Challenges in transboundary karst water resources management

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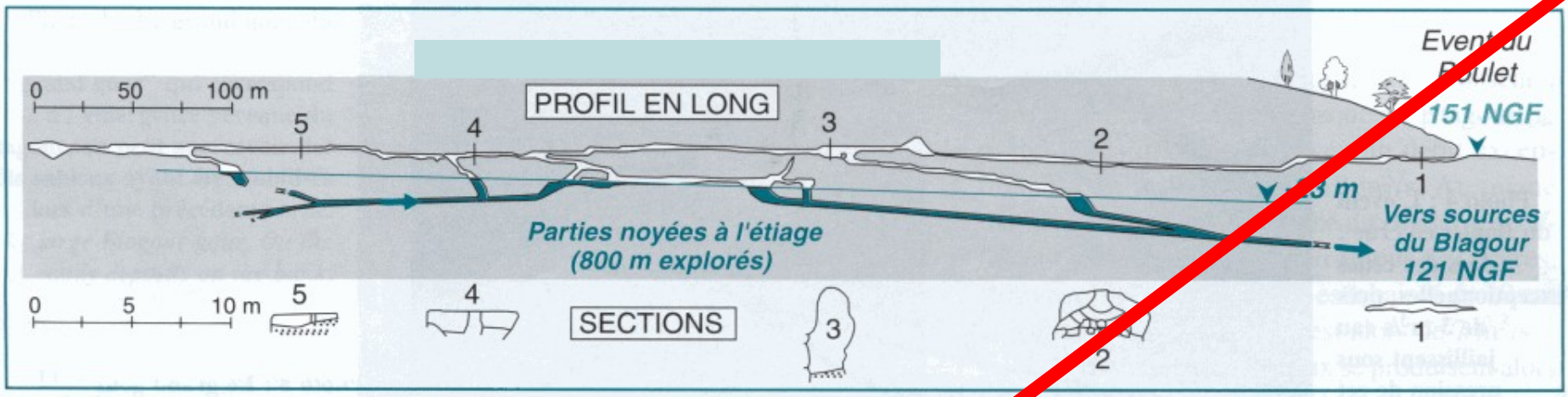
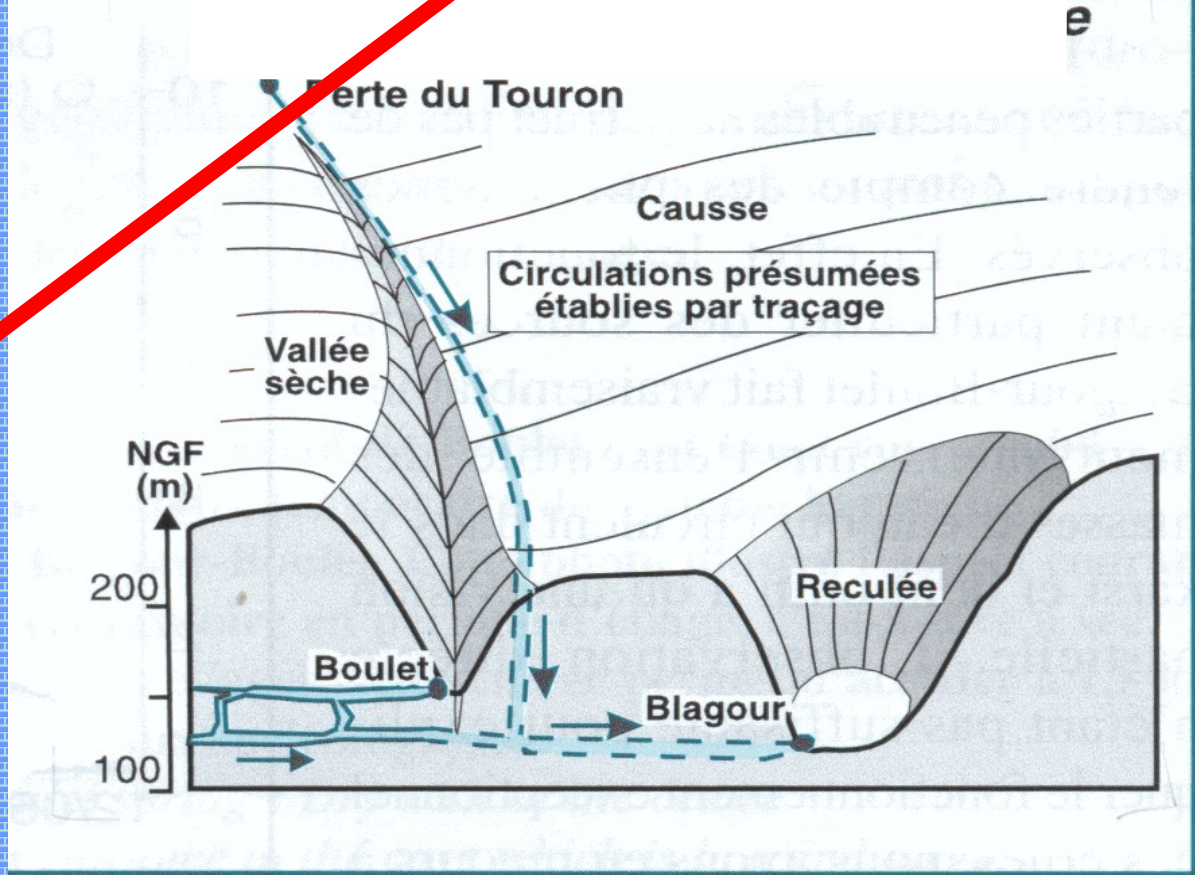
Karst terrains are typified by a wide range of closed and few open surface depressions, a well-developed underground drainage system, and strong interaction between circulation of surface water and groundwater. Karstification is a continuous process governed by natural and man-made interventions. Water circulation over and throughout karst terrains significantly differs from that in other types of terrain. The main reason is rapid rates of infiltrations and the influence of the solutionally enlarged fractured aquifers. Karst aquifers are generally continuous. However, numerous underground karst features strongly influence the continuity of karst aquifer, and commonly it does not function as a simple continuum within a catchment.

Permanent and intermittent karst springs



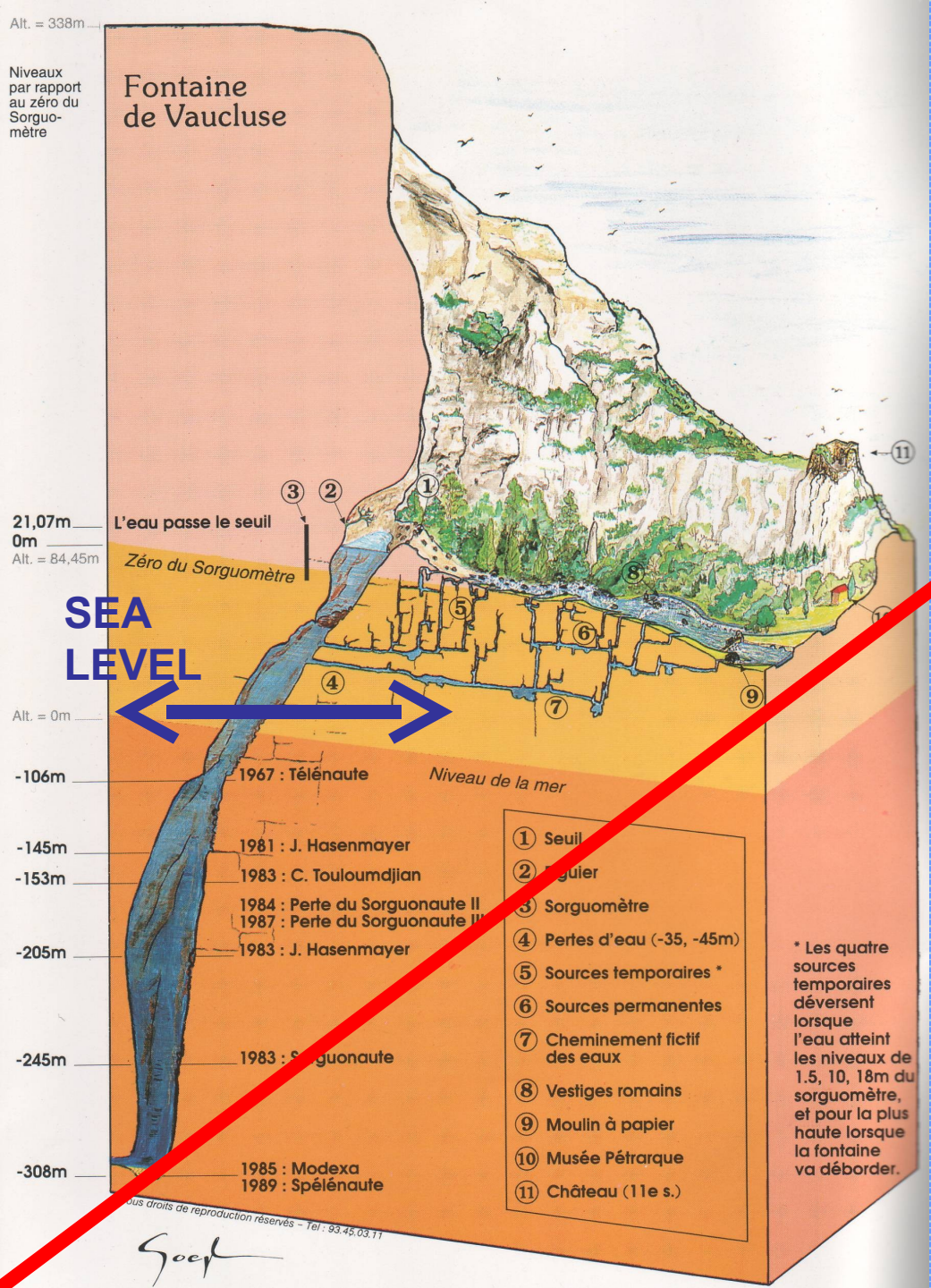


Interactions between surface and subsurface in karst are very strong. Water circulation in karst systems shows the extreme heterogeneity and variability of hydrogeologic, hydrologic, hydraulic, ecological and other parameters in time and space. Karst systems are some of most complex and difficult to decipher.

