Climate Change Adaptation in Western Balkans

Drim/Drin-Buna/Bojana River Basin Flood Early Warning System

Selected Stations + Operational Priorities and Future Needs – A Consultation Document

REPORT QUALITY CONTROL

Drim/Drin-Buna/Bojana River Basin Flood Early Warning System
Selected Stations + Future Network Needs and Operational Priorities

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ACRONYMS

AWS – Automatic Weather Station (defined as recording and transmitting synoptic data at least hourly)
AWLS – Automatic Water Level Station
CIS - Common Implementation Strategy (of the WFD)
CS – Climate Station (defined as manually recording climate data at least daily)
CCAWB – Climate Change Adaptation in Western Balkans
DBM – Database Management
DBMS – Database Management Software
DDBB – Drim/Drin-Buna/Bojana (river basin)
EDA – Environmental Data Acquisition
FEWS – Flood Early Warning System
GPL – General Public Licence (software)
INSPIRE - Infrastructure for Spatial Information in the European Community Directive 2007/2/EC
NHMS – National Hydrometeorological Service
RBMP – River Basin Management Plan
SDI-12 - Serial Data Interface (@1200 baud)
SQL – Search and Query Language (database operating system)
QPF – Quantitative Precipitation Forecast

TWG – Technical Working Group (of the DDBB)
WFD – Water Framework Directive (2000/60/EC)
WIS – WMO Information System
WISE – Water Information System for Europe
WML – Water ML 2.0 (OGC Open communication standard for hydrometeorological data)

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EXECUTIVE SUMMARY

Part 1 - Context and Terms of Reference

The programme 'Climate Change Adaptation in Western Balkans' is a joint cooperation between the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and relevant government ministries in Macedonia, Albania, Kosovo, Montenegro and Serbia. In the framework of the project a Regional Round Table workshop on the "Establishment of a Flood Early Warning System for Lower Drim/Drin River" was organised in Tirana, September 2012. One of the identified needs was to prepare a detailed specification for a short-list of priority meteorological and hydrometric Stations in order to provide the starting point of a fully functional basin wide Flood Early Warning System (FEWS), ultimately incorporating the critical links of **data acquisition, data communication, flood forecast, decision support, notification, coordination and action**.

An experienced international HydroInformatics Consultant was appointed to prepare specifications for hydrometeorological equipment for the Flood Early Warning System (FEWS) for Albania, Kosovo, Macedonia and Montenegro, and assess data acquisition systems in each National Hydrometeorological Service in regard to receiving, storing and analysing incoming online data from stations. The outcome of this work was a series of five Part 2 separate Procurement Specifications containing the detailed technical requirements of a finalised short-list of meteorological and hydrometric Stations that will form the initial flood early warning system across four countries. An additional 6th document covers the outline proposals for the development of a regional web based flood early warning and decision support system. These Reports are primarily intended for Procurement Contract Bidders and provide the necessary specifications, installation needs and Bills of Quantities sufficient for the procurement process.

This Part 1 Report summarises the field-work and observations made by the Consultant during June-July 2013, with a strong emphasis on the practical needs of a basic flood early warning system. This includes not only the rationale and selection of the priority Stations, but also the priorities for improving the discharge measurement capabilities of the hydrometric (water level) network, and the need to develop cooperative capacity in transboundary hydrological modelling and flood forecasting. The future needs of the Drim/Drin-Buna/Bojana FEWS to contribute meaningfully to the European Flood Awareness System (EFAS) is also considered. The Part 1 Report is intended primarily for future discussion between GIZ and the hydrometeorological staff of the individual national hydrometeorological Services (NHMSs). In our view the realistic timescale for a fully reliable and sophisticated regional network is likely to be 10 years or more, but it is also expected that a basic flood warning network and rudimentary early warning procedures might be available in 2-3 years as a result of this project.

Part 2 - Rationale for Selected Stations

This Section gives brief summary of the main issues concerning flood propagation and control in the river basin. The Drim/Drin-Buna/Bojana (DDBB) river basin covers an area of approximately 19,700 km², and is one of the major transboundary river basins in south-east Europe, falling across five international borders, with a wide range of climatic conditions, topographic variation, river types and control structures. Common to all sub-basins is the continental climate regime which is characterised by high levels of precipitation during winter months, typically stored for 2-3 months as snowpack, followed by intense and rapid snowmelt during April to June giving rise to large fluvial discharges, but high autumn rainfalls are also an important cause of flooding.

Of central importance to the regulation of floods in the river basin, (and the monitoring requirements set out in this study) are the eight dams and reservoirs located across the four principal countries, and the lakes of Prespa, Ohrid and Shkodra. In combination these waterbodies form a vast volume of storage that has significant potential to both absorb and regulate major floods, but depending on the inflows and operation of the reservoirs, also represent a major downstream risk due to uncontrolled releases.

Obviously the placement of flood early warning Stations ideally should be representative of these main drivers BUT at the most practical level there are also critical issues of access, security and maintenance that are equally important to the suitability of particular Stations. These criteria are explained under Sections 2.3 to 2.7 (Macedonia, Kosovo, Albania and Montenegro). The precise specifications for each Station are covered in the Part 2 procurement documents.

The assessment is considered for each country in two phases, a priority procurement phase which GIZ proposes to fund out of its 2013/14 budget, and longer term, there are additional Stations identified in the review process that are NOT part of the current procurement but which are particularly important for site specific reasons. Funding should be sought for these additional Stations.

Inspection of Tables 2-1 to 2-8, and Figures 2-26 and 2-27 show that at full deployment, (including Stations identified as a second phase priority) there would be 37 meteorological stations and 39 hydrometric stations contributing to the Drim/Drin-Buna/Bojana Flood Early Warning System. In our view this is a sufficiently dense network to provide adequate advance warning of potential major floods at the river basin scale, and there is also adequate provision for Stations placed at critical locations to be able to monitor and calibrate the passage of flood waves in real-time in the trans-boundary context. Further into future, the current proposals also facilitate the potential to develop simplified localised precipitation-runoff and flood forecasting models by combing data from meteorological and hydrometric Stations located in the same catchments.

There remain some obvious gaps in the network density or altitude coverage that may require some consideration and reinforcement in the longer-term. As with many regional networks, high altitude deployment for snowpack measurement is relatively poor. For example, in the current proposals there are only five out 37 meteorological Stations sited above 1000m, but these higher altitudes are critical with respect to the prevailing climatic regime, whereby significant flood risk arises in the late winter/spring months due to snowmelt. The second unresolved issue is the gaps in spatial coverage, particularly for the meteorological network. Generally as Figures 2-26 and 2-27 show the spatial coverage and equidistant distribution is actually good but there remain some minor gaps that should be covered longer-term.

Part 3 - Operational Priorities and Future Needs

Very significant technical and co-operational challenges lie ahead to create an effective and sustainable regional Flood Early Warning System. The installation of new data sensors is only the first link in a long and complex flood management chain. Such a detailed level of regional cooperation has not in fact been attempted before in any form of river basin management in the Balkan area.

All of the engaged National Hydrometeorological Services (NHMSs) are operating under difficult financial, technical and staff capacity limitations, and their outputs and competencies are significantly below what would be expected of acceptable international standards, particularly with regard to data processing and distribution. A Hydrometeorological Yearbook has not been produced by any of the NHMS since pre-2000 with the commendable exception of Macedonia in 2006. Much of the hydrometric data recorded by the NHMSs is not fully processed i.e. into useable discharge information, nor is it being stored in appropriately accessible formats.

These issues are symptomatic of NHMSs that are not delivering on their minimum functions, and which require substantial operational improvement. In common, all of the NHMSs are not receiving the appropriate level of financial support from central Government.

Of particular concern is that none of the NHMSs have dedicated permanent staff to maintain and supervise the monitoring Stations with the occasional exception of the manned climate Stations. In spite of modern technological advances, all monitoring Stations, especially hydrometric Stations, require frequent (i.e. at least monthly) visits to check Stations, clean stilling wells, download data, and clean, service and calibrate sensors. This level of maintenance is rarely seen in the DDBB countries.

The national hydrometeorological monitoring networks must therefore be regarded by central Government as essential critical infrastructure, and properly funded. This message has been conveyed to all Balkan Agencies and Ministries with environmental responsibilities by donors and consultants on countless occasions. It is repeated again.

A massive change in NHMS 'mind-set', staff effort and financial allocation towards station calibration and timely processing of discharge data is required in every NHMS. This approach to data excellence and a focus on the priority 'raison d'être' of an NHMS (i.e. to continuously **collect, process and distribute data**) has been lost since 1990).

Without this re-established focus a Flood Early Warning System will never succeed because the emphasis on data continuity, accuracy and reliability is absent. These three elements are even more critical for a real-time flood early warning service. Many professional hydrologists would argue that it is not practical or realistic to bring any of the DDBB NHMSs into a potentially complex and high profile regional flood warning system unless its technical competence, financial resources and operational effectiveness are at a high level.

In spite of these undoubted difficulties and challenges, the counter-argument can be that inter-Agency cooperation in the development and operation of a regional Flood Early Warning System supported by a major donor may be the necessary catalyst that will drive necessary improvements in funding, technical competence and operational sustainability. The commitment and expertise of many of the individual experts in the DDBB NHMSs is unquestioned. The failings are in management and funding generally.

GIZ proposes, and the Consultant is fully supportive of, a Memorandum of Understanding between GIZ and each of the National Hydrometeorological Services (NHMSs) for various duties and obligations arising from engagement in the DDBB Flood Early Warning System.

It is evident from recent visits to each of the NHMSs that they share many of the same practical and operational problems. There are skills and expertise of certain experts in the NHMSs that would be beneficial to the other professionals. A priority **recommendation** would be to formulate a Technical Working Group consisting of all DDBB countries, composed of not only NHMS Departmental Heads, but more importantly the hydrologists, meteorologists and data engineers who will have to day to day engagement with the national networks and the Flood Early Warning System. Long-term the Technical Working Group itself would need to be supported by a small Secretariat with overview and coordination responsibilities, but this may take some years to evolve and to establish funding.

To date, all of the NHMS in the DDBB system have demonstrated generally poor levels of commitment to Station upkeep. In some NHMSs, some Stations have been neglected for months, if not years, and irreplaceable data from major events has been lost. Maintaining monitoring Stations at 90%+ reliability is a challenging and never-ending task. It requires trained and committed staff working to a formal maintenance programme, properly supported with adequate staff, equipment and vehicles. Environmental networks do not maintain themselves. For this reason the proposed MoU stipulates a specific budget line for this purpose.

Typically we would recommend that within international best practice every monitoring Station should be visited and inspected at least once every three months. It is a **recommendation** that the Station maintenance reporting is therefore also submitted at 3 monthly intervals by the member countries.

For hazard warning, evacuation, floodplain mapping and flood damage costing purposes, water level is actually more relevant than the discharge. Therefore a hydrometric Station used only for water level still has some value in the flood forecasting arena. However, ignoring the capability to compute discharge from this same Station is a significant waste of financial and technical input, because the lost 'added value' of the data invariably outweighs the cost of obtaining it in the long-term. It is a significant problem therefore that all of the NHMSs are significantly under-performing with respect to international best practice in terms of carrying out current meterings and processing level data to discharge. This is undoubtedly one of the most challenging tasks for any NHMS, but an up to date discharge database is a clear indicator of a properly functioning NHMS, and a significant commitment to increased current metering and data processing systems is urgently required.

It is **recommendation** that GIZ support a review into the effectiveness and affordability of various packages on the market to identify a hydrological data analysis/reporting single package that could be commonly rolled out between all NHMS to assist with hydrological data management, storage and Yearbook formulation. This could be made part of the regional IT procurement contract that is part of this project.

A significant issue for the DDBB Technical Working Group will be how to effectively process and quality control raw data transmitted from the early warning sites in real-time. This applies equally to meteorological as well as hydrometric sites. In a flood emergency, it will always be necessary for the NHMS to man a control room and have experienced professionals on hand who have good knowledge of the characteristics of the catchments and rivers to make rapidly informed judgements about potential data errors.

Although most of the historical hydrological data are available now only as Mean Gauged Daily Flow, these data contain lessons of immense importance with regard to general catchment hydrometeorological behaviour, antecedent conditions, and precipitation-runoff relationships, all of which are critical elements in flood forecasting. It is a **recommendation** that the individual NHMSs should digitise (if not already done) the historic flood events from 1950 to 1990 to develop a library of 'reference floods' incorporating the full hydrograph. Daily mean flow will be sufficient for this purpose. Most important of all, the annual maxima of all floods from 1950 – 190 should be assessed statistically to determine the annual probabilities of a range of flood discharges. This is an essential first step in the development of an effective flood forecasting system.

It is foreseeable that the DDBB Flood Early Warning System will require the development or use of unified data systems, maps etc., and most probably through shared Geographic Information System (GIS) data. The EU Member States and the European Commission have jointly developed a common strategy for supporting the implementation of the Water Framework Directive, known as the Common Implementation Strategy (CIS). The main aim of this strategy is to allow a coherent and harmonious implementation of this Directive by using common standards, terms and procedures across all components of the WFD. The Floods Directive (2007/60/EC) is a daughter directive, and the development of Flood Management Plans (of which flood warning is an intrinsic part) are expected to conform to the general data standards of the Water Framework Directive. It is **recommendation** that all of the NHMSs become familiar with and adopt the data conventions and standards set out in the Water Framework Directive Common Implementation Strategy (CIS), especially Documents 9 and 22.

With regard to regional flood management planning and flood warning systems, a most important early objective for all the NHMSs is to implement a standard system for the identification and coding of national waterbodies. To date none of the DDBB NHMSs have adopted the European standard, which is an urgent task. The European Commission has agreed that the European coding standard for all hydrological features will be a modified version of the Pfafstetter system. It is a **recommendation** that the four NHMSs should coordinate their river basin and river body numbering systems to be in line with WFD and WISE requirements. This will achieve consistency for flood monitoring and reporting across the river basin and would have to be carried out in any case as and when a transboundary River Basin Management Plan is developed for the Drim/Drin.

It is also a recognised problem that the four DDBB countries are using different projections and datums for their mapping systems. Clearly a regional network should use a common reference system for both spatial location (X,Y), and vertical elevation (Z). The agreed EU standard for geodetic referencing is the European Terrestrial Reference System 89 (ETRS89) which uses a wide network of highly accurate geodetic GPS stations, the EUREF Permanent Network. It is **recommendation** that the four NHMSs should cooperate and collaborate with respect to the positioning and elevation of all the hydrometeorological Stations of the DDBB system to achieve a common reference system for all these Stations using the EU standard reference systems.

Part 4 - Early Considerations for a Unified Flood Forecasting System

Currently none of the four NHMSs operate an effective fluvial flood early forecasting system at national level. There are of course reasonably effective meteorological early warning systems in Macedonia and Montenegro, but this does not extend to a monitoring and real-time reporting of fluvial conditions in response to meteorological inputs. There are no hydrological models used for flood forecasting in Macedonia, Montenegro or Kosovo. Albania has little practical experience of operating the Flood-PROOFS model that is installed within its DEWETRA early warning system.

It is the **recommendation** of this Report that application of highly sophisticated flood forecasting models such as Flood-PROOFS and LISFLOOD are probably not appropriate in the early years of the DDBB Flood Early Warning System (FEWS). During this time it is more practically useful for the staff to focus on basic (rough) forecasting methods and developing sound hydrometeorological expertise of their sub-basins rather than being distracted with expensive and complex computer models that may frequently deliver outputs that are wrong or misleading due to unreliable or incomplete data.

Irrespective of the individual national emergency response plans, it is still necessary for the four NHMSs to agree and coordinate the use of simple and effective transboundary early warning protocols. International best practice has shown that it is useful to communicate risk to the general public with simple web based systems and colour coded messages. The most logical and technically efficient way to operate such a system is via a 'regionally based' data server and web site rather than on a 1 to one basis between each NHMS which is informationally inefficient and complex. It is a **recommendation** that the NHMSs coordinate to agree that at the river basin scale, a consistent set of flood alert status levels, messages and colours are used with the same meaning and same degree of quantification in each DDBB country. These can be represented on a simple website updated in real-time. The physical location of such a server is actually irrelevant, since all the data would be accessible to all NHMS in near real-time.

Elementary hydrometeorology should not be overlooked in a Flood Early Warning System. Often, a broad scale regional forecast based on simple assessment can be more effective than a highly complex distributed analysis based on too many sources of information at the micro-scale which can often produce conflicting information.

Continuous monitoring of antecedent conditions is of critical importance for early flood forecasting. Increasing lead time significantly increases the potential to lower the level of damages and loss of life. There is a clear sequence of catchment conditions that can be monitored at a basic level of analysis to provide rough forecasting and flood early warning at decreasing time resolutions: **Winter snowpack, Reservoir State, Daily and Seasonal Norms, Antecedent Rainfall, Antecedent River Level.**

With regard to inter-Agency data exchange, there are already in place internationally agreed data formats. Meteorological data that is internationally compliant with respect to data transfer should comply with the formats and protocols defined by the World Meteorological Organisation (WMO) Information System (WIS). Hydrometric data is now subject to the recently agreed international standard of WaterML2 for hydrological time-series, and the European Flood Alert System (EFAS) is also complying with this standard. The GIZ procurement has sought to ensure that all the data systems and software supplied will comply with these standards. Therefore, when the national Flood Early Warning System data servers are installed, they should theoretically be able to share data with a minimum of reconfiguration.

One of the most significant technical issues to be addressed by the four NHMSs is the standardisation of event probabilities at the river basin scale. In fact, even at the national level, it is necessary to standardise data analysis so that different events (meteorological and hydrological) can be compared statistically on a like for like basis. A Standardised Index is a probabilistically based measure of precipitation (or water level or discharge) deviation from the long-term average that allows direct comparison between Stations or river basins. It allows an analyst to determine the probability of an observed relative to the historical record. Because the index is numerically quantified, it means that statistically consistent flood warning triggers and responses are initiated across all sub-basins irrespective of the actual data values. This is probably the biggest single advantage of the standardised approach.

Advanced forecasting and long lead-times for early warning will most likely require complex hydrological rainfall-runoff modelling AND considerable training of flood forecasting specialists in the DDBB arena. This is perhaps some 5-8 years+ in the future, and will first require the consistent and continuous operation of a very reliable data acquisition network in every country in order to establish suitable datasets and acquire the necessary expertise. This is yet to be proved.

The individual NHMSs may prefer to operate their own preferred advanced forecasting software for national purposes. HOWEVER in the context of the DDBB Flood Early Warning System there is still a need to identify appropriate regional hydrological modelling tools that can be used conjunctively by all the NHMS, either as distributed sub-models or as a single 'mega-model'. Three models that have particular relevance to the Drim/Drin-Buna/Bojana basin are the HEC-HMS, Flood-PROOFS and LISFLOOD rainfall-runoff models. They all have particular merits and disadvantages.

The Meon Report recommended further collaboration with the European Flood Awareness System (EFAS) in order to transmit data from the DDBB Flood Early Warning System, and in exchange, receive medium-range flood forecasts for Europe, via the Dissemination Centres, with a forecast lead-time between 3 to 15 days. Membership of EFAS is of course a desirable target in the medium term. However, the Meon Report and this Report have concluded that the capacities and resources of the four national NHMSs are unlikely to meet acceptable criteria for data reliability and quality for some years. The priority must be for each NHMS to demonstrate that **nationally** it can maintain a first class data network with minimum outage time and high levels of data quality, and **regionally** that it has reliable data archive and communication systems which it is prepared to share fully and transparently before becoming part of the EFAS network.

1. CONTEXT AND TERMS OF REFERENCE

1.1 Project Context

1.1.1 Climate Change Adaptation in Western Balkans

The programme 'Climate Change Adaptation in Western Balkans' is a joint cooperation between the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and relevant government ministries in Macedonia, Albania, Kosovo, Montenegro and Serbia.

On behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), GIZ advises and supports the governments of the involved countries in the development and implementation of adaptation strategies in regards to climate change. Amongst other activities, this project aims to reduce the risks and impacts of flood and drought as well as strengthening regional cooperation in the field of integrated water resources management.

Riparian countries in the Drim/Drin river basin signed a Memorandum of Understanding in 2011, creating a way forward for establishing an international river basin organisation.

1.1.2 Establishment of a Flood Early Warning System

In the framework of the project a Regional Round Table workshop on the "Establishment of a Flood Early Warning System for Lower Drim/Drin River" was organised in Tirana, September 2012.

One of the outcomes of this workshop was the necessity to establish an expert team with the mission to visit all four providers of hydro-meteorological information in Albania, Macedonia, Kosovo and Montenegro, and to estimate their needs in developing national and regional Flood Early Warning Systems (FEWS) as well as steps to be taken to be included in the European Flood Awareness System (EFAS).

The expert team consisted of focal points from the national Hydrometeorological Services (NHMSs) of four countries in the Drim/Drin-Buna basin – Macedonia, Kosovo, Albania and Montenegro as well as 2 international consultants. The outcome of this investigation was a comprehensive overview Report [1]

The report was presented at a regional workshop held in Tirana, February 2013. The team of consultants presented in the Final Report the state of each country in regard to establishing a FEWS (gaps and needs analysis).

Furthermore the Report suggested provisional locations for hydrometeorological stations in the Drim/Drin-Buna/Bojana catchment to be included in the FEWS.

In the next phase it was suggested that a short-list of specific stations needed to be further prioritised and specifications for the procurement process prepared. These stations are intended to communicate real-time information to the respective national Hydrometeorological Services through robust and user friendly web-enabled software interfaces that will inform not only regional flood early warning requirements, but local ones as well.

1.2 Terms of Reference

1.2.1 Scope of Work

This study has been carried out by an Individual Consultant (www.waterconsultant.com) appointed directly by GIZ. According to the stated Terms of Reference, the expert was to carry out the following tasks:

1. Prepare specifications for hydrometeorological equipment for the Early Warning System for Albania, Kosovo, Macedonia and Montenegro.

2. This will be done jointly with experts from the respective State Hydrometeorological Services. The new stations (hydrological and meteorological) need to be compatible to existing equipment in-country and also existing IT systems. At the same time regional data sharing must be possible in near to real-time between the countries.

3. Assessment of IT systems in each Hydrometeorological Service in regard to receiving, storing and analysing incoming online data from stations. If current IT systems are not capable the missing equipment needs to be included in the procurement list. Also IT specifications for the regional operational centre (Albania NHMS) should be assessed.

4. Collection of information on existing cross-sections and rating curves

5. Collection of site specific information including photo documentation, GPS coordinates and development of rough Bills of Quantities and first sketches for sites where construction measures are required.

1.2.2 The Reporting Process

This study is reported in 2 parts:

Part 1 – Selected Stations + Operational Priorities and Future Needs

This Report summarises the field-work and observations made by the Consultant during June-July 2013, with a strong emphasis on the practical needs of a basic flood early warning system. This includes not only the rationale and selection of the priority Stations, but also the priorities for improving the discharge measurement capabilities of the hydrometric (water level) network, and the need to develop cooperative capacity in transboundary hydrological modelling and flood forecasting.

[1] Establishment of a Flood Early Warning System in the Drin Basin - Assessment Study for Gaps and Needs in Establishing a DEWS – Final Report, May 2013.

The future needs of the Drim/Drin-Buna/Bojana FEWS to contribute meaningfully to the European Flood Awareness System (EFAS) is also considered.

The Part 1 Report is intended primarily for consideration by GIZ and the hydrometeorological staff of the individual national hydrometeorological Services (NHMSs).

Part 2 – Equipment Specifications and Preparatory Works – 4 Countries + Regional Centre

Five separate Procurement Specifications contain the detailed technical requirements of a finalised short-list of meteorological and hydrometric Stations that will form the initial flood early warning system across four countries. An additional 6th document covers the specification for the development of a regional web based flood early warning and decision support system.

These Reports are primarily intended for Procurement Contract Bidders and provide the necessary specifications, installation needs and Bills of Quantities sufficient for the procurement process.

Some of the proposed early warning Stations are already functioning as part of the existing national networks, particularly in Montenegro and Albania, but the majority require either upgrading (reinforcement) or complete new installations (rehabilitation). GIZ proposes to promote these improvements through the appointment of specialised instrumentation firms who have expertise in hydrometeorological monitoring and data management.

Since the equipment needs and operational methods are somewhat different in the four recipient countries, GIZ proposes to procure the necessary equipment and expertise through separate contracts specific to each country.

1.3 Previous Gap Analysis Report – Prof. Meon 2013

This follow-on study does not reiterate the general findings of the Meon 2013 Report, which provides useful overviews and gap analysis of the current institutional capacities. The study proposed a large number of meteorological (38) and hydrometric (37) Stations for a comprehensive flood warning network (Level 1 Stations), to be followed later by subsequent L2 and even L3 Stations.

This is perhaps desirable in the very long-term with expert staff and adequate institutional resources and budgets, but in our view is not practical or achievable in the short to medium term (i.e. this procurement and even a 2nd phase 5-8 years hence).

The primary reasons for this are:

i) A limited budget allocated by GIZ for the initial procurement, which we fully endorse.

ii) Currently the resources, budgets and capacities of the individual NHMSs are somewhat inadequate to effectively deliver even national level flood warnings and forecasts, let alone a regional transboundary flood warning system.

iii) The sustainability and maintenance of meteorological and hydrological Stations generally is a key issue, and the four NHMSs have yet to demonstrate that they can maintain selected Stations to an acceptable international standard of reliability.

In all four countries, the commitment to undertaking sufficient current meterings at hydrometric (flow gauging) Stations to sustain adequate rating curves is generally poor, with the possible exception of Montenegro, and consequently, the continuous and correct calculations of discharge (which is a critical element of hydrological modelling and flood forecasting) will not be feasible for some years.

