United Nations Educational, Scientific and Cultural Organization / Federal Institute for Geosciences and Natural Resources, Germany / Global Environment Facility - International Waters: Learning Exchange and Resource Network

Mapping global karst groundwater: a tool to enhance water security

SIWI World Water Week

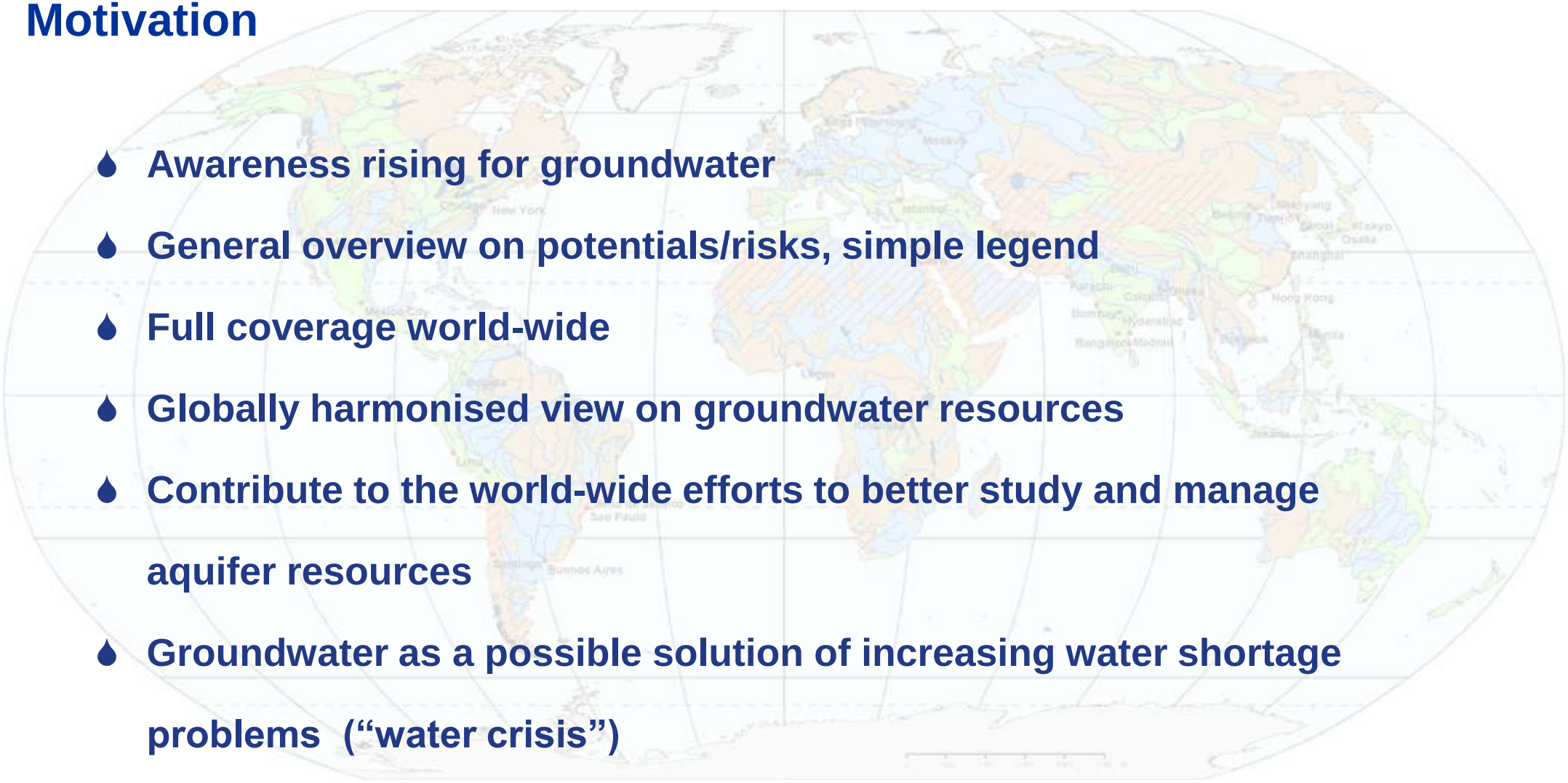
Stockholm , SIWI, Sunday 26 August | 12.00-12.45

The World-wide Hydrogeological Mapping and Assessment Programme – WHYMAP

Dr. Stefan Broda

Federal Institute for Geosciences and Natural Resources (BGR), Berlin

Motivation



- Awareness rising for groundwater
- General overview on potentials/risks, simple legend
- Full coverage world-wide
- Globally harmonised view on groundwater resources
- Contribute to the world-wide efforts to better study and manage aquifer resources
- Groundwater as a possible solution of increasing water shortage problems (“water crisis”)

The WHYMAP Network

IHP National Committees

IGCP

UNESCO Regional Offices

IAEA Isotope Hydrology Section

Vice Presidents (8 regions)

IAH Commissions

National Committees

CGMW Regional Vice Presidents

International programmes, institutions, e.g. GRDC, INBO, GWP …

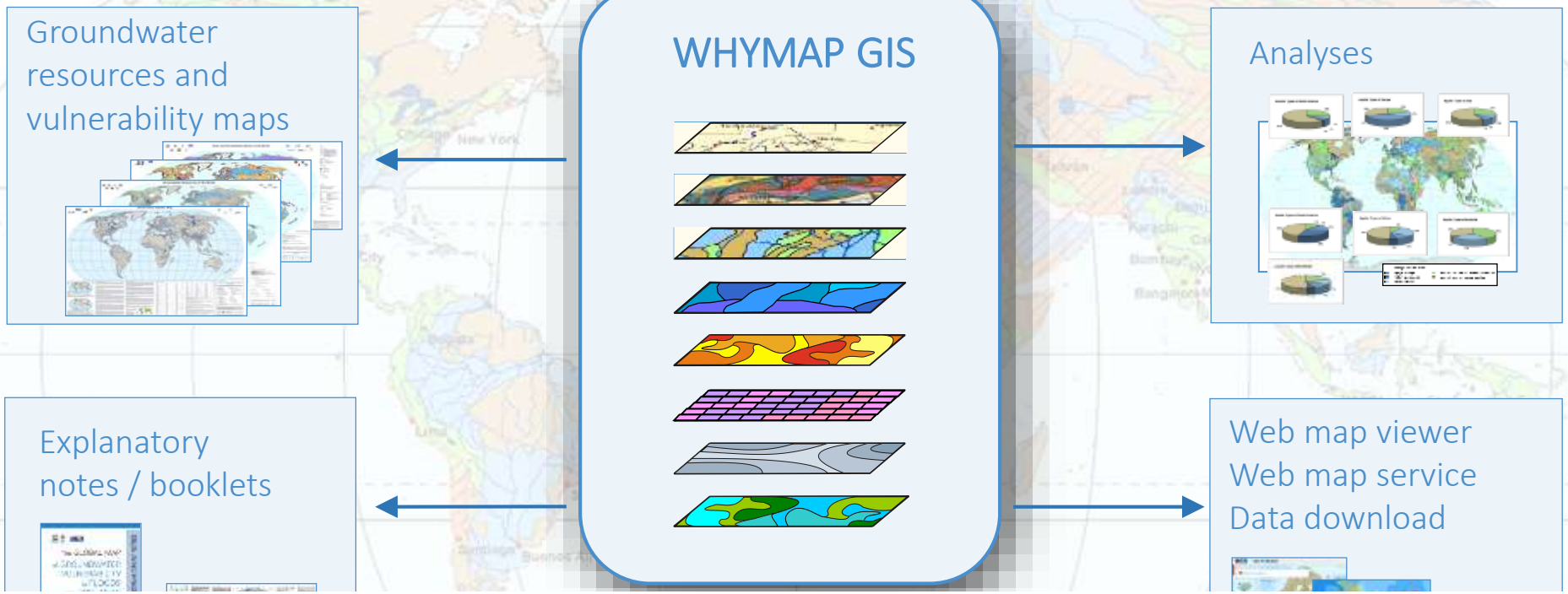
Regional organisations, e.g. OSS, SADC, OAS …

Individual freelance contributors

Universities, e.g. University of Frankfurt, Karlsruhe Institute of Technology…

BGR UNESCO

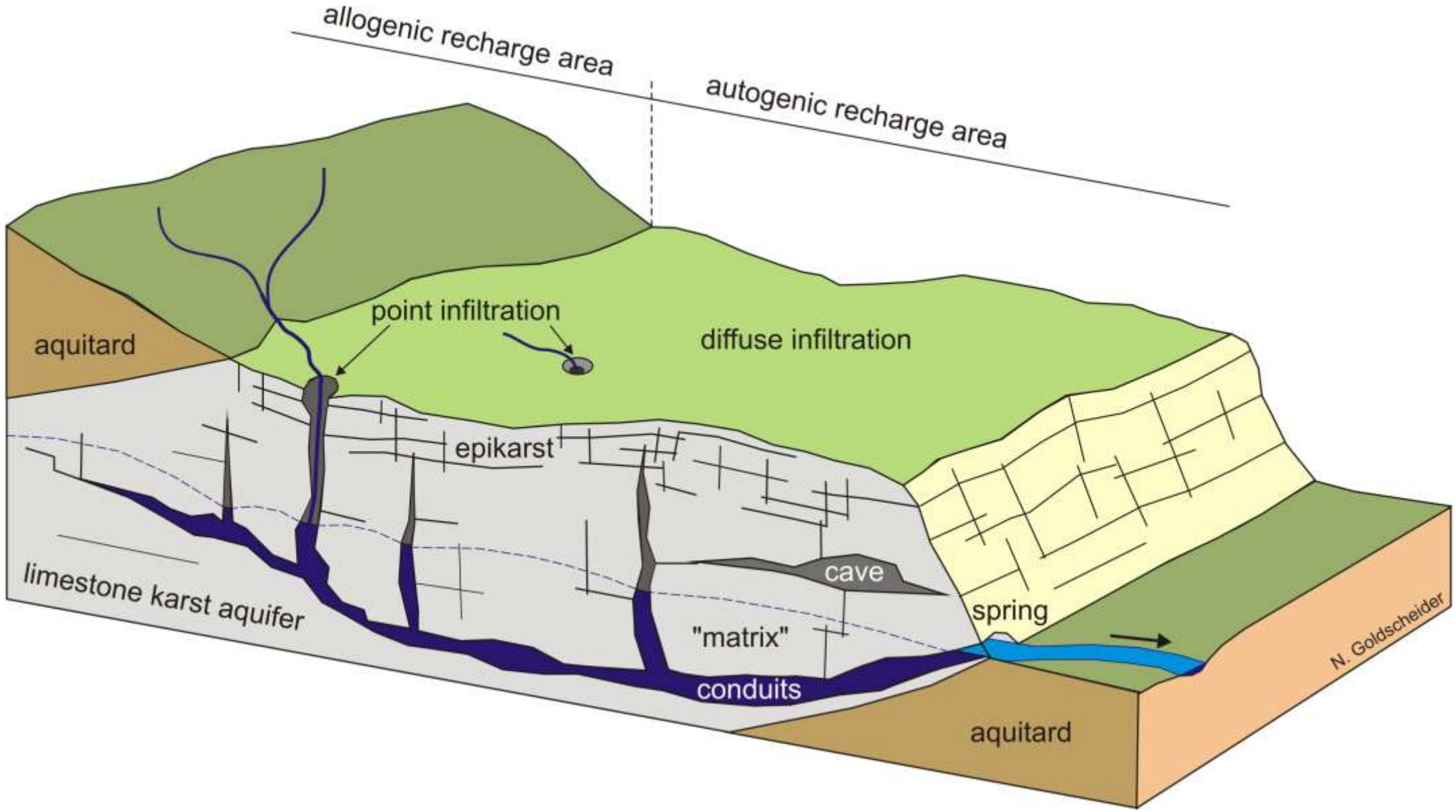
Products

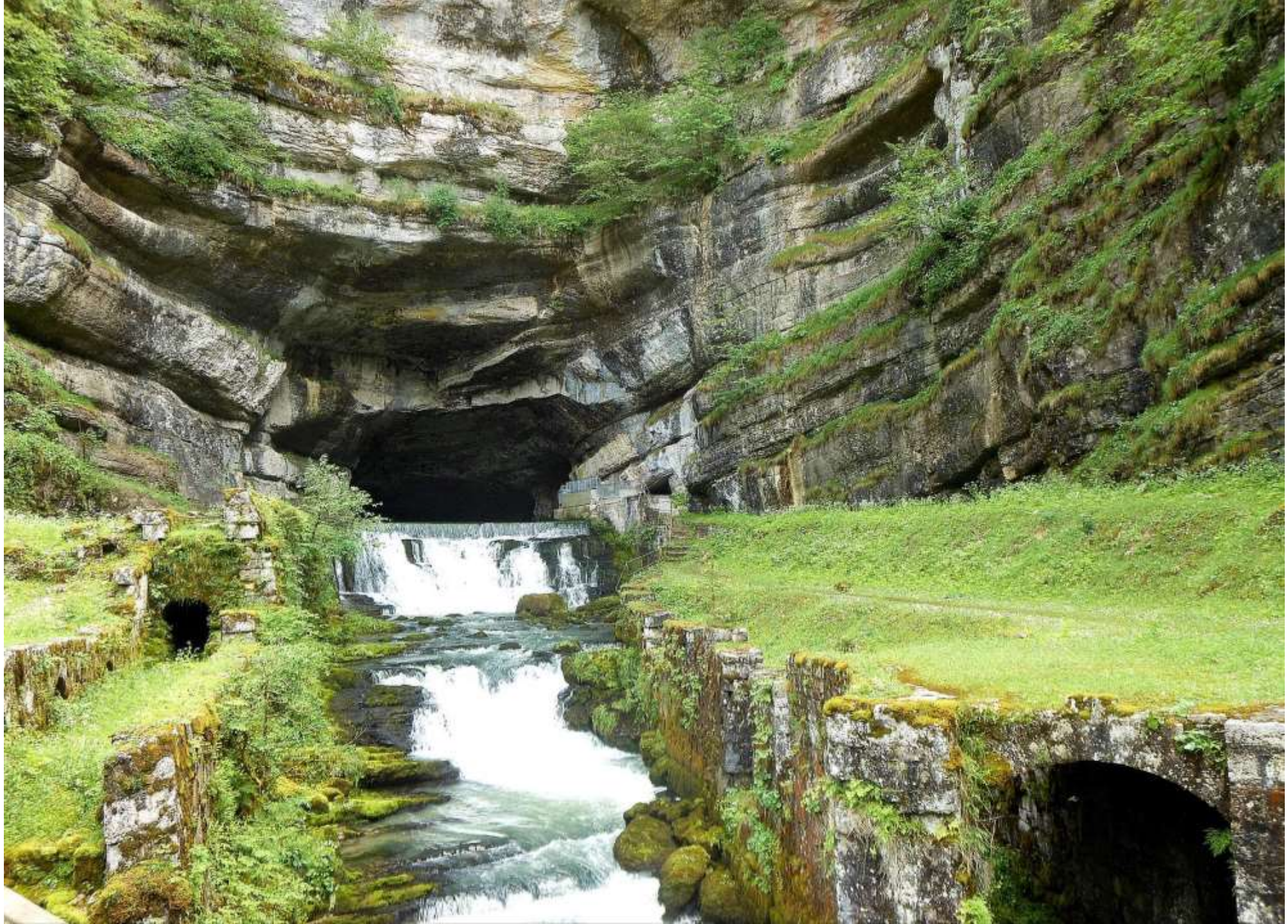


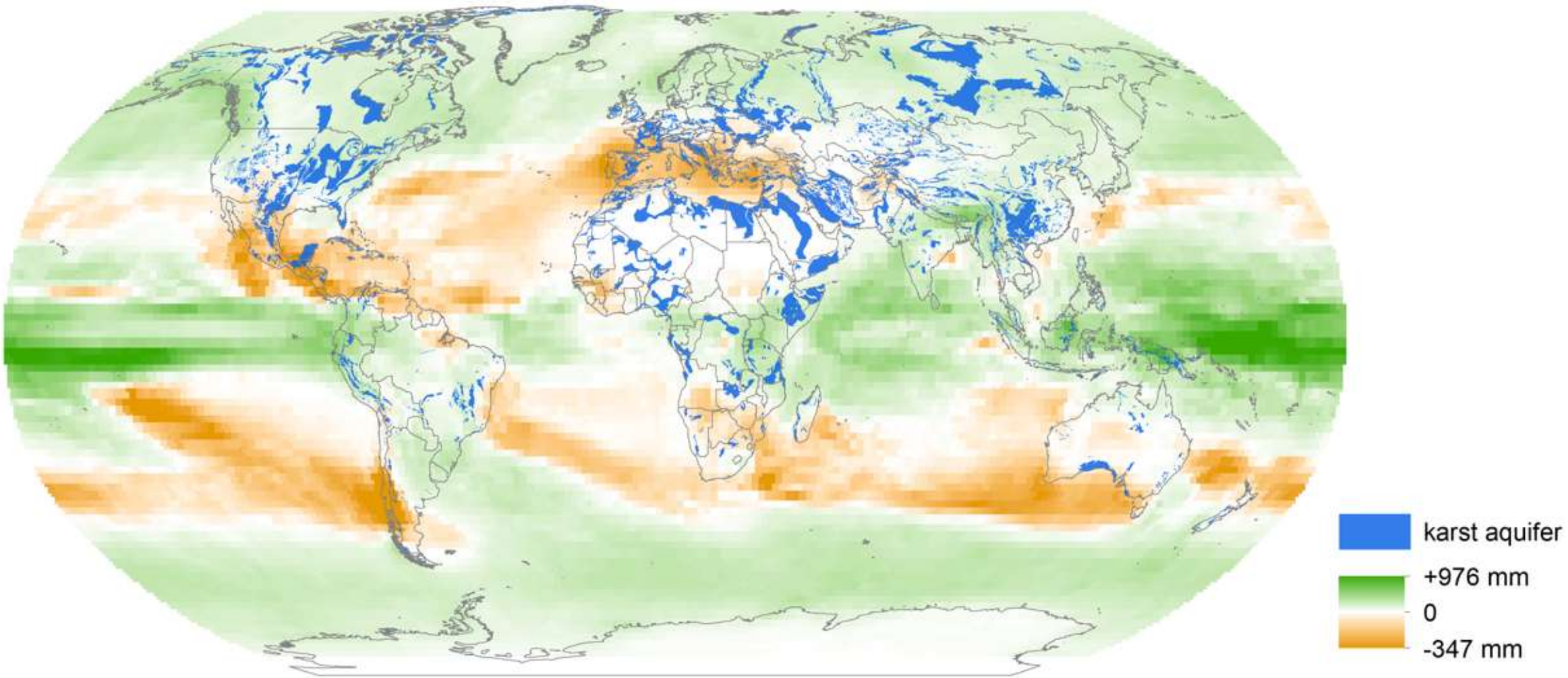
More information at: www.whymap.org

WHYMAP online viewer: www.whymap.org/whymap-viewer

books etc., e.g. small sketch-maps


allogenic recharge area
autogenic recharge area
aquitard
point infiltration
diffuse infiltration
epikarst
cave
spring
limestone karst aquifer
"matrix"
conduits
aquitard
N. Goldscheider





Precipitation change

United Nations Educational, Scientific and Cultural Organization / Federal Institute for Geosciences and Natural Resources, Germany / Global Environment Facility - International Waters: Learning Exchange and Resource Network

Mapping global karst groundwater: a tool to enhance water security

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Karlsruhe Institute of Technology

WOKAM, the new WHYMAP:

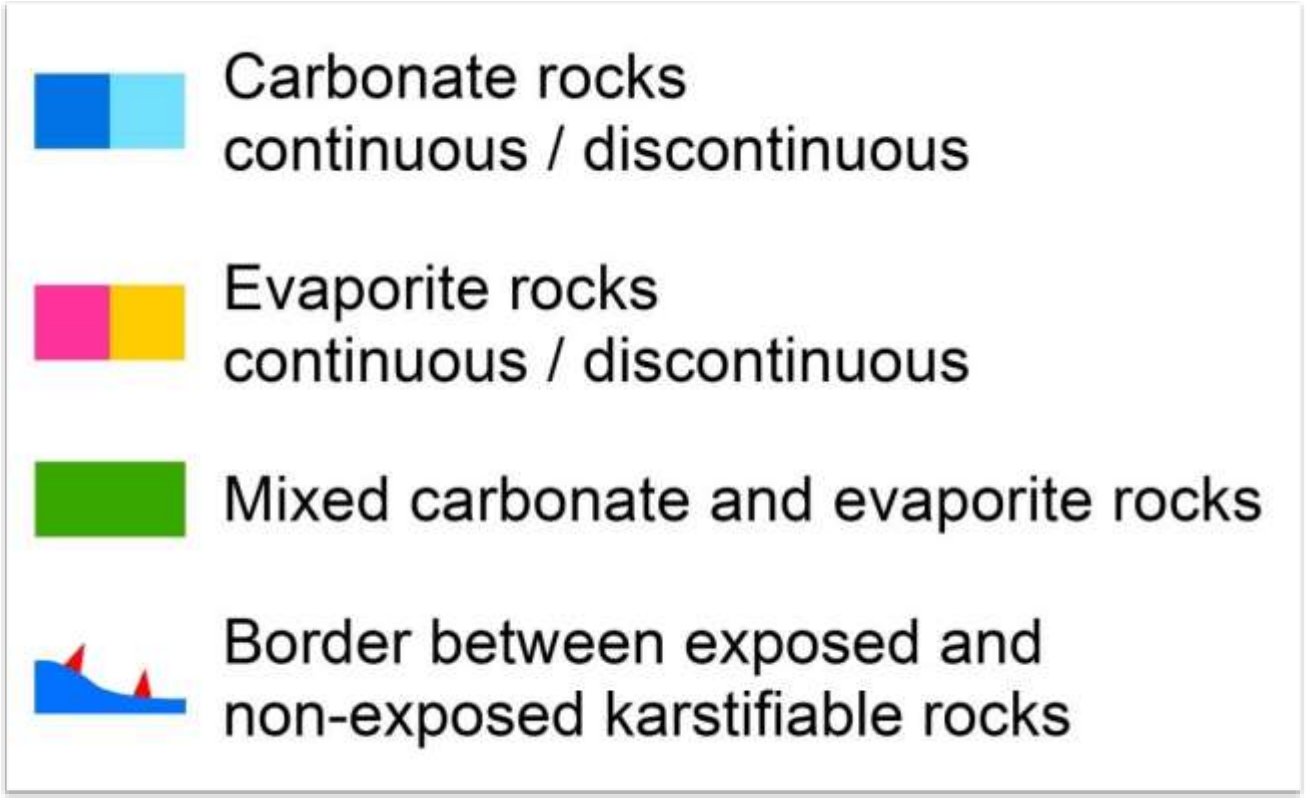
A global approach for karst aquifer mapping

Zhao Chen, Nico Goldscheider (project leader), Augusto Auler, Michel Bakalowicz, Stefan Broda, David Drew, Jens Hartmann, Guanghui Jiang, Nils Moosdorf, Andrea Richts, Zoran Stevanovic, George Veni, Aurélien Dumont, Alice Aureli

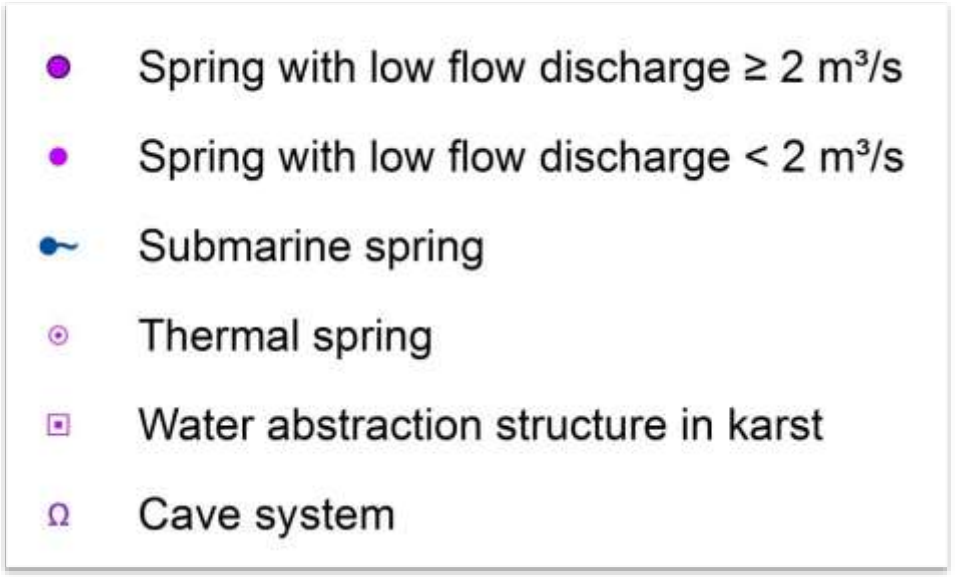
+ Regional Experts (acknowledgements)

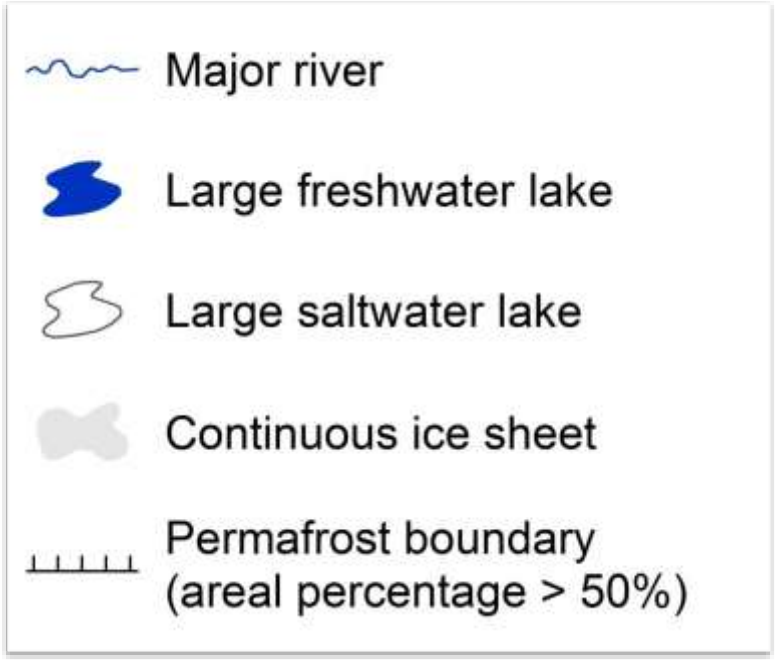
Institute of Applied Geosciences – Division of Hydrogeology

WOKAM – Mapping units and legend



- Continuous: karstifiable rocks > 65%
- Discontinuous: karstifiable rocks 15 – 65%
- Mixed: > 15% of each rock type

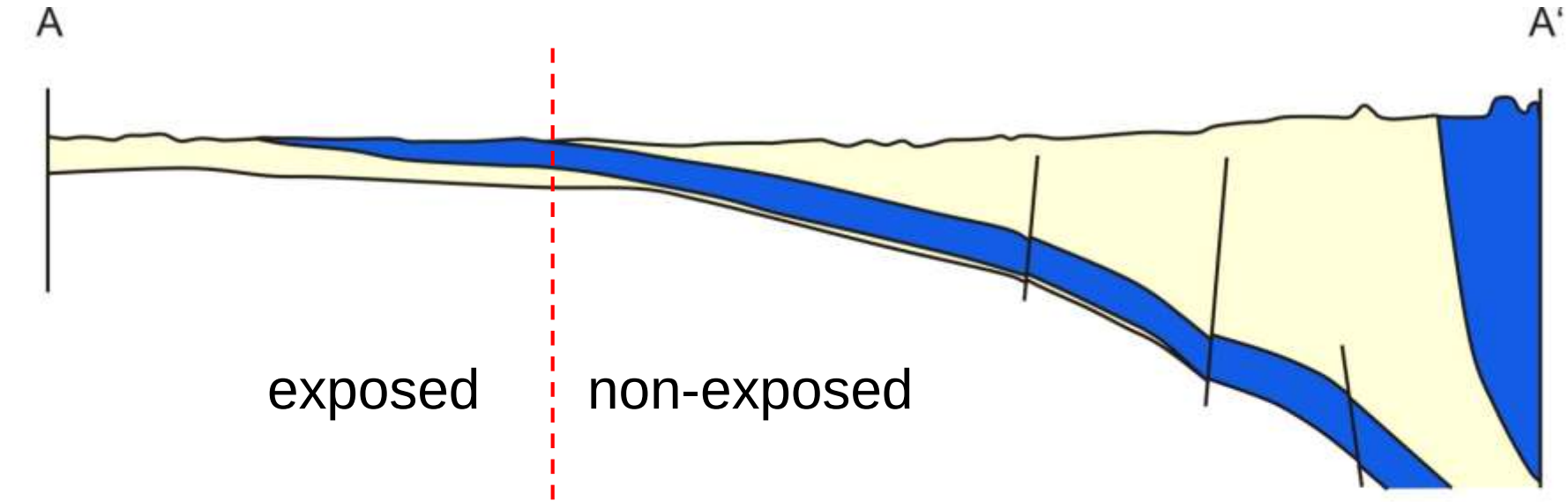




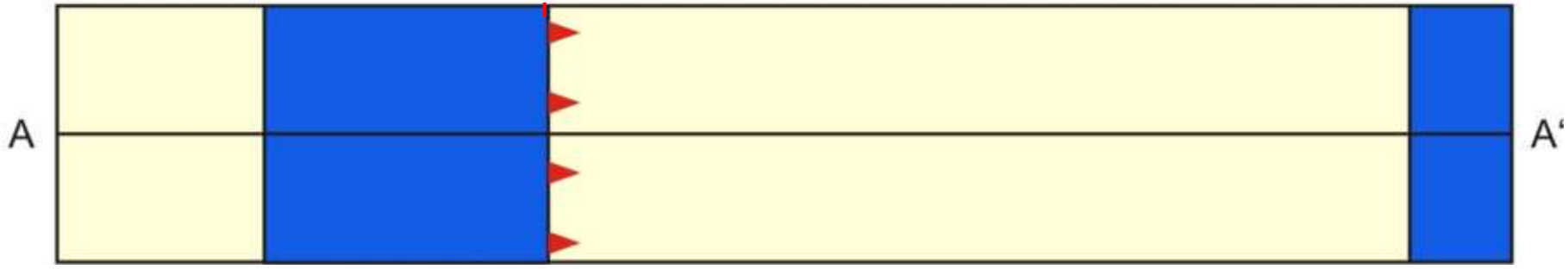
Presentation of non-exposed carbonate (or evaporite) rocks

➔ potential deep freshwater or thermal-mineral water resources

Profile:



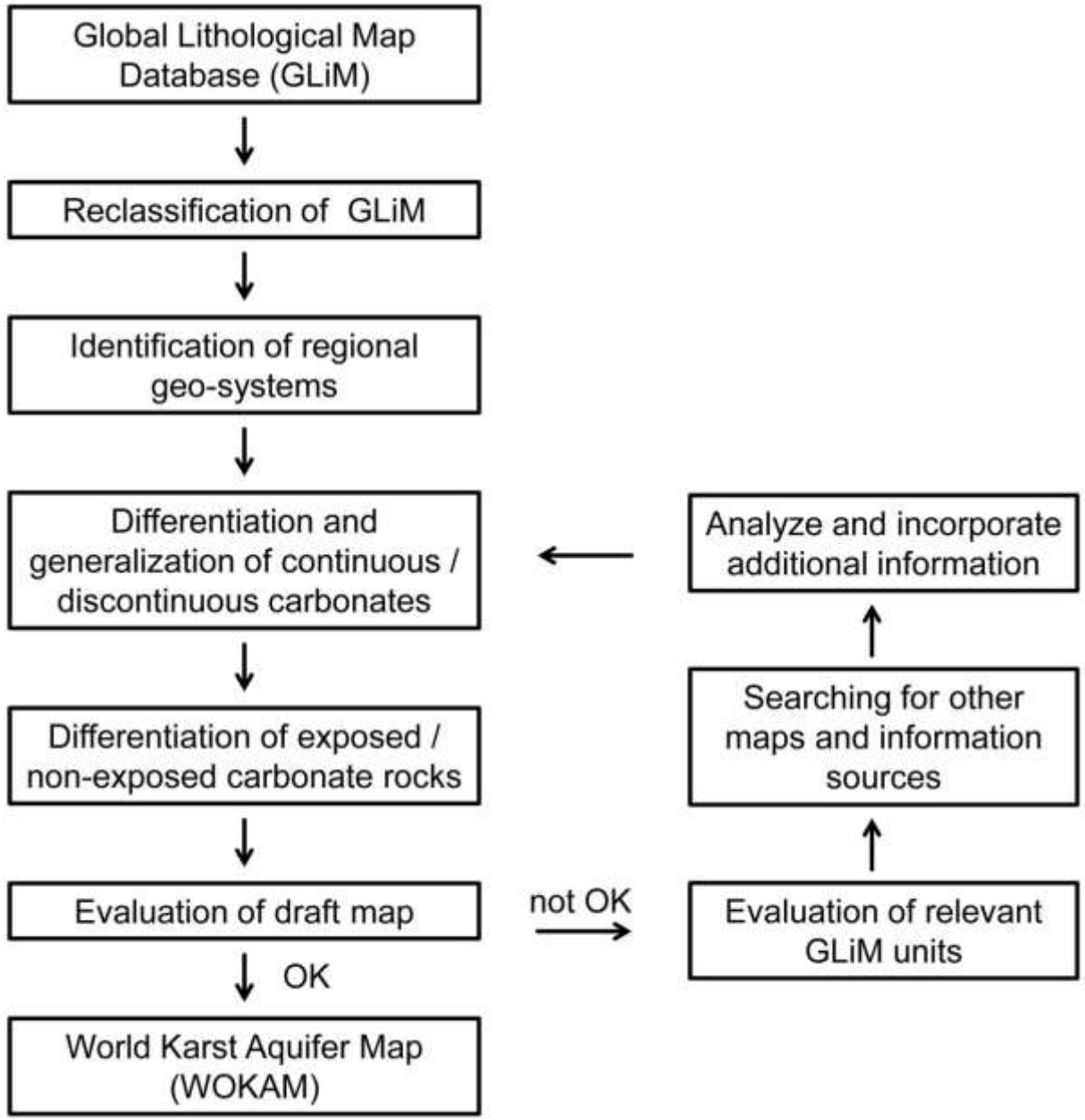
Map:



Chen et al. (2017)

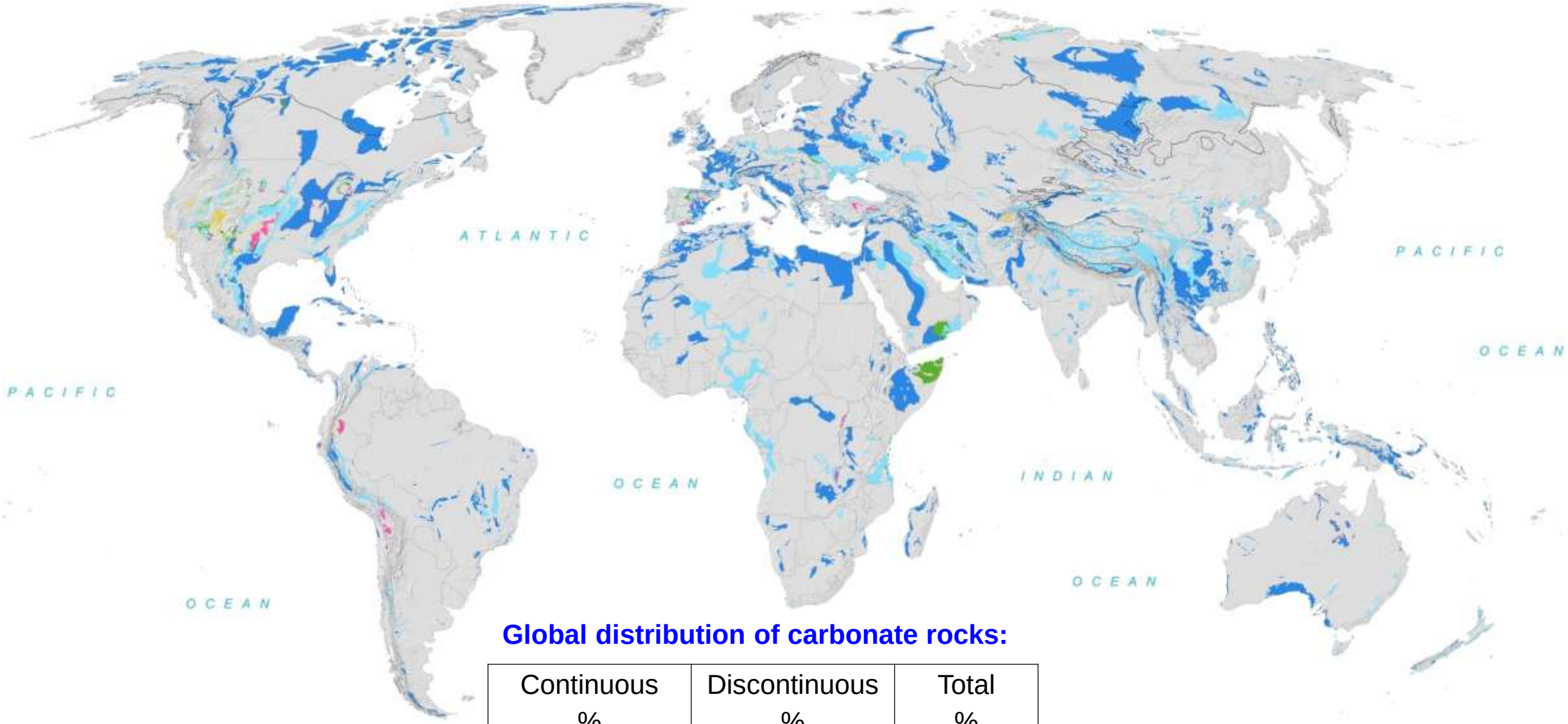
WOKAM Workflow

- Five major work steps
- Working scale 1:10 Million
- Printing scale 1:40 Million
- Sphere Robinson Projection
- Mapping procedure and map of Europe were already published in Hydrogeology Journal (2017)



Chen et al. (2017)

The World Karst Aquifer Map (1:40 Million)

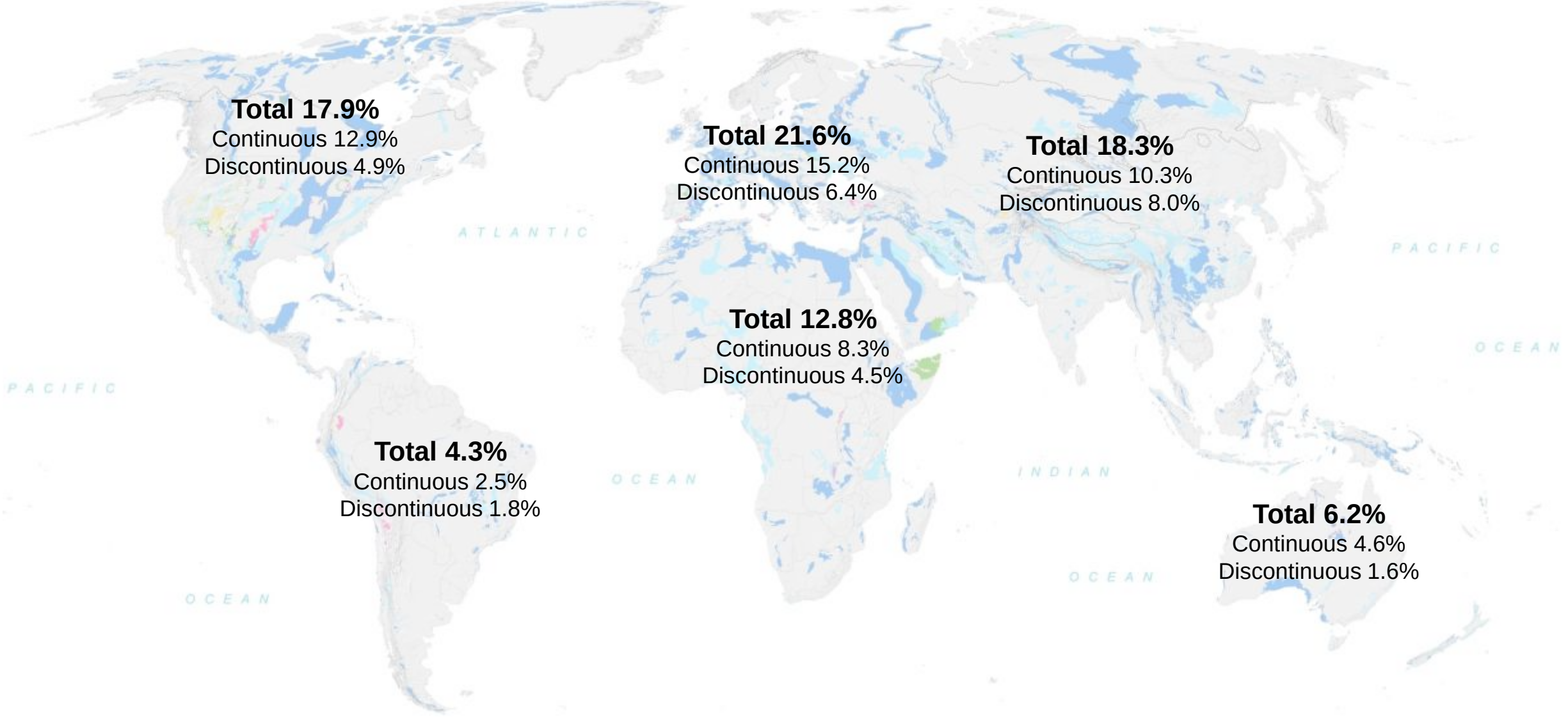


Global distribution of carbonate rocks:

Continuous %	Discontinuous %	Total %
9.3	**5.4**	**14.7**

Without Antarctica

The World Karst Aquifer Map (1:40 Million)



Total 17.9%
Continuous 12.9%
Discontinuous 4.9%

Total 21.6%
Continuous 15.2%
Discontinuous 6.4%

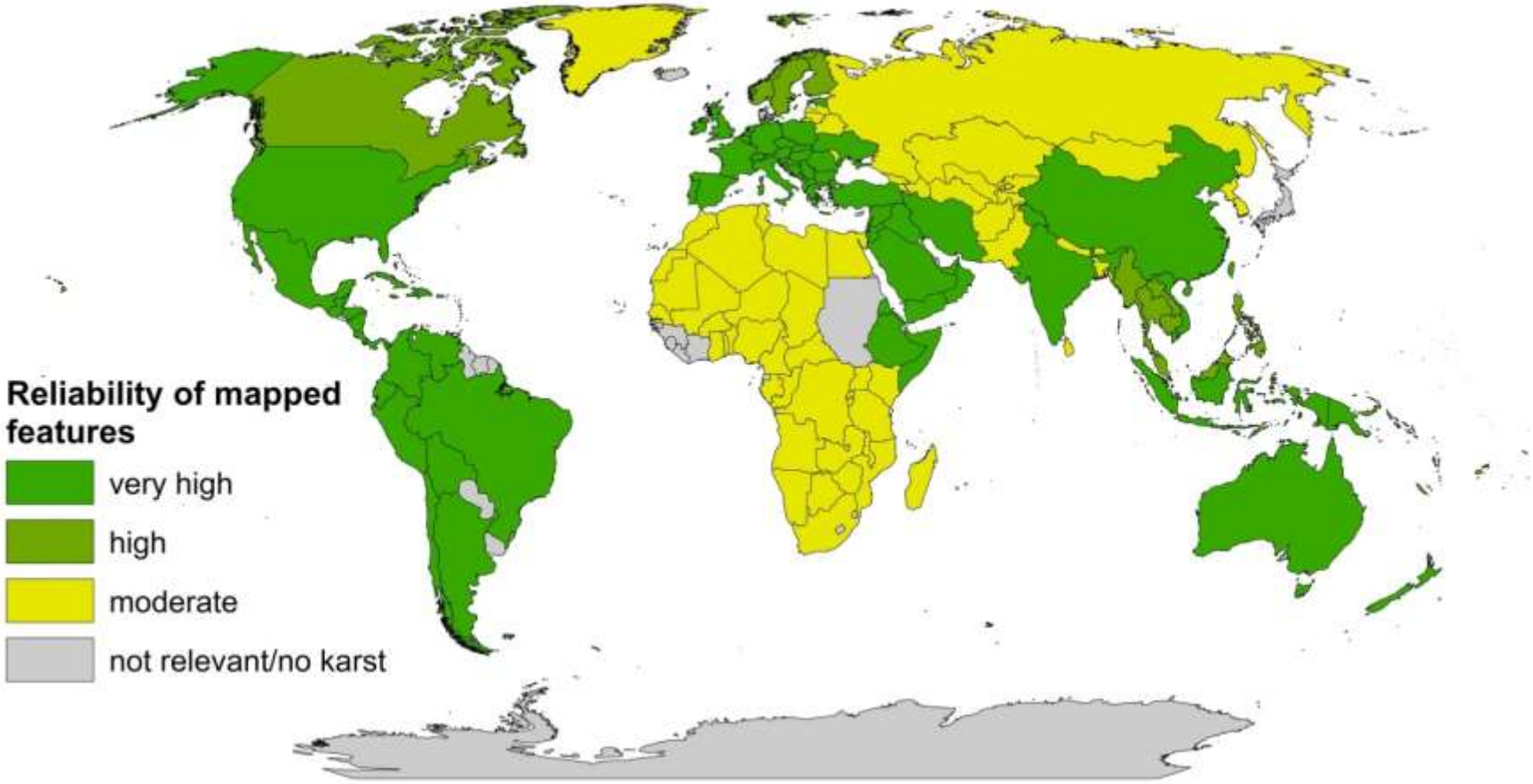
Total 18.3%
Continuous 10.3%
Discontinuous 8.0%

Total 12.8%
Continuous 8.3%
Discontinuous 4.5%

Total 4.3%
Continuous 2.5%
Discontinuous 1.8%

Total 6.2%
Continuous 4.6%
Discontinuous 1.6%

Reliability map



- Heterogeneous availability and quality hydrogeological maps and data
- Different availability of **Regional Experts**
- This map was created to the best knowledge of the WOKAM team. Suggestions and input for its improvement are welcome: www.whymap.org/wokam-contact

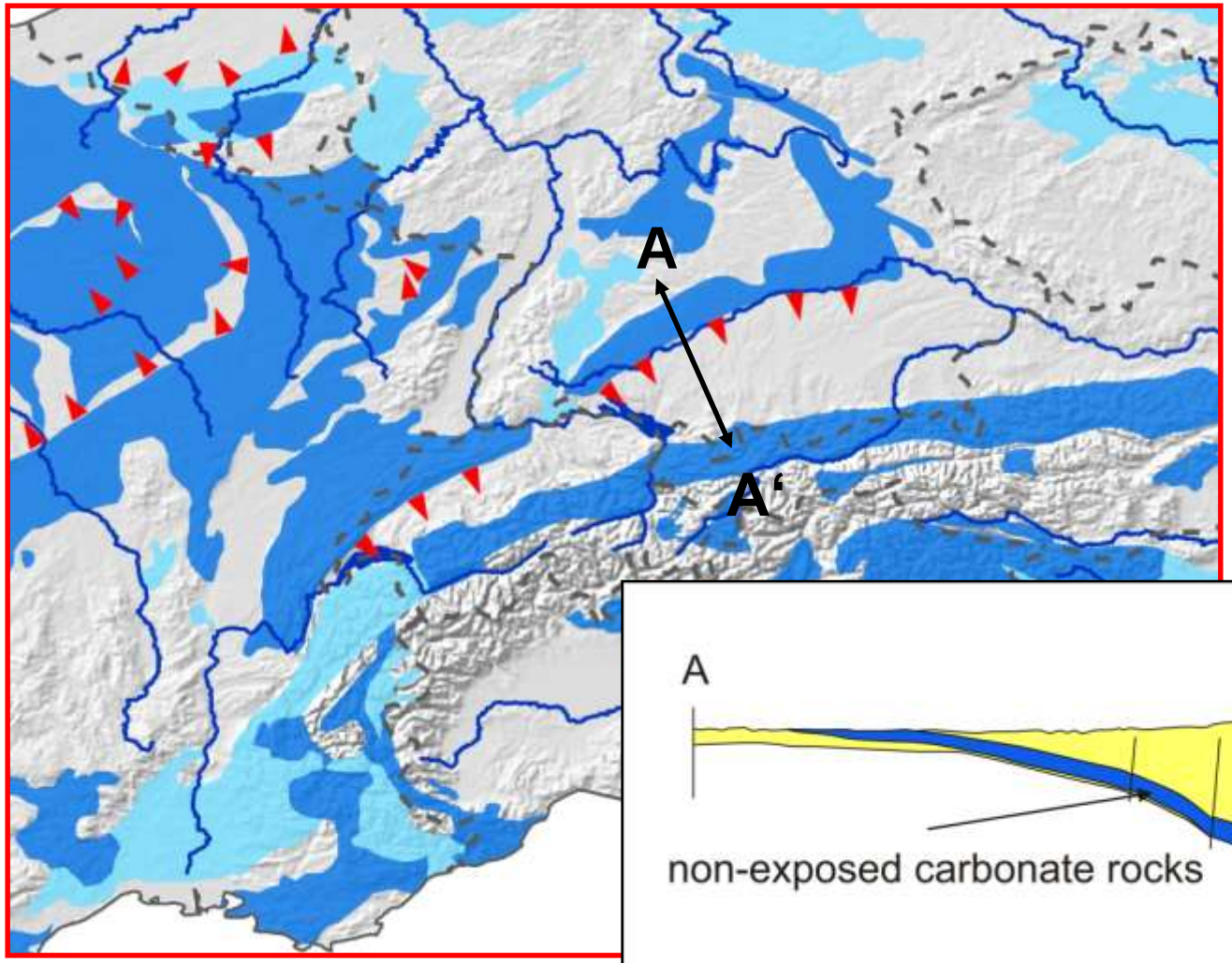
Karst Aquifer Map of Europe

Carbonate rocks in Europe:

Continuous %	Discontinuous %	Total %
15.2	**6.4**	**21.6**

Detailed statistics is published in the paper of the WOKAM team (Chen et al. 2017)

Karst Aquifer Map in detail



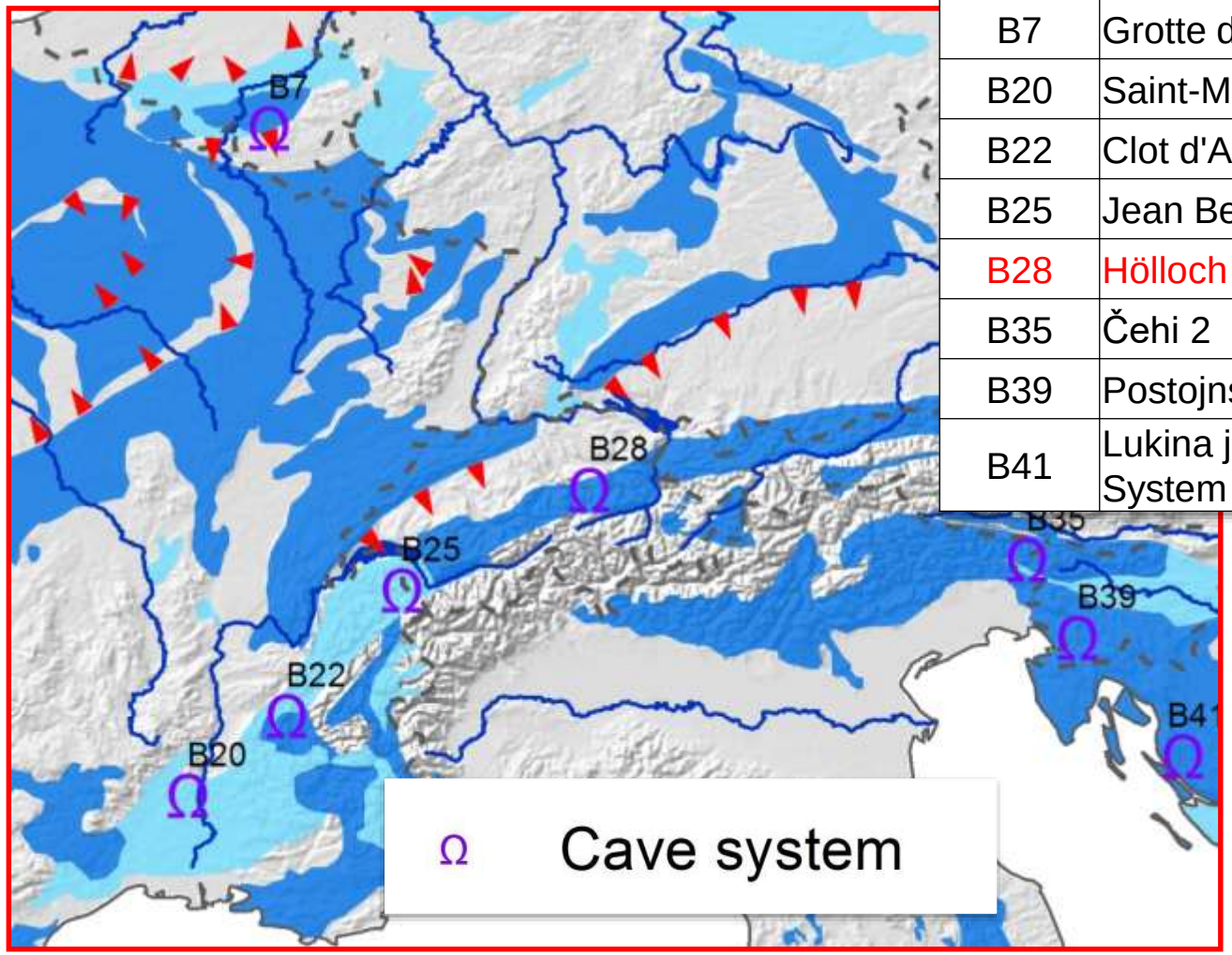
Carbonate rocks
continuous / discontinuous

Please note the scale:

1 cm : 400 km

3.2 cm x 2.5 cm

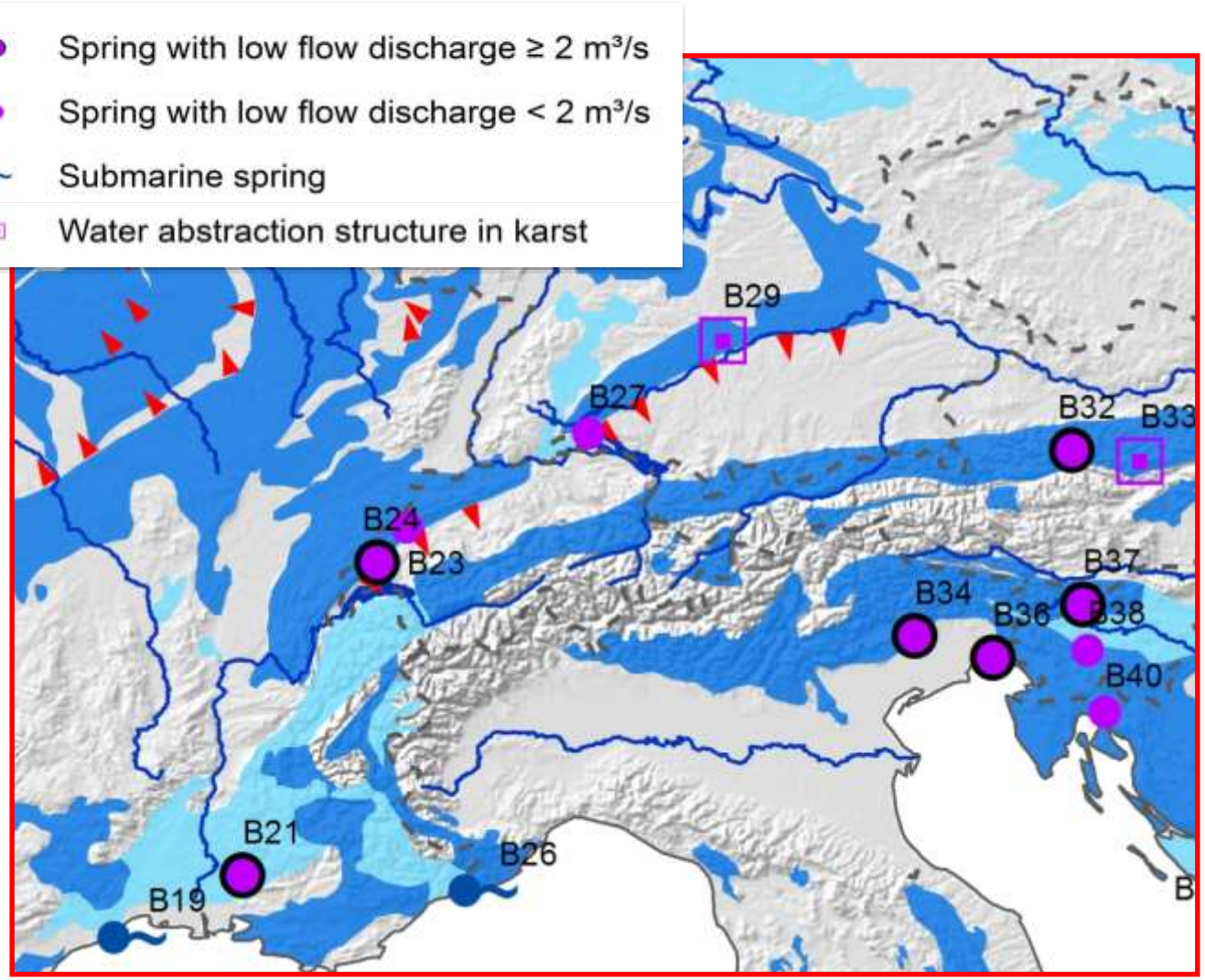
Karst Aquifer Map – with *selected* caves



No.	Name	length [km]	depth [m]
B7	Grotte de Han-sur-Lesse	5.7	50
B20	Saint-Marcel d'Ardéche Cave	51.2	233
B22	Clot d'Aspres Cave System	40.0	1066
B25	Jean Bernard Cave System	20.5	1602
B28	Hölloch	200.4	939
B35	Čehi 2	5.3	1502
B39	Postojnska jama	20.6	115
B41	Lukina jama – Trojama Cave System	3.7	1431

Caves were selected based on dimensions, and on hydrological and regional significance, with the help of regional experts.

Karst Aquifer Map – with *selected* springs



No.	Name	Low [m³/s]	High [m³/s]
B19	Source de la Vise	0.5	n.d.
B21	Fontaine de Vaucluse	4	150
B23	Source de l'Areuse	0.7	39
B24	Source de l'Orbe	2	80
B26	Mortola Springs	n.d.	n.d.
B27	Aachquelle	1.1	28
B29	Buchbrunnenquelle	0.6	1.5
B32	Pießlingursprung	2.2	40
B33	Kläfferquelle	0.4	34
B34	Livenza Group	11,4	n.d.
B36	Timavo	30,2	n.d.
B37	Bistrica	2,1	63
B38	Ljubljanica	1,5	120
B40	Riječina	0	150

Evaluation by Regional Experts – Acknowledgements (1)

Romeo Eftimi (Albania), Boban Jolović (Bosnia & Herzegovina). Aleksey Benderev (Bulgaria), Želimir Pekaš (Croatia), Bruno Arfib, Stéphane Binet, Laurent Cadilhac, Jacques Chabert, Cyril Delporte, Bernard Ladouche, Pierre Marchet, Jean-Christophe Maréchal, Paul-Henri Mondain, André Tarrisse (France), Judit Mádl-Szőny (Hungary). Gültekin Günay (Turkey), Jo De Waele, Francesco Fiorillo (Italy), Milan Radulović (Montenegro), Jacek Rózkowski (Poland), Costa Almeida, António Chambel (Portugal), Iancu Orăşeanu (Romania), Alexander Klimchouk (Ukraine), Alleksander Osintsev, Gennady Amelichev, Nikolay Maksimovich, Andrey Ostapenko, Vladimir Rezvan, Eugeny Zakharov, Andrei Filippov (Russia), Peter Malik (Czech Republic & Slovakia), Nataša Ravbar (Slovenia), Juan Jose Duran, Bartolomé Andreo (Spain), Tony Waltham (UK), Henning Moe (Norway), Paul Williams (Papua New Guinea & New Zealand), Ken Grimes (Australia) …

Evaluation by Regional Experts – Acknowledgements (2)

