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REGIONAL STRATEGY FOR SUSTAINABLE HYDROPOWER IN THE WESTERN BALKANS

Background Report No. 2

Hydrology, integrated water resources management and climate change

Final Draft 4

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Contents

List of abbreviations and symbols

Abbr. & Symbols	Description / Meaning
ALB	Acronym used for Albania
a.s.l.	Above sea level
BAT	Best available technology
BiH	Acronym used for Bosnia and Herzegovina
BR	Background Report
CO2	Carbon Dioxide
DG NEAR	Directorate-General for Neighbourhood and Enlargement Negotiations
EAF	Ecologically Acceptable Flow
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EU	European Union
FBiH	Federation of Bosnia and Herzegovina, entity of Bosnia and Herzegovina
GEF	Global Environment Facility
GHG	Greenhouse gases
HPP	Hydro power plant
ICPDR	International Commission for the Protection of the Danube River
IFI	International Financing Institution
IPA	Instrument for Pre-accession
IPF	Infrastructure Project Facility
IPF3	Infrastructure Project Facility - 3rd Technical Assistance Window
IRBM	Integrated River Basin Management
IRC	International River Commission
ISRBC	International Sava River Basin Commission
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
KESH	Korporata Elektroenergjitike Shqiptare (a power utility of Albania)
KOS	Acronym used for Kosovo
MCA	Multi-Criteria Assessment (a methodology used in the sub-project)
MNE	Acronym used for Montenegro
Mott MacDonald-IPF Consortium	The Consortium carrying out the sub-project under WBIF-IPF3
NGO	Non-governmental organisation
RB	River Basin
RBD	River Basin District
RS	Republika Srpska, Entity of Bosnia and Herzegovina
SE	South-East
SEA	Strategic Environmental Assessment
SER	Acronym used for Serbia

Abbr. & Symbols	Description / Meaning
TA	Technical Assistance
ToR	Terms of Reference
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WBEC-REG-ENE-01	WBIF designation of this sub-project
WBIF	Western Balkans Investment Framework
WB6	Western Balkans consisting of 6 countries: Albania, Bosnia and Herzegovina, Kosovo, the former Yugoslav Republic of Macedonia, Montenegro and Serbia
WFD	Water Framework Directive (Directive 2000/60/EC)

MOTT MACDONALD IPF CONSORTIUM

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0 PREAMBLE

The REGIONAL STRATEGY FOR SUSTAINABLE HYDROPOWER IN THE WESTERN BALKANS[1] — referred as "the Study" — is a sub-project under implementation by the WBIF-IPF3 Consortium led by Mott MacDonald, with the European Commission, DG NEAR D.5, being the Contracting Authority for the WBIF-IPF3 contract.

The six Western Balkans beneficiary countries comprise Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Kosovo*, Montenegro and Serbia - the WB6 region.

The work programme of the Study includes 13 Tasks as stipulated in the Terms of reference (ToR):

- Task 1: Hydropower role (past and future) in the regional and national context;
- Task 2: Assessment of the current situation in the institutional-organisational framework relevant for hydropower development;
- Task 3: Assessment of the current situation in the legal-regulatory framework relevant for hydropower development;
- **Task 4: Assessment of hydrology baseline, water-management by country and by river basin with transboundary issues;**
- Task 5: Grid connection issues in network development context;
- Task 6: Identification of HPP projects and acquiring relevant information for the HPP inventory and investment planning;
- Task 7: Environmental, Biodiversity and Climate Change Analysis on (i) river basin level and (ii) country-level of identified hydropower schemes;
- Task 8: Establishment of the central GIS database;
- Task 9: Development of a web-based GIS application;
- Task 10: Multi-Criteria Assessment (MCA) of prospective hydropower projects;
- Task 11: Drafting of Regional Action Plan on Hydropower Development and compilation of Final report on the Study;
- Task 12: Establishment of IT-supported Information and Document Management System (IDMS);
- Task 13: Training and dissemination of Study results.

The Study deliverables encompass separate Background reports (BR) that focus on specific technical issues in professional areas related with hydropower sector development, e.g.:

- Background report n° 1 (BR-1) – Past, present and future role of hydropower
- **Background report n° 2 (BR-2) – Hydrology, integrated water resources management and climate change considerations**
- Background report n° 3 (BR-3) – Environment considerations
- Background report n° 4 (BR-4) – Regulatory and institutional guidebook for hydropower development
- Background report n° 5 (BR-5) – Transboundary considerations
- Background report n° 6 (BR-6) – Grid connection considerations
- Background report n° 7 (BR-7) – Inventory of planned hydropower plant projects
- Background report n° 8 (BR-8) – Identification of potential sustainable hydropower projects

This Background Report no. 2 (BR-2), is an output and deliverable of Task 4. Background Report 4 (BR4) is also an output of Task 4.

* This designation is without prejudice to position on status, and is in line with UN Security Council Resolution 1244/99 and the International Court of Justice Opinion on the Kosovo declaration of independence.

[1] The designated WBIF code of this sub-project is WBEC-REG-EN-01.

Enlargement process

The EU Enlargement process is the accession of new countries to the European Union (EU). It proved to be one of the most successful tools in promoting political, economic and societal reforms, and in consolidating peace, stability and democracy. The EU operates comprehensive approval procedures that ensure new countries will be able to play their part fully as members by complying with all the EU's standards and rules (**the *"EU acquis"***). The conditions of memberships are covered by the Treaty on European Union.

Each country moves **step by step** towards EU **membership as it fulfils its commitment**s to transpose, implement and enforce the Acquis.

The EU relations with the Western Balkans countries take place within a special framework known as the **Stabilisation and Association Process (SAP)** in view of stabilising the region and establishing free-trade agreements. To this end, all WB6 countries have signed contractual relationships (bilateral **Stabilisation and Association Agreements, or SAAs**) which entered into force, depending on the country, between 2004-2016.

The **accession negotiations** are another step in the accession process where the Commission monitors the candidate's progress in meeting its commitments on 35 different policy fields (chapters), such as transport, energy, environment and climate action, etc., each of which is negotiated separately.

At the time of writing (November 2017), there are four WB6 countries that have been granted **Candidate Country** status: the former Yugoslav Republic of Macedonia, Montenegro, Serbia and Albania, while Bosnia and Herzegovina and Kosovo have the status of **Potential Candidate** countries at this date. With two countries, Montenegro and Serbia, the **accession negotiations** have already started and several of the chapters of the EU *acquis* have been opened.

To benefit from EU financing for projects, each country **should respect the EU legislation relevant to that project,** even if the national legislation has not been yet fully harmonised with the EU acquis.

The "Regional Strategy for Sustainable Hydropower in the Western Balkans" aims to set guidelines for a sustainable development of hydropower in the Western Balkans.

EU Acquis relevant to the Study

In the context of this Study, **the most relevant thematic areas are spread mainly over two Acquis Chapters** (15 on Energy and 27 on Environment) relating to water resources, energy, hydropower development and environmental aspects including climate change.

- Chapter 15 Energy Acquis consists of rules and policies, notably regarding competition and state aid (including in the coal sector), the internal energy market (opening up of the electricity and gas markets, promotion of renewable energy sources), energy efficiency, nuclear energy and nuclear safety and radiation protection.
- Chapter 27 relates to 10 sectors / areas: 1 - Horizontal Sector, 2 - Air Quality Sector, 3 - Waste Management Sector, 4 - Water Quality Sector, 5 - Nature Protection Sector, 6 - Industrial Pollution Sector, 7 - Chemicals Sector, 8 - Noise Sector, 9 - Civil Protection Sector, and 10 - Climate Change Sector.

Commission President Juncker said in September 2017 in his State of the Union address that: *"If we want more stability in our neighbourhood, then we must also maintain a credible enlargement perspective for the Western Balkans".* To Serbia and Montenegro, as frontrunner candidates, the perspective was offered that they could be ready to join the EU by 2025. This perspective also applies to all the countries within the region. This timeline also corresponds to the period for preparing such major infrastructures and their lifetime. Consequently, WB6 countries have to demonstrate now that they are and will develop sustainable hydropower according to EU rules.

Relevant pieces of EU legislation and international agreements

Hydropower development should be done while respecting relevant EU legislation and international agreements to which the WB countries are Parties. This includes:

- Renewable Energy (Renewable Energy Directive 2009/28/EC)
- Energy Efficiency Directives (2012/27/EU; 2010/30/EU; 2010/31/EU)

- Environmental Impact Assessment Directive (Directive 2011/92/EU as amended by Directive 2014/52/EU) and Strategic Environmental Assessment Directive (Directive 2001/42/EC)
- Water Framework Directive (Directive 2000/60/EC)
- Habitats Directive (Directive 92/43/EEC) & Birds Directive (Directive 2009/147/EC)
- Floods Directive (Directive 2007/60/EC)
- Paris Agreement on climate change
- Aarhus Convention (the UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters)
- Espoo Convention (the UNECE Convention on Environmental Impact Assessment in a Transboundary Context)
- Berne Convention (the Berne Convention on the Conservation of European Wildlife and Natural Habitats)

The framework conditions and legal obligations for hydropower development stem from the EU acquis and international obligations, the implementation of which should be supported through the Energy Community Treaty (to which all of the WB6 countries are signatories) as well as International River Basin Organisations.

As **Contracting Parties (CPs) to the Energy Community Treaty (ECT),** the WB6 countries have obligations and deadlines to adopt and implement acquis closely related to the energy sector / market development and environment such as:

- Electricity (Directive concerning common rules for the internal market in electricity (Directive 2009/72/EC); Regulation on conditions for access to the network for cross-border exchanges in electricity (Regulation (EC) 714/2009); Regulation on submission and publication of data in electricity markets (Regulation (EU) 543/2013))
- Security of supply (Directive concerning measures to safeguard security of electricity supply and infrastructure investment (Directive 2005/89/EC)
- Infrastructure (Regulation on guidelines for trans-European energy infrastructure (Regulation (EU) 347/2013)
- Energy Efficiency Directives (2012/27/EU; 2010/30/EU; 2010/31/EU)
- Renewable Energy (Renewable Energy Directive 2009/28/EC)
- EIA Directive (Directive 2001/92/EU);
- SEA Directive (Directive 2001/42/EC);
- Birds Directive (Directive 79/409/EEC);
- Directive on environmental liability with regard to the prevention and remedying of environmental damage (Directive 2004/35/EC as amended by Directive 2006/21/EC, Directive 2009/31/EC)
- Large Combustion Plants Directive 2001/80/EC

Note: We recognise that close coordination between the energy, environment and climate change legislation and policies is necessary in the context of sustainable hydropower development.

However, to avoid duplications in the BRs, issues related to the WFD and Floods Directives are addressed in more detail in BR-2 (Hydrology, integrated water resources management and climate change considerations) and BR-5 (Transboundary considerations), respectively while all other Directives (in addition to the WFD and Floods Directives) comprising the EU environmental legislative package (Habitats, Birds and SEA/EIA) are addressed in more details in BR-3 (Environment considerations).

Small Hydropower Plants in the Regional Strategy for Sustainable Hydropower in the Western Balkans

While the 390 small hydropower plants in the Western Balkans 6 region represent almost 90% of all hydropower plants, they only produce 3-5% of the total hydropower generation and constitute 7% of the total hydropower capacity, most of hydropower energy and capacity in the region being delivered by the large hydropower plants.

This raises the question of the role of small hydro power plants and the pertinence of further developing such infrastructures. Their contribution to the global energy production and security of supply, or to the renewable energy sources targets, is extremely limited. In parallel, their impacts on the environment are severe, as they create multiple interruptions in water flows and fish passages, increase habitat deterioration and require individual road access and grid connections. Furthermore, while most of these small hydropower plants were commissioned after 2005, when the state-support schemes – mainly feed-in tariffs – which will be phased out after 2020 and hence it is expected that the private sector interest in developing small hydropower plants will diminish significantly.

Due to the large number of small hydropower existing plants and projects, and due to the questions on their role and pertinence, the Regional Strategy for Sustainable Hydropower in the Western Balkans focused on major hydropower contributors to the power system, that is to say large hydropower plants of a capacity above 10 MW. Nevertheless, wherever possible, small hydropower plants have also been addressed in the study.

1 INTRODUCTION

1.1 Background to Hydrology and Related Issues of the Hydropower Schemes in the WB6 Region

Alternative options for potential private and/or public investment development projects in the river systems of the WB6 Region involve not only new dams and water storage reservoirs for hydropower, but also other water uses such as: developing agricultural irrigation systems, new touristic resorts and various water-related facilities for urban and industrial water supply.

These developments will be implemented in different river basins, where different socio-economic conditions exist and therefore different preferences and objectives prevail. Alternative hydropower options should consider environmental consequences, impacts to ecosystems and human health, and financial and social risks while optimising water power use. The impacts on the environment and their prevention should be weighed against the economic benefits and social consequences.

Since the 6 countries of the WB6 Region are candidates or potential candidates and committed to transpose and implement EU legislation, the in-depth understanding of mutual interdependencies across borders still has to mature. Therefore, an urgent need for cooperation and the application of EU guidelines for Integrated Water Resources Management (IWRM) in the shared river basins has emerged.

The concept of IWRM or Integrated River Basin Management (IRBM) has been defined as a process that promotes the coordinated development and management of water, land and related resources to maximise the resultant economic and social welfare (efficiency) in an equitable manner without compromising the sustainability of vital ecosystems.

Despite the usual emphasis on “environmentally sound energy”, hydropower (particularly those with storage reservoirs) has multiple effects; it is well-known that some reservoirs are emitting both CO_2 and methane and have indirect impacts on river outflow areas to the sea with decreased deposition of silt. There is a small greenhouse effect connected to run-of-river hydropower reservoirs; however, the effect is much larger considering the reservoirs of large dams. Dissolved methane builds up from decayed plants and trees, which remain under tamed streams. Methane is estimated to have up to 25 times the impact on climate change than CO_2 and is released mostly through the dam turbines. However, per the most recent IPCC Assessment Report - No. 5, the global warming potential indicator should be increased from 25 to 84-86: http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf

Climate change, following strong scientific consensus and international political commitments, has become a fact in everyday conversations, in the media, among various experts and among ordinary people. There are many ways to mitigate the rise of greenhouse gases (GHG); the most notable is minimising the use of fossil fuels. In this context, the extended usage of hydropower could be an answer; but some questions arise regarding hydropower and climate change. If hydropower is a renewable resource, it does not automatically mean that GHGs are not emitted from a reservoir at all. The question is then what is the contribution of reservoirs to climate change emissions and from where are these emissions sourced?

Seasonal changes in water depth mean there is a continuous supply of decaying material. This presents a concern to countries, many of which will rely heavily on hydropower operations in the future.

More frequent and intense extreme events like floods affect water quality, water infrastructure integrity and increase fluvial erosion, which on the other hand, introduces different properties of pollutants to water resources. One of the most significant consequences of flooding is the intensive sedimentation of reservoirs, which is expected to intensify in future because of still-developing climate change. It is believed that the source of the GHGs lies in sediments’ capacity to develop slime foil.

1.2 Objectives

The Study follows a regional and **River Basin approach** in line with the WFD and applicable guidelines (e.g. ICPDR). For that reason, among others, the Study did not attempt to develop National Hydropower Master-Plans. That will require both SEA (planning) and EIA (project design) procedures and their associated public consultation processes. Instead, the objective was to prepare a baseline for policy documents that are typically adopted by governments or even parliaments in some cases. The Study contains numerous recommendations that will help national authorities in the development of their own plans, following at a later stage. Therefore, it is evident that the Study results are limited to recommendations rather than any mandatory solutions for the WB6 countries, for which the countries clearly retain their sovereignty in decision-making as long as that policy-making is compliant with the applicable national and international legislation in force.

When one or more interventions in a river system are planned, like water controlling measures such as reservoirs, then the **cumulative impacts** will be significant, and must be assessed. It would be too early at this Study development phase to assess concrete cases of cumulative effects of selected HPPs in the WB6 region. For that purpose, at least a conceptual design of a HPP, or a cascade of HPPs, together with planned reservoirs, would be needed to identify measures to alleviate and compensate for cumulative impacts.

It should be understood in the planning stages, when dealing with development of HPP schemes in the region, before even starting preparations, measures for overcoming sediment trapping, not stopping the migration of water organisms, salami slicing of river habitats, or extensive hydro-peaking and drying up of the river for that matter, must be all part of a coherent technical concept and may require considerable funding to achieve.

Assessment of the cumulative effects along main rivers in terms of selected key environmental categories such as water discharges, sediments and biodiversity issues of river (sub)basins with other major river basins (e.g. at the confluence of Drina and Sava) was not done at this stage. Obviously cumulative effects can be assessed correctly, by modelling, once (i) a RBMP is available, and (ii) the dynamics, number and specific technical designs of the proposed individual HPPs in each river basin, including their possible mitigation measures are established. The readiness of strategic planning documents in the WB6 region is still at an early stage. Being guided by the need to provide at least basic cumulative effects assessment inputs for the process of prioritisation, qualitative assessment depending on specifics and data available was prepared and used for MCA.

None of the prioritised HPP projects can obtain location or building consent without a proper cumulative impact assessment done in the process. These projects are cleared for further consideration and development after integrated water resources planning has been done under a completed environmental (including cumulative) assessment.

Considering hydropower development in the region, namely for the prioritised projects, which are subject to further exploration and potentially the future designation of Natura 2000 sites and no-go zones by countries, a full scope cumulative impacts assessment will be needed. To collect the needed data, priority should be given to WFD requirements (notably the systematic development of river basin management plans).

The Study provides information on the **environmental monitoring** of water quantity, the current requirements of the **Water Framework Directive** (WFD) for WB6 Candidate and Potential Candidate countries, which all committed to transpose and implement the Acquis (through Stabilisation and Association Agreement, accession negotiations, etc.) and its considerations and the likely implications on hydropower development in the medium-term future.

The WFD is a key environmental directive and exemptions from achieving good water body status should be considered only in exceptional cases. Before considering the application of exemptions for a certain water body, all relevant requirements from EU legislation for the protection of water have to be fulfilled, despite the fact that exemptions are set out in Article 4 and the planning process. The analysis done for eventual exemptions should be kept as simple as possible, but must include the needed detail. The level of information should be determined by the decision's complexity and foreseen consequences of making an unsatisfactory decision. When consensus among stakeholders is reached in an early decision-making phase, data gathering efforts may be relaxed.

Article 4(7) of the WFD is to be invoked in the case of hydropower as it implies "new modifications to the physical characteristics of a surface water body or alterations of the groundwater level" (as first indent of 4(7)) and / or "deterioration from high or good status […] because of new sustainable development activities" (second indent of 4(7)). Balancing sustainable economic development with environmental and other considerations is the way to respect Article 4(7). There are numerous ways to make this feasible, as indicated by the ICPDR guidance to Article 4(7) guidance and the forthcoming guidance of the EU. In addition to the public interest argument in 4(7)c, there are another three conditions which are not simple but not impossible.

The provision of this Article would allow exemption under exceptional circumstances, not related to normal planning procedures. One reason for such a determination could be public interest, namely to ensure the security of electrical energy. Electricity production in the Western Balkans is currently below demand. Recent expectations in electricity consumption in the region due to general economic development are higher than supply capacity. Due to this increase, besides introducing energy efficiency measures, it is necessary to provide additional electricity generation resources locally. Planned hydropower production facilities, as part of the broader strategy to increase the production of renewable energy, will help to increase the autonomy, reliability and competitiveness of the regional electricity system and this is therefore of national importance – thus constituting an important argument for an exemption under Art 4(7) c of the WFD. Exemption is always based on the principle of the best public interest, that is, ensuring the security of supply of electrical energy and assuming there is no 'significantly better environmental option such as other sources of renewable energy.

The science on **climate change** is compelling, however the application of this science to infrastructure development projects such as hydropower at location-specific projects has not yet been fully resolved and remains controversial between practicing engineers and other climate stakeholders. By acknowledging the baseline of long-term climate processes and climate change as a whole, which has been presented by leading international institutions like UN and EEA, this background report has examined all currently-held views and opinions relating to climate change in the context of hydrology and hydropower development. Therefore, this report develops and endorses key recommendations for hydropower development and water regulating structures based on the latest elaboration of mitigation and adaptation measures available through literature sources.

By the introduction of simplification in the **river and hydrology network classification,** the very complex system of water streams in the WB6 countries was made more transparent and manageable for the purpose of the Study. The Study deals with: 4 Drainage Basins (DB) (1 Black Sea and 3 Mediterranean), 13 Watersheds (WS), 17 River Basins (RB), 10 Sub-RBs, 26 Rivers, 77 Tributaries 1, and 25 Tributaries 2T. The difficult nature of territorial divisions in the catchment areas will surface again when water-management plans are scaled down from larger regions to smaller areas. This case is illustrated by the Sava RB Management Plan, which was harmonised in principle within all the countries of this RB, but when the details and solutions for the Drina RB will be decided, like changing the water balance, connectivity etc., the complexity of resolving such issues within larger River Basins will emerge in full.

1.3 Activities

This regional study on the potential for developing sustainable hydropower production rests upon safeguarding protected areas and adopting sound environmental and water management principles. This part of the Study, Background Report No. 2, relating to Hydrology and associated topics, was prepared based on well-established environmental principles.

For sustainable hydropower development practices, beyond EU legislation (notably the need to do SEA and EIA at an earliest stage of HPP planning), additional guidance has been developed. The European Commission is providing a range of guidelines, notably with the forthcoming guidance document on Natura 2000 and hydropower as well as guidelines from other organisations, such as those of the ICPDR, the International Hydropower Association (IHA), and financial institutions.

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In the framework of the Study, the Strategy developed, among other relevant factors, considered alternatives of HPP development, accounting for cases with and without the realisation of the reservoirs or HPPs, or reservoir alternatives having different water table levels, for example. A certain amount of consultation was carried out with the project beneficiaries and NGOs on the various options. These SEA principles have been reflected throughout the development of the report and are interwoven with other salient issues. The current hydrology and hydrographic descriptions, including the water setting of river basins is presented, together with some quality issues and biodiversity. The MCA process (BR-8) and BR-3 on Environment considerations elaborate on these inputs for the estimation of impacts, which were taken forward into the MCA criteria.

The collection and assessment of hydrological data are at two levels, (1) by Water Catchment Area (i.e. river basin) and (2) by Country. During this activity, the project team initially experienced a reluctance in countries to deliver daily discharge data. Eventually, data was obtained through local experts for Albania, Bosnia and Herzegovina, Serbia, and the former Yugoslav Republic of Macedonia; however, the data differed in both quality and measurement periods. The data that were analysed were generally of poor quality and were not suitable to carry out the energy potential estimation throughout the Region, which was initially conceptualised. To achieve this, harmonised hydrological data by period, site / river basin and quality needs to be available. The daily discharge data collected for this Study is available in a digital form and can be supplied upon request.

The hydrological data available is therefore either inadequate or in some cases missing. For the hydro power potential calculation or climate change modelling, the data available either does not exist or is of poor quality. For example, for the estimation of hydropower energy potential, a run-off model was created. This model proved to be a useful tool for the estimation of hydropower potential, in a case with relatively good meteorological data and in the absence of measured data. Measured water table values at least at two river profiles sufficed for model calibration purposes.

Data limitations are often stated as one of the reasons for unsustainable hydropower planning. However, data are limited for various reasons; in any case data exist and are not absent as suggested, allowing for an acceptable degree of reliable planning. Concerning hydrologic data, there is a message that has been passed to the region, namely that the requirements of the WFD and other relevant legal acts are much higher than they were in the past, so the measurement, collection and storage of data must be action prioritised at a national level.

Recommendations on the way forward regarding hydropower development in the region do not depend solely on data. Namely, there are other issues, like the enforcement of EU environmental legislation, water management organisation, the transboundary platform and alike to be resolved before the proper planning of hydropower is initiated. Data are criticised for a reason; however, it is not within the scope of this Strategy to deal with this topic in general terms, except to provide an insight into problems encountered related to hydropower prioritisation.

The impact of climate change on the run-off should be at about the same levels throughout the Region, therefore, climate change has very limited impact on the comparisons of hydropower development – i.e. the prioritisation of HPP-candidate investments, being one of the objectives of the Study – because it affects electricity production differentially only slightly across the region. Those differences are too small to be considered in the comparative performance assessment and ranking of HPP candidates. However, on an individual basis, the effect of climate change will play an important role in that specific HPP's electricity production assessment. At present, the effect of climate change on watershed run-off is not discernible, and there is not enough consensus about what will happen to hydrology over a period of 40/80 years of prospective HPP life, although clearly the trend of discharge is expected to be decreasing over that period. Other relevant and appropriate sources (existing studies and reports, see References list) were used to develop the study conclusions in respect of hydrology and related issues such as WFD requirements, cumulative impacts and climate change.

The Feasibility Study of every project development will deal with climate change in line with the best available guidance provided, for example, by Jaspers: technical assistance partnership between three partners (European Commission, EIB and EBRD).

Several information exchanges and country visits were conducted to obtain correct information and additional insights into the planning processes in individual WB6-countries relating to rivers and water resource development. including hydropower.

1.4 Links with other tasks of the Study

Links in the text are made to BR-5 on Transboundary considerations and to BR-3 on Environment considerations relating to defining technical limits for the development of HPPs and providing clear indicators on the assessment of the HPPs, environmental requirements stemming from climate change, biodiversity needs and the assessment of cumulative impacts.

2 DRAINAGE BASINS OVERVIEW

2.1 Black Sea Drainage Basin

The major Rivers and Tributaries in the Black Sea Drainage Basin are the Sava and Morava Rivers.

2.1.1 Danube River Basin: An Overview

2.1.1.1 Geomorphology

The Danube flows for a distance of 2,826 km and enters the Black Sea east of Izmail (Ukraine) and Tulcea (Romania). The Danube is the second largest river in Europe and drains an area of approx. 801,093 km^2. The basin drains parts of 19 countries with a total human population of 83 million (census in 2002). The average altitude of the basin is 458 m.

A characteristic feature along the entire river is the alternation between flat basins and deep gorges. Immediately downstream of the Porta Hungarica, the Danube forms a vast internal delta, and the slope decreases to 0.08–0.03‰. The main right-bank tributaries include the Leitha, Raab, Drava, Sava and Velika Morava Rivers.

The Lower Danube is a typical lowland river fringed by (formerly) wide floodplains. In the 1960s, major flood-plain sections (5,500 km^2, or 72% of former floodplains) were cut off from the river and transformed into agricultural land, poplar plantations, and fish ponds. Despite the loss of floodplains, the Lower Danube represents an ecologically highly valuable section, with numerous islands, natural banks and floodplain remnants.

The Danube basin fully or partially covers nine Eco Regions: the Alps, Dinaric Western Balkan, Hellenic Western Balkan, Eastern Balkan, Central Highlands, the Carpathians, Hungarian Lowlands, Pontic Province and Eastern Plains. For the transitional and Black Sea coastal waters, Romania and Bulgaria have proposed to define the Black Sea Eco Region.

2.1.1.2 Climate and Hydrology

Due to its large size, its distinct west–east orientation, and its diverse relief, the basin exhibits a large climatic heterogeneity. The Upper Danube is influenced by an Atlantic climate with high precipitation and mild winters, whereas the eastern regions are under a continental influence with low precipitation and dry and cold winters. Parts of the Drava and Sava Rivers are influenced by a Mediterranean climate. The heterogeneity of the relief, especially the differences in the extent of exposure to predominantly westerly winds, as well as the differences in altitude, di- versify this general climate pattern. This effect leads to distinct landscape regions that exhibit major differences in climatic conditions.

Precipitation ranges from <500 to >2,000 mm. Average annual precipitation peaks in the highest parts of the Alps (3,200 mm) but is as low as 350 mm in the Black Sea and delta regions. Snow cover between November and February/March is expected at an elevation >1,500 m a.s.l. Average peak precipitation occurs in July in the western part of the basin, in May/June in the south-eastern parts, and in autumn in the areas influenced by the Mediterranean. The highest average annual temperature (+11 to +12 °C) occurs in the Middle and Lower Danube and in the lower Sava valley.

Figure 2.1: River Basins pertaining to Sava and Danube River Basin in the Black Sea Drainage Basin

Spatial and seasonal differences in precipitation have strong effects on the surface run-off and discharge regime of the Danube and its main tributaries. For example, Austria (22% of total flow) and Romania (18%) contribute most to the total flow of the Danube, reflecting the high precipitation in the Alps and Carpathian Mountains.

In the Lower Danube, the flow regime has been modified by the Iron Gate dams as well as by the large water management schemes along the Olt, Arges, Siret and Prut Rivers (Romania). The suspended sediment load decreased from around 40 million tons/year (maximum of 106 million tons in 1940) to a low of 7.3 million tons/year today. The basin has experienced many disastrous floods.

2.1.1.3 Water Quality and Nutrients

Over the last 50 years, water quality has become a key issue for the Danube and the coastal zone of the Black Sea. In addition, the self-purification capacity of the river suffered from toxic industrial wastewater inputs. In the early 1980s, construction of wastewater treatment plants (WWTP) led to a major reduction of biodegradable organic matter and improved the water quality in the Upper Danube. Water quality in the Middle and Lower Danube remained relatively high (class II) between 1950 and the 1970s, but deteriorated afterwards due to rapid industrial development, poor pollution control, and inputs from heavily polluted tributaries.

The economic breakdown in downstream countries also led to significant reductions of total Phosphorus (P) from agricultural and industrial sources. In combination with the retention of P in the Iron Gate reservoirs, P loads decreased to levels found in the 1950s. The present total nitrogen (N) load into the river is still 2.2 times higher than in the 1950s, although inputs have slightly decreased since the peak in the 1980s.

The total annual nutrient load in the river was estimated to be around 750,000 tons N/year and 68,000 tons P/year. For nitrogen (N), the main sources are groundwater (from agricultural inputs) and WWTPs (about 67% of all sources). For phosphorus, WWTPs and land erosion are the dominant sources (>80% of all sources), emphasising the importance of point sources of phosphorus. The relative contribution of different countries and of different sub-catchments varies considerably for P and N. Today's total N and P loads are up to 10 times above natural background values.

In a recent study, it has been shown that the Iron Gate reservoirs are of relatively low importance in retaining sediments and nutrients. The numerous dams along tributaries and the mainstream upstream of the Iron Gate reservoirs may account for these differences, as well as the natural retention capacity of small tributaries. Less than 4% of the dissolved silica in the river is retained in the Iron Gate reservoirs, pointing to the role of the large number of other reservoirs within the basin in nutrient retention. Regardless, the Iron Gate reservoirs still play an important role in the retention of suspended sediments and P.

Nitrate is the main component of N transported in the river (>70% of total N), and nitrate concentration decreases with increasing river size. Ammonia and nitrite contribute <10% to the total N load.