It is NOT therefore desirable to impose new significantly large networks for such an important objective as flood early warning where the NHMSs have not yet proved their ability to maintain such a system.

Reflecting this, GIZ requested additionally that a top priority 'short-list' of essential Stations be extracted from the analysis, so called Level 1-A Stations for immediate consideration. This short-list is repeated in Table 1-1 below, and relate to Figures 9-9 and 9-10 of the Meon Report.

Table 1-1 – Proposed Level 1-A Stations (after Meon)

	Hydrometry		Meteorology	
Country \ Organisation	GIZ	Kesh	GIZ	World Bank
Macedonia	H 1,4 H 1,13 (H 1,11)		M 1,1 M 1,4 M 1,9	
Kosovo	H 2,4		M 2,1 M 2,8 M 2,6	
Montenegro	H 3,5 H 3,7		M 3,3 M 3,5 M 3,9	
Albania	H 4,4 H 4,8 H 4,10 H 4,17	H 4,7 H 4,11 H 4,13	M 4,2 M 4,9	M 4,4 M 4,6 M 4,11 M 4,12 M 4,17 M 4,20

Source: Meon [1] (Table 9.3)

1.4 An Updated Approach – This Report

This Report focuses on the detailed and practical needs of a limited number of individual flood early warning Stations (and the management of the transmitted data) in order to deliver the very early stages of a robust and reliable flood warning network which (for the reasons given previously) is significantly less ambitious and comprehensive than that advocated by Meon et al., but is likely to be more practical and sustainable under current institutional capabilities.

The detailed field investigations carried out in this study have confirmed the suitability of many of the Stations identified in Table 1-1, but there are some important modifications which are explained in Section 2.

We have also altered the numbering system of individual Stations for procurement purposes because there are a significant number of alternative Stations not identified in Table 1-1 (therefore new Stations under this system may cause confusion) and also we have a preference to use the ISO country identifier (MK, AL, ME etc) as a prefix rather than simple numbering for clarity in procurement.

We fully endorse Prof. Meon's comments that:

"In particular, well functioning and robust data systems need to be established to guarantee a smooth and reliable data transmission from the NHMSs to the Drim/Drin Early Warning Centre and reversely. Standardisation of database software, data storage, data quality checks and data transmission filters is considered essential".

Sensor installation, data acquisition and telemetry through to elementary database management are well established procedures for the NHMSs in Macedonia and Montenegro, but not in Albania or Kosovo. The significant new challenge of the Drim/Drin-Buna/Bojana (DDBB) early warning system is that for the first time, reliable and continuous precipitation and water level data will have to be rapidly quality controlled at local level and shared in near to real-time across four national boundaries.

It is therefore very much the case that the data management and information technology components of the procurement (and the reliable and robust functioning thereof) are perhaps equally important in order to demonstrate 'proof of concept' i.e. that a regional transboundary FEWS is actually possible and workable.

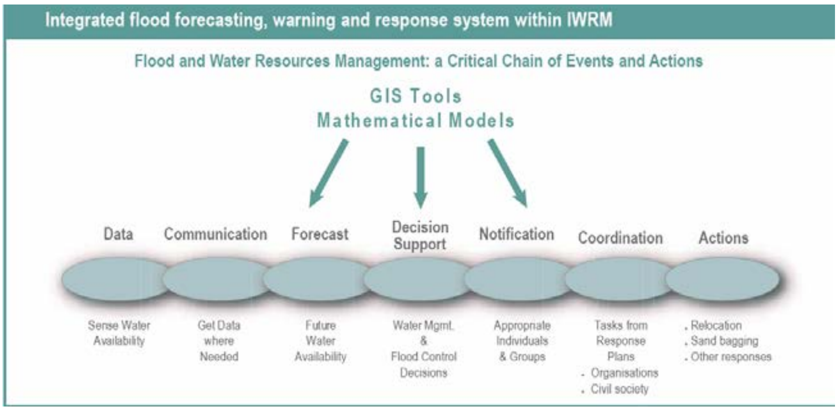
1.5 Integrated flood forecasting, warning and response system within IWRM

According to the UN Guidelines [2], integrated flood management follows a well defined 'results chain'. Any part of the chain not fit for purpose will undermine the effectiveness of the entire system (Figure 1-1).

This Report is primarily concerned with data acquisition (the first link) but this should be assessed within the wider context of flood management generally. Therefore there are also some outline considerations of communication, forecasting and decision support in this Report (links 2, 3 and 4), but it is intended mainly as an overview summary and a consultation document for discussion between the donor (GIZ) and the member States of the Drim/Drin-Buna/Bojana (DDBB) river basin Technical Working Group as to how best to move forward the potentially very demanding and complex needs of a major early warning network in a large river basin.

The realistic timescale for full implementation of the flood management chain is likely to be 10 years or more in our opinion.

Figure 1-1 – UN Model of Integrated Flood Management



[2] Guidelines for Reducing Flood Losses, UN/ISDR 2001

2. RATIONALE FOR SELECTED STATIONS

2.1 The Drim/Drin-Buna/Bojana River Basin

The Drim/Drin-Buna/Bojana (DDBB) river basin covers an area of approximately 19,700 km², and is one of the major transboundary river basins in south-east Europe, falling across five international borders (see Figure 2-23). The basin comprises three main sub-basins: the Crn Drim (Black Drin) which rises to the south in the Prespa and Ohrid lakes area of Greece, Macedonia and Albania; this confluences at Kukës in central Albania with the Drini i Bardhë (White Drin) which rises from the western uplands and mountain ranges of Kosovo, and further downstream, the Drim/Drin River then has a confluence at Lake Shkodra/Skadar with the Moraça River which rises in the western uplands and mountains of Montenegro.

Common to all sub-basins is the continental climate regime which is characterised by high levels of precipitation during winter months, typically stored for 2-3 months as snowpack, followed by intense and rapid snowmelt during April to June giving rise to large fluvial discharges.

However, the three largest floods on record (January 1962, January 2010 and December 2010) all occurred in the middle of winter, and resulted from exceptionally heavy and prolonged rainfall in the preceding month(s) rather than snowmelt. The highest rainfall amounts are quite often in the autumn months October to December.

Of central importance to the regulation of floods in the river basin, (and the monitoring requirements set out in this study) are the eight dams and reservoirs located across the four principal countries, and the lakes of Prespa, Ohrid and Shkodra. In combination these waterbodies form a vast volume of storage that has significant potential to both absorb and regulate major floods, but depending on the inflows and operation of the reservoirs, also represent a major downstream risk due to uncontrolled releases.

Obviously the placement of flood early warning Stations ideally should be representative of these main drivers BUT at the most practical level there are also critical issues of access, security and maintenance that are equally important to the suitability of particular Stations. These criteria are explained under Sections 2.3 to 2.7.

Sections 2.3 to 2.7 short-list the core components of the Flood Early Warning System individual to each country with respect to the regional flood warning effectiveness. Stations are further divided by those that are appropriate in the '1st phase' procurement, and those in a nominal 2nd phase[3] that may be equally important in hydrometeorological terms BUT require e.g. significant preparatory works, confirmation of observer reliability, site security or access to land etc before further funds are committed.

[3] GIZ has NOT officially confirmed that future funding will be available at this time

2.2 Key Drivers for Flood Potential and Control in the River Basin

Due to time constraints, this study has not examined the detailed hydrometeorology of the river basin, which would require an in-depth review of historical data and catchment characteristics.

There IS available from most of the four countries accurate detailed daily flow and precipitation data for the period October 1962 to January 1963 (since the Yugoslav era operated a first class hydrometric system). Until December 2010, January 1963 had the largest flow on record in the river basin. Since that time of course all the eight major dams have been built but there are still significant lessons within these data sets to help understand flood development and propagation of major floods within the various sub-basins, and it is a **recommendation** that the historical data sets be digitised and examined by all the national hydrologists as an aid to developing a good understanding of catchment flood response and future national and regional flood risks.

It may be useful however to provide a very brief summary of the principal catchment issues with respect to flood potential, propagation and attenuation.

2.2.1 Macedonia

The Macedonian component of the DDBB river basin (4200 km²) is dominated in the south by the major lakes of Prespa (259 km²) and Ohrid (358 km²), which will have a major attenuating effect on local floods (Figure 2-1). The lakes are surrounded by moderately high mountains with relatively minor watercourses but with steep channel gradients and short travel times, hence the potential for localised flash flooding.

Figure 2-1 – Southern Limit of Lake Ohrid

The meteorological potential for flood generation is the lowest of the four sub-basins, with long-term annual rainfall in the southern parts of Macedonia typically being 700-800 mm/year, much less than in the other sub-basins. Accumulated snowpack might thaw rapidly however depending on air mass temperatures, with disproportionate flood peaks.

Lake Prespa contributes inflow to Lake Ohrid by means of major uncontrolled karstic springs, which provides further attenuation in the system. Currently the Lake Prespa level is several metres below historical levels.

Due to elevated groundwater levels and extensive low lying floodplains, groundwater flooding is a persistent problem on the northern shores around Lake Ohrid.

Outflow from Lake Ohrid into the Crm Drim is partially controlled by stop-logs at the lake boundary (see Figure 2-2), and fully controlled by radial gates located 800m downstream of the lake edge in the centre of Struga. Closure (or opening) of the gates could have a major influence on downstream flood generation, but this is very dependent on the starting level of Lake Ohrid, which is generally kept relatively high and with only a modest amount of freeboard i.e. typically less than 1.0m.

The extensive floodplains on Lake Ohrid's northern shore with the limited channel capacity at Ložani give further potential for natural flood attenuation (see Figure 2-3).

Figure 2-2 – Partial Control of Lake Ohrid Outflow at Struga

As an example of the significant attenuation potential of Lake Ohrid a continuous inflow of 112 m³/s (highest recorded outflow) would take 18 days to raise the level by 0.5m if the gates were fully closed.

Figure 2-3 – Crn Drim at Ložani

The long-term annual average flow downstream of Lake Ohrid at Station Ložani is approximately 23 m³/s , with a flood peak of 112 m³/s measured in November 1985.

12 km downstream of Lake Ohrid the Drim passes into the Globocica Dam, but this is a relatively narrow incised waterbody and attenuation effects on the flood-wave will be minimal.

The Drim river basin is dominated in the north of Macedonia by the Radika river system that collects numerous minor steep tributaries over a main length of 50 km, and drains southward directly into the Debar Reservoir.

Meteorological potential for flood risk is somewhat higher in the north part of the sub-basin than the south; annual precipitation is in the order of 1000 mm+, and a significant component of this will reside as snowpack during winter months. The long-term annual average flow at Station Boskov Most at the downstream end of the Radika is approximately 18 m³/s, but the highest flood peak is estimated at 262 m³/s, more than 2x the magnitude of the flood peak from the southern lakes region. Consequently the Radika River plays an important part in local flood risk.

Figure 2-4 – River Radika at Station Boskov Most

To some extent flood peaks may/can be absorbed by the Debar Reservoir (surface area 12 km², 520 Mm³) but in common with the majority of the Dams in the DDBB basin, reservoir levels tend to be kept near maximum at all times by ELEM, the operating Authority, in order to maximise hydropower potential and therefore attenuation impacts may be limited.

Of greater significance to regional flood risk is perhaps the impact of unscheduled releases from Debar Dam, which lies immediately upstream of Albania. The flood-wave from such a release will travel very quickly down the Drin i Zi towards Kukës and the Fierzë Dam. Close communication between ELEM, KESH and the respective NHMSs is therefore essential.

To date the largest flood in the Macedonian sub-basin derives from the November 1962 – February 1963 event, although November 1985 was also significant.

Figure 2-5 – Debar Dam and Station Debar

2.2.2 Upstream Albania

The 85 km reach of the Crn Drim/Drini i Zi between the Debar Dam in Macedonia and the confluence of the Drim/Drin with the Drini i Bardhë (White Drin) at Kukës in Albania is characterised by a narrow mountainous catchment, typically 30-40 km in width, with numerous steep tributaries rising from elevations of 2000m approximately and discharging directly into the Drin (see Figure 2-6).

Meteorological potential for flooding is characterised by annual precipitation values of approximately 950 mm/year at elevations of 600 mASL, increasing to > 1000 mm/year at Station Fushë Lurë (elevation 1048 m).

Because of this efficient catchment configuration, flood peak potential increases significantly inside the Albanian upstream sub-basin. For example, the long-term annual average flow at Station Kovashica is 75 m³/s. In the worst case, the Macedonia sub-basin might contribute 30-40% approximately of the peak at Station Kovashica assuming no artificial controls. The 1962 flood peak was 925 m³/s at this location.

Figure 2-6 – Drini i Zi between Kovashica and Stravica

Because of the confined river channel and limited floodplain, flood-waves can be expected to pass fairly rapidly down the reach between Debar and Kukës. Assuming a wave celerity of say 1.5 m/s, a flood peak would take approximately only 16 hours between Debar and Kukës.

2.2.3 Kosovo

The Kosovo sub-basin of the DDBB basin is dominated by the Drini i Bardhë (White Drin) and the flood potential of this major river is often under-estimated. For example, the contributing area of the Drin within Kosovo is 4630 km², and therefore exceeds that of the Macedonia sub-basin.

Furthermore, apart from the offline Radoniqi Reservoir at Gjakova (113 Mm³), there are no artificial controls on flood peaks.

Meteorological potential for flooding is driven principally by high autumn rainfalls (300 mm+ Oct-Dec), and high levels of snowpack accumulation (Dec-Mar) in the western mountains ranges above Gjakova, Junik and Pejë. Junik in the western foothills receives 1400 mm/yr precipitation, Prizren in the south 780 mm/yr. Flash flooding potential is high in the towns at the foot of the ranges (Deçan, Gjakova, Pejë).

The uniformly dendritic character of the Drin i Bardhë system over a large area means that storm movement from any direction may help to lessen flood peak accumulation through the variation in timing across different catchments.

Between Istok and Prizren, the Drin i Bardhë has a meandering course through the extensive Dukagjini alluvial floodplains, which will significantly attenuate flood flows if antecedent conditions are drier than average. Equally, prolonged rainfall especially in autumn months may saturate the Dukagjini floodplains and create significant flood potential in downstream Albania, as happened in 2010.

Figure 2-7 – Drin i Bardhë near Rahovec

Station Kepuzi (destroyed/discontinued) in the mid-point of the Kosovo sub-basin has a long-term annual average discharge of 25 m³/s. The outlet of the Kosovo sub-basin near the border with Albania is monitored at Station Gjonaj, which has a long-term annual average discharge of 49 m³/s.

Proportional to the catchment area this is a relatively low flow rate, but the flood peak potential is disproportionately high.

The highest recorded flood dates from November 1979 at 830 m³/s. (2010 flood data may have equalled or exceeded this but no data are available). This is closely comparable in terms of proportional catchment area to the 925 m³/s peak flow recorded for Station Kovashica in upstream Albania.

Because of the large catchment area and the lack of artificial controls in the Drini i Bardhë catchment, the Kosovo sub-basin has potential to create significant flood-risk in downstream Albania, and relative to other sub-basins is very deficient in its monitoring capacity and flood warning capability.

2.2.4 Downstream Albania (the high Dam cascade)

The White and Black Drin rivers separately discharge to the head of the Fierzë reservoir at Kukës, collectively now the Drin River. This location is therefore highly significant in two regards:

i) Kukës is a key monitoring point for the timing of the flood peaks from the two major contributing sub-basins (Drin i Bardhë and Crn Drim/Drini i Zi).

Simultaneous flood-peaks on these two rivers are likely to create very high flood potential in downstream Albania and/or Lake Skadar region, depending on the operation of the Albanian high Dams. Separation of peaks may result in a lower combined downstream peak but a much more prolonged duration flood. Both scenarios are of importance.

ii) Monitoring of the Fierzë Reservoir water level at its upstream end at Kukës will enable modelling of the flood wave through the Fierzë Reservoir.

The Fierzë Reservoir has a river length of 70 km approximately, and the time taken for the flood wave to pass through the reservoir to the Dam (perhaps 24-36 hours) will be very dependant on the hydraulic gradient along the reservoir.

Since there will be only two monitoring points upstream and downstream, but the intermediate hydrodynamics may be complex (including sudden drawdown at the Dam for example), Fierzë will probably require hydraulic modelling in future years, and monitoring Stations at each end will provide the necessary calibration points.

From Kukës onwards, the Drin system is completely dominated by the characteristics and operation of the three major Dams, Fierzë (73 km²), Koman (12 km²) and Vau i Dejës (25 km²) which are all operated by KESH to generate electricity from hydropower.

Of these Fierzë clearly has the greatest potential to control or to create downstream flood risk depending on its operation.

Currently the individual and sequential operation of these Dams in order to manage flood risk is virtually non-existent. It is also astonishing that these major high dams are operated with minimal automated telemetry.

Figure 2-8 – Fierzë Dam at Fierzë

Currently there is no automatic recording of water level or precipitation at any of the three Dams available to third parties, for example the NHMS. Consequently the impacts of floods from upstream, or indeed the consequences of unscheduled releases, cannot be assessed.

As the flood events of January and December 2010 demonstrated, the three Dams in isolation and combination have the potential to create (as well as absorb) significant flood risk from upstream.

It is alleged that in 2010, the very severe natural regional flood was made worse by the fact that the reservoirs were being held at their normal very high level to optimise hydropower output and therefore had no capacity to absorb flood inputs from upstream.

With a sudden rise in levels at Fierzë, unscheduled releases had to be made in order to protect the integrity of the Dam. Since the Dams are all in close sequence, a major release from Fierzë cannot be contained by the two downstream Dams, and therefore releases had to be made from all the Dams simultaneously, causing significant flooding and evacuation of parts of the Shkodra area.

Figure 2-9 – River Drin between Koman and Vau i Dejës

It is clear that with a fully functioning regional Flood Early Warning System, such a chaotic situation could and should be avoided. With perhaps upto 48 hours notice the reservoirs can be drawn down by at least 1-2 m, thereby providing significant absorption of flood peaks. The incoming flood volumes are likely to restore the hydropower potential within the same event.

In the reach between Kukës and Vau i Dejës there is significant additional meteorological potential for flood generation. Several large tributaries (especially the Valbonë) drain to the Drin from the Albanian high Alps between Bajram Curri and Theth in northern Albania, where many peaks rise above 2000 m.

Precipitation depths in this region are some of the highest in the Drin Basin; Station Bajram Curri records 1800 mm/yr, Station Theth 2880 mm/yr. Autumn rainfall and snowpack accumulation December to March is therefore considerable with all its associated risks.

Flood peaks from these tributaries can be enormous. For example Station Gri on the Valbonë (long-term average annual flow 33 m³/s) drains a catchment similar in area to that of Station Boskov Most (Macedonia) but delivered a peak of 1630 m³/s in January 1963, compared to the Boskov Most peak of 262 m³/s.

The Drin is confined in narrow steep sided mountain valleys between Fierzë to Vau i Dejës, and therefore the flood wave towards the downstream Dams will be relatively fast.

Figure 2-10 – Albanian High Alps near Theth

The high Dams in Albania have significant potential to minimise regional flooding and the disruption and damage to many thousands if properly managed, and a key focus of the Drim/Drin-Buna/Bojana Flood Early Warning System must be to improve the quality and timeliness of flood forecasting data to the operating Authorities in Macedonia (ELEM) and in Albania (KESH) so that in times of flood emergency the Dams can be operated properly to safeguard life and property, as is required best practice with Dam operators all over the world.

Production of electricity cannot be regarded as the sole and primary function of these Dams. The flood damage cost caused in December 2010 (€ 18 Million estimated) probably far outweighed the opportunity cost of the electricity generated by maintaining the reservoirs at an excessively high level during one of the worst regional floods of the last 50 years.

2.2.5 Montenegro

The contributing area of the Montenegro sub-basin to the Drin system is coincidentally identical to that of Kosovo at 4630 km².

Although not as high as the Albanian Alps, mountain peaks in the north part of the sub-basin frequently exceed 1500m, and precipitation in these areas is also very high (Station Dragovica Polje 1930 mm/yr). Precipitation in Montenegro is generally the highest of the four sub-basins. Station Podgorica at an elevation of only 50 mASL records 1660 mm/yr, and all other long-term inland Stations approach or exceed 2000 mm/yr, more than double the majority of Stations in Macedonia for example.

Figure 2-11 – Station Dragovica Polje

The principal river systems comprise the Morača River draining the northern mountain ranges, and the Zeta River draining the western karst dominated highlands from Nikšić eastwards.

The Morača in particular is often incised into narrow gorges for much of its length, and therefore has a high wave speed and short transit times until it reaches Podgorica, downstream of which larger alluvial floodplains are encountered. The long-term annual average flow is 159 m³/s, but the peak has reached 2073 m³/s in November 1979.

On the River Zeta at Station Danilovgrad, the long-term average annual flow is 78 m³/s, with a historical maximum of 577 m³/s (December 2000).

Figure 2-12 – River Morača upstream of Podgorica

2.2.6 *Lake Skadar/Shkodra Region*

At its downstream limit the Montenegro sub-basin is dominated by the 370-530 km² Lake Shkodra/Skadar, shared between Albania and Montenegro. Technically the Montenegro sub-basin is only part of the Drim/Drin system in so far as the outlet of Lake Skadar via the Buna River then confluences 5 km downstream with the Drin, the combined rivers becoming the Buna/Bojana system (see Figure 2-13).

Figure 2-13 – Monitoring Stations at Lake Shkodra

Source: Google Earth™

The Shkodra/Buna/Drin system is monitored by the Albania NHMS at four locations at the confluence. Station Shirokë monitors the lake level; the other three Stations should have discharge evaluation capability (see Figure 2-13).

The Montenegro sub-basin has a major influence on the levels of Lake Skadar, which in turn affects the potential for significant flooding around the shores of the lake both in Albania and Montenegro. The township of Golubovci (Montenegro) on the northern shore was severely affected, as was the city of Shkodra (Albania).

Shkodra also lies on the right bank of the River Kiri, and although Station Mes has a long-term average flow of only 15 m³/s, its historical fllod peak is 1150 m³/s. It descends over 2000 m in less than 45 km from the high Alps, therefore the potential for major flash flooding is considerable.

The hydrodynamics of flooding around Lake Skadar/Shkodra are complex, but will basically involve one or a combination of the following:

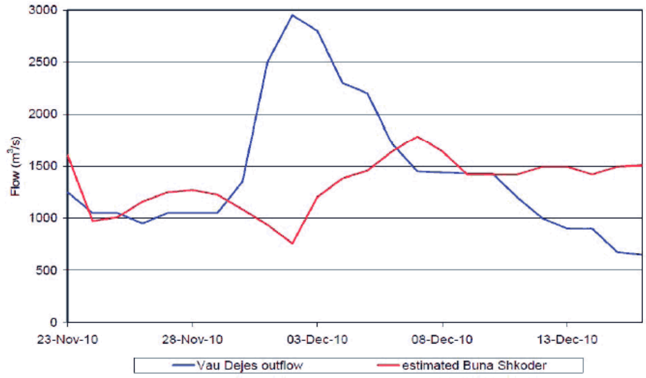
i) High discharge from the Montenegro sub-basin elevating lake levels directly (River Moraça).

ii) At high level in the lake, a backwater effect can be created in the incoming River Moraça, which can create localised flooding upstream.

iii) High natural discharge or major releases in the Drin downstream of the Vau i Dejës Dam, which in turn creates a high tailwater in the Buna/Bojana River downstream of the Lake Shkodra outlet, thereby reducing the hydraulic gradient of Lake Shkodra and therefore elevating levels still further

iv) Fluvial flooding created by extreme discharges in the Kiri River flooding the right bank.

Figure 2-14 – Hydraulic Interactions between River Drin and Lake Skadar 2010



Source: Mott MacDonald 2012

Figure 2-15 – Flooding of Shkodra 2010

http://www.bbc.co.uk/news/world-europe-11931554

Downstream of the Buna/Drin confluence, the Buna/Bojana meanders through flat coastal plains for 42 km to the sea. There is of course significant potential for major fluvial flooding in this region, hence the Buna/Bojana carries major levees or dikes on the Albanian (left) bank.

Because of the slack channel gradients of the Buna/Bojana downstream of Shkodra, backwater effects may have a significant influence on the outlet of Lake Shkodra.

The key monitoring Stations in this locality are Station Dajç on the Albanian side and Station Fraskanjel 11 km downstream on the Montenegrin side. Station Dajç has a long-term average annual discharge of 680 m^3/s. The historical maximum is not recorded, but reached a Stage of 7.15m in December 2010. Discharge data for Station Fraskanjel is not available, but the historical maximum Stage is also given as 4th December 2010. Station Fraskanjel marks the limit of the monitoring for the Drim/Drin Flood Early Warning System.

Figure 2-16 – Left-bank Levee at Station Dajç

The following sections now summarise the existing and proposed monitoring Stations that will contribute to the DDBB Flood Early Warning System.

Tables 2-1 through to Table 2-8 summarise the status of all the Stations for each NHMS, and additionally provide a historical maxima summary where available, as well as an assessment of the discharge calculation capability of each Station, defined by the availability of recent current meterings.

Due to the poor operational status of the majority of the hydrometric Stations and the data management capabilities of the four NHMSs in the Drim/Drin-Buna/Bojana river basin in 2010, very regrettably there is very little data available for the January 2010 and December 2010 flood events, which are reportedly the largest encountered since 1963.

A detailed résumé of each Station is not provided in the text below. Only where a Station has particular significance is it discussed further, and this usually applies to Stations that have been selected for this procurement, or discontinued/damaged Stations that are NOT part of this current procurement but still have some particular importance.

