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POPOVO POLJE, A DIFFERENT VIEW

POPOVO POLJE, DRUGAČEN POGLED

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Borut Juvanec: Popovo polje, a different wiew

Popovo polje is a longitudinal karst basin at the level of 250 metres above sea level, surrounded by higher hills, not far from the Adriatic Sea. Water power can be used for powering certain water devices, such as mills, mill-stamps, saw-mills, irrigation etc. All these devices except sawmills can be found in this region. The typical architecture on Popovo polje is closely connected with stone: dwellings, economic buildings, especially salaš (drying and storing device for corn), irrigation devices on the Trebišnjica river but the most attractive are mills, especially ponor mills. A ponor mill is a unique system in the world, using the oscillating level of water. A classical millwheel with a vertical axle – almost a turbine – is set into a vertical cylinder, which uses water power, independent of its level. The architectural frame is made of stone but the rotating elements are wooden, in particular the rotating waterwheel with scoops. Mills located on karst ponors with special behaviour are called 'estavelle' mills, with the wheel rotating in both directions. The problem with these jewels of the cultural and technical heritage is that they are abandoned and forgotten. The most important aspects of saving them are uncovering them, recalling them to memory and preventing them from disappearing, restoring them to working order and presenting them to the public. The conclusions are very clear: not even owners are aware of these important objects. We professionals must restore this heritage to life, to the public, by raising the awareness of the local people of the work and culture, with beneficial economic effects.

Key words: karst, ponor (swallow hole), watermill, waterwheel, turbine.

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Borut Juvanec: Popovo polje, drugačen pogled

Popovo polje je tipična vzdolžna kraška kotlina na višini 250 metrov nad morjem, nedaleč od Jadranskega morja, obkrožena z višjim hribovjem. Moč vode lahko uporabimo kot energijo za pogon nekaterih vodnih strojev: mlinov, stop, valjalnic, žag, namakalnih sistemov, itn. Na tem območju najdemo vse naštete, razen žag, kar je na kraškem terenu povsem logično. Arhitekturne značilnosti so vezane na kamen. Objekti so predvsem bivalne hiše, gospodarski objekti, posebej salaš kot sušilna naprava za koruzo, namakalni sistemi na reki Trebišnjica, predvsem pa so to 'ponor mlinice', mlini na ponorih. Ponor mlinica je edinstvena v svetovnem merilu, uporablja nihajočo višino vode. Je mlin z vertikalno osjo vodnega kolesa – skoraj turbine. Sam mlin je nameščen v vertikalnem okroglem obodu. Konstrukcija mlina je seveda kamnita, razen notranje konstrukcije z lesenim kolesom, ki ima enake lesene žličke. Nekateri mlini, ki stojijo na estavelah (ponorih, ki požirajo, a tudi bruhajo vodo), imajo konstrukcijo, prirejeno za delovanje v obeh smereh. Največji problemi teh mlinov je, da padajo v pozabo in da fizično propadajo. Najpomembnejša naloge so zato iztrganje pozabi in izginotju, rekonstrukcija v stanje delovanja in predstavitev spomenikov ljudske kulture javnosti. Sklep je zato povsem jasen: ta kulturna dediščina je danes pozabljena in je niti njeni lastniki ne poznajo več. Zato moramo predvsem strokovnjaki to pomembno kulturno dobrino vrniti v življenje, da bo dvigala zavest lokalnega prebivalstva, na področju kulture, a z ekonomskimi učinki.

Ključne besede: kras, ponor (požiralnik, bruhalnik), vodni mlin, mlinsko kolo, turbina.

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INTRODUCTION

Dinaric Karst, called Kras by Slovenes (Kranjc 1997), starts at the top of the Adriatic Sea and ends with the Ionian islands in Greece (Kranjc 2012). The main characteristic is limestone, pressed into layers. Some strata are permeable and some impermeable, enabling a number of effects caused by the water. The Karst was mentioned some two thousand years ago in Posidonius' works (first century BC; Kranjc 1997).

Underground structures include holes and caves with magnificent halls, corridors, passages, rimstone dams, stalactites and stalagmites; a variety of natural and man-made structures can also be found above ground. The main elements on the surface are entrances to the underground world, mainly ponors, estavelles (on flood plains), stony landscape and the stone architecture.