In the Upper Danube, major floods (with a probability of once in 10 to 100 years) can transport between 25–65% of the total annual P-load. Dissolved silica, another key nutrient important for algal growth in aquatic ecosystems, exhibits a mean concentration between 4.7 and 8.4 mg/L in the Danube and increases with river size.

Today, the mainstream of the Danube has relatively good water quality (classes II to II–III). A few tributaries have water quality lower than class III for single nutrient parameters. Since 2000, the organic carbon load (expressed as TOC) and the BOD5 (biological oxygen demand during 5 days) have been monitored in the Danube and its tributaries. The TOC load increases from 70,000 tons/year to 550,000 tons/year from the Upper to the Lower Danube. The Tisza and Sava are main contributors of TOC.

2.1.1.4 Biodiversity

The Danube River Basin is a 'hot spot' for European freshwater biodiversity based on traditional zoogeographic and recent phylogeographic studies. The Danube is rich in biodiversity because of its orientation and history. The predominantly East–West alignment of the basin made it a corridor for migration and re-colonization, both before and after the ice ages as freshwater organisms moved between the Ponto-Caspian and central Asian biogeographic regions to the east and the Alpine and Mediterranean regions to the west. The mainstream of the Danube was un-glaciated, and served as a 'refuge'. As the ice sheets retreated, freshwater species expanded from this refuge to the rest of Europe. The Danube delta also is a meeting point of Palaearctic and Mediterranean biogeographic zones with a high number of wetland habitats and a rich biodiversity. Since sub-Mediterranean flora and fauna is commonly found in northern Serbia and along the mainstream of the Danube up to the Iron Gates, it is assumed that the Vardar and Morava Rivers (the so-called 'Vardar breach') played a major role in connecting the Danube with the Mediterranean.

2.1.2 Sava River Basin – Water Management Overview

The 945-km long Sava River is the largest tributary of the Danube by volume (average discharge: 1,572 m^3/s) and the second largest, after the Tisza, by catchment area (95,793 km^2). Today, the Sava basin is an international basin: 40% is in Bosnia and Herzegovina, 26% in Croatia, 15.4% in Serbia, 11% in Slovenia, 7.5% in Montenegro and 0.1% in Albania. Several tributaries such as the Kolpa/Kupa, Una and Drina Rivers cross international boundaries. About 8.8 million people live in the basin. Belgrade, Zagreb, Sarajevo, Ljubljana and Banja Luka are the largest cities (1.6 million, 780,000, 304,000, 280,000 and 225,000 inhabitants, respectively). Some 37% of the basin is arable land, and 45% is forested.

2.1.2.1 Geomorphology

In Croatia, downstream of Zagreb, the Sava meanders through a wide valley covered with fertile soils and fringed by wetlands (average slope: 0.04‰). The Sava passes by the valley of the Kolpa/Kupa River and for 311 km the Sava constitutes the border between Croatia and Bosnia and Herzegovina: from the confluence of the tributary Una almost to the confluence of the Drina. In Serbia, it remains a typical lowland river with a channel width of up to 1,000 m before it enters the Danube in Belgrade. In the downstream section, alluvial sediments and igneous rocks with Neogene marls and shale prevail. The Sava drains the south-eastern fringe of the Alps and the north-eastern Dinaric Mountains as well as the southern Pannonian lowland. Although most of the catchment is in the Alps and Dinarids, the river traverses a wide lowland valley. Most major tributaries enter from the right side. About 25% of the basin is karstic.

Table 2.1: General Characterisation of Danube River Basin

	Sava	Una	Sana	Vrbas	Bosna	Drina	Velika Morava
Mean catchment elevation (m)	541						631
Catchment area (km^2)	95,793	9,828	4,252	6,273	10,809	20,319	37,571
Mean annual discharge (km^3)/average flow (m^3/sec)	49.6	238		114	164	387	8.74
Mean annual precipitation (cm)	105.4						77.8
Mean air temperature (°C)	9,2						9,3
Number of ecological regions	4						3
Dominant (≥25%) ecological region(s)	27; 52						9
Land use (% of catchment)							
Urban	2.1						1.7
Arable	36.9						38.8
Pasture	5.8						7.3
Forest	45.3						42.6
Natural grassland	8.4						8.8
Sparse vegetation	0.7						0.5
Wetland	0.1						0
Freshwater bodies	0.7						0.3
Protected area (% of catchment)	0.8						0
Water stress (1–3)							
1995	2						2
2070	2.9						2.9
Fragmentation (1–3)	2						2
Number of large dams (>15 m)	18						3
Native fish species	50						35
Non-native fish species	5						7
Large cities (>100,000)	5						1
Human population density (people/km^2)	92						116
Annual gross domestic product ($ per person)	3,664						702

2.1.2.2 Climate, Hydrology and Biogeochemistry

The Sava basin exhibits a mixture of Alpine and Mediterranean climates. Average annual air temperature is 9.2 °C and average annual precipitation is 1,000 mm. Maximum precipitation is approx. 3,800 mm in the Julian Alps and in the upper Kupa region, and minimum precipitation is 600– 700 mm in the Pannonian Plain. The Sava has a nival-pluvial flow regime with a spring peak caused by snowmelt in the Alps and a second peak in autumn caused by heavy rainfall.

The average annual discharge of the river is 1,572 m^3/s at its mouth, with an annual peak discharge of around 6,400 m^3/s (1% probability of occurrence). The Drina River is the largest tributary with an average discharge of 370 m^3/s. The Sava contributes about 25% of the total Danube discharge from 15% of the Danube basin surface.

Together with the Tisza, the Sava dominates the discharge regime in the Lower Danube, causing two distinct seasonal maxima. The impounded section of the Iron Gate I and II dams extends 100 km upstream into the lower Sava near Belgrade.

Until the 1990s, the Sava was affected by heavy pollution from various industries, as well as from agricultural activities (agrochemicals, pesticides and pollution from animal farms). These activities reduced during the conflict in the 1990s, but have been resumed since 2000. The Sava is the main recipient of wastewater from many cities, including Zagreb (Croatia) and is impacted by polluted water of the tributaries Kupa and Bosna as well as smaller tributaries in the Zagreb region.

Thermal pollution from conventional power plants and a nuclear power plant (Krško in Slovenia) occurs along the Slovenian Sava sections. Today, the specific organic pollution in the basin is above the Danube average. The basin contributes 102,362 tons N (23% of the Danube basin) and 9,829 tons P (43% of the Danube basin) to the total annual load of the Danube River.

2.1.2.3 Biodiversity

For the Serbian river section, 62 macroinvertebrate species have been recorded. Molluscsa (Gastropoda: 12 species, Bivalvia: 11 species) and Oligochaeta (16 species) dominate assemblages, and the community structure indicates habitat degradation and organic pollution. Five non-native species are reported to occur. The bivalve Corbicula fluminea (Asian clam) and oligochaete Branchiura sowerbyi show high frequencies, while the bivalve Anodonta (Sinanodonta) woodiana exhibits high abundances. About 55 fish species, including the sterlet (*Acipenser ruthenus*), are found in the Sava River. The Nature Park 'Lonjsko Polje' in the middle Sava forms the largest remaining inundation area in the entire Danube basin (510 km^2). There, floodplain waters contain at least 35 fish species. This area is an important spawning area for wild carp (*Cyprinus carpio*). Further, 43 dragonfly species have been identified during a seasonal survey. The Nature Park provides breeding habitats for 22 bird species of special conservation concern in Europe, among them are rare birds such as the ferruginous duck (*Aythya nyroca*), white tailed eagle (*Haliaeetus albicilla*) and corncrake (*Crex crex*).

2.1.2.4 Human Impacts and Management

Major sections of the river still exhibit a relatively natural geomorphic structure and hydrological regime and are fringed by large protected wetlands. The mainstream is navigable for almost 600 km (from the mouth at Belgrade up to the city of Sisak, 60 km downstream of Zagreb) for small vessels and for 377 km (up to Slavonski Brod) for large vessels. The mainstream has been regulated for flood protection only in a very few, short sections (e.g. in Zagreb). In the central basin, only about 40% of the alluvial wetlands were converted into arable land or drained. Large parts of the city of Zagreb were built on the former floodplain. In the 1960s, the city expanded to the southern banks of the Sava and floods became an increasing threat.

The regulation of high water by the central Posavina flood control system is carried out via three relief canals protecting the towns of Zagreb (Odra Canal), Karlovac (Kupa-Kupa Canal) and Sisak (Lonja-Strug Canal), 15 distribution facilities and large alluvial retention areas for storage. This system has proven effective since its design in 1972, and the channels and facilities have been integrated into the existing limited flow river network. This is a system that, with the necessary retention and expansion areas in the lower central basin, and governed by the criteria established for the regulation of the water masses, ensures an unaltered water regime in the Mačkovac exit control profile (maximum: 3,000 m^3/s).

Two Ramsar sites – Lonjsko Polje and Crna Mlaka - and three important bird areas – Sava Wetlands, Odransko Polje and the Pokupsko depression – form a unique blend of natural landscape elements and European riverine lowlands. Further, large retention areas and alluvial wetlands are situated on the left Sava bank in the Spačva–Bosut depression at the border with Serbia.

Along the Serbian section, a 771-km long flood control embankment separates a former large inundation area. In Slovenia, four large and several small hydropower plants are in operation along the mainstream, one remaining to be constructed. A chain of hydropower reservoirs is planned in the Croatian section upstream of Zagreb, and additional multi-purpose reservoirs are foreseen. In Bosnia and Herzegovina, 12 hydropower plants are in operation along mountainous tributaries, greatly reducing sediment transport. Sediment management remains a key issue in the entire basin.

Increasing human activities in the headwaters of the Sava and main tributaries, such as urbanisation, industrial development and agricultural monoculture, have increased the impact from organic, inorganic and hazardous pollutants.

During the dry season, water supply systems are sometimes unable to meet the water demands of consumers due to management and capacity problems. Today, most people are connected to the public water supply, but few are connected to wastewater treatment systems (e.g. a negligible number in Bosnia and Herzegovina) and urban sewage is directly discharged into the river. In Zagreb, a wastewater treatment plant has been in operation since late 2007. In Serbia and Bosnia and Herzegovina, unprotected landfills along the river remain a permanent risk. Industrial pollution and pollution from agriculture cause major transboundary challenges for some city water supplies, e.g. Zagreb and Belgrade.

With its large alluvial wetlands and undisturbed lowland forests, the basin provides a major environmental resource. Four Ramsar sites have been designated: Cerkniško jezero (intermittent karstic lake, 7,250 ha, Slovenia), Lonjsko Polje (500 ha, Croatia), Bardaca (3,500 ha, Bosnia and Herzegovina) and Obedska Bara (30,000 ha, Serbia). The headwaters of the Sava are in Triglav National Park and Plitvice Lakes National Park (a UNESCO World Heritage site since 1979), and Croatian tributaries are found along the Risnjak National Park. Numerous important hotspots of biodiversity and Natura 2000 sites exist in the basin.

Currently, flood protection in most parts of the middle and lower basin relies on flood-protection embankments as well as on natural retention areas in some parts. In particular, the Nature Park Lonjsko Polje in Croatia serves as a natural retention area and is a good example of how to link flood control measures with the conservation of natural and cultural landscapes of national and international importance.

During the past two decades, pollution decreased due to reduced industrial production and a weak economy. The riparian states of the Sava are presently in a post-conflict recovery period and pollution levels are slightly increasing again. The International Sava River Basin Commission (ISRBC) was established in late 2002 and held its constitutional session in mid-2005. The general objectives of the ISRBC are to strengthen transboundary cooperation for sustainable development of the region. The ISRBC works in close cooperation with the International Commission for the Protection of the Danube River (ICPDR). Currently the Sava Basin Management Plan (in accordance with the WFD) and a Flood Risk Management Plan (in accordance with the EU Floods Directive) are under preparation. Unfortunately, there are plans to regulate the river stream of the remaining near-natural meandering section in the middle Sava, and a navigation channel between the Sava and Danube Rivers in Croatia is under consideration. The ecological value of the alluvial forests and retention areas impacted by the proposed navigation channel would be much higher, if the application were successful, and help to preserve the natural riverbed and its floodplains.

2.1.2.5 Sava River Tributaries

The Una River is the right Sava River tributary, with the mouth at the 507 km from source. With a catchment area of 9,368 km^2, the Una River is the third biggest Sava River tributary in BIH. The Una River spring is in the Suvaja mountain plinth, 214.7 km from the mouth, with spring level at 420 m a.s.l. The total difference in elevation from the spring to the mouth is 335 m (85 m a.s.l.), and the average riverbed slope is 1.56 m/km.

Una River

The main left Una River tributaries are: the Klokog and the Ţirovac. The main right Una River tributaries are: the Unac, Krušnica and Sana, Mlječnica and the Moštanica River. Roughly 35.7% of the Una River Basin (3,346 km^2) is located on Republika Srpska (RS) territory, and around 49.3% (4,613 km^2) on Federation of Bosnia and Herzegovina (FBiH) territory and ca. 15.0% (1,409 km^2) on Croatian territory.

The Una River Basin belongs to the moderate continental climate zone, with an average annual precipitation of 1,245-1,400 mm, total precipitation of 11,663 hm^3 and average runoff of 6,824 hm^3.

The Lower Una River course is the section from Novi Grad to Kozarska Dubica, in a total length of 75 km (mouth of right tributary – Sana River, 112 m a.s.l.) with a total difference in elevation of ca. 27.5 m and average riverbed slope of 0.47‰. In this section, the Una River is a huge lowland river with lot of meanders and islands, with variable riverbed width and water depth. The towns of Novi Grad, Kostajnica and Kozarska Dubica are situated in this section.

Vrbas River

The Vrbas River is the Sava River right tributary, being discharged at 419 km from the mouth of the Sava River. With a catchment area of 6,386 km^2, the Vrbas is the smallest Sava River tributary in BIH.

The Vrbas River spring is in the Vranica mountain plinth, with a spring level at 1,715 m a.s.l .The total difference in altitude from the source to the spring (88 m a.s.l.) is 1,627 m, and the average river bed slope is 6.92 m/km.

The main left Vrbas River tributaries are: Pliva and the Krupa River. The main right Vrbas River tributaries are: Bistrica, Ugar, Svrakava, Vrbanja, Turjanica and Povelić.

About 63% of the Vrbas River Basin (4,008 km^2) is located in RS and about 37% (2,378 km^2) is located in FBIH.

Bosna River

The Bosna River is a Sava River right tributary, being discharged into the Sava River at Šamac, 306 km from the Sava River mouth. With a catchment area of 10,457 km^2, the Bosna River is the second biggest tributary of the Sava River in BIH. Around 3,043 km^2 (29% of the total river basin area) is located on the RS territory and around 7,414 km^2 (71%) on FBIH territory.

The Bosna River spring is located in Sarajevsko polje, in Igman mountain plinth, with a spring level on 494.7 m a.s.l. The total difference in altitude from the spring to the south (76.4 m a.s.l.) is 418.2 m and the average river bed slope is 1.53 m/km. The main left tributaries of the Bosna River are: Fojnica, Lašva and the Usora River. The main right tributaries of Bosna River are: Ţeljeznica, Miljacka, Stavnja, Krivaja and the Spreča River.

Drina River

The Drina River is the largest right tributary of the Sava River, with a total river basin surface of 19,570 km^2, with mouth into the Sava River (175 km) and a total course length to Šćepan Polje in Montenegro of 346 km.

According to size, the Drina River Basin is the fourth-biggest river basin on the territory of the WB6, after the Sava, Morava and Vardar River Basins. With a total runoff of 120,000 hm^3/year, the Drina River Basin covers 11.2% (13,000 hm^3/year).

The total length of the Drina River is around 346 km and the total difference in elevation from Šćepan Polje to the mouth is 366 m, so that the average riverbed inclination is roughly 1.06 m/km. The total length of the Drina River together with the Tara River is 496 km. The river course is formed in Montenegro after the merging of two mountainous streams - the Tara and Piva Rivers - that drain very rugged mountains of northern part of Montenegro with a confluence at the location of Bastasi (Šćepan Polje).

The total watershed of the Drina River Basin (with the Piva and Tara Rivers) is located in the following states: Bosnia and Herzegovina - 37.1%, Serbia - 30.5%, Montenegro - 31.6% and Albania - 0.8%.

Significant left Drina River tributaries are: Janja, Drinjača, Ţepa, Prača, Bistrica, Sutjeska and the Piva River. Significant right Drina River tributaries are: Jadar, Lim, Rzav, Ćehotina and the Tara River.

2.1.3 Velika Morava River Basin – Water Management Overview

The Velika Morava ('Great Morava') corresponds to the lower section of the Morava basin in Serbia. The Morava is the lower-most large right-bank tributary of the Danube upstream of Iron Gate. The Morava drains 40% of the entire country, in total an area of approximately 38,000 km^2. Small parts of the catchment are in Bulgaria (approx. 3%) as well as in the former Yugoslav Republic of Macedonia and Montenegro (<0.5% each). 4.5 million people inhabit the basin and the catchment consists of 39% arable land and 43% forest.

2.1.3.1 Geomorphology

The Morava catchment has three sub-basins: (i) the catchment of the Velika Morava that extends from the confluence of the Južna (Southern) and Zapadna (Western) Morava near the city of Stalač (130 m a.s.l.) to its confluence with the Danube, (ii) the catchment of the Južna Morava and (iii) the catchment of the Zapadna Morava. The Velika Morava has an average channel width of 140 m (maximum: 325 m) and a water depth (surface to bottom) of 1-4 m. Height of the river banks (from bank edge to thalweg or water surface) is 3-16 m.

The Velika Morava crosses densely-populated and cultivated areas for around 180 km. It receives 32 tributaries before it enters the Danube near the city of Smederevo. The Velika Morava valley contains among the most fertile soils in Serbia and is therefore important for crop production. Alluvial terraces and marshy bogs fringe the mainstream. The alluvial sediments consist of a mixture of Quaternary loess, Neogene lacustrine sediments, Mesozoic flysch sediments and Paleozoic schists.

The 230-km long Južna (Southern) Morava drains south-eastern Serbia (catchment area: 15,446 km^2). Its two major headwaters originate from the Macedonian-Serbian and Rilo-Rhodope Mountains and merge near the city of Bujanovac at 400 m a.s.l. Although the Južna Morava is considered a lowland river, it crosses a series of alluvial plains separated by constrained sections. Several of its tributaries are relatively natural with densely forested catchments and clear waters.

The 308-km long Zapadna Morava River drains south-western Serbia (catchment area: 15,567 km^2). Its headwaters are ramified, originating in the Golija (1,350 m a.s.l.), Mucanj and Tara Mountains in the Dinaric Alps (western Serbia). Its headwaters merge at 302 m a.s.l. The largest tributary is the Ibar River (catchment area: 7,500 km^2, length: 272 km). It originates in eastern Montenegro at 1,360 m a.s.l., flows eastwards to Mitrovica (Kosovo), then north until it meets the Zapadna Morava near the city of Kraljevo.

2.1.3.2 Climate, Hydrology and Biogeochemistry

The Morava River basin has a predominantly continental climate with an average annual temperature of 11-12 °C (January: 1 to +1 °C, June: 22-23 °C). Precipitation is highest in May and June and lowest in February and October. In the alluvial plains, average annual precipitation ranges between 600 and 700 mm. Precipitation increases to 800-1,300 mm with increasing altitude. The Južna Morava flows through a dry valley with an average precipitation of <600 mm.

The average discharge of the Morava is 277 m^3/s (average low flow: 50 m^3/s; peak flow with 1% probability of occurrence: 2,464 m^3/s). Discharge peaks during the short snowmelt period in spring. Major floods occur when snow melting and heavy rains coincide, and its tributaries exhibit a torrential character with frequent flash floods associated with landslides. Erosion is prevalent in the entire basin, in particular, in the almost completely deforested Južna Morava sub-basin. High sediment yields reduce the flow capacity in the downstream Velika Morava River and increase flood risks. Flood protection embankments and chains of reservoirs have been constructed to reduce flood risks. All major cities as well as many industrial facilities and waste disposal sites are found in flood prone areas.

About 60% of the phosphorus (P) input originates from point sources such as industrial areas, wastewater treatment plants, as well as through the prevalent use of P in detergents. Less than 10% of the rural population and approx. one third of the urban population is connected to public sewerage systems. About fifth of the P-input originates from erosion, in particular from fertile arable lands. The annual load of P from the basin is 1,841 tons/year (in 2004) and contributes approx. 8% to the total P load of the Danube. Dominant pathways for nitrogen input is groundwater (approx. 40%) and point sources (i.e. urban areas; 25%). Top soils in the basin have a high N-content resulting in an annual load of 28,246 tons/year (in 2004), 6% of the Danube basin. Based on the saprobic index, the Morava River is classified as 'critically polluted' at its mouth, and BOD5 values are considerably higher compared to most Danube tributaries.

Downstream of the confluence with the Velika Morava, Danube river sediments (bed and suspended sediments) contain elevated Lead (Pb) concentrations (52-70 mg/kg) and increased levels of faecal coliforms.

Recent changes in the Serbian economy have resulted in a significant reduction of pollutants. The economic decline and transformation to private ownership have resulted in a significant change in industrial production. BOD5 and ammonium concentrations show decreasing trends. Today, BOD5 is as low as <4 mg O^2/L and ammonia has stabilised to around 500 mg/L. Nitrate and orthophosphate concentrations range between 1.5 and 2 mg/L and <400 mg/L, respectively. The Zapadna Morava and its tributary the Ibar are the most polluted rivers in the catchment as well as in Serbia. They receive large volumes of untreated wastewater from non-sustainable industrial complexes such as lignite mines, power plants and saw-mills.

2.1.3.3 Biodiversity

In a recent survey, 42 fish species have been recorded for the Velika Morava River. Cyprinidae predominate and Salmonidae, Esocidae, Cobitidae, Balitoridae, Siluridae, Ictaluridae and Percidae are also abundant. In the headwaters, cold-stenotherm invertebrates dominate the macroinvertebrate community, especially Plecoptera, Ephemeroptera, Trichoptera and Amphipods (mainly Gammarus spp.). Artificial ponds and reservoirs are mostly eutrophic and their benthic communities are represented by Oligochaeta (family Tubificidae, genera like Limnodrilus, Potamotrix, Tubifex) and Diptera (family Chironomidae, Chaboridae) (MEP 2003). Since 2005, the Chinese pond mussel (Anodonta (Sinanodonta) woodina) has been reported in the lower Velika Morava. Its abundance exceeds the native mussel Unio pictorum by a factor of 5, and it is now spreading into other tributaries of the Danube such as Sava River. The non-indigenous tubificid worm Branchiura sowerbyi has a scattered distribution in the basin.

2.1.3.4 Human Impacts and Management

Between 1960 and 1995, the Morava basin underwent major hydro-engineering activities. The Velika, Zapadna, and Južna Morava Rivers, as well as some of their tributaries, have been regulated, meanders have been cut off, and the river courses shortened. Marshlands have been transformed into fish ponds (today approx. 4,000 ha), and comprehensive drainage systems have been put in place to increase the proportion of arable land. Extensive flood embankments (total length ranges between 1,181 and 2,015 km, depending on source) disconnect the floodplains from the river. Several multipurpose dams and reservoirs have been constructed that are used for flood protection, irrigation, municipal water supply (e.g. Prvonek, Barje, Gruza dams), and hydropower generation (e.g. Medjuvršje, Gazivode reservoirs; volume: >10 million m^3). Moreover, the dredging of sand and gravel has affected the hydromorphology of the rivers, and the forecasted increase in industrial activities could further degrade water quality.

2.2 Mediterranean Drainage Basin

MAJOR RIVERS AND TRIBUTARIES in the Mediterranean Drainage Basins: Adriatic, Ionian, and Aegean (Adapted from: Trockner- “Rivers of Europe”)

This section covers the four major River Basins that encompass the bio-geographical diversity of the Balkan Peninsula (Figure 2.2). All rivers discharge into the Mediterranean; one river enters the Aegean Sea Axios/Vardar, three the Adriatic Sea (Neretva-Trebišnjica, Drini/Drim and Vjosa/Aoos), while the River Basin of Bistrica discharging into the Ionian Sea is not elaborated further.

The river basins are transboundary. The Drini/Drim River drains parts of Albania, Kosovo, Montenegro, the former Yugoslav Republic of Macedonia and Greece. Despite its relatively small size, it is classified among the most international rivers worldwide. The Neretva and Trebišnjica Rivers are today connected through PSHPP Čapljina and th underground karst flow in the area located in Bosnia and Herzegovina and Croatia – Neretva has an estuary in the Adriatic, while Trebišnjica River is a "sinking river” that used to sink in the natural regime in the area of Popovo polje (due to the fact the area is in karst geology, it used to reappear downstream through numerous sources in the Hutovo Blato area, the left Neretva bank, as well as in sources along the coast to Croatia); the Axios/Vardar enters Greece from the former Yugoslav Republic of Macedonia, while the Vjosa/Aoos flows from Greece towards Albania.

Figure 2.2: Drainage network of selected River Basins in the Mediterranean part of the Balkans

Three River Basins - Axios/Vardar, Drini/Drim, Neretva-Trebišnjica - are considered as very large (>10,000 km^2), while Vjosa/Aoos is large (1,000–10,000 km^2). The Drin, Neretva-Trebišnjica, and Aoos drain mountainous catchments with mean altitudes >800 m a.s.l.; the Axios/Vardar drains mid-altitude (mean altitude: 300–800 m a.s.l.) catchments. Most Balkan rivers form deltaic plains; some of them are wetlands of international importance. Table 2.2 summarizes the main physiographic characteristics of all catchments.

Table 2.2: General characteristics of the Balkan Rivers for the Mediterranean Drainage

	Neretva	Drin/Drim	Axios/Vardar	Aoos/Vjosa
Mean catchment elevation (m)	848	868	747	849
Catchment area (km^2)	13,311	20,585	24,604	6,813
River length	255	285	380	260
Discharge (km^3/year)	11.9	11.4 (21.4[a])	3.62	5.55
Specific discharge (L/s km^2)	28.3	17.5 (26.3[a])	6.7[b]	25.8
Mean annual precipitation (cm)	117.7	105.3	62.9	100.2
Mean air temperature (°C)	9.2	8.9	9.9	11.8
Number of ecological regions	2	4	4	2
Dominant (≥25%) ecological regions	27; 39	9; 53	9	39; 53
Land use (% of catchment)				
Urban	0.7	0.7	1.4	1

	Neretva	Drin/Drim	Axios/Vardar	Aoos/Vjosa
Arable	16.3	21.7	34	16
Pasture	8.3	4.3	8.1	0.5
Forest	29.2	36.6	32.1	35.7
Natural grassland	40.2	26.2	23.4	39.3
Sparse vegetation	3	5.2	0.3	6.9
Wetland	0.4	0.8	0.2	0.1
Freshwater bodies	0.7	4.5	0.5	0.5
Protected area (% of catchment)	0.9	5	1.8	15.6
Water stress (1–3)				
1995	1.1	1.1	2.9	1.7
2070	1.1	1.2	2.9	1.7
Fragmentation (1–3)	3	3	2	2
Number of large dams (>15 m)	5	5	17	1
Native fish species	31	56	36	17
Non-native fish species	12	16	5	1
Large cities (>100,000)	1	3	1	0
Human population density (people/km^2)	38	98	83	44
Annual gross domestic product ($ per person)	2,014	2,562	3,229	4,407

Note: [a]) including Buna/Bojana River

The **Neretva-Trebišnjica** River Basin rises in Bosnia and Herzegovina (97.5% of its basin) and enters southern Croatia forming a large delta. The Basin contains the largest karstic river in the Dinaric Mountains and connects the Neretva-Trebišnjica River to the Trebišnjica River with an underground river system.

The **Drini/Drim**, the largest Albanian river, runs through a mountainous area towards the coast. It provides the third greatest river discharge in the European Mediterranean. The river has two main branches: the White Drin drains Kosovo* and the Black Drin originates from Lake Prespa (transboundary lake between the former Yugoslav Republic of Macedonia, Albania and Greece) and Lake Ohrid (transboundary lake between the former Yugoslav Republic of Macedonia and Albania). Before it enters the Adriatic Sea, the Buna River joins the Drin. The Buna drains Lake Shkodra/Skadar, the largest Balkan lake (shared between Albania and Montenegro).

The **Vjosa/Aoos** flows through an almost pristine mountainous landscape in NW Greece before it enters Albania (64% of the total basin). It forms a large delta. Its largest tributary is the transboundary Drino with a catchment area of 1,320 km^2 (80% located in Albania).

The **Axios/Vardar**, located in the central Balkan Peninsula, drains the second largest catchment in the Balkans. The river drains 83% of the former Yugoslav Republic of Macedonia and small parts of Bulgaria, Serbia and Greece before it enters the Aegean Sea (Thermaikos Gulf). Major tributaries are the Crna (5,890 km2) and the Bregalnica (4,307 km2). The river has hydrologic connection to Lake Doirani/Dojran, shared between Greece and the former Yugoslav Republic of Macedonia.

2.2.1 Biogeographic Setting

The Balkan Peninsula is situated at the bio-geographical crossroads between continental Europe, western Asia and the Mediterranean and Black Seas. Rich aquatic fauna and flora with noticeable number of endemic species characterise the Region. High biodiversity is a consequence of the region's geologic and paleoclimatic history as well as the geophysical variety of inland water bodies. During the Pleistocene, glaciers were restricted to mountain summits. The lowland areas provided refugia for the continental freshwater fauna and flora. Despite their rather small size, the Balkan rivers and streams host highly diverse freshwater communities. The high degree of endemism, compared to the rest of Europe, is perhaps the most remarkable feature of the Balkans. For example, Greece contains the largest number of freshwater fish species and the highest proportion of endemic fish in Europe.

The relative isolation of the river basins through geological history has forged distinctive biogeographic boundaries and a complex historical sequence of biotic isolation and fragmentation (e.g. interruption of dispersal routes). One of the most distinctive long-standing bio-geographical barriers is the Dinarides–Hellenides mountain chain that separates the western and eastern biotic assemblages. Phylogenetic studies confirm a west–east split of the Balkan's aquatic and terrestrial biota. Even widespread species, such as the Pond Turtle (Emys orbicularis) and common reptiles, are split into western and eastern phylogroups.

The isolation of the western Balkan river basins since Miocene times has favoured a rich endemic aquatic fauna. Furthermore, there are marked latitudinal gradients in species composition and richness. Species richness increases from south to north while the proportion of endemic species increases from north to south. The catchments south of the Aoos River are depauperate compared to the more northern basins. However, almost all primary freshwater fishes as well as several amphibians and reptiles are endemic to this area.