In this project there are basically three levels of Station identified for each country:

- Meteorological or Hydrometric Stations that are in an operational state and are therefore already part of the national monitoring network. Due to a lack of current meterings, these Stations may not have had discharge calculations associated with them for many years.

- Meteorological or Hydrometric Stations that are either discontinued or damaged and which will be brought back into operational status as part of this procurement since their absence compromises the effectiveness of the DDBB regional flood early warning system. These are largely consistent with the Level 1-A Stations identified by Meon, but there are some variations due to practical considerations.

- Meteorological or Hydrometric Stations that are discontinued, damaged or proposed. However, the preparatory works (including land status and observer availability) or the rehabilitation requirements are too prolonged for the Station to be included in this procurement. However, several of these Stations are of historical importance or highly relevant to flood early warning, and therefore should be considered for rehabilitation in the near future.

2.3 Priority Stations for Flood Warning in Macedonia

2.3.1 Stations in the 1st Phase Procurement

Meteorological Stations

Refer to Table 2-1 and Figure 2-26. The DDBB Flood Early Warning System is not adequately covered by the current meteorological network. Only two automated meteorological Stations (Ohrid and Resen) are operational, and these cover only the southern part of the basin. There are no Stations above 1000m.

ELEM operates good quality automated meteorological Stations at the Globocica and Debar Dams and collects regular data, but the NHMS does not receive these data in real-time.

Figure 2-17 – Climate Station Debar (ELEM)

Since the ELEM meteorological Stations are located at critical locations within the Macedonia sub-basin, it is a **recommendation** that the NHMS cooperate closely with ELEM in future to obtain and share meteorological data. Meteorological data from upstream high altitude Stations such as Lazaropole, Mavrovo and Štirovica will be of special usefulness to ELEM with respect to operation of the reservoirs and therefore the benefits are mutual.

The DDBB Flood Early Warning System project assumes that the ELEM Stations are a critical and essential part of an effective early warning network.

The GIZ procurement proposal is for four Stations to be reinforced/rehabilitated. Lazaropole and Mavrovo are existing long-term climate Stations operated by the NHMS, but these are not automated. The GIZ project will significantly upgrade these Stations with a range of sensors to establish comprehensive WMO compliant Automatic Weather Stations.

Stations Kuratica and Štirovica were discontinued by the NHMS and ELEM respectively pre-2010. However, Kuratica (1107m) will provide useful data mid-way between Ohrid and the Radika system to the north. Štirovica is essentially a new Station, but located at an old ELEM precipitation gauge. It is the highest Station in the network (1452m) and therefore will provide essential data for snow depth and snow melt.

Stations Štirovica, Lazaropole and Mavrovo all lie within the Radika catchment, and therefore data can be used in future to develop and calibrate a hydrological model of this system for the river gauges at Volkovija and Boskov Most.

Hydrometric Stations

Refer to Table 2-2 and Figure 2-27. With respect to flood warning capability, the Macedonia sub-basin is highly deficient. There is only one automated Station at Resen, a relatively minor river draining to Lake Prespa with little impact downstream of Lake Ohrid therefore. Stations Botun and Ohrid are active but operating with manual chart-recorders, and are therefore of no use for real-time flood warning.

The GIZ procurement proposal is for four Stations to be upgraded/rehabilitated with pressure type sensors and GPRS compatible dataloggers.

Stations Globocica Dam and Debar Dam are under the control of ELEM, but automatically record water level at the Dams. Since reservoir level is critical to the Flood Early Warning System, it is essential that the NHMS cooperate with ELEM to share data of mutual interest.

2.3.2 Stations in the 2nd Phase Priority

Meteorological Stations

Two Stations of importance identified in this project that are not part of the procurement are Stations Struga and Slivovo.

Station Struga (674m) is important because it lies adjacent to Lake Ohrid at lake level and is therefore more representative of lake conditions. (Station Ohrid (764m) is elevated above the town). However, there is no Observer for the Station, and the site, which is not properly established, requires the cooperation of a local hospital. It is a **recommendation** that the NHMS actively seek to reinstate this Station, and obtain written permissions to install equipment and appoint a reliable local Observer.

Station Slivovo (959 m) was previously a long-term precipitation monitoring Station, discontinued by the NHMS pre 2010. The site is important because it is at relatively high altitude, and especially because it lies at the head of the Sateska river system. The Sateska is gauged downstream at Station Botun, and therefore Station Slivovo can provide useful meteorological data for inputs to a hydrological model. The old site is no longer viable. An alternative site has been proposed in the centre of the village, but there are no formal agreements in place. It is a **recommendation** that the NHMS actively seek to reinstate this Station with village cooperation, and obtain written permissions to install equipment and appoint a reliable local Observer.

Hydrometric Stations

One Station of importance identified in this project that is not part of the procurement is Station Volkovija. This has been discontinued for many years but it is of importance to flood warning because it is at high altitude (905m), therefore giving advanced warning of snow-melt conditions, and it lies in the headwaters of the Radika system. It is has a long historical record at a good stable location. In conjunction with the gauging station at Boskov Most, and the three meteorological stations, Volkovija will provide useful calibration data for future hydrological modelling.

It is a **recommendation** that the NHMS provide details on how they would operate and maintain this Station on a regular basis for flood warning purposes.

Figure 2-18 – Discontinued Station Volkovija

2.4 Priority Stations for Flood Warning in Kosovo

2.4.1 Stations in the 1st Phase Procurement

Meteorological Stations

Refer to Table 2-3 and Figure 2-26. Generally the meteorological network in the Kosovo sub-basin has been in a poor state of functionality for many years. There is only one long-term climate station operating at Pejë, but with no automated data. Even this Station, with a full-time Observer, is very poorly maintained.

The GIZ procurement proposal is for three Stations (including Pejë) to be reinforced/rehabilitated. Potentially good new sites have been identified at Prizren (395m) and Junik (575m). Each location will be automated with new raingauges and GPRS compatible dataloggers.

Hydrometric Stations

Refer to Table 2-4 and Figure 2-27. Because of significant operational and management problems in Kosovo, the hydrometeorological network is virtually non-operational. This is very serious with respect to a reliable real-time Flood Early Warning System, and special efforts will have to be made with this network to improve its effectiveness. To date two major international and one national rehabilitation project since 2002 have all failed to produce a reliable and functioning network.

Because of the poor record of reliability and maintenance in the Kosovo network, a conscious decision has been made to rehabilitate only two hydrometric stations at this time. These two sites (Station Rugova, 581m) and Station Gjonaj (300m) are however usefully representative of their catchments. Rugova records runoff from the Alps on the western border, and Gjonaj is the last measuring point for the Drini i Bardhë inside the Kosovo sub-basin.

Both Stations do not appear to have suffered the persistent vandalism and theft that has been encountered at most of the hydrometeorological Stations in Kosovo, and in both, the current meter cable and winch-gear is still intact. Therefore the Stations should be able to produce reliable and calibrated discharge data fairly easily.

Figure 2-19 – Station Gjonaj, Drini i Bardhë

2.4.2 Stations in the 2nd Phase Priority

Meteorological Stations

The Prizren site is particularly important because it replaces the long-term national climate station in the centre of Prizren which was discontinued pre 2010, and never replaced by the NHMS. It is important to re-establish this Station as soon as possible to continue the historical record. If the NHMS can demonstrate a good reliable record for this site, then it should be upgraded with additional meteorological information such as wind data.

The project recognises that snow at Junik is likely to be significant, but currently there is no Observer identified for this site, and its security is uncertain. Therefore, if the site can be properly maintained, and a reliable Observer appointed, it is a **recommendation** that this site be upgraded in future with additional sensors for snow, humidity, pressure, temperature, and possibly wind data.

There is a significant 'data gap' in the northern part of sub-basin. Station Istok was established in factory grounds in 2002 as an isolated raingauge. This is not automated, and has rarely recorded useable data. However, the site is secure and it is a **recommendation** that the NHMS enter into a formal agreement with the site owners to establish a proper long-term Automatic Weather Station at this location inside a demarcated boundary.

An isolated raingauge has been operating at Station Gjakova since 2002, but it has an internal datalogger which is usually malfunctioning. As for Istok, the **recommendation** is to relocate the Station within the existing site to a less intrusive location, and seek formal agreement with the site owners to allow an increased number of sensors inside a demarcated boundary, and to establish a long-term Automatic Weather Station.

There is a significant data gap covering the north-east part of the sub-basin. Historically there has been a manual raingauge at the village of Radishevë, since discontinued.

This site has not been inspected, but it will be necessary to reactivate an automatic gauge in this area in future to provide meteorological input data for the River Klina. It is a **recommendation** that the NHMS investigate the status and condition of this site, and the availability of an Observer.

In 2004 this Consultant established a manual raingauge location at Radoniqi Dam (439m) a useful location for reservoir monitoring and meteorological generally in the Gjakova region. The site is totally secure and professional staff are usually on-hand 24/7 at the Water Treatment Works adjacent to the Dam. The NHMS undertook to cooperate with Regional Water Company 'Radoniqi' to share data but no action ever ensued. It is a **recommendation** that if this arrangement can be properly supported, an automated raingauge be installed at the Dam which can contribute to the Flood Early Warning System as well as providing useful data for the operation of the reservoir, releases from which reach the Drini i Bardhë via the Bistrica Prue.

Hydrometric Stations

Sub-basin Kosovo is equal in size to that of sub-basin Montenegro, but has no operational river gauges compared to seven in Montenegro. Special efforts will be required if Kosovo is to contribute actively to the Flood Early Warning System, not least because it generates significant runoff, AND this runoff is largely unattenuated.

If the NHMS can be properly resourced and managed, then it is a **recommendation** that a further five existing hydrometric stations be rehabilitated and upgraded. This will require the NHMS to make special efforts with the local municipalities, schools and police to prevent future thefts and vandalism, something that has been recommended by several international consultants but never acted upon.

Of these the most important Station is Kepuzi. Kepuzi (363m) is sited on the Drini i Bardhë midway between the uppermost gauge at Drelaj (947m) and Gjonaj (300m) near the Albanian border and is critical inn terms of observing/calibrating the timing of the flood wave from the northern catchments. It was one of the primary hydrometric Stations in Yugoslavia, with a 35 year record, discontinued 1989, reactivated 2002, and vandalised shortly afterwards.

The NHMS proposal is to relocate the gauge some 10km downstream at a riverside restaurant. This remains an option BUT the Consultant's strong preference and **recommendation** is to rehabilitate the gauge in its existing location providing the security issues can be resolved. This will provide continuity of record. Secondly, moving the gauge introduces a major new inflow on the right bank from the Bistrica e Deçanit which will mean the historical record becomes redundant.

In fact the original Yugoslav stilling well at Station Kepuzi is still intact and probably could be made operational. It is somewhat less obtrusive than the new gauging hut installed in 2002. It is a **recommendation** that some exploratory de-silting works be carried out to see if the still well is still operational. If so, a high security and vandal proof automated water level sensor + GPRS transmission might be feasible. Current meterings could be undertaken at the road bridge 300m upstream.

Station Klina (389m) was destroyed by the local Municipality pre 2010 due to local channel improvement works, and installation of a new water level sensor will be very difficult. It is an important Station because the River Klina drains all of the north-eastern part of the sub-basin. The most practical solution may be to install a radar based system on the railway bridge 200m upstream of the town centre bridge, which in fact was the location of the original gauging station. It is a **recommendation** that the NHMS enter into discussions with the appropriate authorities to see if this can be implemented.

Figure 2-20 – Site of Original River Gauge, Station Klina

2.5 Priority Stations for Flood Warning in Albania

2.5.1 Stations in the 1st Phase Procurement

Meteorological Stations

Refer to Table 2-5 and Figure 2-26. Due to the comprehensive funding provided on the recent World Bank network rehabilitation project, many of the meteorological Stations in Albania are newly installed, although not yet fully operational.

The GIZ project proposes to reinforce data capability at four long-term precipitation Stations (Peshkopi, Krumë, Theth and Ura Shtrenjtë). These manual Stations will be automated. Pehskopi, an important long-term climate Station will have additional investment to provide wind-speed/direction, pressure, air temperature and humidity thereby providing a WMO complaint Automatic Weather Station.

Because of the lack of precipitation monitoring in the Fierzë valley, it is proposed to install an automatic raingauge at Fierzë Dam in conjunction with water level monitoring.

The highest Station is at Theth (833m) and this will be additionally equipped with air temperature and humidity sensors.

Hydrometric Stations

Refer to Table 2-6 and Figure 2-27. Many hydrometric Stations have been newly installed as part of World Bank funding and these will be part of the Flood Early Warning System network. As of September 2013, most of these Stations are connected to the Tirana control room but are not fully operational in terms of flood warning.

Before it was even operational, the important Station at Kovashica (450m) immediately downstream of the Debar Dam in Macedonia had been vandalised and now will not be in function. Continuing theft and vandalism will compromise the Flood early warning network unless the NHMS takes enforcement action with the police and local Municipalities.

The GIZ project proposes five further Stations to be rehabilitated. River Gauging Stations at Gri, and Dajç need significant work (new stilling wells) to brig them into operation.

A significant drawback of the World Bank project is that none of the high Dams were equipped. With regard to flood forecasting and warning, the status of the reservoirs at Fierzë, Koman and Vau i Dejës is completely critical but water level at these locations is not monitored.

The GIZ project proposes to rectify this situation by installing radar type water levels sensors at the three Dams. The cooperation of KESH is not confirmed at this time, but without these installations the effectiveness of the DDBB forecasting and warning capability is severely restricted. It is a **recommendation** that the Albania NHMS make every effort to establish full cooperation with KESH in the exchange and use of data from the reservoirs. There are significant mutual benefits in data cooperation: KESH obtains advance warning of inflows generally, (useful for hydropower optimisation), magnitude and timing of flood peaks for dam safety, and the NHMS receives data regarding reservoir state, which will be an essential variable in modelling simulations and flood forecasting downstream.

2.5.2 Stations in the 2nd Phase Priority

Meteorological Stations

Two potentially valuable Stations are not covered in the GIZ procurement, Stations Goricë e Madhe and Bushat. Goricë e Madhe (927m) is sited in a strategic position at high altitude in the Lake Prespa region, and would therefore be of value to Macedonian flood forecasting as well as providing useful boundary condition data for catchment modelling. Station Bushat is considered a low priority at this time due to its downstream location well south of Lake Shkodra.

Station Theth (833m) in the Albanian high Alps will encounter significant snowpack in winter, and is an important 'indicator' Station for snowmelt. It is a **recommendation** that consideration should be given to equipping this Station with an automated snow depth sensor such as the Campbell SR50A. This installation should await the trials and feedback from the Macedonia NHMS.

Hydrometric Stations

Three Stations not covered by the GIZ procurement are Station Kukës (303m, not yet existing), Station Gjader Mnelle (033m) and Station Shirokë (006m, Lake Shkodra).

Currently the level of the Fierzë reservoir at its upstream end (65 km from the Dam) is not monitored. However, the confluence of the Drini i Zi and the Drini i Bardhë at this location, coupled with the start of a very long routing reach to the Dam makes this location hydraulically very important for future model routing and real-time calibration of forecasts.

There is evidence that a Station was installed here historically and the west side bridge location at Kukës would appear to be still suitable (Figure 2-21). Subject to suitable safeguards and security of the Station, it is a **recommendation** that the NHMS consult with the appropriate Authorities to reinstate Station Kukës at the bridge crossing.

Station Gjader Mnelle is located on the main highway bridge crossing the Gjadri River which is a tributary of the Drin joining just below the Vau i Dejës Dam. Whilst flash floods may be significant locally, the catchment is relatively small and flood peaks from here will peak significantly earlier than the main river system. This Station is of very limited value therefore for regional flood warning. Security of the Station will also be very difficult to maintain.

We understand the Albania NHMS has already obtained funding to reinstate the water level station at Shirokë, and it will not be considered further. It will be a necessary part of the DDBB FEWS however.

Figure 2-21 – Discontinued Instrument Platform - Kukës

2.6 Priority Stations for Flood Warning in Montenegro

2.6.1 Stations in the 1st Phase Procurement

Meteorological Stations

Refer to Table 2-7 and Figure 2-26. Of the four national sub-basins, Montenegro currently operates the most reliable meteorological network. However, since 2008+, in excess of 50 manual raingauge sites with Observers have been discontinued. The NHMS is now reliant solely on nine national Automatic Weather Stations, only two of which (Nikšić and Podgorica) are located within the Drim basin, covering the Zeta and Moraça Rivers. There are no high altitude automated meteorological Stations operational at this time.

Consequently it will be necessary to reinforce the meteorological network at several critical locations. The GIZ proposal is to rehabilitate three Stations. Two of these at Dragovica Polje (605m) and Virpazar (14m) will operate as precipitation Stations only. Station Danilovgrad (52m) is a long-term Climate Station with automated transmission of precipitation data, but with limiting GSM capability. It will be upgraded with GPRS capability.

Station Virpazar was a Climate Station sited at Lake Skadar, discontinued since 2008. We consider it necessary to reactivate this Station in order to properly reflect weather conditions at the lake. It is in a designated location, with a local Observer.

Hydrological Stations

Refer to Table 2-8 and Figure 2-27. The Montenegro hydrometric network is also the most reliable of the four networks, also with the largest number of recent current meterings. There are three functioning hydrometric Stations in the Moraça catchment, and three Stations covering Lake Skadar.

However, all of these Stations are using GSM transmission technology, and the GIZ project proposal is to upgrade all the Stations with GPRS modems and compatible dataloggers.

The most complex of the rehabilitations will be the reinstatement of the river gauging station at Danilovgrad. Currently the whole of the River Zeta is totally ungauged, a major gap in the national network generally, as well as a big omission in the flood warning capability. This will require a new stilling well, and equipment enclosure etc.

2.6.2 Stations in the 2nd Phase Priority

Meteorological Stations

With the GIZ project, good coverage of the Montenegro sub-basin is achieved EXCEPT for the headwaters of the River Zeta. Historically there was a manual raingauge at Bogetiçi, but this was discontinued in 2008. Since the Zeta is the most important tributary of the Moraça, and it will be gauged at Danilovgrad, it is a **recommendation** to reinstate an automated precipitation gauge at this location to provide upstream runoff data. The site is secure and there is an Observer locally.

Station Dragovica Polje (605m) is one of the highest precipitation Stations in the Montenegro sub-basin. It is located in an area of high snowpack in winter, and is at the headwaters of the Moraça system. It is a **recommendation** that if NHMS Montenegro can establish a reliable Observer at this location, plus a permanent land agreement, this Station should be further funded to full Automatic Weather Station status.

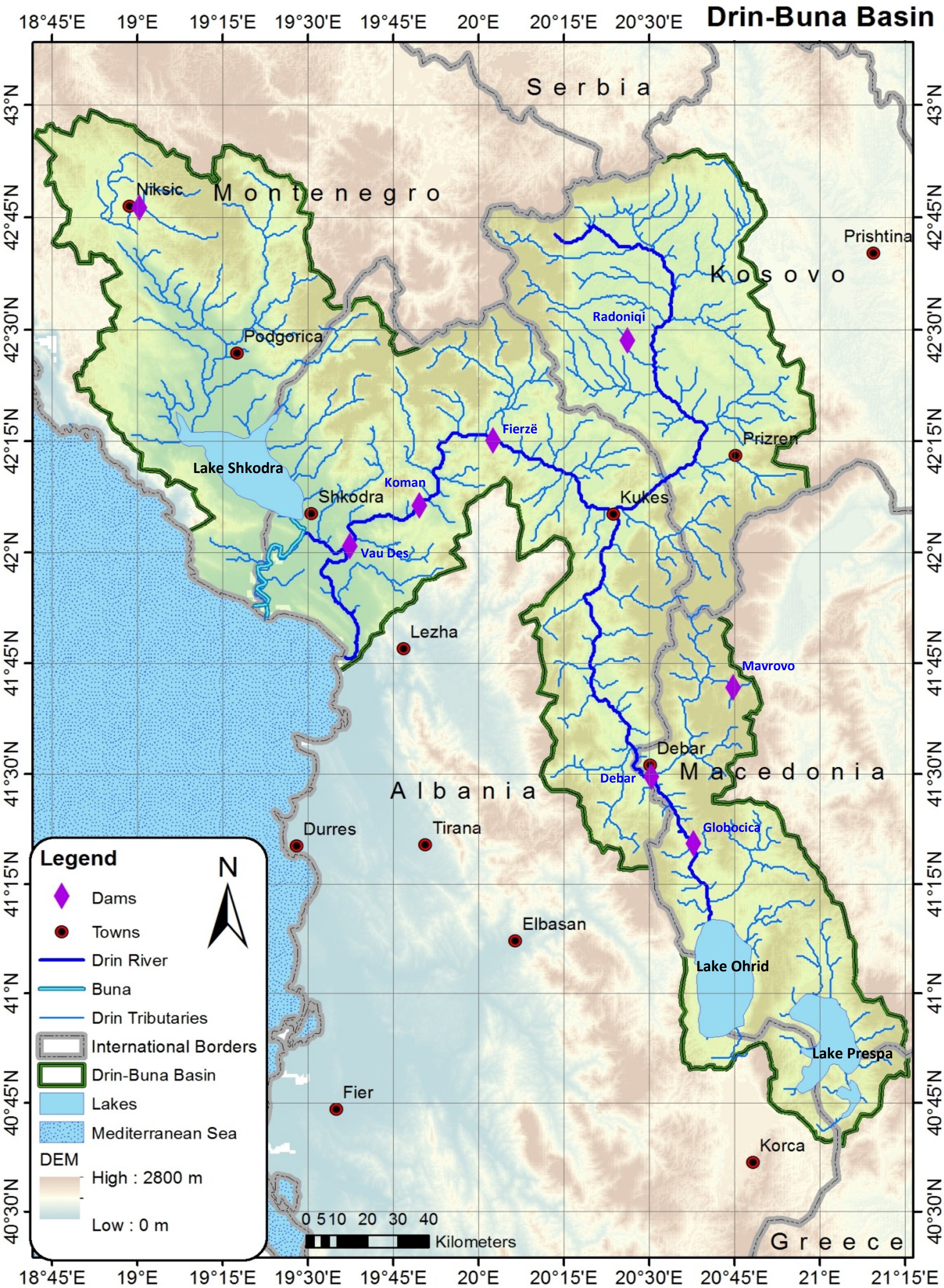
Hydrometric Stations

Historically there was a long-term gauge at Station Tragaj (92m) on the River Cijevna, discontinued since 2008. However, the Cijevana is equal in importance and magnitude to the River Zeta, and is also an important transboundary river with its headwaters inside Albania. Since the World Bank has funded a new gauging Station at Tamare (235m) upstream on the same river in Albania, it is a high priority to reinstate this Station for flood warning purposes. Data from the two Stations can be used to observe/calibrate runoff development and flood routing from high altitude.

It is a **recommendation** that NHMS Montenegro seek to reinstate this Station with a reliable Observer and security safeguards.

Figure 2-22 – Discontinued Station Tragaj, River Cijevna

Figure 2-23 – Drim/Drin – Buna/Bojana River Basin



Source: After Meon (2013)

2.7 Summary - A Flood Warning Network Fit for Purpose

2.7.1 Current Proposals

Inspection of Tables 2-1 to 2-8, and Figures 2-26 and 2-27 show that at full deployment, (including Stations identified as a second phase priority) there would be 37 meteorological stations and 39 hydrometric stations contributing to the Drim/Drin-Buna/Bojana Flood Early Warning System.

In our view this is a sufficiently dense network to provide adequate advance warning of potential major floods at the river basin scale, and there is also adequate provision for Stations placed at critical locations to be able to monitor and calibrate the passage of flood waves in real-time in the trans-boundary context.

2.7.2 First Priorities and Realistic Expectations

The primary intention of the GIZ project is only to lay the foundations of a reliable long-term early warning network. In view of the many significant challenges that lie ahead (both technical and managerial) it will take some years, possibly more than a decade, to deliver a first class complex early warning system (incorporating integrated regional modelling and early warning procedures).

However, assuming that a core of reliable Stations ARE functioning with automated data telemetry, there should be significant early benefits to each NHMS individually and to the region as a whole.

- Foremost, the framework of a Flood Early Warning System is in place even if it is based initially only on simple indicators such as precipitation depth and monitored river levels

- DDBB countries for the first time start to cooperate and share data and expertise. Collectively, DDBB professional staff can benefit from more training and professional support than they would as individual institutions.

- A well organised and functioning DDBB FEWS can be a high-profile mechanism to attract funding and technical assistance from other donors in future.

- Improved monitoring and data sharing systems lay the foundation for the development of a DDBB River Basin Management Plan (RBMP) which will be a high priority expected by the EU once the DDBB countries gain EU membership.

2.7.3 Future Considerations Long-term

Further into future, the current proposals also facilitate the potential to develop simplified localised precipitation-runoff and flood forecasting models by combining data from meteorological and hydrometric Stations located in the same catchments, in each of the national sub-basins, for example:

- River Sateska catchment in upstream Macedonia
- River Radika catchment in downstream Macedonia
- River Eriniku catchment in western Kosovo
- River Valbonë catchment in central Albania
- River Morača in upstream Montenegro
- River Zeta in western Montenegro

For the foreseeable future, it is in our view unnecessary to monitor every secondary or tertiary river system in the DDBB basin, as suggested by Meon [1] (Section 9.3). The expense, operational support and maintenance costs of such a network would be beyond the capacities of all of the NHMSs, and it is debatable whether the increasingly micro-scale data would actually contribute effectively to regional flood warning.

The lead times of many of the steep minor (tertiary) rivers will be in the order of 1 – 2 hours, and therefore it is also unlikely that localised flood warning could be effective at this scale.