Both the visible nature and built culture are of the same importance to the underworld system. While the underground world is made by nature, man and mankind are human, thus also natural. The products of the karst inhabitants are consequently the same: they show the common culture of the karst space.

While the scientific treatment of the underground karst is very successfully done by karstology professionals (Lučić 2009; Lewarne 1999, Kranjc 2011 *et al.*), a link to the surface realizations is missing. Architecture and surface nature are very close connected to the spatial culture, the landscape, and much more could be accomplished in connection with the underworld.

Ponor mills on Popovo polje are not the only watermills in Herzegovina (Bugarski 1968) but they are certainly the most interesting. In particular, the idea and execution of watermills on Popovo polje, with direct use of natural peculiarities, are evidence of all the visible and the invisible elements, of the landscape and the underworld and works made by both nature and man – as the common characteristics of the karst space.

Nature has created important structures in the underground, almost architecture. Man has made architecture on the surface. Karstologists are professionals who perform important research of nature (inside and outside) but architecture is certainly part of this natural and built culture. In order to understand the whole complexity of the karst, both karstologists and architects must explore the two sides together.

POPOVO POLJE

Popovo polje is a longitudinal basin at a height of 225-250 metres a.s.l., with the River Trebišnjica running through it. It is some ten kilometres long and several kilometres wide (Lučić 2009). It is surrounded by higher hills and is not far from the Adriatic Sea, at a distance of approximately 20 kilometres.

The most important element is the River Trebišnjica, with its karst characteristics. It normally has a relatively fast flow, controlled by a dam on the upper part (power plant), and some smaller weirs down towards the town of Trebinje.

The riverbed has very rich meanders, the edges of which are strengthened by concrete margins, made some ten years ago. Margins at a height of some metres are successful only for a limited period of the year, and the flooding period with higher water is much longer than the 'normal' water level.

Villages are located very intelligently, high on the edges of the plain – above flood level.

There is a local proverb that all economic activities are possible – but only for one hundred days a year.

Every village on the outskirts of the Popovo plain has its own threshing-floor. It can be used for cereals but there has been no tradition of cereals for many years. Climate changes have changed the economy; people have forgotten the sowing of cereals, but the 'guvno' or threshing floor is living evidence of such agriculture.

A salaš, or vertical drying and storing device, is connected to all homesteads. However, since the recent fighting in Bosnia and Herzegovina, these objects have been abandoned although they have not yet disappeared.

In general, Popovo polje is a typical karst, horizontal, longitudinal plain, encircled by hills, with villages on its edges, with a road on one side and a former narrow gauge railway on the other.

WATER POWER

Water power can be used for powering certain water devices, such as mills, mill-stamps, saw-mills, irrigation etc. All these devices except saw-mills can be found in this region.

Water can be used for powering wheels. The stream of water can be directed at the wheel from the upper side or from below.

The stream can be slow, with a large amount of water, or high speed and at pressure but with a limited jet. The amount of water, its speed (rate of fall) and required effect are the elements that differentiate the types of waterwheel or turbine.

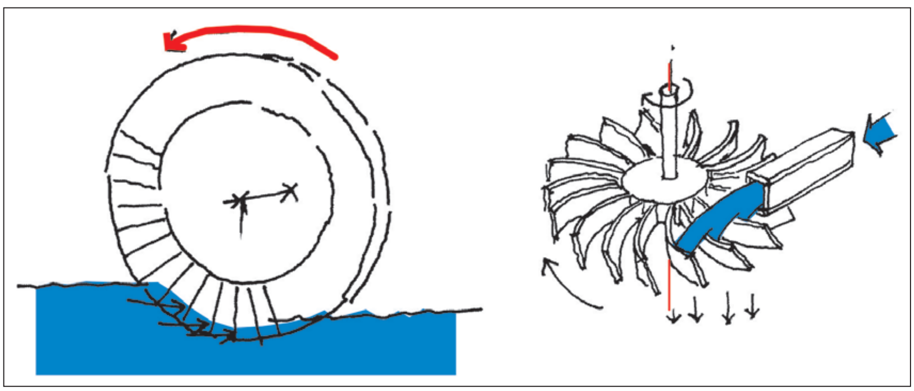

Fig. 1: Simple waterwheel for an irrigation system on the Trebišnjica river and sophisticated system of Pelton's turbine (in theory) (Juvanec 2015b).