An important geological feature of the Balkans, with strong biogeographic implications, is the high proportion of karstic subterranean rivers, especially in the western part. They contain remarkable subterranean communities. This area is a 'hot spot' of hypogean biodiversity with unique life forms such as the Olm Proteus anguinusin in the Neretva-Trebišnjica-Trebišnjica River Basin.

A definitive biogeographic characterisation of the Balkans remains difficult because underlying biogeographic patterns are interrupted by several idiosyncrasies and inherent river basin attributes (numerous lakes, peninsular effects). There exist major discrepancies among researchers on how to define and delineate biogeographic regions for terrestrial, aquatic, or semi-aquatic biota in this region. Since aquatic biodiversity has not been well inventoried in many parts of the Balkans, the satisfactory baseline knowledge of species distributions and the validity of the systematic taxonomy are far from complete.

2.2.2 Physiography, Climate and Land use

2.2.2.1 Geomorphology, Landform, Geology

The Balkan Peninsula is a rough Alpidic orogen of the Mediterranean type, with large thrust sheets, ophiolites[2], repeated events of metamorphism and related granitic intrusions, and sedimentation of thick carbonate, flysch and molasse deposits.

There are two ophiolite zones; the predominant one extends around 1,000 km along the Dinarides–Hellenides mountain range (Dinaric Mts to Mount Orthrys in Greece), and the second extends eastwards along the Axios basin. Two shorter ranges climb in the ophiolite zones, running across the former Yugoslav Republic of Macedonia and Greece, where Mt Olympos peaks at 2,917 m a.s.l.; the second highest point in the Peninsula.

Due to its relatively young geology, the Balkan Peninsula is characterised by highly fragmented hydrographic networks and is drained by many small and medium-sized mountainous rivers. Rivers run through steep, narrow mountain valleys, have flashy flow and sediment regimes, and descend abruptly to the coast. However, there are a few larger low-gradient rivers crossing the Balkans along prevailing thrust belts and related rift valleys that form extensive flood and deltaic plains.

The Dinarides–Hellenides mountain range forms a series of nearly parallel ridges, plateaus and depressions, dissected by steep-sided valleys. A number of rivers, among others Neretva-Trebišnjica-Trebišnjica and Vjosa/Aoos, that emerge along the western slope of this mountain range lie exclusively or almost exclusively in the External Balkanides. Their basins consist of Mesozoic-Palaeogene carbonates covered by Palaeogene flysch. Magmatic and metamorphic rocks are absent in the basins of Neretva-Trebišnjica, whereas the headwaters of Vjoa/Aoos drain small ophiolite outcrops and the mountainous surroundings of Evrotas basin include small portions of schists.

[2] An ophiolite is a section of the Earth's oceanic crust and the underlying upper mantle that has been uplifted and exposed above sea level and often emplaced onto continental crustal rocks.

The Neretva-Trebišnjica-Trebišnjica River Basin is the largest stream in the Dinaric Mountains flowing for almost 250 km through a karstic area. It emerges at about 1,100 m a.s.l. at the base of the Zelengora Mts (2,032 m a.s.l.). The headwaters are dominated by Triassic and Jurassic limestone and dolomite. The river flows through a sequence of bedrock canyons and plains. In the last 30 km, the river widens and branches, spreading into a 200 km² deltaic plain. The Neretva-Trebišnjica Delta, one of the largest wetlands along the Dalmatian coast, includes small shallow karstic crypto-depression lakes, marshes and lagoons, fringed by limestone outcrops.

The Vjosa/Aoos River originates at the base of the Pindos Mts (Mavrovouni peak 2,159 m a.s.l.) and flows through deep gorges and steep ravines. The Voidomatis tributary (384 km²), a partially intermittent river with a steep gradient (1.6%), flows through the renowned Vikos Canyon and joins the Aoos in the Konitsa plateau just upstream of its confluence with the Sarandaporos tributary (870 km²). The Gamila summit, an imposing alpine ridge with enormous vertical slopes, is one of the few glacial landscapes in Greece. Here, the unique alpine lake Drakolimni (Dragon- lake) is located at an altitude of 2,050 m a.s.l. Flowing in a SE– NW direction, the Aoos is joined by the tributaries Drino, Zagori and Bence. The lower meandering river channel is on average 25 m wide. The delta, with a well-defined cuspate shape, hosts the Natra Lagoon (33 km²). Carbonates (mainly limestones), overlain by flysch, cover most of the catchment. Recent deposits include Messinian evaporites and Pliocene molasses that outcrop between alluvial sediments.

The Drin/Drim River flow from the eastern flanks of the Dinarides–Hellenides mountain range and is (except the lower Drin) within the Internal Balkanides. They drain ophiolites, acid metamorphic rocks (gneisses, micaschists, amphibolites and phyllites), granitoid intrusives and Mesozoic carbonates.

The Black Drin starts from the unique Prespa/Prespansko and Ohrid Lakes and flows NNW–SSE along a rift valley fringed by the steep forested Shar Mts (up to 2,500 m a.s.l.). Its drainage area includes mafic/ultramafic rocks (Midrita ophiolite belt with important Cr, Fe and Ni ores), granites, volcanic and volcano-sedimentary series. The White Drin mainly drains Neogene lacustrine and marine deposits of the Kosovo plateau and meets the main branch of the Drin in Albania. Triassic-Cretaceous limestones, flysch/ molasse and recent deposits form the lower basin. The river forms a delta with coastal lagoons.

The Vjosa/Axios River Basin starts at 750 m a.s.l. at the western slopes of Crna Gora Mountain (2,062 m a.s.l.) and is bound to the north and west by the Shar Planina Mountain range (2,748 m a.s.l.) and to the east by the 'Surrounding' Mountain Ranges (2,252 m a.s.l.). In the headwaters, it receives the Treska-tributary (2,068 km²) before entering the Skopje-Veles plains. The tributaries Pcinja (2,840 km²), Bregalnica and Crna join the river before it enters Greece through the narrow Klisura Valley. Finally, it forms a wide bird-foot type delta in the Thermaikos Gulf. The delta is also fed by the Aliakmon, Loudias and Gallikos Rivers forming the most extensive wetland area in Greece (area: 600 km²). The mountainous areas consist of metamorphic rocks, granitoids and volcanic formations (43.5% of the basin), Mesozoic limestones (11.4%) and ophiolites (7.7%). Igneous and volcanic rocks are associated with mixed sulphides and are important sources of Pb–Zn ores. Flysch and molasse cover 5.6% of the basin. Lacustrine and terrestrial Neogene and alluvial sediments (31.9%) fill the river valleys and the delta.

2.2.2.2 Climate

Altitudinal gradients, a diverse mountainous relief, and the influence of the Mediterranean and Black Seas create diverse climatic conditions in the Balkan Peninsula. In general, the climate is characterised by a distinct bimodal seasonality and a strong N–S gradient, with increasing temperature and decreasing precipitation towards the S–SE (Table 2.2). The S–SE Balkans suffers from prolonged droughts. In the past decades, average precipitation decreased and the frequency and severity of droughts increased. In 2007, during prolonged summer heat waves, heavy wildfires destroyed thousands of km² of Balkan forests.

The Adriatic and Ionian basins receive a much higher precipitation compared to the eastern Balkans. The Dinaric Alps exhibit a moderate continental climate with cold winters but warm and humid summers, while the higher mountains have a subalpine climate with extended periods of snow cover. Therefore, many rivers show steep climatic gradients along their course. The mean annual air temperature in the Neretva-Trebišnjica basin is 9.2 °C but reaches >16 °C downstream of Mostar. The Drin basin has the lowest average air temperature (8.9 °C) of all examined basins, although its downstream section exhibits a Sub-Mediterranean climate with mild, wet winters and hot summers (mean annual air temperature: 16-18 °C). Similarly, the upper section of the Aoos basin experiences a moderate Sub-Mediterranean and the lower section a Mediterranean climate. The highest precipitation occurs along the central Adriatic Mts. In the Dinaric Mts, precipitation exceeds 300 mm, with up to 550 mm in SW Montenegro. In Albania, mean precipitation ranges from 300 mm (Albanian Alps) to 130 mm (southern part). The annual precipitation east of the Dinarides–Hellenides range is 25–50 cm less than in the western peninsula. The upper Axios basin exhibits a climate like continental European with long cold winters. The area south of Skopje is considered as one of the driest regions in the former Yugoslav Republic of Macedonia. In winter, the dry 'Vardar' N-wind creates harsh cold conditions.

Local orographic effects influence the Mediterranean climate, typical for Albania and most of Greece. A southward and a less significant eastward increase in air temperature and evapotranspiration occurs. Many river stretches in S and SE Greece have intermittent flow regimes.

2.2.2.3 Land Use Patterns and Human Pressures

In most catchments, evidence of human appearance dates to the late Pleistocene (Middle Palaeolithic). During that period, the Balkan landscape experienced distinct cycles from deciduous forests to dry steppe, indicating weak glaciation. During the Neolithic era, humans started cultivating cereals and legumes, and breeding domestic livestock. The first settlements were established along rivers and around lakes taking advantage of good grazing conditions and naturally irrigated land. Prehistoric deforestation and soil erosion have been attributed not only to climate change but also to human activities. Since the Minoan period, rivers and streams have traditionally been used as natural sewage systems. In addition, humans managed rivers by building dams or diverting channels to protect their settlements against floods.

Large-scale deforestation occurred during the Roman, Byzantine and Ottoman Empires. However, up to the 19th century, when major shifts of settlements and land use ensued, many areas in the Balkans were considered a wilderness and were scarcely populated. During the 20th century, farming technologies improved, although animal- drawn ploughs and cartwheels are still common in Albania, and parts of former Yugoslavia. In the 1920s-1940s, massive land reclamation took place in Greece to create new land for people displaced from Asia Minor. This resulted in the drainage of lakes, marshes and lagoons (e.g. Ardjan in the Axios area), and channels of large rivers were rearranged. Land reclamation continued with the construction of extensive irrigation networks. Thus, northern Greece lost 1,150 km^2, or 73%, of its original wetlands. In Albania, extensive land reclamation and irrigation projects have occurred during the past 50 years resulting in a significant loss of its native forests and marshes.

The first dams were already constructed between the 1st and 5th century BC in ancient Alyzia, one of the most important cities of Acarnania near the Acheloos River Basin in South Greece. In the 1950s, the first large dams were constructed in the Balkans. In the Neretva-Trebišnjica basin, around 50 km^2 of wetlands were drained, several large dams constructed, and water transferred between basins. During the last decades, less agricultural intensification compared to northern Europe has been observed. However, increasing overall trends in the intensification process are apparent in the plains, especially in Greece, with increasing trends in agrochemical consumption and extensive agriculture in mountainous areas.

Landscape features and agriculture are intimately linked. The north-eastern areas where almost treeless open landscapes prevail are intensively used for arable crops. The Dinaric and Albanian Mts are characterised by extensively cultivated landscapes. In Albania and Greece, sharp contrasts between open cultivated and wilderness areas occur. Cereals are grown at a large scale and olives cover hillsides where possible, while Mts are used for extensive grazing. Yields are low due to moderate to high erosion creating stony soils (cambisols, luvisols), the dry hot climate and intersection of arable land by shrublands. The lower Axios/Vardar, including the main delta, is a fertile landscape, intensively cultivated and densely populated. Consequently, the plains of Thessaloniki (lower parts of Axios River Basin), have been designated as Nitrogen Vulnerable Zones (Directive 91/ 676/EEC).

Before the conflict, Bosnia and Herzegovina was the industrial heartland of former Yugoslavia. Most of its rivers were severely polluted. Today, the Neretva-Trebišnjica-Trebišnjica is affected by the disposal of untreated municipal and industrial wastewaters. Intense agricultural production (mainly citrus orchards) is limited to the delta area. The first significant morphological alteration occurred in the 1880s, when the Austrian–Hungarian government channelled 22 km between Metković and Ušće. This part of the river is regularly dredged to ensure navigation and prevent flooding. Before dam construction and land reclamation, the lowlands were frequently inundated during winter forming a large deltaic lake. Dam construction resulted in salt water intrusion in the lower Neretva-Trebišnjica and the destruction of the delta; of the initial 12 distributaries, only three remain.

The Drin flows through mountainous terrains and wide, densely populated valleys. The lowland section has been diked. In the Albanian part, half of the arable land is irrigated, whereas mountainous areas remain virtually undisturbed. In the upper basin, iron and chromium mining along with industrial activity affect Lake Ohrid, while copper, chromium, iron and nickel mining and processing (at a reduced rate in recent years) contaminate the middle and lower river sections as well as Lake Shkodra. Lake Shkodra is also polluted by the Morača River that carries wastewater from an aluminium smelter near Podgorica. Unsustainable agricultural practices have led to an increase in non-point pollution and erosion. Gravel extraction from the riverbed favours bed incision. Moreover, the river and lakes are affected by untreated or insufficiently treated municipal wastewater. Besides large reservoir construction, other major hydrological interventions include stream diversions to Lakes Prespa and Ohrid. Finally, illegal logging impacts many tributaries.

In the Vjosa/Aoos basin, traditional agro-silvo-pastoral activities have been applied since the end of the 2nd millennium BC. Today, most of the catchment remains in a wild, almost untouched state with restricted agriculture, forestry, cattle breeding and some aquaculture. The river receives untreated effluents from five urban settlements (Konitsa, Permet, Argirokastro, Tepelen, Mamalje, Selenica), small-scale industrial areas and by-products of petroleum extraction in the lower section. There are no major dams disrupting the main river course. The lower part was diked in the 1960s and about one-third of the Narta lagoon has been converted into a commercially operated salina. Local gravel and sand extraction and deforestation lead to bank erosion and sediment deposition. Despite human impacts, the Vjosa/Aoos River is considered as one of the least modified rivers in Europe.

In the Axios/Vardar basin, near Lake Doirani, early human impacts date back 2800 years BP, when deforestation and stock-breeding led to a replacement of native woody vegetation by xerothermic plants. In the 4th century BP, the river mouth of the Axios was 30 km further inland and the ancient cities of Pella and Skydra were located along the coast. Massive sedimentation led to the formation of Lake Yiannitsa, one of the largest deltaic swamps along the Aegean coast. In the early 1930s, drainage led to the loss of 70% of the former delta wetlands. During the last 40 years, groundwater exploitation from numerous irrigation wells considerably lowered the water table, and the delta area subsided at a rate of up to 10 cm/year. Consequently, the sea has expanded up to 2 km inland forcing authorities to construct coastal embankments. The basin is densely populated and the Axios is one of the most impacted rivers of the Balkans. In the former Yugoslav Republic of Macedonia, the main point pollution sources are untreated industrial and municipal wastewater especially from metal and chemical industries such as agrochemical manufacturing from the cities of Veles and Skopje. Wastewater treatment plants exist only for a few cities. The most important nutrient point source is the fertilizer plant of Veles.

In the former Yugoslav Republic of Macedonia, about 50% of the catchment has been converted into agricultural land, including around 800 km^2 of irrigated land. Untreated municipal wastewater releases 4,700 tons/year N and 857 tons/year P into the river. In the Greek catchment, water demand for irrigation and agricultural pollution constitute the most important human pressures. There, almost 80% of the catchment is intensively cultivated, including around 1,400 km^2 of irrigated land. Industry, mainly food processing plants, plays a limited role because the bulk of the effluent is treated. The total annual input of nitrogen and phosphorous from industrial sources is 15 tons and 12 tons, respectively.

2.2.3 Hydrology and Biogeochemistry

2.2.3.1 Hydrology and Temperature

Hydrological data are mainly derived from UNESCO (www. rivdis.sr.unh.edu) and from the Hellenic Public Power Corporation (Tables 2.2 and 2.3). Because the eastern Balkan basins exhibit a semi-arid climate, specific discharge is low, ranging between 4 and 14.9 L/s/km^2. The Drin and Neretva-Trebišnjica Rivers rank 3rd and 4th in the total annual discharge of all rivers in the Mediterranean region (after the Rhone and the Po Rivers). A large proportion of Balkan rivers is affected by hydropower generation. Most rivers are strongly fragmented by dams and flow regulation (Table 2.2). The Axios/Vardar and Vjosa/Aoos are 'moderately fragmented'.

The hydrological and thermal regime depends on the seasonal distribution and type of precipitation (rain or snow), as well as on hydrogeological features (e.g. karstic or alluvial aquifers, degree of surface/subsurface flow interactions). Balkan rivers reveal a strong seasonal hydrology, mostly flashy in nature and with low summer flow.

Three flow regime types are identified: (I) a pluvial type with discharge maxima in winter, (II) a pluvio-nival type with maximum discharge in winter and a second peak in spring (snowmelt) and (III) a nivo-pluvial type with maximum discharge in spring and a second peak in winter.

Type I rivers include the Neretva-Trebišnjica-Trebišnjica River, with 63–78% of annual runoff between November and March. The Drin and Aoos belong to type II, while the Axios is flow regime type III river. In type II and III rivers, 20–30% of the runoff is derived from snowmelt. Dam operations smooth seasonal variations and result in a modification of the hydrological regime downstream of reservoirs.

Based on the ratio between the long-term maximum and minimum monthly discharge, four groups of rivers can be distinguished. For regulated rivers such as the Neretva-Trebišnjica-Trebišnjica and in the middle section of the Drin, the seasonal variation ranges between 1.5 and 3. The Axios exhibits moderate seasonal variations with ratios between 3.2 and 7. The Aoos and lower Drin (Vau Deze) show high hydrologic variation with ratios between 7.6 and 15.

Rock permeability drives baseflow contribution in river flow and regulates seasonal runoff variation and floods. The correlation between the ratio and the percentage contribution of baseflow in river runoff shows that high baseflow contribution smoothens seasonal hydrologic variation.

Over the past 40-45 years, the Balkan rivers have undergone dramatic discharge reduction, a common phenomenon for the entire Mediterranean region (UNEP/ MAP 2003). In addition, a severe drought at the end of 1980s - beginning 1990s created major water shortages. Besides climate variability and change, evaporation from reservoirs and extensive water abstraction for irrigation have diminished river runoff. The Axios (57%, 1961-2000) has experienced a 57% discharge reduction (1961-2000), followed by the Drin (31%, 1965-1984). The annual discharge of the Aoos decreased by 24% (Greece) and 19% (Albania) (1964-1987).

On average, the Neretva-Trebišnjica reveals the lowest mean annual water temperature (Table 11.3). The Neretva-Trebišnjica, with a low snowmelt contribution to river runoff and substantial karstic flow, shows weak seasonal variation. The Bileća Reservoir outflow smoothens seasonal variation and alters the thermal regime in receiving water bodies. Based on long-term records (1948-2005), the mean annual temperature of the Neretva-Trebišnjica increased by 0.27 °C (average: 0.017 °C/year), the maximum annual temperature increased by 0.42 °C and the minimum temperature by 1.7 °C. This is a general trend that holds true for all Greek rivers (Table 2.3).

The Neretva-Trebišnjica, despite a high annual precipitation, has a low stream density, because water is percolating underground. Karstic springs contribute substantially to surface flow (Stambuk-Giljanović 1999). Trebišnjica, one of the longest 'subterranean' rivers in the world, supplies water to the Neretva-Trebišnjica delta through karstic springs. In addition, excess water from Trebišnjica is artificially transferred to the Neretva. Maximum runoff occurs in December and minimum in July-August. The upper basin is characterised by a nival-pluvial flow regime, a high specific discharge (over 45 $L/s/km^2$), and high-water level fluctuations (up to 14 m near Mostar). Five hydropower plants in Bosnia and Herzegovina (Jablanica, Rama, Grabovica, Salakovac and Mostar) impound a total area of 36 km^2 and store around 1,070 million m^3.

Table 2.3: Discharge characteristics of the Balkan Rivers (in m3/s), Long-term discharge variation (mean annual discharge) in selected Balkan rivers.

River	Station	Period	A (km^2)	NQ	MNQ	MQ	MHQ	HQ	MHQ/MNQ
Neretva[a]	Opuzen	1946–2005	13,300	23	48.3	69.5	114	193	2.4
	Metković	1946–2005	12,311	43	60.7	93.2	163	297	2.7
Drin/Drim	Ura e Dodes	1976–1984	5,400	27	47.8	98.2	164	302	3.4
	Van Deze	1960–1968	12,368	13	66.8	339	613	772	9.2
Aoos/Vjosa	Konitsa	1963–1971	665		4*	27	58*		
	Dorze	1965–1984	5,420	21	36.1	146	260	595	7.2
Axios/Vardar	Skopje	1978–1990	4,650	6.6	24.3	57.3	102	164	4.2

River	Station	Period	A (km^2)	NQ	MNQ	MQ	MHQ	HQ	MHQ/MNQ
	Axioupoli	1961–2000	20,200	3.4	29.7	115	275	949	9.2

*A: catchment area upstream of gauging station, NQ: lowest measured mean monthly discharge, MNQ: arithmetic mean of the lowest measured mean monthly discharge, MQ: arithmetic means annual discharge, MHQ: arithmetic means annual of highest mean monthly discharge, HQ: highest measured mean monthly discharge, * arithmetic mean of month with minimum/maximum discharge, MAX/MIN: ratio between the month with maximum discharge and the month with minimum discharge.*

[a] *Water level.*

The Drini River originates from the Lake Ohrid-Prespa karstic system. The Prespa Lake (surface area: 274 km^2, basin: 1,300 km^2, mean depth: 16 m, maximum depth 47 m) contributes to Lake Ohrid about half of its karstic groundwater inflows. During the past 20 years, a decline of the water level in Lake Prespa has been observed. Lake Ohrid discharges 0.69 km^3/year through an artificially-controlled outlet into the Black Drin. It is a deep lake (mean depth: 155 m, maximum depth: 288 m) that covers 358 km^2 and drains 1,310 km^2. Lake Shkodra (basin area: 5,180 km^2) receives its waters mainly from the Morača River (99 km long) and drains into the 44km-long Buna River that joins the Drin 1.5 km before the mouth into the lake. The hydrologic regime of Buna River and the water level of the Shkodra depend on the flow of the Drini. During winter floods, the Drin floods back into the Buna, and consequently the lake experiences flooding from Drini water. Thus, the lake surface varies from 372 to 542 km^2 and the maximum depth exceeds more than five times the mean (8 m). Snowmelt in the upper part of the river causes discharge maxima in May, while in the lower section maxima occur in December.

Seasonal discharge variation increases downstream (Table 2.2). Two hydropower plants are in the former Yugoslav Republic of Macedonia (Globočica and Špilje) and three in the lower Drin in Albania (Komani, Vau Deza and Fierza). Fierza, covering 97 km^2, is the largest in Albania.

The Vjosa/Aoos catchment has a high stream density (0.92 km/km^2) and a high runoff coefficient (0.95 at Konitsa) due to the dominance of flysch. Maximum flow occurs in December and minimum in August and September. Between 21% and 25% of the flow originates from snowmelt and approx. 66% from rain. Seasonal hydrological variation decreases from the headwaters downstream. A small artificial lake (surface area 11.5 km^2, total storage capacity 260 million m^3) was created at the subalpine plateau (1,400 m a.s.l.) that diverts 10% of Aoos water towards the Arachthos basin.

The Axios still exhibits a near-natural flow regime. The highest flow occurs in April and the minimum in August. Rain and snow contribute 53% and 30%, respectively, to total flow. The mean annual runoff of Crna is 1.18 km^3, of Treska 0,76 km^3, of Bregalnica 0.44 km^3 and of Pcinja 0.40 km^3. Until recently, floods caused major damages. For example, the city of Skopje was destroyed in 1963. To control floods, 17 large dams have been constructed at river tributaries in the former Yugoslav Republic of Macedonia with a total storage capacity >500 million m^3. A small irrigation dam at the delta remains closed between May and September, allowing only approx. 1 m^3/s to pass during the dry period. Doirani Lake has an area of 40 km^2 (basin area: 272 km^2), a total volume of 50.7 million m^3, and a maximum depth of 10 m. Overflow water enters the Axios through an artificial canal. Since the end of the 1990s, the water level of Lake Doirani has been receding as a result of drought and overexploitation for irrigation in Greece.

2.2.3.2 Sediment Loads (Long-Term Trends)

Balkan rivers tend to have naturally high sediment fluxes due to high relief ratios, high seasonal climatic variation, easily erodible rock formations and sparse vegetation. Fluxes have further increased due to massive deforestation, fire, grazing and other human activities such as mining.

In the Western Balkans (the Aoos, Drin and Neretva-Trebišnjica basins), high precipitation in combination with flysch bedrock causes specific sediment yields of 1,000-16,000 tons/km^2/year. In autumn, heavy initial rains on desiccated soils often cause landslides, especially where unconsolidated sediments prevail. During the first flush events, often 50-95% of the annual sediment transport occurs. In the eastern basins, where magmatic and metamorphic rocks prevail (Axios) and sediment transport mainly peaks during snowmelt, sediment yields are low and range between 9 and 200 tons/km^2/year.

The organic fraction of suspended sediments transferred by major Balkan rivers is low (on average 2.83% POC, 1.69% PN). More than 50% of the inorganic fraction consists of muscovite-illite (27%) and silica (25%).

In general, total sediment flux increases with the catchment area. Hence, the total load of the Axios, Drin and Neretva-Trebišnjica Rivers varies between 12 and 23 million t/year. However, high sediment transport also occurs in small narrow mountainous basins such as the Aoos with 8.4 million t/ year.

The long-term decline in river runoff, in combination with enhanced sediment retention in reservoirs, has resulted in a dramatic reduction in sediment fluxes during the past 50 years. For example, the sediment transport of the Drin experienced a 13-fold sediment reduction compared to preindustrial rates. Today, the proportion of the annual sediment flux trapped behind reservoirs is very high generally. Consequently, deltaic areas of dammed rivers are not expanding or have even started to decrease in size. Global sea level rise will further accelerate the destruction of many deltaic areas of the Balkans.

2.2.3.3 Nutrients and Water Pollution

Table 2.2 lists basic information about dissolved oxygen and nutrient concentrations in the Balkan Rivers. To ensure comparability among rivers, data from the lower-most monitoring station has been considered. On average, the Balkan rivers are well oxygenated with oxygen concentrations ranging from 10.5 mg to 7.2 mg/L.

The upper Aoos presents minimum concentrations of DIN (dissolved inorganic nitrogen). Of all examined rivers, the Drin shows the maximum DIN, followed by the Axios. The Drin also exhibits the highest nitrate concentration, followed by the Axios.

The lower Aoos (in Albania) exhibits ‘poor’ nitrate quality status. The Neretva-Trebišnjica present a ‘moderate’ status and the Aoos (in Greece) a ‘good’ status. Concerning nitrite, rivers that received ‘bad’ status are the lower Aoos (in Albania), followed by the Axios. The Drin and the upper Aoos (in Greece) are classified as ‘moderate’, while the Neretva-Trebišnjica have ‘good’ status.

In general, Balkan rivers are enriched with nitrate in winter (December–February) because of arable land flushing, while dilution during spring and insignificant nitrate point discharges in summer keep nitrate concentrations low. While some rivers show an increase in nitrate concentration with discharge, indicating the prevalence of flushing processes, others (e.g. the Axios) show a decreasing trend with discharge, indicating the prevalence of dilution processes. Total Phosphorus exhibits maximum levels at the rising limb of the hydrograph (mainly October) due to initial flushing. Ammonia peaks that occur in winter or spring may be attributed to organic matter mineralization. Increased Total Phosphorus and ammonia levels during low flow originate from municipal and industrial (e.g. seasonal food processing industries) effluents, although a prevalence of denitrification processes cannot be excluded.

Regarding long-term nutrient variation, during a trial period of measurements, the Axios shows a gradual increase in nitrate concentration reflecting agricultural intensification.

In the Neretva-Trebišnjica, it has been observed that Total Phosphorus concentration once increased in the period 1995-1997 and thereafter gradually decreased having its lowest point in the year 2001.

According to the Directive 75/440/EC regarding the quality of drinking waters, the Aoos, and Lakes Prespa and Doirani satisfy the conditions for their classification at A1 class. The Axios generally satisfies the Directive’s conditions, despite occasional high nitrate, ammonia and phosphorous concentrations. The other Balkan countries apply national criteria concerning water quality for different uses (drinking, swimming, recreation).

2.3 Management and Conservation

2.3.1 Economic Importance

Most Balkan rivers are too shallow and steep to be navigable with large motorised vessels. For example, only the lower sections of the Neretva and the Buna/Bojana are used for trade and communication.

Agriculture is by far the most important water consumer, for example in the former Yugoslav Republic of Macedonia (80%) and Albania (72%). Agricultural water use accounts for only 0.65% in Bosnia and Herzegovina.

Large portions of agricultural land are irrigated in Albania - 49%, compared to the former Yugoslav Republic of Macedonia - 11% and all other Balkan countries (between 0.2% and 2%).

In Albania, Bosnia and Herzegovina, Serbia and Montenegro, hydropower represents a substantial source of power (97%, 59% and 40%, respectively, of total electricity production). In the former Yugoslav Republic of Macedonia, the share of hydropower is about 20%. Dams along the Drin supply major energy for Albania - about 90%. Similarly, the Neretva is used as a main electricity source for Bosnia and Herzegovina. Most reservoirs have multipurpose functions (e.g. irrigation, urban water supply, cooling of thermoelectric plants, aquaculture, recreation). In most Balkan countries, there are major demands for further hydropower development, reflecting the expected strong economic growth in this region, starting from relatively impoverished economies. There is also the obligation for EU Member States and Energy Community member countries to increase the share of energy from renewable sources in total energy production.

The most important lakes for fisheries are Lakes Shkodra (annual production: 950 tons/year), Ohrid (230 tons/year, declining in recent years), and Prespa (100 tons/year). Lake Ohrid has been declared as a mixed cultural/natural heritage site by UNESCO, which has stimulated the local tourist market.

2.3.2 Conservation and Restoration

Conflicts and political instability over the past centuries have created difficulties for both conservation and research.

This has inhibited a thorough inventory of species, habitats types, conservation areas and conservation resources at the regional level. Hence, freshwater biodiversity patterns remain poorly documented and the underlying processes are far from being well understood. The protection of the natural aquatic heritage is often unsatisfactory and poorly planned because the focus has been mainly on forested lands or sites of outstanding scenic beauty. Greece was one of the first countries in this region that implemented protected forested areas. The implementation process has been very slow. A major problem remains the administrative complexity on issues of nature conservation, management and enforcement of legislation. Additional problems arise from institutional ineffectiveness, financial constraints, legal problems, the deficiency of public involvement and limited political commitment to conservation.

