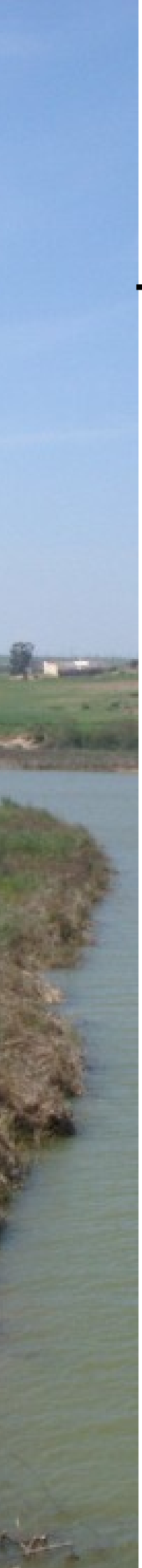

Assessment and Provision of Environmental Flows in Mediterranean Watercourses

- Basic Concepts, Methodologies and Emerging Practice

Mediterranean Case Study

THE RIŽANA RIVER: ENVIRONMENTAL FLOW ASSESSMENT

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THE RIŽANA RIVER:
ENVIRONMENTAL FLOW ASSESSMENT

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1. BACKGROUND

Study area: location and characteristics

The Rižana River in the Slovenian Istria area is 14 km long and drains a watershed area of 204.5 km^2. Similar to many parts of the Mediterranean the area is very poor water sources. The Rižana River has a karstic hinterland consisting of limestone formations characterized by sinks, ravines and underground streams. Its estuary is in the Adriatic Sea. The main year-round source of water for the Rižana is a large karst spring. The Rižana also flows into Škocjanski zatok, which is the largest brachial wetland in Slovenia. It is highly significant as a biotope for endangered flora and fauna species and has enjoyed legal protection since 1998, under the Act for The Protection of Škocjanski Zatok Nature Reserve (IUCN category IV). The Nature Reserve is managed by DOPPS – BirdLife Slovenia. In 1999, a five year (1999 - 2003) wetland management action plan titled, "The Programme for the Protection and Development of Škocjanski Zatok Nature Reserve" was approved by the Slovenian government. A LIFE Nature III project (titled Restoring and Conserving Habitats and Birds in Škocjanski Zatok) started in 2001. One expected result of the project is the identification and implementation of measures to improve fresh and salt-water inflow to the lagoon.

The area has a sub-Mediterranean climate with mild winters and relatively high summer temperatures from May until the end of September. During this period, droughts are quite frequent. The average annual precipitation amounts to approximately 1,000 mm in the coastal areas, whereas in the upper stream area of the Rižana River average precipitation is approximately 1,150 mm.