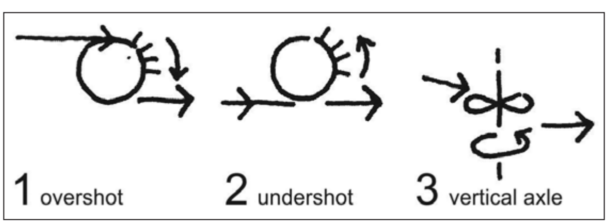

Fig. 2: Drive directions of wheels: overshot (clockwise) and undershot (anticlockwise) principles, and simplification of the Pelton's turbine with vertical axle (Juvanec 2015b).

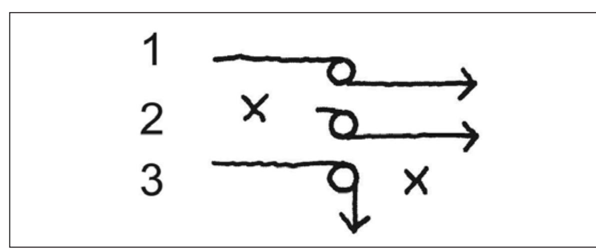

Fig. 3: Position on the water: watermill in: 1 the middle of a brook, 2 at the beginning and 3 at a swallow hole, where the water disappears (Juvanec 2015b).

Several types of elements can be used in the rotating wheel: paddles for slow motion, blades for faster work, as well as scoops and buckets for the fastest devices. Slow motion can be used in slow rivers with a large amount of water but well-designed scoops, like buckets, are effective with strong waterjets and a limited amount of water.

While a waterwheel is a simple solution, made by carpenters, turbines are complex work for highly trained engineers.

The first turbine, dating from 1827, was the work of Benoit Fourneyron, while the first practical principle of a turbine was invented by Pelton (impulse turbine, still in use today for small waterjets with relatively high pressure). The next step came with a reaction type, designed by James Francis, which was improved by Viktor Kaplan in 1912. Today's turbines are the same, although more sophisticated in terms of both design and materials.

A waterwheel can have a horizontal axle or a vertical one. Theoretically, wheels with vertical axles turn quicker but generate less power, while physically bigger wheels with horizontal axles turn slower but more powerfully.

Waterwheels can use fast or slow streams, small jets or a really big quantity of water. Technically, wheels are known as overshot or undershot wheels. The former rotate in the direction of the water, while slow rivers turn undershot wheels in the opposite direction. Wheels with vertical axles are more or less Pelton's turbines, even though they are made of wood.

The second feature depends on the origin of the water itself. A watermill can stand in the middle of the stream, at the beginning or at its end. Water cannot disappear in the technical sense: the end of a stream is the end only on the surface. The water can be swallowed into an underground hole, a ponor.

On Popovo polje, more or less all the wheels have vertical axes, even watermills on occasional stream near the village of Ravno.

Irrigation systems use the power of the river at weirs with a height of some metres or so, and all are turned by the water below.

PARTICULARITIES OF POPOVO POLJE

The value of Popovo polje is its natural karst characteristics and its architectural and other cultural elements.

Nature itself has karst features: a lot of stone, mostly limestone, slow rivers with meanders and seasonal floods and, the most important thing Vjetrenica cave. This important cave has been researched by local and cavers. The interesting object is well-known 'human fish' (Proteus).

Typical architectural features found in Popovo polje are closely connected to stone. There are dwellings, economic buildings, especially salaš (drying and storing device for corn), irrigation devices on the Trebišnjica river. The most attractive, though, are mills, especially ponor mills.

All the settlements are located on the edge of the plain, and the dwellings are close to one another, some ten metres higher than the highest level of the flood water of the Trebišnjica river. For most of the year, the plain is flooded as a very big lake and all the fields are covered by water.

The houses are longitudinal buildings with pavilion roofs. Economic buildings are small, located close to the houses.

The rarest object is a stone shelter. Such shelters are in use not only in karstic landscapes but can be found from Yemen to Iceland, and from the Canaries to Palestine (Juvanec 2016). The most characteristic detail is the construction: corbelling. This is a composition of horizontal layers, overlapping each over, with a ground plan close to a circle. The nearest similar objects, found in Croatia, are bunja in Dalmatia, trim on the island of Hvar, vrtujak on Korčula, and kučarica in the neighbouring region – Konavle (Juvanec 2005). These local objects, called 'poljarice' (sing.: poljarica), can be found near the village of Hutovo, on the edge of Popovo polje.

