actual state and trends in terms of quality and quantity. The main obstacle for this was a lack of monitoring data at both regional and local scales, such as in the vicinity of solid waste and wastewater disposal (treatment) sites, mines, intensive agriculture areas, and industrial facilities handling and generating hazardous materials. Therefore, an urgent message from the TDA is a request for improvement of the groundwater monitoring network throughout the region and the need to intensify capacity building in the public sector.

The comprehensive regional analysis conducted during the first year of the project was followed by an analysis of the main issues of transboundary concern. The latter concentrated on the transboundary aquifers (TBAs) shared among the project countries and produced following suggestions for priority actions in all the TBAs:

- Establishment of a common groundwater monitoring program
- Harmonisation of criteria for delineation of source protection zones as a basis for harmonised policy/regulatory framework
- Definition of legal framework for establishment and law enforcement in transboundary sanitary protection zones.

A detailed inventory of non-point and point sources of pollution will be needed prior to the establishment of a common groundwater monitoring program. A proposal for a common groundwater monitoring program is currently being prepared in the framework of DIKTAS and will be an input to the Strategic Action Programme (SAP).

Additional input for SAP will be provided through three case studies to be conducted within the area of three TBAs in the region. One of the case studies will be dedicated to the establishment of a common groundwater monitoring program and the other to harmonisation of criteria for delineation of source protection zones. The intention is to produce proposals that could be replicated in other transboundary aquifer areas. The third case study will focus on an observed problem of groundwater pollution. This study needs to establish the causes of the pollution and to propose concrete measures to mitigate and/or eliminate the pollution. The proposal will also serve as a basis for the SAP preparation. The SAP preparation will be conducted according to the GEF guidelines and will include:

- Developing a long term vision for the region;
- Brainstorming ways to attain the Ecosystem Quality Objectives
- Assessing the acceptability of the options (both economic and political)
- Setting short-term targets and priority actions
- Developing targets, frameworks and indicators and
- Drafting the SAP and National Action Programmes (NAPs).

These activities will be conducted by the members of the DIKTAS Project Team (re)organised into regional and national Drafting Teams with assistance of various stakeholders. The country National Inter-ministerial Committees (NICs) will be closely involved in this process and the final documents will be discussed, commented and adopted by the DIKTAS Steering Committee and the Consultative and Information Exchange body (CIE).). Additional information on the DIKTAS SAP activities can be found via the DIKTAS portal at http://diktas.iwlearn.org.

References

Béla Galgóczi and Bruno S. Sergi (2012): Social and economic trends in south-east Europe. European Trade Union Institute (ETUI), Brussels.

Bešić Z.1972. Geology of Montenegro, Vol.2. Karst of Montenegro (in Serbian), Spec. ed. Geol. Soc. Mont., Podgorica, p. 415.

Bijedić A. et al., 2012. Water management strategy of the Federation of B&H, Water Management Institute, Sarajevo

Biondić B. & Goatti V. 1984: Sanitary protection zones of fresh water springs in the community of Rijeka (in Croatian). Proc. of VIII Yug. Symp. of hydrogeol. and eng. geol. vol. 1, Budva, 281–289.

Bonacci, O. 1987. Karst Hydrology; with special reference to the Dinaric Karst. Springer-Verlag, Berlin; 184 p.

Bonacci, O. 2008. Challenges in transboundary karst water resources management. Proceedings of IV Transboundary Water management conference, CD, session 1 (2), Thessaloniki, 2008.

Božičević S. 1966. Caves, potholes and ponors with water in Dinaric karst area (in Croatian). Krš Jugoslavije, Jug. Akad. Zn.i Um. Zagreb, 6:105-136.

CIA (2012) World Factbook, available at: https://www.cia.gov/library/publications/the-world-factbook/geos/kv.html

Cvijić J. 1893. Das Karstphänomen. Versuch einer morphologischen Monographie. Geographischen Abhandlung, Wien, V(3); 218-329.

Cvijić J. 1900. Karst poljes of Western Bosnia and Herzegovina. Glas of Serbian Royal Academy. Vol. LIX, Belgrade, 59-182.

Cvijić J. 1918. Hydrographie souterraine et evolution morphologique du karst. Receuil des Travaux de l'Institute de Géographie Alpine, 6; 375-426.

Cvijić, J. 1960. La Géographie des terrains calcaires. Academie Serbe des Sciénces et des Arts, Beograd, Monographies, T. CCCXLI; 212 p.