During the past two decades, interest in inland water protection has increased, although the focus has been primarily on lentic systems and selected wetland habitats. Biodiversity conservation, ranging from genetic diversity to landscapes, rarely targets rivers or streams in the Balkans. An exception is deltaic wetland areas. In fact, all the larger deltas contain protected areas such as Ramsar Sites, with statutory zonation designations. Human and natural factors are often deeply interdependent in these complex systems. Within the wider area of deltas, there are some unique habitats such as karstic ponds (deep cryptic depressions) either in marshes or in coastal lakes and lagoons, such as those encountered in the Neretva delta. Nonetheless, there are some upland riverine areas that have been assigned conservation status. These include some spectacular limestone gorges along the Vjosa/Aoos, and significant portions of the Axios/Vardar, and several other headwater streams in the major river basins. Quite often, the main river channels are not included in conservation frameworks, and thus remain vulnerable to alteration.

International treaties and designations have greatly assisted conservation efforts (UNESCO conservation designations). One of the most important steps in promoting the conservation of aquatic habitats was the signing of the Ramsar Convention for the protection of wetlands. In Greece, there are the Axios/Vardar Delta and Lake Small Prespa. In the former Yugoslav Republic of Macedonia, there is one site at Lake Large Prespa. Lake Shkodra and the River Buna are Ramsar sites in Albania and Montenegro. The Ramsar Convention also protects the Neretva Delta together with two sites in Croatia and Bosnia and Herzegovina. EU Directives have also promoted the designation and conservation of protected areas in the Balkan states.

The management of natural areas in the former Yugoslav Republics is still in a transitional stage. In the former Yugoslav Republic of Macedonia, a forestry corps is responsible for the management of designated protected areas (covering about 7.3% of the land area), but its tasks mainly involve inspections. This country plans to extend the protected area surface area to 12% of its national territory, establishing 250 Protected Areas. In Bosnia and Herzegovina, even though international assistance has helped to develop the framework of an environmental law, legislation remains incomplete and the management of protected areas is far from being satisfactory. In Montenegro, a comprehensive set of acts devoted to the management of Protected Areas has not been completed. However, the existing national legislation (the National Parks Law) covers several issues of management of the four officially designated National Parks, including Shkodra Lake. Serbia's protected areas are classified according to the criteria recommended by the World Conservation Union (WCU), and the Ministry of Environment coordinates their management according to national laws. In Albania, the actual management of protected areas and national parks is the responsibility of the Ministry of Agriculture and Food. This Ministry intends to reorganise protected areas, grouping several national parks together and increasing the total surface of Protected Areas and National Parks from 165,000 hectares to over 449,000 hectares (15.6% of the country's area). However, enforcement and monitoring within Albania's protected areas is inadequate, and management plans do not yet exist for most areas. To strengthen the protection of biodiversity and the management of protected areas at the regional level, Kosovo is actively participating in several regional and transboundary initiatives and projects.

2.3.3 Restoration Activities and Potential

Ecological restoration efforts have traditionally concentrated on conservation actions for endangered species and protected area habitat enhancement. Most projects are carried out at a local scale such as riparian tree planting. EU funding has been instrumental in promoting this type of active restoration. NGOs, Government Research Institutes, and University Departments have been active often in cooperation with the local and federal Government. Active river restoration has not been extensively implemented and there is a major lack of post evaluation or project monitoring.

3 CLIMATE CHANGE IN THE WESTERN BALKANS AND HYDROPOWER

3.1 General issues of climate change

3.1.1 EU Policy in Climate Change

The current EU climate change policy represents a demanding and determined strategy in the fight against climate change, demonstrates a high level of responsibility and awareness of the global problem by EU Member States and its citizens, and can be considered as a model for the rest of the world as such. It is based on the acquis communautaire in the fields of climate action and ozone layer protection that comprise several climate-related legislation: (i) Greenhouse Gas Monitoring and Reporting, (ii) EU Emissions Trading System, (iii) Effort Sharing Decision, (iv) Carbon Capture and Storage, (v) Transport/Fuels, (vi) Ozone Layer Protection, (vii) Fluorinated gases, and (viii) Forests and Agriculture.

One of the world's most ambitious climate protection targets set for 2020 has been set up by the EU, and is on track to reach the 20% greenhouse gas (GHG) emissions decrease goal over the pre-industrial (1990) levels. For 2030, the EU's policy framework is based on ongoing endeavours by 2020 and even more ambitious climate protection targets as well as broader energy sector targets adopted in October 2014, updated in the 2016 Winter Package, notably:

- At least 40% cuts in **GHG emissions** (from 1990 levels);
- At least 27% share for renewable energy in gross final energy consumption;
- At least 30% improvement in energy efficiency.

Thereafter, the long-term strategy aims to fully transform the EU into a competitive low-carbon economy through realization of measures including GHG emissions reductions of 80-95% percent over 1990 levels by mid-century. Achieving this goal relies on long-term investment in low-carbon technologies, use of renewable energy, energy efficiency, and deployment of smart grid infrastructure.

International action in climate change is essential since national boundaries are meaningless in this regard. The EU was instrumental in the development of the United Nations Framework Convention on Climate Change (UNFCCC), signed in 1992, and the Kyoto Protocol (1997), which limits GHG emissions from developed countries. Today, however, more than half of global GHG emissions come from developing countries. To address this, the EU has led an international effort for a new UN global climate agreement, which has been adopted at the 2015 Climate Change Conference in Paris. Climate action is globally guided by the Paris Agreement (2016). Its central aim is to strengthen the global response to climate change by keeping the temperature rise well below 2 degrees C above pre-industrial levels and to pursue efforts to limit temperature increase even further to 1.5 degrees C.

Although the Agreement has already entered into force, implementation will begin in 2021.

3.1.2 Understanding of the relationships and impacts

The literature on Climate Change has become vast during the last decades. An increase in worldwide damage associated to an increased intensity and frequency of climate-related disasters has been driving climate change interest, research and political actions due to the global impacts of a changing climate. Especially the Balkans region as a whole has been under significant scrutiny in this context in order to guide the application of EU and other funds towards Mitigation and Adaptation actions that should (i) reduce GHG emissions and (ii) adapt to climate change impacts, respectively.

The science on climate change is compelling, however the application of that science to infrastructure development projects such as hydropower at location-specific projects has not yet been fully resolved and remains difficult to apply by practicing engineers and other climate stakeholders.

By acknowledging the baseline of long-term climate processes and climate change as a whole, which has been presented by leading international institutions like the UN and the European Environment Agency (EEA), for the purpose of this report, we have examined all currently held views and opinions relating to climate change in the context of hydrology and hydropower development. As a consequence, this report endorses the key recommendations for hydropower development and water regulating structures based on the latest elaboration of mitigation and adaptation measures available from literature sources, and in particular, the EC / Climate Action position on climate change, available via https://ec.europa.eu/clima/change/consequences_en. However, the purpose of the present report is not to discuss the climate topic as such, but to present the rationale for reasoning behind the ranking of priority investments in HPP projects in our study from the climate change point of view.

On the mitigation side of Climate Change, the substitution of currently prevailing fossil-fuelled power plants by renewable energy based power generation (of which hydropower is one possibility), will have an immediate positive effect on total GHG emissions. Balanced against these CO2 emission savings is the question of the volume of GHGs (mainly CO2 and methane) that are emitted from the water reservoirs. This question is addressed in more detail later in Section 3.2.3; however, current opinion points to the fact that reservoirs in temperate zones could actually represent a sink for GHG if they are maintained correctly.

Several authors report trends of decreasing annual average flow in the rivers and streams of the Balkans. The most referential work related to the Western Balkans is the UNEP's "Outlook on climate change adaptation in the Western Balkan Mountains", 2015 and "Climate Change in the West Balkans", ENVSEC, UNEP, 2012. Based on our assessment of the quality of hydrological data gathered in the region within the scope of the Study, such as daily discharges, it is apparent that overall trends of decreasing flows are an indication for what could happen in the future. This requires a solid analysis of planning, design, operation and maintenance of the HPP. Adaptation options must be part of the design, perhaps to be realised during large maintenance projects – by which time more and better data will be available. Moreover, water demand and water use in the river basins in which the HPP will be constructed should be taken into account. If not, the hydropower generation design parameters will not reflect the economic potential during the life cycle of the HPP.

It is notable that electricity generated in the region from hydropower does not demonstrate a decreasing trend for last two decades, as might be expected if average annual flow rates were diminishing (see Figure 3.1). This could be explained by the increase in HPP, and improved turbine efficiency. Therefore, in planning HPP development, decreasing potential production capacity based on reducing hydrological yield forecasts should be represented by hydro-meteorological scenarios. On the basis of scientific community consensus, the reduction of hydropower potential over the period of several decades is expected due to the lowering of hydrological yield (run-off) caused by climate change. This run-off reduction remains an economic trade-off, at the potential expense of agriculture, drinking water, navigability and environmental quality.

For reasons of optimising electricity generation in any climate scenario, we have not adjusted/reduced electricity production figures of the HPPs under consideration in this project, either for existing HPPs or for prospective greenfield projects. In other words, scientific consensus on possible impacts of climate change on precipitation, production of hydropower and consequently on economic / profitability of HPPs have not been modelled within the frame of this project.

Future temperature increase will have roughly the same effect on hydropower potential in the region (with slight differences). Therefore, climate change has very limited impact on the comparison of advantages of hydropower development – the prioritisation of HPP-candidate investments is one of the objectives of the Study – due to the fact that it affects electricity production with slight differences across region. Those differences are too small to be considered in a comparative performance assessment and the ranking of HPP candidates in our Multi Criteria Assessment (BR-8). However, on an individual basis, the effect of climate change will play an important role in electricity production assessment. Therefore, we would suggest that the possible reduction of electricity generation in an individual HPP planned (or an extra section on possible impacts of Climate Change) becomes a standard part of sensitivity analysis during the feasibility stage of any HPP project development.

For the purpose of more reliable hydropower generation planning, all countries in the region are advised, as a matter of top priority, to improve their hydrological data gathering network for future integrated water resources planning. However, gathering discharge/meteorological data and modelling rainfall/run-off is not an objective per se, but serves better decision-making and planning on river basins.

Examined long-term weather records demonstrate a large over-year variability (long-term fluctuations) with no systematic signatures across different locations/climates. General Circulation Models reproduce the broad climatic behaviours at different geographical locations and the sequence of wet/dry or warm/cold periods on a mean monthly scale. However, such model outputs at annual and climatic (30-year) scales are not relevant in the context of HPP development in the Western Balkans. Also, they do not reproduce the natural over-year fluctuation and, generally, underestimate the variance and the index of dependence (correlation) of the observed series; none of the models currently in use proves to be systematically better than the others in forecasting over-year variabilities.

Based on case studies made at four HPPs referenced in the World Bank, 2015, Water & Climate Adaptation Plan for the Sava River Basin, two important conclusions were made regarding the effect of climate change on discharge:

- From an analysis of the seasonal energy production, the general trend is that for the near future there would be more energy available in winter and autumn whilst there would be a small decrease in spring. For the distant future until 2070, a decrease in the spring and summer energy production is expected by 4% and 10% on average, respectively, whilst the winter and fall energy production is expected to increase by 11% and 5% on average, respectively. However, seasonal variability may not cover the temporal scale of drought spells, often covering a number of days, or weeks.
- Forecasting of precipitation in future is not going to stop. On the basis of presently known forecasts, it can be concluded, referring to World Bank 2015, that although impacts of climate scenarios vary over the SRB, this is unlikely to affect the hydropower sector in the near future (based on the logical frame provided), whilst in the more distant future water availability is likely to decrease and with it the energy produced from the hydropower facilities. If the trend of temperature rise continues, climate change will cause detrimental effects on water resources. Taking into account the worldwide resolution to combat climate change and present action in slowing down temperature increase, it is believed that the trend will get under control if the desired values are reached.

Detailed assumptions (Water & Climate Adaptation Plan for the Sava River Basin) were made regarding the effect of climate change on discharge:

- A general conclusion is that all models simulate a temperature increase across the SRB, with larger values for the period 2041-2070. Precipitation change is more complex, but in general shows an increase during the winter and a decrease for the summer months. The summer precipitation deficit is more pronounced in the 2041-2070 period.
- The SRB is also especially sensitive to climate change due to present socio-economic factors that are particularly bad since the general migration of the population away from agricultural areas towards cities.
- Core activities within the SRB that have been found to be important in the context of climate change are: navigation, flood protection, agricultural water management/irrigation, hydropower and public water supply, as the sectors that are most vulnerable to the impacts of the increasing temperature and decreasing river discharges.

The assessment of effects on the hydropower sector due to climate change provided the following conclusions:

- Impacts are principally associated with direct effects on power generating potential, but also indirectly through increased general demand for energy for heating and cooling due to higher or lower temperatures.
- With increasing evaporation/ET due to future temperature increase, a larger decrease of hydropower production is expected to occur on reservoir type and pumped storage type dams that have a high storage area/volume ratio and small reservoirs. Other types of HPP would show smaller effects, but still experience a decrease in hydropower generation.
- A decrease in river runoff would affect power generation with a reduction on all hydropower facilities, but run-of-river schemes that are solely dependent on runoff will be affected in particular.
- Floods in the autumn/winter and droughts in the spring/summer would mostly affect run-of-river HPPs and HPPs with small reservoirs. With this climate change parameter, an overall power generation decrease is expected.

Case studies were made at four HPPs, chosen by their significance in the power sector and their proximity to existing hydrological stations with reliable data. The following conclusion was made:

- Results for the distant future showed larger variance between the climate models. Energy production would change between -8% decrease for the HPP Bočac and +4% increase for the HPP Bajina Bašta, although the order of the magnitude of these changes is still in the range of the modelling and measurement uncertainties.

The general trend in most cases, however, was a decreasing hydropower production.

Furthermore, at this point of study, it is reasonable to assume that both drought and flooding will become more extreme compared to the present state, while the average discharge, important for hydropower production, is going to remain the same in the mid-term period. Consequently, adaptation of hydropower facilities to climate change characterised by the occurrence of extreme low and high discharges could be in reservoir development. **Reservoir volumes should be sized to compensate for the increased seasonal water imbalance in future.**

3.1.3 Climate Change in the context of Western Balkans

Several existing EU policies and initiatives contribute to climate change adaptation in respect of broader water issues. The most important ones are the Water Framework Directive (WFD), the EU Floods Directive, the EU Policy on Water Scarcity and Droughts and the 2013 EU Strategy on Adaptation to Climate Change.

Although climate change is not explicitly included in the text of the WFD, the expected impacts may have a significant influence on Integrated River Basin Management (RBM) planning and therefore, must be carefully considered in all aspects of WFD implementation. The step-by-step and cyclical approach of WFD river basin management makes it well-suited to correctly incorporating climate change issues.

In 2007, the European Commission issued a document: “Adapting to climate change in Europe – options for EU action” (COM/2007/354). This document defined priority actions in respect of adapting to the effects of climate change, one of which is: “Early action for adaptation strategies development in the areas where current knowledge is sufficient”. This led to the European Commission issuing a white paper: “Adapting to climate change: Towards a European framework for action” (COM/2009/147), which was issued in April 2009 and sets out a framework to reduce the EU’s vulnerability to the impact of climate change.

The “EU Strategy on adaptation to climate change” (COM/2013/216), adopted by the European Commission in April 2013, sets out a framework and mechanisms for taking the EU’s preparedness for current and future climate impacts to a new level. Implementation of the EU Adaptation Strategy is based on eight actions. Action No. 7: “Ensuring more resilient infrastructure”, states the following activities:

- The Commission will launch a mandate for European standardisation organisations to start mapping industry-relevant standards in energy, transport and buildings and to identify standards that need to be revised to achieve better inclusion of adaptation considerations.
- The Adaptation Strategy package provides guidelines to help project developers working on infrastructure and physical assets to climate-proof vulnerable investments.
- Drawing on the results of its Communication on Green Infrastructure, the Commission will explore the need to provide additional guidance for authorities and decision makers, civil society, private business and conservation practitioners to ensure the full mobilisation of ecosystem based approaches to adaptation.

At present, the WB6 countries are at different stages of preparing, developing and implementing national adaptation strategies. The extent of development of these national adaptation strategies depends on the magnitude and nature of the expected impacts, assessments of current and future vulnerability and their capacity for adaptation.

Potential climate change impacts because of the pressures on water environment (e.g. water reservoir realisation), which are in direct confrontation with some WFD objectives (e.g. maintaining good status of water bodies) must be resolved on a priority basis in and among WB6 countries while developing their strategies addressing climate change. Even though the WFD does not explicitly refer to adaptation to climate change, it was agreed that from the second planning cycle onwards climate-related threats and adaptation planning should be incorporated in RBMPs (as in the drafting of guidance document No. 24 River Basin Management in a Changing

Climate (EC 2009)[3]). The present legal framework is set-up in such a way that the WFD is the legislation to be complied with, while climate change adaptation could be a case of “overriding public interest” as a part of the Article 4(7) procedures. However, the useful outcome is resolution between both sides: climate change and water management must be clearly compared against WFD objectives. Consequently, there is a real risk that climate funding may support initiatives that are harmful for the socio-ecological systems. This generally defines “maladaptation”, and avoiding maladaptation is a first key concrete step towards adaptation in a broader sense.

As a consequence of the identified changes in water environment, potentially by the climate change impacts, water storage will be considered as a measure. Reservoirs are mostly in confrontation with some WFD objectives (e.g. maintaining good status of water bodies). This situation can trigger Article 4(7) and in such case an exemption should be fulfilled.

At present, the Western Balkan countries are abundant with water resources. Within Europe, the WB6 Countries are among some of the most water-rich with regard to the amount of water available per person (10,600 m3/cap, which is twice the European average). Most of this water originates from the mountainous headwaters, and several countries receive a significant share of their water from other countries through Transboundary Rivers. Water resources have always played an important role in the economy of Western Balkans countries, and have been exploited for irrigation, drinking water supply, industrial needs, livestock production and tourism. Water resources are also used to generate electricity. On average, according to IEA statistics, about 49 % of all electricity generated in WB6 comes from hydropower, although this is much higher in Albania (almost 100%), and Montenegro (59.8 %). Hydropower generation can be affected by accelerated evaporation and drought, and changes in the timing and volume of flow to storage systems. More frequent extreme events, such as flooding, may also threaten all types of energy infrastructure, with the associated increase of maintenance costs.

The six Western Balkan countries experience a range of climates disproportionate to the size of the geographic area they represent. As the region is characterised by countries which have mixed source and riparian watershed areas, intensive water development and water-use combined with increasing hydrological variations and extremes exacerbated by climate change is expected in the near future. Dry season flows have decreased and rivers sometimes remain nearly dry. On the contrary, the lower reaches are vulnerable to devastating floods and considerable loss of lives and livelihood and damages to infrastructure and crops are occurring in the last decades. In addition to the hydropower potential utilisation which is enabled by adequately positioned and designed reservoirs, flood protection capacity and irrigation potential represent a great opportunity for climate change adaptation.

Albania has a Mediterranean climate with mild, wet winters and hot, dry summers, as does the southern part of Montenegro and the coastal/lowland areas of Bosnia and Herzegovina. The climate in the remaining areas of Bosnia and Herzegovina ranges from temperate continental to alpine. The far north of Montenegro has a continental climate, and the central and northern parts have some characteristics of mountain climate, but with Mediterranean Sea influence on temperature and precipitation.

The climate of Serbia varies from temperate continental in most areas to continental in the mountains to Mediterranean subtropical and continental in the south-west. The climate in the former Yugoslav Republic of Macedonia varies from sub-Mediterranean to moderate continental/ sub-Mediterranean to hot continental to cold continental to a range of alpine sub-climates.

The Western Balkans is particularly exposed to the effects of extreme events, including heat, droughts, and flooding. Heat extremes will be the new norm for the Western Balkans. In a 2°C temperature level increase, highly unusual heat extremes are projected for nearly a third of summer months compared to virtually all summer months in a 4°C maximum level increase. Unprecedented heat extremes are projected to occur for 5–10% of summer months in a 2°C level increase, compared to about two-thirds of summer months in a 4°C level increase.

The risk of drought is high. Projections indicate a 20% increase in the number of drought days and a decrease in precipitation of about 20–30% in a mid-century 4°C maximum. Projections for 2°C increase levels are uncertain. At the same time, projections suggest an increase in riverine flood risk, mainly in spring and winter, caused by more intense snow melt in spring and increased rainfall in the winter months (precipitation projections are, however, particularly uncertain).

[3] http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52013SC0132

Most crops are rain-fed and very vulnerable to projected climate change. While there are no projections that encompass the entire region, and projections for individual countries remain uncertain, clear risks emerge. For example, projections for the former Yugoslav Republic of Macedonia indicate potential yield losses of up to 50% for maize, wheat, vegetables, and grapes for around 2°C global warming by 2050. Pasture yields and grassland ecosystems for livestock grazing may be affected by sustained drought and heat, and decline over large parts of the Western Balkans. The effects of extreme events on agricultural production are mostly not included in water resources use assessments, but higher vulnerability and completion has been indicated in future water resources use.

Energy systems are very vulnerable to extreme events and changes in river water temperatures; changing seasonality of river flows can further impact hydropower production. On average one-fifth of electricity production in the most Western Balkans countries depends on hydroelectric sources. Reductions in electricity production would be affected by an increase in cooling demand.

Extreme climate events and the appearance of new disease vectors pose serious risks to human health. The increased incidence and intensity of extreme heat events could cause the seasonality of temperature-related mortality to shift from winter to summer across continental Europe. Albania and the former Yugoslav Republic of Macedonia are considered particularly vulnerable to heat waves. The net total number of temperature-related deaths is projected to increase for the period 2050–2100 above 2°C warming levels.

3.1.4 Selected references to scientific sources

The Balkans is getting warmer and is projected to continue this warming trend generally in proportion to the expected increase in global temperatures. Similarly, the region is receiving less precipitation in the long-term and is projected to experience further decreases, although precipitation patterns will continue to vary according to terrain, elevation and proximity to the sea. The effect of warmer temperatures on evaporation, together with the decline in precipitation, will tend to make the region drier.

All six Western Balkans countries conform to the general warming trend, with Albania expecting more frequent droughts. In the former Yugoslav Republic of Macedonia - where the frequency and intensity of floods and droughts have already increased - the sharpest declines in precipitation are expected to occur in the summer period, along with the greatest increase in temperature, while winter precipitation is expected to remain unchanged. Serbia has experienced more frequent and intense droughts. Precipitation in both Serbia and Bosnia and Herzegovina has increased in some areas, and declined in others. Montenegro has been experiencing more frequent extreme heat since 1998, but annual precipitation has remained fairly constant with some fluctuations around the norm, and some analysis detects a slight downward trend.

The reference document prepared by the World Bank Group in 2014 “Turn the Heat Down – Confronting the New Climate Normal” brings into vision relevant information regarding climate change in the Western Balkans region, despite dealing on a world scale. This document is of relevance for assessing impacts of Climate Change on general water uses, thus its statements are considered in the frame of EU policies. Some of the key statements interesting for the Study are summarised in further text.

There is growing evidence that warming close to 1.5°C above pre-industrial levels is locked-in to the Earth’s atmospheric system due to past and predicted emissions of GHGs, and climate change impacts such as extreme heat events may now be unavoidable.

As the planet warms, climatic conditions, heat and other weather extremes which occur once in hundreds of years, if ever, and are considered highly unusual or unprecedented today would become the “new climate normal” as we approach 4°C - a frightening world of increased risks and global instability.

If temperatures rise toward 4°C, which is the worst case scenario, regions in the Western Balkans and Central Asia could encounter reduced water availability, becoming in some places a real bottleneck. Higher risk of drought results in potential declines for crop yields, urban health risk, and energy generation. In the former Yugoslav Republic of Macedonia, yield losses are projected of up to 50 percent for maize, wheat, vegetables and grapes at 2°C warming increase. Precipitation changes are projected under continued warming with substantial, adverse consequences for water availability. Central America, the Caribbean, the Western Balkans, and the Middle East and North Africa stand out as hotspots where precipitation is projected to decline between 20–50% in a 4°C world. Shifting of the timing of water flows, and a higher risk of drought in the Balkans, carries consequences for crop yields, urban health, and energy generation. Flood risk is expected to increase slightly along the Danube, Sava and Tisza Rivers.

After mid-century and especially with warming leading to a 4°C increase worldwide, destabilised water availability poses a risk for agriculture and competing conditions on hydropower generation. In the Western Balkans, extreme heat with a strong decrease in precipitation and water availability are projected to lead to large reductions in crop yields, adverse effects on human health, and increasing risks to energy generation conditioned in a possible 4°C temperature increase; but would already be present in a 2°C world.

Most countries in the Western Balkans depend on hydroelectric sources for at least one-fifth of their electricity production. Reductions in electricity production would be concurrent with an increase in cooling demand which is projected to increase by 49% in a 4°C world. The situation varies throughout the region; with temperatures averaging towards 4°C, it is projected that decreased hydropower potential in Croatia could amount up to 35%.

Very few scientific studies about regional impacts on water resources and river runoff levels are available for the Western Balkan countries, with most projections done on a broader European level. There is a lack of area-wide hydrological data, especially since the 1990s. Water availability over summer months In the Balkans is assumed to decrease considerably until the end of the century. In the northern parts of the Balkans, spring and winter riverine flood risk can increase. Results from a global study show severe decreases in annual discharge in the Western Balkans of more than 45% in a 4°C world, if the Climate Change would ever come to that point.

Furthermore, due to the increased incidence of droughts and extreme river low flows, the mean number of days during which electricity production will be reduced by more than 90% is projected to increase threefold; from 0.5 days per year (in present days) to 1.5 days per year from 2031–2060 under 1.5°C global warming. The challenge to meet growing energy demands in the Western Balkans will be further intensified by a reduction in energy generation from hydropower sources as the result of decreases in precipitation.

According to the above statements extracted from “Turn the Heat Down – Confronting the New Climate Normal” about predictions of hydropower potential decrease in the Western Balkans region, it is clearly impossible to extract exact and unique value of changes pertaining to the climate differencing on a micro scale in the region. On the one hand climate change is evident, science in that regard is compelling; on the other hand, valuing the change of precipitation and run-off would be effectively possible to obtain only for each River Basin under consideration.

In the sense of project planning and the objectives of present Study, which are set at the comparison of best HPP projects, it would be useless to deal further in detail with the assessment of hydropower potential decrease. As aforementioned, this will affect all hydropower potential with some differences in the region. Overall, it can be concluded that there will be some decrease of hydropower potential in the future, but on the other hand this loss could be compensated by sufficient reservoir space and better management of available water resources from the side of HPP operators.

3.1.5 Climate Change vs. Water Run-off in the Region

The WB6 and surrounding countries face a number of common water issues, including weak transboundary cooperation and water quality / pollution. Climate change poses additional challenges to water availability, quality and management. Following the breakup of former Yugoslavia, almost all river basins became internationally shared in addition to the four transboundary lakes that existed in Yugoslavia at that time.

Most countries share one or more of these river basins, making this an important area for regional cooperation and coordination. However, transboundary water cooperation remains generally weak, with low political prioritisation, insufficient institutional capacity, weak information exchange, lack of joint monitoring and in some cases conflicts, constituting some of the main factors surrounding weak transboundary cooperation.

Water quality is also a cause for serious concern. Discharge of wastewater is a major source of pollution for both surface and groundwater sources, and wastewater treatment is generally either poor or non-existent. Although freshwater quality is high in mountain streams and in the upper reaches of rivers, wastewater from urban areas and industry has polluted the course of lower rivers, including water streams like the Sava River in Serbia or the Sitnica River in Kosovo.

Climate change will exacerbate the already existing pressures on water resources and will pose significant risks to sectors where water is a limiting factor, including agriculture, industry and livelihoods. Almost all climate projections agree that the countries in the region will experience a significant decrease in precipitation in the twenty-first century, accompanied by an increase in drought conditions and therefore a decrease in water availability.

For the region as a whole, annual run-off is expected to decrease by up to 15% if warming is 2°C above pre-industrial levels, and by up to 45% in a 4°C world. The seasonality of rainfall will also change. Longer low-flow periods in rivers and a significant reduction in low-flow magnitudes are expected during the summer season, which will bring a number of problems, such as water shortage, irrigation problems, drop of the underground water table, etc.

Higher temperatures will also shift the snowline upwards. By the year 2050, a reduction of up to 20 days in snow cover is expected across the Balkans and up to 50 days in the Dinaric Arc. More intense rainfall and increased snowmelt during the winter will increase the river flood risk in both winter and spring across the region, but the time of greatest risk will change from spring to winter for snow-influenced rivers.

Albania contains glaciers with a spatial area of less than 0.05 km^2, which are some of the lowest-altitude glaciers in the Northern Hemisphere. Although their ice has been steadily thinning and their glacier fronts have retreated, they have survived until now due to local influences in climate and topography, including avalanches and wind-drift snow and shading. In Montenegro, there are no glaciers left; the only areas of permanent snow deposition are at Debeli Namet. However, predicted future warming (especially in the summer) alongside drier conditions might result in the disappearance of all glaciers within the coming decades.

The tendency of lowering total volume of the run-off in the Balkans is probable but not the only valid scenario. Whilst the probability is very high that flood and drought extremes will continue in the future, it is also probable that about the same levels of average annual discharge will continue. Any forecasts of climate change effects made regarding water quantity, on the basis of hydrology data gathered from the region, are unreliable as data are generally neither adequately gathered nor are they precise enough. Typically, the hydrology data available in the WB6 Region are questionable, even for the calculation of hydropower production and do not represent a sound baseline for Climate Change assessment

3.1.6 Power Sector overview

The energy sector is considered highly important for the economic growth of the Western Balkan countries, where there is large potential for the development of this sector to bring new investments to the region. A high dependence on imported energy, especially on oil and natural gas, raises various concerns for the security of energy supply and the need to diversify the supply sources with renewable energy such as biomass, solar and wind energy, as well as introducing energy efficiency.

Current patterns of energy use in the Western Balkans lead to significant impacts on the environment. The region as a whole has a high carbon intensity due to its heavy dependence and use of coal (lignite) in power generation. Other environmental concerns include pollution from energy combustion (e.g. indoor and local air pollution from inefficient and improperly used stoves) and deforestation and land degradation (from excessive use of wood for fuel). Taking into consideration all of these features, the energy sector in the region is assessed as one of the major sources of GHG emissions, air pollutants (acidifying substances, ozone precursors and particulates) and oil spills. The main domestic resources of electricity generation in the region are lignite and hydropower. Serbia, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia and Kosovo depend mainly on lignite(coal)-fired thermal hydropower plants for electricity generation. Albania derives almost all its electricity from hydropower. Bosnia and Herzegovina, and Montenegro also have significant hydropower capacity. There is also a high level of shared energy infrastructure across countries, with extensive daily and seasonal exchanges of electricity occurring. The energy intensity (an indicator of energy efficiency) of the Western Balkans is high. Energy intensity can be attributed to three main factors: the degraded state of the energy infrastructure; high-energy losses during transformation, transmission and distribution; and inefficiency in the end-use sector.