In terms of economic buildings in the villages: one of the elements of each homestead is a 'salaš', a drying and storing shed. This typical object has the basement and both gables in stone, with a wooden roof construction, covered by fired clay tiles. The longitudinal walls are closed with wattle, which protects the corn against the sun but enables fresh air and the wind.

Today, since the Bosnian war, more or less all the objects have been abandoned: the wooden constructions and tiles have disappeared but the stone constructions can be seen in the villages.

Each village has a threshing floor (originally: 'guvno') for common use: with the changed economy they are now out of use but remain as a memory of the former agriculture.

The main particularity of Popovo polje is the River Trebišnjica, with its slow meanders and, of course, all the typical karstic features: a lot of stone, stony landscape, underground caves, ponors (swallow holes) and estavelles. Especially estavelles are very important because they enable the use of water in two directions.

PONOR MILL (PONOR MLINICA)

A ponor mlinica is a unique system in the world, using the oscillating level of the water. A classical mill with a vertical axle – almost a turbine – is set into a vertical cylinder, which uses the power of the periodic flood water, independent of its level, but in a seasonal rhythm.

The main characteristic is the use of available natural possibilities: flood water, with its flood level, and ponor or swallow hole.

The normal current in the riverbed of the Trebišnjica

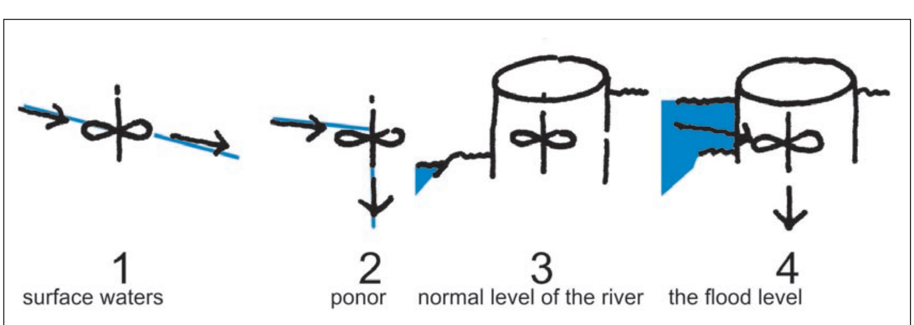

Fig. 4: Theory, the principle of a mill with vertical axle – 1 the stream comes and drains on the surface; 2 the stream comes on the surface and drains into the underground hole; 3 ponor mill and the river at normal level; 4 seasonal use of flood water in Popovo polje (Juvanec 2015b).

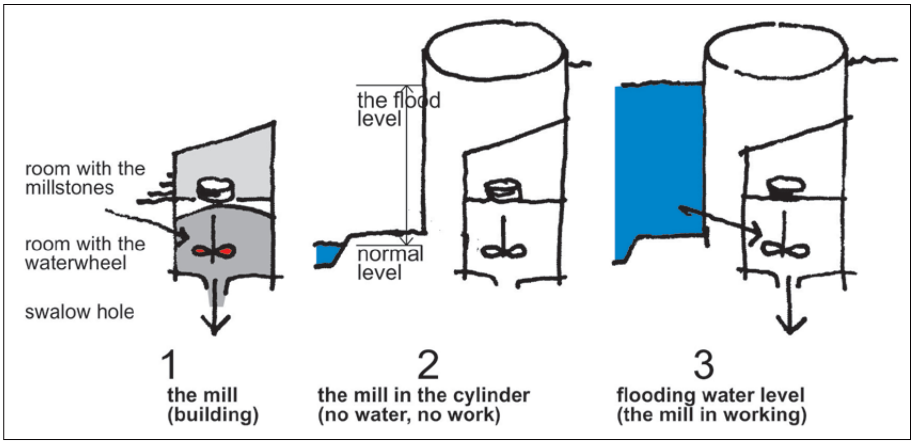

Fig. 5: Practice of the mill in Popovo polje – 1 the mill with three elements in the vertical axle, the millers room, room with power turbine, and the ponor itself; 2 the mill in the shaft, no water, no work; 3 seasonal flood water, working mill (Juvanec 2015b).

is fast and big floods reach a height of up to 40 metres. Seasonally, Popovo polje becomes a really big lake.