One of the root causes of problems of karst waters management are impossibility and/or difficulty in catchment boundaries and areas definition, as well as their changes in time and space. The determination of the catchment boundaries and the catchment area is the starting point in all hydrological analyses and one of the essential data which serve as a basis for water resources management. The differences between the topographic and hydrologic catchments in karst terrain are, as a rule, so large that data about the topographic catchment are useless in water management practice. Very often the position of the karst catchment boundaries depends upon the groundwater levels which strongly and sharply change in time. In some situations at very high groundwater levels, fossil and inactive underground karst conduits are activated, causing the redistribution of the catchment areas, i.e. overflow from one to other catchment.

The root causes of karst water resources management peculiarity and heterogeneity are :

- heterogeneous and anisotropic surface and underground morphologic karst forms;
- existence of well developed, complex, deep, and mostly unknown positions and dimensions of underground karst cracks, joints, fissures, impermeable layers, conduits etc;
- strong interaction between circulation of surface water and groundwater;
- high and fast oscillations of groundwater;
- strong and direct but inadequately known links between inflow (swallow-holes) and outflow (karst springs) karst features;
- generally small storage capacity of the karst medium;
- fast, turbulent groundwater transport through karst conduits and at the same time slow, laminar flow through karst matrix;
- natural endogenic and exogenic processes, and influence of man's induced structures and/or activities (dams, reservoirs, motorways development, water pumping, water abstraction etc) which influence fast and/or slow changes of the water regime;


Alt. = 338m
Niveaux par rapport au zéro du Sorguo-mètre
Fontaine de Vaucluse
21,07m
L'eau passe le seuil
0m
Alt. = 84,45m
Zéro du Sorguomètre
SEA LEVEL
Alt. = 0m
-106m
1967 : Télénaute
Niveau de la mer
-145m
1981 : J. Hasenmayer
-153m
1983 : C. Touloumdjian
1984 : Perte du Sorguonaute II
1987 : Perte du Sorguonaute III
-205m
1983 : J. Hasenmayer
-245m
1983 : Sorguonaute
-308m
1985 : Modexa
1989 : Spélénaute
1 Seuil
2 Déversoir
3 Sorguomètre
4 Pertes d'eau (-35, -45m)
5 Sources temporaires *
6 Sources permanentes
7 Cheminement fictif des eaux
8 Vestiges romains
9 Moulin à papier
10 Musée Pétrarque
11 Château (11e s.)
* Les quatre sources temporaires déversent lorsque l'eau atteint les niveaux de 1.5, 10, 18m du sorguomètre, et pour la plus haute lorsque la fontaine va déborder.
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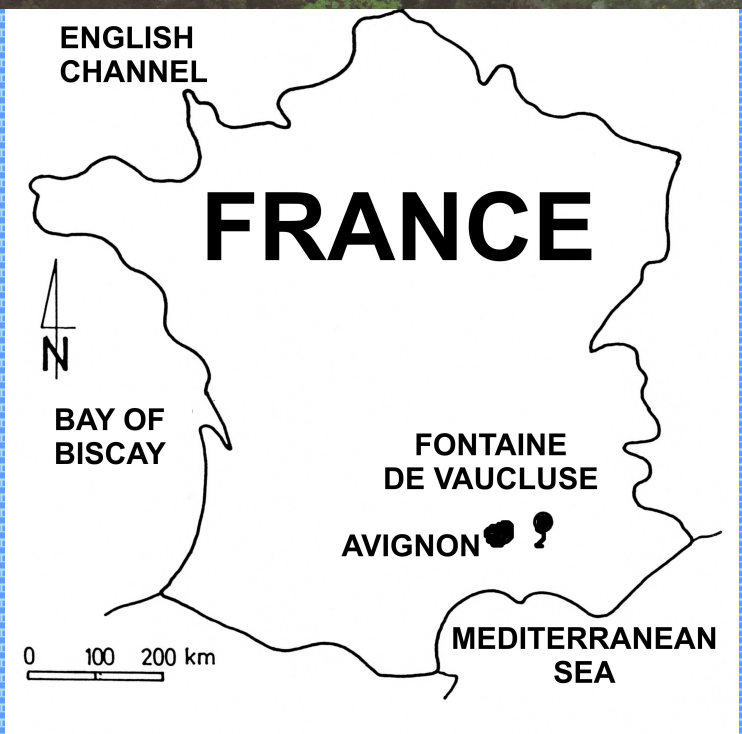
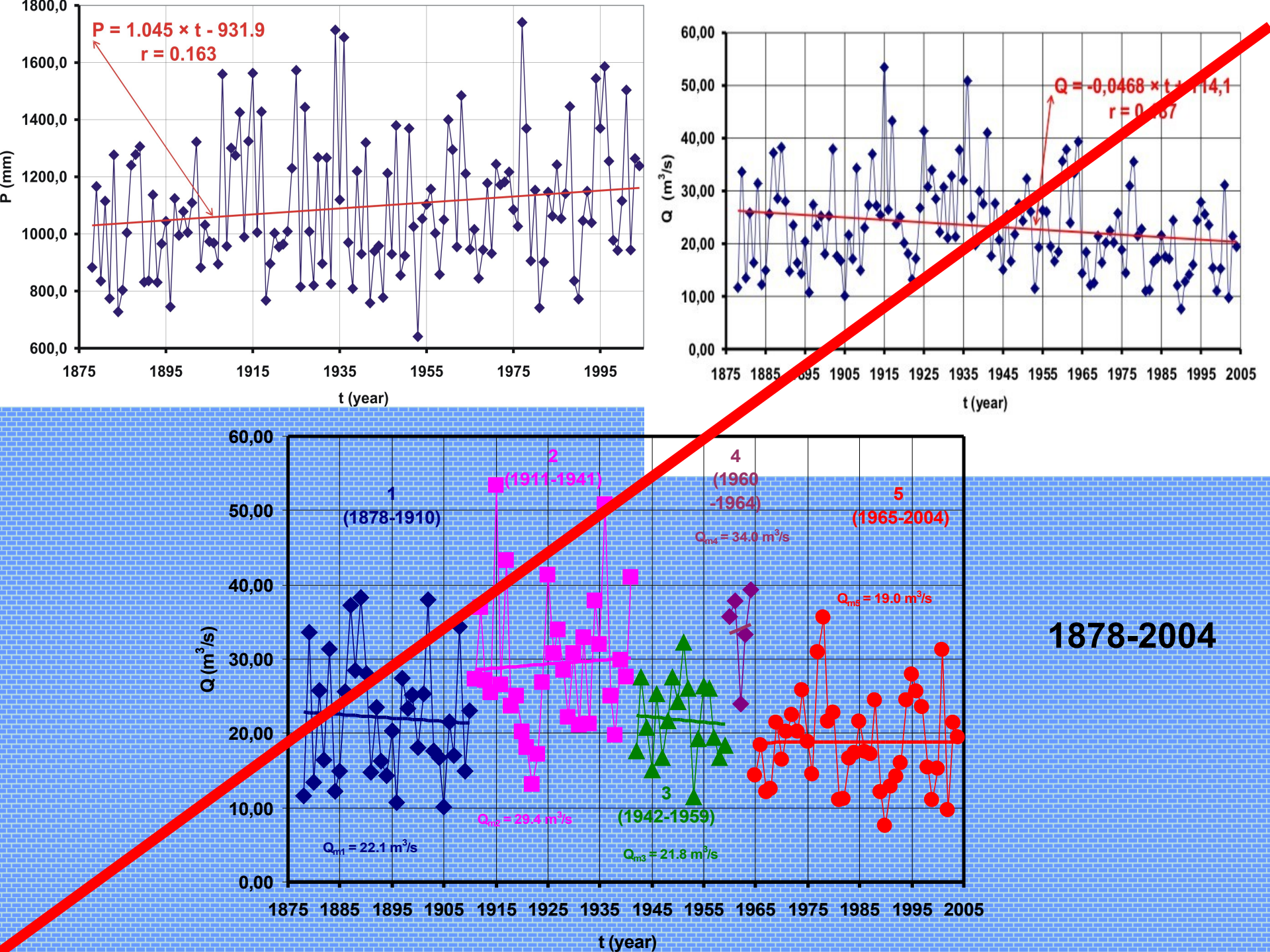

ENGLISH CHANNEL
FRANCE
N
BAY OF BISCAY
FONTAINE DE VAUCLUSE
AVIGNON
MEDITERRANEAN SEA
0 100 200 km


P = 1.045 × t - 931.9
r = 0.163
P (mm)
t (year)
Q = -0,0468 × t + 114,1
Q (m³/s)
t (year)
1
(1878-1910)
2
(1911-1941)
3
(1942-1959)
4
(1960
-1964)
5
(1965-2004)
Qm1 = 22.1 m³/s
Qm2 = 29.4 m³/s
Qm3 = 21.8 m³/s
Qm4 = 34.0 m³/s
Qm5 = 19.0 m³/s
Q (m³/s)
t (year)
1878-2004

Karst water resources, because of their unique hydrologic and ecologic characteristics, are extremely susceptible to contamination. The surface and especially subterranean environment in karst provide a range of habitats with very different chemical and biological processes. Karst ecosystems are sensitive to environmental changes.