Energy systems within the region are very vulnerable to extreme environmental events and changes in river temperatures. The extent and nature of these prospective impacts depend on the degree to which countries rely on different energy sources. Thermal power production is vulnerable to changes in climate through water availability and temperature, due to the high dependence of these power plants on cooling water. Lower levels in lakes and rivers, reduced run-off, accelerated evaporation and warmer water also reduce the amount of water for cooling or cause restrictions on cooling water intake or discharge, constraining generation capacity.

Due to the fact that water surface of reservoirs compared to river surface is larger, reservoirs are receiving more insolation, which is subsequently increasing water temperature. Temperature increase is limited to water surface layer and according to experience remains at the surface because the mixing of water is relatively low in reservoirs. Layers below the upper one are protected from additional heating, the temperature remaining about at the same level as in a river on average. Consequently, thermal pollution was not considered an important issue for the present Strategy, but it will be when reservoir planning continues. The increase of water temperature has been identified along the majority of river streams in the Region, limiting the availability of cooling water for Thermal Power Plants and favouring external cooling towers.

Taking into account the effects of climate change on river water temperatures and river flows, the capacity of nuclear and fossil-fuelled power plants in Southern and Eastern Europe could face a 6–19% decline for the time period 2031–2060 compared to 1971–2000.

More frequent extreme events, such as flooding, will also threaten all types of energy infrastructure and possibly drive up maintenance costs, although studies assessing this are limited. Much of the energy infrastructure in the Western Balkans countries was built in the 1960s and 1970s and is already in need of thorough rehabilitation and replacement. Climate change is expected to pose risks to power transmission network functions, and to reduce efficiency or alter structural integrity, especially for older, poorly maintained network facilities.

Accompanying the expected decreases in annual river discharge and the changing seasonality of river flows, overall hydropower production in Europe, including the Western Balkans, is expected to decrease by 1.66 TWh, or 1.43% compared to 2005 production levels. One study from Croatia predicts that energy generation from hydropower could decrease by 15–35% in a 4°C world temperature increase. Given that severe decreases of up to 15% in annual discharge are expected across the Western Balkans in a 2°C higher world, similar reductions in hydropower generation are possible elsewhere.

Presently, trends electricity generation reduction as a result of reduced annual flows cannot be noticed on graphs depicting generation from hydropower in the WB6, such as the data presented bellow in Table 3.1.

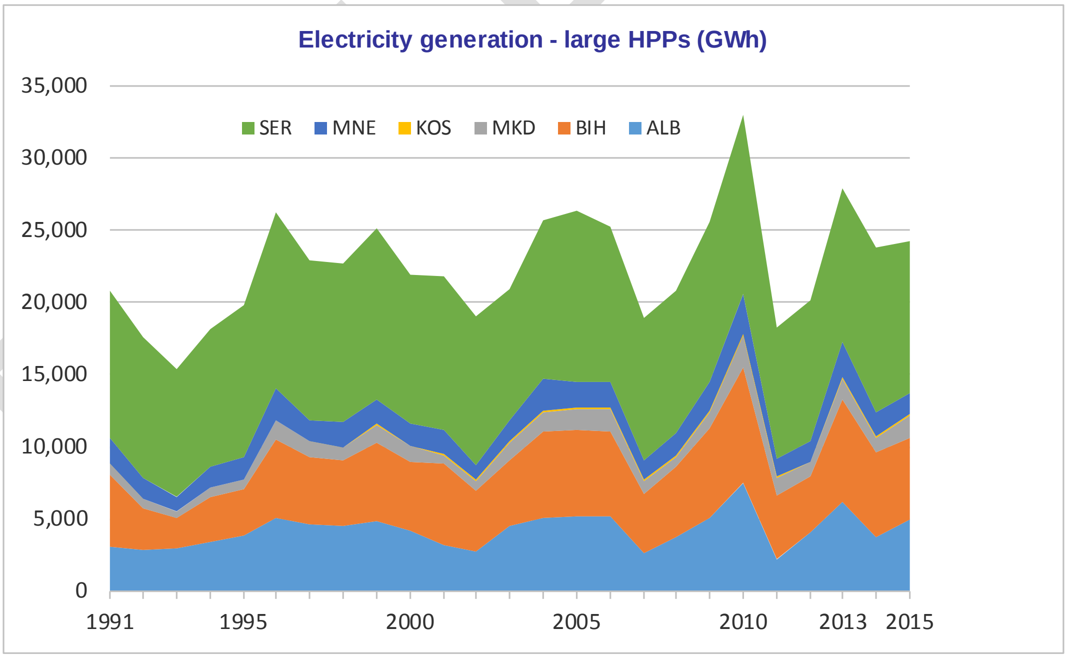

Figure 3.1: Electricity generation in WB6 (1991 – 2015)

From the demand side, the trend of warmer winter temperatures and even hotter summers are expected to flatten the electricity consumption profile, as the demand for cooling energy rises and heat energy declines. Electricity systems may strain to meet the heavier demands for air conditioning, particularly if they rely on hydropower.

Economic development, population growth (at mid-term, while at short term decline of population is happening)) and climate impacts (decreased production and power generation disruption) may together contribute to a rise in electricity prices and the risk of electricity shortages in the region.

3.1.7 Policy responses: Global and Regional

Global level

Over the past 20 years, governments have been intensifying their consideration of the threats posed by climate change by progressively implementing strategic policy actions to tackle such changes, and in parallel, advancing scientific knowledge on the climate system for more informed decision-making.

The global policy response so far has mostly centred on *mitigating* climate change by reducing anthropogenic GHG emissions. The setting of binding reduction targets via international instruments, such as the Kyoto Protocol, to the UNFCCC, has pursued this strategy. Most industrialised nations listed in Annex I of the Convention, including the EU, have committed to GHG reductions until the end of 2020.

The complementary response to mitigation is *adaptation*, which entails facing the consequences of unavoidable changes by adjusting to new climatic conditions and climate variability, regardless of future emissions. At the global level, the UNFCCC and the Kyoto Protocol refer specifically to adaptation in several of their Articles and require the Parties' cooperation in this area. Industrialised countries have committed to supporting the most vulnerable developing countries who have limited capacities to cope with the impacts of climate change - UN, 1992.

Within the UNFCCC process, adaptation covers five key elements needed to enable knowledge sharing and learning, namely:

- Observation of climatic and non-climatic variables;
- Assessment of climate impacts and vulnerability;
- Planning;
- Implementation;
- Monitoring and evaluation of adaptation actions (UNFCCC, 2015).

In order to allow the functioning of such adaptation components, UNFCCC Parties should ensure technical and institutional capacities, as well as technological and financial support.

A new, legally-binding agreement on climate involving both developed and developing countries for the period from 2020 onwards was adopted by the 21st Session of the Conference of the Parties (COP21) in Paris (30 November-11 Dec 2015). Acknowledging that the primary focus of the agreement is reducing global GHG emissions and thus succeeding the Kyoto Protocol, Parties have made several proposals to also address adaptation and the issue of loss and damage, among other key elements, under the future climate regime.

The global goal on the adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal has been established (Article 7, Paris Agreement).

There are two topics interesting from the climate change point of view foreseen for the 2017-20 perspective: Integrated approaches to adaptation, including exploring the nexus water-agriculture-energy-environment, and Coordination across multiple level of governance with a focus on cities and transboundary adaptation. It is generally believed that the interdependencies between water and (hydro)power or water and agriculture will be more important in the future and therefore a full analysis incorporating such dependencies will be needed and required once it comes to hydropower assessments. Due to its significance, these linkages were further commented and discussed throughout this report wherever deemed necessary. In the BR-5 on Transboundary Issues there is an extensive coverage of the water nexus related to hydropower planning. The water resources nexus is discussed throughout this and BR-5 under different headings focusing on multipurpose and integrated use of water resources. Presently hydropower potential is the dominant focus within the water nexus, however, in the next phases concerning river basin planning and management, the multipurpose use will be emphasised in due detail.

While UNFCCC is global in scope, adaptation must be tailored to the context and the subjects involved, as it is a function of the specific impacts of climate change of a country, region, or territory.

With respect to the evolving scientific information on climate change, the IPCC Fifth Assessment Report (WGII AR5) dedicated to impacts, adaptation and vulnerability has shifted the focus of the analysis towards risks related to a changing climate. Such an approach highlights that risks are generated by three main components: vulnerability (lack of preparedness) and exposure (people or assets in peril) resulting from socioeconomic pathways and societal conditions which depend on changes in both the climate system and socioeconomic processes, coupled with hazards (triggering climate events or trends).

Actions to reduce future risk should target each of these factors either separately or jointly. In this light, adaptation can be seen as a dynamic process through which countries and communities become more capable of preventing or managing the impacts of climate change by reducing risks, increasing resilience and addressing sustainable development needs.

Regional level

Since climate change is likely to negatively affect countries at temperate zones to the same extent as countries at lower latitudes, adaptation has proved to be a major issue for developed nations, too. The EU Member States have widely engaged in adaptation and started to tackle these challenges through the establishment of adaptation strategies at all levels. The European Commission (EC) officially adopted the European Adaptation Strategy in 2013, following the release of a Green Paper in 2007 and a White Paper in 2009 that respectively opened the way to more attentive consideration of adaptation issues in Europe and outlined the fundamental concepts of the future Strategy.

Several cooperation initiatives are increasingly being undertaken on adaptation to climate change in the Western Balkan countries as a region. The EU has financed cooperation programmes and projects for the broader South-East Europe transnational region and other initiatives as part of the EU accession process to support candidate countries to transpose and implement a new set of climate change legislation.

3.1.8 WB6 country plans and supporting UNFCCC

Four of the six Western Balkans countries included adaptation plans in their national communications to the UNFCCC. These plans are outlines and generic statements of intent to adopt more detailed strategies related to specific challenges, and they are indicative of the direction a country is likely to follow. However, hydropower electricity production has not been explicitly mentioned in either of those countries.

In the short term, **Albania** intends to focus on improving its monitoring and warning systems for coastal areas, agriculture and forestry. Longer-term plans contemplate participation in the Drought Management Centre for South-Eastern Europe; the construction of a range of coastal protection structures; and the development of land management strategies – such as levelling and terracing – together with water control measures for agriculture.

Adaptation plans in **Bosnia and Herzegovina** centre on coping with drought. Measures under consideration include modifications in crop rotation, the application of new technologies to improve soil structure, the installation of windbreaks and the establishment of a drought early warning system. The plans also envision an information and education campaign related the public health and climate change.

The former Yugoslav Republic of Macedonia plans for adaptation contemplate extensive measures covering several areas – water resources, agriculture, forestry, biodiversity, public health and tourism. The water resources strategies include both structural and management initiatives. The agriculture measures include improvements in irrigation practices and the expansion of irrigated areas in combination with other changes in agricultural practices.

The **Montenegro** adaptation plans also consider agriculture, biodiversity and public health, but have a special focus on coastal zone protection. The adaptation measures include improvements in monitoring and infrastructure, and call for the eventual relocation of 10-20% of the urbanized coastal population.

Serbia has also included adaptation into its INDC.

3.1.9 Legal background to Climate Change

Albania is highly vulnerable to climate change, and economically reliant on the sectors that are at risk from climate change. The Paris Agreement entered into force in 2017. Albania's Third National Communication (2016) goes beyond the reporting commitments by developing a Greenhouse Gases inventory for 2000-2009, updating the mitigation analysis in line with EU objectives and the INDC document and developing an action plan for the adaptation of coastal areas.

Bosnia and Herzegovina (BIH). The Paris Agreement entered into force in 2017. Third National Communication was submitted to the Convention Secretariat in 2016, containing The Inventory of greenhouse gases covering the period 2002 – 2009, and 2012 and 2013. This report also covers the revision of the First Biennial Update Report on Climate Change for 2010 and 2011 and the Second Biennial Report on 2017.

The former Yugoslav Republic of Macedonia Government submitted its Third National Communication to the UNFCCC Secretariat in 2014 with the Greenhouse Gases Inventory. The First Biennial Update Report was carried out in 2015. Taking into consideration the EU association process, the former Yugoslav Republic of Macedonia needs to develop a comprehensive policy and strategy on climate change, in accordance with the expected EU 2030 policy framework for climate and energy.

Domestic financial support for climate adaptation activities is limited: there are no allocations for climate change response within the relevant ministries' budgets. The projects handling climate change were therefore mainly funded by international organisations such as the UNDP, GEF and USAID, as well as bilateral and multilateral donors.

Montenegro became a member of the UNFCCC as a non-Annex 1 Party in 2007 and signed the Paris Agreement in 2016. It prepared and submitted its Second National Communication in 2015. The Biennial Update Report was submitted in 2016. The Government of Montenegro adopted its national Strategy on Climate Change by 2030. The Strategy has a strong focus on mitigation, but strongly recommends development of the National Adaptation Plan, for which it provides detailed guidance.

Montenegro is in the process of transposing and implementing the *acquis communautaire* into its national legislation, particularly in the environment and energy sectors, which is supported by its membership of the Energy Community. Based on the Proposal of the new Law on Environment, Montenegro needs to adopt a national plan for climate change mitigation and another to combat desertification and soil pollution.

As with other Western Balkans countries, funding for climate change is heavily dependent on international support (EU funds, EBRD, KfW, GEF/UNEP, GIZ), although some projects are implemented through national budget funding.

Serbia joined UNFCCC as a non-Annex I Party in 2001, and signed the Paris Agreement in 2017. Under the Convention, Serbia does not have GHG emission reduction commitments, but it has obligations to establish and implement measures and activities that contribute to achieving the objectives of the Convention. The First Biennial Update Report was submitted in 2016. It submitted its Second National Communication in 2017. It contains an overview of realised adaptation measures, and also an analysis of the climate change impacts and risks for water management, forestry and agriculture sectors, since they have been identified as vulnerable and important to national development goals. Considerable progress has been made to harmonise national legislation with the EU requirements. The Air Protection Act deals with climate change mitigation. It foresees adoption of the Air Protection Strategy (including response to climate change).

The national budget contributes to financing climate change projects, but its funds are not enough to meet climate change adaptation requirements for Serbia. Climate change responses are therefore mainly financed through projects funded by international donors and ministry programmes, although these sources are not strictly oriented to adaptation.

Kosovo is highly vulnerable to climate change since two of its most important economic sectors – agriculture and forestry – are climate dependent. Kosovo has not yet been recognised by the United Nations system. Consequently, it is not eligible for the ratification of international conventions, although it could participate in negotiations as an observer under UNSCR 1244. Kosovo is, however, committed to aligning its legislation with the EU legislation, given its EU approximation process. Additionally, the climate change adaptation strategy is relevant for Kosovo to meet the EU approximation requirements, particularly in its assessment and management of flood risks under the EU Floods Directive.

While there is a need for innovative approaches to secure adaptation, current institutional arrangements are insufficient to manage these new challenges adequately. The authority responsible for climate change is the Ministry of Environment and Spatial Planning (MESP), namely its Department of Environmental Protection, while Kosovo Environment Protection Agency (KEPA) monitors the state of the environment.

National funding allocations to environmental issues are still not sufficient, and it is expected that domestic funding will remain low for the foreseeable future. Therefore, the funding for adaptation will heavily depend on the private sector, international donors and the EU funds. Establishment of an environmental fund was foreseen for the end of 2015, but this task still didn't receive priority status.

Specific consideration of mountain areas is particularly poorly represented in the climate change policies of all the countries. Most countries are in the initiation stages of their overall policy response to climate change, with most climate considerations being either donor-driven or a part of EU accession requirements. Most countries have started recognising the importance of and vulnerability to climate change, especially of the sectors reliant on natural resources. Concrete and innovative responses to climate change adaptation are still in the inception phase, hampered by limited capacity and sources of funding for adaptation.

3.1.10 Sectorial Climate Change Strategies for Water

Water sector legislation is quite similar in all of the Western Balkan countries. The water sector is regulated at the state level in all countries, except in BIH where the entity governments are responsible for the adoption of legislation, planning and development of the sector. There are no direct references within policies which link climate change in general, or climate change in mountain regions specifically, to water management. However, water legislation deals with water-related natural disasters such as flooding, which can be associated with climate change in certain cases.

BIH, Croatia, Serbia and Slovenia are Parties to the Framework Agreement on the Sava River Basin (FASRB). The purpose of this agreement includes the establishment of sustainable water management and the undertaking of measures to prevent or limit hazards on the Sava River, which was the biggest national river in former Yugoslavia. One of the projects implemented under this Framework Agreement was the pilot project on climate change, entitled "Building the link between flood risk management planning and climate change assessment in the Sava River Basin", which was finalised in 2013. Through expanded and strengthened collaboration among the countries in the Sava River Basin, the project's goal was to address transboundary management of floods while taking into account the impacts of climate change under different scenarios and the perspective adaptation measures. The project outcomes included several reports and studies, including the Report on climate change adaptation measures for flood protection in the Sava River Basin (2014).

3.1.11 Effects of Climate Change on Flood Management and Hydropower

Flood Management

Current flood protection in the river basins of WB is insufficient for effective flood management for many reasons, including inadequate infrastructure, poor maintenance, the lack of coordination in the basin in terms of monitoring, forecasting, and warning systems, and so on. This was starkly evident during the destructive floods of May 2014, which were assessed as some of the worst floods on record.

The main predicted impact on future flood management is not only climate related, but associated also with future social, economic, and infrastructure development. Without a doubt, the impact that climate change will have on flooding in the future is significant and should not be underestimated, since the flood hazard is increasing. Although the modelling results indicate that the climate-induced impact will be smaller in the downstream plains than in the upstream mountainous regions, the role of flood protection infrastructure should not be ignored, as the infrastructure protecting the upstream regions is at the same time increasing the downstream risk.

In Croatia, for example, the May 2014 floods proved that the existing natural retentions have a limited capacity to

accept major flooding, thereby emphasising the need to increase this means of flood protection to complement the aging and insufficient system of embankments or to retain more volume in the upper river sectors. In the same period, severe flooding occurred in the northern part of Bosnia and Herzegovina, and central parts of Serbia. Dozens of people were killed in the floods, tens of thousands fled their homes, and several million people were directly or indirectly affected. Flooding caused enormous damage. The floods were caused by extreme rainfall and low soil infiltration rates due to previous precipitation, as well as inadequate spatial and water resources planning.
Catastrophic events with floods occurred in the region during 2014, once more pointing out and raising the issue of the importance of urgent activities regarding an integral solution for the river Bosna on that part of the river which is placed within the territory of Republic Srpska.

The trend towards urbanisation can be expected to continue in the future, thus increasing the vulnerability of the bigger cities along major rivers and the smaller towns that are all prone to flooding when the river and its tributaries rise. The May 2014 flood proved that the urban areas are at greatest risk; flood protection for these areas, including for critical infrastructure (e.g., roads, railway, pipelines, etc.), should therefore be prioritised. This implies that capital expenditure for flood protection will need to increase in the future, possibly at the expense of agriculture areas, which should be reduced if it is deemed necessary. Clearly, carefully designed adaptation measures for long-term flood planning must be developed.

Mutual Benefit: Flood Management Plus Hydropower Development

The operation of the reservoirs, existing or new, must consider downstream users and needs (water cooling for thermal power plants, irrigation, drinking water, navigation, ecologic/hydro morphology aspects, ecologically-acceptable flows, etc.).

Given downstream flooding problems in this region; designing a flood buffering capacity also as climate change adaptation for the reservoirs would be advisable when considering new projects. The design of these projects should include dam safety aspects (during extreme inflow events) and measures for coping with periods of extreme low inflow, due to the likely occurrence of extreme inflows in the future.

Buffering capacity of reservoirs to mitigate flooding is proposed mostly for big reservoirs in the Region on Drina and Drim Rivers. Needs of downstream water uses will be elaborated in planning phase, however Integrated Water Resources Planning and Management have been extensively explained throughout the Strategy.

All WB6 countries need to improve their disaster risk reduction capacities as an adaptation measure, mechanisms and infrastructures for flood prevention and in parallel develop hydropower where environmental conditions would allow for that by:

- Developing sound flood risk management plans and introducing adequate land use planning, promoting sustainable land use practices that improve water retention. In parallel, work on flood defences and climate resilient infrastructure of both structural (grey) and natural (green) type needs to be enhanced, providing for climate-proofing of vulnerable investments, adding sufficient storage volume in reservoirs where environmentally and economically feasible.
- Co-operating regionally for upgrading contingency planning and emergency measures, including adaptation measures and sharing of data and information, coordinating and standardising hydro-meteorological data collection and analysis and sharing it in the region for weather and flow forecasts. Extending co-operation to management of water balance in order to retain maximum flood volume in head reservoirs.
- Intensifying efforts for further and full alignment with the EU Water Framework Directive and Floods Directive.

- WB6 countries should prioritise the implementation of the Danube and Sava Basin Management Plans. The Sava Basin Management Plan should be scaled down for integrated development and implementation in each country. Countries should review the river basin management planning needs and improve maintenance standards in river infrastructure, in coordination with the ICPDR and the ISRBC and in full alignment with both the Floods and Water Framework Directives;
- WB6 countries should develop coherent river basis management plans.

All these improvements should be done by considering existing local, national, and transnational and EU level activities to optimise the synergies between different levels of action.

Hydropower

The impact of climate change on hydropower is principally associated with its direct effects on power generating potential, that is river flows. There will also be indirect effects, however, involving an increased demand for energy for heating and cooling due to the projected higher and lower temperatures.

A decrease in river runoff would affect power generation through a reduction in the amount of water available at all HPPs, but would particularly affect run-of-river schemes that are solely dependent on river runoff due to the absence of reservoir storage capacity. Floods in the autumn/winter and droughts in the spring/summer would also mostly affect run-of-river HPPs, as well as those with small reservoirs. With increasing evaporation, due to future rising temperatures, hydropower production is expected to decrease in the reservoirs that have a high storage volume and small reservoirs. Other types of HPPs would face smaller effects but will still experience a decrease in hydropower generation.

It is expected that power generation from the hydropower sector will be lower in the future although seasonal variations could be significant as well. Case studies were prepared at three HPPs (one in the Vrbas Sub-River Basin and two in the Drina River Basin)[4] that were chosen for their significance to the power sector and their close proximity to existing hydrological monitoring stations with reliable data. Hydropower operators are generally reluctant to share their operational data with water agencies, thus creating an impediment to the modelling work. The case studies showed negligible or small changes (less than ±5%) in average annual energy production potential in the near future for all HPPs except for Bočac in BIH, where one climate model predicts an increase of 9%. Changes are somewhat more pronounced in the distant future, by which time a larger variation among the climate models becomes apparent, and where again the most notable changes are at HPP Bočac. The general trend in most cases is decreasing electricity production.

An analysis of the seasonal energy production at HPP Bajina Bašta in Serbia shows a general trend of more energy available in the near future in winter and autumn and a small decrease in spring. For the distant future, a greater production decrease can be expected for the spring and summer seasons (4% and 10% on average, respectively) and an increase in winter and autumn (11% and 5% on average, respectively). It should be noted, however, that currently, power companies in the region generally fail to carefully optimise the operation of reservoir-type HPPs, and the projected magnitude of decrease in power production might be compensated for by an increase in production under well-optimised operational rules without unnecessary spilling of water instead of storing it for the time being. For that, additional volume in reservoirs at source would be required. By the optimal operation of the downstream chain of plants for synchronised production without spillage of water, the losses on the climate change side would be potentially compensated. In the medium-term, a better coordination model between electricity production and water management while minimising water spillage would be needed.

3.1.12 Concluding remarks

Albania's high exposure and sensitivity ranks it as the most climate-change vulnerable country in the region. Each of the countries faces its own challenges with political and economic instability, demographic changes and limited institutional capacity, among others. The generally low adaptive capacity rankings (in the "The Environment and Security Initiative"- (ENVSEC)), 2012, Climate change in the West Balkans), reflect the difficulty of these challenges and the relatively short time the countries have had to make progress. The individual country adaptation plans and the South-East European Climate Change Framework Action Plan are promising beginnings, and participation in the Global Environment Facility, the Dinaric Arc and Balkans Environment

[4] Water & Climate Adaptation Plan for the Sava River Basin, Final Report – August 2015

Outlook and the EU Stabilisation and Association process are further evidence of progress.

All this work lays the foundation for the even more challenging regional work that lies ahead. A regional strategy for the management of water resources appears to be the key to successful climate change adaptation in the Western Balkans. The water resources in the region have a high exposure and sensitivity to climate change, and the fates of the flood protection, agricultural and energy sectors are all closely tied to the water sector. With so many transboundary river and lake basins, the countries of the region have the best chance of managing their water resources in a cooperative fashion, whether through existing agreements or new ones, or a series of bilateral efforts.

Many policies, for instance, on land use planning, environmental protection, flood protection and renewable energy plans, have long sought to manage the risks e.g. extreme weather events, floods, and droughts which are determined by climatic and environmental conditions. Sound and sustainable policies at the national and transboundary levels should, however, acknowledge the new conditions where the baseline (environmental and political) is changing and a mutually agreed approach is needed. An appropriate response therefore needs to be developed to strengthen policies that will directly or indirectly contribute to resolving issues through Transboundary Management.

Transboundary Management should be integrated in the development of planning, programmes and budgeting across a broad range of economic sectors, through the establishment of effective long-term policy frameworks. Such a coordinated, integrated approach in Transboundary Management is needed to address the scale, complexity and urgency of addressing hydropower within water resources management and within the climate change challenge.

Transboundary water bodies, like rivers, lakes and groundwater pose a particular management challenge because of competing national interests, which are potentially present everywhere in the Region. Harmonisation therefore requires transboundary cooperation, based upon river basins and bio-geographic regions. While most measures will have to be implemented at the national or local level, where operational capacities exist, it is essential that efforts be coordinated in an equitable, acceptable and cost-effective manner at the level of the transboundary basin.

Policymakers should aim to establish effective communication on multiple levels involving all actors like individual citizens, local authorities, stakeholders from relevant sectors and policymakers at the international level. This effort goes hand in hand with similar efforts in climate change, flood protection, water supply, renewable energy etc. and needs to be adequately coordinated. These different levels of dialogue should support each other, for example through the establishment of consultative mechanisms at both the national and transboundary levels.

Since the effects of climate change remain uncertain at present, legal frameworks, especially those including water allocation, should be flexible enough to respond to any projected or unforeseen change. Flexibility can imply an ability to change the rules, for example in order to introduce new knowledge, or an option to apply a variety of policies, which can include the use of water resources for electricity supply. There are a number of possible options, which can be used to make transboundary agreements acceptable throughout river basins and in fact whole drainage basins. However, their selection will depend on the national and transboundary circumstances and the agreement of all riparian countries.

Transboundary waters agreements or the regulations to implement them should address large variations in water availability and how to handle them. For instance, specifying water allocations to be delivered from upstream to downstream countries in percentage figures compared to the overall flow rather than in total numbers could permit more flexible reaction to flow variability as a consequence of climate change. In addition, when negotiating transboundary agreements, countries should not only take into account optimistic water availability scenarios, but also all realistic hydrological extremes:

- **Including special provisions addressing temporal and spatial redistribution of water resources in transboundary water agreements** is recommended. Agreements with specific water allocations, for instance, may give the upstream country the possibility of delivering less water than foreseen in the treaty (but at least a specified minimum amount), during a limited period of time and with an acceptable justification, such as a severe drought period. This can be balanced by a compensation mechanism, i.e. the upstream country should deliver more water in the following period. Or it could be combined with accompanying mechanisms such as a prioritisation of water uses for drought cases. The agreement should clearly specify the conditions for invoking the provision and required consultations between the riparian countries for such cases.

- Another option for flexibility is **the inclusion of periodic reviews of water allocations**. Such reviews and possible adjustments should be supported by seasonal forecasts that take account of climate change. This can on the one hand complicate the application of the agreement and possibly have high political costs, but on the other hand it should prevent non-compliance caused by changes in resource conditions.
- **Developing formalised communication** between Parties through joint bodies, for example, provides a means for solving possible water conflicts and baseline for negotiating water resources allocations in the face of changing climatic conditions, thus removing the need to rely entirely on inflexible rules on resource sharing.

3.1.13 Recommendations

According to the recommendations of the EU CIS on Climate change, the issue of climate change is recognised on a river basin-wide scale. When the results of on-going projects are available, a more detailed analysis of the effects of climate change on the water catchments and on water management will be possible.

In complying with UNFCCC obligations and reporting requirements, the countries of the Western Balkans have already demonstrated an increased knowledge and awareness of climate change risks and adaptation. The following covers the **specific needs of reservoir planning and hydropower use** that are both *adaptation measures*; the *mitigation effect* of hydropower is indirect by replacing GHG-emitting electricity production facilities with hydropower.

In order to establish a climate change management platform in the region, the following recommendations could be taken into account:

- **Collection and monitoring of specific data on climate change trends and risks**

There is currently insufficient access to relevant disaggregated climate / environmental data in the Western Balkans river basins, although this is essential for informed decision-making and the development of appropriate policies and actions. Specific actions could include developing dedicated national and regional data monitoring programmes for climate change risks and adaptation.

Improved organisation and coordination of data records, data collection, analysis and storage is needed. Substantial historical data exists from the past century that has not been digitised, such as data in hydrologic yearbooks of the former Federal Hydro-meteorological Service of Yugoslavia. This data is valuable for investigating climate and hydrology in the region, especially having in mind that large gaps during 1990's prevent having continuous records of acceptable lengths.

In order to make this data available for various analyses, it needs to be digitised. A possible solution can be provision of a central repository for this data, possibly with e.g. ISRBC and other institutions of similar character, which could be accessible online to users. In addition, data on water resources management, such as withdrawals, discharges, and reservoir levels and releases, are extremely difficult to collect and practically hinder any water balance assessments in the basin.

Heat is easily conserved and by mixing waters of different temperature levels it is summed-up. Water temperature upstream of the thermal power plant cooling intake is considered essential for the quantification of the hydropower reservoir potential. Reservoirs are possibly increasing water temperature levels or receive heat from the release of heated cooling water, therefore cumulative effects with cooling water are significant. In this respect water temperature is crucial and adequate measurements should be effectuated.

The riparian countries should build upon the existing valuable data record by promoting mandatory reporting procedures (even through a legislative process) for essential data from riparian governments. For example, hydropower operators should be requested to provide all their operational data so that modelling tasks could be successfully completed. This could be implemented by inviting hydropower plant owners/operators to join a working group to study, analyse, plan or mainstream climate change considerations in their business operations.