There remain some obvious gaps in the network density or altitude coverage that may require some consideration and reinforcement in the longer-term:

- As with many regional networks, high altitude deployment for snowpack measurement is relatively poor. For example, in the current proposals there are only five out 37 meteorological Stations sited above 1000m, but these higher altitudes are critical with respect to the prevailing climatic regime, whereby significant flood risk arises in the late winter/spring months due to snowmelt.

  Measurement of the snowpack and its thaw potential will be a critical element of winter flood forecasting. The difficulty lies with the ease of access to such Stations, appointing reliable Observers who can visit the Station at least weekly, and the problem of recording precipitation as snow or hail.

  One solution is to use a state of the art Universal Precipitation Gauge (UPG) such as the OTT Pluvio² ™ which operates on a balance principle and records any type of precipitation. The OTT Pluvio² evaluates each measurement and compensates for external influences such as temperature, wind, and evaporation. Because it is designed to operate continuously, a UPG is more suitable for remote locations, though security is a major issue since gauges typically cost €3,000+.

Figure 2-24 – Universal Precipitation Gauge

Source: OTT Hydrometry

A second alternative and somewhat less expensive would be to use an acoustic snow depth sensor such as the Campbell Scientific SR50A, in conjunction with an external air temperature gauge to make approximations of the snowpack and its thaw potential.

Figure 2-25 – Acoustic Snow Depth Sensor

Source: Campbell Scientific

Both of these sensors have been specified within this project, and if successful could be deployed in other locations throughout the DDBB basin.

- The second unresolved issue is the gaps in spatial coverage, particularly for the meteorological network. Generally as Figures 2-26 and 2-27 show the spatial coverage and equidistant distribution is actually good. The most significant remaining gaps are:

  - Precipitation data east of Lake Prespa, Macedonia. (Impacts will be heavily attenuated by Lakes Prespa and Ohrid however, so this is not a major issue for DDBB regional flood warning).

  - Precipitation data south of Prizren, Kosovo, where transboundary rivers flow directly into Fierzë Reservoir

  - Precipitation data north-east of Klina, Kosovo (Historically a gauge was sited at Radisheva, believed to be discontinued).

  - Precipitation data at high altitude between Junik and Pejë, Kosovo. (A good potential location exists above the Hydropower Station above Deçan which could be activated).

  - Precipitation data at high altitude on the Valbonë River above Bajram Curri. This is one of the major high altitude tributaries, but there is no high altitude meteorological Station.

  - Precipitation data in central Montenegro between Dragovica Polje and Podgorica. (Manual Stations in this area were all discontinued by the NHMS).

  - Precipitation data in western Montenegro between Bogetići and Danilovgrad. (A good manual Station in this area was discontinued at Bogetići by the NHMS).

Figure 2-26 – Overview All Potential Meteorological Stations

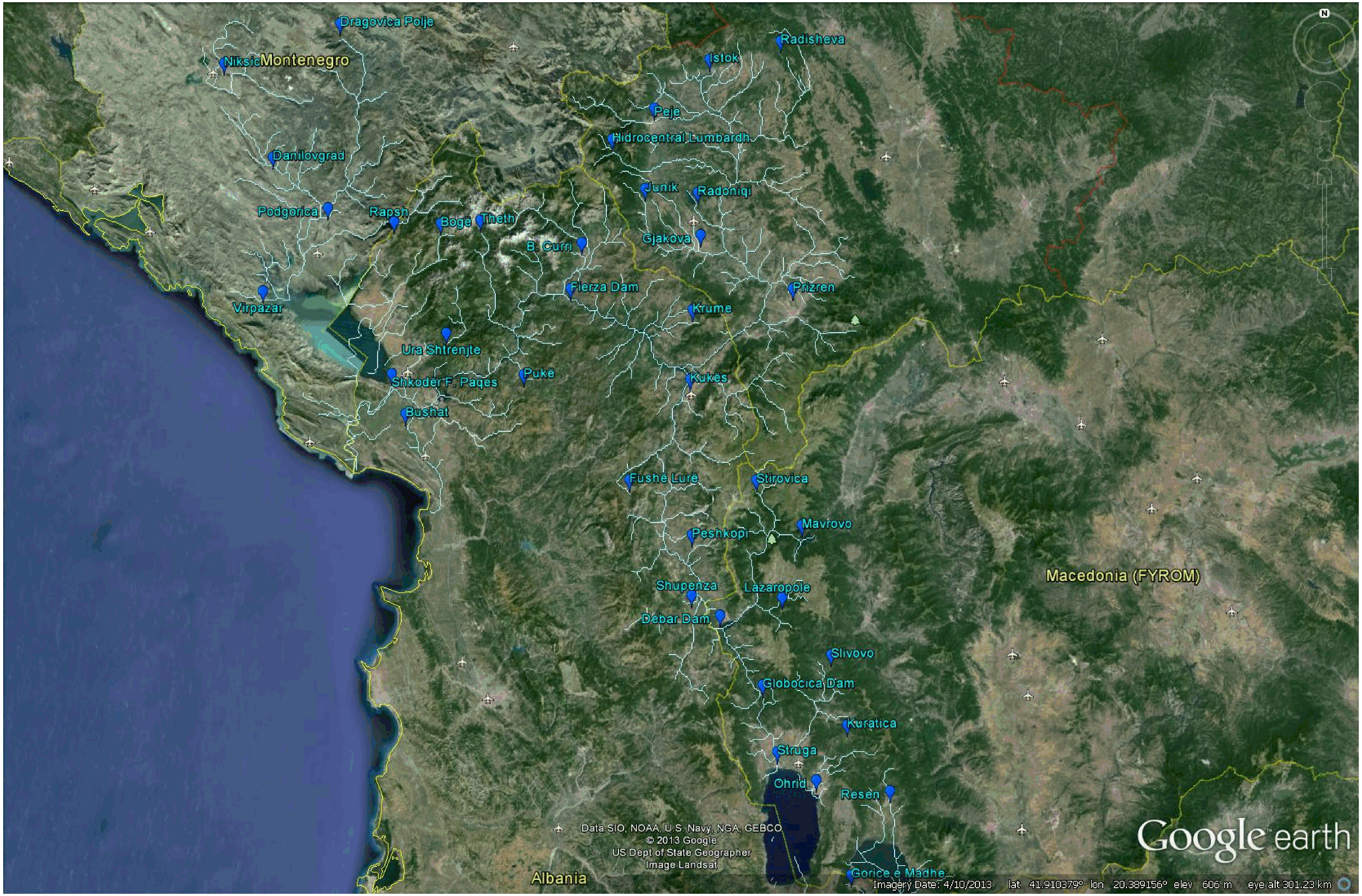


Figure 2-27 – Overview All Potential Hydrometric Stations

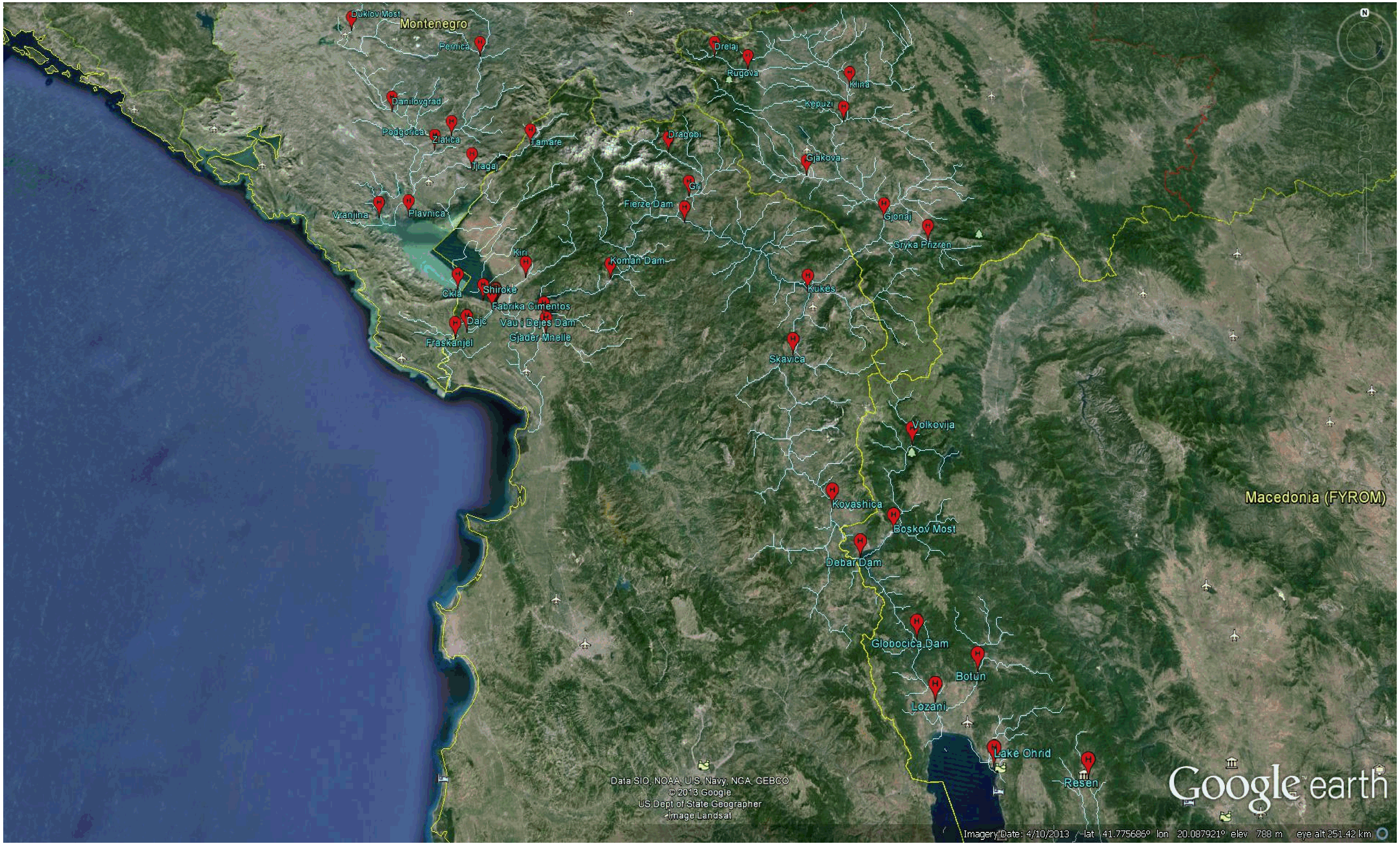


Table 2-1 – Flood Warning Proposed Meteorological Stations - Macedonia

River Basin	Station	Elevation (m)	GPS Position (Lat Long dd.ddd)	Operational Status	Current Data Capture & Telemetry	Annual LTA (mm)	Highest Daily P (mm) (date)	01 Oct – 31 Dec 1962 (mm)	Highest 1 Day P Jan 1963 (mm)	Other Parameters at Station
Golema Reka	Resen	890	41.08862 : 21.02195	Active	240V + SEBA RG50 + SEBA MDS5 + GSM	716	?	475	32	Temperature, Humidity, Pressure, Wind, Radiation
Drim	Kuratica	1107	41.24266 : 20.89173	Discontinued	Observer	810	?	593	54	None
Drim	Ohrid	764	41.11474 : 20.79728	Active	240V + SYMMETRON HD2013R + SR3T1 + GPRS	690	?	574	51	Temperature, Humidity, Pressure, Wind, Radiation
Drim	Struga	674	41.18083 : 20.67885	Discontinued	No Observer					
Sateska	Slivovo	959	41.40431 : 20.84418	Discontinued	No Observer	924	?	484	56	None
Drim	Globocica Dam	700	41.33578 : 20.63470	Active (ELEM)	240V + OTT PLUVIOMETER + GSM	?	?	-	-	Temperature, Pressure
Radika	Štirovica	1452	41.80719 : 20.61792	Discontinued (ELEM)	None	?	?	?	?	None
Radika	Mavrovo	1291	41.70263 : 20.75727	Active	Observer	993	?	613	55	Temperature, Humidity, Pressure, Wind, Radiation, Snow
Radika	Lazaropole	1339	41.53738 : 20.69586	Active	Observer	1050	?	712	12	Temperature, Humidity, Pressure, Wind, Radiation, Snow
Drim	Debar Dam	607	41.49580 : 20.50533	Active (ELEM)	240V + OTT PLUVIOMETER + GSM	?	?	-	-	Temperature, Pressure

Station automated and online as part of national network | Station selected for upgrade through GIZ procurement | Station requires improvement and future funding

Table 2-2 – Flood Warning Proposed Hydrometric Stations - Macedonia

River	Station	Elevation (m)	GPS Position (Lat Long dd.ddd)	Operational Status	Current Data Capture & Telemetry	Annual LTA (m³/s)	Highest Stage (m) (dd.mm.yy)	Highest Discharge (m³/s)	Jan 1963 max Discharge (m³/s)	Discharge Calibration Method	Total Current Meterings (n)	Highest Current Meter Stage (m)	Last Current Meter (yyyy) (n)
Golema Reka	Resen	890	41.08862 : 21.02195	Active	240V + 12V + PLS + SEBA MDS5 + GSM	0.89	1.70 (16.11.62)	33.4	17.1	Staff gauge + Observer	?	?	?
Lake Ohrid	Ohrid	696	41.11172 : 20.79773	Active	OTT Limnigraph	-	1.42 (23.02.63)	-	-	Staff gauge + Observer	-	-	-
Sateska	Botun	768	41.27658 : 20.78209	Active	OTT Limnigraph	5.93	2.85 (16.11.62)	183	95	Staff gauge + Observer	209	0.80 (1959)	2010 (3)
Drim	Ložani	700	41.22404 : 20.66879	Suspended	OTT Limnigraph (blocked)	22.60	2.31 (27.11.85)	112	?	Staff gauge + Observer	129	2.27 (2010)	2010 (3)
Drim	Globocica Dam	691	41.33745 : 20.63591	Active (ELEM)	240V + SISGEO WLL + Cable	-	?	-	-	Staff gauge + Observer	-	-	-
Radika	Volkovija	905	41.72187 : 20.66920	Discontinued	None	?	2.71 (12.05.58)	?	?	Staff gauge	134	1.14 (1996)	2001 (1)
Radika	Boškov Most	612	41.54412 : 20.59919	Damaged	None	17.7	2.40 (16.11.62)	262	164	Staff gauge	?	?	?
Drim	Debar Dam	593	41.49297 : 20.50626	Active (ELEM)	240V + SISGEO WLL + Cable	-	?	-	-	Staff gauge + Observer	-	-	-

Station automated and online as part of national network | Station selected for upgrade through GIZ procurement | Station requires improvement and future funding

Table 2-3 – Flood Warning Proposed Meteorological Stations - Kosovo

River Basin	Station	Elevation (m)	GPS Position (Lat Long dd.ddd)	Operational Status	Current Data Capture & Telemetry	Annual LTA (mm)	Highest Daily P (mm) (date)	01 Oct – 31 Dec 1962 (mm)	Highest 1 Day P Jan 1963 (mm)	Other Parameters at Station
Bistriça e Pejës	Pejë	508	42.66566 : 20.30511	Active	Observer + Manual	848	181 (23.07.94)	364	18.2	Temperature, Pressure, Wind, Humidity, Radiation, Cloud
Lumi Istogut	Istok	461	42.77770 : 20.47896	Not Active	SEBA RG + SEBA MDS 3 Insider + HT-100	621	62 (12.04.98)	-	-	
Klina	Radishevë			Discontinued						
Eriniku	Junik	575	42.47856 : 20.27582	Not Constructed	None	1412	-	-	-	-
Bistrica e Deçan	Radoniqi	439	42.47064 : 20.44064	Suspended	Observer + Manual	-	-	-	-	
Eriniku	Gjakova	375	42.37276 : 20.45015	Active	SEBA RG + SEBA MDS 3 Insider + HT-100	1014	115 (17.09.72)	430	33.0	
Bistrica Prizrenit	Prizren	395	42.24745 : 20.73547	Discontinued	None	780	121 (03.07.73	246	65.2	

Station automated and online as part of national network Station selected for upgrade through GIZ procurement Station requires improvement and future funding

Table 2-4 - Flood Warning Proposed Hydrometric Stations - Kosovo

River	Station	Elevation (m)	GPS Position (Lat Long dd.ddd)	Operational Status	Current Data Capture & Telemetry	Annual LTA (m³/s)	Highest Stage (m) (dd.mm.yy)	Highest Discharge (m³/s)	Jan 1963 max Discharge (m³/s)	Discharge Calibration Method	Total Current Meterings (n)	Highest Current Meter Stage (m)	Last Current Meter (yyyy) (n)
Bistriça e Pejës	Drelaj	947	42.70043 : 20.14207	Active - Uncalibrated	SEBA PLS + SEBA MDS Insider + HT-100 or HDA	4.2	1.9 (17.11.79)	83.5	13.70	Staff gauge + Cableway	6	0.91	2008 (1)
Bistriça e Pejës	Rugova	581	42.66188 : 20.24990	Active - Uncalibrated	SEBA PLS + SEBA MDS Insider + HT-100 or HDA	5.9	3.5 (19.11.79)	194	8.62	Staff gauge + Cableway	6	1.40	2008 (1)
Klina	Klina	389	42.61527 : 20.57731	Damaged/Discontinued	None	1.5	2.8 (19.11.79)	49.2	-	Bridge	1	0.39	2007 (1)
Eriniku	Gjakova	351	42.36927: 20.42050	Active - Uncalibrated	SEBA PLS + SEBA MDS Insider + HT-100 or HDA	11.5	4.0 (17.11.79)	424	-	Staff gauge	-	-	-
Drini I Bardhë	Kepuzi	363	42.51614 : 20.54905	Damaged/Discontinued	None	24.7	4.65 (19.11.79)	358	166	None	-	-	-
Drini I Bardhë	Gjonaj	300	42.25424 : 20.64922	Active - Uncalibrated	SEBA PLS + SEBA MDS Insider + HT-100 or HDA	48.6	729 (18.11.79)	830	-	Staff gauge + Cableway	1	1.55	2003 (1)
Bistriça e Prizren	Gryka Prizren	543	42.19451 : 20.77379	Active - Calibrated	SEBA PLS + SEBA MDS Insider + HT-100 or HDA	4.42	288 (18.11.79)	134	-	Staff gauge + Bridge	3	0.55	2007 (1)

Station automated and online as part of national network Station selected for upgrade through GIZ procurement Station requires improvement and future funding

Table 2-5 – Flood Warning Proposed Meteorological Stations - Albania

River Basin	Station	Elevation (m)	GPS Position (Lat Long dd.ddd)	Operational Status	Current Data Capture & Telemetry	Annual LTA (mm)	Highest Daily P (mm)	(date)	01 Oct – 31 Dec 1962 (mm)	Highest 1 Day P Jan 1963 (mm)	Other Parameters at Station
Drini i Zi	Goricë e Madhe	927	40.8954 : 20.9012	Active - Manual	Manual reading 07:00	929	130.2	15.11.62	763.8	48.2	Temperature, precipitation
Drini i Zi	Shupenza	531	41.5423 : 20.4181	Active - Automated	SP + ETG r102 + Weblogger + GPRS	865	90.0	11.01.63	549.4	90.0	Temperature, precipitation
Drini i Zi	Peshkopi	644	41.6812 : 20.4197	Active - Manual	Manual reading 07:00	941	100.1	02.02.59	438.7	71.3	Temperature, Wind-speed, Barometric, humidity,
Drini i Zi	Fushë Lurë	1048	41.8086 : 20.2283	Active - Automated		1572	117.8	21.11.65	827.7	91.6	Temperature, Wind-speed, Barometric, humidity,
Drini i Zi	Kukës	354	42.0399 : 20.4158	Active - Automated		966	100.0	24.09.68	541.8	82.8	Temperature, Wind-speed, Barometric, humidity,
Drini i Zi	Krumë	516	42.1992 : 20.4236	Active - Manual	Manual reading 07:00	1066	95.0	20.10.60	1245.7	60.5	Temperature, precipitation
Valbonë	Bajram Curri	330	42.3549 : 20.0790	Active - Automated		1802	110.2	02.03.65	908.8	78.5	Temperature, Wind-speed, Barometric
Drin	Fierze Dam	295	42.2489 : 20.0444	Not constructed							
Drin	Theth	833	42.4056 : 19.7644	Active - Manual	Manual reading 07:00	2878	294.0	25.11.69	1366.9	100.0	Temperature, precipitation
Drin	Pukë	781	42.0498 : 19.9005	Active - Automated		2106	288.0	21.10.46	1251.6	162.8	Temperature, Wind-speed, Barometric, humidity,
Kiri	Ura Shtrenjte	124	42.1456 : 19.6588	Active - Manual	Manual reading 07:00	3022	270.7	23.09.68	1352.9	97.0	Temperature, precipitation
Lake Shkodra	Bogë	920	42.3970 : 19.6410	Active - Automated		3164	420.4	15.12.63	1443.2	147.3	Temperature, Wind-speed, Barometric, humidity,
Lake Shkodra	Rapsh	735	42.4016 : 19.4939	Active - Automated		---	---	---	---	----	Temperature, precipitation, Barometric, humidity,
Buna	Shkodër F. Paqes	035	42.0514 : 19.4886	Active - Automated		2148	291.0	26.09.52	941.5	79.9	Temperature, Wind-speed, Barometric, humidity,
Buna	Bushat	016	41.9592 : 19.5332	Active - Manual	Manual reading 07:00	1739	330.5	23.09.68	930.2	43.1	Temperature, precipitation, evaporation

Station automated and online as part of national network   Station selected for upgrade through GIZ procurement   Station requires improvement and future funding

Table 2-6 - Flood Warning Proposed Hydrometric Stations - Albania

River	Station	Elevation (m)	GPS Position (Lat Long dd.ddd)	Operational Status	Current Data Capture & Telemetry	Annual LTA (m³/s)	Highest Stage (m) (dd.mm.yy)	Highest Discharge (m³/s)	Jan 1963 Discharge (m³/s)	Discharge Calibration Method	Total Current Meterings (n)	Highest Current Meter Stage (m)	Last Current Meter (yyyy) (n)
Drini i Zi	Kovashica	450	41.5967 : 20.4412	Active - uncalibrated	SP + ETG ULS + ETG r102 + Weblogger + GPRS	74.7	--	925	925	Bridge + Observer	3	--	2007
Drin i Zi	Skavica	310	41.9237 : 20.3540	Active - uncalibrated	SP + ETG ULS + ETG r102 + Weblogger + GPRS	100	--	1370	1370	Bridge	3	--	2007
Drini I Zi	Kukës	303	42.0755 : 20.4064	Not constructed	-								
Drin	Fierzë Dam	295	42.2489 : 20.0444	Not constructed	-	219	297	4360	4360		--	--	--
Valbonë	Dragobi	512	42.4300 : 19.9938	Active - uncalibrated	SP + ETG ULS + ETG r102 + Weblogger + GPRS	10.9	--	402	402	Bridge + Observer	3	--	2007
Valbonë	Gri	202	42.3163 : 20.0579	Discontinued (2007)	-	33.0	--	1630	1630	---	3	--	2007
Drin	Koman Dam	194	42.1078 : 19.8257	Not constructed	-	-	176	--	--	---	--	--	
Drin	Vau i Dejës Dam	079	42.0151 : 19.6359	Not constructed	-	324	76	6530	4812	---	--	--	--
Gjadri	Gjader Mnelle	033	41.9793 : 19.6452	Discontinued	-								
Kiri	Mes	064	42.1141 : 19.5751	Active - uncalibrated	SP + CAE ULM20 + SPM20 + GPRS	15.0	--	1150		Staff Gauge		--	
Drin	Bahcallek	026	42.0426 : 19.4921	Active - uncalibrated	SP + ETG ULS + ETG r102 + Weblogger + GPRS	352	10.15 (2010)	4812	4812	Bridge + ADCP		-	
Cijevna	Tamare	235	42.4554 : 19.5603	Active - uncalibrated	SP + ETG ULS + ETG r102 + Weblogger + GPRS	25.5		546	546		3	--	2007
Lake Shkodra	Shirokë	006	42.0596 : 19.4547	Active	-	-	10.50 (2010)	----	-----	Staff Gauge + Observer + Water level	--	--	--
Buna	Liqeni i Shkodres	006	42.0506 : 19.4920	Active - uncalibrated	SP + ETG ULS + ETG r102 + Weblogger + GPRS	320	10.31 (2010)	3930	3100	Bridge + ADCP	5	--	2013
Buna	Fabrika Cimentos	006	42.0393 : 19.4827	Active - uncalibrated	SP + ETG ULS + ETG r102 + Weblogger + GPRS	672	--	6060- 8000	6060- 8000	Water level only	5	--	2007
Buna	Dajç	005	41.9855 : 19.4151	Active - uncalibrated	12V + SEBA DS22 + MDS-5	680	7.15 (2010)			Staff gauge + Observer + ADCP	1	--	2013

Station automated and online as part of national network   Station selected for upgrade through GIZ procurement   Station requires improvement and future funding

Table 2-7 – Flood Warning Proposed Meteorological Stations - Montenegro

River Basin	Station	Elevation (m)	GPS Position (Lat Long dd.ddd)	Operational Status	Current Data Capture & Telemetry	Annual LTA (mm)	Highest Daily P (mm) (date)	01 Oct – 31 Dec 1962 (mm)	Highest 1 Day P Jan 1963 (mm)	Other Parameters at Station
Morača	Dragovica Polje	605	42.8605 : 19.3171	Discontinued (2011)	Observer + None	1933	165 (19.10.61)	855	80.9	-
Morača	Podgorica	050	42.4333 : 19.2833	Active - Automated	240v + Lambrecht 1518 H3 + SYNMET + GPRS	1659	227 (15.12.87)	795	52.5	Temperature, Wind, Barometric, Humidity, Global radiation, Soil Temperature
Zeta	Nikšić	647	42.7667 : 18.9500	Active - Automated	240v + Lambrecht 1518 H3 + SYNMET + GPRS	1986	276 (13.10.75)	821	95.1	Temperature, Wind, Barometric, Humidity, Global radiation, Soil Temperature
Zeta	Bogetići	391	42.6776 : 18.9689	Discontinued (2011)	Observer + None					
Zeta	Danilovgrad	052	42.5505 : 19.1079	Active - Automated	240v + Lambrecht 15189 H3 + LogoSens + GSM	2206	250 (18.10.92)	903	80.1	Temperature
Lake Skadar	Virpazar	014	42.2394 : 19.0830	Active - Manual	Observer + None	2429	372 (05.03.05)	1327	-	-

Station automated and online as part of national network | Station selected for upgrade through GIZ procurement | Station requires improvement and future funding

Table 2-8 - Flood Warning Proposed Hydrometric Stations – Montenegro

River	Station	Elevation (m)	GPS Position (Lat Long dd.ddd)	Operational Status	Current Data Capture & Telemetry	Annual LTA (m^3/s)	Highest Stage (m) (dd.mm.yy)	Highest Discharge (m^3/s)	Jan 1963 max Discharge (m^3/s)	Discharge Calibration Method	Total Current Meterings (n)	Highest Current Meter Stage (m)	Last Current Meter (yyyy) (n)
Morača	Pernica	179	42.7128 : 19.3710	Active - Calibrated	SP + OTT Thalimedes + GSM	29.2	5.54 (01.12.10)	812	477	Staff gauge + cableway	374	2.78	2012 (4)
Morača	Zlatica	53	42.4836 : 19.3073	Active - Calibrated	SP + OTT Thalimedes + GSM	58.7	10.32 (01.12.10)	1369	-	Staff gauge + cableway	129	8.56	2012 (4)
Zeta	Danilovgrad	33	42.5544 : 19.1063	Discontinued	Observer	77.8	12.95 (31.12.00)	577	417	Staff gauge + bridge	97	7.90	2012 (4)
Morača	Podgorica	25	42.4472 : 19.2588	Active - Calibrated	SP + OTT PLS + LogoSens + GSM	158.7	12.26 (17.11.79)	2073	1773	Staff gauge + cableway	359	10.14	2012 (4)
Cijevna	Tragaj	92	42.3947 : 19.3829	Discontinued (1989)	None	25.1	4.35	532	438	Bridge	187	2.21	2012 (0)
Lake Skadar	Plavnica	4.6	42.2720 : 19.2030	Active - Calibrated	240v + OTT Thalimedes + GSM	-	5.88 (4.12.10)			Staff gauge + water level only	N/A	-	-
Lake Skadar	Vranjina	5.0	42.2681 : 19.1131	Active - Calibrated	SP + OTT PLS + DuoSens + GSM	-	4.40			Staff gauge + water level only	N/A	-	-
Lake Skadar	Ckla	4.8	42.0851 : 19.3769	Active - Calibrated	SP + OTT Thalimedes + GSM	-	5.69 (4.12.10)			Staff gauge + water level only	N/A	-	-
Bojana	Fraskanjel	-0.1	41.9693 : 19.3836	Active - Calibrated	SP + OTT PLS + SLD + LogoSens + GSM	-	6.36 (4.12.10)			Staff gauge + ADCP	--	-	-

Station automated and online as part of national network | Station selected for upgrade through GIZ procurement | Station requires improvement and future funding

3. OPERATIONAL PRIORITIES AND FUTURE NEEDS

3.1 Current Performance Measures of the NHMSs

3.1.1 Benchmarks of a Successful NHMS

Very significant technical and co-operational challenges lie ahead to create an effective and sustainable regional Flood Early Warning System. Such a detailed level of regional cooperation has not in fact been attempted before in any form of river basin management in the Balkan area.