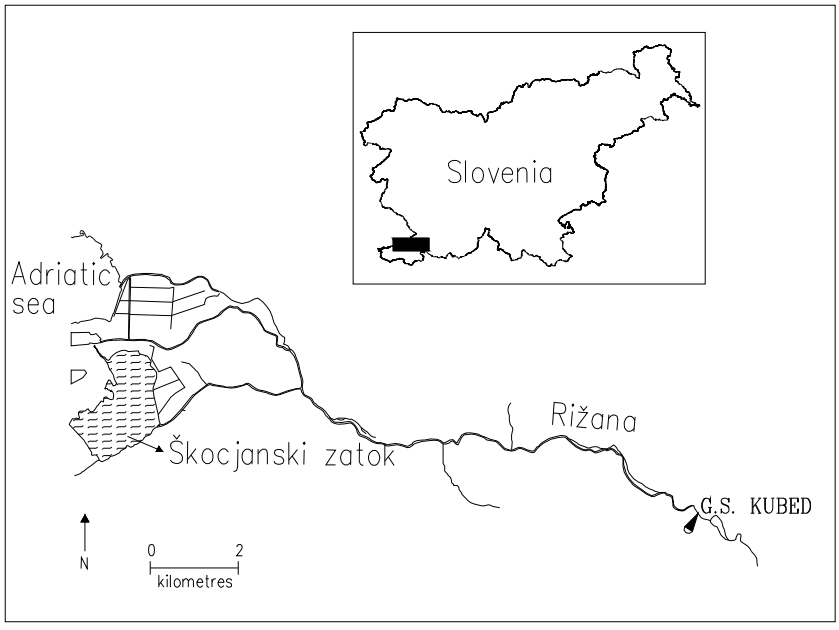

Figure 1. The Rižana River

The Rižana River has status as a sport and fishing water-body. Mill-brooks along the river are environmentally protected for the sustainable fish-hatching of marble trout (*Salmo trutta marmoratus)*. In the vicinity of the river, the fish communities of *Ostryo - Quercetum pubescentis*, *Carici humulis - Centaureetum rupestris* and *Bromo - Chrysopogonetum grylli* are frequently found. Riparian

vegetation along the watercourse is quite degraded due to intensive land cultivation and road development.

The karstic (limestone) plateau that forms the hinterland of the Rižana River has hydro geological features that result in low summer flows in the Rižana. Flows at the Kubed gauge station for a thirty-year period (1996–1995) are presented in Box 1. This gauge station is located on a stretch of river below the spring (see Figure 1) where abstractions are made for the municipal water supply system, where the maximum off-take capacity is 0.240 $m^3 s^{-1}$.

Box 1. Hydrological data for the Rižana River at the Kubed gauge station (1966–1995)

Parameter	Value
Catchment area	204.5 km^2
Mean annual flow	4.101 $m^3 s^{-1}$
Mean minimum flow	0.222 $m^3 s^{-1}$
Minimum flow	0.010 $m^3 s^{-1}$
Q82	0.500 $m^3 s^{-1}$
Q95	0.160 $m^3 s^{-1}$

The amount of water available in the Rižana River in any season depends on combination of groundwater levels, precipitation and inflows from its minor tributaries. The tributaries are short and steep, having the characteristics of torrents that dry up in summer periods. Minor water abstractions along the watercourse during the higher flow periods (i.e. in spring and autumn) do not essentially change the hydrology of the river. In drought periods the water quantity decreases markedly due to the abstractions.

Photo 1. The Rižana River

Photo 2. The Rižana River

The need for an Environmental Flow Assessment (EFA)

Water abstraction from the Rižana River dates back to the early 19th century when the Rižana valley was the granary of the city of Trieste and surrounding region. There were 33 mills working in the valley, of which none are in operation today. The Rižana River has been the source of municipal water supply since 1935. After 1960, these water abstraction started to increase due to the growth of population and the development of tourism. Today, the Rižana River is the most important source of water supply for the Slovenian coastal area.

Downstream, there are additional water abstractions for fish farms and industry and some unregulated water abstractions for the irrigation in summer. The increasing density of population with all relevant and phenomena such as settlements, agriculture, industry, tourism, trade, traffic and landfill-sites can be observed downstream and numerous hydro technical interventions were carried out. The demand for drinking water as well as industrial and agricultural exploitation of the Rižana River exceed the water available in the river. The consequences can be observed primarily in the summer period when, due to the deterioration of the aquatic environment, several cases of fish kill have occurred.

In 1986, on the basis of hydrologic calculation and in response to regulations, the Ministry of the Environment and Spatial Planning determined 0.110 m^3s^{-1} as the minimum flow value in summer dry period. However, the first systematic analysis of the state of Rižana River's water condition was carried out in 1993. The study included flow recommendations for the improvement of water quantity in the riverbed. The growing recognition of multidisciplinary Environmental Flow Assessment of other watercourses in Slovenia led to the study on the Determination of Environmental Flow for the Rižana River in 1996, commissioned by the Ministry of the Environment and Spatial Planning. The project group included independent researches, dealing with hydrology, hydraulics, morphology, biology and landscape architecture.