- **Strengthen planning focus to adaptation policies**

Most existing policies in the Western Balkans fail to address climate change issues while policies to deal with climate are being developed. Specific actions that could be taken include the acknowledgement of the important contribution of ecosystems to adaptation purposes and the development of adaptation actions with a stronger focus on operation of reservoirs on the whole rivers. These actions should be built on a solid foundation of accessible data for informed decision-making.

- **Improve policy evaluation**

Expected outcomes from policy focus areas – defined by using quantitative indicators – should be agreed upon, which would allow progress to be monitored against the objectives and to improve policy performance evaluation. Where appropriate, priority should be given to the implementation of existing laws and policies, rather than to the development of new legislation.

- **Support development of sustainable solutions, economy of size and practices in the fields of water, renewable energy**

Mutually initiated and realised projects, which in turn also provide benefits for climate change adaptation and disaster risk reduction, will receive adequate support from communities. It is stressed again that reservoirs with sufficient capacity amounting to the seasonal balance of water quantity will be a crucial intervention in the river quantity regulation that would compensate for the flow extremes on both drought and flood sides.

A new hydrologic study of the river basins should be undertaken. It should take into account longer time series, including recent years. The results of such a study will be of invaluable importance for water balance analysis and water management studies.

The HEC-HMS[5] hydrological model is distributed among the riparian countries and could be further developed by undertaking modelling of the river basin modelling. This work needs to be coordinated by the RB institutions in the further development of the hydraulic (HEC-RAS)[6] models.

Although risk concerning climate change effects for the hydropower sector is considered a priority, the stakeholders indicate relatively low priority to proposed structural and non-structural measures for coping with decreasing discharge for hydropower. Measures are consisting from: improved hydrological forecasting to facilitate operational rules and utilization of HPP capacity; building large dams with voluminous reservoirs that can cope with extreme events; flexible design for installed capacity; etc.

- **Provide climate change specific information in planning documents**

Among other objectives, the Study aims at building climate resilience in the river basins of Western Balkans. These could be implemented through developing a multi-purpose water storage capacity that would provide a significant long-term response to the hydrological variability and climate change induced challenges. It would also allow the development of hydropower, and thus participate in climate change mitigation. However, this option is to be compared with alternatives prepared in later stages of the planning process to assure the best solutions from technical, economic, social and environmental point of view.

The planning, financing and constructing reservoirs requires addressing multiple social, environmental, technical and economic challenges through a comprehensive set of feasibility studies.

The feasibility studies will apply a step-wise approach to allow strategic decision making on the most appropriate project solution and the associated way forward before embarking on subsequent stages. The major project planning documents are: (i) pre-feasibility assessment and strategic decision making; (ii) feasibility studies; (iii) environmental and social studies; (iv) integrated water resources development studies; (v) Public-Private-Partnership (PPP) feasibility and financing strategy; and (vi) project management communication, consultation and monitoring including Safety Assessment Management.

[5] The Hydrologic Modeling System (HEC-HMS) by Hydrologic Engineering Center, US Army Corps of Engineers, is designed to simulate the complete hydrologic processes of dendritic watershed systems. The software includes many traditional hydrologic analysis procedures such as event infiltration, unit hydrographs, and hydrologic routing.

[6] River Analysis System (HEC-RAS) software is performing one-dimensional steady flow, one and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modeling.

The climate resilience strengthening would be consistent with national policies and strategic frameworks and has the potential to be a major asset for adaptation to the increasing hydrological extremes and enhancing climate change resilience. It will have important socio- economic effects through the mitigation of the extreme floods and droughts impacts, provision of water for hydropower, irrigation, and other multi-purpose benefits including mechanisms for local benefit sharing, improved social equity, etc. It will also ensure environmental flows are managed and maintained.

Due to significance of climate change for water related infrastructure development, such as reservoirs, it would be of the utmost importance to include adequate chapters on climate change in feasibility studies and other relevant planning documentation. Capacity in integrating and mainstreaming the potential mitigation and adaptation measures with the reservoir development plan must be utilised to the maximum.

- **Further harmonize national legislation with relevant EU laws and policies**

In view of the progressive integration into the EU, national legislation should be further improved and harmonised with the relevant directives, such as the EU Floods Directive and the EU Water Framework Directive, that take into account future climate impacts and provide regular methodological updates and revisions according to the latest scientific information on climate change.

- **Increase regional coordination and cooperation on climate change adaptation**

Regional coordination and transnational synergies should be strongly promoted. Policy makers should consider a regional approach for investments in prevention and preparedness in various sectors to avoid duplications and improve coordination. Regional adaptation strategies and plans would further ensure sustainability at the national level. The EU Stabilisation and Association Process and its Regional Environmental Network for Accession could become the organising focus for a regional approach to adaptation.

There is obviously a need to effectively plan for the climate induced changes in the river basin within WFD requirements. Rising mean temperature has a very high certainty of occurring. Precipitation that is highly variable across the basin and seems to have a changing seasonal distribution propagates its uncertainty into the hydrologic trends within the basin. Therefore, options to reduce the severity of the impacts associated with rising mean temperatures and variable precipitation need to be identified by careful planning and by promoting adaptation measures than can cope with such changes. In this regard, the results of this study should provide a basis for stakeholders and decision makers for future developments in the basin.

Implementing the following activities will be required regarding addressing climate change in respect of the WFD:

- **Review of the WFD programme of measures with regard to projected climate conditions:**
  - Taking account of likely or possible future changes in climate when planning measures today, especially when these measures will have a long lifetime and are cost intensive, and assess whether these measures will still be effective given likely or possible climate changes;
  - Designing measures based on the pressures assessment carried out previously including climate projections;
  - Selecting sustainable adaptation measures, especially those with cross-sector benefits and which have the least environmental impact, including GHG emissions;

- **Required revisions of monitoring programmes to detect climate change impacts**

While there is no doubt that water uses could be heavily affected by climate change, the WFD should also be used to gain an insight into the uncertainties associated with such a comprehensive method of assessment and to understand how effects can be dealt with on either at planning or operational level. The consideration of climate in hydropower production presented in this section is therefore not intended for use in a detailed design of projects, but rather to support decisions about the scope and extent of necessary analyses carried out in prioritization of hydropower plants.

- **Analysis of water scarcity probability on a river basin scale**

Based on past and current water demands and on future trends incorporating climate change projections.

Assessment of how the potential negative changes will affect the socioeconomic system behind the water resources system.

3.2 Greenhouse gas emissions & absorptions from hydropower schemes in the Western Balkans

3.2.1 Introduction

Inland water bodies, such as freshwater lakes, are known to be net emitters of carbon dioxide (CO_2) and methane (CH_4). In recent years, significant GHG emissions from tropical, boreal, and mid-latitude reservoirs have also been reported. At a time when hydropower is increasing worldwide, better understanding of seasonal and regional variations in GHG emissions & absorptions is needed in order to develop a predictive understanding of such fluxes within man-made impoundments.

3.2.2 Organic matter and GHG

The high GHG emissions from hydroelectric reservoirs were originally argued to be due to the decomposition of flooded organic soil and vegetation. This understanding of the role of reservoirs needs to take into account the balance between GHG emissions and absorption prior to, and after, the impoundment of a certain area. Net GHG emission was considered close to zero prior to impoundment, as the GHG sink of terrestrial photosynthesis being a part of the natural carbon cycle would compensate emissions from rivers. After flooding, the GHG neutral terrestrial system is replaced by a system with net GHG emissions to the atmosphere.

This focus on the flooded organic matter further leads to the understanding that with reservoir aging, the amount of decomposable flooded organic matter is gradually reduced and GHG emissions from reservoir surfaces would decline. Indeed, a long-term assessment of GHG emissions from the tropical Petit Saut reservoir showed that CO_2 and CH_4 emissions are high in the first two years after impoundment after which emissions rapidly decline when the more labile flooded organic matter is decomposed. Emissions of CO_2 from Brazilian reservoirs were predicted to be concentrated in the first 10 years after flooding. Later, the evidence from Canadian systems showed a similar trend and suggested that CO_2 emissions from reservoirs older than 10 years tend to equal the emissions from natural lakes and rivers. Similar results were also reported for a Swedish reservoir, which was compared with a natural lake.

It is presently agreed that other sources of carbon inflow to reservoirs besides flooded organic matter should be used in calculations. During their complete lifetime, organic matter and nutrients from the drainage basin are continuously flushed into the systems through tributary rivers and aquatic primary production rates tend to increase. Once in the reservoirs, organic matter derived from the catchment and from aquatic primary production mineralizes at different rates, the latest being usually more labile. Most of the organic matter mineralisation and, thus, most of the GHG production in reservoirs, occurs in the sediment. Furthermore, it has become clear that GHG emitted from reservoir surfaces is not necessarily produced within the system, as tributary rivers may export large amounts of GHG to reservoirs.

3.2.3 Environmental effects on reservoirs and the consequences for GHG emissions

By definition, hydropower is a renewable source of electricity in which power is derived from the energy of water moving from higher to lower elevations. The amount of energy generated depends both on the accumulated water volume and on the difference in height, the head between the water inlet and the outflow. While reservoirs perform an important function, their effect on landscapes is remarkable: a fragment of river and its adjacent terrestrial environment are transformed in a new freshwater system, the reservoir. The construction of reservoirs clearly represents one of the major human effects on the hydrological cycle. The effects of such transformation, however, are greater than purely the hydrological level.

Prior to dam construction, rivers generally have rapid water flow rates, which vary with catchment size and topography and respond to the seasonality in the upstream precipitation regime. Precipitation regimes also control variations in river water level, which usually varies within a predictable range. Rivers naturally emit large amounts of CO2 due to terrestrial organic matter decomposition but these are emissions of carbon that are just returning to the place they came from, a natural carbon cycle. Because the turbulent flow keeps oxygen concentrations high, CH4 emissions hardly occur except in highly organic matter-rich rivers. In compensation, terrestrial vegetation surrounding a river course usually functions as a CO2 sink, since photosynthesis tends to exceed respiration. Furthermore, rivers play a crucial role in removing carbon from the global cycle by carrying large amounts of terrestrial material to the ocean where parts of it remain permanently buried.

Enhanced primary biological productivity in reservoirs may reduce GHG emissions to the atmosphere through algal carbon dioxide fixation during the summer period, but most of this carbon is later decomposed and returned to the atmosphere. In eutrophic reservoirs with anoxic hypolimnia, a relatively large amount of decomposed organic carbon is recycled as CH4. Considerable amounts of CH4 can be released if favourable conditions exist in the reservoir. Because of the higher climate change potential of CH4 compared to CO2, this return of CH4 to the atmosphere could, in return, offset any favourable effect of algal fixation.

The construction of dams implies the creation or extension of a flooded area. This implies that flooded terrestrial vegetation no longer performs photosynthesis. Instead, the organic matter stored in vegetation, as well as in flooded soil, becomes available for bacterial decomposition (with the subsequent release of CO2 and CH4). It means that the flooded terrestrial area shifts from being a net sink to a net source of carbon to the atmosphere. The amount of GHG emitted from decomposition of flooded vegetation depends on the size of the flooded area, as well as on the quantity and quality of organic matter.

The further enlargement of a flooded area with reservoir formation comes with an increase in water volume and causes water residence time (or turnover time) at individual impoundments to increase from less than one day to several years in the case of large dams. The river water velocity reduction in reservoirs results in a decrease of sediment-carrying capacity and in the sedimentation of particulate matter pertaining to rivers.

Reservoirs are often constructed at the lower end of large drainage basins, where rivers usually carry terrestrial material from the entire upstream drainage basin erosion base. Despite being favourable in the sense of energy potential utilisation – it guarantees maximal water inflow and, thus, enhances the potential for energy generation – this strategy implies that high amounts of terrestrial material constantly flow into and accumulate in the reservoirs. Globally, it has been estimated that reservoirs may cause the amount of material delivered to the oceans to decrease by more than 50%. Organic matter settled at the bottom of the reservoir has a higher chance to get mineralized than when it would have settled at the ocean bottom (see Section 4 for details). As a consequence, the net global emission of GHG is enlarged. Nevertheless, it should also be noted that part of the organic material deposited in the sediment of reservoirs is not mineralized and may accumulate for long timescales.

Due to the transition from a turbulent-shallow river to a relatively static-deep system, reservoirs tend to undergo thermal stratification, especially in warm regions. The process of thermal stratification is triggered by differences in water density and leads to the formation of water layers: epilimnion (top), metalimnion (intermediate) and hypolimnion (bottom). Once these layers occur, there is little mixing happening between layers unless some stress (e.g. wind, shift in temperature or increase in water inflow from rivers) from outside breaks water column stability. The establishment of stratification has important effects on oxygen dissolved in water and on GHG emissions from reservoirs.

3.2.4 Conclusions and future research needs and future perspectives

Reservoir creation is not GHG neutral with respect to the production of electricity by hydroelectric generation, as has been suggested by one group of authors[7]. Although there is uncertainty present in all estimates, they show that reservoir fluxes are of a similar magnitude to other fluxes already included in efforts to understand anthropogenic changes taking place in the global carbon cycle. We understand the carbon cycle in principle, but balance of its quantities over time is still controversial. But at the end of the day, the efforts made should result in knowledge and information about the level of GHG in the atmosphere and carbon budget in general, be it

[7] Reservoir Surfaces as Sources of Greenhouse Gases to the Atmosphere: A Global Estimate, 2000, Vincent L. St. Louis, Carol A. Kelly, Éric Duchemin, John W. M. Rudd, and David M. Rosenberg.

increased or decreased.

Researchers have been unable to balance the global carbon budget because more CO_2 is being emitted from human sources than can be accounted for by either the well-documented rise in CO_2 concentrations in the atmosphere or uptake by oceans, resulting in a missing “sink” for CO_2. The scientific community has been estimating increases to this unknown sink of CO_2 by approximately 20%, and by that effectively increasing the unnatural CO_2 emissions to the atmosphere.

Fluxes of greenhouse gases to the atmosphere from all reservoirs are anticipated to increase in the future because reservoirs are needed as a relatively clean alternative to energy produced by fossil fuel combustion and because of needs for water and food as well as the industrial and recreational demands of a growing global population.

Now it has become clear that hydroelectric reservoirs represent a renewable but not a carbon-free source of electricity. Attempts to determine the carbon footprint of hydropower production have led to significant scientific advances. However, it is still a long way from a full assessment of the role of hydroelectric reservoirs as sources of GHG to the atmosphere.

The assessment of the net role of reservoirs as sinks or sources of GHG to the atmosphere requires more than measurements of carbon fluxes at the water-atmosphere interface of reservoirs. For example, the net change in the carbon cycle due to reservoir construction should consider pre-impoundment carbon sinks and sources from the original river course and the adjacent terrestrial landscape. Scenarios of pre- and post- impoundment fluxes, however, are neglected in most estimates of emissions. Even more importantly, there is a need to evaluate the net effect of reservoirs as a sink of atmospheric carbon, by comparing carbon burial in reservoirs with carbon burial prior to impoundment (i.e. in the ocean).

The role of reservoirs sediment in the global carbon cycle is still poorly understood. Despite the importance of sediment as the main site for organic matter mineralisation and GHG production (especially CH_4) sediment carbon fluxes in reservoirs are restricted to few measurements. Additionally, reservoirs accumulate large amounts of carbon in the sediment, which compensates at least part of the emissions. There is an urgent need, thus, for research focusing on this potential carbon sink pathway.

Most of the GHG assessments in hydroelectric reservoirs have looked at emissions from decaying biomass after impoundment, compared to the previous emissions from terrain. Some studies have used a full life-cycle assessment, which considers the emissions during the construction phase of dams. However, little attention has been given to the fact that every hydropower plant has an individual operation lifespan after which its reservoir (impoundment) should be decommissioned. Reservoirs may be put out of use and dams removed due to failures (e.g. geological instability, need for river renaturation and landscape recovery, etc.). It has been estimated that about 600 dams were removed in the last 100 years in the USA alone.

With reservoir termination, part of the sediment accumulated at the reservoirs’ bottom will be flushed down river if not otherwise controlled (e.g. dredged). Sediment fate is an important factor determining the amount of carbon returning to the atmosphere – a greater fraction of dredged sediment becomes available for mineralisation whereas organic carbon flushing downstream rivers may ultimately accumulate the ocean.

With the continuous and integrated research focusing on revealing the actual role of hydroelectric reservoirs in the global carbon cycle, gaps in knowledge tend to be reduced quickly. Recent advances have resulted in important tools for reducing GHG emissions from reservoirs through changes in reservoir management and, even more importantly, through the GHG-intelligent design and location of new hydropower plants. It is now known, for example, that future hydropower projects should seek for better GHG emission/MWh ratios by reducing flooded area to the maximum extent, removing terrestrial vegetation prior to impounding and preserving the vegetation in the drainage basin to avoid soil erosion.

In order to avoid inflow of the excess carbon in a reservoir, a catchment area above the dam should be managed as well in regard to wastewater treatment from urban areas and fertilizers from agricultural land, which are increasing biomass in reservoirs and as a consequence the deposition of organic matter. Regular flushing of small reservoirs and exchange of water will also help in avoiding anoxic zones in the reservoir, which are main sources of methane.

However, due to fact that GHG emissions are not a reason that could block development of reservoirs; reservoirs in fact are not emitting any of the fossilized carbon contributing to an increase of atmospheric levels, it means that carbon balance will not particularly limit a development of reservoirs in temperate zones.

Summary of Conclusions

- The science of climate change and relevant results are acknowledged in this section. Climate change is a fact and has been taken into account recommending adaptation measures of planning adequate head storage reservoirs.
- There is strong evidence (see Figure 3.1) that for the last two decades electricity generation from hydropower in the Western Balkans has remained at about the same level despite already quite obvious implications of the climate change. Under constantly changing hydrology conditions it was found out that years 2010 and 2013 gave highest electricity yield in the last 60 years of data gathering in our project. Therefore, forecasts of dropping electricity production due to climate change are deemed unaccounted for in a mid-term period. While there is no doubt that water uses could be heavily affected by climate change, gaining an insight into the uncertainties associated with such a comprehensive assessment effects are to be dealt best in an operational level of project preparation. As a consequence, a model of electricity production decrease was not introduced in the study nor were the negative economic effects of climate change. The model of electricity production decreases has to be done at the project realisation stage in order to have the overall picture and to reduce uncertainties.

4 WATER FRAMEWORK DIRECTIVE IN THE WESTERN BALKANS

4.1 Introduction

Establishing reference conditions is important for developing ecological quality classification systems according to the Water Framework Directive 2000/60/EC (WFD). Identifying natural watercourses is not an easy task in the cultural landscape of the Balkans because centuries of varied land use and settlement combined with pollution and widespread hydro-morphological modifications obscure the natural physical and biogeochemical structure and processes. Balkan landscapes, like other Mediterranean landscapes, usually show a mix of degraded and regenerating biophysical features. However, most of the mountainous parts of Balkan river basins, especially along the country borders, can be considered as minimally disturbed. Sporadic ecological quality assessment studies carried out in Greece confirm that several headwaters and tributaries in the Axios and Aoos, basins satisfy the EU criteria regarding hydro-geomorphological, chemical and biological (mainly based on macroinvertebrates) reference conditions.

The water resources in the Balkan Peninsula are temporally and spatially unevenly distributed among and within countries. Some countries face localised water shortages, while most major rivers and lakes are transboundary, creating conflicts of interest. Almost all Balkan countries face daunting water resource challenges because of urgently required investments in water supply, sanitation, irrigation and hydropower based on IWRM Plans. The role of hydropower in resolving those challenges is not direct; it comes primarily as increased water reserve in storage basins (co-financing uses like irrigation, supply, etc. from other budget lines) and secondarily as the provision of electricity supply from renewable sources. At the same time, water quality deteriorates (e.g. Axios/Vardar, Drini/Drim), water exploitation for irrigation increases, fragmentation by large dams is a major pressure (e.g. Drin, Trebišnjica); flooding remains a major threat (e.g. Drini/Drim, Vjosa/Aoos, Neretva), droughts increasingly exhaust water resources.

Except for Greece, Bulgaria, and Croatia, which are EU Member States, all other Balkan countries are in the process of integration. This obliges compliance with EU policies, rules and regulations concerning water, here in particular, with the WFD, which is the basic water management legal instrument. However, economic, political and structural constraints impose considerable impediments on the application of the EU environmental legislation. Water management traditions and approaches differ among countries, reflecting differences in political systems, administrative structures and relevant institutional frameworks.

For Balkan countries, constraints arise from long-standing sectorial planning traditions, heavy investment requirements (e.g. in sanitation and waste treatment infrastructure), poor administrative capacities and little experience of dealing with multidisciplinary issues. Additional difficulties arise from the deteriorating government services and public infrastructure following severe civil conflicts that have recently affected the economies of some countries. Hence, policies and strategies for water use and management have evolved on different principles, reflecting the long duration of the previous period of central planning culture and practice. In accordance with the prevailing political and administrative structures, management has followed a top-down approach based primarily on sectorial planning, in which different sectors and services were separated and handled by different ministries and agencies.

In Serbia, the water legislation has several shortcomings hampering the effective management of water resources including lack of a clear institutional framework. In Bosnia and Herzegovina, water management is under the authorities of two entities; the Federation of Bosnia and Herzegovina and Republika Srpska, which have two independent water laws and organisational structures based on the WFD. Geopolitical and administrative boundaries in the Neretva-Trebišnjica basin make the optimal management of the river basin, delta and coastal zone complex and difficult. In the former Yugoslav Republic of Macedonia, Kosovo and Albania, despite the adaptation of WFD principles in their respective water laws, there is a clear lack in implementing a modern water resource management into reality.

The speed of legal and institutional reforms required for the implementation of the WFD is generally slow in all countries, which was also the case in the past for countries which are now EU MSs: e.g. Croatia, Greece, and Bulgaria. In general, despite the recent elaboration of preliminary River Basin Management Plans, there is limited progress in implementing the Directive, particularly for the assessment and classification of the ecological status of water bodies. Concerning the management of shared basins, the one-sided exploitation of water resources and pollution impact by upstream parties cause critical deficiencies of water quantity and quality to downstream countries, including surface and groundwaters and wetlands. The Neretva is example of a shared water body where such a situation has occurred. To face the transboundary nature of water supply and sanitation issues, the Balkan countries adopted the Water Convention of the United Nations Economic Commission for Europe, which entered into force in 1996. The provisions of the WFD and the Water Convention include the design and implementation of joint plans, joint river authorities, transboundary river basin units and coordinated national measures at a basin scale, and provide the platform for the management of shared water basins between member states and non-EU countries.

However, joint international management is either insufficient or completely missing for most shared rivers and lakes despite agreements, protocols and treaties signed for the rivers Neretva (not fully in force), Drin (between Albania and the former Yugoslav Republic of Macedonia), Aoos, Axios, and for Lakes Shkodra, Ohrid, Prespa and Doirani. In most cases, political obstacles, lack of resources or inefficient collaboration in a technocratic level have not allowed proper implementation. An example of poor transboundary cooperation is the case of the Drini basin, where major problems relate to floods and water quality. Moreover, the Axios/Vardar basin has been at the heart of numerous conflicts between Greece and the former Yugoslav Republic of Macedonia for decades, despite agreements on water management that date back to 1959. In contrast, the case of Lake Prespa is an excellent example of how transboundary environmental issues can encourage international cooperation among neighbouring nations (Greece, the former Yugoslav Republic of Macedonia and Albania). Lake Ohrid provides another example of effective measures being taken for cooperative management of transboundary lakes. Overall, the Balkans represent one of the most important areas for potential transboundary cooperation in protected area management worldwide. Indeed, at least 50% of the sites of international importance in the region are transboundary, including all the large lakes Shkodra, Ohrid, Prespa and Doirani, many large rivers and important deltas. Moreover, in the IUCN Strategic Plan for South Eastern Europe, 37 priority sites have been identified for transboundary cooperation in protected areas development. In hydropower, there are still issues to be resolved despite the long-term standstill on Drini/Drim, Drina, Ćehotina, Trebišnjica and some other river basins with shared hydropower potential.

All Western Balkan countries are now committed to the European integration progress and to joining the EU. They must consequently accept the ***acquis communautaire (****the body of EU legislation which candidate and potential candidate countries must adopt to become EU members)* and transpose and ensure its implementation into their national legislation. One major challenge – and not just for new member states – is the Water Framework Directive (WFD), which introduces new rules for water management based on river basins rather than on state administration.

A country will automatically accept the terms of all international treaties to which the EU is part when it becomes a Member State. This means that the Balkan countries, as candidates or pre-accession states, must comply with these requirements even if they have not yet ratified them. Serbia, for example, complies with the Espoo Convention and the Strategic Environmental Assessment Protocol without being part of either. The same holds true for the Aarhus convention.

In any case, Western Balkan countries would benefit by signing up to international treaties already ratified by the EU, particularly as doing so would strengthen their environmental policies and commitments at a national level and serve as a framework for transboundary cooperation on environment. Accepting the principles underpinning international instruments protecting the environment and water resources, and working within that framework would certainly bring wide-ranging benefits, stability and security to the region of the Balkans.

How Western Balkan countries comply with EU requirements in this respect depends on how successful they are in changing the national water management systems, which they inherited from the socialist centralist governed era. This means accepting new, and for the most part very advanced, approaches to water management, which involve active co-operation with all neighbouring countries sharing a river basin. Over the last decade and more, all Balkan countries, except Serbia, have passed new water legislation, replacing outdated water management methods and facing up to future challenges.

4.2 National and international water management practice

When comparing traditional water management approaches with today's dynamic development of "good status" water governance, the conclusion is that practices from the past are based predominately on a "top-down" mechanism of decision making. This does not provide for public involvement in decision-making and rarely addresses environmental issues except in official statements. To make matters worse, this approach lacks the proper instruments and instances to implement its stated commitments. Water resources are treated case-by-case, skipping the integrated water resources management approach and its reasoning covering an entire river basin including the ecosystem and other segments. Former institutional arrangements and their workings have stayed well out of the public focus.

With today's approach to water management, not to mention the importance of global climate change, national authorities with various responsibilities must work together closely. Different government departments are in charge of protecting water quality and aquatic ecosystems, supplying water for public consumption, and use by industry and the public sector. Others oversee navigation, hydropower production or indeed measures to protect the community against floods or other water-related hazards. Each player in this game has a specific responsibility for a specific field. Water management systems need to be much more integrated at all levels (international, national, regional and municipal) in future. This may also involve developing partnerships bringing together the relevant public authorities, the private sector and civil society.

If the Western Balkans countries plan to achieve sustainable development, water management platforms clearly need to change a great deal. To make such a change possible, new concepts must be accepted and implemented, backed by UNECE and EU policy requirements and which serve as the basis for cooperation between the international organisations to which Balkan countries belong. Future action should embrace new approaches to water management. This involves replacing existing legal instruments, at a national and international level, with others reflecting current trends in the sustainable management of water resources.

4.3 WFD environmental objectives and management objectives

The WFD requires that Member States implement the necessary measures to prevent the deterioration of the status of all bodies of surface water and that the following environmental objectives are achieved by 2015:

- Good ecological/chemical status of surface water bodies;
- Good ecological potential and chemical status;
- Good chemical/quantitative status of groundwater bodies.

The River Basin Management Plan should provide an overview of the status assessment results for surface water bodies and groundwater bodies for the entire River Basin as well as risk assessment classifications where data is not available and/or WFD compliant methods are not applied. WB6 countries are committed to transpose and ensure implementation of the WFD, therefore they need to define respective RBMPs, while it is already clearly an obligation for non-EU RBs shared with EU MS. To ensure a complementary approach at the basin-wide level, which is of use for national planning and implementation, visions and specific management objectives have been defined for all Significant Water Management Issues and groundwater bodies.

Given the specific situation in non-EU countries, measures to achieve agreed management objectives will be implemented within a timeframe and transitional periods, being part of the negotiation process in which the EU has a role to endorse. In new EU MSs, these measures are to be implemented according to the commitments and deadlines set down in their accession treaties with the EU. These provide guidance for countries about attaining the agreed goals of recognising the basin-wide importance and also assist with the achievement of the overall WFD environmental objectives. These visions are based on common values and describe the principle objectives for the River Basins involved. The respective management objectives describe the first steps towards the environmental objectives in the River Basin under consideration emphasising use of hydropower.

4.3.1 Hydro-morphological alterations - Vision and management objectives

The vision of hydro-morphological alterations is the balanced management of past, current and future changes of the riverine environment, so that the aquatic ecosystem of the River Basin functions holistically and all native species are present.

Management objectives:

- Anthropogenic barriers and habitat deficits do not hinder fish migration and spawning;
- Floodplains/wetlands of RB are protected, conserved and restored ensuring the development of self-sustaining aquatic populations, flood protection in the RB;
- Improvement of hydrological characteristics does not affect the aquatic ecosystem regarding its natural development and distribution;
- Future infrastructure projects are conducted in the RB in a transparent way using best environmental practices and best available techniques – deterioration of a good status and negative transboundary effects are prevented, mitigated or compensated to acceptable levels;
- Impoundments: Impounded water bodies are designated as heavily modified and therefore good ecological potential needs to be achieved. Due to this fact, the management objective foresees measures at the national level to improve the hydro-morphological situation to achieve and ensure this potential;
- Water bodies affected by hydro-peaking are designated as heavily modified and a good ecological potential must be achieved. Therefore, the management objective foresees measures at the national level to improve the situation to achieve and ensure this potential.

Invasive alien species - Vision and management objective

The vision for invasive alien species is to establish a coordinated basin-wide policy and management framework to minimise the risk of invasive alien species to the environment, economy and society. This will include a commitment to not knowingly introduce high-risk invasive alien species, for example into the Sava River Basin.

Considering the problem of invasive alien species as a long-term issue, the vision is to prevent the introduction of harmful alien organisms and eliminate or reduce their adverse effects to acceptable levels.

Quantity and quality of sediments

Based on an evaluation of sediment balance and sediment quality and quantity, the objective is to ensure the integrity of the water regime regarding quality and quantity and to protect wetland, floodplains and retention areas.

4.3.2 Exemptions of WFD according to Articles 4(4), 4(5), 4(6) and 4(7)

Exemptions from the provisions of the WFD are defined within Article 4, outlining the conditions under which the achievement of good status or potential may be phased or not be achieved, or under which deterioration may be allowed. Article: 4(4), 4(5), 4(6) and 4(7)[8] [9]describe these distinct conditions, which are in short:

- Article 4(4) allows an extension of the time limit so that good status or potential is, under certain conditions, achieved only after 2015;
- Article 4(5) allows the achievement of less stringent objectives under certain conditions;
- Article 4(6) allows the temporary deterioration of status in case of natural causes or "force majeure";
- Article 4(7) allows for the deterioration of status or non-achievement of good status or potential under

[8] Common Implementation Strategy for the Water Framework Directive (2000/60/EC), Guidance Document No. 20 – Guidance Document on Exemptions to the Environmenta Objectives

[9] Sustainable Hydropower Development in the Danube Basin – Guiding Principles, ICPDR 2013

certain distinct conditions.