All of the engaged National Hydrometeorological Services (NHMSs) are operating under difficult financial, technical and staff capacity limitations, and their outputs and competencies are significantly below what would be expected of acceptable international standards, particularly with regard to data processing and distribution, as evidenced by Meon (see Figure 3-1).

As an example, the two primary benchmarks of any NHMS performing to acceptable international standard would be:

- Continuously available and reliable online and real-time availability of data such as water level and precipitation from network sensors.
- The annual production of a quality assured Hydrometeorological Year Book, incorporating the daily data and various statistics from each hydrometric or meteorological Station in the networks.

In both cases these benchmarks indicate that the NHMS is fulfilling its priority functions: that the majority of the Stations are operational, that maintenance and field support is adequate, and that data are being processed and checked in a timely manner, and properly digitised and archived for future reference.

In respect of the first benchmark, Macedonia and Montenegro have demonstrated a reasonable degree of functionality, and both operate moderately effective short-term weather forecasts on the basis of their limited AWS networks with data being available in near real-time on their respective websites.

The Montenegro hydrometric Stations are generally in a good state of functionality (21 out 23 online Stations active with live data, September 2013), the Macedonia Stations much less so with only 5 out of 18 online Stations active with live data (September 2013). Albania has not yet rolled out its new ETG WINNET™ interface to public access, and Kosovo has no online system at this time.

With respect to annual Yearbooks, the situation is very problematic. Macedonia NHMS produced an excellent Hydrometric Annual Yearbook in 2006, a model of best practice for other Balkan NHMSs to follow (using the HydroPro™ data processing software). Apart from this, a Hydrometeorological Yearbook has not been produced by any of the NHMS since 1990 approximately. Much of the hydrometric data recorded by the NHMSs is not fully processed i.e. into useable discharge information, nor is it being stored in appropriately accessible formats.

These issues are symptomatic of NHMSs that are not delivering on their minimum functions, and which require substantial operational improvement. In common, all of the NHMSs are not receiving the appropriate level of financial support from central Government

The challenge is all the greater when one considers that the four NHMSs in question have very different levels of competence and management approaches.

3.1.2 Station Maintenance

Of particular concern is that none of the NHMSs have dedicated permanent staff to maintain and supervise the monitoring Stations with the occasional exception of the manned climate Stations. In spite of modern technological advances, all monitoring Stations, especially hydrometric Stations, require <u>frequent</u> (i.e. at least monthly) visits to check Stations, clean stilling wells, download data, and clean, service and calibrate sensors. Many of these functions can be carried out by local Observers with appropriate training and equipment.

A concept that does not appear to have been understood by national Environment Ministries is that national hydrometeorological networks require significant staff effort and continual proper funding in order to maintain them even at a very basic level. If data are lost for any length of time, this undermines the entire purpose of the NHMS, and in the fullness of time these data gaps <u>will</u> severely compromise the national ability to identify and prepare for climate change impacts, which are predicted to be more severe in south-eastern Europe than in any other part.

The national environmental monitoring networks must therefore be regarded by central Government as essential critical infrastructure, and properly funded. This message has been conveyed to all Balkan environmental Agencies and Ministries by donors and consultants on countless occasions. It is repeated again.

To this Consultant's knowledge, none of the NHMSs are deploying adequate field staff to maintain station operability. With the hydrometric stations especially, as evidenced by Tables 2-2, 2-4, 2-6 and 2-8, recent current meterings (the calibration process by which water level data are converted to discharge) are virtually non-existent. Unless water level data are routinely converted to discharge data with reliable <u>and recent</u> rating curves, the data from these stations are of little value with regard to basic hydrology, flood forecasting and climate change impacts.

A massive change in NHMS 'mind-set', staff effort and financial allocation towards station calibration and timely processing of discharge data is required in every NHMS. This approach to data excellence and a focus on the priority 'raison d'être' of an NHMS (i.e. to continuously **collect, process and distribute data**) has been lost since 1990). Historically the Yugoslav national network was an example of international best practice (see Figure 3-1). Modern and affordable software packages such as HydroPro™ greatly simplify this task (Figure 3-2).

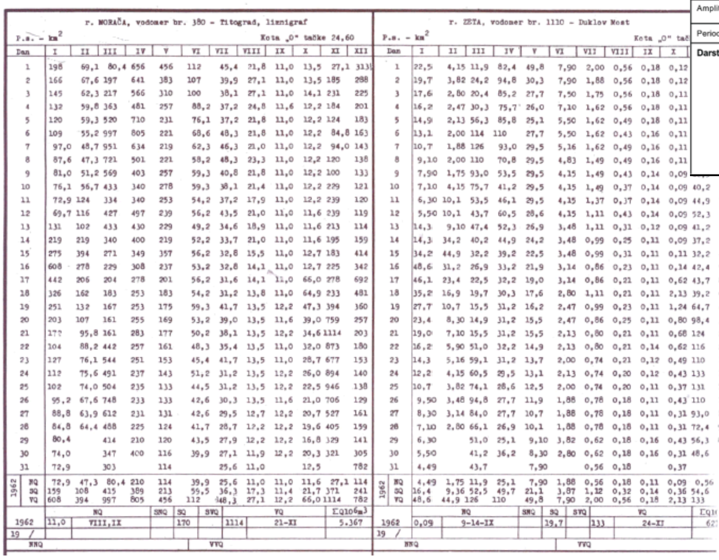
Without this re-established focus a Flood Early Warning System will never succeed because the emphasis on data continuity, accuracy and reliability is absent. These three elements are even more critical for a real-time flood early warning service. Many professional hydrologists would argue that it is not practical or realistic to bring any of the DDBB NHMSs into a potentially complex and high profile regional flood warning system unless its technical competence, financial resources and operational effectiveness are at a high level.

In spite of these undoubted difficulties and challenges, the counter-argument can be that inter-Agency cooperation in the development and operation of a regional Flood Early Warning System supported by a major donor may actually be the catalyst that will drive necessary improvements in funding, technical competence and operational sustainability.

Shared problems and experiences, in combination with common telemetry systems and data platforms may serve to improve NHMS effectiveness.

Accordingly, the remainder of this Report seeks to identify the main criteria for success and sustainability of the Flood Early Warning System. There is less focus on 'hi-tech' academic issues such as hydrological and hydraulic modelling and distributed model flood forecasting (the NHMSs are not prepared or equipped at this time), rather an emphasis on practical day to day requirements, and robust and simple techniques that are more likely to be effective in the short and medium term.

Figure 3-1 – Example Best Practice Yearbook, Yugoslavia 1963

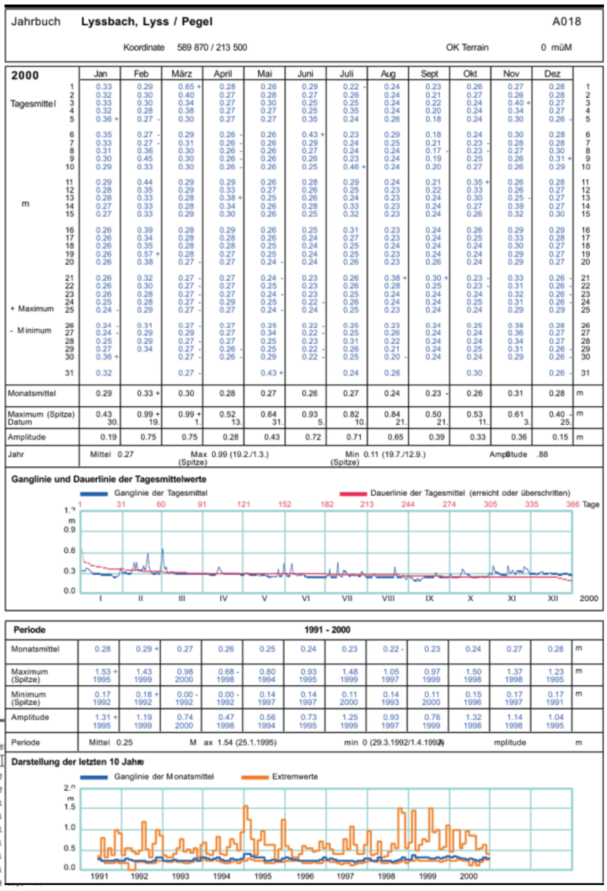


The issues from Section 3.4 following are raised approximately in the order in which they need to be addressed.

This Final Report is not a mandatory document. Ultimately the NHMS professionals have to organise and coordinate themselves. External donors and their Consultants can only act as external catalysts. Accordingly, this document, apart from providing general guidance to GIZ, is primarily intended as a consultation document for discussion between GIZ as the donor/coordinator and the NHMS professionals themselves.

The commitment and expertise of many of the individual experts in the DDBB NHMSs is unquestioned. The failings are in management and funding generally.

Figure 3-2 – Example Best Practice Yearbook, Switzerland 2000



Source: HydroPro™ Software

Figure 3-3 – Current Organisational Competencies for Flood Early Warning

Macedonia: Present Conditions with Regard to EWS

Country	Meteo-Data / Transmission	Hydrological Data / Hydraulic Data / Transmission	Database (Met&Hyd)	Num. Meteo – Forecast (focus on quant. precip.	Modeling Hydrological / Hydraulical	Flood Forecast	Flood Warning Procedure
Macedonia	About 7 meteo (=climat.) stations (part. gaps; 5 pre-sently in operation), about 30 rain gauges (about 19 presently in operation)	About 20 - 23 stations (11 presently in operation - many located at the lakes (Ohrid & Prespa)); rating curves are missing or need update	Meteo: CliData Hydro: HydroPro (in use 2000-2005); presently data stored in EXCEL	General forecast by international forecast models (Non-hydrostatic Mesoscale Model - NMM), Global Forecast System (GFS); Europ. Centre for Medium Range Weather Forecast (ECMRW) EUMETSAT images;	No	No quantitave flood forecast, but sector of weather forecast gives "adequate" alarm	Only qualitatively by weather forecasters – based on extreme weather conditions; data send to Crisis Management Centre
Evaluation	1 - 2	1 - 2	M: 2, H: 1 - 2	1	0	1	2 - 3

0	1	2	3	4
not available / not adequate	poor	fair	good	very good

Kosovo: Present Conditions with Regard to EWS

Country	Meteo-Data / Transmission	Hydrological Data / Hydraulic Data / Transmission	Database (Met&Hyd)	Num. Meteo – Forecast (focus on quant. precip.	Modeling Hydrological / Hydraulical	Flood Forecast	Flood Warning Procedure
Kosovo	1 Meteo station (no online stations, 3 meas. per day) about 19 prec. stations – some have data loggers – read out once a month	In past up to about 18 stations – presently about 5 in operation - only water level – some with data logger, read out once a month; no cross sections; uncomplete rating curves (low flow only)	Meteo: Excel (2000 – 2012) Hydrol: WISKI Data base as a service – 2003 (KISTERS) currently in EXCEL, ASCII	No – general weather forecast from international models (EUMET_SAT), ETA model, MEKENZI	No	No	Only qualitatively Major flood problems in other basins
Evaluation	1	1	M: 1-2, H: 1-2	0	0	0	0

0	1	2	3	4
not available / not adequate	poor	fair	good	very good

Albania: Present Conditions with Regard to EWS

Country	Meteo-Data / Transmission	Hydrological Data / Hydraulic Data / Transmission	Database (Met&Hyd)	Num. Meteo – Forecast (focus on quant. precip.	Modeling Hydrological / Hydraulical	Flood Forecast	Flood Warning Procedure
Albania	About 76 meteo stations: 65 climatic / ther-mometric stations, 9 pluviometric, etc. (diff. types) Presently no online transmission, data are written into booklets; manual data transfer	Historical: 52 stations – in paper format; Presently only 1 online station, Uncomplete information about the status of stations and data trans-mission; Histogram for 1991 ff not available	Since '50 – presently no database Archived data in paper format Digitalization of period 1991 – now in process (completed) No information about rating curves	Based on intern. models – own data not in use	Hydrol. Model covering the whole Drin basin is presently built up; Hydraulic model: WB model for Lower Drin available (HECRas), own model is presently built up based on WB model	Not based on modeling, but on historical and actual data and experience	Alert levels are existing (also from experience) – Warning procedure via transmission of bulletins to ministry (2-3 times a day – in case of emergency more often)
Evaluation	1 – 2	1	2 – 3	1 – 2	1	1 -2	3

0	1	2	3	4
not available / not adequate	poor	fair	good	very good

Montenegro: Present Conditions with Regard to EWS

Country	Meteo-Data / Transmission	Hydrological Data / Hydraulic Data / Transmission	Database (Met&Hyd)	Num. Meteo – Forecast (focus on quant. precip.	Modeling Hydrological / Hydraulical	Flood Forecast	Flood Warning Procedure
Montenegro	About 5 meteo – 2 online, 3 manually obs.; 11 rain gauging stations - manually operated and transferred by post	9 stations (all online) – but no station at Zela River Bathymetry of lake Shkoder is available (for Montenegrin part) Partially cross-sections from Buna River available	Meteo: currently CliData – since 2009; WISKI (bought 2003) but problems in applic.; EXCEL, ASCII, Hydras3 (Ott); ORACLE; Hydrol: EXCEL, ASCII and WEBSITE (online-stations); since 2002 strong decrease in data storing	Weather forecast, no numerical forecast (Non-hydrostatic Mesoscale Model; NMM ETA-model)	Currently no models in operational use In close future IHMS will receive a predictive hydrological model from Italy	Qualitative forecast based on water levels and rainfall Observations transferred to Ministry of Civil Protection (MoCP)	IHMS: Announcement to Ministry of Civil Protection (MoCP)
Evaluation	2 – 3	3	M: 3, H: 3	1	1	1	3

0	1	2	3	4
not available / not adequate	poor	fair	good	very good

Source: Meon (2013) [1]

3.2 Memorandum of Understanding – Implementation Agreement

GIZ proposes, and the Consultant is fully supportive of, a Memorandum of Understanding between GIZ and each of the National Hydrometeorological Services (NHMSs) for various duties and obligations arising from engagement in the DDBB Flood Early Warning System.

Commitment to such a regional system has already been made at high level. However, there are a significant number of details to be agreed at an operational level between the NHMSs. Broadly, the MoU should seek agreement and commitment in the following areas:

- Active commitment to transboundary cooperation in flood early warning
- Continual exchange of data and expertise
- Appointment and funding of permanent Observers at monitoring Stations
- Regular visits to and maintenance of Stations
- Regular calibration checks on sensors, including especially current meterings for hydrometric Stations
- Regular reporting of Station status to the DDBB 'secretariat'.
- Dedicated budget line in each NHMS annual budget for Flood Early Warning System Station maintenance and system support.

3.3 Formulation of Drim/Drin-Buna/Bojana (DDBB) Technical Working Group

It is evident from recent visits to each of the NHMSs that they share many of the same practical and operational problems. There are skills and expertise of certain experts in the NHMSs that would be beneficial to the other professionals.

At this early stage of the DDBB Flood Early Warning System (FEWS) there remain unanswered issues about methods of cooperation, levels of data sharing, flood warning responsibilities etc. These criteria should not be imposed by external donors or consultants. Rather the NHMSs should evolve for themselves how they can operate and coordinate effectively.

Accordingly, a priority **recommendation** would be to formulate a technical working group for the DDBB comprised not only NHMS Departmental Heads, but even more importantly the hydrologists, meteorologists and data engineers who will have to day to day engagement with the national networks and the Flood Early Warning System.

This technical working group (TWG) could for example meet formally on a bi-annual basis (each NHMS acting as a rotational host) to discuss issues and to present working papers on any aspect of early warning systems. In the interim, field visits or training sessions from national or international experts could also be procured.

The TWG needs to be administered by an informal (but funded) 'secretariat' that would coordinate and supervise meetings, collate and distribute maintenance and status reports, and possibly have oversight of the DDBB Flood Early Warning System website.

Priority tasks for agreement for this TWG include for example:

- The formation and funding of a DDBB technical secretariat
- Reporting standards and frequency of reporting
- Design and content of a FEWS overview website
- Mechanisms for regional or bilateral communication and coordination.

3.4 Station Operational Reliability

3.4.1 Commitment to Regular Maintenance

To be of value, any environmental monitoring Station should record quality data 24/7/365. However, in long-term routine monitoring (e.g. for climate change impacts), the occasional failure of a Station for a period of a few weeks can be acceptable. Lost data can be reconstructed by reference to other analogue (comparison) Stations.

To date, all of the NHMS in the DDBB system have demonstrated generally poor levels of commitment to Station upkeep. In some NHMSs, some Stations have been neglected for months, if not years, and irreplaceable data from major events has been lost.

However, engagement in a Flood Early Warning System raises the stakes immeasurably. There must be much greater focus on Station reliability, because flooding may occur at any time with extremely short lead times. A national or regional emergency is not the time to find that several critical Stations are out of commission, or giving inaccurate readings.

Maintaining monitoring Stations at 90%+ reliability is a challenging and never-ending task. It requires trained and committed staff working to a formal visit/maintenance programme, properly supported with adequate staff, equipment and vehicles. Environmental networks do not maintain themselves. For this reason the proposed MoU stipulates a specific budget line for this purpose.

3.4.2 Commitment to Regular Reporting

In the interests of transparency, such a commitment to regular Station maintenance in our view requires regular reporting to a technical secretariat. Such reports would be open to inspection by any NHMS and open to all.

Such reports would not be complex or onerous. They could consist of a simple template and a check sheet indicating for example:

- Date of visit
- Maintenance carried out

- Sensor Calibration checks
- Data record checked/downloaded
- Station telemetry test

Typically we would recommend that within international best practice every monitoring Station should be visited and inspected at least once every 3 months. It is a **recommendation** that the Station maintenance reporting is therefore also submitted at 3 monthly intervals.

On this basis, simple arithmetic shows that a basic network of 12 meteorological and 12 hydrometric Stations would require operational staff to be in the field on average 2 days every single week on a continuous basis. 48 Stations + (as in Albania) would require a permanent field team in operation 4 days every week. Due to limited staff resources, it is a matter of record that all of the DDBB NHMSs frequently do not visit Stations for many months, and it is therefore not surprising that many Stations go offline, usually with a loss of data that can never be recovered, or sites progressively deteriorate to the point of uselessness (Figure 3-4).

It is understood that due to a poor appreciation by central Governments of the importance of long-term environmental data, the NHMSs are under-funded and poorly supported. However without adequate funding, the national monitoring networks cannot be sustained and the prospects for an effective Flood Early Warning System are also limited.

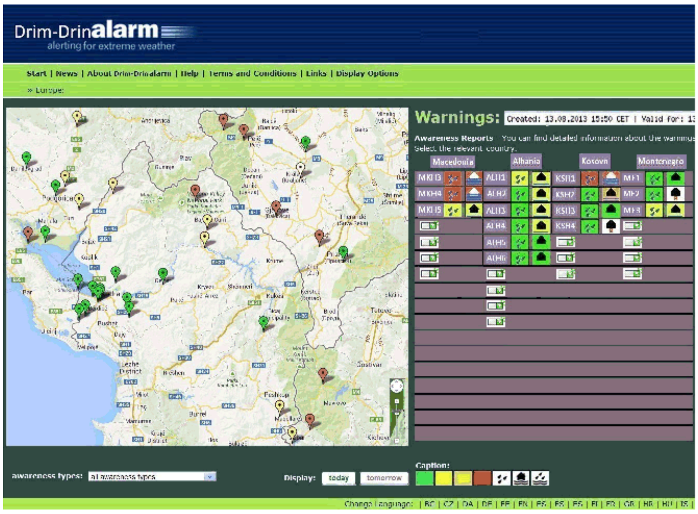
Figure 3-4 – Gauging Site Deterioration in 10 Years

Modern telemetry has the advantage that sensor malfunctions can be flagged at the control centre. However, this does not cover issues such as sensors working incorrectly, the site being vandalised, or carrying out general maintenance such as vegetation clearance.

For this reason it is proposed under the GIZ project procurement to develop a customised DDBB FEWS website that will show the exact operational status of each meteorological and hydrometric Station in the Flood Early Warning System. This task will be completed in a 2nd phase of the project.

Such transparency should greatly assist in ensuring that individual Stations are properly maintained and contributing to the regional network, as well providing basic but informative data on environmental conditions.

Figure 3-5 - Example Control Panel for Station Operational Status



The EU based MeteoAlarm website (www.meteoalarm.eu) is an excellent example of how hazard early warning can be conveyed through a simple web page.

3.5 Rating Curves and Discharge Measurement

3.5.1 Water Level as a Flood Hazard Indicator

Water level in isolation is actually a reasonable proxy indicator for potential flood hazard. A higher than usual river level is obviously indicative of flood conditions developing. Observed levels at a particular hydrometric station are often used to make simple forecasts of level at a downstream vulnerable location based on empirical data.

Probabilistic values can also be related to water level provided the geometry of the Station has not changed significantly over time, giving an indication of the relative magnitude of the flood.

For hazard warning, evacuation, floodplain mapping and flood damage costing purposes, the water level is actually more relevant than the discharge. Therefore a hydrometric Station used only for water level still has some value in the flood forecasting arena.

However, ignoring the capability to compute discharge from this same Station is a significant waste of financial and technical input, because the lost 'added value' of the data invariably outweighs the cost of obtaining it in the long-term.

3.5.2 Added Value of Discharge

The primary purpose of River Gauging Stations ('Hydrometric Stations') (other than lake or reservoir based) is to measure discharge, both for short-term flood warning and also long-term water balances

Discharge is critical in several respects:

- Volumetric quantities in the river system can be correlated to catchment meteorological inputs to obtain runoff quotients for example which are essential for general hydrological modelling and flood forecasting
- Volumetric quantities are essential in order to determine potential inflows to lakes and reservoirs, the storage of which is fundamental to flood peak routing
- Discharge quantity and its variability are essential components of Ecological Minimum Flow, a critical parameter in the Water Framework Directive procedures.
- Long-term measures of volume, flow duration and flow rate are essential for water resource availability, reservoir yield calculations, hydropower potential and climate change impacts.