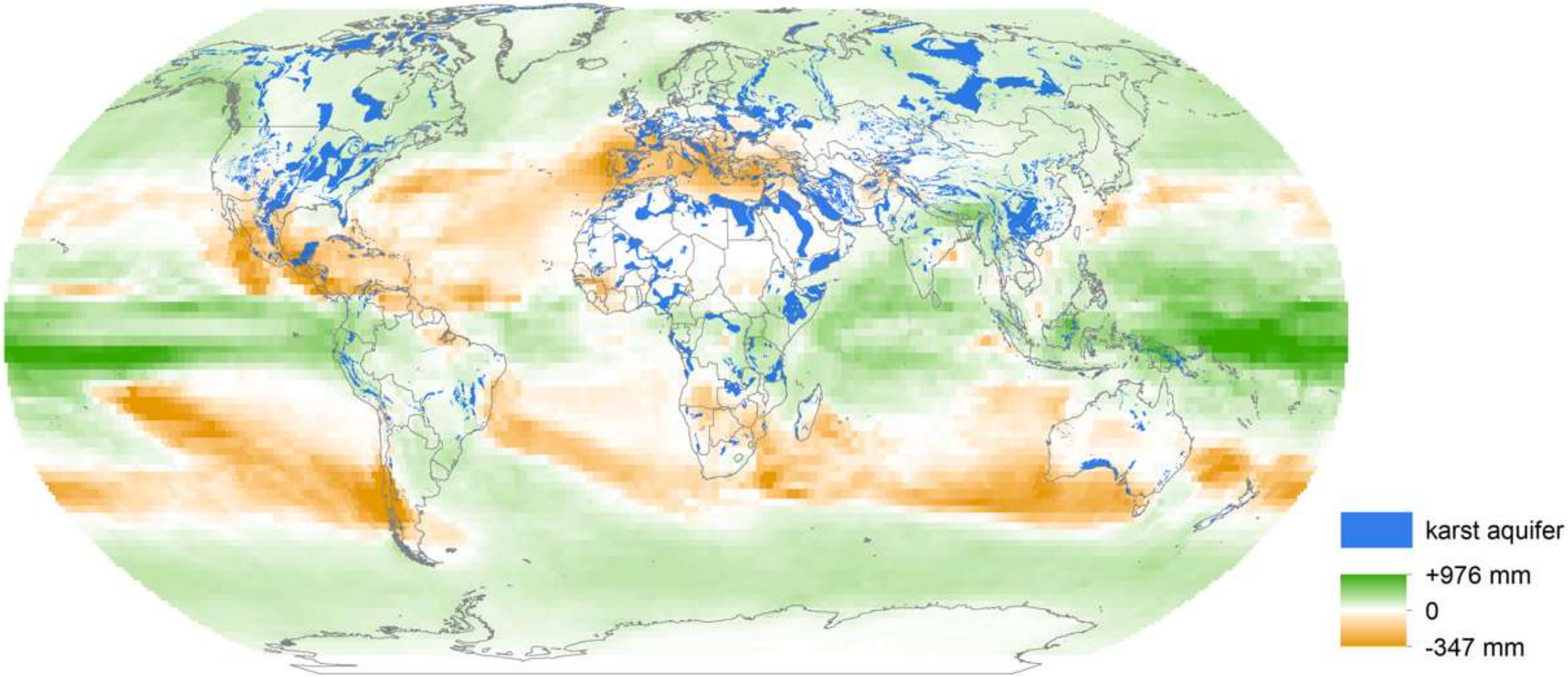
… Tien Chung Ho (Vietnam), Jérôme Perrin (India), Ikhwan Muhammad, Eko Haryono (Indonesia), Ezzat Raeisi (Iran), Issam Bou Jaoudé (Lebanon), Randolf Rausch, Heinz Hötzl (Saudi Arabia), Michael Laumanns (Southeast Asia), Terry Bolger (Laos), Yuanhai Zhang (China), Seifu Kebede (Ethiopia), Thierry Bussard (Libya), Bouabib El Mansouri (Morocco), Michael Laumanns, Gil Mahé (Africa), Stephen Worthington, Chas Yonge (Canada), Eve Kuniansky, Andrew Long, Daniel Doctor, Mark Kozar, Van Brahana, Emily Hollingsworth, Mike Flannigan, Arthur Palmer, David Weary (USA), Keith Christenson (Central America), Jim Coke, Peter Sprouse (Mexico), Gabriel Redonte, Mariana Paparás (Argentina), Jean-Loup Guyot, Jean Sébastien Moquet (Bolivia), Jean Sébastien Moquet (Ecuador), Lucas Warren, Jaime Leonardo Baez Presser (Paraguay), Jean-Loup Guyot, Jean-Yves Bigot, Jean Sébastien Moquet (Peru), Franco Urbani (Venezuela). **Thank You!**

- Financial support: IAH and UNESCO
- Self-funded / honorary work of all project members and regional experts
- Map prepared at KIT and BGR
- Part of the WHYMAP program

Chen Z, Auler AS, Bakalowicz M, Drew D, Griger F, Hartmann J, Jiang G, Moosdorf N, Richts A, Stevanovic Z, Veni G, Goldscheider N (2017) The World Karst Aquifer Mapping project: concept, mapping procedure and map of Europe. Hydrogeology Journal, 25(3): 771-785.

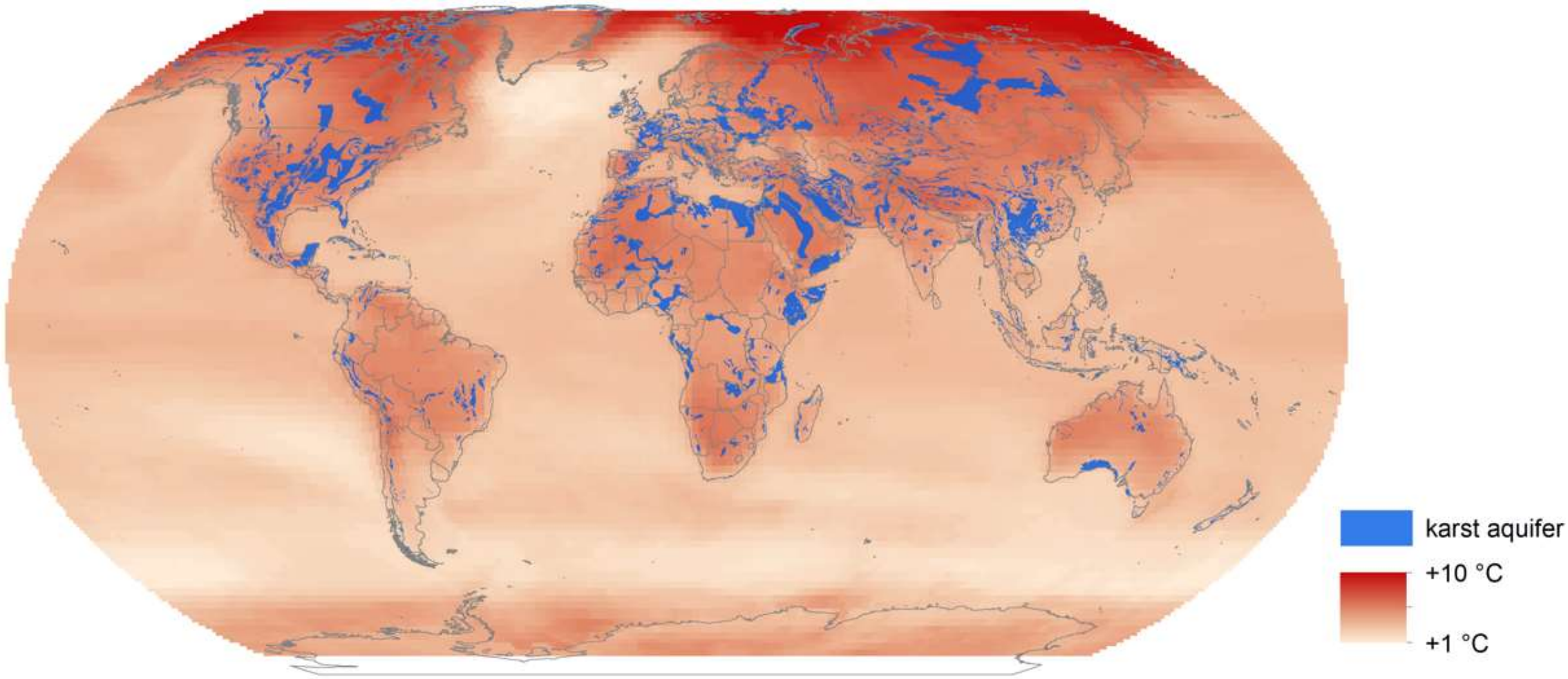
Impact of climate change in karst regions

(change of annual precipitation amount by 2100 after GCMs)

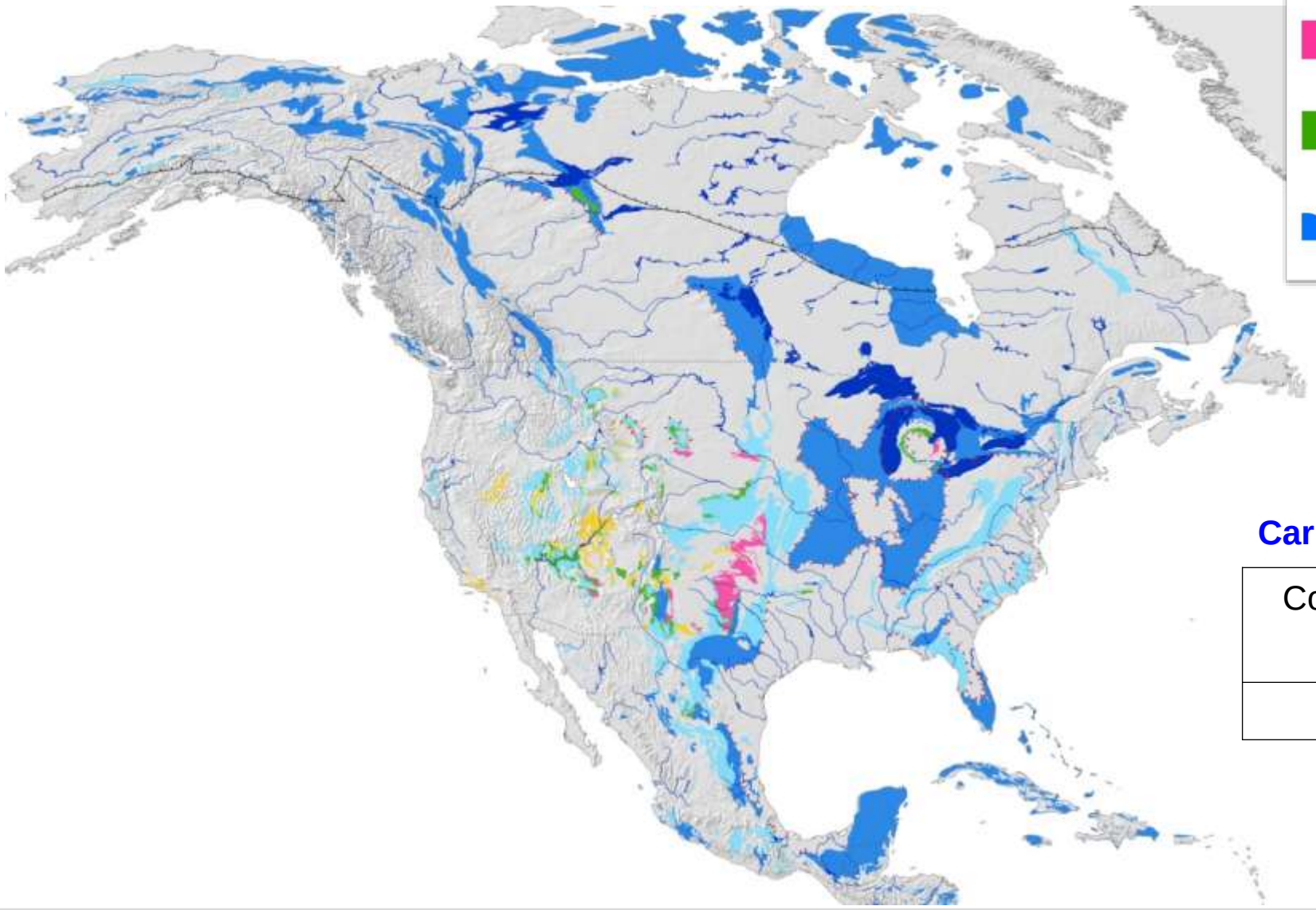


Impact of climate change in karst regions

(change of annual mean temperature by 2100 after GCMs)



Karst Aquifer Map of North America



Carbonate rocks
continuous / discontinuous

Evaporite rocks
continuous / discontinuous

Mixed carbonate and evaporite rocks

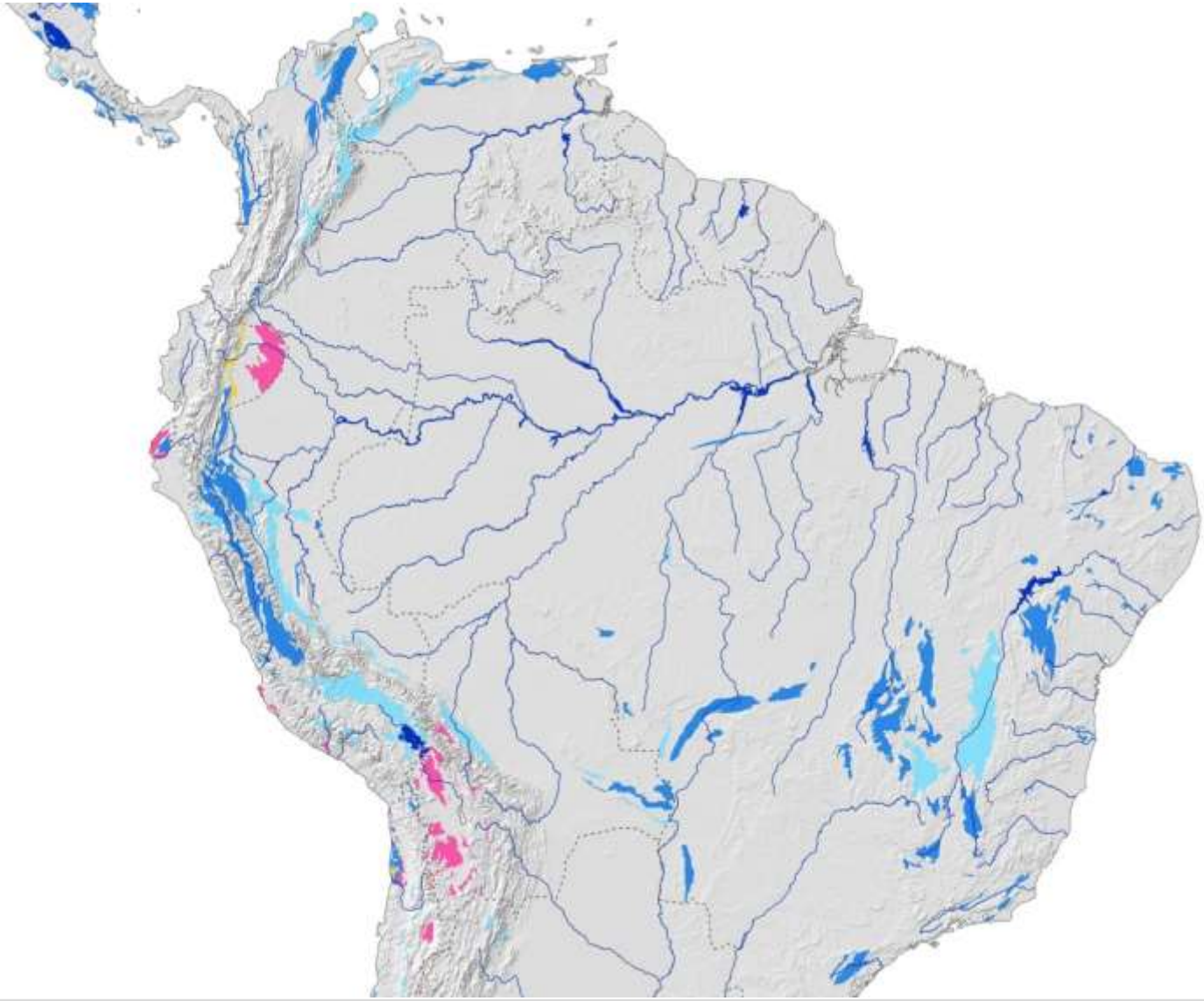
Border between exposed and
non-exposed karstifiable rocks

Carbonate rocks in North America:

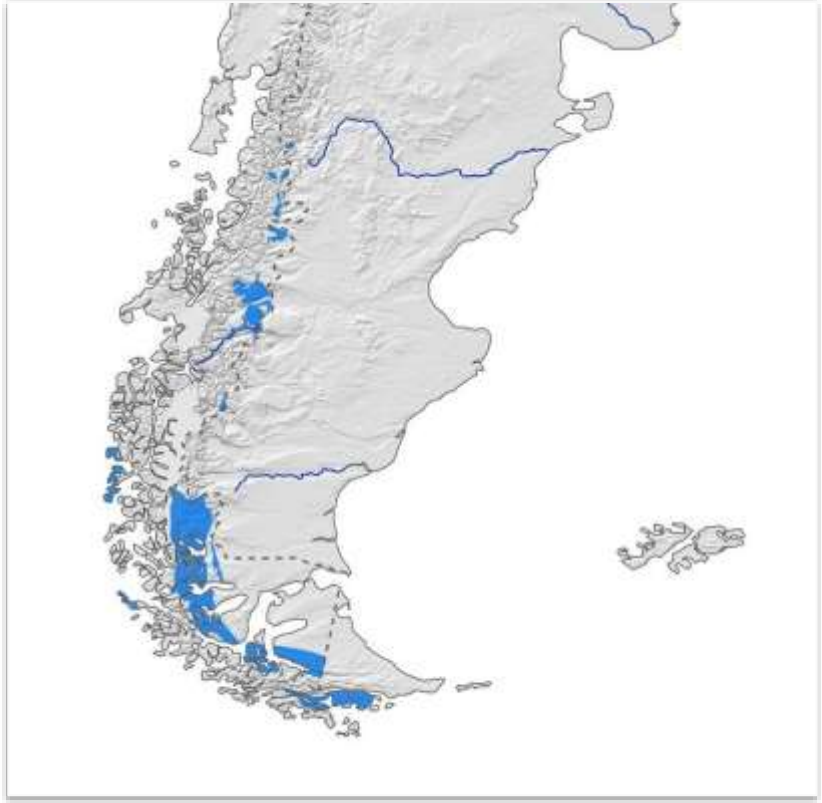
Continuous %	Discontinuous %	Total %
12.9	**4.9**	**17.9**

Including Greenland

Karst Aquifer Map of South America



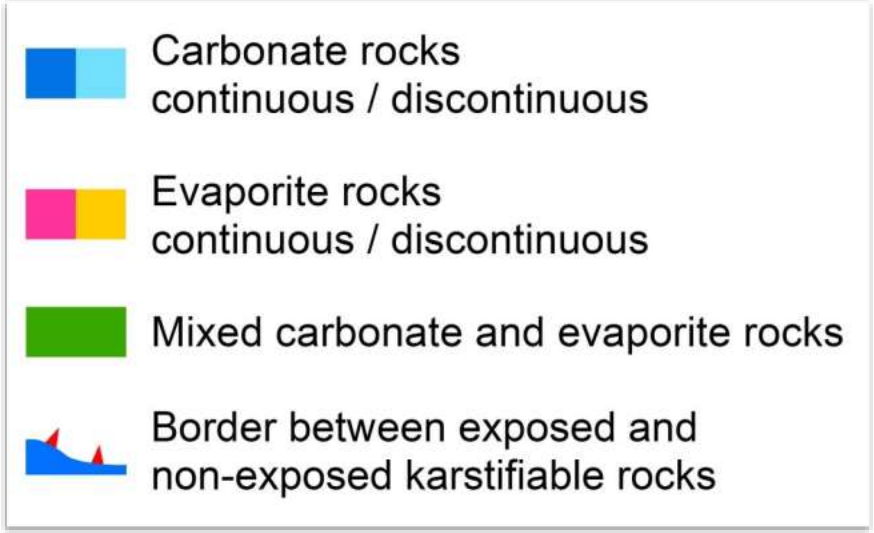
Detail: Patagonia

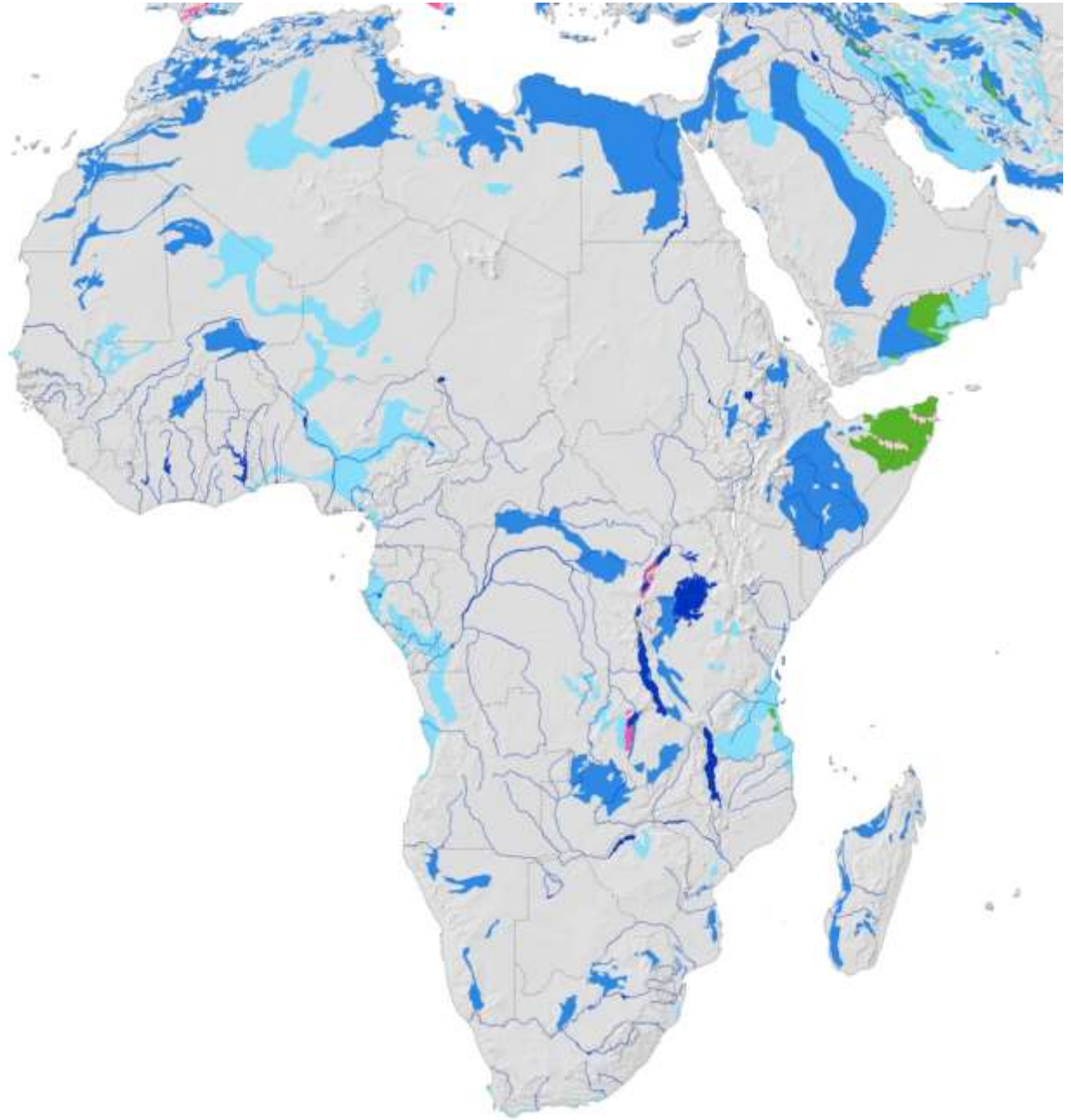


Carbonate rocks in South America:

Continuous %	Discontinuous %	Total %
2.5	**1.8**	**4.3**

Karst Aquifer Map of Africa



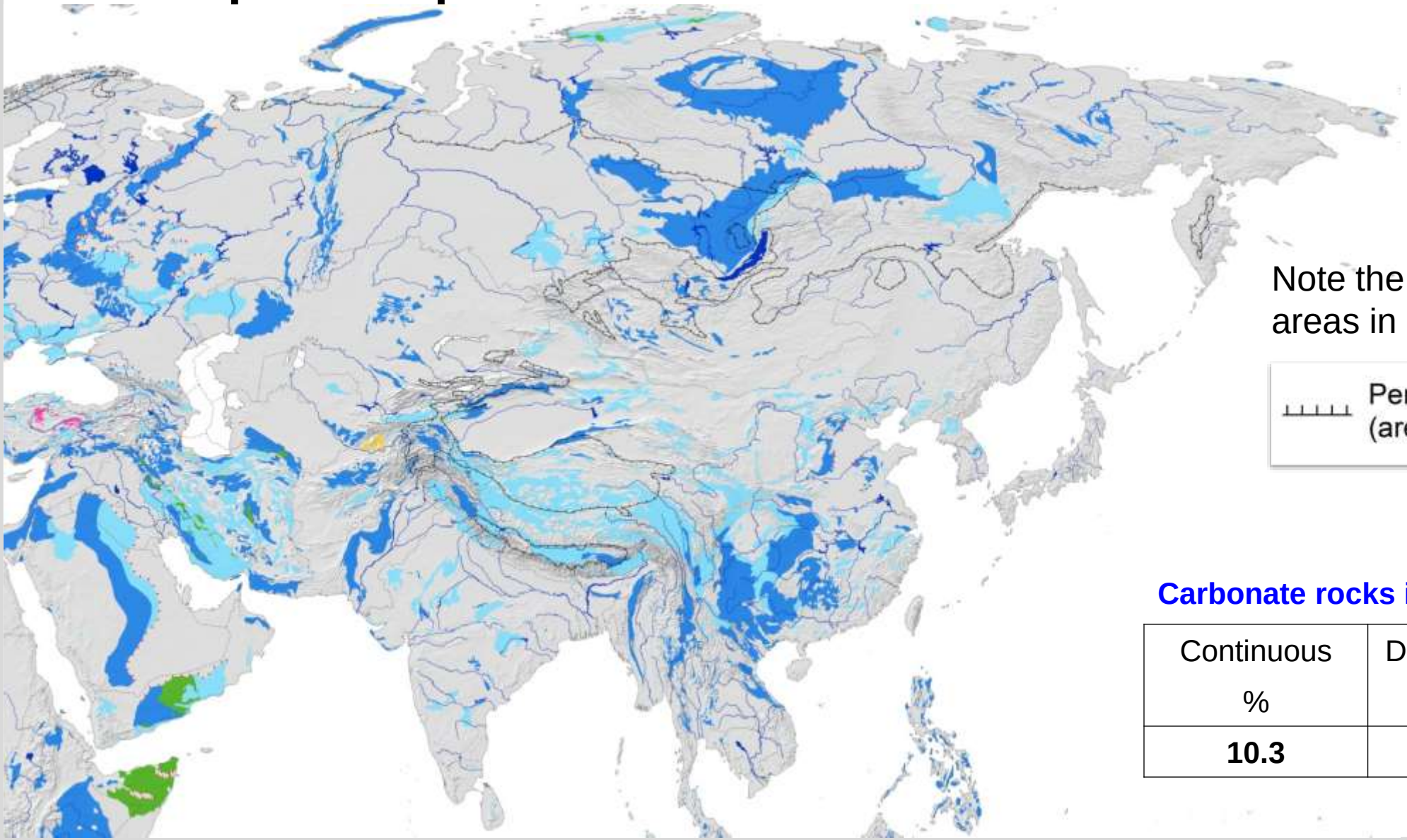


Carbonate rocks in Africa:

Continuous %	Discontinuous %	Total %
8.3	**4.5**	**12.8**

Including many metamorphic carbonate rocks

Karst Aquifer Map of Asia



Note the large permafrost areas in Siberia and Tibet.

Permafrost boundary (areal percentage > 50%)

Carbonate rocks in Asia:

Continuous %	Discontinuous %	Total %
10.3	**8.0**	**18.3**

Karst Aquifer Map of Australia and Oceania

Carbonate rocks in Australia and Oceania:

Continuous %	Discontinuous %	Total %
4.6	**1.6**	**6.2**

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United Nations Educational, Scientific and Cultural Organization /
Federal Institute for Geosciences and Natural Resources, Germany /
Global Environment Facility - International Waters: Learning Exchange and Resource Network

Regional and local scale case studies –

DIKTAS and regional waterworks for the Montenegrin Coast

Prof. Zoran Stevanović, Chair of the Karst Commission of IAH
University of Belgrade, Serbia
zstev_2000@yahoo.co.uk

DIKTAS

PROJECT

Dinaric Karst Transboundary Aquifer System (2010-2015)

The Transboundary Diagnostic Analysis and the Strategic Action Program for the Sustainable Management

UNDP

gef

United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

DIKTAS AREA

Dinaric Karst - „Classical“ karst region where science on karst – Karstology was born

DIKTAS - I Phase (Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System) was GEF project implemented by UNDP and UNESCO's IHP, aimed to improve the understanding of shared water resources and to facilitate their equitable and sustainable utilization, including the protection of dependent ecosystems in the four countries of Dinaric karst: Albania, Bosnia & Herzegovina, Croatia and Montenegro.

Dinaric karst also includes parts of Italy, Slovenia, Serbia, FRY Macedonia.

DIKTAS

- Project **partners**: Albania, Bosnia-Herzegovina, Croatia and Montenegro
- Regional partners: Slovenia, Greece and Italy
- International partners: GWP-Med, IGRAC, IAH Karst Commission, Karst Research centres…

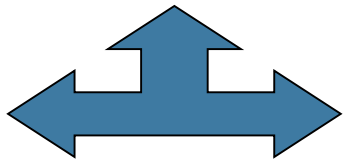
- The full size GEF regional project
  2010-2015
- Budget ca M$5.2
- PCU hosted by the Water Agency in Trebinje, BiH

Project Components of DIKTAS

Transboundary Diagnostic Analysis (TDA)

I - Improving the understanding of the resource and of its environmental status

II - Establishing cooperation mechanisms among countries sharing the aquifer



Strategic Action Program (SAP)

III - Facilitating harmonization of policies and priority reforms

IV - Stakeholder Participation, Consultation and Communication

DIKTAS – Working Plan

The project is addressing the issue of sustainable management of karst groundwater and ecosystems and is a collective effort to:

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

1. **Transboundary Diagnostic Analysis (TDA; 2011-2013)**
2. Environmental status indicators
3. A multi-country consultative body (CIE)
4. Environmental quality targets & a joint harmonized monitoring program
5. A coordination mechanism with other projects
6. National Inter-ministerial Committees (NICs)
7. **A Strategic Action Program (SAP)**
8. A partnership conference
9. Stakeholders Analysis and information and communication activities
10. Targeted capacity building programs
11. IW:LEARN activities.

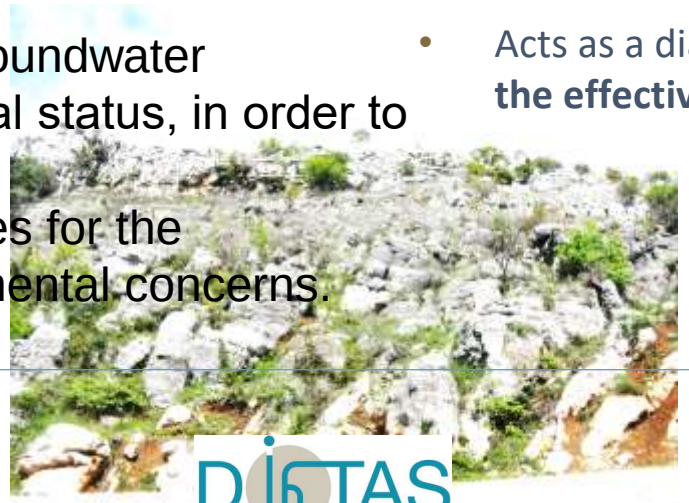
DIKTAS T D A

The DIKTAS Project followed a methodology common to GEF projects, based on conducting a **Transboundary Diagnostic Analysis (TDA)** and preparing a **Strategic Action Programme (SAP).**

The **TDA**, a substantial scientific and technical assessment, was used to enhance the understanding of the groundwater resources' environmental status, in order to identify, quantify, and set priorities for the transboundary environmental concerns.

TDA

- Is a scientific and technical **fact-finding analysis**
- It is an objective assessment and **not a negotiated document**
- Identifies, quantifies, and sets priorities for the water-related environmental & water resources **problems** that are **transboundary** in nature.
- Acts as a diagnostic tool for measuring **the effectiveness** of SAP implementation



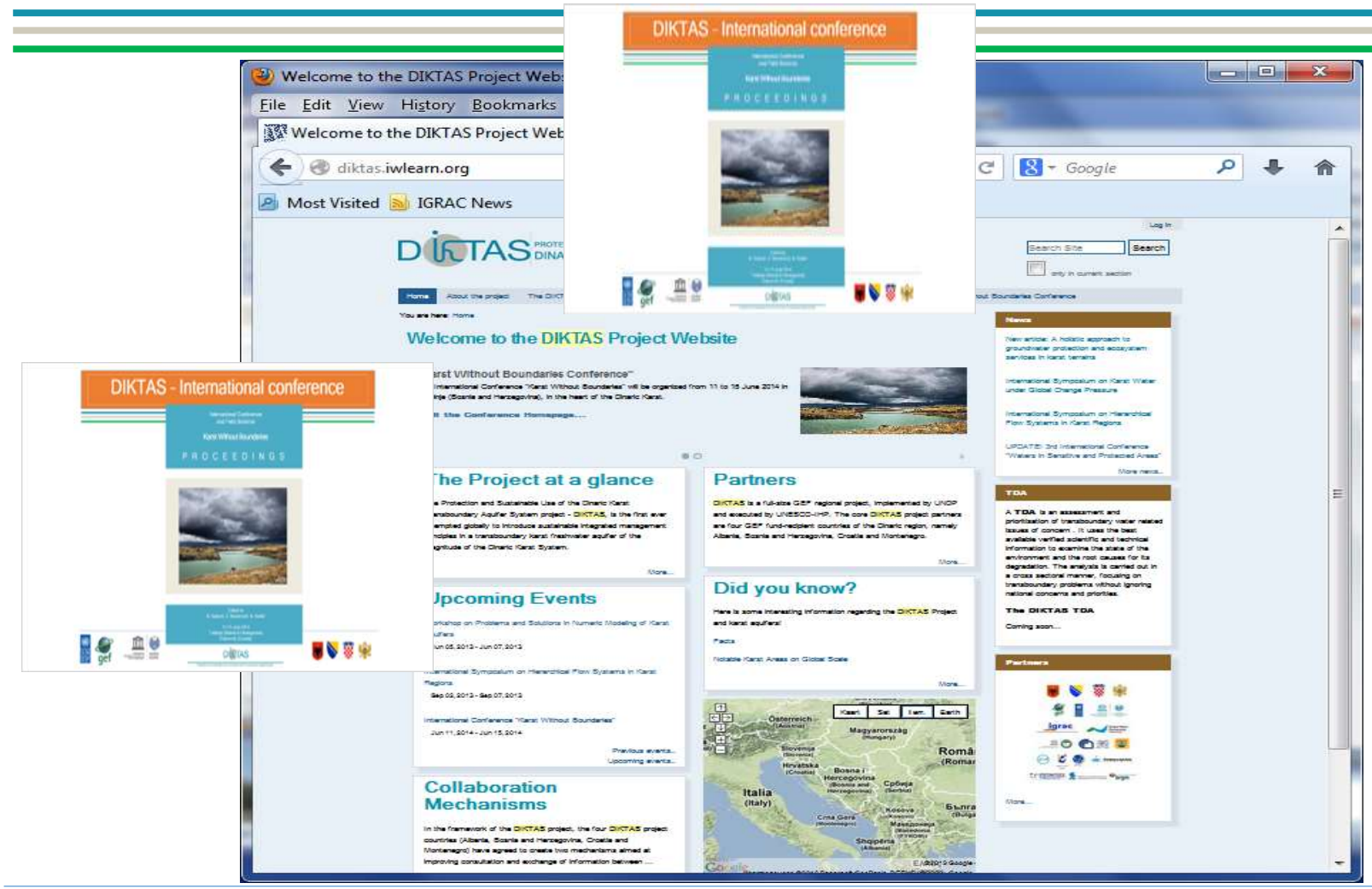
DIKTAS T D A

- The Project Team was organised in four **Working Groups** (WGs), reflecting the main issues of regional analysis:
  - WG1 - hydrogeological characterization
  - WG2 - environmental and socio-economical assessment
  - WG3 - assessment of legal and institutional frameworks and policies
  - WG4 - stakeholder analysis

DIKTAS - GIS HG Map

http://diktas.iw

DIKTAS - Web site



DIKTAS - International conference

International Conference
and Field Seminar

Karst Without Boundaries

P R O C E E D I N G S

Edited by
N. Kukurić, Z. Stevanović, N. Krešić

11-15 June 2014
Trebinje (Bosnia & Herzegovina)
Dubrovnik (Croatia)

DIKTAS

Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System

DIKTAS

Local and international capacity building

International Course

Characterization and Engineering of Karst Aquifers

Trebinje, Bosnia & Herzegovina,
June, 2014, 2015, 2016, 2017, 2018...

This course is supported by:

United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

NORTHERN ARIZONA UNIVERSITY

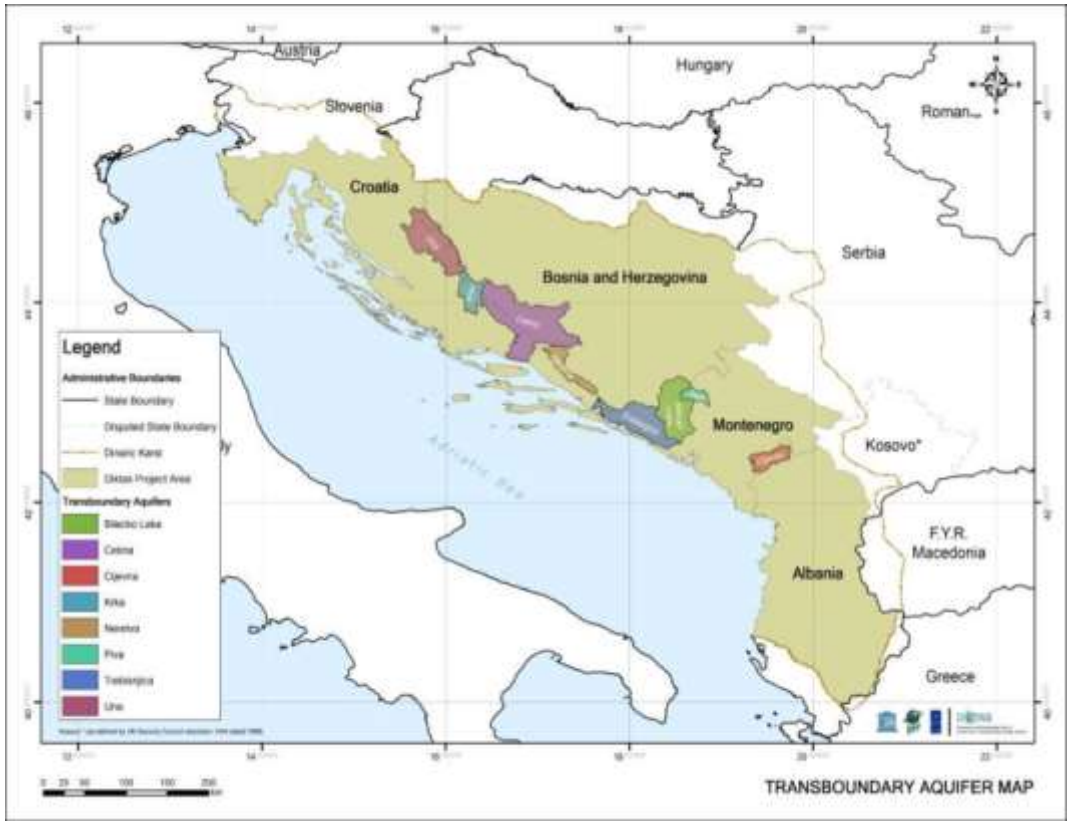
During the past five years and same number of courses around 100 participants from 22 countries were join the lectures and field seminars. They were lectured every year by 10 professors from different countries, half of them rotated every year.

DIKTAS

DIKTAS T D A

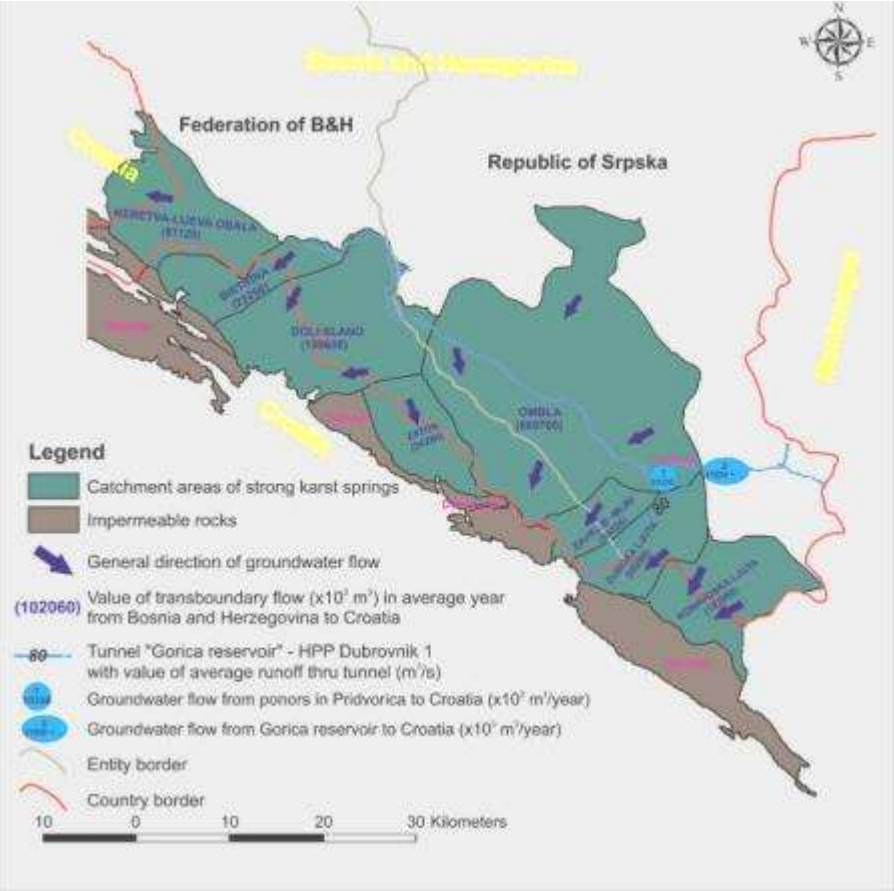
After the regional analysis was completed, transboundary aquifers were delineated and in depth analysis of the **transboundary aquifer areas** was conducted.