The main conditions for exemptions under Article 4(7) determine that Member States will not be in breach of the WFD in the case that:

- failure to achieve good groundwater status, good ecological status or, where relevant, good ecological potential or to prevent deterioration in the status of a body of surface water or groundwater is the result of new modifications to the physical characteristics of a surface water body or alterations to the level of bodies of groundwater, or
- failure to prevent deterioration from high status to good status of a body of surface water is the result of new sustainable human development activities and all the following conditions are met:
    a. All practicable steps are taken to mitigate the adverse impact on the status of the body of water;
    b. The reasons for those modifications or alterations are specifically set out and explained in the River Basin Management Plan required under Article 13 and the objectives are reviewed every six years;
    c. The reasons for those modifications or alterations are of overriding public interest and/or the benefits to the environment and to society of achieving the objectives set out in paragraph 1 are outweighed by the benefits of the new modifications or alterations to human health, to the maintenance of human safety or to sustainable development, and
    d. There are no significantly better environmental options.

Hence, Article 4(7) of the WFD sets out the conditions for derogation in the event of new modifications to the physical characteristics of a body of surface water, alterations to the level of bodies of groundwater or new sustainable human development activities.

The application of the WFD requires an analysis at several levels, having regard to the directive's ultimate objective of protecting water as a shared asset and which takes the form of maintaining, improving and prohibiting the deterioration of the aquatic environment in the EU.

The possibility of exemptions is provided for EU MS, and the reasons should be set out in their national RBMPs. WB6 countries have pre-accession or accession status and therefore currently have no formal legal obligation to report exemptions but are certainly invited to approach the exemption issue same way. It is expected that countries would not be motivated to attempt to gain exemptions in all possible situations, but may consider exemptions selectively, after a more comprehensive examination of their interests in the area of WFD application.

It is crucial to recognise the practical interaction that exists between the WFD and other Directives. These interactions relate mainly to the SEA for plans and programmes, the EIA for projects and the Habitats and Birds Directives for protected areas. Article 4.7 cannot be used as an exemption from fulfilling the legal requirements of these other Directives.

A reason for the modification could be public interest, namely to ensure the security of supply of electrical energy and assuming there is no 'significantly better environmental option' (Art 4(7) c WFD)) such as other sources of renewable energy. Electricity production in the Western Balkans is currently insufficient. Recently, electricity consumption is increasing faster than production. Due to this increase, it is necessary to provide additional electricity resources. The planned hydropower production facilities will allow the use of a renewable and affordable energy source, thereby providing an increase in the autonomy, reliability and competitiveness of the regional electricity system and this can, under these circumstances, be deemed of national importance.

Additional benefits will include a reduction of erosion processes, an improvement of overall flood protection by the construction of flood-prevention infrastructure, the creation of opportunities for waterway usage, an increase in safety and operation of existing thermal energy facilities and the promotion of tourism and recreation.

All exemptions from the environmental objectives applied in the RBM Plan are temporally classified as Article 4(4) exemptions, i.e. an extension of the deadline to achieve good status. There are two sets of reasons to justify such exemptions:

(i) Transitional reasons regarding the EU accession process – for WBs assessed to achieve good status by implementation of basic measures scheduled after certain year, in line with transitional periods agreed. Essentially, it is a question of limited capacities (firstly, financial ones), recognized by the European Commission, which hinder compliance with the previous EU legislation in a shorter time period.

(ii) Technical reasons - for river basins assessed to need further supplementary measures to provide appropriate improvement of the water status. Technical infeasibility is justified by both the limited time for preparation of the Programme of Measures as well as gaps in data and knowledge: there was no sufficient and/or reliable information on the real status and risks, on the cause of some problems, effectiveness of basic measures, costs and effects of different supplementary measures at disposal for solving some problems; hence appropriate solutions could not be identified.

A final selection of supplementary measures, accompanied by an application for permanent exemptions in terms of Article 4(5) – less stringent objectives, Article 4(7) – new modification, as well as Article 4(3) - final designation of Heavily Modified Water Bodies, is postponed to the second planning cycle. In the meantime, an extensive data collection and knowledge improvement exercise could be undertaken to fill the gaps.

4.3.3 WFD Economics

The WFD requires that river basins in Europe are considered not only in hydrological, but also in economic terms. Economic principles are addressed in WFD Article 5 (and Annex III) and Article 9.

Article 9 requires that by 2010 EU Member States take account of the principle of cost- recovery, including environmental and resource costs. The "polluter pays" principle is the key to establishing who should pay for existing and future water services. More specifically, Member States must ensure that water pricing policies provide adequate incentives to water users to use water efficiently and to ensure that different water uses contribute adequately to the recovery of the costs of water services.

The WFD does not specifically address transboundary river basin management plans in this regard, but it is recognised that an improvement of basin-wide cost recovery of water services is also an essential tool for the protection and efficient use of water resources in the particular River Basin and that countries apply this principle within their territory. A co-ordinated approach within a river basin is a central element of the WFD. The implementation success of the Directive depends on the willingness to co-operate beyond regional and national boundaries including the implementation of the cost recovery and "polluter-pays" principle.

4.3.4 Integrating water protection in River Basin developments

The Water Framework Directive must implement integrated water management in practice in order to achieve environmental goals and to ensure sustainable water resources use. It closely interacts with issues relating to development sectors such as hydropower and flood protection among other possibilities. Many future sectorial development activities in a particular River Basin may have negative impacts on water status and should therefore be addressed. Furthermore, they should be integrated into transboundary solutions, seeking for multiple functions with controlled effect on environment, covering also measures originating from the EU climate energy package, e.g. utilisation of sustainable energy sources, decreasing flood risk, accumulating water for use in drought periods, etc.

4.3.5 Flood protection

Although flooding is a natural occurrence, changes to flood frequency, duration, timing and water quality (e.g. runoff pollution) because of management practice can significantly affect the ecological status by influencing the biological and hydro-morphological quality elements. In the context of the WFD, the key issue is to recognise the links between flood management and the factors influencing water quality objectives such as hydro-morphological alterations and changes in longitudinal and lateral connectivity. If this is taken into consideration, future flood management plans can include the concept of ecological status and propose integrated solutions, such as providing areas with a diversity of habitats that will also act as flood storage. When looking for synergies between flood risk management and river basin management, it is necessary to point out that in a particular River Basin there could be a system of preserved retention areas. The correct management of these areas will provide a win-win solution by achieving the WFD environmental objectives and ensuring an effective flood protection system. The existence of flood protection dykes could compromise the attainment of a good water status and the possible compensation measures should be carefully considered taking into account the principles of better environmental options, disproportionate costs and overwhelming public interest.

4.3.5.1 Best practices to achieve the environmental objectives

It should be possible to develop sustainable flood protection in a particular River Basin without compromising the environmental objectives of the WFD. All flood risk management activities should be planned and carried out in line with Article 9 of Directive 2007/60/EC, which requires taking appropriate steps to coordinate the application of the Floods Directive with the WFD, focusing on opportunities for improving efficiency, information exchange and for achieving common synergies and benefits regarding the environmental objectives of the WFD.

Flood protection is one of the main causes of river and habitat continuity interruption. A normal part of flood action plans are technical flood defence measures (construction of new dykes and consolidation of the banks). These plans must however be combined with the measures for restoration of river and habitat continuity interruptions. Appropriate regulations regarding land use and spatial planning (e.g. limitations related to land use in flood-prone areas) must be adopted in parallel with flood protection activities.

Specific proposals include the following:

Accidental pollution due to flooding is an important issue. Accidental pollution can originate from industrial facilities and from sites contaminated by former industrial activities or waste disposal. Pollution from rivers during flooding can reach protected retention areas. Consideration should also be given to treatment plants if they are in a floodplain. Flood events should be managed in such a way that water surplus related pollution is reduced via suitable preventive measures taking into consideration the land use management of floodplain / wetlands. Wetlands can play an important role in flood and drought mitigation as well as in nutrient reduction. They act as sponges, soaking up rain and storing floodwater and runoff. Wetlands release floodwaters back into streams with delay, making the risk of flooding lower.

4.3.6 Hydropower

Hydropower has been identified in the first implementation report of the WFD as one of several causes of hydro-morphological alterations and there is a risk that significant water system degradation and biodiversity loss will continue in the future, if infrastructure developments are implemented without fully taking WFD measures into account.

Hydropower is one of the main hydro-morphological driving forces identified in the risk analyses. It is therefore essential to organise a broad discussion process in close cooperation with the hydro-power promoting sector and all relevant stakeholders to harmonize integrating environmental principles into the use of existing hydropower plants, including a possible increase of their efficiency, as well as in the planning and construction of new hydropower plants.

4.3.6.1 Best practices to achieve the environmental objectives

At present, a stakeholder dialogue and the development of guiding principles on hydropower generation and the WFD is under continued preparation at the ICPDR. The aim of this activity is to facilitate a dialogue between the hydropower and environmental sector to achieve a common understanding of the topic with the objective of developing common guiding principles on hydropower development and the WFD, as stated in the Danube Declaration 2010.

The key challenge is to get the key players from water and energy sectors from all countries in the region on board. Participation is considered a prerequisite for achieving a mutual understanding of the challenges for achieving a joint agreement. Measures to encourage more sustainable energy production include, among others, the following two measures directly addressing hydro power generation:

A. Development of a pre-planning mechanism for the allocation of suitable areas for new hydro power projects. This pre-planning mechanism and its criteria would pave the way for new hydropower plants by identifying the best sites and balancing economic benefits and water protection. It should also consider climate change impacts (e.g. lower or higher water levels). This should be based on a dialogue between the different competent authorities, stakeholders and NGOs. The licensing process could be streamlined in areas deemed suitable.

B. Development of a comprehensive action plan for the sustainable development of the hydropower generation potential of the river and its tributaries. This plan would pave the way for the coordinated and sustainable development of new power stations in the future and the retrofitting of existing power stations such that the environmental impact is minimised. The options for using hydropower to respond to fluctuations in the electricity demand should be explored – using reservoirs to maintain a high-water level in preparation for the demand peak.

In addition to the above-mentioned specific activities, the following key recommendations should be adopted regarding hydropower development to ensure the environmental objectives of the WFD are met:

- Pre-planning mechanisms allocating “no-go” areas for new hydro-power projects should be developed. This designation should be based on a dialogue between the different competent authorities, stakeholders and NGOs.
- To minimise the need for new sites, the development of hydropower capacities could be supported by the modernisation and upgrading of existing infrastructure.
- The development of hydropower should be accompanied by measures that ensure the sustainable development of water dependent ecosystems, by applying clear ecological standards for new facilities, or for existing facilities by their modernisation as well as the improvement of operating conditions. New hydropower plants should all have fish and water organism migration passes and should respect ecologically acceptable flow regimes.
- An analysis of the costs and benefits of a project is necessary to enable a judgement on whether the benefits to the environment and society of preventing the deterioration of status or restoring a water body to good status are outweighed by the benefits of new modifications. This does not mean that it will be necessary to monetise or even quantify all costs and benefits to make such a judgement.

The size of the project is not the relevant criteria to trigger Article 4.7. The relevant approach is to assess if a given project will result in the deterioration of the existing quality status of a water body. Consequently, projects of any size may be accounted for under Article 4.7.

4.3.7 Programme of Measures

The Programme of Measures (PoM) responds to all the significant pressures to achieve the agreed environmental objectives (WFD Article 4) and visions on a basin-wide scale. It builds upon the results of the pressure analysis (Chapter 3), the water status assessment (Chapter 6) and includes the measures of basin-wide importance. It is based on the national programmes of measures. However, the specific situation in accession and non-EU countries must be considered. The PoM includes the “basic” measures to be implemented to achieve the objectives defined by the management plan in accordance with EC/national laws. Where applicable, “supplementary” measures are proposed. Supplementary measures are those measures designed and implemented in addition to the basic measures, with the aim of achieving the desired environmental objectives.

Priorities for the effective implementation of national measures on a basin-wide scale are highlighted and are the basis of further international coordination. The implementation of measures of basin-wide importance is ensured by their integration into the national programme of measures of each WB6 country. A continuous feedback mechanism from the international to the national level and vice versa will be crucial for the achievement of the environmental objectives in a particular River Basin.

The management objectives will be achieved by the implementation of measures focusing on the following Hydromorphological alterations and pertaining measures:

- Interruption of river and habitat continuity;
- Hydrological alterations;
- Morphological alterations.

The following measures are required to be implemented according to a timeframe which is realistic and acceptable to all countries:

a) Interruption of river and habitat continuity - measures

- Specification of number and location, funding needs and funding sources for the building of fish migration passes and other measures to achieve and improve river continuity, which are intended to be implemented by the deadline;
- Specification of location, extent and measure type, funding needs and funding sources for restoration, conservation and improvements of habitats which are intended to be implemented by certain date;
- Construction of fish migration aids and/or other measures to achieve / improve river continuity in the main water stream and its tributaries to safeguard reproduction and the self-sustaining of migratory species;
- Restoration, conservation and improvements of habitats and their continuity for migratory species in the water bodies.

Exemptions should be made due to the high costs of constructions and technical limitations. In this case, less stringent objectives are set, i.e. to avoid a deterioration of river continuity because of future infrastructure projects.

Assessing funding needs for the implementation of measures and identifying funding sources are crucial steps. If countries commit themselves to this, it will also help create pressure on the European Commission and the Council to allocate sufficient funds to these measures in future funding programmes for the EU and Accession countries in Cohesion Policy and IPA programmes.

b) Hydrological alterations – measures

Measures which should have been implemented relate to exemptions due to the construction of new hydropower plants to mitigate impacts on water bodies caused by hydrological alterations.

During the next cycle of WFD implementation which is intended to mitigate the negative impact of water level fluctuation upstream and downstream of dams, to adjust water abstraction to ensure good ecological conditions, to ensure an ecological water flow and reduce bank and bottom erosion, the following measures should be considered:

- Water abstractions: Ensuring sufficient residual flow below a water abstraction, meeting ecological flow requirements (i.e. for ensuring fish migration or for meeting good status in the section influenced by the water abstraction);
- Hydro-peaking: Possible measures could include compensation reservoirs. The ecological status of the water body/bodies affected can be improved through operational modifications (e.g. downstream "buffer" reservoirs) that reduce the volume and frequency of artificially generated abrupt waves and avoid extreme water level fluctuations.
- Impoundments: Morphologically restructuring the headwater sections of impoundments;
- Restoration of natural river morphology where possible and, if it is not possible, implementation of the "no net loss" principle.

Given the specific situation in non-EU countries, the above measure is to be implemented in a timeframe that is realistic and acceptable to all non-EU countries.

c) Morphology alterations – measures

For most water bodies which are "not at risk", measures should be aimed at their protection and maintenance and avoiding their deterioration. The measures may include:

- Law enforcement regarding riparian zone maintenance;
- Control over sand and gravel extraction;
- Avoiding reduction of floodplain size.

For the remaining water bodies, which are "possibly at risk", additional investigations are needed to define the causes of morphological quality deterioration. A final decision on whether a water body is defined as "at risk" or "not at risk" will depend on the results and the relevant measures should then be taken.

For the smallest part of water bodies, which are "at risk" the relevant measures required to improve and restore their quality should be implemented.

Other possible measures which should be encouraged are:

(i) restoration of the meandering character of the river;
(ii) restoring and mitigating the effects of dredging; and
(iii) planting of natural vegetation along the river courses.

The implementation of the following measures is proposed for future hydropower development projects, both for individual plants and hydropower cascades:

- Conduct of an Environmental Impact Assessment and Strategic Environment Assessment in conjunction with the requirements of the WFD Article 4(7) during the planning phase of future infrastructure projects if required;
- Fulfilment of the conditions set out in the WFD Article 4, in particular the provisions for new modifications specified in Article 4, Paragraph 7;
- Recommendations for stakeholders regarding the implementation of best environmental practices and best available techniques.

4.3.8 Special considerations for EU (potential) Candidate countries

The EU enlargement process, including support from relevant EU financial instruments, will facilitate ever-closer cooperation between Member States and EU-Candidate, or potential-candidate countries. Transboundary cooperation with other, so called 'third' countries may be difficult owing to differing policy and legislative frameworks, financial problems, and strict controls of movements across the future external border of the EU (due to the creation of a common EU immigration and visa regime for all EU external borders).

Challenges in coordinating funding for management of transboundary waters on the EU external borders (IPA in the EU-Candidate countries), need to be overcome. A 'soft law' instrument, the UN/ECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 1992) is also relevant, but does not substitute the formal agreements sought between countries under the WFD.

Water-related multilateral agreements facilitated by the United Nations Economic Commission for Europe (UNECE) are:

- **Convention** on Environmental Impact Assessment in a Transboundary Context (EIA, Espoo Convention, Espoo 1991) **Convention** on the Transboundary Effects of Industrial Accidents (Helsinki 1992)
- **Convention** on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention, Helsinki 1992)
- **Convention** on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus Convention, Aarhus 1998)
- **Protocol** on Water and Health (London 1999)
- **Protocol** on Strategic Environmental Assessment (SEA Protocol, Kiev 2003)
- **Protocol** on Civil Liability and Compensation for Damage Caused by Transboundary Effects of Industrial Accidents on Transboundary Waters (Kiev 2003)
- **Protocol** on Pollutant Release and Transfer Registers (PRTR Protocol, Kiev 2003)

5 CUMULATIVE EFFECTS AND IMPACTS ON RIVERS WITH RESERVOIRS

The advantages of hydropower as a highly-reliable, GHG absent and renewable source of electricity production has to be balanced with the need to maintain the ecological status of hydropower-affected water stretches in order to meet cumulative impact assessment objectives. Details of the cumulative impact assessment process are elaborated in further detail in Section 6 of BR-3 on Environmental considerations. Here, an introduction to the significance of cumulative impacts is presented. There is also a reference to cumulative impacts in BR-5 on Transboundary considerations, where the assessment of impacts at the border line or wherever required at project level for the division of water resources between adjacent riparian countries, assumes greater significance.

A qualitative analysis of cumulative effects was done at the level of MCA through an expert's assessment and remains filed within working documents, but to move forward with a development plan, a proper assessment of the cumulative effect of existing infrastructures and prospective projects must be prepared. This would require the collection of a significant amount of information, the completion of missing data and updating of old data. The systematic development of river basin management plans would not only allow for compliance with the requirements of the EU Water Framework Directive but also enable collection of the data essential for cumulative impact assessment.

It is important to ensure that existing and forthcoming EU policies to promote hydropower ensure coherence with the Water Framework Directive and/or other EU legislation related to the environment and that those policies clearly consider impacts on both the affected water bodies and their adjacent wetlands.

In general, holistic approaches towards hydropower development and use are required. Their focus should be at the catchment level and not only site-specific or at the water body level; such is the nature of cumulative effects.

(1) Biological continuity (understood as upstream and downstream migration) and ecologically acceptable flow (EAF) were identified as priority considerations for the improvement of water ecological status.

For upstream migration, many solutions are available (e.g. fish passes and fish ladders, but also fish lifts, fish stocking, catch & carry programmes, artificial spanning practice etc.) to mitigate the negative impact of migration barriers – but more work needs to be done on the evaluation and monitoring of their effectiveness. Much research leading to technical innovations still has to be undertaken, especially related to downstream migration in combination with turbine damage.

(2) Hydro-morphologic changes. The past developments of hydropower generation and related activities such as flood defence facilities have often resulted in major hydro-morphologic changes in the river basins.

There might be a risk of conflict between the implementation of different policies if cumulative assessment fails to identify hydro-morphologic impacts. The WFD and cumulative assessment puts a strong emphasis on the quality of hydro-morphologic conditions, as they support the type-specific aquatic communities that constitute good ecological status;

(3) Changes in water balance and flow should be agreed upon between riparian countries. Excessive abstractions of water from rivers and lakes for irrigation, urban supply, inter-basin transfers, or other consumptive purposes can significantly decrease downstream flow rates and diminish aquifer recharge. Conversely, large discharges of water from Storage Basins can modify the downstream flow patterns. These, in turn, are bound to modify downstream aquatic ecosystems, and changes in water balance could lead to the desiccation of wetlands, reduced capacity for digesting wastewater discharges, and lowered water tables. In principle, head storage basins are beneficial for all market-orientated downstream water resources users, in the respect that flood protection is of crucial importance on rivers.

6 CLASSIFICATION OF WATERSHEDS AND RIVER BASINS IN THE WB6 REGION

6.1 Introduction to Use of Watershed Classification

The requested “river basin” management approach in the Study, has been introduced by the Water Framework Directive and followed as the commonly agreed principle in the several issued guidelines, e.g. Guiding Principles on Sustainable Hydropower Development in the Danube Basin, and in worldwide practice generally. The principle states that water management must be enacted throughout the whole catchment area and not on a river-by-river basis.

In case of planning hydro power plants, the river basin management approach has often been questioned by WB6 country beneficiaries due to its uncertain definition, most usually evident in open transboundary issues and in the division of River Basins. Depending on a study’s needs and the purpose of that study, a RB could be defined differently in each given situation. Therefore, in one situation a RB could be treated as a Watershed, while in another situation the same territory could be treated at a Sub River Basin level. Observed, for example, from the ICPDR perspective, the Danube Basin (in fact Drainage Basin with the river mouth in the sea) is a clearly defined and unanimously used term. For ICPDR, the Danube River is the main water-stream and all other inflows are classified as tributaries. The Sava River is one of the main tributaries (Tributary 1 level as it flows to Danube) or in other words, in the eyes of ICPDR, the Sava River Basin is a (Sub)River Basin of the Danube Basin. Following this concept, Drina would then be a Tributary 2 as it flows to Sava first, and Ćehotina would be a Tributary 3 water-stream etc.

However, when moving from the regional level to the national level of BiH, for example, the Drina River is observed as its own River Basin and Ćehotina is its Tributary 1. In the eyes of the local community in the Ćehotina watershed, they would even see Ćehotina as a river. So, the further down the classification we go, the higher the grading attributed to the water-streams in the eyes of local observers. Therefore, we introduced the (Sub)River Basin as additional hydrographical element in the adoption of Classification used in this study.

In the absence of a unique or unambiguous definition of River Basin from the above point of view, for the purpose of this Study, which has a clear regional character, we have to decide on a clear classification system of hydrographical elements from the Drainage Basin down to the last but still relevant tributary in the Study. One such last level is the water stream where an HPP infrastructure, either existing or prospective (of more than 10 MW only) is considered.

The logical framework of the study Classification is thus based on the concept of following the water-stream from the point (A) of the respective river discharge in the sea back to the smallest tributary (point B) still used for HPP schemes development in the Study.

Rivers and River Basins (RB) which are not foreseen for the HPP development schemes in the Study, are not included in the Classification. Those rivers like, for example: the Tamis, Tisa and others further North in the Danube RB are intentionally omitted for easier comprehension of the hydrography in the Region. Therefore, the Classification contains only those RBs and water-streams, which are (i) identified as valid hydropower potential for consideration in the Study (greenfield HPP projects contained in the HPP-DB database addressed in BR-7) and (ii) water-streams and RBs that host the existing HPPs. – both of more than 10 MW of installed capacities per single HPP (containing one or more turbines and power generation units) or in some cases a set of HPPs of even smaller capacities that can be observed clearly as a cascade that altogether exceeds 10 MW of capacity).

It is worth noting that the HMP-GIS application (for detail, see BR-7) also contains additional rivers and water-streams where small HPPs currently exist or where they are planned.

The definitions of terms with respect to a catchment area (i.e. run-off) used in the classification are as follows:

a. **Drainage Basin (DB)**- area behind a point of entry of the rivers to the sea to the source point of all water-streams found in that particular area;

b. **Watershed (WS)** - run-off area, but also large river system;

c. **River Basin (RB)**- area within watershed draining through main water-stream and several tributaries;

d. **(Sub)River Basin (SRB)** - smallest unit within River Basin.

By introducing such simplifications, we made the very complex system of water streams in the WB6 countries more transparent and manageable for the purposes of the Study. Eventually, we deal with: 4 DBs (1 Black Sea and 3 Mediterranean), 13 WSs, 18 RBs, 10 SRBs, 27 Rivers, 78 Tributaries 1, and 25 Tributaries 2 in the Study. For further detail regarding classification of hydrographic elements (drainage basin, watershed, river basin, (sub) river basin, river, tributaries), see Figure A1.1 in Annex 1.

The difficult nature of territorial divisions in the catchment area will surface again when Water-management plans will be made, scaled down from larger to smaller ones. This case can be illustrated by the Sava RB Management Plan, which was harmonised in principle within the countries comprising this RB, but when details and solutions at Drina RB level will be decided, such as the change of the water balance, connectivity etc., then the complexity of resolving such issues will emerge in full.

The classification of RBs and SRBs is very important, and there are 18 RBs in total. According to the applied methodology in the TOR they should be observed and analysed separately in many terms, for example, hydropower potential (if data exist), hydrology and (integrated) water management, several environmental issues (biodiversity – fauna/flora, habitat, protected areas etc.), applicable ichthyology, existing and planned HPP schemes, mitigation measures, applicable SEA/EIA recommendations etc. In most cases, the end of one RB/SBR represents the beginning of another, and these points represent either confluences of water streams or cross-border points between the WB6 countries, where assessment of cumulative effects is most sensitive and the subject of bilateral negotiations.

In the Study, we defined cumulative (often also regarded as “downstream”) effects in terms of ecologically acceptable flows (EAF), sediments and fish-related issues. This has been done in qualitative terms and to a very limited extent also in a quantitative manner, as the latter is hardly possible to model in circumstances of unclear plans due to missing Integrated Water Management Plans and the unclear scope and dynamics of the construction of new HPPs in the future. Consequently, many assumptions have had to be made about water use and HPP commissioning.

Four of the WB6 countries pertain to the Danube DB, exceptions in this respect are Albania and the former Yugoslav Republic of Macedonia. Four WB6 countries (Bosnia and Herzegovina, Kosovo, Montenegro and Serbia) are members of the International Commission for the Protection of the Danube River (ICPDR, Vienna). Responsibility for integrated RB management in these countries has been partially shared with the International Sava River Basin Commission (ISRBC, Zagreb) at the Sava RB level. Montenegro is not taking part in ISRBC activities.

The list below shows part of the proposed Classification system (the example case of the Danube RB). The principle adopted in this table is that rivers are represented from the Drainage Basin to the last-mentioned Tributary in terms of distance from the respective sea.

It should be read as follows (selected issues only):

- The Danube RB in the WB6 consists of the Sava and the Velika Morava RBs, and it is shared between BiH, CRO, MNE, SER and SLO;
- Further detailed, it consists of 7 SRBs (Drina, Bosna, Vrbas, Una, Zapadna Morača, Južna Morava and Timok);
- In the Sava RB, the confluence of the Una SRB is the most remote from the DR of Black Sea, after which comes the Vrbas, Bosna and Drina SRBs;
- In the Drina SRB, there are 3 main rivers (Piva and Tara in MNE and later Drina in BiH);
- In the Bosna SRB, for example, the main river is Bosna, which has Spreča as the most remote (or first from the last point on the water-stream) Tributary 1, the next inflow comes from Krivaja, then Fojnička rijeka and finally, Babina rijeka;
- Krivaja (Tributary 1) has also its own tributaries (Tributary 2 level), first comes Orlja and the last one is Strupčanica;

- There are /may be other rivers and tributaries associated but these are not shown because currently there are no HPPs in operation or no HPPs of more than 10 MW are planned in HPP-DB;
- For each RB, SRB, river and tributary it is immediately visible in which WB6 country they flow or how they are shared between the countries;
- If accompanied with an appropriate map indicating rainfall catchment areas, the presented information is close to complete.

Names of the rivers in Albania are based on data submitted and cannot be regarded as “approved” (could differ in spelling). A main concern is that different naming may exist between water-streams used on the maps and in the HPP-DB Excel-based spread sheet prepared in the Study. Names of main water-streams in Albania were checked and confirmed by National experts to safeguard harmonisation with official classification and done in accordance with Decree on organisation of Water-Management Authorities in Albania from 04/05/2016.

Smaller Tributaries, usually connected to small HPP, are often omitted due to their large number. They should be located through the major river.

Based on a list of rivers which are selected for the development of hydropower schemes, the following division of river basins in the WB 6 region applies:

- Black Sea Drainage Basin
    - Watershed Danube River
        - RB Sava River:
            - SubRB: Una, Vrbas, Bosna, Drina
        - RB: Morava River
- Adriatic Drainage Basin
    - RB: Neretva, Morača, Drin, Semen, Vjosa
- Aegean Drainage Basin
    - RB: Vardar
- Ionian Drainage Basin
    - RB: Bistrice

6.2 The European Water Framework Directive

The best model for a single system of water management is management by river basin - the natural geographical and hydrological unit - instead of according to administrative or political boundaries. Initiatives taken forward by the States concerned for their river basins have served as positive examples of this approach, with their cooperation and joint objective-setting across Member State borders, or in the case of the Rhine even beyond the EU territory. While Member States respect the river basin approach within their national boundaries, despite some differences stemming from tradition of water management, this could not be the case at present in river basins shared with non-EU countries. For each river basin district - some of which will traverse national frontiers - a "river basin management plan" will need to be established and regularly updated, and this will provide the context for the transboundary co-ordination requirements preferred in cases where the neighbouring non-EU country is sharing the same river basin with a EU Member State.

6.3 Concluding remarks

The river basis water catchment area must be considered as the key spatial unit to understand and manage ecosystem processes and biodiversity patterns. However, biological information is mostly available at the country rather than the catchment level. In addition, available data are unevenly distributed across Balkans and limits potential comparability. Riverine floodplains and deltas are among the least studied ecosystems yet are the most threatened.

Although all the West Balkan countries have fresh water resources sufficient to meet the needs of sustainable development, climate change is expected to have an impact on the water regimes. As the requirements for drinking water grow, and the demands for hydropower production increase, the water resources of the region may come under pressure from users with conflicting interests.

New international boundaries add yet another complexity. Twenty years ago, the Balkans had six international river basins. Now, because of the new international borders, they have thirteen, as well as four transboundary lake basins.

The implications for the development of adaptation strategies are enormous. The water resources problem is more regional than national in scale, and effective adaptation in the region cannot occur on a strict country-by-country basis. This means that the Balkan countries must work together on regional adaptive strategies, and that their capacity to cooperate on mutual problems is a major element in their overall adaptive capacity.