Čičić S. & Skopljak F. 2004. Geological and hydrogeological conditions of Vrelo Bosne catchment area (in Bosnian).- Voda, Sarajevo, 37, 4-10.

Eftimi R. 1971. Discharge regime of Selita Spring (in Albanian). Permbledhje Studimesh, Tirana, 2, 65–76.

Eftimi R. 1998. Some data about the hydrochemistry of karst water of Dajti Mountain (in Albanian). Studime Gjeografike, Tirana, 11, 60–65.

Eftimi R. 2010. Hydrogeological characteristics of Albania. AQUAmundi. Vol. 1. 1: 79-92.

Elekltroprivreda Crne Gore, 2012. Osnovna djelatnost, Elektroprivreda Crne Gore website. Retrived from: http://www.epcg.co.me/01_01.html. March 12, 2013

EU Phare Programme. 1997. National Water Strategy for Albania, Tirana, Albania

European Commission (2011) AMECO online database, version updated in November 2011, available at: http://ec.europa.eu/economy_finance/db_indicators/ameco/zipped_en.htm

European Environmental Agency (EIA), 2011, Corine land cover 2006 (CLC2006), EIA, 2011, Denmark.

Eurostat (2011) Pocketbook on the enlargement countries, 2011 edition, available at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KSGM-11-001/EN/KS-GM-11-001-EN.PDF

Ford D. 2005: Jovan Cvijić and the founding of karst geomorphology.- In: Stevanović Z & Mijatović B. (eds.): Cvijić and karst, Spec. ed. Board on karst and spel. Serb. Acad. of Sci. and Arts, Belgrade, 305 -321.

Herak M. 1972. Karst of Yugoslavia. in Herak, M. and Stringfield, V.T. (eds), Karst: Important Karst Regions of the Northern Hemisphere. Amsterdam, Elsevier Publishing Company. 25-83.

Hrkalović U., Čubrilo S., 2007. The framework water management development strategy of the Republic of Srpska, The Republic Directorate for Water of the Republic of Srpska, Bijeljina,

Hrvacevic S., 2004. The surface waters of Montenegro. Elektroprivreda Crne Gore. Niksic

Hrvatović H., 2006. Geology of Bosnia and Hezegovina, Geological Institute of the Federation of B&H, Sarajevo

International Monetary Fund (2012) World Economic Outlook Database, available at: http://www.imf.org/external/pubs/ft/weo/data/assump.htm

Jolović B., 2009.National hydrogeological report for Bosnia and Herzegovina, Preparatory stage of DIKTAS Project, Zvornik

Komatina M., 1975. Hydrogeological characteristics of the central part of the Dinarides karst, Geological and geophysical survey, Beograd

Komatina M. 1983. Hydrogeologic features of Dinaric karst. In: Hydrogeology of the Dinaric Karst. Mijatovic B (ed.). Spec. ed. Geozavod, Belgrade. 45-58.

Kovačević S., Lončarević M. 2003. Long-term water supply of Sarajevo canton (in Bosnian). Voda, Sarajevo, 35: 4-9.

Krešić N. 1988. Karst and caves of Yugoslavia, Naučna knjiga, Belgrade, 149 p.

Magdalenić A., 1970. Defined groundwater connections of karst waters in the Cetina river basin, Hydrogeology of the Cetina river basin, MGO faculty, University in Zagreb,

Mijatović B. 1984. Hydrogeology of the Dinaric Karst. International Association of Hydrogeologists, Heise, Hannover. Vol. 4: 254 p.

Milanović P. 1981. Karst hydrogeology. Water Resources Publications, Littleton, CO..434 p.

Milanović P. 2000. Geological engineering in karst. Zebra Publishing Ltd., Belgrade. 347 p.

Milanović P. 2005. Water potential in southeastern Dinarides. In: Stevanović Z. & Milanović P. (eds): Water Resources and Environmental Problems in Karst—CVIJIĆ 2005,. Spec. ed. FMG. Belgrade, 249–257.

Milanović P. 2006. Karst of eastern Herzegovina and Dubrovnik littoral. ASOS, Belgrade, 362 p.

Ministry of Agriculture, Forestry and Water Management of Montenegro, 2001, Water management master plan of Montenegro, Ministry of Agriculture, Forestry and Water Management, Podgorica, Montenegro

Ministry of Agriculture, Forestry and Water Management of F B&H, 2009. "The Water Management Strategy of the Federation of Bosnia and Herzegovina, primordial report, Zavod za vodoprivredu Sarajevo i Zavod za vodoprivredu d.o.o mostar, Sarajevo, B&H

Ministry of Public Works and Transport of Republic of Albania, 2011, National water supply and sewerage sector strategy 2011-2017, Ministry of Public Works and Transport of Republic ofmkii Albania, Tirana, Albania

Ministry of Rural Development, Forestry and Water Management of Croatia, 2008, Water management Strategy, Croatian waters, Zagreb, Croatia.