Before they built the large power plant and the weirs below Trebinje, there were a lot of classical watermills, on the riverbed deep in the gorge of the Trebišnjica.

The second feature is the use of swallow holes (in karstology known as 'ponors'). At the locations of these ponors, not far from the river, they built vertical cylinders in stone. The construction is a dry stone walling system, with no cement or mortar – but the flood water, full of clay, seals the construction as it returns to the riverbed and it becomes impermeable.

Deep at the bottom of the cylinder, there is a mill on two levels: the upper one with stone wheels for grinding, and the lower part with a powered waterwheel. The mill is reachable by spiral steps in the walls.

The water comes through a controlled entrance (the latest systems in use were made of iron or steel but the original devices were wooden). The water was drained away into the underground sink (ponor).

There are a lot of mills on Popovo polje. Except for some 'classical' mills, located in series on the stream near Ravno, they are all ponor mills. Lewarne reports at least two estavelle mills with turbines, working in two directions (Lewarne 1999). In 2015, I found 14 of them (Juvanec 2015a) but more objects are hidden in the bushes. All mills are in bad condition, abandoned and neglected, hard to find and hard to explore because of snakes and mines from the last war in Bosnia and Herzegovina. Caving equipment is needed in the ponors for the safety reasons. Time for exploration is also important, because of sudden floods.

CONSTRUCTION

Limestone is used for the construction of the architecture, but the rotating elements are wooden, especially the rotating waterwheel with scoops. Some of the mills use the bidirectional function of estavelles by allowing rotation in both directions. The mills are located near the edge of the flood area.

The ground plan is circular or semi-circular, with a flat wall on the opposite side to the river, because of the steps and for building the mill. Steps lead down along the circular wall – to the entrance of the mill itself.

The object has two rooms on two levels – the upper room with grinding stones, dedicated to the miller, and below the space for the powering device: the turbine. The third level is the natural ponor (the shaft).

The turbine is powered by water entering through a hole (in the wall, with control device for inflow). Historically, this device was very primitive, made of wood, and reachable from the top. All the outside shutters are made of steel, and aided with screws and cogwheels.

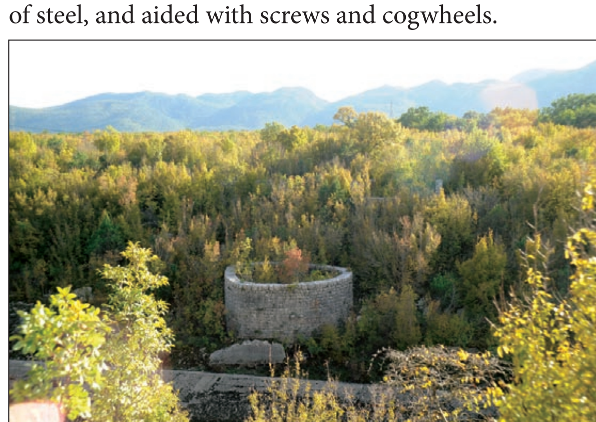

Fig. 6: Cylinder, visible from the other bank of the Trebišnjica river, Dobromani (Juvanec 2015b).