2. EVOLUTION OF ENVIRONMENTAL FLOW APPROACHES IN SLOVENIA

Characteristics of Slovenia

There are several different hydro-morphological types of running waters in Slovenia, including lowland, karst and mountain running waters. Current water abstractions are for drinking water, energetic use, fish farming, irrigation, technological purposes - and higher levels of abstraction are still

planned. Most of the existing and planned water abstractions are in small river basins where no information about the quantity of water exists.

In order to determine the environmental impacts, the knowledge of structure and function of the ecosystem is indispensable. Environment flows assessment (EFA) requires that each part of running water is treated individually and that the Environmental flow (EF) is determined through interdisciplinary co-operation. Because of specific hydro-geological conditions in particular sections of running waters, first of all, low-flow values should be determined by means of simultaneous measurements of water flows in low flow periods.

Definition of Environmental Flows in Slovenia

In Slovenia the determination of environmental flows is required prior to approving licenses for water abstractions from running waters. This is reflected in the existing Environmental Protection Act and the new Water Act, which came into force in 2002. As Slovenia is in the process of inclusion into the European Union, in future this will also entails the application of the EU Water Framework Directive (WFD). The Directive requires the step-wise achievement of good ecological status (GES) on surface water resources by 2015, wherein environmental flow assessments are an important tool.

The first definition of minimum flows of running waters in Slovenia (Uradni list SRS, 1976) was defined as a quantity of water, which enabled the survival of water organisms. This formed the basis for granting permission, according to specific regulations, to ensure the availability of water supply for drinking and economic purposes. However, this was not sufficient for the protection of ecological balance in the river system, and from the point of view of the environment preservation and the diversity of organisms, it was often catastrophic. The evaluation of minimum flow was usually given by angler's societies, but in many practice, the water users paid damages and high levels of abstraction resulted in no water during low flow period. For this reason, Ministry of the Environment and Spatial Planning financed the research project begun in 1992 to define the criteria for evaluating the provision of the quantity and quality of water to remain in the riverbed. The project was completed in 1994 (Vrhovšek et al., 1994) and later in 2002 (Smolar-Žvanut et al., 2002) was upgraded.

Environmental flow provision in Slovenia (also referred to as ecologically acceptable flow) requires a definition of the quantity and quality of water, which is needed to preserve the ecological balance in the running water and in the riparian zone. This means preservation of the structure and the function of the ecosystem, which it is reflected in diversity of species. In this definition, the EF is the quantity of water, which enables the survival, and reproduction of water organisms in different hydraulic habitats.

The basis for determination of Environmental Flow

In the research project cited above (Vrhovšek et al, 1994) the following theoretical starting points were chosen for selecting the criteria for EF assessment:

1. The Republic of Slovenia has to preserve and protect the running waters.
2. EF should be determined before any impacts, which could have an influence on the structure and functioning of the running water as an ecosystem, occur in the river system or in the geographic area.
3. Ascertaining the structure and the function of the ecosystem: flora, fauna and the basic ecological factors in the running water and in the riparian zone should be inventoried, including underground water pumping and the flow out of water-storage basins.
4. Special attention should be paid to rare and endangered plant and animals species respectively, i.e. the groups important for the preservation of the ecological balance.
5. Assessment of water habitats, which have to be specially protected or require a special flow regime, should be carried out.
6. For each man-made change of quality and quantity of water in the river system, a new assessment of EF is required.

Methods for EF assessment

On the basis of hydrological, hydraulic, morphological and ecological criteria appropriate for different river types, separate hydrological-based and ecological-based methods were developed to undertake environmental flow assessments in Slovenia (i.e. those developed in the research project sponsored by Ministry of the Environment and Spatial Planning that was cited earlier - Vrhovšek et al., 1994). In the following years, the methods underpinning both the hydrological and ecological-based approaches were improved. By 2002, both methods are used in practice, though they are not legalized by decree as yet (Smolar-Žvanut et al., 2002).