In total, eight TBA are selected for detailed analyses: Una, Krka, Cetina, Neretva, Trebišnjica (all shared by CRO and B&H), Bilećko Lake and Piva (B&H and MNE) and Cijevna/Cemi (MNE and ALB). Six of these TBAs belong to the Adriatic Sea catchment area and only two (Una, Piva) are part of the Black Sea basin. The TBAs comprise of in total a surface area of 12,000 km^2, which is around 10% of the entire study area. The surface area of individual TBA varies from 668 km^2 (Krka) to 3,455 km^2 (Cetina).



DIKTAS-TDA

Examples of complexity : transboundary aquifers B&H -Croatia



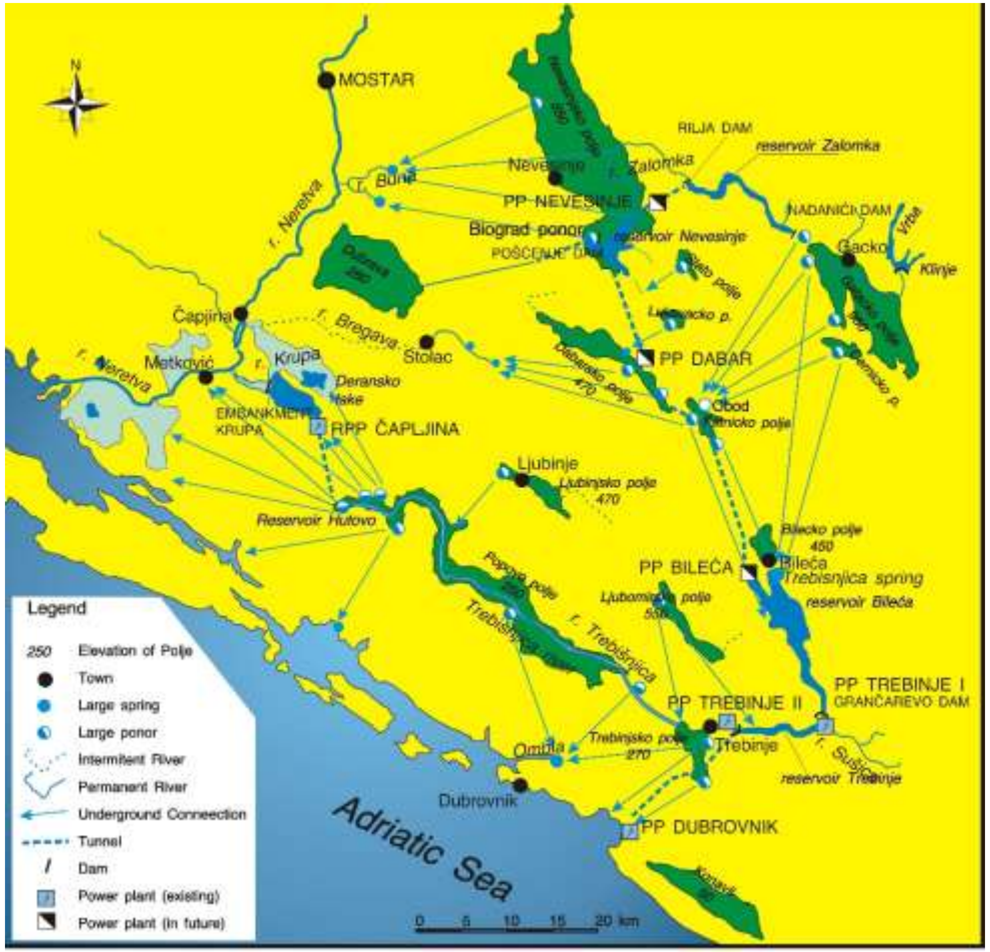
No	Transboundary aquifer name	Shared between	General direction of groundwater flow
1	Una	B&H, Croatia	From Croatia to B&H
2	Krka	B&H, Croatia	From B&H to Croatia
3	Cetina	B&H, Croatia	From B&H to Croatia
4	Neretva	B&H, Croatia	From B&H to Croatia
5	Trebišnjica	B&H, Croatia	From B&H to Croatia

-All relevant documents are used in process of delineation of TBA: geological and hydrogeological maps, studies, national water management strategies, RBC Reports-e.g. Cetina, RBMP e.g.Trebišnjica-Neretva and Sava etc.

-Results : -delineateded TBA between B&H and Croatia

-base for characterisation of TBA

DIKTAS T D A



N
MOSTAR
r. Neretva
r. Buna
Nevesinje
r. Zalomka
RILJA DAM
reservoir Zalomka
PP NEVESINJE
Biograd ponor
POŠĆENJE DAM
reservoir Nevesinje
NADANIĆI DAM
Vrba
Gacko
Klinje
Čapljina
r. Bregava
Stolac
Metković
r. Neretva
r. Krupa
Deransko lake
EMBANKMENT KRUPA
RPP ČAPLJINA
PP DABAR
Obod
Fatničko polje
Ljubinje
Ljubinjsko polje
470
Reservoir Hutovo
Popovo polje
Bilećko polje
450
Bileća
PP BILEĆA
Trebišnjica spring
reservoir Bileća
Ljubomirsko polje
r. Trebišnjica
PP TREBINJE I
GRANČAREVO DAM
PP TREBINJE II
Trebinjsko polje
270
Trebinje
Ombla
r. Sušica
reservoir Trebinje
Dubrovnik
PP DUBROVNIK
Adriatic Sea
0 5 10 15 20 km
Legend
250 Elevation of Polje
Town
Large spring
Large ponor
Intermittent River
Permanent River
Underground Connection
Tunnel
Dam
Power plant (existing)
Power plant (in future)

DIKTAS T D A

Environmental and Socio-Economic Analysis

The analysis of the environmental and socio-economic situation in the DIKTAS project countries showed a degree of similarity and regional interconnectivities. The countries share the same or similar geographic characteristics, the common or related history and similar trends.

The four countries represent very important sources of clean water, protected and unprotected nature, specific local economies, habits, traditions and future prospects. Each of the countries has many possibilities for development based on the wise exploitation of natural resources; tourism is and will most probably be one of the major sources of economic growth in the years to come.

DIKTAS T D A

Legal and Institutional Framework and Policy

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

By the adoption of the Water Laws in all four countries, the key provisions of the EU Water Framework Directive (WFD) have been transposed into their legislation including designation of authorities for water management and identification of the river basin districts. The countries are making significant efforts to develop a wide range of secondary legislation, but these are not yet completed.

DIKTAS T D A

A SWOT analysis was performed to map the
strengths, weaknesses, opportunities and threats the karst management is currently faced with, by collecting information on the legal, institutional and policy
setting in the region. Common approaches and principles as well as areas of concern shared among partner countries were identified, along with contradicting national strategies and gaps in national legislations that may have an adverse effect on decision making related to the water resources management framework.

A Stakeholder Analysis was used to identify the characteristics and understand the
opinions and perceptions of the stakeholders regarding the management of the water resources. A number of stakeholder groups including water management competent ministries, regional authorities, research institutions, tourism
organizations, NGOs working on nature and ecosystems, as well as private sector
industries and hydropower units, were consulted for the preparation of the TDA and the SAP through focus group meetings, roundtables and internet
sed tools.

The main findings of the TDA

The main challenges in groundwater management include: cross-sectoral coordination, lack of implementation of IWRM principles in groundwater governance, as well as lack of public administration capacity and public participation in decision-making procedures.

The inappropriate disposal of solid waste and wastewater was recognized as the most important threat to groundwater. Karst groundwater pollution is also owed to agricultural and industrial activities. Infrastructure for hydropower production, a significant
part of energy production in all DIKTAS countries, has negative impacts. The lack of financial means, the unregulated market economy and the weak environmental values have an overall negative impact on the management of the karst water resources. Due to lack of monitoring at local and regional level there is limited assessment of the status quo and future trends with regards to karst groundwater quality and quantity.

DIKTAS T D A

The outcomes of TDA show that state of groundwater in the DIKTAS project region is **in general good** with a few exceptions and with a number of **serious potential threats**.

The main threat to the groundwater quality in the DIKTAS region is **solid- and waste water disposal.**

Agriculture and **industry** also pollute groundwater and form a major threat but to a lesser degree that the waste.

Currently **no common legal and institutional framework** and no common criteria exist for **a) the delineation of water source sanitary protection zones,** and **b) setting cost-efficient measures for groundwater protection in the Dinaric Karst region**

There is a **concern of some stakeholders about impact of hydrotechnical constructions in the region**, especially in Bosnia and Herzegovina

The main findings of the TDA –

Weakest point: Lack of GW Monitoring

Croatia: Characterization of GW bodies completed; Monitoring is taking place in accordance with EU WFD (Hrvatske Vode responsible).

B&H: Characterization of GW bodies recently completed under IPA; methodology for GW status/risk assessment established; inappropriate monitoring.

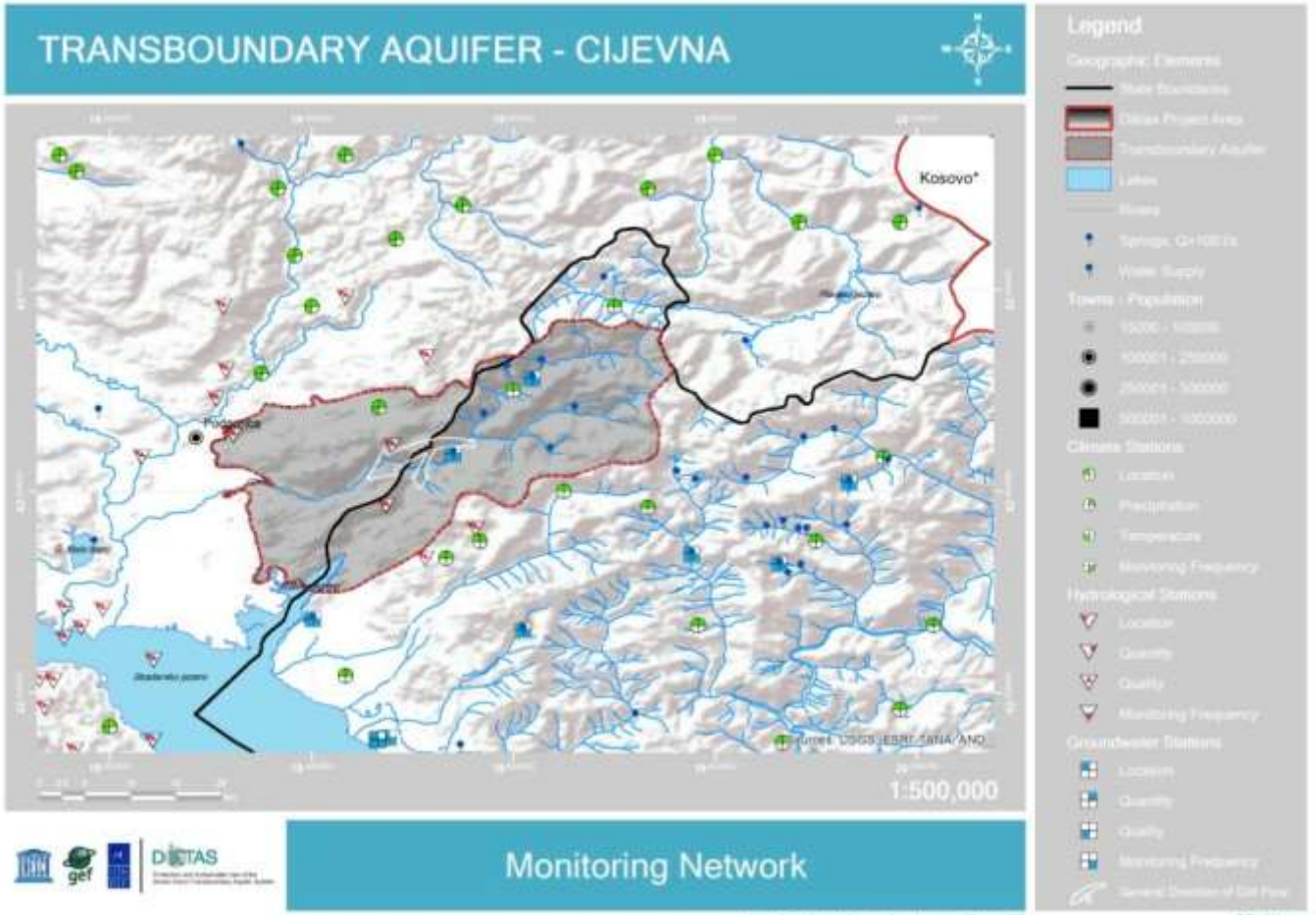
Albania: Preliminary characterization of GW bodies performed within CEMSA project. Currently, characterization undertaken by Albanian geological Survey (scale 1:200 000); rare GW monitoring.

Montenegro: Characterization of GW bodies firstly made in 2005 (ICPDR), a new one is taking place; Methodology for GW status/risk assessment is actually creating; almost no any GW monitoring.

DIKTAS T D A

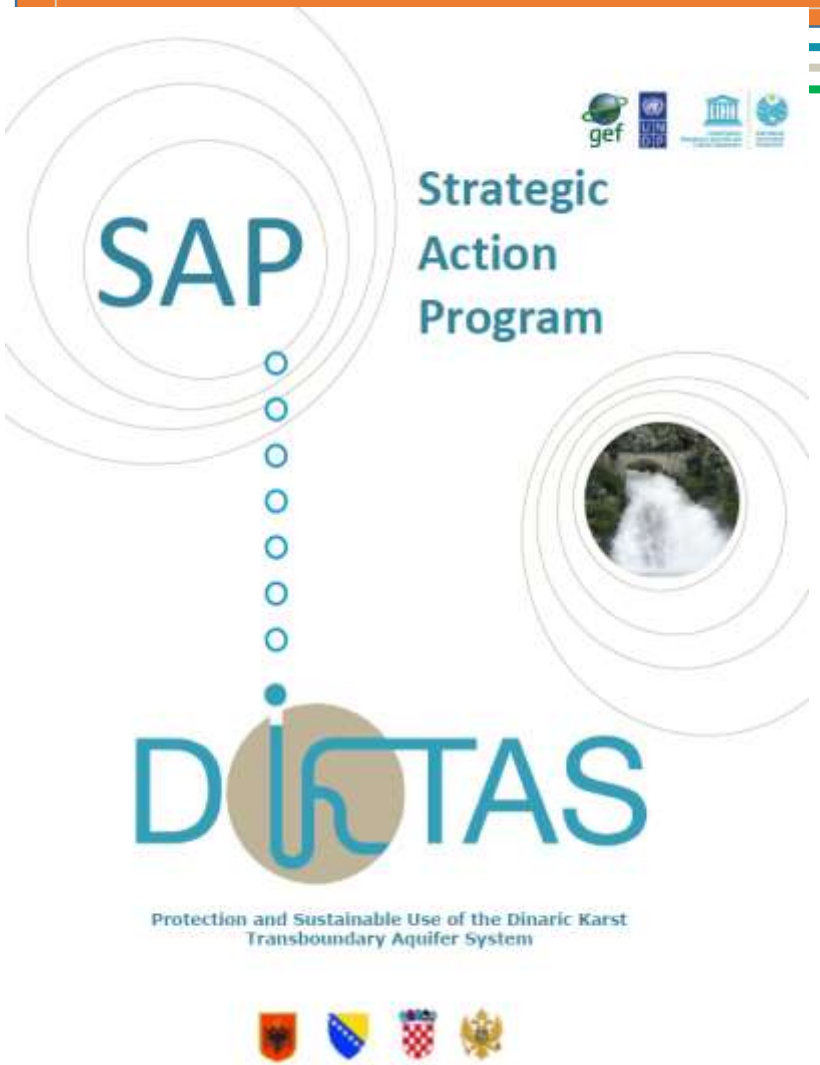
Proposed Actions	Proposed for TBAs, not exclusive to facilitate actions
1. Establishment of a common groundwater monitoring program;	All TBAs
2. Improvement of wastewater treatment especially in the Bihać region	Una, Neretva (Ljubuski town)
3. Harmonisation of hydrogeological criteria for delineation of source protection zones as the basis for policy harmonisation and protection of karst springs in B&H, Croatia, Montenegro and Albania, used for public water supply;	Una, Neretva, Cetina, Bilećko Lake, Cemi/Cijevna
4. Create future projections of water demands depending on socio-economic analysis	Una, Neretva, Trebišnjica, Cetina, Bilecko Lake
5. Definition of common criteria for: a) delineation of the sanitary protection zones and b) for setting cost-efficient measures for groundwater protection in karst areas;	All TBAs
6. Definition of legal framework for establishment and law enforcement in sanitary protection zones	Una, Neretva, Cetina
7. Inventory of non-point and point sources of pollution (landfills, septic tanks, quarries, wastewater discharges, and others);	All TBAs
8. Establishment of regulations between the countries to set up regulatory frameworks concerning the discharge of wastewaters into the land stressing the importance of a unified policy	All TBAs
9. Fostering better control of the current agricultural and similar practices;	Neretva
10. Promotion of eco-tourism	Neretva
11. Existing ways of usage of land and water should be determined and a plan for future utilization should be drafted in order to minimize the negative effects on water resources.	Cetina
12. Identification of the permanent and local sources of pollution in Albania and Montenegro and their influence in these countries;	Cemi/Cijevna
13. Future systematic investigation of potential Groundwater Dependent Ecosystems (GDE) characteristics and proposal of special protection measures for possible joint management plan of the Cijevna River as a joint Natura 2000 site.	Cemi/Cijevna

DIKTAS T D A



DIKTAS-TDA

DIKTAS S A P



- **Negotiated policy document,** based on the **TDA**
- Establishes clear **priorities** for action
- Identifies policy, legal and institutional **reforms** and investments required
- The preparation of a SAP is **a cooperative process** among key stakeholders in the countries of the region.

DIKTAS S A P

Vision and the Long Term Objectives

Based on the outcomes of the TDA and other DIKTAS project activities, a concept SAP document was prepared by the DIKTAS Project Team and subsequently discussed by the project countries and the project Steering Committee.

Reduction: From 5 objectives to 3 strategic (priority) actions

The five Water Resources & Ecosystem Quality Objectives identified by the SAP:
Ensure **sufficient groundwater availability** in dry periods, to support water supply and environmental flow.
Maintain and improve (where required) **karst groundwater quality**.
Ensure **protection of Groundwater Dependent Ecosystems**, specific features and their ecosystem services for the future.
Support **equitable use** of groundwater resources.
Raise awareness and build capacities related to karst water and dependent ecosystems management.

DIKTAS S A P

SAP/ Strategic Action 1:

Joint design and testing of a regional groundwater quantity and quality **monitoring network** and associated data exchange and analysis protocols.

SAP/ Strategic Action 2:

Harmonization of criteria for (content and extend) of **sanitary protection zones**.

SAP/ Strategic Action 3:

Application and promotion of joint principles of sustainable management and equitable use of transboundary Dinaric karst aquifers.

DIKTAS-SAP

The expected benefit from execution of proposed SAP activities is manifold. These activities will substantially contribute to:

Ensuring sufficient quantities of groundwater in dry periods in the areas of transboundary aquifers by improving bilateral cooperation among the neighbouring countries; based on:

- Appplication of methodology to determine the maximum permitted abstraction quantities for renewable groundwater resources and
- Criteria for water allocation between the aquifer countries under the general principle of equitable use.

Meeting the prerequisites for the development and improvement of integrated river basin management plans as required by the EU WFD, taking into account the specifics of the Dinaric karst. This implies:

- Improvement and development of national monitoring of karst groundwater quantitative status and prepared monitoring programme for every individual transboundary aquifer, which is an obligation for every country in the process of implementing the EU WFD.
- Development of coordinated methodology for establishment and implementation of national monitoring of karst groundwater chemical status, which is also an obligation for every country in the process of implementing the EU WFD.
- Adoption and implementation of guidelines for the preparation of a register of GWDEs in the process of implementing the EU WFD.