Precopulatory mating individuals of ***Bryocamptus zschokkei*** copepods found in dripping water

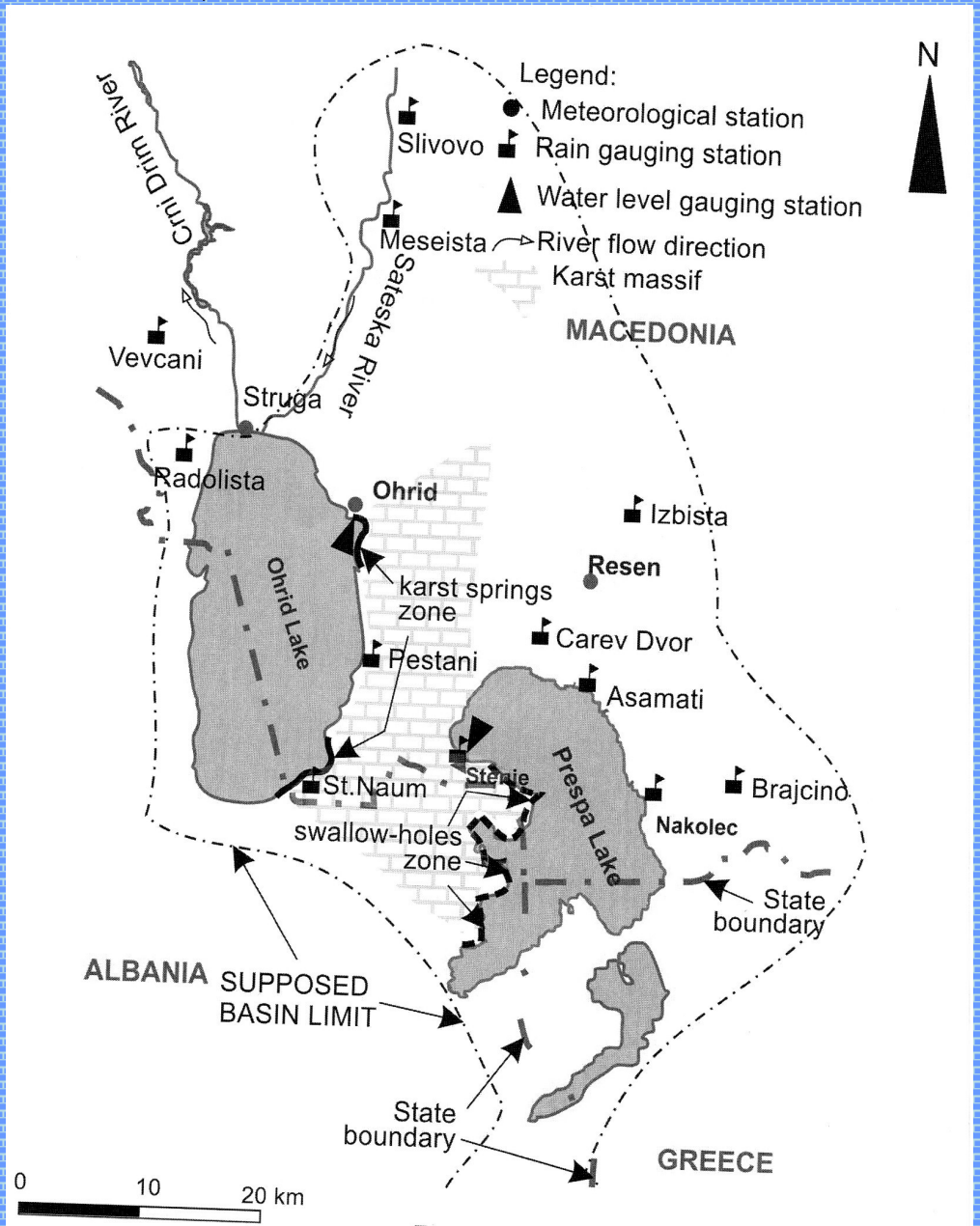
Leptodirus hochenwartii *reticulates* is an obligate terrestrial subterranean beetle species from south-west Dinaric karst

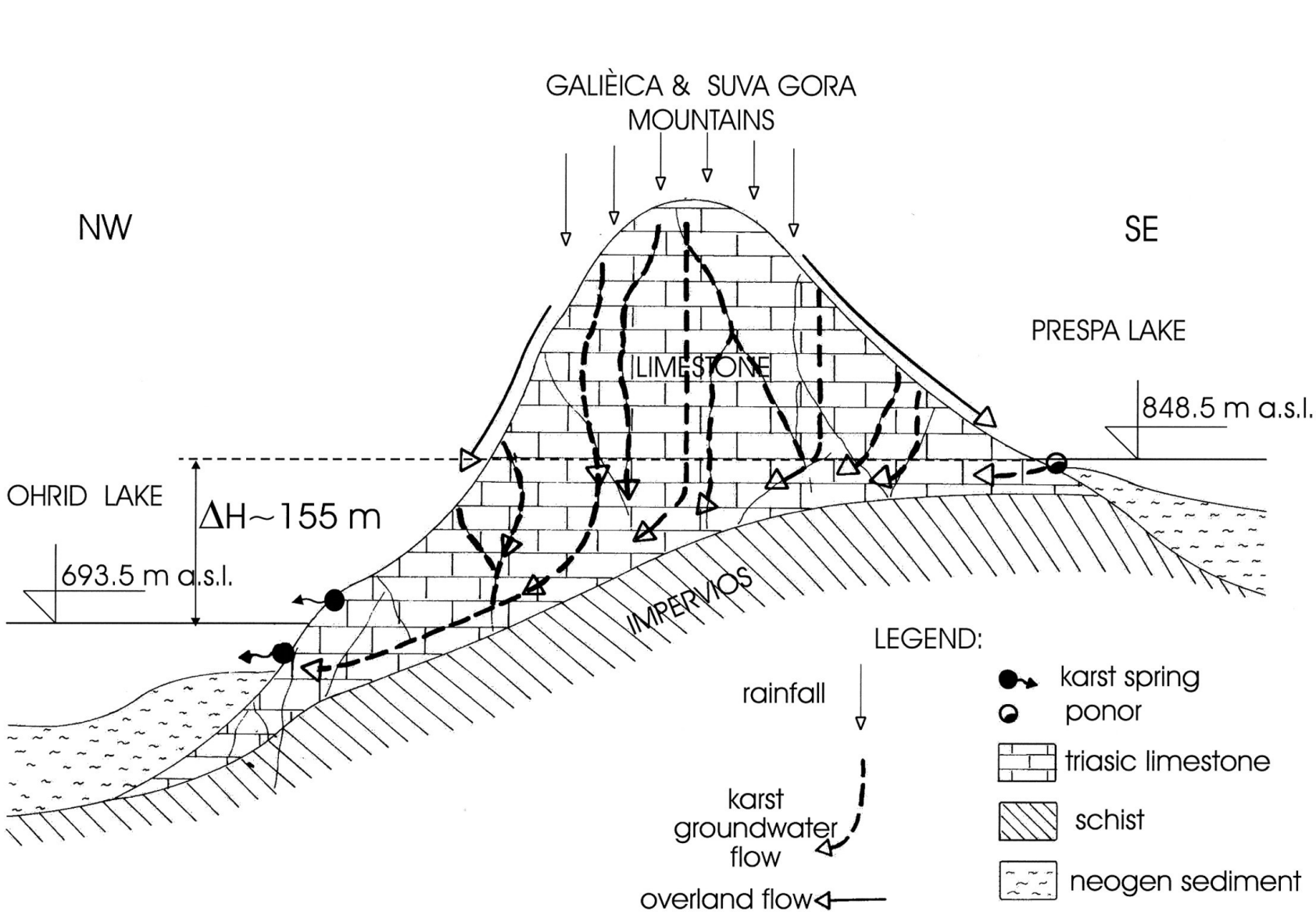
The importance of maintaining biological diversity goes far beyond mere protection of endangered species and beautiful landscape. It is necessary to obtain a thorough understanding of how aquatic and terrestrial ecosystems functions and interact in very complex, vulnerable and in time and space extremely dynamic karst systems. All previously mentioned imperatively requires that ecological aspects of transboundary karst water resources management should be treated much more carefully than in case of other types of terrains.

In cases of karst surface water and groundwater management, water crises are increasingly serious all over the world.

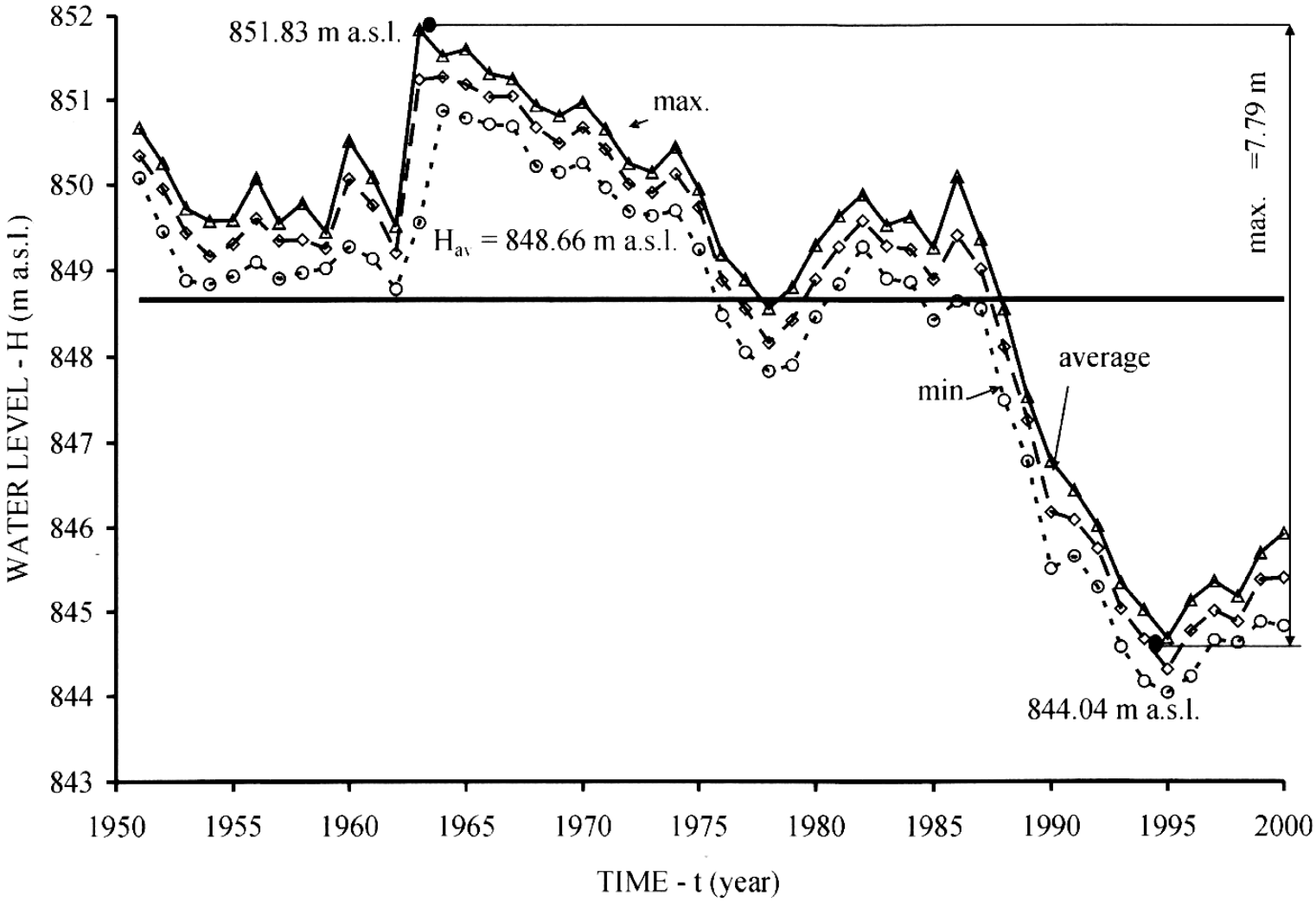
Proteus anguinus
an obligate aquatic subterranean salamander species from Dinaric karst