It is important to decide which method is best suited to a particular river and planning function. In a research project (Smolar-Žvanut et al., 2002) it was proposed that EF should be assessed according to ecological-based methods in the following situations:

- if the running water is in a preserved or legally protected area;
- if there are rare, endangered or protected species of flora and fauna in the running water or in the riparian zone;
- if the spawning grounds are endangered by water abstraction;
- if water abstraction is irreversible and does not ensure at least the quantity of water equal to the mean minimum flow value in the watercourse;
- if in the section of water abstraction, at least a 0.8 value of the mean minimum flow is not ensured in the riverbed;
- if the inventory of habitats, the field work or ecological estimation require the application of further ecological methods;
- if the public interest demands multi designation of the running water;
- if there is a number of interdependent abstractions in the watercourse;
- if the watercourse is on the border between the two countries;
- if a discharge of wastewater occurs in the section of water abstraction.

In other cases, the EF should be determined by the hydrological method.

The starting points for the definition of an EF in both methods are the basic hydrological and hydraulic parameters, such as the mean annual flow, the mean minimum flow, the minimum flow, etc. Where there is very limited, or no hydrological data, it has been suggested that hydrological observations should be carried out for two years for new water abstractions, especially in the minimal flow periods. Unfortunately, in practice, the measurements occur only once a year in the period of low flow. In some cases, a special analysis of flow in the months of low flow is required and consequently, a flow duration curve is constructed. In addition to the hydrological data, basic ecological data such as an inventory of habitats and hydro-morphological estimation are needed by the hydrological method for the determination of EF.

In the application of the ecological method, sampling of zoobenthos and phytobenthos at pre-chosen sampling points in the affected river sections are carried out. The number of sampling points depends on the breadth of the riverbed, the structure of habitats and the water velocity. In the affected section, hydrological and morphological measurements are made; while at the sampling points, the river depth, local velocities and the size of substrata are measured. The inventory and diversity of water organisms, the changes in biomass of phytobenthos are determined as well as an inventory of macrophytes, and flora and fauna of the riparian zone. It is suggested also that that ichthyologic research be also carried out. On the basis of the analysis, the existing situation is described. Depending on the quantity, length and duration of water abstraction and the characteristics of the running waters, the research can be reduced or extended. For example, in accordance with the Rio de Janeiro Convention of biological diversity, special attention should be paid to rare and endangered species.

Because of the seasonal dynamics of organisms and different flows during the year, the analysis should be performed during the whole year in different seasons, according to seasonal appearance of water organisms. The frequency of sampling is higher in the low flow periods when the effect of water abstraction on water organisms is higher. The EF is assessed according to biotic and abiotic parameters, which are critical where the ecological balance is still preserved. In Slovenia, special attention is needed to ensure sufficient quantity and quality of water as well as flow dynamics that brings about excessive growth of the phytobenthos.

More broadly, the EF should be determined for every user of water separately. Where the level of water abstraction has increased, or where the flow regime downstream the dam is changed, a new value of EF should be determined. The EF options should be discussed by experts at a workshop and decisions scientifically-based, after further consultation with the water use interests.

Application of EF Assessments on Slovenian Rivers

The Ministry of the Environment and Spatial Planning required that EFAs be undertaken on all running waters, where an EF had not yet been specified. As a result, from 1992 the EF was assessed for more than 180 sections of running waters ain Slovenia according to the methods described above. Most of EFs were assessed for the existing water users (123 study sites).

The independent researches involved in developing the criteria for EF played a major role in the programme of studies to determined most values of EF in Slovenia. The time needed to complete a particular study varied from a few months for small streams to two years for larger rivers. The EFA sought to increase water flow in the riverbed in a manner improved conditions for organisms in the water and in the riparian zone. This typically meant that especially in the low-flow periods, smaller quantities of water could be abstracted from the running waters.

For most small streams, the EF was determined according to the hydrological method. For the rivers with large water abstractions, the value of EF was mostly determined according to the ecological method. If it was possible, experiments were made with trial increases of the flows downstream of dams and the evaluation of habitats at different flows.