It is a significant issue therefore that all of the NHMSs are under-performing with respect to international best practice in terms of carrying out current meterings and processing level data to discharge, see Table 2-2, 2-4, 2-6, 2-8. Montenegro NHMS outperforms the other Agencies in respect of current meterings, but in common with the other NHMSs there is still a significant backlog amounting to years of unprocessed and unavailable discharge data.

This is undoubtedly one of the most challenging tasks for any NHMS, but an up to date discharge database is a clear indicator of a properly functioning NHMS, and it is a **recommendation** that significant commitment to increased current metering and data processing systems is urgently required from each NHMS.

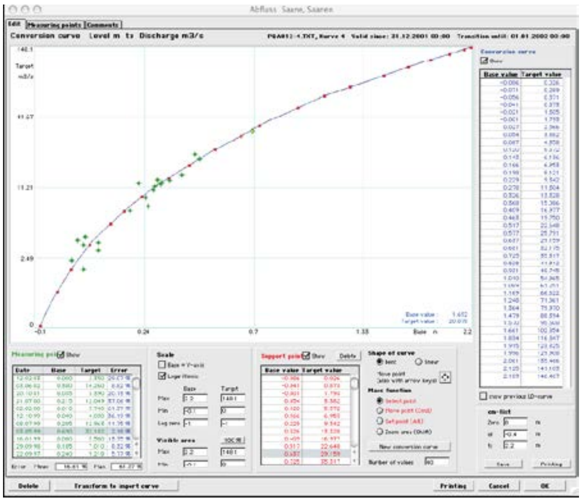
Data analysis and reporting packages such as the HydroPro™ software are ideal tools for the automated production of rating curves, data tables and Annual Reports. Macedonia NHMS has used HydroPro™ with success in the past, and it could be usefully implemented in other NHMSs. (www.hydrometrie.ch)

Montenegro NHMS has sporadically used the WISKI™ package from Kisters, but this is significantly more complex and expensive by comparison, and is most likely beyond the budgets and needs of the DDBB NHMSs. (www.kisters.eu)

It is a **recommendation** that GIZ carry out a review into the effectiveness and affordability of various packages on the market to identify a hydrological data analysis/reporting single package that could be commonly rolled out between all NHMS.

There would be significant savings in purchase and licence costs by this approach, as well synergies in training and developing expertise amongst the DDBB NHMS hydrologists.

Figure 3-6 – Rating Curve Editor – HydroPro™



Source: HydroPro™ Software

3.6 Real-time Data Quality Control

A significant issue for the DDBB Technical Working Group will be how to rapidly process and quality control raw data transmitted from the early warning sites. This applies equally to meteorological as well as hydrometric sites.

Conventionally, NHMS have weeks if not months to inspect data for errors, and correct accordingly before the data are posted to the national archive. In a flood warning situation, this time delay is not available, and the process of error scrutiny has to be automated as far as possible. The modern sensor/telemetry systems procured for this project should all have in common the following primary data checks:

- Automated SMS/email alarms in the event of a sensor malfunction
- Software flags if a water level or meteorological variable exceeds a certain predefined threshold or a rate of change or a jump in value between readings

All may be symptomatic of data errors, which are not uncommon in extreme weather situations, and these can be flagged and inspected in real time within the data acquisition software BEFORE they are transmitted to the data server.

However, in a flood emergency, it will always be necessary for the NHMS to man a control room and have experienced professionals on hand who have good knowledge of the characteristics of the catchments and rivers to make rapidly informed judgements about potential errors.

This hydrological expertise can be supported by the following analytical approaches that should be built in to any data acquisition software or analysis package being used for flood warning:

- The observation of data trend at the Stations over the previous 1, 2, 6, 12 hours is often a useful marker for identifying sudden data errors
- Comparison with the data outputs of upstream or neighbouring Stations may indicate data inconsistencies
- Comparison with historical major floods can be very useful, since the majority of catchments tend to behave in consistent ways, the principal difference being the antecedent or boundary conditions

Ultimately however, the most effective way to ensure data reliability and quality control is to regularly visit all monitoring Stations, and maintain the sites and equipment to a high standard.

Without this input, data accuracy will always be an uncertain issue, and may severely compromise the effectiveness of the Flood Early Warning System.

3.7 Historical Reference Floods

Due to the Balkan conflict, regrettably many Stations became dysfunctional after 1990, and a 25 year era of lost data is now inevitable. However, until late 1980's, the Yugoslav regime operated a first class hydrometeorological network. The Annual Yearbooks from this period are mostly still available in hard-copy.

Although most of the historical hydrological data are available now only as Mean Gauged Daily Flow, these data contain lessons of immense importance with regard to general catchment hydrometeorological behaviour, antecedent conditions, and precipitation-runoff relationships, all of which are critical elements in flood forecasting.

Downstream of the new high Dams obviously the flow regime is now significantly altered, but the impacts of dam operation can be simulated and interposed with the historical hydrographs.

It is a **recommendation** that the individual NHMSs should digitise (if not already done) the historic flood events from 1950 to 1990 to develop a library of 'reference floods' incorporating the full hydrograph. Data packages such as WISKI and HydroPro allow the incorporation of historic floods against real-time observations for forecasting purposes. Antecedent meteorological conditions from these flood dates should also be studied for future reference.

Most important of all, the annual maxima of all floods from 1950 – 190 should be assessed statistically to determine the annual probabilities of a range of flood discharges. This is an essential first step in the development of an effective flood forecasting system.

3.8 River Basin Coordination

3.8.1 *Water Framework Directive and Floods Directive*

EU accession is at a very early stage for all of the DDBB countries. However, it is necessary that they all subscribe to the best practice 'European standard' of integrated river basin management as set out in EU Directive 2000/60/EC, and there are ongoing projects in all the countries to promote pilot River Basin Management Plans (RBMPs).

The Floods Directive (2007/60/EC) is a daughter directive, and the development of Flood Management Plans (of which flood warning is an intrinsic part) are expected to conform to the general data standards of the Water Framework Directive.

It is foreseeable that the DDBB Flood Early Warning System will require the development or use of unified data systems, maps etc., and most probably through shared Geographic Information System (GIS) data.

Since 2001, the EU Member States and the European Commission have jointly developed a common strategy for supporting the implementation of the Water Framework Directive, known as the Common Implementation Strategy (CIS). The main aim of this strategy is to allow a coherent and harmonious implementation of this Directive by using common standards, terms and procedures across all components of the WFD.

http://ec.europa.eu/environment/water/water-framework/objectives/implementation_en.htm

The goal of the GIS Working Group set up under the Common Implementation Strategy was to elaborate such specifications and to make them available in the form of Guidance Documents.

With respect to regional river basin initiatives, there are two critical documents:

- CIS Guidance Document No. 9 – Implementing the GIS Elements of the WFD, 2003
- CIS Guidance Document No. 22 - Updated Guidance on Implementing the Geographical Information System (GIS) Elements of the EU Water Policy, 2009.

The Water Data Centre, hosted at the European Environment Agency (EEA) provides the main European entry point for GIS water related data as part of WISE (Water Information System for Europe). The central access point provides:

- interactive maps, data and data viewers
- European datasets and indicators

It is **recommendation** that all of the NHMSs become familiar with and adopt the data conventions and standards set out in the Water Framework Directive Common Implementation Strategy (CIS), especially Documents 9 and 22.

www.eea.europa.eu/themes/water/dc

3.8.2 GIS Reporting Concepts in the WISE Framework

Within the WISE Framework all GIS data produced should as far as possible comply with consistent concepts and standards. This concept is driven by the INSPIRE Directive 2007/2/EC which seeks to ensure that the spatial data infrastructures of the Member States are compatible and usable in a Community and transboundary context. The Directive requires that common Implementing Rules (IR) are adopted in a number of specific areas (Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting).

http://inspire.jrc.ec.europa.eu/

Since the EU standard for geographic reporting covers all water related reporting, unique identification of spatial objects and spatial datasets is of fundamental importance for data management in the WISE environment. The principles also generally apply to the development of GIS data layers developed as part of RBMPs within the WFD framework.

3.8.3 The Identification and Coding of National Waterbodies

With regard to regional flood management planning and flood warning systems, a most important early objective for all the NHMSs is to implement a standard system for the identification and coding of national waterbodies. To date none of the DDBB NHMSs have adopted the European standard, which is an urgent task.

The European Commission has agreed that the European standard for all hydrological features will be a modified version of the Pfafstetter system [4]. The Pfafstetter system follows a systematic approach as it is derived from topological relationships of the underlying drainage system. The numbering schema is self-replicating from the largest to the smallest drainage system. With Pfafstetter codes it is possible to identify all nested sub-basins within the larger basin and the "parent" basin from a sub-basin. All upstream sub-basins or river segments as well as all downstream segments are identifiable at each location of the river network. Details of the creation of the code are explained in the CIS Guidance Document 22.

It is a **recommendation** that the four NHMSs should coordinate their river basin and river body numbering systems to be in line with WFD and WISE requirements. This will achieve consistency for flood monitoring and reporting across the river basin.

3.8.4 European Coordinate Reference System and Datum

It is also a recognised problem that the four DDBB countries are using different projections and datums for their mapping systems. Clearly a regional network should use a common reference system for both spatial location (X,Y), and vertical elevation (Z).

[4] CIS Guidance Document No: 22 - Updated Guidance on Implementing the Geographical Information System (GIS) Elements of the EU Water policy, Appendix 7

The agreed EU standard for geodetic referencing is the European Terrestrial Reference System 89 (ETRS89) which uses a wide network of highly accurate geodetic GPS stations, the EUREF Permanent Network.

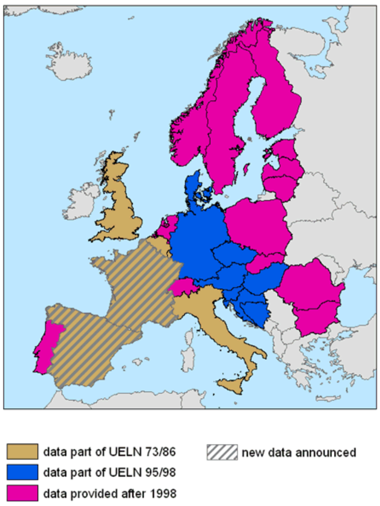
http://www.euref-iag.net/euref_egrs.html
http://epncb.oma.be/_networkdata/stationmaps.php

With regard to vertical referencing, the EU has adopted the European Vertical Reference Framework (EVRF) System EVRS2007.

http://www.bkg.bund.de/nn_164806/geodIS/EVRS/EN/EVRF2007/evrf2007__node.html__nnn=true

It is **recommendation** that the four NHMSs should cooperate and collaborate with respect to the positioning and elevation of all the hydrometeorological Stations of the DDBB system to achieve a common reference system for all these Stations using the EU standard reference systems.

Figure 3-7 – Data Status of UELN/EVRS2007 Network



Source: http://www.euref-iag.net

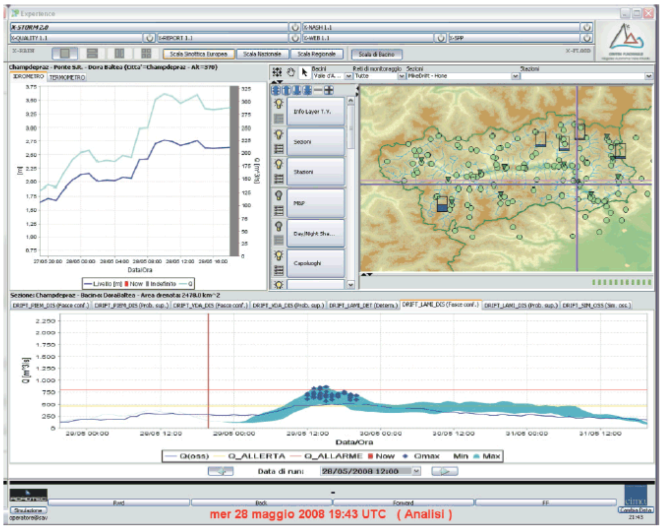
4. EARLY CONSIDERATIONS FOR A UNIFIED FLOOD FORECASTING SYSTEM

4.1 Current Situation

Currently none of the four NHMSs operate an effective fluvial flood early warning system even at national level. There are of course reasonably effective meteorological early warning systems in Macedonia and Montenegro, but this does not extend to a monitoring and real-time reporting of fluvial conditions in response to meteorological inputs. There are no hydrological models used for flood forecasting in Macedonia, Montenegro or Kosovo. Albania has no practical experience of operating the Flood-PROOFS model.

Albania NHMS has introduced into its control room at Tirana the most sophisticated package of the four NHMSs, the DEWETRA package from CIMA. DEWETRA is a real-time integrated system for risk forecasting, monitoring and prevention. Within the DEWETRA shell, a dedicated flood forecasting model can be used, Flood-PROOFS™.

Figure 4-1 – Flood-PROOFS Probabilistic Based Forecasting



Source: www.cimafoundation.org

It is of course desirable that each NHMS should in the long-term develop national flood forecasting capability appropriate to its needs and resources.

However, it is the **recommendation** of this Report that highly sophisticated flood forecasting models such as Flood-PROOFS and LISFLOOD are probably not appropriate in the early years of the DDBB Flood Early Warning System (FEWS).

The data demands of such models are enormous, and as with all such complex packages, the training, knowledge and financing required to use them are also considerable.

The lesson from the UK National Flood Forecasting System (NFFS) established in 1996 with one of the most comprehensive and reliable networks in Europe is that even after 15 years of intensive research and application, accurate flood routing and forecasting is still not fully achieved.

Realistic expectations are required in the early years (1 to 5??) of the FEWS. All of the NHMSs are significantly under-staffed, with relatively few hydrologists and meteorologists. Experience from Western Europe has shown that good quality effective flood forecasting requires three critical success factors:

- A meteorological and hydrometric network that has 95%+ spatial and temporal reliability.

  A network that has several/many missing or unreliable Stations means that the boundary conditions for the model and the run-time simulations (forecasts) cannot be properly established. The margins of error associated with the forecasts therefore make them almost meaningless.

  The potential reliability of the FEWS network is completely unproven at this stage, and the reliability record of many of the Stations in the DDBB system is not at all encouraging.

- Highly trained meteorologists/hydrologists who are not only intensely familiar with their local weather systems and catchment flood characteristics but are who are also trained in forecasting models and techniques and 'real-time' operations such as flood warning protocols.

  The current staff numbers in all of the NHMSs are below the necessary minimum to deliver effective functions. It is necessary to identify at least 2/3 meteorologists and 2/3 hydrologists who are semi-permanently available for emergency duty in order to man control rooms on a shift basis.

- A fully equipped emergency control room/flood forecasting centre. Such a control room should be fully equipped with access to all hydrometeorological data in real-time (e.g. the DDBB Flood Early Warning System), should have permanently reliable internet connections and access to outside broadcasts, and powerful PCs capable of processing large data quantities or complex models.

  The flood monitoring control rooms do not of course replace the national emergency control rooms that are existent in all DDBB countries, usually within the Departments or Sectors for Emergency Management or similar and usually within the Ministry of Interior.

  The flood control rooms are however the central coordinating point for complex decisions to be made about hydrometeorological impacts and probabilistic forecasts and the issues of flood warnings AND for these decisions to be communicated to professional colleagues in the other NHMS Flood Warning control rooms.

These flood monitoring control rooms are not present in Macedonia, Kosovo and Montenegro at this time.

The overriding message is that, practically, there is likely to be several years of 'running in' of new Stations, data acquisition and data processing methods before the FEWS network becomes fully reliable and operational.

During this time it is more useful for the staff to focus on basic (rough) forecasting methods and developing sound hydrometeorological expertise of their sub-basins rather than becoming distracted with expensive and complex computer models that may frequently deliver outputs that are wrong or misleading due to unreliable or missing data.

The fluvial outputs from the Macedonia and Kosovo sub-basins are of course particularly important to downstream conditions in Albania and Montenegro. Likewise, extreme weather conditions in Montenegro or Albania moving from the south or west might provides useful early warning to Macedonia or Kosovo.

It is a **recommendation** that the NHMSs should as early as possible develop a coordinated strategy and set of procedures for the manning and communication between flood monitoring control rooms not only during flood emergencies but also in advance of potential flood emergency situations. The greater the lead time, the greater is the awareness and capability to minimise flood damage.

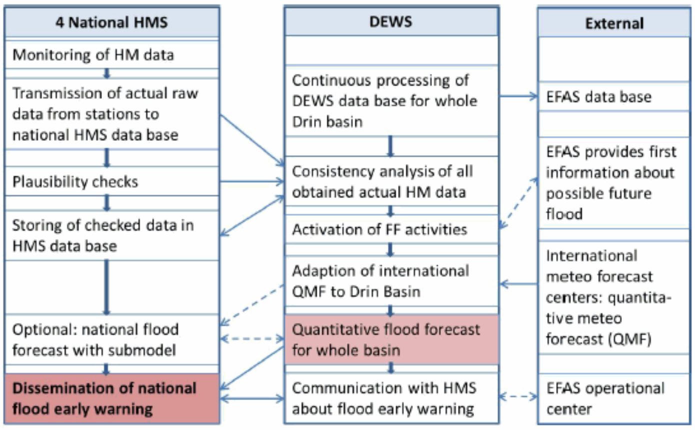
4.2 Rationale for Integrated Regional Flood Warning

Whilst this GIZ procurement focuses necessarily on the rehabilitation/reinforcement of individual Stations in order to generate the essential data (and this will be of significant benefit to the individual NHMSs with strengthened networks for routine monitoring) the end primary purpose is to deliver a functioning regional Flood Early Warning System.

This requires commitment and cooperation from the individual NHMSs to a common good. The Drim-Drin-Buna/Bojana basin is a major transboundary basin, and within the context of the EU Water Framework and Floods Directives, Member States would be expected to cooperate fully and transparently in terms of their data sharing, expertise and management of impacts at the basin scale.

To this end the GIZ project has proposed the development of a regional web-based flood warning system that is also part of this procurement. The overall approach was set out by Meon [1] (Meon Report Figure 9.2). The optimum sequence of activities and exchanges between the individual national hydrometeorological services, the DDBB operational centre and external institutions was set out by Meon, shown here as Figure 4-2.

Figure 4-2 – Optimum Interactions for Regional Flood Warning



Source: Meon [1]

The conceptual operation of a regional IT centre (DEWS as per Meon) was set out by Faulkner [5] as a procurement document.

Central to the approach is the need to collate data from the individual NHMSs in near real-time, and operate a web based system that broadcasts this shared data via a simple but informative website. It is not workable or logical for each NHMS to share with every other NHMS its real-time data. This leads to excessive data exchange paths (12 as opposed to 4 with a central server) plus considerable complexity in how the data are shared with third parties other than the NHMSs.

It is important to emphasise that a regionally based flood warning system is not just for the NHMS benefit. Indeed, it is the general population, municipalities and critical infrastructure providers who should be the main beneficiaries of such as system. This requires a simple, robust, easily accessible and common format source for information distribution i.e. a web-site.

This can be configured easily to give varying levels of information to different users as necessary BUT at the simplest level it is essential that a web based interface provides everybody with the following critical information:

- The locations of the Early Warning Stations (spatial relevance)
- The status of the Station(s) according to some predefined levels of alert (temporal relevance) (see Section 4.3).

Simple web-based systems such as this are proven to be highly effective for early warning provided that the public, municipalities and infrastructure providers have clear sets of actions based on these levels of alert
The key to successful regional early warning is automation via a reliable website and SMS messaging. Monitoring Stations can

[5] DDBB River Basin Flood Early Warning System – Web Based Decision Support System (Draft)

be programmed to send SMS alerts automatically with a significant change in data to ANY registered user 'Balkan-wide', and scripts running on the data acquisition software can automate colour coding on the web-site depending on the data state compared to historical or operational criteria.

Excellent examples of simple, automated web-based early warning systems include:

- www.meteoalarm.eu
- www.wunderground.com

As has been emphasised many times to the individual NHMSs, and Figure 4-2 makes clear, this system does not in any way replace or supersede the national flood warning and flood forecasting responsibilities. At the national scale, these have priority. However, upstream sub-basins also have unavoidable international responsibilities to continually monitor and inform downstream sub-basins of impending hydrometeorological conditions.

The most logical and technically efficient way to operate such a system is via a 'regionally based' data server and web site rather than on a 1 to one basis between each NHMS which is informationally inefficient and complex. The physical location of such a server is actually irrelevant, since all the data would be accessible to all NHMS in near real-time. More important is the requirement to have a single Agency that has administrative responsibility for ensuring that the regional data server is operational 24/7/365, and that the web-site is updated in real-time.

Accordingly the most logical place for the data server is in the country most affected by regional flood events as previously agreed i.e. Albania providing it can guarantee the necessary IT support and web reliability required.

There are unquestionably significant benefits for every country in the DDB FEWS, irrespective of their location, (less so for flooding in Macedonia and Kosovo since these are upstream river basins), but these sub-basins will still benefit from regional meteorological data. It is not just about data. Cooperation and integration yield wider benefits in terms of training, professional experience and future funding.

Regional flood forecasting as envisaged by Meon is an altogether more complex activity, and will require the development of a calibrated basin wide forecasting model dependent on very high reliability of data inputs. Such an integrated model is probably some years in the future, by which time the individual and cooperative roles of each NHMS in the DDBB Flood Early Warning System will be clearer.

In the interim, it is more important to develop basin wide common standard and formats for simple and clear public information and warning, discussed below.

4.3 Common Standards for Flood Early Warning

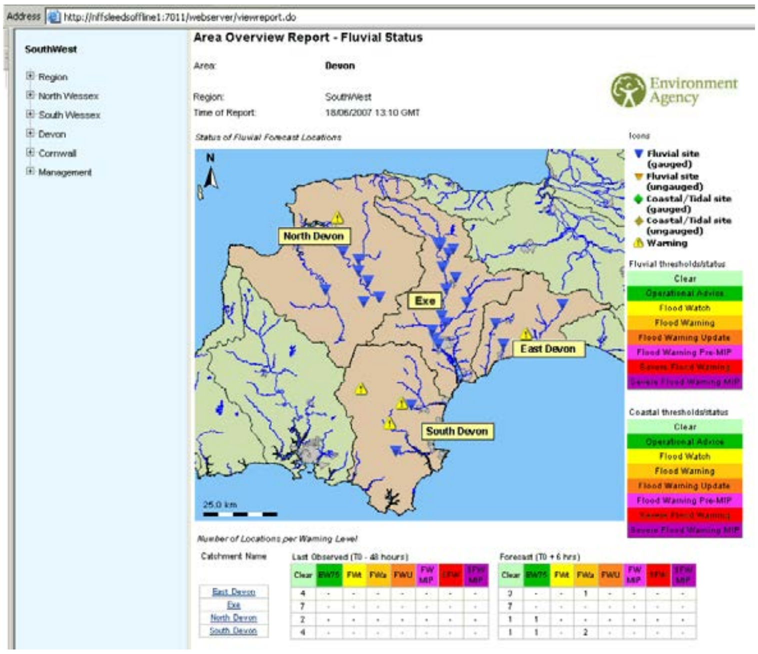
4.3.1 International Sources

To achieve commonality of approach between the four NHMSs, it is useful that they should refer to three major reference documents:

- Integrated Flood Forecasting, Warning and Response System (Part 3 of "Guidelines for Reducing Flood Losses", UN/ISDR 2001)
- Guidance on Flash Flood Management – Recent Experiences from Central and Eastern Europe, APFM, 2007
- Manual on Flood Forecasting and Warning, WMO No. 1072, 2011

These documents contain a wealth of guidance and practical steps for effective flood forecasting and warning systems. For an integrated river basin approach, it is of course essential that the four NHMSs develop standardised procedures.

Figure 4-3 - Multi Level Warning System – UK NFFS



Source: UK National Flood Forecasting System

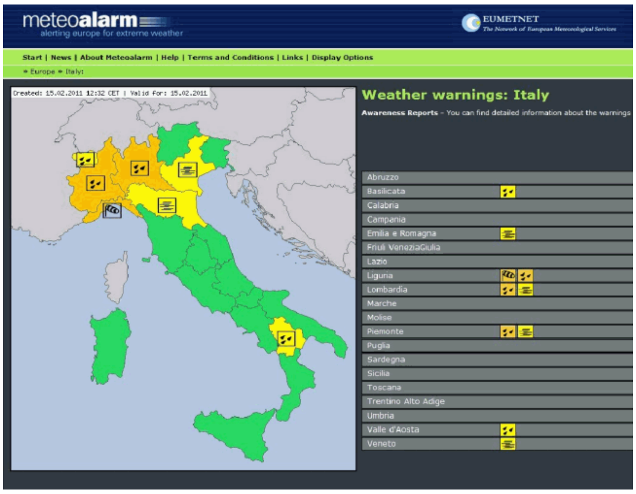
4.3.2 Standardised Levels of Alert

Irrespective of the individual national emergency response plans, it is still necessary for the four NHMSs to agree and coordinate the use of simple and effective transboundary early warning protocols.

Most national Agencies in the EU have adopted a similar approach to quantifying and visually communicating hazard warning. The UK Environment Agency operates actually eight levels of flood warning, but these are all consistently colour coded in all forms of communication (see Figure 4-4).

The European MeteoAlarm system uses an identical 'weather awareness' colour coded system and a simple set of icons to communicate meteorological hazard. A similar system is envisaged for the DDBB Flood Early Warning System website (Figure 4-5. (www.meteoalarm.eu).