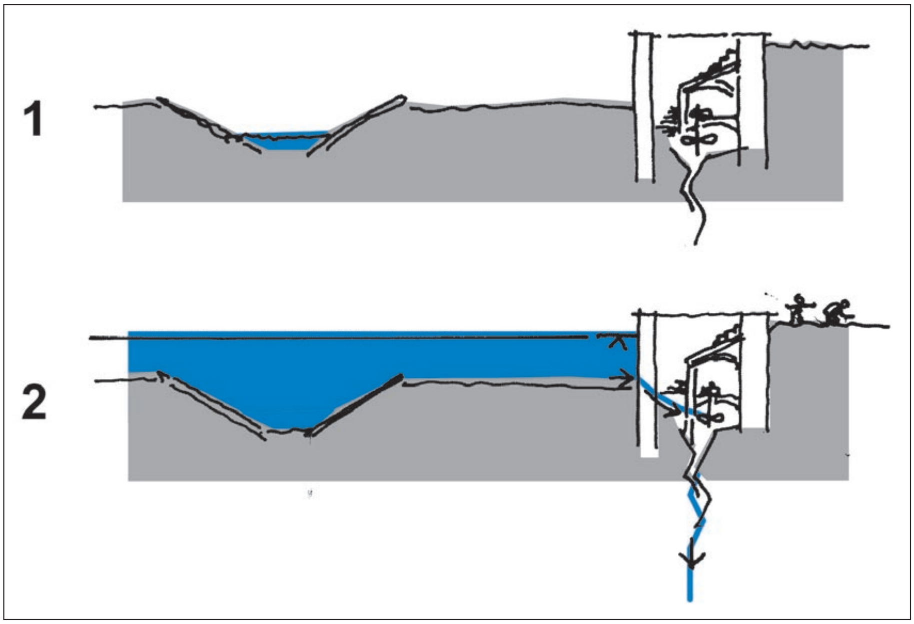

Fig. 7: Water levels of the Trebišnjica river: 1 normal level in the riverbed, practically 100 days in the year; 2 flood level (Juvanec 2015b).

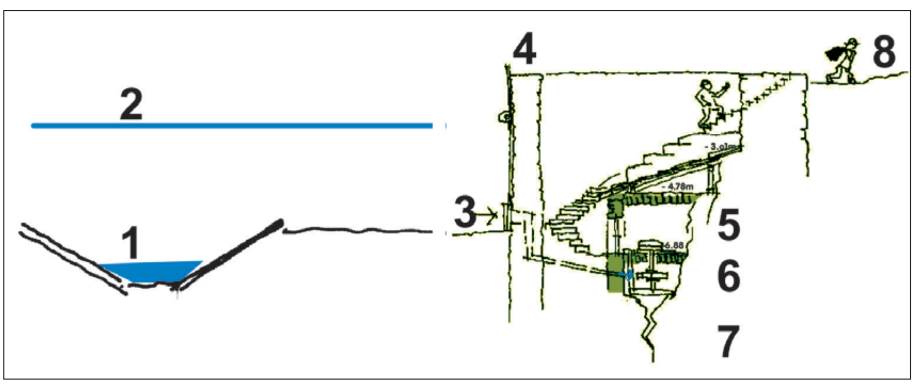

Fig. 8: Elements of the ponor mill: 1 normal level of the water in the riverbed; 2 flood level; 3 entrance of water to the mill; 4 the cylinder, walls around the mill house; 5 miller's room; 6 room with turbine; 7 swallow hole or ponor; 8 entrance from the terrain (Juvanec 2015b).

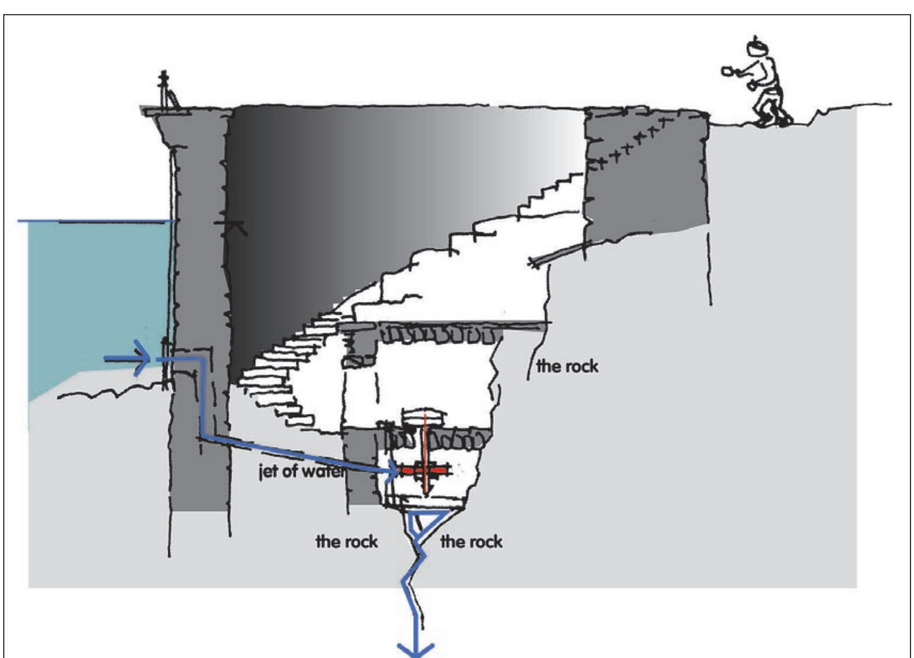

Fig. 9: Documentation: cross section of Kusalovića mlinica at Poljice Popovo. The roof has collapsed and the wooden shutter for the water has been replaced with steel machinery (Juvanec 2015b).