OHRID AND PRESPA LAKES
(ALBANIA, MACEDONIA AND GREECE)

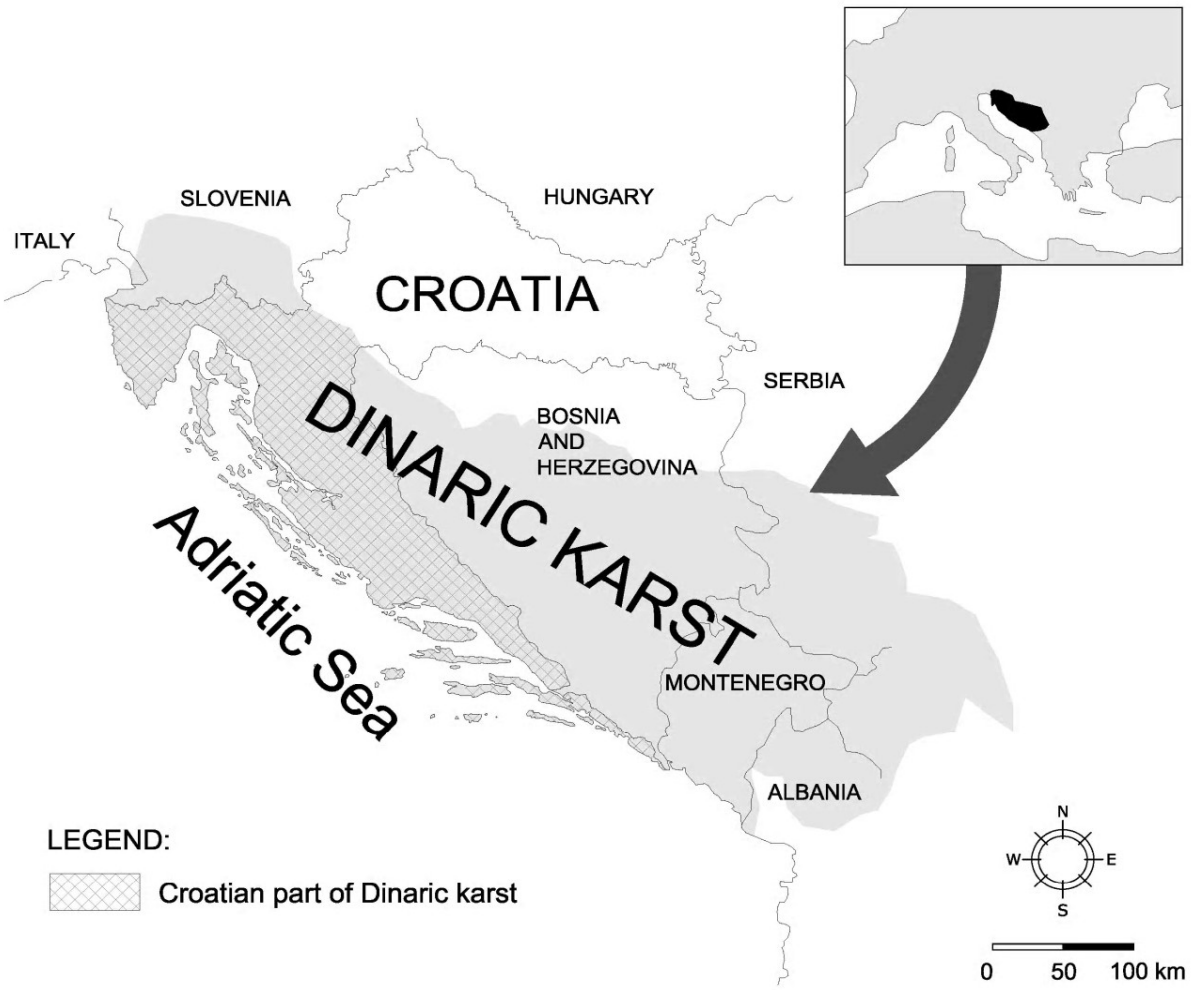


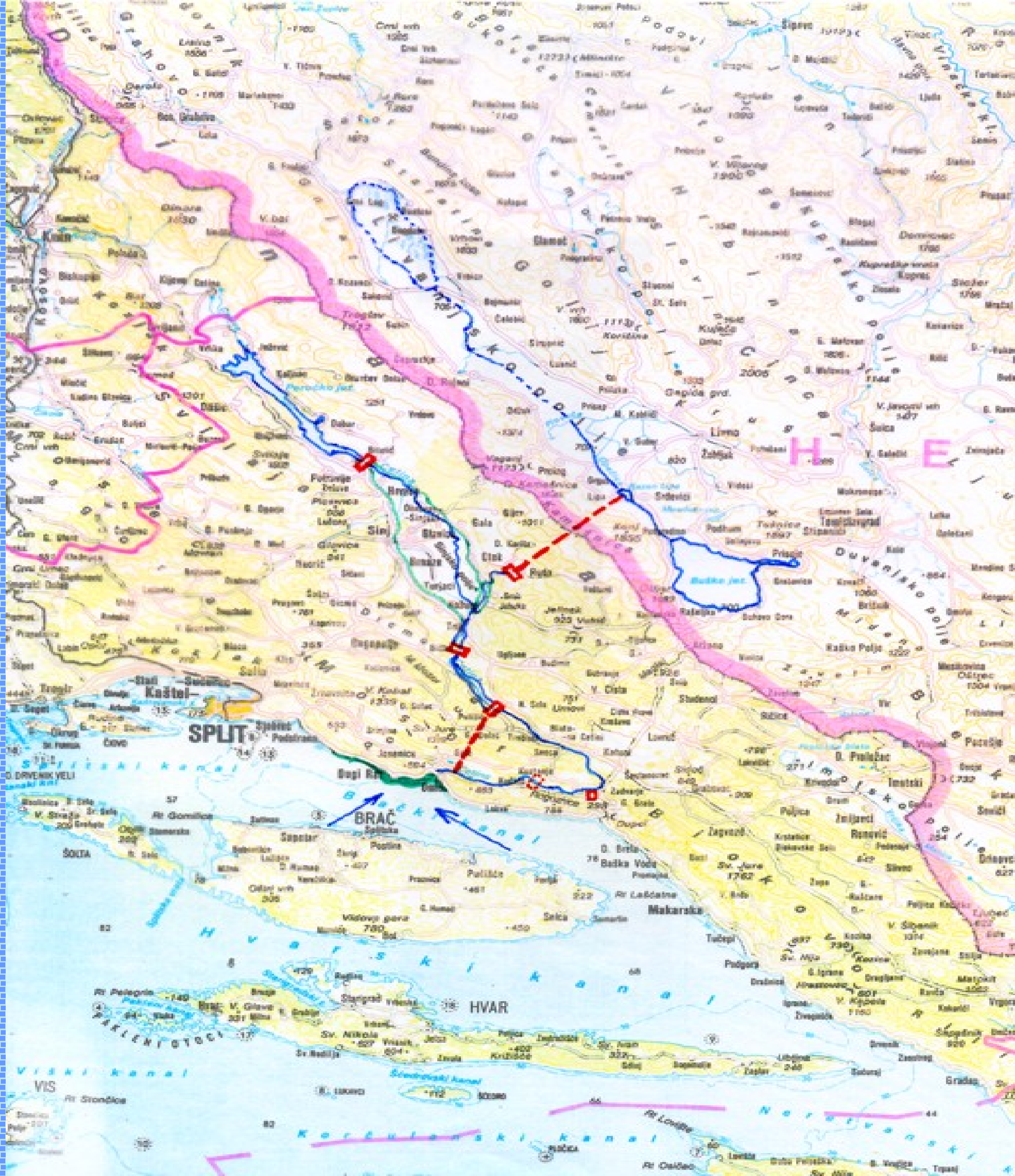

GALIÈICA & SUVA GORA
MOUNTAINS
NW
SE
PRESPA LAKE
LIMESTONE
848.5 m a.s.l.
OHRID LAKE
ΔH~155 m
693.5 m a.s.l.
IMPERVIOS
LEGEND:
rainfall
karst
groundwater
flow
overland flow
karst spring
ponor
triasic limestone
schist
neogen sediment

Lake Prespa at Stenje
characteristic annual water levels
(1951-2000)