7 ASSESSMENT OF HYDROLOGIC DATA IN THE WESTERN BALKANS

7.1 Introduction

The WFD Article 8 'Monitoring of surface water status, groundwater status and protected areas, and the WFD Annex V (dealing with water body status, monitoring etc.), foresees monitoring action on water courses in detail.

Article 8 requires Member States to put in place monitoring programmes to establish a coherent and comprehensive overview of water status within each River Basin District. Such monitoring must cover both surface and ground water, and must be operational by a defined period. Three types of monitoring are required: 'surveillance', 'operational' and 'investigative', as detailed in WFD Annex V. Additional monitoring is needed for the protected areas (for habitats/species or drinking water abstraction) identified under Annex VI.

Annex V (untitled) is lengthy and complex. Basically, it sets out the criteria to be used for assessing surface water 'ecological status' and groundwater 'quantitative status', together with the corresponding monitoring programmes and reporting procedures required.

For surface water bodies Annex V covers:

- The scientific/technical parameters, definitions and standards to be used for the classification of ecological status: '*high*', '*good*' or '*moderate* for each of the surface water body types identified in Annex II (including high, good or moderate ecological **potential** for artificial or heavily modified water bodies).
- Design of surveillance monitoring programmes (to be used in combination with the impact assessment procedure in Annex II) for developing the monitoring components of RBMPs.
- Design of 'operational monitoring' for (a) establishing the status of water bodies at risk of failing to meet the WFD environmental objective of 'good status'; and (b) assessing the effectiveness of the Programme of Measures in improving the ecological status of such water bodies.
- Design of 'investigative monitoring'.
- Frequency of monitoring.
- Additional monitoring for protected areas (both drinking water abstraction points and protected areas for habitats and species).
- Presentation and reporting of ecological status and monitoring information.

The WFD principal requirements of monitoring are the following:

- Establish monitoring programmes/networks needed for a coherent and comprehensive overview of water status including wetlands within each RBD;
- Cover both surface-water and ground-water bodies, as well as coastal waters;
- Include 'surveillance', 'operational' and 'investigative' components;
- Additional monitoring for protected areas.

An implementation of the Water Framework Directive comprises practical reference to establish monitoring programmes/networks needed for a coherent and comprehensive overview of water status including wetlands within each River Basin. Therefore, effective monitoring is an essential component of "good practice" in river basin planning and management, and a central element of measuring progress in WFD implementation:

- Work on establishing monitoring networks (including evaluation of existing monitoring) must be carried out at an early stage of WFD implementation;
- Steps should be taken to establish the level and type of monitoring needed for maintaining an overview of changes in pressures and impacts, which may reflect shifts of root causes;
- Existing data — held by different governmental and non-governmental bodies (e.g. water supply companies, environmental agencies, conservation NGOs, local municipalities) — should be sought out

and used as much as possible. It is important to ensure that data set 'links', are in place to provide the integration and/or aggregation of information needed for effective river basin planning and management.

7.2 Assessment of the existing national monitoring networks and quality of data with emphasis on hydropower

7.2.1 Bosnia and Herzegovina

Controls and analyses of surface water quality in Bosnia and Herzegovina were systematically carried out from 1965 to 1991 at 58 gauging stations of river basins and sub-basins of the rivers: Una, Vrbas, Ukrina, Bosna, Drina, Neretva and Trebišnjica. (Analyses from that period did not include groundwater, lakes and reservoirs). Controls were based on ad-hoc water sampling. Physical-chemical parameters of water quality were defined three times a year (spring, summer, autumn) and biological parameters twice a year (summer and autumn).

In 2009, 42 physical-chemical and four microbiological quality elements on 47 sites in the Sava RB were monitored. Two biological quality elements (phytobenthos and benthic in-vertebrates) were monitored on 33 sites. Frequencies of monitoring of physical - chemical quality elements were three times/year, biological quality elements were monitored two times per year. On some sites, 34 organic toxic substances are monitored. In 2009, the quantitative monitoring was organised twice at the same time as monitoring of quality parameters.

The existing monitoring sites in Federation of Bosnia and Herzegovina cannot be at present assigned as sites of operational and surveillance monitoring. The reference monitoring programme is under construction.

According to the Water Law (Office gazette FBA, No. 70/06), organisation of the hydrological and quality monitoring and monitoring of the ecological status in the Sava RB in FBA is the task and obligation of the Sava River Watershed Agency, Sarajevo.

In the Republika Srpska, as one of the entities in Bosnia and Herzegovina (approx. 48% of the total territory), the surface water quality monitoring (including water level and flow, where possible) has been performed by the Ministry of Agriculture, Forestry and Water Management of the Republika Srpska and Water Agency for Sava River District, since the year 2000. In 2007, the surface water monitoring network was revised with the main goal of meeting the WFD-compliant monitoring requirements as far as possible. For rivers with catchment area >1,000 km^2 the monitoring network consists of the following elements:

- Surveillance monitoring I: Monitoring of surface water status-rivers (SM 1, nine sites);
- Surveillance monitoring II: Monitoring of specific pressures; (TNMN monitoring stations, SM 2, nine sites);
- Operational monitoring (OM, 22 sites).

Within SM 2, the list of parameters for assessment of trends and their monitoring frequencies (annually/12 x per year), is the same as the joint monitoring activity of all ICPDR Contracting Parties, which produces data on concentrations of selected parameters in the Danube and major tributaries.

Monitoring of water quality and quantity in rivers in Federation of Bosnia and Herzegovina exists, but is not in accordance with the WFD. The monitoring programme is, mostly, organised at the same monitoring sites as before 1992.

Monitoring of water quality in the Adriatic Sea RBD was resumed in 2000. Beside former gauging stations, the analysis also included some new stations in the Neretva River Basin.

Monitoring of water flow and quality is being improved; more efforts are needed in biological monitoring. This will allow the assessment of the status on water supply, demand and quality, in a basin with a rather complex hydrogeology, providing the basis for adequate planning and regulation on a river basin level. The essential balancing of competing water demands, considering social, economic and environmental considerations, through a comprehensive and coordinated strategy agreed by the two countries (CRO-BIH), may follow. Enhancement of the national institutional capacity to plan, implement and enforce management measures on water demand and water use is indispensable.

7.2.2 Serbia

The Hydro-meteorological Service of the Republic of Serbia has been running systematic monitoring of quantity and quality of both surface and groundwater. Up to 2010, the monitoring was carried out in accordance with the Law on Waters and the Act on the systematic surface and ground water quality monitoring adopted by the Government of the Republic of Serbia. Since the new Law on Water was adopted by Serbia, the conditions for the gradual adaptation of monitoring system to WFD requirements have been created. In the next two years, according to the Water Law, water quality and water management by-laws and the issues of the financial investments and tariffs will be the subject of work by the Ministry of Agriculture, Forestry and Water Management – Directorate for Water. A set of by-laws will cover the water status monitoring methodology, and will provide a system compliant with WFD principles. The Republic Directorate for Water is responsible for the conception and implementation of an integrated national policy, including the policy of international cooperation. Up to now, the subdivision of monitoring network to SM 1, SM 2 and OM has not been performed, except in the case of the Trans National Monitoring Network (TNMN) reporting network. In addition, a preliminary proposal for the subdivision of monitoring stations has been prepared for the Kolubara River Basin (part of SRB), as a pilot area for WFD implementation. Systematic water regime monitoring with simultaneous assessment of the water quantity and quality provides reliable data on the state of the water resources as the basis for water resources management, flood protection and water pollution control. In accordance with the surface and groundwater flow regime, a network of monitoring stations and a monitoring programme have been established aiming to assess the condition of waters in space and time, in Serbia. The main objective of setting the qualitative monitoring system is to obtain the large amount of data which have been further gathered in the RHMS database. They have been published annually in RHMS Annual Reports – separately for data on surface waters, groundwater and water quality. The monitoring network and parameters covered at each station is defined by the Annual Monitoring Programme. The network encompasses 147 monitoring stations at rivers and channels in the whole territory of Serbia. The assessment started in the 1960s with approximately 55 stations and has been enlarged, mainly until the 1990s, to the present number. Within the last ten years, there have not been any major changes to the network design, except the introduction of 15 additional monitoring sites at the Kolubara River Basin (interim and supplementary interim monitoring). Therefore, for most stations, long-term series of data are available.

The monitoring stations are generally subdivided into i) main stations, ii) primary stations and iii) secondary stations. At each monitoring station assigned to categories i), ii) or iii), there are hydrological gauging stations in operation for the frequent survey of water levels and discharges. Monitoring stations without any classification do not dispose of any hydrological gauging stations. If applicable, the discharge is assessed in parallel while sampling the other parameters.

National surface water monitoring is carried out on 129 profiles at 73 watercourses on a monthly basis, 24 times a year on state border profiles and main monitoring locations.

7.2.3 Albania

Analogue observation data (currently in paper form) of meteorological and hydrological services are being digitalized. For the meteorological service, data from the period 2001 to 2012 was digitalised by this project.

The following information about the hydrological service was obtained from an interview at the Department of Climate and Environment. The number of existing hydrological stations located in the Drin Basin (River Drin and tributaries) in Albania is about 52. Nine of them are located in the Buna catchment.

The meteorological data investigation shows a high density of stations although the location and condition of some stations are unclear. Several stations have been renamed and relocated during the period 1961-2013. A few historical time series data exist for precipitation and air temperature (daily minimum, maximum, and average), which contain randomly distributed data gaps. Time series data for additional meteorological parameters are rare. Some data mainly exists in paper format and need to be digitised for future use. Considering the use of data for hydrological modelling, further data preparation should include the parameters of snow, radiation and wind. All data from about 1991 up to present are stored in one consistent data base. Data from earlier time periods have been collected during this project from different sources, each with varying data formats. Some data (especially current precipitation data) are frequently checked for quality and plausibility.

However, some historical data are not consistent over the evaluated period and show implausible changes of the rainfall regime (e.g. the station Theth or Dragobi).

Several water level and discharge time series data exist on a daily scale for some stations for the requested period 1961-2013, although data are incomplete.

For historical hydrometric data, a unique data base does not exist. Consequently, data have been provided from different sources. The transformation of time series of water level data to discharge stopped in 2000. Water level time series data and point measurements of discharge and water level are stored from about 1991 up to the present in a new data base.

Improvement to the data situation is recommended by preparing a historical data base similar to the meteorological data base. In most cases the quality of existing data has not been verified. Among others, the data of the stations Rasek, Prekal, Shkodër contained several data errors. Catchment sizes and operating periods are uncertain for most stations. A further plausibility check is recommended. This deficit is especially problematic for stations in the lower part of the Buna/Bojana system which is prone to flooding. In this region, discharge calculations are not available which impedes an accurate reproduction of the discharge regime in the model.

Information was obtained for water level series only. The existence and status of rating curves is unknown. Obviously, automatic recording and online-transmission of water level data is not available, except for one station. All data are transmitted from the gauging observer to the headquarters by post at the end of each month. It is currently unknown how many of these stations are in operation and in what operational state they are.

The available data series of water level were checked for gaps. The histograms have been created for all mentioned hydrological stations until the year 1990. From 1991 up to now histogram data were not provided. According to the results of the questionnaire, this period is characterised with large gaps in the data series of observations.

Presently, the available hydrologic and meteorological data series recorded from about 1991 up to present are being digitalized by a private company under supervision of IGJEUM and financial support of the World Bank.

The lake Shkodra (Skadar) is an important element of the Drin/Drim – Buna/Bojana River Basin. Therefore, a detailed storage elevation curve is needed to rebuild the characteristics of the lake as part of the hydrological modelling.

The influence of groundwater and karst springs is still uncertain as information could not be provided. Further investigation is necessary.

The dam cascade is an important influencing factor and offers a high potential to improve the existing flood risk management. Therefore, close cooperation with operator of the Drin Cascade, KESH, is essential. KESH hydrometric data include hydrographs for daily reservoir inflow, side inflow and spillway outflow from 1991 till 2010. Additional data such as turbine outflow and/or total outflow from each reservoir and storage elevation curves for the three reservoirs is required for eventual calibration purposes and will help optimise a combined and multi-objective reservoir operation with the help of modelling.

In general, precipitation data are evaluated as sufficient for building up a rough hydrological model while other meteorological parameters are rare. Due to long time periods of missing information, hydrometric data are judged to be insufficient for an accurate characterisation of the flow regime especially in the downstream Buna/Bojana river system.

7.2.4 Montenegro

Surface water quality monitoring in Montenegro is performed in a traditional way, not taking into account the requirements of the WFD. It is operated by the Hydro-meteorological Institute of Montenegro in Podgorica. The parameters and frequencies are focused mostly on the protection of the drinking water abstraction areas.

About 12 hydrological stations are in the Drin Basin in Montenegro. The main parameters measured are water level and water discharge, in some of them water temperature as well. Analysis of water quality is done according to the Water Law by Institute for Hydrometeorology and Seismology, Montenegro - IHMS / Sector for Analysis of water and air quality. Analysis is done every year on all water bodies in Montenegro (rivers, lakes and sea), following the Annual programme prepared by the Water Directorate.

Currently there are 7 functioning automatic stations in the Adriatic River Basin, and 11 automatic stations in the Black Sea Drainage Basin. There is one Hydrometric Station in the Adriatic Drainage Basin manually observed (Gornje polje) and two manual observation Stations in the Black Sea basin (Plav and Gradac).

The IHMS provided topographic, meteorological (precipitation, snow, relative humidity, sunshine duration, air temperature, wind, radiation) and hydrometric data (water level and discharge) on a daily scale for the selected period 1961 – 2013.

The investigation of meteorological data show almost complete time series data for the requested period for all parameters. However, the quantity of data for other parameters (except precipitation) is limited to the two main stations in Nikšić and Podgorica. Wind data and radiation data have been delivered on an hourly scale for the period 2008-2013. Especially for radiation, more historical data would be useful. Snow data are only available in digital format for the station Nikšić. All precipitation data are stored in one data base with a consistent data format which facilitates the input into a hydrological model. The quality of data is judged to be sufficient although some precipitation data (for example at the station Cevo) show a non-linear behaviour over the evaluated period. Critical for hydrological modelling is the fact that all stations are located at altitudes lower than 1,000 m a.s.l. which highly influences the amount of precipitation.

Hydrometric data investigation included water level and discharge data as well as storage-elevation curves, bathymetry data and rating curves. For water level and discharge complete time series data are available on a daily scale. The data are stored in one data base with one consistent data format.

The available data series were checked for gaps. The histograms were created for the following hydrological stations: Plavnica and Ckla (Skadar Lake), Podgorica, Zlatica and Pernica (Morača river), Fraskanjel (Bojana), Brodska njiva (Crnojeviča River), Duklov most (Zeta), Međurječje (Mrtvica).

In general, the hydrological data are considered consistent. Nearly 50% of the water level series have large gaps between 2002 and today. For historical evaluation of flood events, data from seven out of nine stations are available (1960s until 2002). For discharge data the situation is worse. Only two stations have data until 2012. IHMS has problems with existing stations in maintenance and very often for spare parts (which are stolen or demolished).

7.2.5 The former Yugoslav Republic of Macedonia

Collected hydrological parameters in the former Yugoslav Republic of Macedonia are: water level; discharge; water temperature; suspended sediments. All data are collected in the Hydro-meteorological Service - HMS and controlled by technician and engineers, and are stored on the HydroPro Data Base since 2004. Older data are still in Excel files. A backup system has been recently installed.

Lack of budget and human resources hampers the capacity of HMS to ensure comprehensive, quality controlled meteorological and hydrological databases. Consequently: the hydrological database is complete from 2004 to now, older data are on excel or analogue form. The meteorological database needs to be quality controlled and it is not complete (2/3 digitised).

Meteorological data are available for the parameters: precipitation, snow, relative humidity, sunshine duration, air temperature and wind with almost complete time series on daily scale. Exceptions are the data of the stations Debar and Slivovo which have at least 10 years of data gaps. The analysis of the data emphasises a trend of increasing precipitation sums. Snow depth is measured at every station. Radiation data are not available presently.

The hydrometric data (water level and discharge data) consist of one unique data format. The two lake stations Ohrid (Ohrid Lake) and Stenje (Prespa Lake), provide information about changes of water level over the years. Storage – elevation curves for both lakes are available as a rough estimation and require further investigation. Karstic springs and the groundwater levels influence the water budget especially of the system of the two lakes, which are joined by an underground connection.

The collected water level data for all gauging stations are incomplete. Daily discharge data are existent for the period 1981-1990 in a consistent format. In the present period data are only available for three stations. The discharge calculations at the stations Špilje and Boškov Most are uncertain. Špilje is an important station covering the main Drim River, but the actual discharge seems to be underestimated. Further work will include a plausibility check of these data. Rating curves are not available presently. A first analysis of the opposed data pairs of water level and discharge performed by the consultant provided several options of estimated rating curves over the recorded period. For example, several rating curves of the stations Brajcino, Botun and Lozani exist. Presently some of the hydrometric stations with historic data available are destroyed or suspended.

Two hydropower plants Globočica and Debar (Špilje) strongly influence the flow regime of the downstream Drim river. For a future implementation of flood forecasting by using a hydrological model, cooperation and data exchange of the HMS with the reservoir operator ELEM will be essential.

In summary, the quantity and quality of meteorological data is sufficient, while the quantity and quality of hydrometric data are critical and require further improvement.

7.2.6 Kosovo

The KHMI Hydrometeorology Institute of Kosovo oversees collecting topographic, meteorological and hydrometric data.

Meteorological parameters, especially precipitation data on daily scale, are the most important data needed for a hydrological model. Regarding river networks, the data situation is critical as many stations have been destroyed during the Kosovo conflict, and data had been lost. KHMI monthly precipitation data for some stations and daily precipitation data for Pristina have been digitised by using hydro-meteorological yearbooks of the former Yugoslavia. The station Pristina is not included in the river basin Drin/Drim – Buna/Bojana. The KHMI has daily data for three stations (Pristina, Pejë, Ferizaj) for the parameters precipitation, snow, relative humidity, air temperature, wind since 2002. The data are incomplete and contain data gaps; the data format is not consistent. The aim of future work should be to build up a transparent and consistent data base for relevant meteorological data.

Historical hydrometric data (water level, discharge) are available from 1960 to 1986 but generally contain big data gaps. In 2003 water level measurements were renewed at some stations but the data are incomplete and with varying quality. Presently none of these stations are operating. The historical data delivered by the KHMI are originally stored in two different data formats divided into data from 1949-1997 and 2003-2013. The unit of the data changes and partly data are stored twice. An insight in hydrometric data for checking rating curves presents a very heterogeneous distribution of observed water level data versus flow data with several regression curves, which vary in slope and height. For future use of the hydrometric data, it is essential to create one transparent, consistent data base, which avoids redundant data storage. Data should be checked for quality and plausibility.

In general, the absence of daily precipitation data as the main important input is critical and impedes the characterisation of the water budget. Estimations of missing precipitation data using regional interpolation are possible but clearly do not substitute data measurements. Furthermore, the hydrometric data situation does not allow a validation of a hydrological balance for the Kosovo river basins for the period from 2001 to 2010. Summarizing, the quantity and quality of collected data is not sufficient to create a first hydrological balance for the sub-basin. Therefore, provisional procedures had to be applied to roughly overcome these deficits in the hydrological analysis.

7.3 Concluding remarks

Data quality for hydrology of the Western Balkans streams is of utmost importance for various purposes from analysing hydropower potential, to climate change and cumulative effects (in transboundary context). Without a reliable set of data with sufficient coverage of the river basin, no analysis would be trusted.

Before the present study started, the intention was to collect discharge data on all rivers in the region for the recalculation of electricity production at selected rivers with prioritised hydropower plants. This was not possible for several reasons; the most important was the difference in the quality of hydrology baseline data across the countries in the region, which differs considerably. Therefore, recalculating electricity production (expecting small differences) could be inconclusive and would lead to a distorted assessment of performance of HPP candidates in MCA L2, and consequently, ranking/grouping of HPPs would be done with misleading results.

8 PROPOSALS FOR CONCRETE FOLLOW-UP ACTIONS IN THE FIELD OF HYDROLOGY AND RELATED TOPICS

Table 8.1: Proposed actions at the regional WB6 level

SN	Brief description of proposed Action	Assumed implementing agent	Anticipated timeframe
1	Implement a full-scale monitoring system on water quantity, including meteorology and surface characteristics enabling analysis of climate change impact on watershed run-off.	Governments, Environmental agencies	Mid-Term
2	Implement WFD not only in strictly legal terms but substantiate water-management organisation and practice.	Government	Short-Term
3	Plan new set of hydrologic studies including modelling of run-off for prioritised river basins.	Government, Utilities	Mid-Term
4	Integrated water management plans are first step of water resources utilisation management at river basin level.	EC DG, IFI, Governments, International development agencies	Continuous, Short-Term
5	Publicise the knowledge acquired through preparatory work on planning and realisation of hydropower stations in the Region	Governments, IFI, EC DG	Continuous
6	Upgrade state owned hydrometeorology systems and expand existing network according to energy, water use and climate change needs appropriately to priority river basins	Governments, Environmental agencies	Continuous
7	Continue realising adequate measures (in detail in BR 3) that consider and protect biodiversity and ecosystem services.	Electric Power Utilities	Continuous
8	Enable exchange of information on the official hydrological and meteorological data in the Region (it is efficient to implement the case of Danube river projects) among all riparian countries (priority at the Drini/Drim River Basin.	Governments, Environmental agencies, Research support	Mid-Term
9	Prepare for public participation activities from the hydrology point of view as equally important with other planning issues.	Governments, Utilities	Short-Term
10	Prepare guidelines for future hydropower projects, based on lessons learned, incl. costing issues, best practice of mitigation considering offsets, followed by development of a comprehensive action plan for the sustainable development of the hydropower generation potential of the river and its tributaries.	EC DG, Governments	Short-Term
11	Pre-planning mechanisms allocating "no-go" areas for new hydro-power projects should be developed. This designation should be based on a dialogue between the different competent authorities, stakeholders and NGOs.	Governments, Utilities	Short-Term
12	Develop specific guidelines on environment and water related rehabilitation of existing hydropower stations and include good description of hydrology related subjects, such as data quality, climate change, tendencies in run-off, etc.	EC DG, IFI	Short-Term
13	While planning, climate change modelling should be done on a project development basis.	Electric Power Utilities	Short-Term

Annex 1: Classification of hydrographic elements

Table A1.1: Classification of hydrographic elements (watercourses, drainage basins, river basins, watersheds)

DRAINAGE BASIN (DB)	WATERSHED (WS)	River Basin (RB)	(Sub) River Basin (SRB)	River	Tributary 1	Tributary 2	Affiliation to WB6-countries: ALB	BIH	KOS	MKD	MNE	SER
BLACK SEA	DANUBE	**Danube** /SER part only/		Danube								■
		Velika Morava /SER/	**Zapadna Morava** /KOS, MNE, SER/	Ibar					■		■	■
			Južna Morava /SER/	Južna Morava								■
					Nišava	*Temska*						■
					Vlasina							■
		Timok /SER/		Timok	*Crni Timok*	*Zlotska*						■
					Beli Timok	*Grliška*						■
						Svrljiški Timok						■
						Trgoviški Timok						■
		Temištica /SER/		Temištica								■
					Visočica							■
		Sava /BiH, MNE, SER/	**Drina** /BiH, MNE, SER/					■			■	■
				Drina				■				
					Rastošnica			■				
					Osanica			■				
					Bistrica			■				
					Čehotina			■			■	
					Lim	*Djurička*		■			■	■
						Grnčar					■	
						Kaludarska					■	
						Ljesnica					■	
						Sekularska					■	
						Trebačka					■	
						Uvac					■	
						Visočica					■	
						Zlorečica					■	
				Piva							■	
					Vrbnica						■	
					Tusina						■	
					Bukovica						■	
					Bijela						■	
				Tara							■	
			Bosna /BiH/	Bosna				■				
					Željeznica			■				
					Kozica			■				
					Babina r.			■				
					Fojnička r.			■				
					Krivaja	*Strupčanica*		■				
						Bioštica		■				
						Orlja		■				
					Spreča			■				
			Vrbas /BiH/	Vrbas				■				
					Bistrica			■				
			Una /BIH, CRO/	Una				■				
					Jezernica			■				
					Sana			■				
ADRIATIC SEA	TREBIŠNJICA	**Trebišnjica** /BiH, CRO/		Trebišnjica				■			■	
					Tihaljina			■				
	NERETVA	**Neretva** /BiH,CRO/		Neretva				■				
					Rama			■				
	BOJANA / BUNA	**Morača** /MNE/		Morača							■	
					Zeta						■	
					Mala rijeka						■	
					Cijevna						■	
		Drin-Bune /ALB/	**Bune/Bojana** /ALB/	Bojana/Bune			■					
					Gjader		■					
			Drini /ALB/	Drini			■					
					Curraj		■					
			White Drin, Drini i Berthe /ALB, KOS/	White Drin, Drini i Berthe			■		■			
					Drini i Berthe		■		■			
					Lumebardhi i Decani				■			
					Restelica				■			
					Lum i Istogut				■			
					Dikance				■			
			Black Drin, Drini i Zi /ALB, MKD/	Black Drin, Drini i Zi			■			■		
					Shale		■					
					Lumi i Zi		■					
					Borjes		■					
					Luma	*Caje*	■					
					Zalli i Okshtunit		■					
					Valbona		■					
					Gomsiqe	*Tetajve*	■					
					Nikaj (Drin-Bune)		■					
					Radika		■			■		
	MAT	**Mat** /ALB/		Mat			■					
					Sete		■					
					Mat (Milot; Kurbin)		■					
					Fan i Madth	*Mati*	■					
					Mirdite		■					
					Fan i Vogel		■					
					Prroni i Gjurajve		■					
	ISHEM	**Ishem** /ALB/	-	Ishem		-	■					
					Gjole		■					
					Zeze		■					
					Dushna		■					
	ERZEN	**Erzen** /ALB/		Erzen			■					
					Radicina		■					
					Sheja e Librazhd		■					
					Zalli i Lunikut		■					
	SHKUMBIN	**Shkumbin** /ALB/		Shkumbin			■					
					Bushtrices		■					
					Qarrishte		■					
					Gostime (Shkumbin)		■					
	SEMAN	**Seman** /ALB/		Seman			■					
					Osumi		■					
					Devolli	*Shishtavecit and*	■					
					Cemerica (Devolli)	*Verces*	■					
	VJOSA /AOOS	**Vjose** /ALB, GRE/		Vjosa			■					
					Smokthine		■					
					Drinos		■					
					Sarantaporos		■					
IONIAN SEA	BISTRICE	**Bistrice** /ALB/		Bistrice			■					
AEGEAN SEA	AXIOS / VARDAR	**Vardar** /MKD, GRE/								■		
				Vardar						■		
					Rakita r.					■		
					Sapunčica					■		
					Zrnovska					■		
					Korab					■		
					Lepenac					■		
					Treska					■		
					Madinar r. and Markova r.					■		
					Lepenac	*Psaca*				■		
					Pčinja	*Kriva Lakavica*				■		
					Topolka and Babuna					■		
					Bregalnica	*Dosnica*				■		
					Reka Crna					■		
					Bosava					■		
	STRUMICA	**Strumica** /MKD, BUL/		Strumica						■		
4	**13**	**18**	**10**	**27**	**78**	**25**	**TOTAL**					

Increasing distance from the Sea (DB) to the Tributary

MOTT MACDONALD IPF CONSORTIUM

Annex 2: List of used literature sources

Section 3: CLIMATE CHANGE IN THE WESTERN BALKANS AND HYDROPOWER

(1) **Greenhouse Gas Emissions from Hydroelectric Reservoirs: What Knowledge Do We Have and What is Lacking**? 2012, Raquel Mendonça, Nathan Barros, Luciana O. Vidal, Felipe Pacheco, Sarian Kosten and Fábio Roland

(2) **Reservoir Surfaces as Sources of Greenhouse Gases to the Atmosphere: A Global Estimate,** 2000, Vincent L. St. Louis, Carol A. Kelly, Éric Duchemin, John W. M. Rudd, and David M. Rosenberg

(3) **Evaluating greenhouse gas emissions from hydropower complexes on large rivers in Eastern Washington**, 2013, Prepared for U.S. Department of Energy by: EV Arntzen S Niehus BL Miller M Richmond AC O'Toole

(4) **Convention on the Protection and Use of Transboundary Watercourses and International Lakes**, Guidance on Water and Adaptation to Climate Change, 2009, Economic Commission for Europe

(5) **Sava River Basin Management Plan**, 2014, International Sava River Basin Commission

(6) **Outlook on Climate Change Adaptation in the Western Balkan Mountains**, 2015, United Nations Environment Programme, GRID- Arendal and Environmental Innovations Association. Vienna, Arendal and Sarajevo. www.grida.no

(7) **Assessment of the Reliability of Climate Predictions Based on Comparisons With Historical Time Series**, April 2008, D. Koutsoyiannis, N. Mamassis, A. Christofides, A. Efstratiadis, S.M. Papalexiou - Department of Water Resources and Environmental Engineering National Technical University of Athens

(8) **Water & Climate Adaptation Plan for the Sava River Basin**, 2015, Final Report

Section 7: ASSESSMENT OF HYDROLOGICAL DATA IN THE WESTERN BALKANS

(1) **Climate Change Adaptation in Western Balkans** Development and Application of a (Rough) Hydrological Model for the Drin/Drim – Buna/Bojana Basin, *September 2014,* Institute for Water Management IfW GmbH, Braunschweig, Germany in cooperation with Leichtweiss Institute for Hydraulic Engineering and Water Resources, Dept. of Hydrology, Water Management and Water Protection University of Braunschweig, Germany *Prepared by: Prof. Dr.-Ing. Günter Meon* and *Dr.-Ing. Gerhard*

(2) *Riedel, M.Sc. Saskia Schimmelpfennig*

(3) **Elements of Good Practice in Integrated River Basin Management** - *A Practical Resource for implementing the EU Water Framework Directive,* 2000/2001, Key issues, lessons learned and 'good practice' examples from the WWF/EC 'Water Seminar Series'

(4) **Sava River Basin Management Plan**, 2014, **ISRBC**

(5) **Sava River Basin Management Plan**, 2014, Background paper No.1 Surface water bodies in the Sava River Basin; ISRBC

(6) **Climate Change Adaptation in Western Balkans, Establishment of a Flood Early Warning System in the Drin-Buna Basin (DEWS),** ***Final Report,*** *May 2013, Institut für Wassermanagement IfW GmbH, Braunschweig, in cooperation with Leichtweiss Institute for Hydraulic Engineering and Water Resources, University of Braunschweig, Germany, Prepared by: Prof. Dr.-Ing. Günter Meon and Dr.-Ing. Matthias Pätsch*