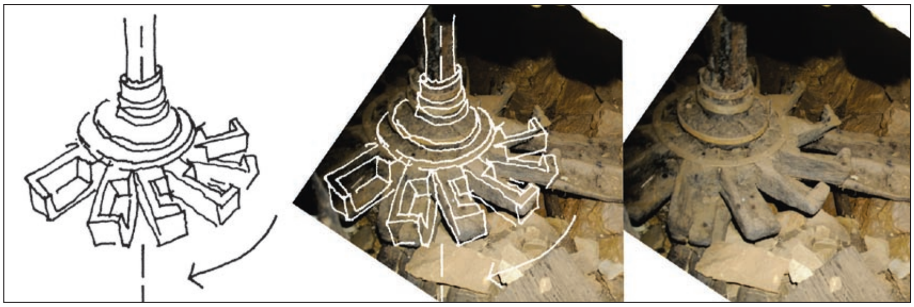

Fig. 10: Wooden waterwheel (turbine): carpentry work, axle, drive spindle and scoops (blades, locally lopatice pl.). In Kusalovića mlinica, the security hoops around the scoops (osiguravajući obrući) are missing; and the spout of water (mlaznica), the base anchor frame (kobila) is not visible (Juvanec 2015b).

The turbine is definitely the most important element of the mill. In 2015, I found only one wooden turbine wheel with scoops (Juvanec 2015a) at Žakovo. The scoops are carpentry work, with flat cuts, but sloped for a better effect. The securing hoop around the scoops is missing or never existed. Lewarne mentions it as a normal element in turbine wheels (Lewarne 1999).

The architecture of the whole object is done in dry stone walling – without cement or other sealing material. Stone above stone provides a permeable construction for the water. In any case, the flood water, full of mud, dust and sand, seals the construction into an impermeable composition. Not only in its construction, the flood cares for ongoing maintenance, during every flood season.

The wall is constructed of half-cut stones: cut outside for a quality flat surface but in their natural shape toward the centre. The middle of the construction is filled with sand and smaller bits. This can be seen on the upper surface of the walls.

The miller's room uses existing bedrock for at least one wall, and is covered with flat stone plates, with carpentry on the wood. The roof normally has one side, inclined to the centre of the mill.

The entrance is made of bigger stones, the biggest being the lintel above it. The door material is wood. Since the grinding produces a lot of dust, the door has to be open for ventilation; so windows are not needed.

The lower room with turbine is often less than two metres high, with a wooden bearing construction, standing on the rock. The swallow hole can be vertical below the construction or horizontal, with essential slope into the underground. This room is normally covered by a stone flat arch – with cut stones. This part of the construction is especially important and has to be very stable, because of the vibration of the millstones.

All the composition uses natural possibilities (rock for the construction and shaft for the work), the vicinity of the river, and the circular shape of the ground plan, strongest against water pressure from outside.

DISCUSSION

Popovo polje remains today more or less in the original state, as it was before the big dam in the upper side appeared, which can control the water level only to a limited extent. The floods appear seasonally, instead of the dam.

While the karstic characteristics have an important influence on life, and the organization of local communities remains as it was, the economy is not. It was changed by using other technologies, and other agriculture means.

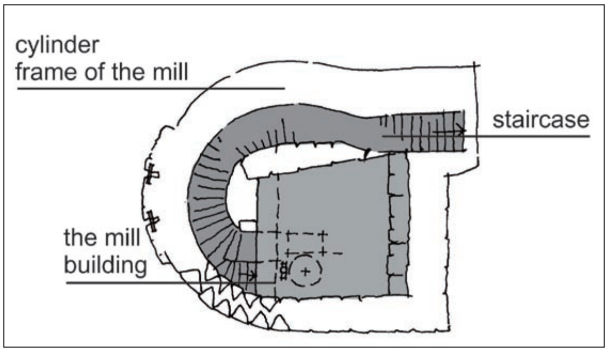

Fig. 11: Ponor mlinica – elements: cylinder or outer walls; mill with three rooms; staircase from the top (terrain). Rectangle in the mill is used as the entrance to the power wheel room, and the circle represents the millstones in the upper room (Juvanec 2015b).