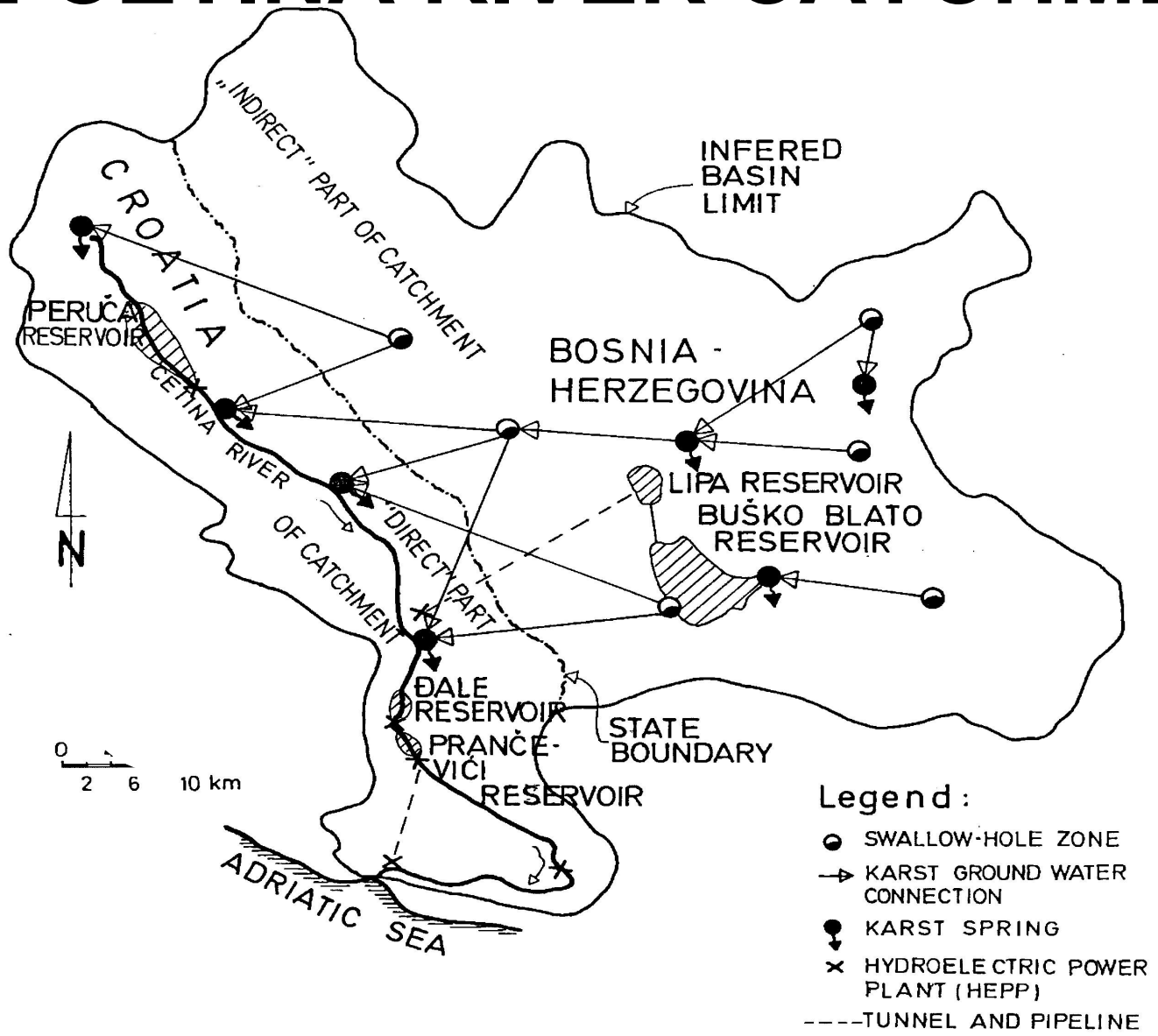
The Dinaric karst covers about 60,000 km^2. It stretches the length of the eastern coast of the Adriatic Sea, from the Bay of Trieste in the north, to the Drim River basin in the south and the Western Morava valley in the east. This karst structure is some 600 km in length, and up to 200 km in width, falling within the borders of seven states: Italy, Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro and Albania. The first detailed karst studies as well as the first theories on water circulation and storage in karst were developed as part of the investigations of the Dinaric karst. The Dinaric karst region is an area of dramatic variety of species, habitats, landscapes and peoples.



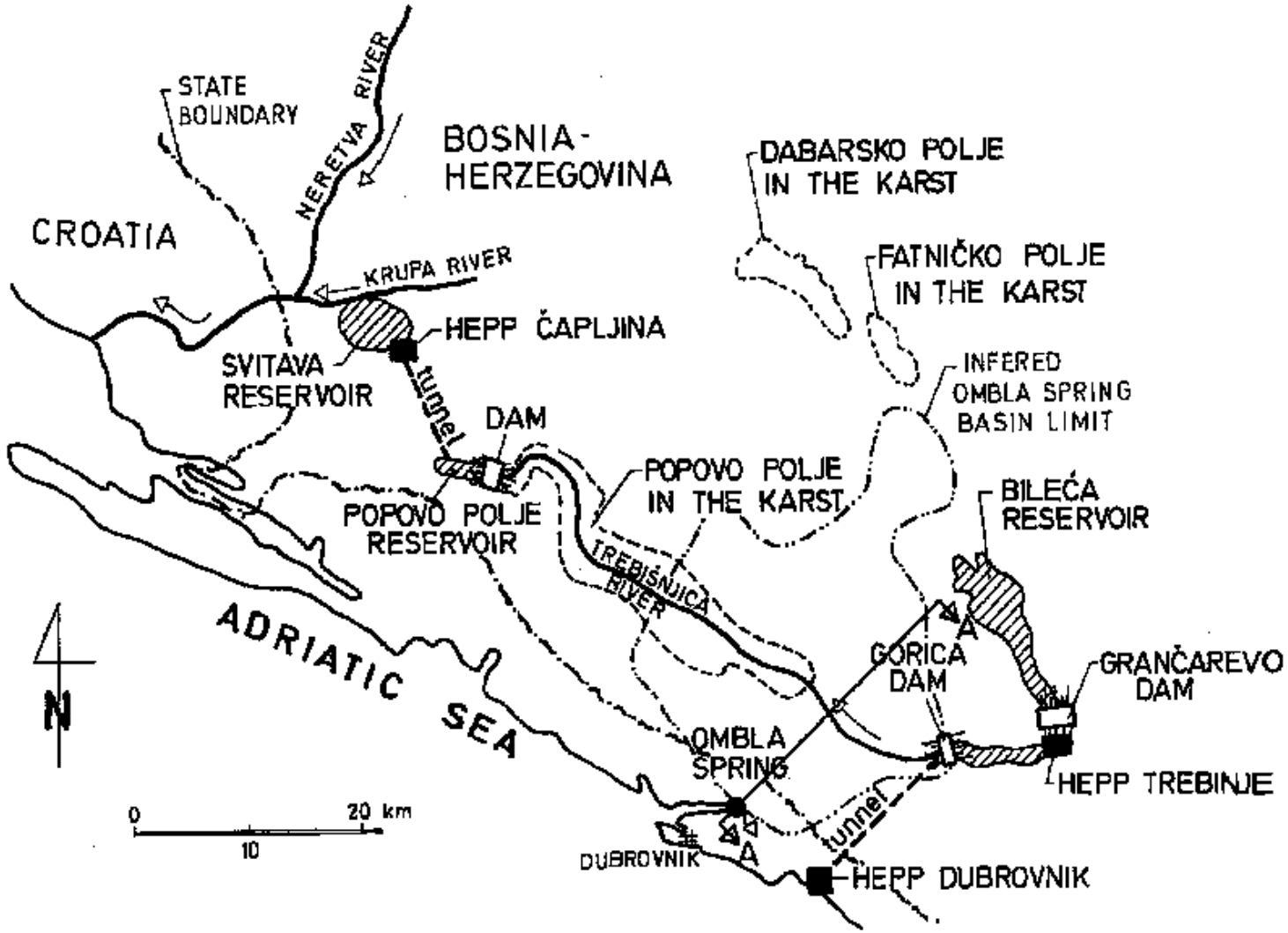


SPLIT
Kaštel
BRAČ
HVAR
VIS
ŠOLTA
Sinj
Livno
Makarska
Imotski
Buško jez.
Peručko jez.
Duvanjsko polje
H E