Miošić N., Samardžić N., 2008., Groundwater flows connections and water supply in holocarstic of Lika and Bihać region, Croatia and Bosnia and Herzegovina, Herald Geological 37, Geological Institute of the Federation of B&H, Sarajevo,

Pekaš Ž., 2012. Hydrogeological report for Croatia, Zagreb. WG1 DIKTAS.

Radojević D., 2012. Hydrogeological report for Montenegro, Podgorica. WG1 DIKTAS.

Pletikapić Z.et al 2012: River basins management plan for Trebišnjica and Neretva - Methodology on identification of the types of groundwater bodies, Elektroprojekt Zagreb and Institute for Water Management Bijeljina, Zagreb

Radulović M. 2000. Karst hydrogeology of Montenegro. Sep. issue of Geological Bulletin, vol. XVIII, Spec. ed. Geol. Survey of Montenegro, Podgorica, 271 p.

Radulović V, Radulović M, 1997. Karst of Montenegro, in: '100 years of Hydrogeology in Yugoslavia' (ed. Z.Stevanović), Spec. ed. FMG, Belgrade, 147-185.

Republic Directorate for Water of Republic of Srpska, 2007. "The Framework Plan of Water Management Development of the republic of Srpska, Bijeljina, Republic of Srpska, B&H.

Roglić, J. 1965. The delimitations and morphological types of the Dinaric karst. Proceedings of 4th Intern. Spel. Cong. also in: Nase jame, Ljubljana, 7 (1-2): 12-20.

Roglić, J. 1972. Historical review of Morphological Concepts. In: Herak, M. and Stringfield, V.T. (eds.), Karst: Important Karst Regions of the Northern Hemisphere. Amsterdam, Elsevier Publishing Company.1-17.

Statistical office of Montenegro - Monstat, 2012. Demographic reports until 2012 , Monstat, Podgorica, Montenegro

Stevanović Z. 2010a. Major springs of southeastern Europe and their utilization.

In: Krešić, N. & Stevanović, Z. (eds.): Groundwater Hydrology of Springs: Engineering, Theory, Management, and Sustainability, Elsevier Inc., 391-412.

Stevanović, Z. 2010b. Intake of the Bolje Sestre karst spring for the regional water supply of the Montenegro coastal area.- In: Krešić, N. & Stevanović, Z. (eds.): Groundwater Hydrology of Springs: Engineering, Theory, Management, and Sustainability, Elsevier Inc., 459-480.

Stevanović Z., Eftimi R. 2010. Karstic sources of water supply for large consumers in southeastern Europe – sustainability, disputes and advantages, Geologica Croatica, 63/2:179-186.

Šarin A., Kostović-Donadini K., 1981. Reserves of groundwater in Dalmatian catchments for 1979/1980. Geol. Survey of Croatia, Zagreb

Šarin A. 1983. Hydrogeologic regional classification of the karst of Yugoslavia. In: Hydrogeology of the Dinaric Karst. Mijatovic B (ed.). Spec. ed. Geozavod, Belgrade, pp. 35-44.

The Secretariat of the Convention on Wetlands, 2013. "The List of Wetlands of International Importance" from 7 May 2013, The Secretariat of the Convention on Wetlands, Gland, Switzerland.

The Vienna Institute for International Economic Studies (2011) wiiw Handbook of Statistics 2011: Central, East and Southeast Europe, The Vienna Institute for International Economic Studies: Vienna.

UNCTAD (2011) World Investment Report, available at:

http://www.unctaddocs.org/files/UNCTAD-WIR2011-Full-en.pdf

UNDP GoAL WaSH Programme Governance Advocacy and Leadership for Water: Sanitation and Hygiene: Volume 1 Bosnia and Herzegovina, 2009, UNDP, Vienna

UNEP, Mediterranean Action Plan, Priority Action Programme, 2000. River Cetina watershed and adjacent coastal area. Environmental and socio-economic profile. PAP, Split

World Tourism &Travel Council, 2011. Ekonomski uticaj putovanja i turizma Crna Gora 2011, World Tourism &Travel Council, London