DIKTAS S A P

- *Development and implementation of coordinated legal mechanisms for integrated and sustainable management of Dinaric karst resources*, including:
  - Adopted national-level decisions on amendments to the existing legislation about implementation of the Rulebook – agreed and adopted on the level of the DIKTAS Project – for determination of sanitary protection zones and accompanying protection measures;
  - Adopted Guidelines – prepared on the level of the DIKTAS Project – for improvement of national institutional and legal frameworks with the aim of achieving more efficient protection and management of GWDEs in the Dinaric karst.

Raising awareness of the public and target groups about karst water and their dependent ecosystems and capacity building through dissemination of specific knowledge in these domains.

DIKTAS S A P

SAP

Strategic Action Program

DIKTAS

Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System

Suggested priority actions include:

The establishment of a **common groundwater monitoring program** followed by intense **capacity building in the public sector**.

The **harmonization of criteria** for the delineation of source protection zones, aimed at a harmonized policy/regulatory framework.

The **establishment of a legal framework** in transboundary sanitary protection zones.

A Shared Vision for the management of the karst water resources is proposed:

To achieve joint sustainable and equitable use and protection of the Dinaric Karst Aquifer System.

Now is under preparation GEF Project Document for DIKTAS Phase II - Implementation of the Strategic Action Plan of the Dinaric Karst Aquifer System: improving groundwater governance and sustainability of related ecosystems

Bolje sestre Intake for Regional Water Supply of Montenegrin Coast – Conception, Research, Solutions, Application

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Department of Hydrogeology
Belgrade, Serbia

Discharge of karst aquifer in Dinaric karst

- Concerning karstic groundwater resources, **the Dinaric region is by far the richest in all of Europe**. Some areas, such as southern Montenegro, are characterized by a very intensive water balance: the average specific yield is over 40 l/s/km^2.
- Some authors stated that in the Dinaric region of ex-Yugoslavia there are 230 springs with a minimal discharge over 100 l/s, while about 100 springs have minimal discharge over 500 l/s.
- In Albanian karst there are roughly about 110 springs with average discharge exceeding 100 l/s. Of these, 17 have discharges exceeding 1000 l/s (Eftimi, 2010).


Alpides
Carpathians
Apeninnes
Dinarides
Pindes
Balkan Mts.
Hellenides
1
2
3
4
5
6
7
8
9
10
11
12
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21
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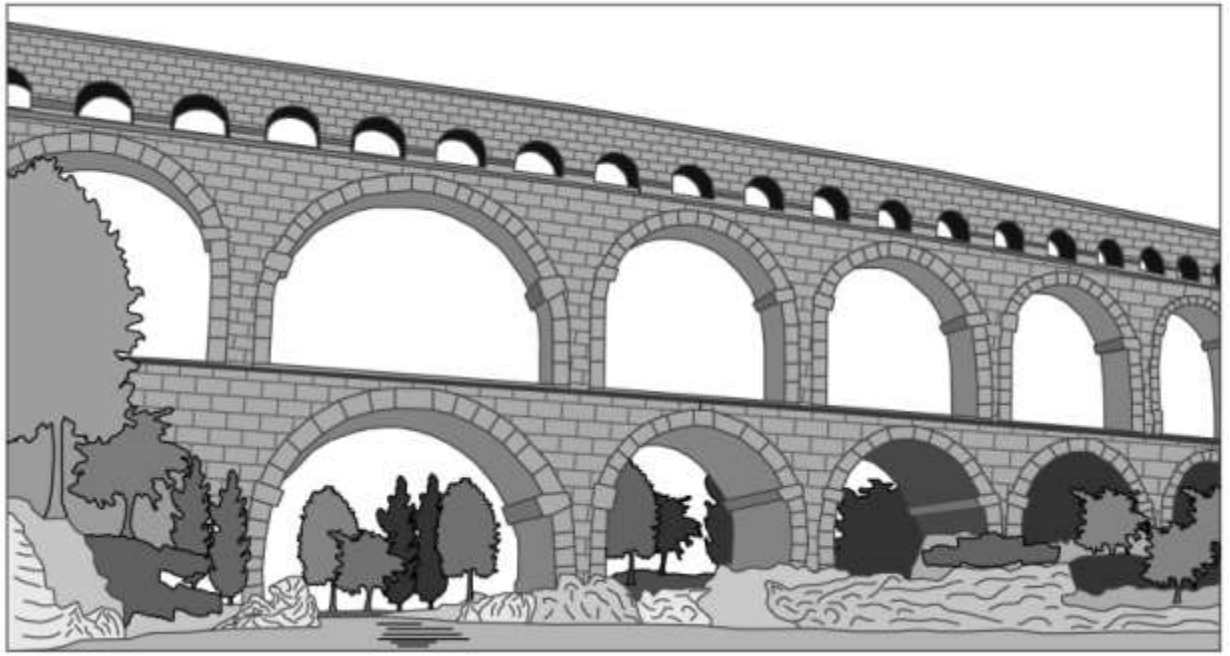
23
24
25
GROUNDWATER
HYDROLOGY OF
SPRINGS
ENGINEERING,
THEORY,
MANAGEMENT, AND
SUSTAINABILITY
NEVEN KRESIC
ZORAN STEVANOVIC
B
H

There are several large cities in SE Europe with populations of over a half of million that depend on karst aquifers and their discharge regimes. Among them are the six capitals Roma, Vienna, Tirana, Skopje, Sarajevo, and Podgorica.

Tapping karstic springs - Traditional way of water supply since Roman time

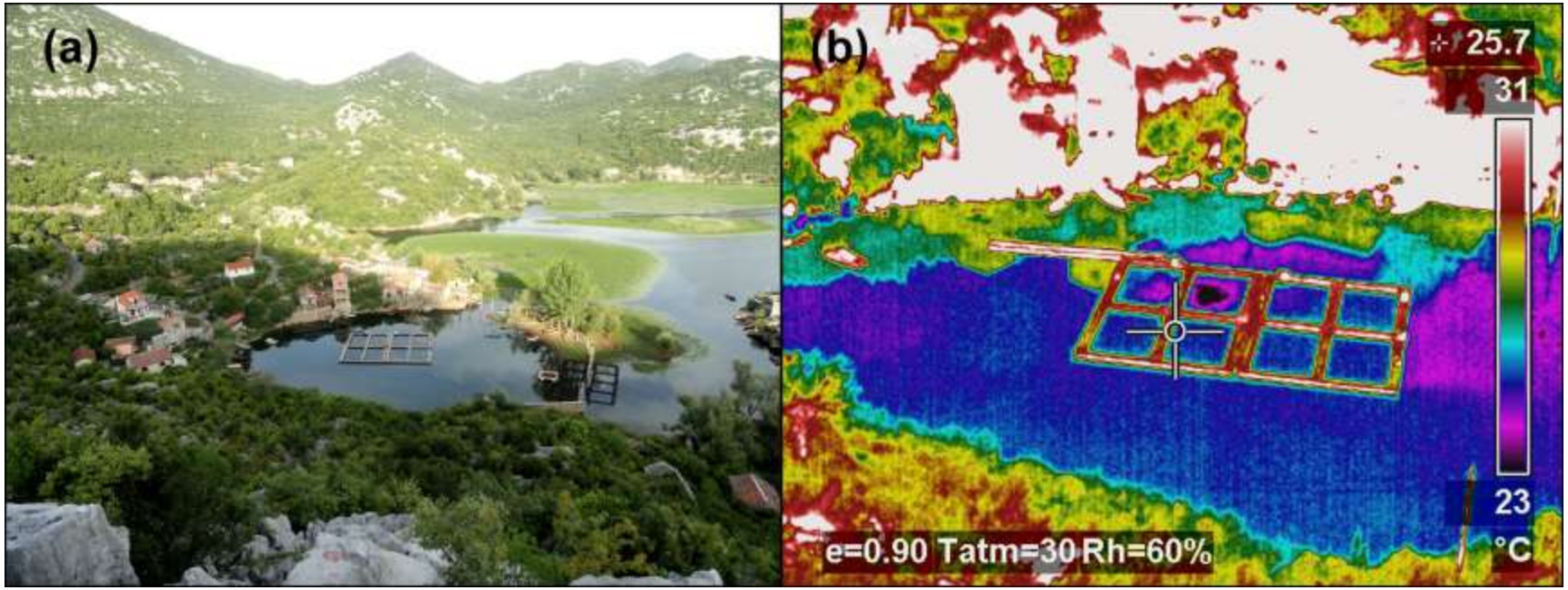
- An ancient art in the region.
- For example, 11 long aqueducts delivered more than 13 m^3/s of water to Rome from distances ranging from 16-91 km.
- Several water supply systems from that time are completely reconstructed but still use the same springs and pipeline routes.

Roman heritage




KOTOR

New intake for Montenegro coast



New intake for Montenegro coast

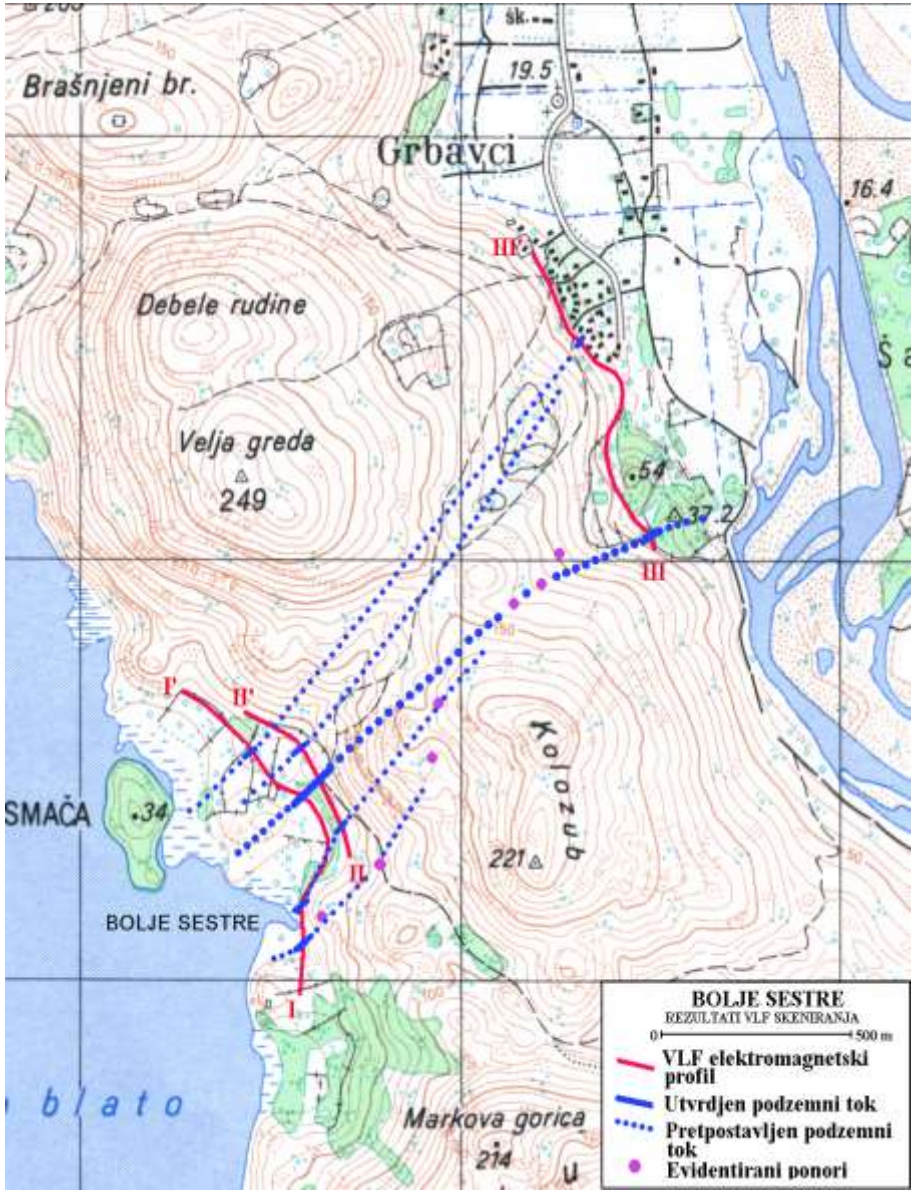
- Sub lacustrian springs in Skadar basin
- The total pipeline length to be ca. 140 km.
- The system is planned for a maximum capacity of 1.5 m^3/s in two stages.
- The water discharges through several registered points near the shore.
- Order: Avoid mixture of water (fresh groundwater and lake)

The identified set of major problems that require adequate responses includes the following:

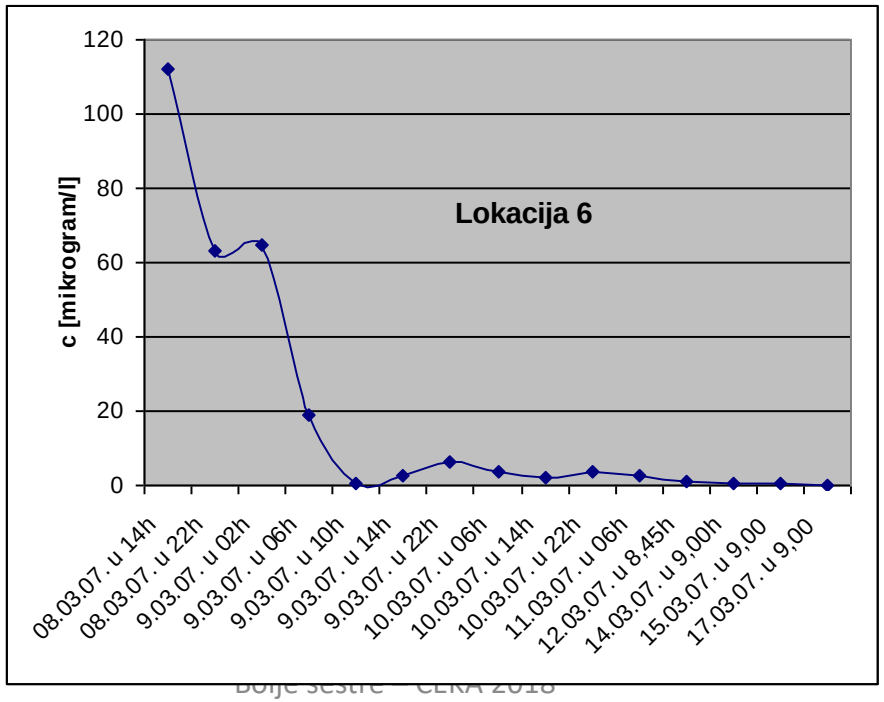
- Source minimal capacity;
- Source intake;
- Source water quality;
- Source protection against pollution;
- Water treatment;
- Water pumping and transfer to the other side of the lake.

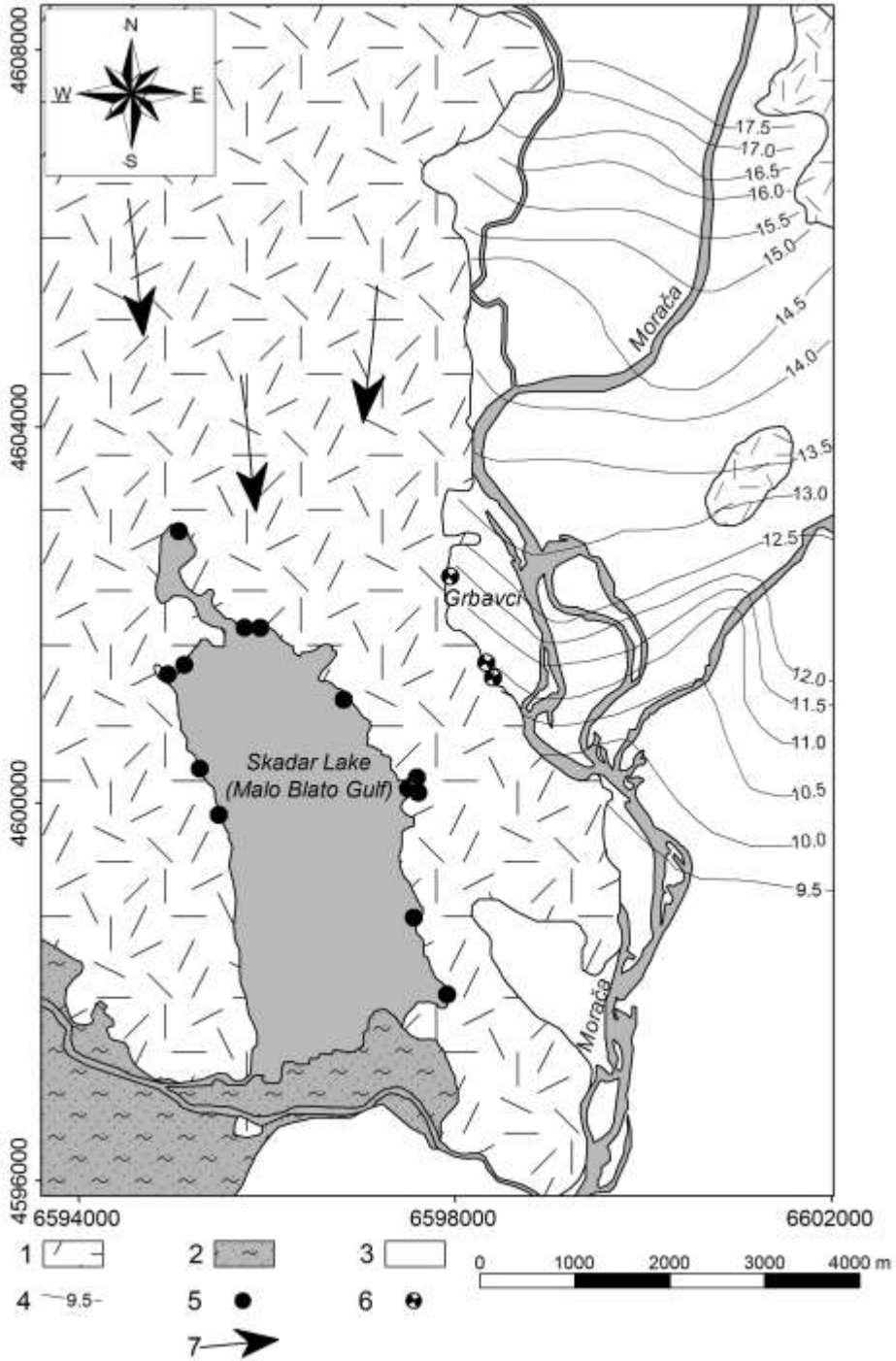
How to manage and achieve all this requirements?

- Complex investigation programme included: hydrology, geophysical survey (geoelectric tomography and electromagnetic VLF method),drilling, tracing tests, hydrogeological mapping, diving, permanent sampling and analyses of the water quality (biological, chemical, radiological).