3. DEFINING THE ENVIRONMENTAL FLOW REQUIREMENTS ON THE RIŽANA RIVER

Because of large water abstractions at the very source of the Rižana River and the negative impacts on Škocjanski zatok wetland, this project group decided to perform the EF assessment according to the ecologic method. Data were collected on all users and polluters of the Rižana River.

The largest water abstraction from the Rižana River is for municipal water supply. The water management consent of 1986 for the Rižanski Vodovod (the water supply company) stipulates that the largest water abstraction can be up to 0.350 m^3s^{-1}, and of this 0.240 m^3s^{-1} for consumption and 0.110 m^3s^{-1} for the preservation of minimum flow. There are water abstractions for two fish-farms located in the upper part of the Rižana River. Downstream of the river there are legal water abstractions for irrigation, in total 0.074 m^3s^{-1}. In addition, uncontrolled water abstractions for irrigation, especially in summer period, should also be taken into account. Among other users, there are water abstractions for industry, like Kemiplas Koper (0.035 m^3s^{-1}), which has also the licence for water use.

There are 30 small discharges of wastewater into the Rižana River, of which seven run directly into the river. The Rižana river is polluted by faecal and industrial wastewaters, including the inflow of rainwater and discharges of wastewater into mill-brooks. In particular, inflow of wastewater from two fish-farms, leaching from agricultural land in the gravitation area (fertilizers, pesticides) should also be mentioned.

Major pollution sources of the Rižana River are located at the lower part of the river Rižana (Box 2).

Box 2: Large Sources of Pollution on the Rižana River	
Polluters	
Industry	Lama Dekani, Kemiplas Koper, Instalacije Koper (Istrabenz Group), Luka Koper, Clariant Polisinteza Koper.
Settlements	There are 31 settlements in the area with the total population of 31,767 (2002). The largest settlement is Koper with 23,726 inhabitants. A part of faecal water runs off to the central wastewater treatment plant in Koper, and treatment plants at Kubed and Žgani and a part of its discharges directly into the Rižana river.
Handicraft, services	In the settlements in the Rižana River basin there are small handicraft workshops, service centres and catering establishments, which wastewaters run off to central treatment plants or directly into the Rižana River.
Wastewater treatment plants (WTP)	There are four wastewater treatment plants in the area: Koper Central WTP , Kubed WTP, Žgani WTP and biologic WTP of the Instalacije Koper company. Except the Kubed WTP, all other WTPs discharge their effluents into the Rižana River.

On the basis of the examination of all water polluters and water users, four sampling sections were selected in the river. Samples of phytobenthos, phytobenthos biomass and zoobenthos were taken for quantitative and qualitative analyses. In all sections, samples were taken in the period of low flow in summer 1996 and in winter 1997. During the sampling period, the flow and the current velocity in the sections were measured. Ichthyological data were collected plus an inventory of macrophytes and riparian vegetation was made. The landscape value of the river was also evaluated at different flows.

In parallel, hydrological and hydraulic analyses were carried out – from the river source its source to its mouth. The project team analysed minimum and mean monthly flows and drew up a flow duration curve. The differences in phytobenthos biomass, expressed as ash-free dry weight, dry weight and chlorophyll *a* were tested with statistical analyses in sampling sections. The percentage of species deficit was calculated for phytobenthos and zoobenthos taxa between individual sections of the river. The quality of water was evaluated using the Pantle-Buck saprobic index, the biological quality of the river was evaluated using the Biological Monitoring Working Party score system (Armitage et al., 1983) and the Extended Biotic Index (modified by Ghetti, 1986).