THE CETINA RIVER CATCHMENT



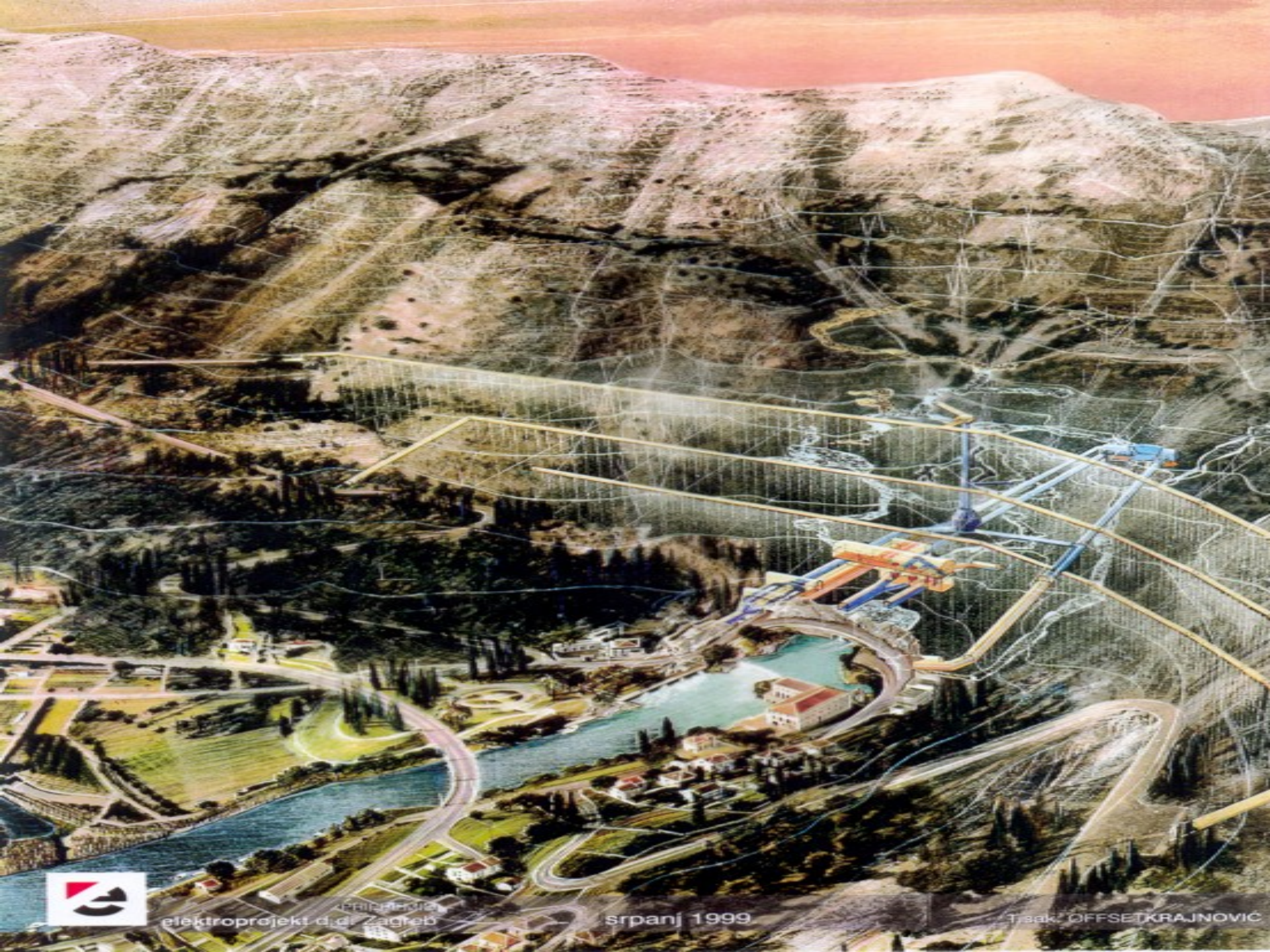
THE MAP OF THE TREBIŠNJICA RIVER BASIN

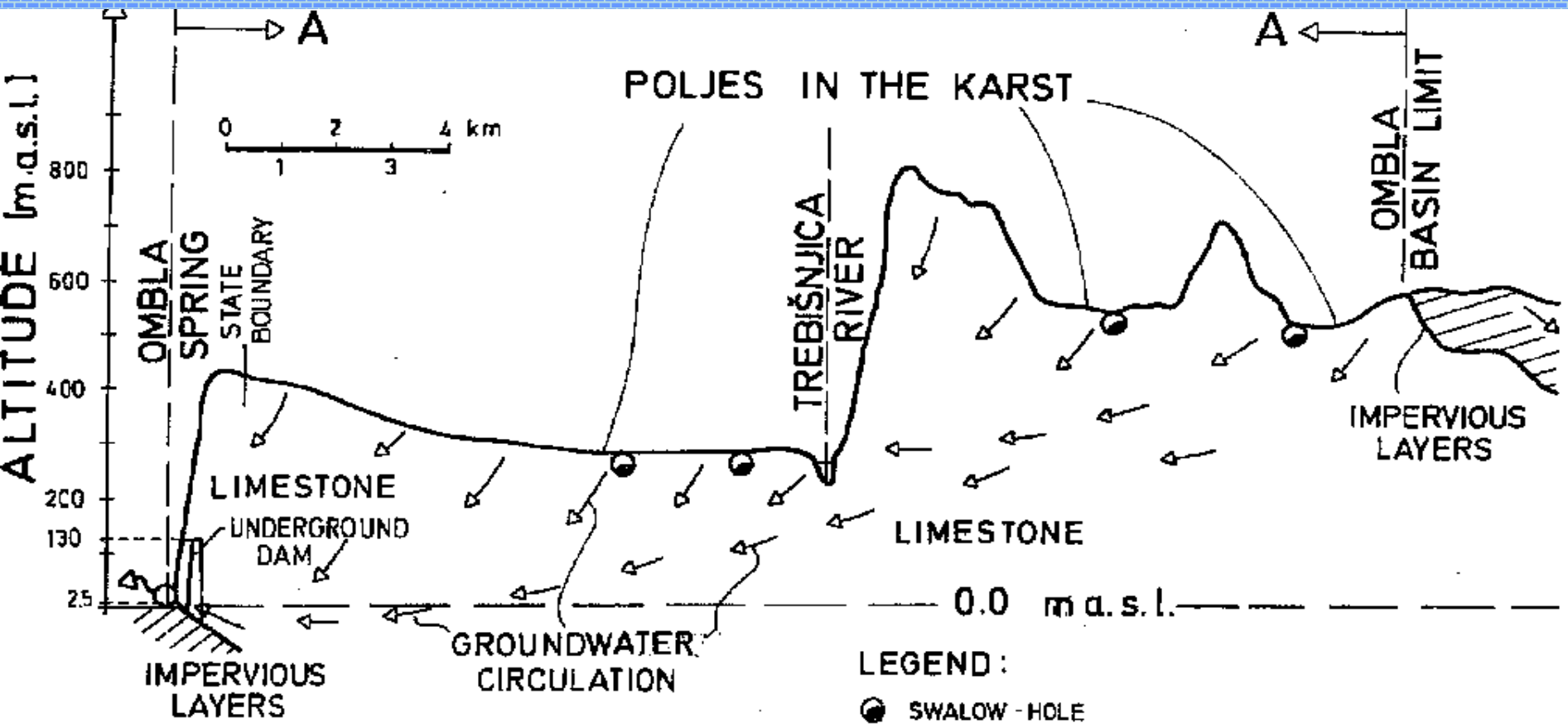


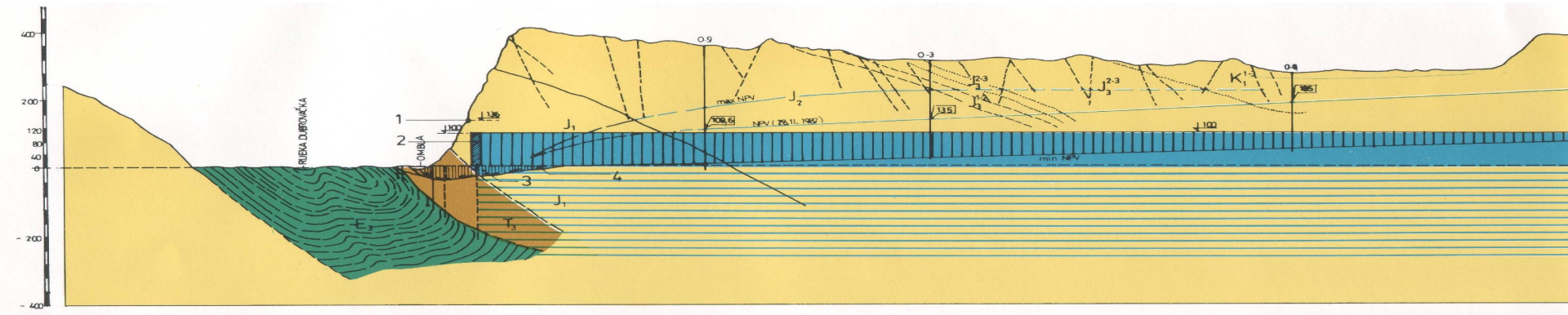
The section of an open streamflow of the Trebišnjica River is included in the catchment of the Ombla Spring. There are permanent water losses into the karst underground along the given section caused by the cracks located at the bottom and banks of the Tebišnjica River. The water losses of the open streamflow along this section, flowing through the Ombla Spring hydrologic catchment, depend upon the inflow discharge and the groundwater levels. The infiltrated water feeds the spring.

In 1978 the river bed of the Trebišnjica River was regulated by building a concrete canal for the discharge of 45 m^3/s. As a consequence the average annual discharge of the Ombla Spring decreased from 30 to 22 m^3/s, whereas changes in minimum and maximum annual discharges were not observed.

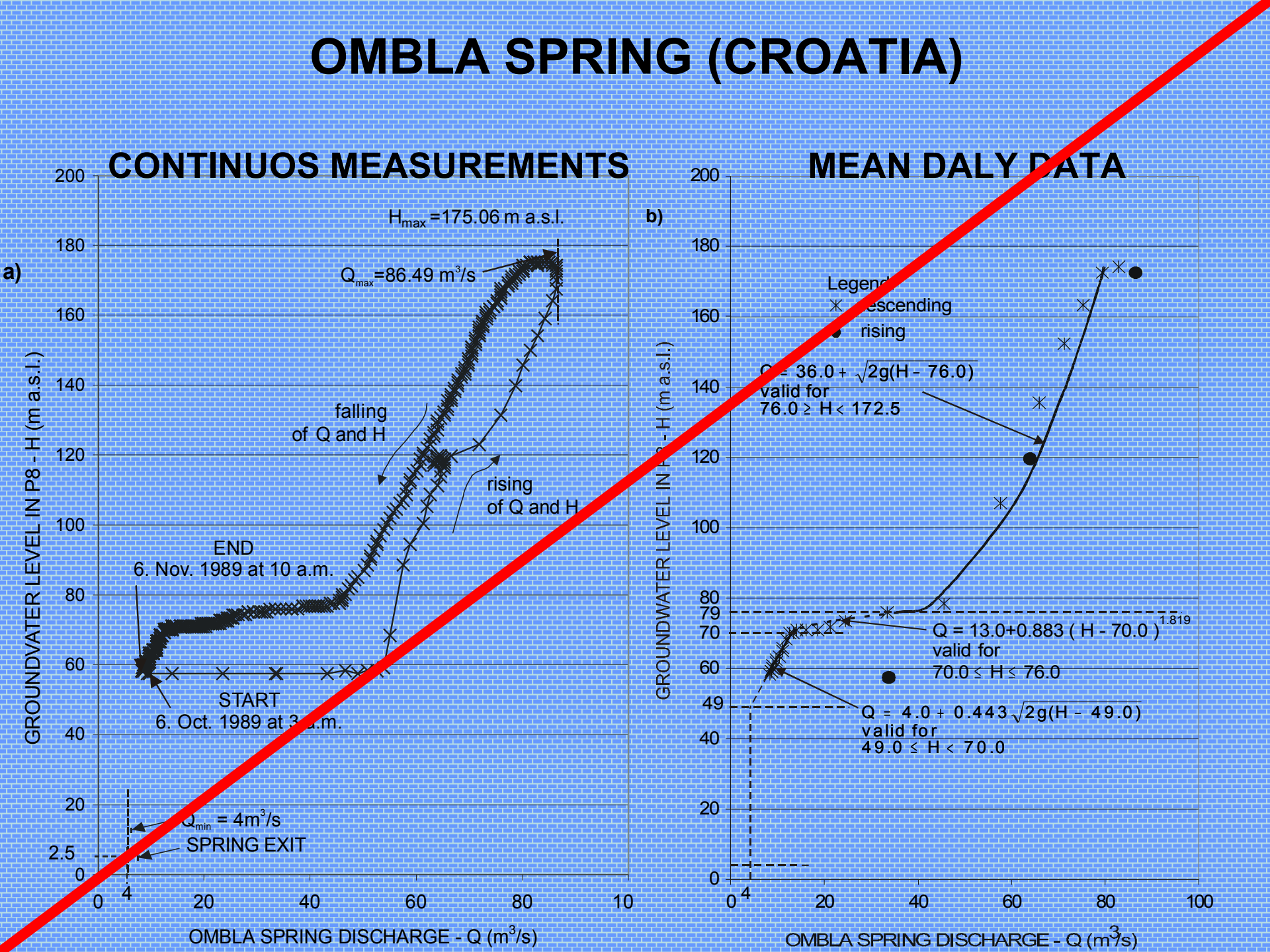
HE OMBLA


elektroprojekt d.d. Zagreb
srpanj 1999
Tisak: OFFSET KRAJNOVIĆ


A
A
POLJES IN THE KARST
0 2 4 km
1 3
ALTITUDE (m.a.s.l.)
800
600
400
200
130
25
OMBLA SPRING
STATE BOUNDARY
TREBIŠNJICA RIVER
OMBLA BASIN LIMIT
IMPERVIOUS LAYERS
LIMESTONE
UNDERGROUND DAM
LIMESTONE
0.0 m a.s.l.
IMPERVIOUS LAYERS
GROUNDWATER CIRCULATION
LEGEND:
SWALOW - HOLE