Brašnjeni br.
Grbavci
19.5
16.4
Debele rudine
Velja greda
249
.54
37.2
III'
III
I'
II'
II
I
SMAČA
.34
BOLJE SESTRE
Kolozub
221
Markova gorica
214
b l a t o
BOLJE SESTRE
REZULTATI VLF SKENIRANJA
0
500 m
VLF elektromagnetski profil
Utvrdjen podzemni tok
Pretpostavljen podzemni tok
Evidentirani ponori

T (h) from tracing	10^{-6} g-l
22	112.2
30	63.1
34	64.5
36	19.0
40	0.38
44	2.42
52	6.43
56	3.78
64	2.32
72	3.80
80	2.76
106	0.79
154	0.47
178	0.71
226	0.0

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W
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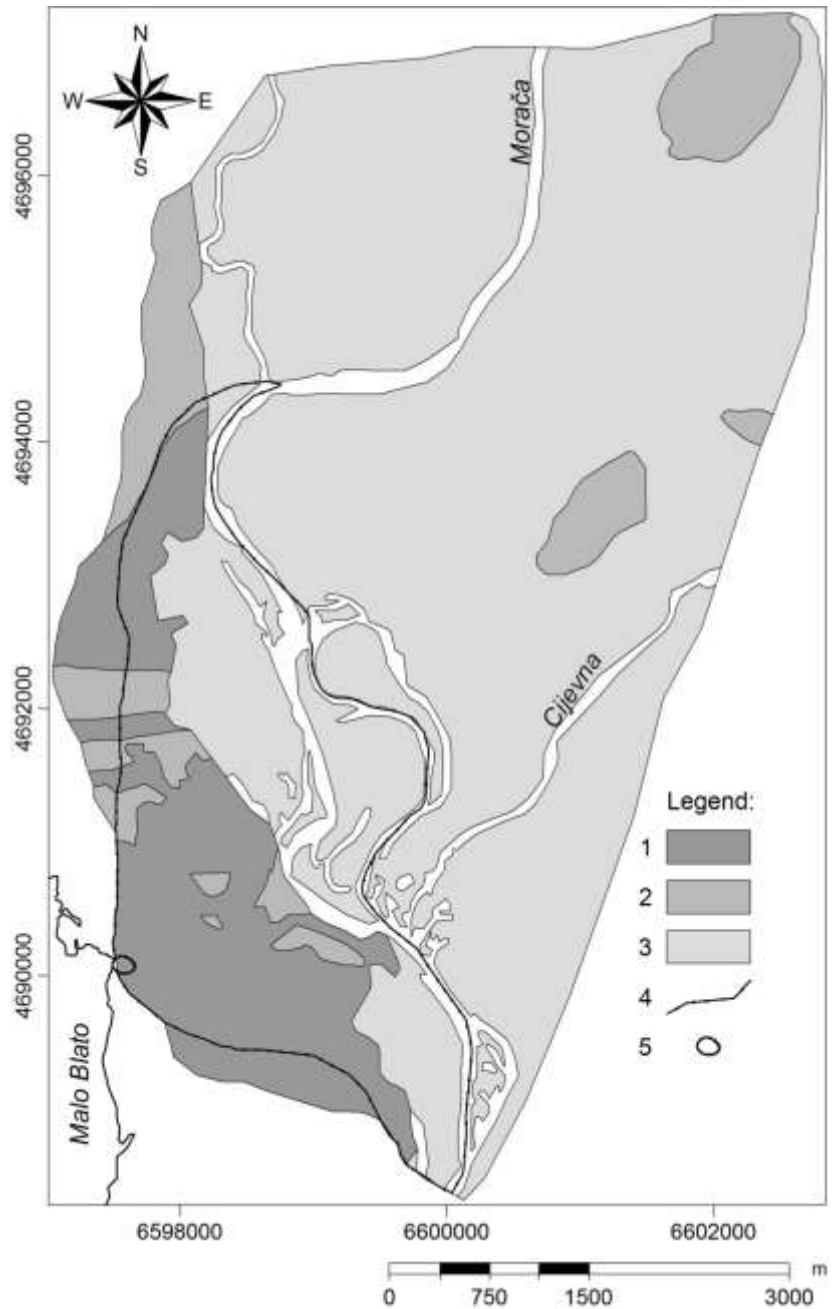
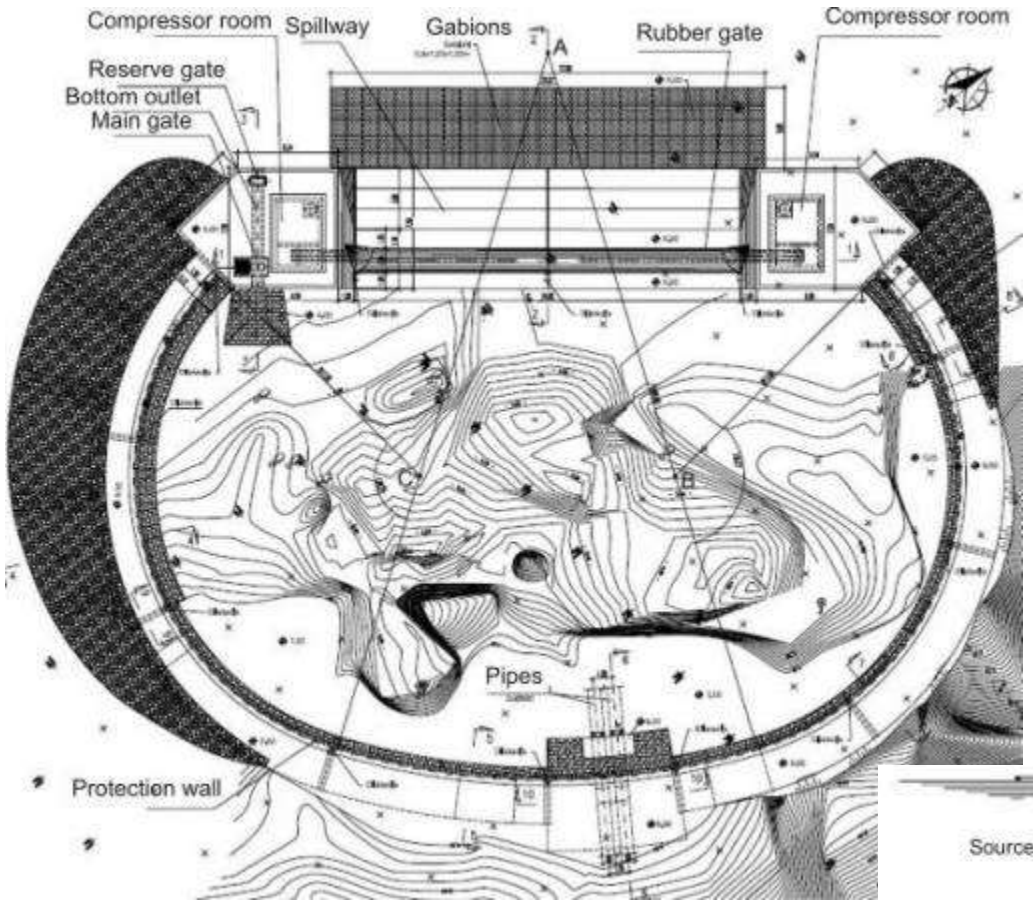
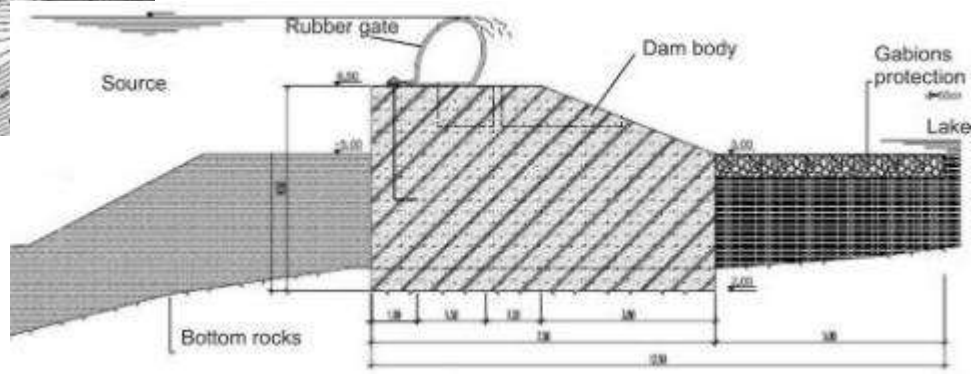
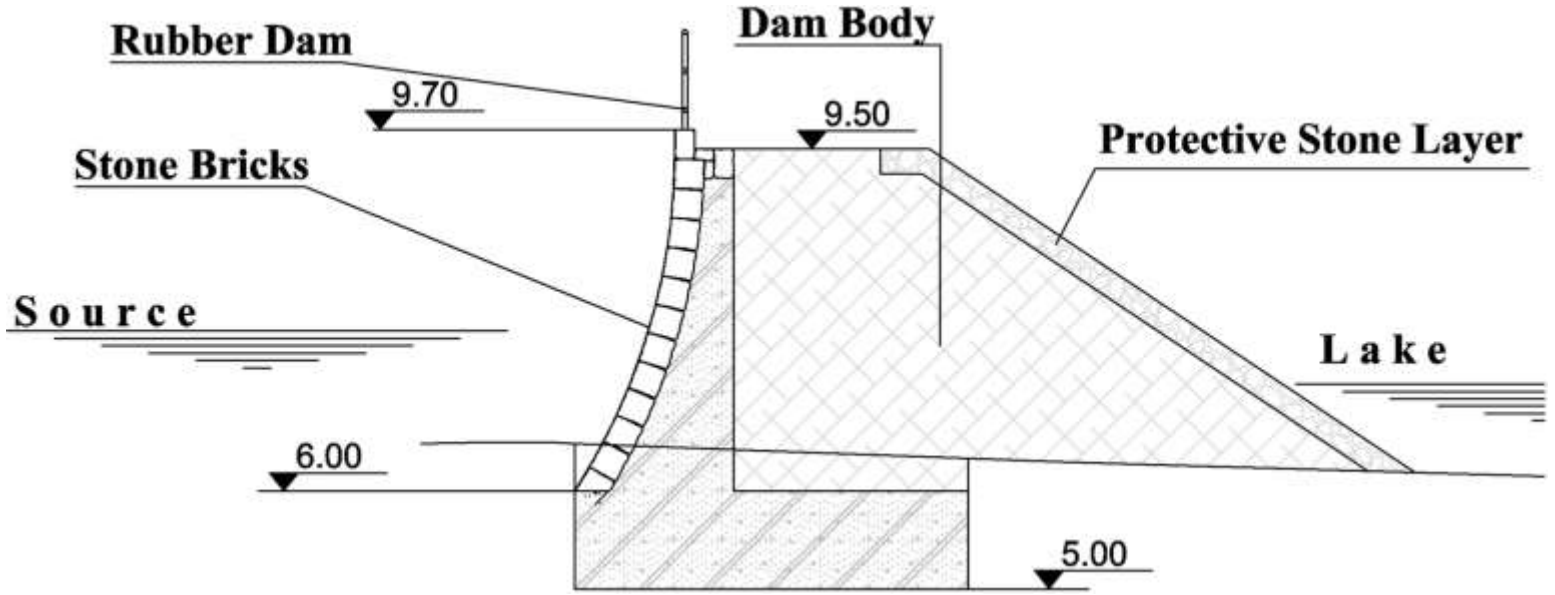
4604000
4600000
4596000
6594000
6598000
6602000
17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
Morača
Grbavci
Skadar Lake
(Malo Blato Gulf)
1
2
3
4
5
6
7
0
1000
2000
3000
4000 m


N
W
E
S
4696000
4694000
4692000
4690000
Morača
Cijevna
Malo Blato
Legend:
1
2
3
4
5
6598000
6600000
6602000
m
0
750
1500
3000

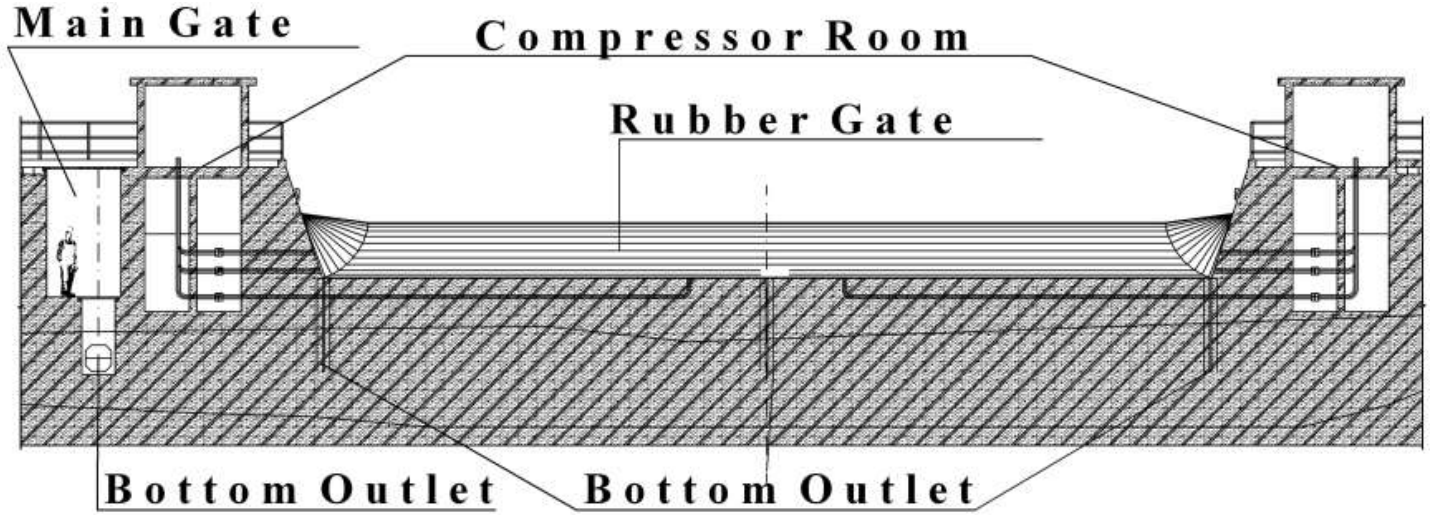
Final Solution: Specific intake - The concrete elliptical coffer dam covers an area of some 300 m^2 and has a rubber gate spillway

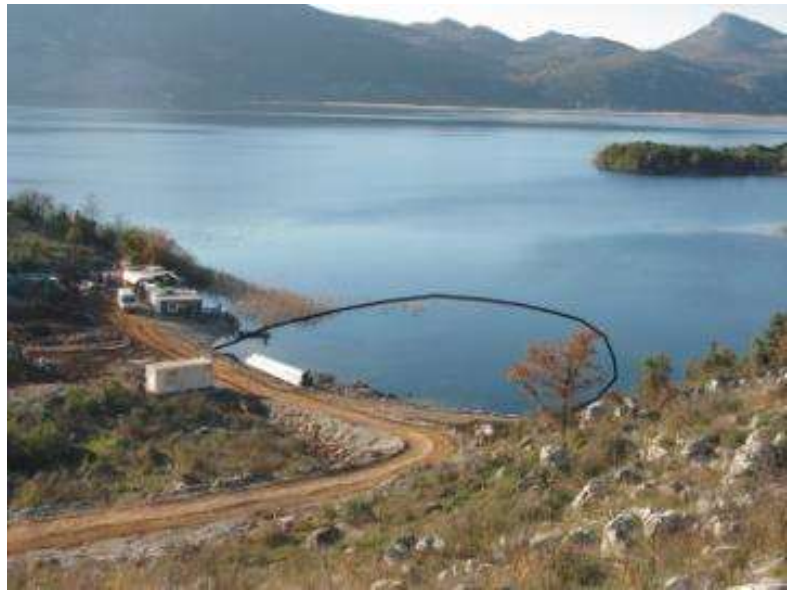


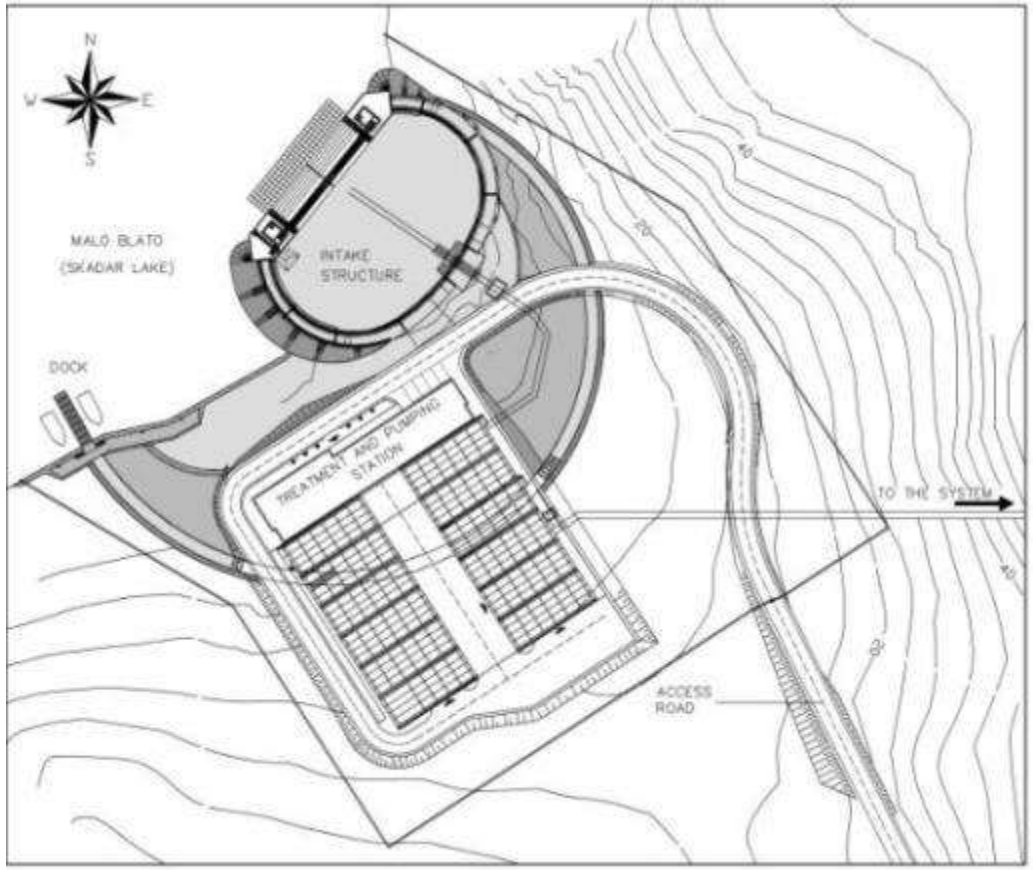




Concrete aside walls (non-flow part) are of an elliptical shape, 5.1 - 7.0m high and with a crest at an altitude of 9.5 m a.s.l. The width of the wall is 0.6m.







It confirmed a very small influence resulting in a maximum decrease in the level of the lake of less than 1cm under the extraction of 1.5 m^3/s (Stevanovic *et al*. 2008)

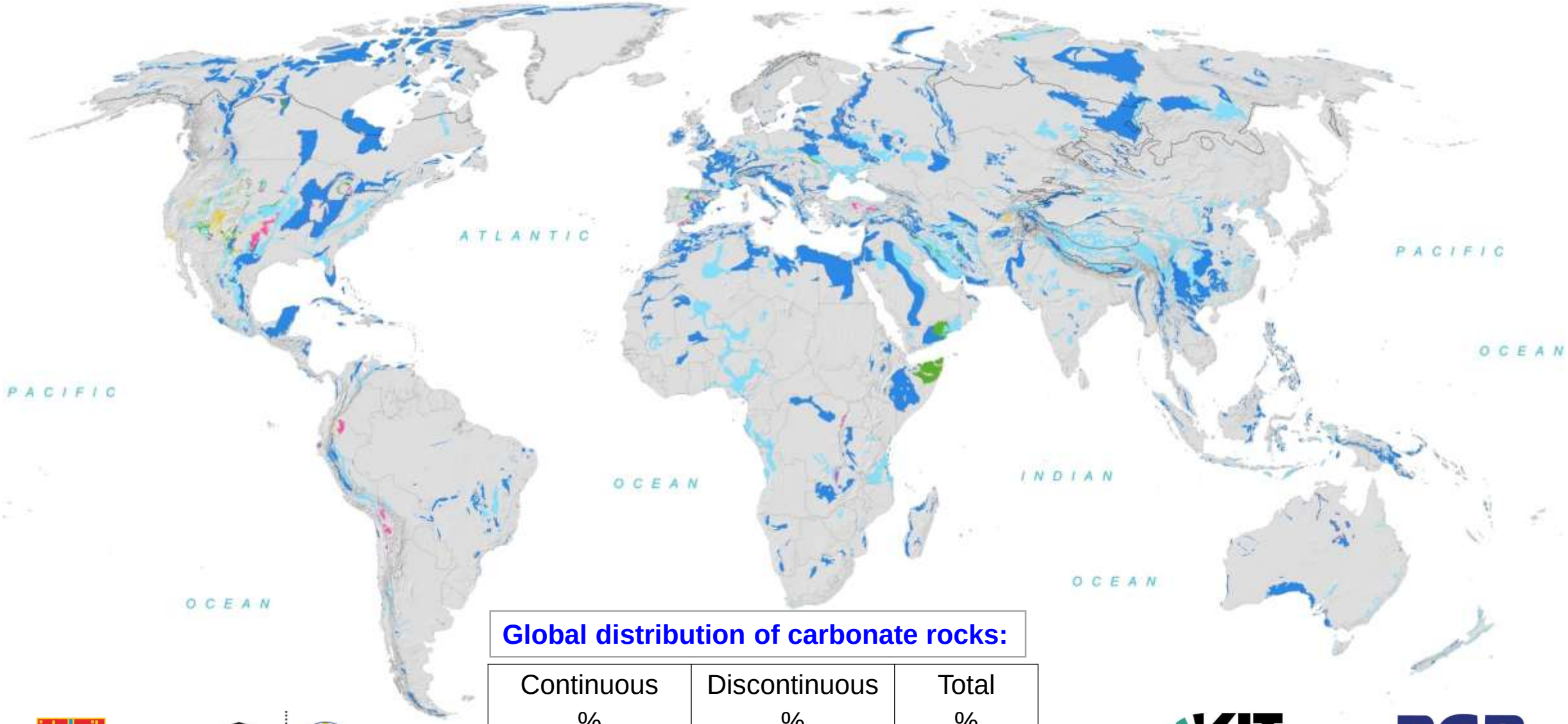
V

„Project which changed the Montenegro“

There is one final fact worthy of special attention: the current cost of the survey on and design of the two intakes and their future construction is calculated to be in the range of 1-2% of the total investment for the implementation of this project!? On proud of involved researchers and engineers.

Thank you for your attention

The World Karst Aquifer Map (1:40 Million)



Global distribution of carbonate rocks:

Continuous %	Discontinuous %	Total %
9.3	**5.4**	**14.7**