Figure 4-4 – Alert Colour Coding in MeteoAlarm



4.3.3 Communication of Real-time Flood Warnings

International best practice [6] has shown that it is useful to communicate risk to the general public with simple colour code based messages. Additionally, not more than five key pieces of information need to be conveyed in order to minimise flood risk impacts:

- The expected time of the flood
- Clear instructions on what to do
- How severe will the flooding be (duration, depth)
- Which areas will be flooded
- The height of the flood in relation to local landmarks

Typically, in the flood warning hierarchy there are not more than five principal colour coded levels, for example:

Table 4-1 – UK Flood Early Warning Codes

Code	Status	Communication Message
	Clear	All Stations Normal
	Operational Advice	Infrastructure operators and key people notified
	Flood Alert	Flooding is possible. General public to be prepared
	Flood Warning	Flooding is expected. Immediate action required
	Severe Flood Warning	Severe flooding will occur. Danger to life. MIP [7]

Of course many of these issues should be covered in Local/Municipal Flood Management Plans, BUT the key message is that the entire flood monitoring, flood forecasting, flood warning and flood management results chain should use a consistent colour coded approach at every level.

In fact as explained in 4.4.3, practical experience shows it is preferable to use a blue schema for floods and red schema for droughts. In this way a single national emergency alert system can be used for both floods and droughts.

It is a **recommendation** that the NHMSs coordinate to agree that at the river basin scale, a consistent set of flood alert status levels, messages and colours are used with the same meaning and same level of probability in each DDBB country.

4.4 Basic Forecasting and Early Warning

Elementary hydrometeorology should not be overlooked in a Flood Early Warning System. Often, a broad scale regional forecast based on simple assessment can be more effective than a highly complex distributed analysis based on too many sources of information at the micro-scale which can often produce conflicting information.

Continuous monitoring of antecedent conditions is of critical importance for early flood forecasting. Increasing lead time significantly increases the potential to lower the level of damages and loss of life. There is a clear sequence of catchment conditions that can be monitored at a basic level of analysis to provide rough forecasting and flood early warning at decreasing time resolutions:

- Winter snowpack (60-90 days)
- Reservoir State (30-90 days)
- Daily and Seasonal Norms (15-30 days)
- Antecedent Rainfall Depth and Intensity (7-20 days)
- Antecedent River Level and Rate of Rise (1-7 days)

For areas prone to flash flooding, the last two conditions assume particular importance as long-duration forecasts are unlikely to be feasible.

4.4.1 Winter Snowpack

The winter snowpack can be an indicator of potential major floods in the spring as much as 3 months in advance.

It is elementary hydrology that extreme build up of winter snow coupled with a sudden thaw will initiate potential flood conditions. This occurred in winter 2007 in Kosovo, with record snow levels. Several hydrologists identified the potential risk many months in advance but it was ignored by the NHMS, and the ensuing spring flood created significant problems at the KEK Power Stations which could have been prepared for.

Unfortunately snowpack is difficult to monitor at high altitude, but it remains one of the primary early indicators of flood hazard. It is a **recommendation** that the Macedonia NHMS monitor and report on the performance of the Campbell Scientific SR50A snow-depth sensors that will be installed in this project. If these are reliable and useful, then similar sensors could be installed at several more high altitude Stations throughout the DDBB basin to provide automatic updates of snow depth and temperature linked in to the DDBB Flood Early Warning System.

[6] Communicating Risk and Uncertainty in Flood Warnings – UK Environment Agency 2009
[7] MIP – Major Incident Plan may need to be activated

4.4.2 Reservoir State

Major Dams and reservoirs represent a major artificial influence on flood propagation and/or attenuation. Monitoring of reservoir levels, in conjunction with the operating rules of the Dam are critical elements in national as well as regional flood warning.

The significant lack of real-time data communication and cooperation between the power generating Authorities in Macedonia and Albania (ELEM and KESH respectively) and the NHMS is a significant hindrance to effective early warning and would not be permitted in Western Europe.

As the events of 2010 showed, unscheduled releases from the high Dams were as much responsible for creating the flood as absorbing it. With proper monitoring of upstream river basins, and rough forecasts, it seems plausible that controlled releases could have been coordinated between all of the high Dams in order to create attenuation storage.

Monitoring of reservoir level is therefore critical to both flood forecasting and warning, and the politics and self-interest of the national power Authorities should not be allowed to stand in the way of national and regional flood protection. Flood damage disruption and costs will far exceed that value of the electricity produced. It is also totally evident that the power generating Authorities would themselves significantly benefit from improved forecasts of upstream inflows into their reservoirs with respect to Dam safety and optimised hydropower management.

For this reason the GIZ project has committed significant funding to improving the data acquisition from the Dams in Albania. KESH has indicated a willingness to cooperate but access to data is not at all assured at this time. The Dams in Macedonia have undergone separate significant international investment with regard to instrumentation and the hydrometeorological equipment at Globocica and Debar, and this data must be shared with the NHMS in order to provide effective flood monitoring, although again this cooperation is not confirmed at this time.

It is a **recommendation** that the NHMSs in Macedonia and Albania, with the full support of GIZ, seek the full cooperation of ELEM and KESH to cooperate and share acquired data for flood control. In the medium term, once reliable long-term (15 day+) flood forecasts become available, it will be necessary to develop pre-emptive reservoir operating rules with respect to different flood inflow magnitudes.

4.4.3 Daily and Seasonal Norms

It is essential to continuously monitor the daily meteorological and river flow values and compare these in real-time to the long-term n-day mean values. 1, 2,7, 15, 30 and 90 day maxima and moving averages of precipitation or river flow are commonly used and can be easily calculated for individual Stations from good quality historical data, and these values can be stored in lookup Tables superimposed over the real-time plots of data being transmitted from the Stations.

Using programs such as SEBA-Hydrocenter™, WISKI™, OTT Hydras 3™ or HydroPro™ immediately shows whether the observed precipitation/river level is above/below the average for that day/week/month, and by how much.

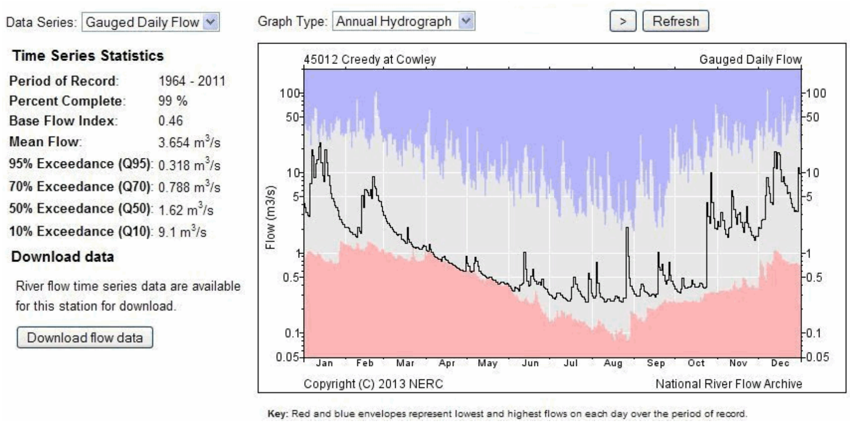
Simple routine monitoring such as this (internal to the flood monitoring centre and possibly infrastructure operators) heightens awareness that antecedent conditions are developing such that further amounts of precipitation and/or runoff may create flood hazard.

At a very early stage, professional, Government and Municipality staff focal points can be put on standby, and the useful lead time for flood awareness can be increased by many days.

This analysis of n-daily and monthly norms and maxima from individual Stations is the first step in defining the necessary alert levels for precipitation amount, precipitation intensity and water level that would be used within the flood warning process. Figure 4-6 is an example from the UK National Flow Archive where the long-term mean daily flow is plotted, together with critical flow statistics from the Flow Duration Curve such as the Q50 and Q10.

It is a **recommendation** that the NHMSs start to process all of the historical daily precipitation and level/discharge data from representative Stations in order to determine the long-term norms, rates of change and the thresholds for flood alerts. Some centralised training in the appropriate methods may be useful.

Figure 4-5 – Quantification of Station Specific Regime with Minima and Maxima



Source: UK National River Flow Archive

4.4.4 Antecedent Rainfall and Rainfall Intensity

As for snowpack, but on much shorter timescale (7-20 days), continuous monitoring and analysis of cumulative rainfall depth provides a critical indicator of hazard potential.

Obviously the gradual depletion of the soil moisture deficit means progressively less buffering capacity in the rainfall-runoff process, and faster and more extreme catchment response to any subsequent major meteorological event.

Since the impact of rainfall depth and rainfall intensity is always relative to altitude and location, such data need to be statistically standardised so that consistent comparisons can be made between Stations. This is explained more under Section 4.4.

4.4.5 Antecedent River Level and Rate of River Level Rise

In the fourth stage, and with the shortest lead-time, rivers at or near bankfull obviously represent significant potential hazard if a subsequent major meteorological event develops.

Providing the alert thresholds have been pre-determined (see 4.4.3), then most dataloggers and/or data acquisition packages have the capability to trigger early warning alarms based on river levels exceeding e.g. bankfull or some other pre-determined level OR a rate of rise over a defined period. An increasing rate of rise may be difficult to detect visually from a PC screen, but most dataloggers can automatically trigger an SMS alarm if a sudden and non-normal change in water level is detected.

Analysis of daily flow data (moving average, maxima and rates of change) have been already **recommended** under 4.3.3.

4.5 Standardisation of Data across Sub-Basins

4.5.1 Data Transfer Formats

With regard to inter-Agency data exchange, there are already in place internationally agreed data formats. Meteorological data that is internationally compliant with respect to data transfer should comply with the formats and protocols defined by the World Meteorological organisation (WMO) WMO Information System (WIS).
http://www.wmo.int/pages/themes/wis/

Hydrometric data is now subject to the recently agreed international standard of WaterML2 for hydrological time-series, and the European Flood Alert System (EFAS) is also gradually complying with this standard.
http://www.waterml2.org/

The GIZ procurement has sought to ensure that all the data systems and software supplied will comply with these standards. Therefore, when the national Flood Early Warning System data servers are installed, they should theoretically be able to share data with a minimum of reconfiguration.

4.5.2 Statistical Standardisation and Index Values

One of the most significant technical issues to be addressed by the four NHMSs is the standardisation of event probabilities at the river basin scale. In fact, even at the national level, it is necessary to standardise data so that different events (meteorological and hydrological) can be compared statistically on a like for like basis.

For example, comparing flood peak flows of say 112 m³/s from Station Ložani (Macedonia) and 134 m³/s at Station Gryka Prizren (Kosovo) with respect to event significance is somewhat meaningless. Absolute values are dependent on the prevailing climate and meteorology and the catchment characteristics, and the respective probabilities of these two values will be completely different.

With respect to deterministic modelling, of course the absolute values are relevant for rainfall-runoff, but in terms of regional comparison and flood probability, data must be standardised (divided by the mean value) and then fitted to a probability distribution so that direct comparisons can be made between events in the same sub-basin or catchment, and/or the same event in different sub-basins.

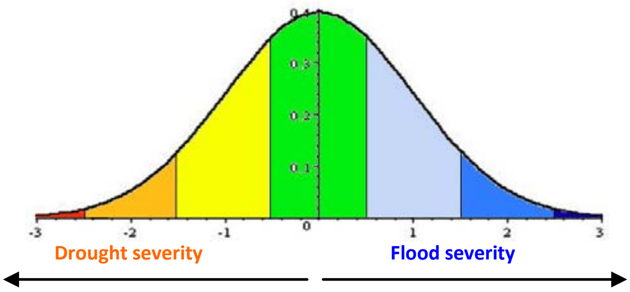
The most common meteorological Index is probably the Standardised Precipitation Index (SPI) which is the main Indicator for drought potential used by the Drought Management Centre for South East Europe (DMCSEE).
www.dmcsee.org

However, the technique can be used for any hydrometeorological dataset, and it lends itself to graphical representation, which is particularly useful for regional flood (or drought) warning.

A Standardised Index is a statistical measure of precipitation (or water level or discharge) deviation from the long-term mean that allows direct comparison between Stations or river basins. It allows an analyst to determine the probability of an observed value relative to the historical record. The index is always specific to a time period and unique to each data station analysed. The index needs to be prepared for different time periods, typically 1_D, 2_D, 7_D, 14_D, 30_D, 60_D and 90_D days, and would generally have to be recomputed after a major event or an extreme wet year.

Such an index is a representation of the number of Standard Deviations (σ) from the data Mean at which an observed value occurs, called the "z-score". The unit of the index can thus be considered to be "standard deviations". Because Standard Deviation is used as the basis for the index, observed values from different events or river basins can be compared directly in terms of the relative severity measured, not the absolute or actual value, which is an essential component of regional flood warning.

Figure 4-6 - SPI Shown in Terms of Standard Normal Distribution



Normalised and standardised Indexes use data fitted to the normal probability function. Normalised distributions have a Mean of 0.0 and Standard Deviation of 1.0, as follows:

For example, an SPI value of 0 in any particular time period (7, 14, 30 days etc) indicates that precipitation conditions coincide with the long-term average condition for that time period. The probability of any value of the index is shown on the Y-axis, so in Figure 4-7 for example the probability of the rainfall value in a specific month being at the long-term mean/median (SPI = 0) is approximately 40%.

(The overall shape of the Normal Probability Distribution function will be different for every hydrometeorological station depending on the data spread and kurtosis).

4.5.3 Probabilistic Based Early Warning and Response

Probabilistic Flood forecasting and early warning is essentially about recognising extreme departures from the norm.

A standardised index is easy to understand and disseminate. Its most valuable property is that it has probabilistic relevance because it is based on the standard deviation characteristics of the data.

In practice the 7_D, 14_D, 30_D, 60_D and 90_D index values are computed from the historical record for each Station, and stored in lookup Tables. From the acquired data in the field, simple programs can continuously monitor the observed e.g. 7_D, 14_D, 30_D mean values and compare them to the historical reference indexes.

If an observed value exceeds a particular index, automatic alarms can be configured. This type of automated analysis is extremely powerful in producing very early warning. For example, simply observing that Station X has recorded 90mm of precipitation in the last 7 days is of little practical value for flood early warning. Is it significant? One must relate it statistically to the data record to know if this is an average, above average OR possibly extreme value. If so, how extreme?

Table 4-2 shows how a standardised index can be interpreted in practical terms for flood early warning. Irrespective of the data type or time period, providing the data has been normalised, any index value I >= (1.0) has an annual occurrence probability of 15.9%. I >= (1.5) = 6.7%, I >= (2.0) = 2.3%, I >= (2.5) = 0.62%.

A value corresponding to the median of the dataset will have a probability of occurrence of 50%. 'Normal' values typically range between 31% and 69% cumulative probability i.e. standardised values between +0.5 and -0.5.

The use of standardised indices therefore removes all subjectivity from basic forecasting and early warning AND can be used to force consistent levels of alert between sub-basins which is of course critical for regional flood warning.

For example, 100mm precipitation in 1 day in sub-basin Macedonia will have completely different flood risk significance from 100mm in sub-basin Albania, and they cannot be meaningfully compared. However, an output that confirms that this is equivalent to a 5% (1 in 20) probability occurrence in Macedonia and a 20% (1 in 5) probability in Albania is much more useful for flood warning and preparedness.

Table 4-2 – Normal Probability Distribution of Standardised Index and Alert Triggers

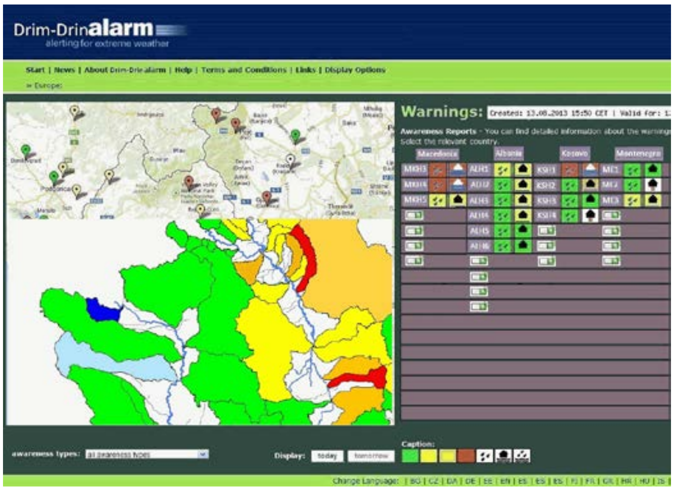
SPI Value (σ)	Cumulative Probability	Description	Colour Code
+ 3.0	0.0014	Extreme flood conditions	
+ 2.5	0.0062		
+ 2.0	0.0228	Severe flood conditions	
+ 1.5	0.0668		
+ 1.0	0.1587	Moderate flood conditions	
+ 0.5	0.3085	Precipitation slightly above normal	
0.0	0.5000	Precipitation conditions fit long-term average	
- 0.5	0.6915	Precipitation slightly below normal	
- 1.0	0.8413	Moderate drought conditions	
- 1.5	0.9332		
- 2.0	0.9772	Severe drought conditions	
- 2.5	0.9938		
- 3.0	0.9986	Extreme drought conditions	

Source: Faulkner 2010

As Table 4-2 shows, it is also possible to then use the standardised index to trigger various levels of flood alert and emergency response. This concept is already in use at the DMCSEE. Index values can be reported numerically (e.g. data alerts) but can also be automatically colour coded on the DDBB website against individual Stations or catchments (Figure 4-6).

Because the index is numerically quantified, it means that statistically consistent triggers and responses are initiated across all sub-basins irrespective of the actual data values. This is probably the biggest single advantage of the standardised approach.

Figure 4-7 – Automatic Colour Coding of Index Values



It is a priority **recommendation** that the individual NHMSs agree to analyse their respective daily meteorological and hydrological datasets to determine the 1_D, 2_D, 7_D, 14_D, 30_D, 60_D and 90_D probability distributions for all Stations within the Flood Early Warning network in order to produce standardised indexes of flood probability.

In due course these functions can be incorporated into the hydrometeorological software packages used in the NHMSs to generate automated web graphics or comparison with predefined alert values.

4.6 Advanced Forecasting and Early Warning

Advanced forecasting and long lead-times for early warning will most likely require complex hydrological rainfall-runoff modelling AND considerable training of flood forecasting specialists in the DDBB arena. This is perhaps some 5-8 years+ in the future, and will first require the consistent and continuous operation of a very reliable data acquisition network in every country in order to establish suitable datasets and acquire the necessary expertise. This is yet to be proved.

The individual NHMSs may prefer to operate their own preferred advanced forecasting software for national purposes. HOWEVER in the context of the DDBB Flood Early Warning System there is still a need to identify appropriate regional hydrological modelling tools that can be used conjunctively by all the NHMS, either as distributed sub-models or as a single 'mega-model'.

It is premature to discuss advanced modelling preferences at this stage, but some options are briefly mentioned which the DDBB Technical Working Group might wish to evaluate in future (4.6.2 to 4.6.5).

4.6.1 Moving from Rough Forecasts to Complex Forecasts

In a review of the first 10 years of the UK National Flood Forecasting System (NFFS) it was concluded that the most significant improvements in forecasting capability came from:

- Improved Stage-Discharge ratings

  This led to better accuracy of flood volumes used in deterministic models and was significant in improving Severe Flood Warnings

- Development of 0-6 hour catchment based radar forecasts

  This meant that flash flooding was much better predicted. It was necessary to link back the radar forecasts into the fluvial prediction models i.e. to interface the meteorological and hydrometric systems

- Improving the quality of the boundary conditions and initialisation parameters for 'cold-start' rainfall-runoff models

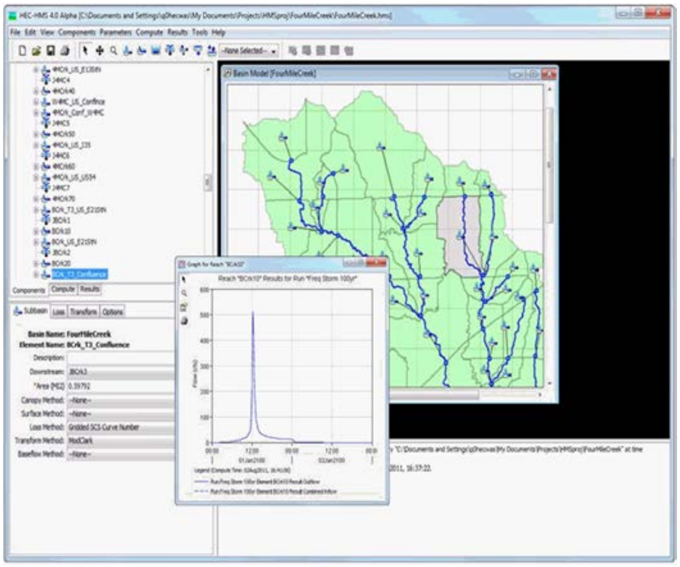
  This meant that models made better use of real-time data ('hot starts') and so were faster to stabilise and therefore more capable to predict short-term outcomes

4.6.2 HEC-HMS Rainfall Runoff Model

HEC-HMS (Hydrologic Engineering Center-Hydrologic Modelling System) was developed by the US Corp of Army Engineers and is free to download.

HEC-HMS is designed to simulate the precipitation-runoff processes of dendritic drainage basins. It is designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff. Hydrographs produced by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation.

Figure 4-8 – HEC-HMS River Basin Model



Source: http://www.hec.usace.army.mil/software/hec-hms/

Meteorological data analysis is performed by the meteorological model and includes precipitation, evapotranspiration, and snowmelt. Six different historical and synthetic precipitation methods are included. Two evapotranspiration methods are included at this time. Currently, only one snowmelt method is available.

A simulation run is created by combining a basin model, meteorological model, and control specifications. Run options include a precipitation or flow ratio, capability to save all basin state information at a point in time, and ability to begin a simulation run from previously saved state information. This makes it useful for flood forecasting purposes.

HEC-HMS is an excellent training model because of the intuitive interfaces, cross-referencing data file systems, and configurable simulation options (multi-scenario optimisation etc). It is used by many Universities. With appropriate data and expertise, a HEC-HMS model will match the capabilities of many of the more 'sophisticated' and expensive commercial packages.

A particularly strong feature is the explicit modelling of control structures such as Dams, gates and weirs.

One of HEC-HMS most powerful features is 'parameter' estimation' whereby input parameters such as snowpack, evapotranspiration or soil moisture can be reverse calculated from observed streamflow, assuming that input data are missing. This is very likely to be the case in the Drim-Drin basin for many catchments.

A disadvantage is that currently it is not well suited to automatically updating with real-time data. It requires the manual configuration of boundary condition files, which could be very time consuming for a large basin.

However, it is evident that river basin hydrology is not well understood at the present time by most staff in the NHMSs. Before embarking on complex flood forecasting tools, some years spent developing a robust and informative 'baseline' river basin model with HEC-HMS would be a) an excellent training exercise b) inexpensive c) feasible on a sub-basin model for each NHMS, which could be easily linked at a later stage as a 'mega-model'.

It is a **recommendation** that the DDB TWG consider the early development of a HEC-HMS based river basin model for application in all sub-basins. This tool would aid considerably the understanding of the key rainfall—runoff processes in the basin, and could be progressively enhanced as a flood forecasting training model. Each sub-basin could be progressed independently by each NHMS, and linked subsequently.

4.6.3 Flood-PROOFS Rainfall Runoff Model

Flood-PROOFS™ (Probabilistic Operational Forecasting System for Small and Medium Catchments) has already been introduced to the Albania NHMS.

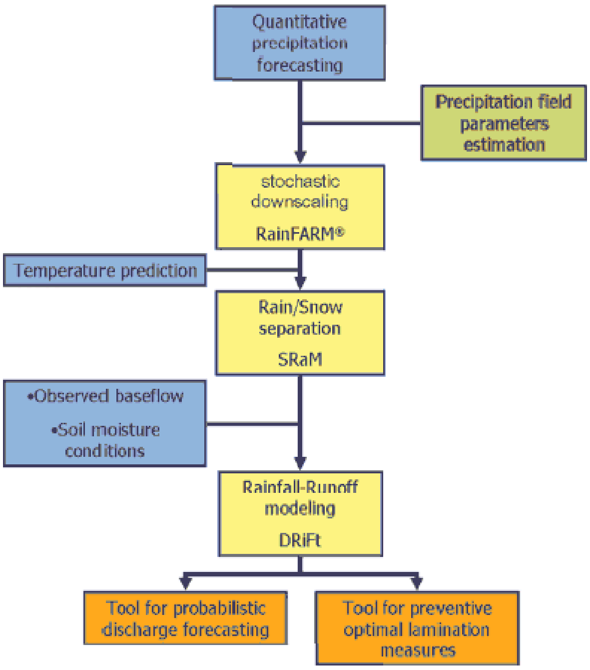
We are of the view that such a model is probably very premature in advance of establishing a reliable data network, and indeed the need for the NHMS hydrologists to first develop a sound hydrometeorological understanding of the sub-basin hydrodynamics.

However, with appropriate data systems and staff expertise, Flood-PROOFS is clearly a powerful and effective flood forecasting tool. It has been specifically developed to run with real time data acquired in the DEWETRA GIS shell and a significant operational advantage is that it can utilise real-time radar data in conjunction with downscaling of the precipitation forecast to produce a fine resolution QPF suitable to small river basins.

To perform a probabilistic discharge forecast a Quantitative Precipitation Forecast (QPF) derived from a Limited Area meteorological Model (deterministic run or Ensemble suite) is fed to a semi-distributed hydrological model DRiFt.