400
200
120
80
40
0
- 200
- 400
RIJEKA DUBROVAČKA
OMBLA
max NPV
NPV (28.11. 1965)
min NPV
1
2
3
4
J1
J2
J3
T3
E3
K1-3
0.9
0.3
0.8
135
100
108.6

OMBLA SPRING (CROATIA)



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A multi-model approach to the simulation of large scale karst flows

C. Makropoulos [a,*], D. Koutsoyiannis [b], M. Stanić [c], S. Djordjević [a], D. Prodanović [c], T. Dašić [c], S. Prohaska [d], Č. Maksimović [e], H. Wheater [e]

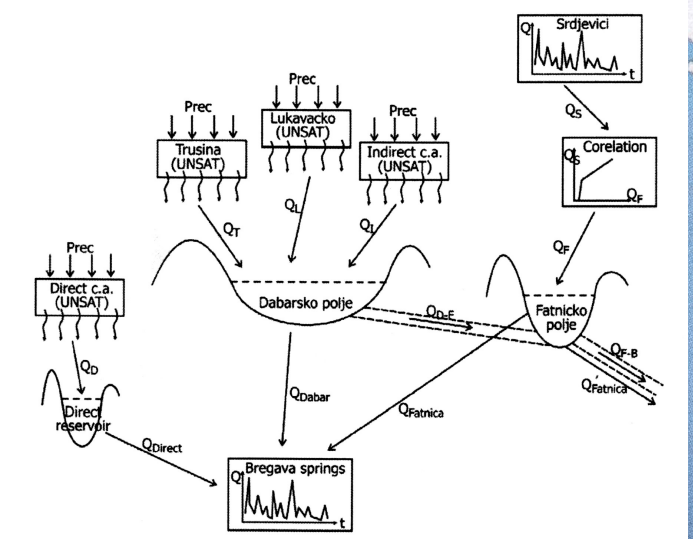


Figure 3 System decomposition in space for the quasi-physically based model.

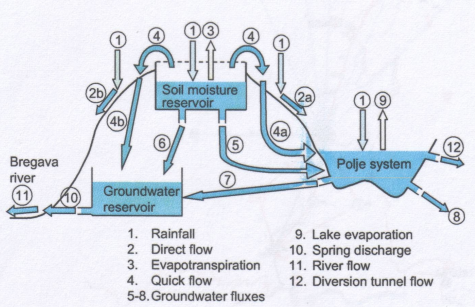
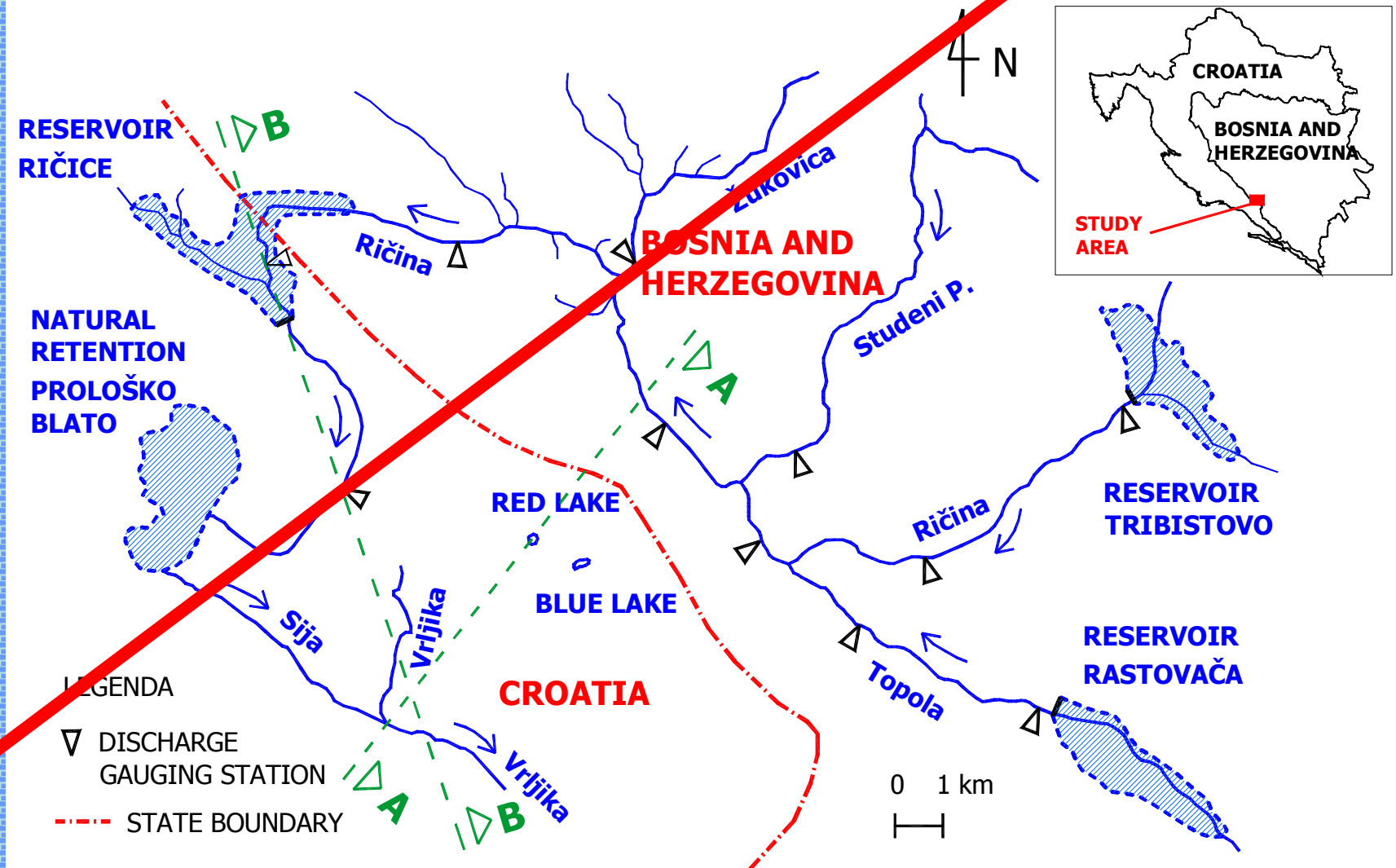


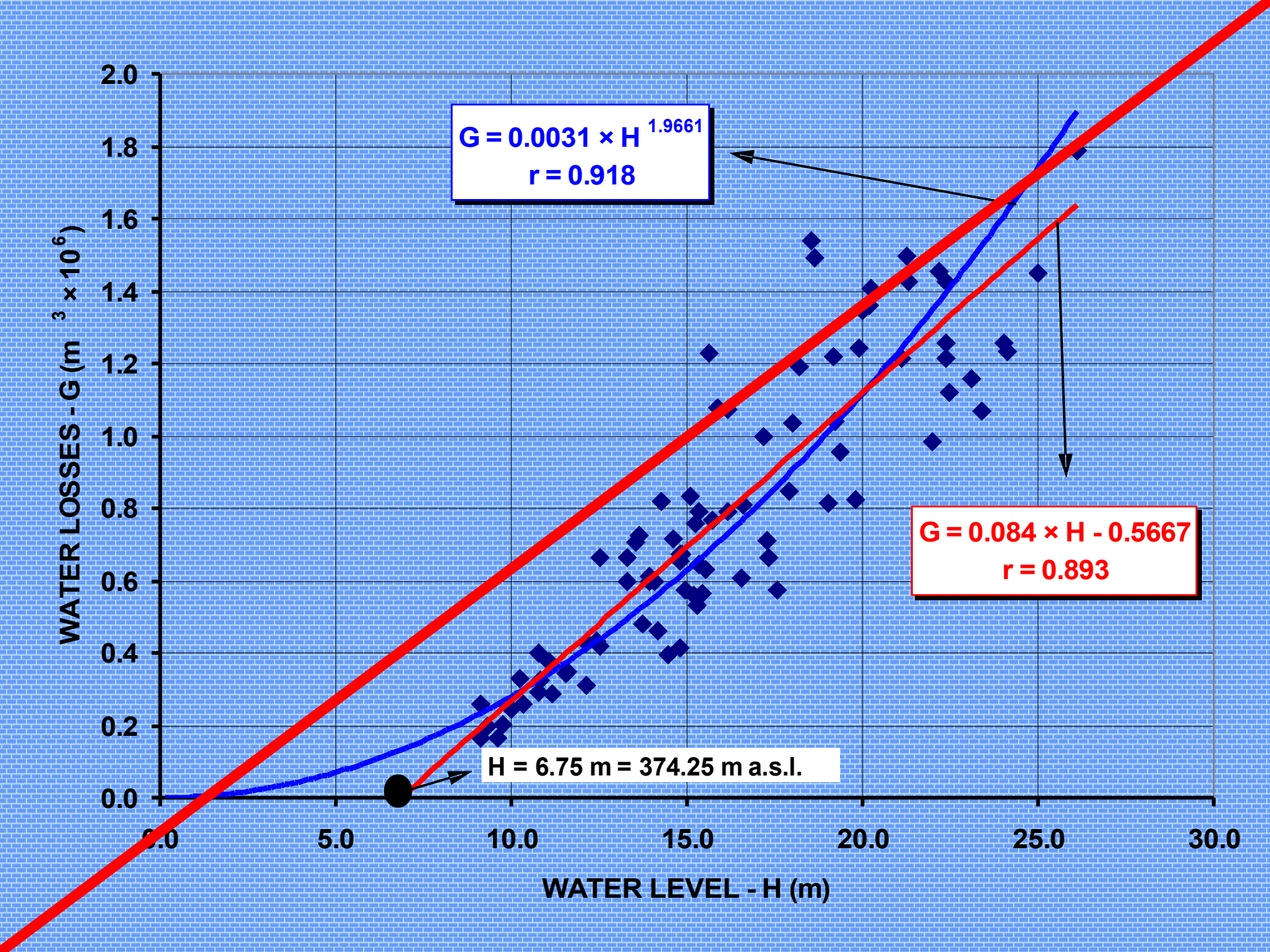
Figure 5 Schematic of the conceptual model.