Study outcome

The results of biologic analyses revealed that the water flow of 0,110 m^3s^{-1} in summer period was too low, thus causing the growth of phytobenthos and a decrease in zoobenthos diversity. With regard to the water supply abstraction, the results of the hydrological analyses showed very low summer flows, which were a direct result of high level of abstraction along the watercourse combined with the intergranular porosity of the substrata. This has led to the deterioration of the aquatic flora and fauna. Taking into consideration the hydrological, ecological, landscape and morphological characteristics and habitat evaluation, the project team proposed an EF value for the Rižana River for the dry summer period of 0.160 m^3s^{-1}. This would reduce the pollution levels, and enable the maintenance of ecological balance both in the river and in the riparian zone. Experts decided the level of EF, taking into account the information detailed above, including the historical levels of abstraction.

The main water users were not involved in the study, because the object of the study was the biological aspect of EF – in an approach that relied on the level of experts to define what quality and quantity of water should remain in the river to prevent its structure and function.

The EF was determined for the Rižana River while the quantity of water flowing through the channel to the Škocjanski zatok wetland was not defined. The present study does not include the impact and

the correlation of the inflow of different quantities of water from the Rižana River to the Škocjanski zatok during the year.

Besides quantifying the EF, the study recommends the following management measures:

1. Rational use of water
2. Regulation of arbitrary and uncontrolled water abstraction.
3. Treatment of wastewater.
4. Prior to any water management developments (setting of thresholds, arrangement of riverbanks), it is necessary to consult biologists.

Future options

The section of the Rižana River before its estuary should be further examined because of the specificity of this biotope and the research results should be taken into consideration with regard to the water regime of the Rižana River. In particular, it is necessary to make a study of the effect of the Rižana River on the stability of the ecosystem in the Škocjanski zatok.

Because of a relatively wet summer of 1996, the actual EF assessment was made more difficult. However, the results showed indisputably, as also the long-term hydrologic observations, that low flows in winter periods were not critical in these circumstances. Thus the project team proposed to concentrate the monitoring and intensify it respectively above all in June, July, August and September. The team recommended that regular analysis should be carried out during these months at the sampling points where research had been done before. The research would include biologic analysis, and regarding the physical and chemical parameters, only the measurements showing organic or industrial pollution physical would be used.

The ecological-based methods developed in Slovenia treat the community of water organisms and not only target species, while the main deficiency is, like in all methods, the lack of evidence that biota responds to changes in flow regime. In future, these methods will require more attention on the fish community and on the EF assessment for water polluters as well.

The team was involved in a separate project on the Revitalization of the Rižana River in 2002, financed by the Municipality of Koper. The main object of the project is quantitative and qualitative identification of the impacts of human activity on water quality, establishment of a list of priority measures relative to the extent of impacts and the possibilities of remediation and preparation of documentation regarding the adopted measures, including the monitoring. The project aims are the revitalization of the Rižana River and the achievement of optimal hydraulic, self-protective and habitat characteristics, drawing up of a long-term programme of co-existence between the nature and man in the Rižana River basin, as well as preservation of bio-diversity in water and riparian space.

Rational use of water, the search for new sources of drinking-water, wastewater treatment, the control of water pollution, the evaluation of outflow from the planned accumulation and the provision of the EF are the most important arrangements that the project team suggested.

4. LESSONS LEARNT AND KEY CHALLANGES

This research consists of an interdisciplinary approach covering biology, hydrology, hydraulics, morphology and landscape architecture. This included the collection of biological and hydrological data in different habitats at the same time.

The Ministry of the Environment and Spatial Planning funded this work on the Rižana River. The estimated value of EF has not yet been complied with in practice. The reason is, that the methodology and methods for EF assessment are not legalized by decree yet. So there is no appropriate legislation which would allow for an increase in the EF value and the opposition of the main user of water –

Rižanski vodovod, the water supply company, as they would have less water at their disposal during dry months.

More broadly, in the last ten years there have been strong efforts to improve the ecological characteristics of Slovenian running waters. An important step in river basin management is the determination and assurance of the EF. In the New Water Act, Article 71 states that EF should be assured for the entire year. The water should be abstracted from the running water only below the conditions, that the ecological status of the running water would not deteriorate. The actual possibility of water potential should be respected and the natural factors incorporated into the management of the environment.

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