Flood forecasting is generated by an ensemble of scenarios, which can be visualised either as a plot of scenario peaks within the forecast envelope (Figure 4-1) or a probabilistic distribution of flood peaks (Figure 4-11). In this example there is a 10% probability that the flood peak will equal or exceed the 2nd Level Warning threshold of 800 m³/s

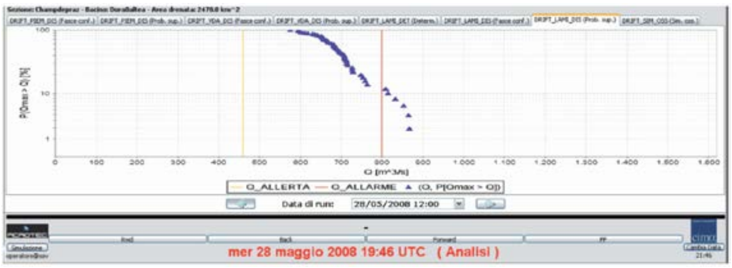
Figure 4-9 – Conceptual Structure of Flood-PROOFS



Source: www.cimafoundation.org

Figure 4-10 – Probabilistic Distribution of Forecast Peak

Note that this probabilistic approach is completely consistent with the standardised Index methodology described in 4.5.2.



Source: www.cimafoundation.org

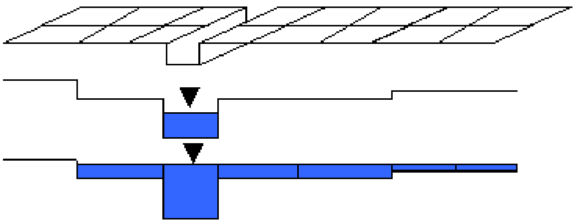
A major potential limitation of Flood-PROOFS at the river basin scale is that it is mainly designed for Alpine environments and small to medium catchments less than 1000 km² where times of concentration are typically less than 12 hours. To cover the entire Drim/Drin basin effectively, enormous data inputs would be required. Therefore it may not be suitable for large scale river basin modelling where the network density is low and wide floodplains may have a significant influence on flood celerity.

http://www.cimafoundation.org/index.php?option=com_content&view=category&layout=blog&id=89&Itemid=874&lang=en

4.6.4 LISFLOOD Rainfall-Runoff Model

LISFLOOD is a GIS-based 1D/2D hydrological rainfall-runoff-routing model designed to be the simplest physically plausible representation capable of simulating dynamic flooding, thereby allowing large areas to be modelled at fine spatial resolution (10-100m cell sizes).

The model was designed to work on a regular Cartesian grid to allow ready integration with available GIS data sets. Effectively, flooding is treated using an intelligent volume-filling process based on hydraulic principles and embodying the key physical notions of mass conservation and hydraulic connectivity.



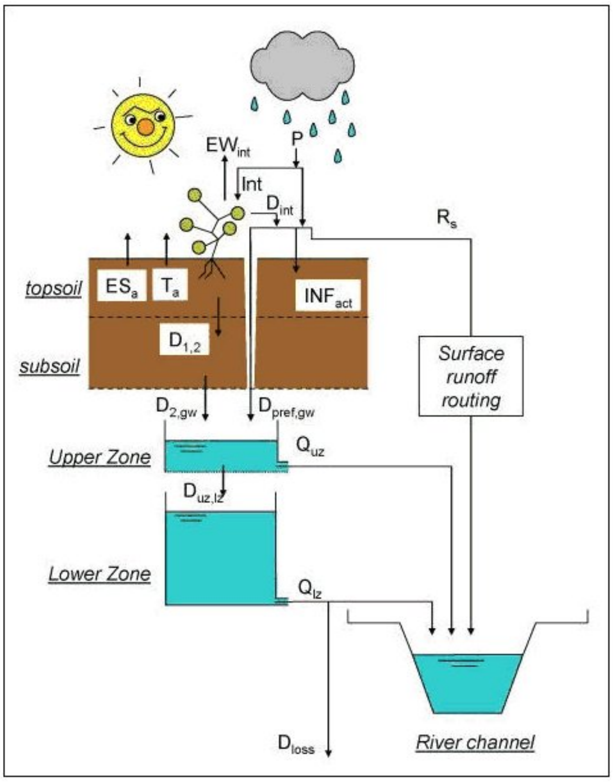
It was developed in 2000 jointly between the University of Bristol (UK) and the EU Joint Research Centre. The specific development objective was to produce a tool that can be used in large and trans-national catchments for a variety of applications, including flood forecasting and assessing the effects of river regulation measures, land-use change and climate change.

It is therefore a particularly appropriate tool for large river basins. LISFLOOD is GIS based, and therefore needs spatially distributed input maps on topography, the river channel network, land cover (CoRINE land use classes), and soils. The driving meteorological variables that are required are rainfall, potential evaporation and daily mean air temperature.

The most significant advantages of LISFLOOD in the context of the DDBB river basin are that:

- It is the river basin model of choice in use by EFAS to generate regional flood forecasts. Since the DDBB Flood Early Warning System may in time contribute to and use forecasts from EFAS, expertise in this model may be an advantage
- It is particularly suitable to large river basins, which Flood-PROOFS is not.
- It is designed to work with Digital Terrain data thereby physically modelling large areas very rapidly.

Figure 4-11 – Conceptual Structure of LISFLOOD



Source: http://floods.jrc.ec.europa.eu/lisflood-model.html

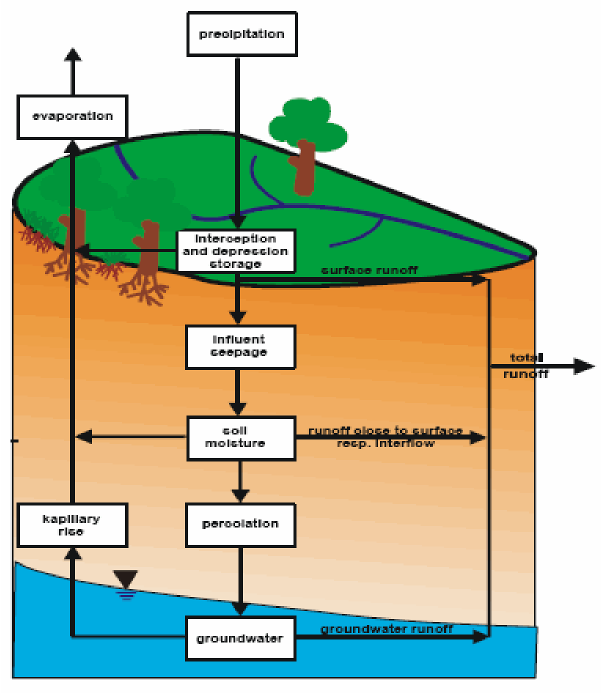
4.6.5 PANTA RHEI Rainfall-Runoff Model

PANTA RHEI is a conventional hydrological or rainfall-runoff model system. It is spatially distributed and supported by GIS. The software code was developed at the Leichtweiss Institute of Hydraulic Engineering and Water Resources (LWI), University of Braunschweig, Germany. The model is currently used for flood forecasting in Lower Saxony, but otherwise is not widely known.

An advantage of the model is its spatially distributed structure. However, most current models share this approach. An essential requirement of a flood forecasting model is the capability to perform complex hydraulic routing of flows especially in large '2D' floodplains. LISFLOOD has this capability for example which is why it is used by EFAS.
The capability of PANTA RHEI appears less sophisticated, as it performs only hydrological routing within the software code.

Hydrologic routing will give the time and magnitude of the flood peak, but not its actual elevation with respect to the channel and floodplain geometry. Hydraulic routing in PANTA RHEI requires linking the hydrological model to a separate hydraulic model, which then introduces another layer of complexity. Generally, for accurate hydraulically based forecasting it is desirable to have a single modelling system.

Figure 4-12 – Conceptual Structure of PANTA RHEI



In the early years of the DDBB Flood Early Warning System, it will be necessary to review the different options, benefits and disadvantages (including training and long-term support needs) of the various models and select one that delivers the broadest advantage overall to all the NHMSs, given that the skills and specific requirements of each NHMS will be different at sub-basin level.

Ideally the preferred model would be useful both at the regional scale and at the sub-basin (local) scale also, thereby avoiding the need to be trained in more than one model with all the additional complexities of different data inputs and outputs.

4.7 EFAS – European Flood Alert System

The Meon Report [1] recommended further collaboration with the European Flood Awareness System (EFAS) in order to transmit data from the DDBB Flood Early Warning System, and in exchange, receive medium-range flood forecasts for Europe, via the Dissemination Centres, with a forecast lead-time between 3 to 15 days.

The computational component is hosted by the European Centre for Medium-Range Weather Forecasts (ECMWF, UK). Since flood warning is a Member State responsibility, only archived flood warnings can be made publicly available. The real-time warnings are made available to the national partner institutes only.

4.7.1 Current EFAS Procedures

EFAS runs a state-of-the-art flood forecasting system with several pioneering products, such as probabilistic flood forecasting for entire Europe on a 5x5 km2 grid using the LISFLOOD model, and novel analysis and communication methods used for interpretation of multiple forecasts.

Flood information is based on ensemble weather forecasts that are pushed through the hydrological model and summarised in an overall probability to exceed critical flood thresholds. The critical thresholds are derived from long-term simulations using observed weather data as input and using the same system set-up as used for the operational forecasts. This means:

- The more and better historical and real-time meteorological observational data are available for the long-term simulations (from country networks), the more robust and reliable are the thresholds and initial conditions.
- The more discharge data are available for the calibration and validation phase, the better the hydrological model can be adapted for the different river basins and the model results improve.
- Where real time hydrological data are provided, the model can also perform post-processing of forecasts at these Stations. In this case the partners can access these data and incorporate them directly into their system, thus allowing them to integrate the 10-15 day probabilistic discharge forecasts of EFAS into their local method.

Ideally, EFAS requires meteorological data of precipitation, temperature, and variables allowing the calculation of evapotranspiration such as cloud cover, wind speed and direction at a temporal resolution of 6 hours. Discharge data needs to be supplied at a time-step of not more than 6 hours. Real-time data undergoes some rudimentary quality checks for min/max and seasonal means, but it is expected that national NHMS will be supplying quality controlled data.

4.7.2 Benefits of EFAS Cooperation

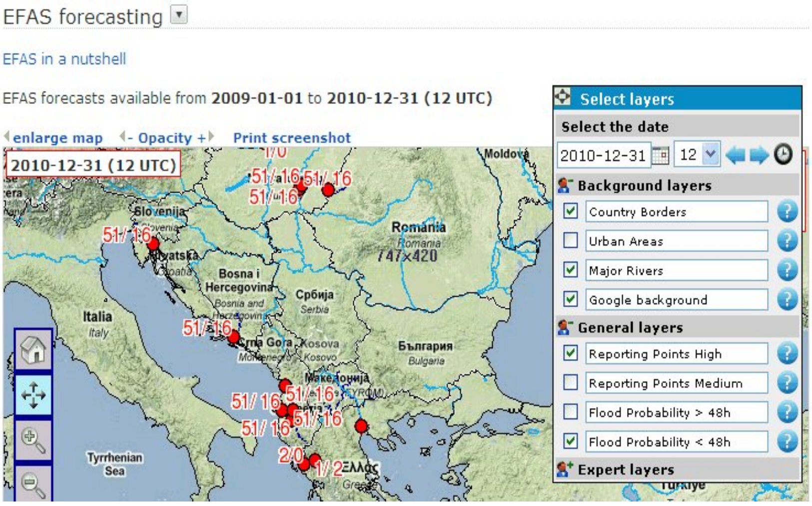
Membership and active collaboration with EFAS is of course a desirable target in the medium term. However, the Meon Report and this Report have concluded that the capacities and resources of the four national NHMSs are unlikely to meet acceptable criteria for data reliability and quality for some years.

For example, EFAS is actively moving its data transfer protocols over to WML2, and until this protocol is also well established in the DDBB NHMSs, datasets will not be compatible. This should be an outcome of the current procurement. There are of course strict criteria for data reliability and accuracy.

The priority must be for each NHMS to demonstrate that **nationally** it can maintain a first class data network with minimum outage time and high levels of data quality, and **regionally** that it has reliable data management and communication systems which it is prepared to share fully and transparently before becoming part of the EFAS network.

Consequently, a **recommendation of** this Report is that the priority focus in Years 1 to 3 should be to demonstrate internationally acceptable first class outputs from reliable networks including data processing and archiving before engaging fully with the EFAS system. It is feasible that due to the generally reliable standard of the Stations in Montenegro, this country could engage earlier with EFAS on a pilot study basis.

Figure 4-13 – EFAS Flood Forecast Capability



However, EFAS has already confirmed with GIZ that the NHMSs can all subscribe to EFAS initially without a commitment to supply data. The DDBB countries will therefore benefit from the EFAS forecasts. Of course, without real-time data from the DDBB Stations, the EFAS forecast for the Drim-Drin basin will be very approximate, but its potential usefulness can be studied.

We would also **recommend** therefore that each DDBB country apply for 'observer' membership of EFAS (without data commitments) to learn from the principles and practices of an existing Flood Early Warning System and understand the wider benefits of regional cooperation.

The following are some of the key benefits membership of EFAS for the Member States' national hydrological services.

- Timely information on possible flood situations across Europe more than 3 days in advance, based on multiple medium-range weather forecasts.
- This allows the national services to compare their own results against another reference model and complement their systems with information derived from different NWP inputs.
- Consistent and coherent probabilistic meteorological and hydrological predictions, allowing users not only to estimate the most likely scenario but also the probability of occurrence of any event of interest.
- Increased interactions between institutions developing meteorological and hydrological numerical prediction systems.
- Participation in EFAS as an exchange platform for information, methods and data.

http://floods.jrc.ec.europa.eu/home.html
www.efas.eu

5. SUMMARY OF RECOMMENDATIONS

5.1 Macedonia

- NHMS Macedonia should prepare evidence for how Meteorological Stations Struga and Slivovo would be supported with an Observer and regular maintenance before these Stations can be funded

- NHMS Macedonia should make every effort to establish full cooperation with ELEM in the exchange and use of data from the reservoirs. NHMS meteorological data from upstream high altitude Stations such as Lazaropole, Mavrovo and Štirovica will be of special usefulness to ELEM with respect to operation of the reservoirs and therefore the benefits are mutual.

- Hydrometric Station Volkovija should be reinstated, but NHMS Macedonia should prepare evidence for how the Station would be supported with an Observer and regular maintenance before it can be funded

- It is a **recommendation** that the Macedonia NHMS monitor and report on the performance of the Campbell Scientific SR50A snow-depth sensors and the Universal Precipitation Gauges that will be installed in this project. If these are reliable and useful, then similar sensors could be installed at several more high altitude Stations throughout the DDBB basin to provide automatic updates of snow depth and temperature linked in to the DDBB Flood Early Warning System.

5.2 Kosovo

- Precipitation Station Junik is likely to be significant, but currently there is no Observer identified for this site, and its security is uncertain. NHMS Kosovo should prepare evidence how the Station would be supported with an Observer and regular maintenance before it can be funded

- If Precipitation Station Junik can be properly maintained, and a reliable Observer appointed, it is a **recommendation** that this site be upgraded in future with additional sensors for snow, humidity, pressure, temperature, and possibly wind data.

- Precipitation Station Istok was established in factory grounds in 2002 as an isolated raingauge. The site is secure and it is a **recommendation** that the NHMS enter into a formal agreement with the site owners to obtain a permanent site. NHMS Kosovo should prepare evidence how the Station would be supported with an Observer and regular maintenance before it can be funded

- Precipitation Station Gjakova requires the relocation within the existing site to a less intrusive location. NHMS Kosovo should prepare evidence how the Station would be supported with an Observer and regular maintenance before it can be funded.

- Precipitation Station Radishevë, since discontinued is important for precipitation input to the Klina river system. It is a **recommendation** that NHMS Kosovo investigate the status and condition of this site and the availability of an Observer before it can be funded.

- An automated raingauge should be installed at the Radoniqi Dam with the cooperation of Radoniqi Water Company which can contribute to the Flood Early Warning System as well as providing useful data for the operation of the reservoir.

- If the Kosovo NHMS can be properly resourced and managed, then it is a **recommendation** that a further five existing hydrometric stations be rehabilitated and upgraded, including Kepuzi, Gjakova, Klina, Drelaj and Deçan. This will require the NHMS to make special efforts with the local municipalities, schools and police to prevent future thefts and vandalism.

- It is a **recommendation** that some exploratory de-silting works be carried out at Kepuzi to see if the stilling well is still operational. If so, a high security and vandal proof automated water level sensor + GPRS transmission might be feasible at this Station.

5.3 Albania

- It is **recommendation** that the Albania NHMS make every effort to establish full cooperation with KESH in the exchange and use of data from the reservoirs.

- Meteorological Station Theth (833m) in the Albanian high Alps will encounter significant snowpack in winter, and is an important 'indicator' Station for snowmelt. It is a **recommendation** that consideration should be given to equipping this Station with an automated snow depth sensor such as the Campbell SR50A.

- Subject to suitable safeguards and security of the Station proved by NHMS Albania, it is a **recommendation** that the NHMS consult with the appropriate Authorities to reinstate Hydrometric Station Kukës at the bridge crossing to monitor the upstream level of Fierzë Reservoir.

5.4 Montenegro

- It is a **recommendation** to reinstate an automated precipitation gauge at Precipitation Station Bogetiçi to provide upstream runoff data for the River Zeta. NHMS Montenegro should prepare evidence how the Station would be supported with an Observer and regular maintenance before it can be funded.

- Precipitation Station Dragovica Polje is located in an area of high snowpack in winter, and is at the headwaters of the Moraça system. It is a **recommendation** that if NHMS Montenegro can establish a reliable Observer at this location, plus a permanent land agreement, this Station should be further funded to full Automatic Weather Station status.

- It is a **recommendation** that NHMS Montenegro seek to reinstate Hydrometric Station Tragaj with a reliable Observer and security safeguards.

5.5 All NHMS – Operational Priorities

- GIZ proposes, and the Consultant is fully supportive of, a Memorandum of Understanding between GIZ and each of the National Hydrometeorological Services (NHMSs) for various duties and obligations arising from engagement in the DDBB Flood Early Warning System.

- A priority **recommendation** would be to formulate a technical working group for the DDBB comprised not only NHMS Departmental Heads, but even more importantly the hydrologists, meteorologists and data engineers who will have to day to day engagement with the national networks and the Flood Early Warning System.

- Typically we would recommend that within international best practice every monitoring Station should be visited and inspected at least once every 3 months. It is a **recommendation** that the Station maintenance reporting is therefore also submitted at 3 monthly intervals.

- The 1950 – 190 historical daily data sets should be digitised and examined by all the national hydrologists as an aid to developing a good understanding of catchment flood response and future national and regional flood risks.

- An up to date discharge database is a clear indicator of a properly functioning NHMS, and it is a **recommendation** that significant commitment to increased current metering and data processing systems is urgently required from each NHMS

- It is **recommendation** that all of the NHMSs become familiar with and adopt the data conventions and standards set out in the Water Framework Directive Common Implementation Strategy (CIS), especially Documents 9 and 22.

- It is a **recommendation** that the four NHMSs should coordinate their river basin and river body numbering systems to be in line with WFD and WISE requirements. This will achieve consistency for flood monitoring and reporting across the river basin.

- It is **recommendation** that the four NHMSs should cooperate and collaborate with respect to the positioning and elevation of all the hydrometeorological Stations of the DDBB system to achieve a common reference system for all these Stations using the EU standard reference systems.

5.6 All NHMS – Considerations for Coordinated Forecasting

- It is the **recommendation** of this Report that highly sophisticated flood forecasting models such as Flood-PROOFS and LISFLOOD are probably not appropriate in the early years of the DDBB Flood Early Warning System (FEWS).

- However, it is wholly necessary to develop a simple web-based decision support system that shows at a basic level the map location of each monitoring Station, and its alert status according to predefined thresholds and an agreed colour scheme.

- The Drim-Drin-Buna/Bojana basin is a major transboundary basin, and within the context of the EU Water Framework and Floods Directives, Member States would be expected to cooperate fully and transparently in terms of their data sharing, expertise and management of impacts at the basin scale.

- It is important to emphasise that a regionally based flood warning system is not just for the NHMS benefit. It is the general population, municipalities and critical infrastructure providers who should be the main beneficiaries of such as system. This requires a simple, robust, easily accessible and common format source for information distribution i.e. a web-site.

- The most logical and technically efficient way to operate such a system is via a 'regionally based' data server and web site rather than on a 1 to 1 basis between each NHMS which is informationally inefficient and complex. It is not workable or logical for each NHMS to share with every other NHMS its real-time data.

- It is a **recommendation** that the NHMSs should as early as possible develop a coordinated strategy and set of procedures for the manning and communication between national flood monitoring control rooms not only during flood emergencies but also in advance of potential flood emergency situations.

- Irrespective of the individual national emergency response plans, it is still necessary for the four NHMSs to agree and coordinate the use of simple and effective early transboundary warning protocols.

- It is a **recommendation** that the NHMSs coordinate to agree that at the river basin scale, a consistent set of flood alert status levels, messages and colours are used with the same meaning and same level of probability in each DDBB country achieved by means of standardised Indices.

- Elementary hydrometeorology should not be overlooked in a Flood Early Warning System. Often, a broad scale regional forecast based on simple assessment can be more effective than a highly complex distributed analysis based on too many sources of data at the micro-scale which can often produce conflicting information.

- It is a **recommendation** that the NHMSs in Macedonia and Albania, with the full support of GIZ, seek the full cooperation of ELEM and KESH to share acquired data for reservoir flood control. In the medium term, once reliable long-duration (15 day+) flood forecasts become available, it will be necessary to develop pre-emptive reservoir operating rules with respect to different flood magnitudes.

- It is a **recommendation** that the NHMSs start to process all of the historical daily precipitation and level/discharge data from representative Stations in order to determine the long-term norms, rates of change and the thresholds for flood alerts for all hydrometric Stations. Some centralised training in the appropriate methods may be useful.

- It is a priority **recommendation** that the individual NHMSs agree to analyse their respective daily meteorological and hydrological datasets to determine the 7_D, 14_D, 30_D, 60_D and 90_D probability distributions for all Stations within the Flood Early Warning network in order to produce standardised indexes of flood probability. Note that this probabilistic approach is completely consistent with the standardised Index methodology described in 4.5.2

- It is a **recommendation** that the DDB Technical Working Group consider the options for the eventual application of a river basin rainfall-runoff model for application in all sub-basins. Such a tool would aid considerably the understanding of the key rainfall—runoff processes in the basin, and could be progressively enhanced as a flood forecasting training model. Each sub-basin could be progressed independently by each NHMS, and linked subsequently. Four principal alternatives have been presented – HEC-HMS, FLOOD-Proofs, LISFLOOD and PANTA RHEI.

- In due course a review of the most appropriate flood forecasting models can be carried out, and a possible training programme prepared. Ideally the preferred model would be useful both at the regional scale <u>and</u> at the sub-basin (local) scale also, thereby avoiding the need to be trained in more than one model with all the additional complexities of different data inputs and outputs.

- With regard to EFAS membership, a **recommendation of** this Report is that the priority focus in Years 1 to 3 should be to demonstrate internationally acceptable first class outputs from reliable networks <u>including data processing and archiving</u> before engaging fully with the EFAS system.

- However, EFAS has already confirmed with GIZ that the NHMSs can all subscribe to EFAS initially without a commitment to supply data. We would also **recommend** therefore that each DDBB country apply for 'observer' membership of EFAS (without data commitments) to learn from the principles and practices of an existing Flood Early Warning System and understand the wider benefits of regional cooperation.

5.7 Expected Deliverables from the GIZ Project

5.7.1 Early Benefits Regionally and Nationally

Assuming that a basic core of reliable Stations is functioning with automated data telemetry, there should be significant early benefits to each NHMS individually and to the region as a whole.

- Foremost, the framework of a Flood Early Warning System is in place even if it is based initially only on regionally shared simple indicators such as precipitation depth and monitored river levels. In itself this will be a major step forward.

- DDBB countries for the first time start to cooperate and share data and expertise. Collectively, DDBB professional staff can benefit from more training and professional support than they would as individual institutions.

- A well organised and functioning DDBB FEWS can be a high-profile mechanism to attract funding and technical assistance from other donors in future.

- Improved monitoring and data sharing systems lay the foundation for the development of a DDBB River Basin Management Plan (RBMP) which will be a high priority expected by the EU once the DDBB countries gain EU membership and will be expected to comply with the Water Framework Directive deliverables.

5.7.2 GIZ Inputs to 2015

Within allocated funds, GIZ envisages being able to support the DDBB Flood Early Warning System during the next 2/3 years for the following specific activities:

- Financing Agreements with individual NHMSs to support preparatory works of sites, field campaigns and some safety equipment.

- Support the establishment of a DDBB Technical Working Group

- Developing a preliminary river basin hydrological model

- Data sharing protocols and trialling of data exchange
- Regional IT set-up with DDBB web-based interface

5.7.3 Stations Still Requiring Upgrading

There remain a number of Stations (20) not considered in this GIZ procurement which are nevertheless very important for comprehensive future flood warning; see Tables 2-1 to 2-8.

- Macedonia – Meteorological (2), Hydrometric (1)
- Kosovo – Meteorological (4), Hydrometric (5)
- Albania – Meteorological (2), Hydrometric (4)
- Montenegro – Meteorological (1), Hydrometric (1).

The majority of these Stations require significant improvement in terms of either land acquisition or entirely reconstructed Stations, which is beyond the budget and timescale of the current procurement. Currently GIZ does not have secured funds for further reinforcement of the network, and cannot make any commitment in this regard.

These Stations have been clearly identified, and most are of importance for national flood warning as well as regional warning. Certainly therefore the individual NHMSs should seek funding for these upgrades, either through international donor support, or even the national budget. The latter approach would be a demonstration of national commitment to environmental monitoring and climate change preparedness.