The RIČICA reservoir was impounded by construction of 45 m high dam on the intermittent Ričina river course situated in the central part of the bare Dinaric karst, on the boundary between Croatia and Bosnia and Herzegovina.

<u>There are considerable water losses from the reservoir.</u>

Tectonic fractures, fissures, joints and other karst features intensify the permeability of the karst deposits.




G = 0.0031 × H 1.9661
r = 0.918
G = 0.084 × H - 0.5667
r = 0.893
H = 6.75 m = 374.25 m a.s.l.
WATER LOSSES - G (m 3 × 10 6)
WATER LEVEL - H (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
5.0
10.0
15.0
20.0
25.0
30.0

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Water losses from the Ričice reservoir built in the Dinaric karst

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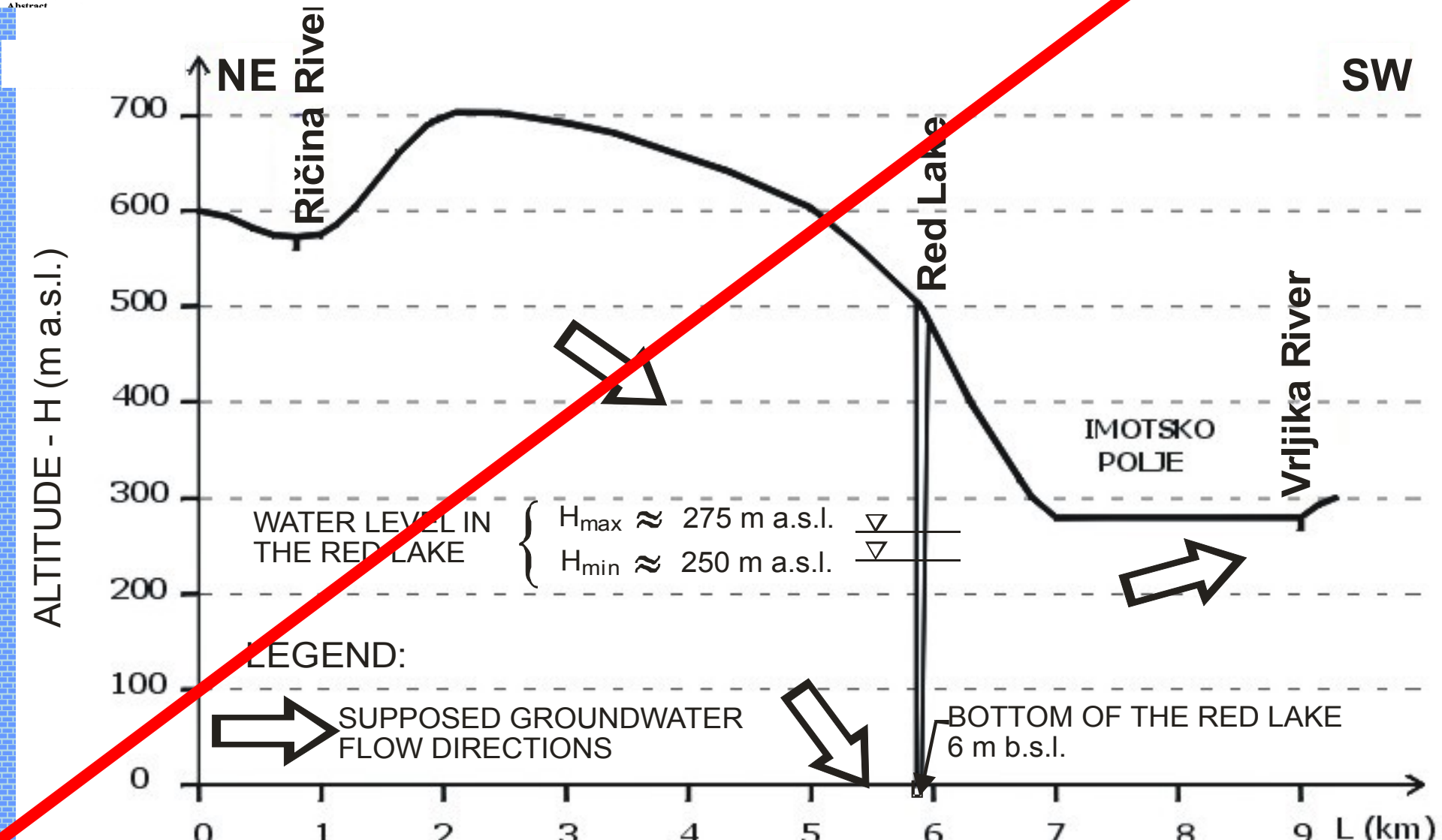
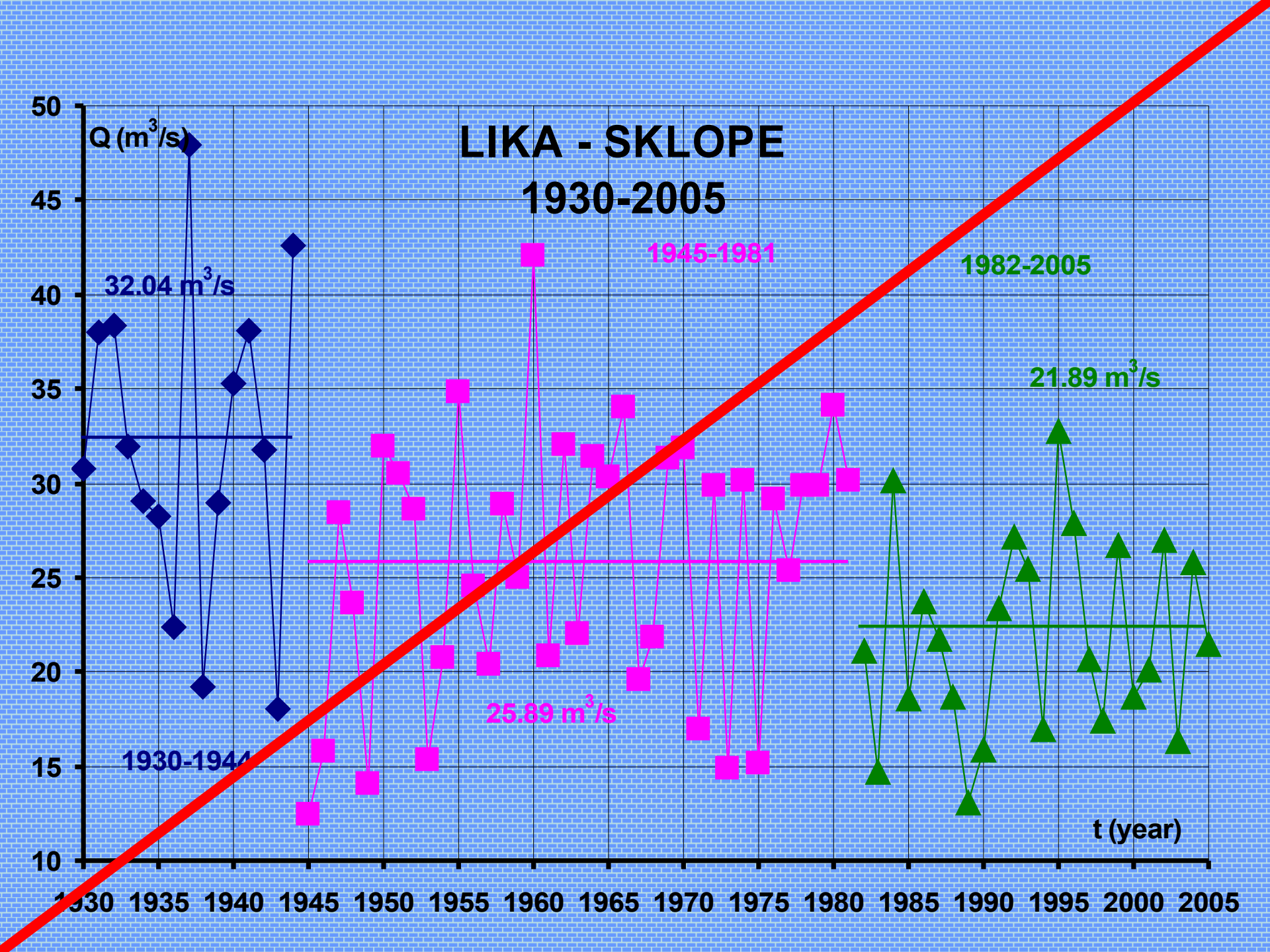
Abstract

Cross section A - A




LIKA - SKLOPE
1930-2005
Q (m3/s)
50
45
40
35
30
25
20
15
10
32.04 m3/s
1930-1944
1945-1981
25.89 m3/s
1982-2005
21.89 m3/s
t (year)
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

CONCLUSION

Hydrology and in karst regions hydrogeology are the bases for any kind of dialog about transboundary karst water resources management. Managing water resources for sustainable development primarily required improved methods for quantifying components of the hydrological cycle on a regional and catchment scales.

Scientists frequently organise symposiums, congresses, conferences, workshops etc. It is an initiative that has to be supported and intensified. However, it is necessary to face that hydrologists, limnologists, geographers, chemists, layers, ecologists, politicians, agronomists, sociologists and all other involved in water related problems in the transboundary karst areas should start to work together. At the moment each scientific and engineering as well as other branches works separately from the other.

Transboundary karst water related problems will be better and more efficiently solved if professional and scientific principles are fully recognised and not affected or influenced by daily politics. Of paramount importance is to ensure a stable exchange of technical information and to create institutions and space where a public, free and open discussion among all the partners in process will be conducted. It is the way to create a long-term strategy for a more efficient internationally shared transboundary karst water management respecting the principles of sustainable development.

Thank You!