Possibilities for the use of water exist, and it is used to a limited extent for irrigation (at 'normal' river levels) and for milling (in flood seasons). The latter is appreciably longer than the former. The irrigation systems work today using cheap energy and no need of maintenance costs for long time.

The ponor mills (as well as the estavelle mills) are abandoned, neglected and forgotten, almost hidden and disappearing both into the bushes and from memory.

The local economy has been changed by new technologies.

CONCLUSIONS

The problem of these cultural, heritage and technical jewels is that they are abandoned and forgotten. The most important task in saving these historical monuments is to uncover them, to prevent people from forgetting them and their disappearance. It is necessary to reconstruct some of them into working condition, to present them to the public.

The work required inventorying, evaluation, documentation, reconstruction, maintenance and presentation to the public.

Inventorying means collecting all the data on use, history, linguistic sources, technology and techniques, materials.

Evaluation is professional work, close connected to several branches. Its results put together all the objects on the preference list.

Documentation consists of technical drawings: environment, objects, details, and schemes of work.

Reconstructing is professional work, continuation of all the previous mentioned procedures.

Organization of permanent maintenance can be done by the local authorities and local people.

Presentation to the public uses all the possibilities – media for publicising the monuments, the work and the people who worked with the objects; presenting their values and raising self-awareness for the entire region.

This work cannot be done only by professionals (architects, engineers, historians etc.) and official state agencies for preservation. They should be organized on a wider level, with the help of specific universities and regional and international karstology associations, experts in the field, and with students, local government and the public. Practical work would start with collecting the data, clearing the surrounding, reconstructing of the buildings, inventorying and documentation (this could be done by students of archaeology, architecture, civil engineering, anthropology and karstology). Presentation of these rediscovered monuments is important and of interest for all, above all the local government and

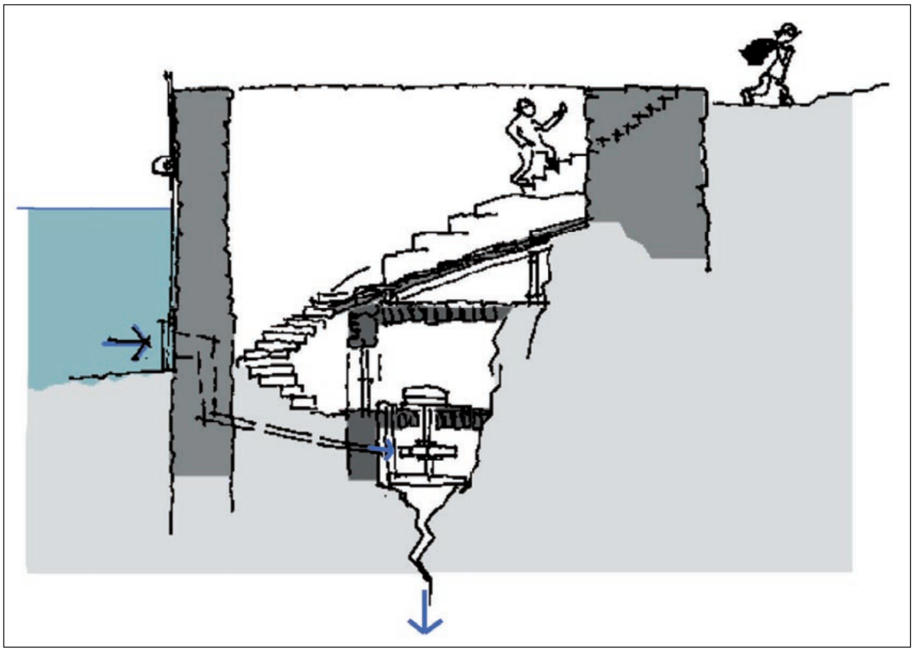

Fig. 12: Reconstruction: cross section with all existing elements and reconstructed roof of stone plates. A steel shutter has replaced original wooden device for opening the spout for the water (Juvanec 2015b).

the entire public. Thematic trails with local information boards can be introduced; finally an open-air museum, or virtual museum, with of the modern technologies and smartphones. The media can play an important and fruitful role in this direction.

These important objects are not even known by the owners or the local community.

We professionals have to make a start on restoring this heritage to life, raising public awareness, making the local people aware of their valuable heritage, together with the economic benefits of taking action.

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