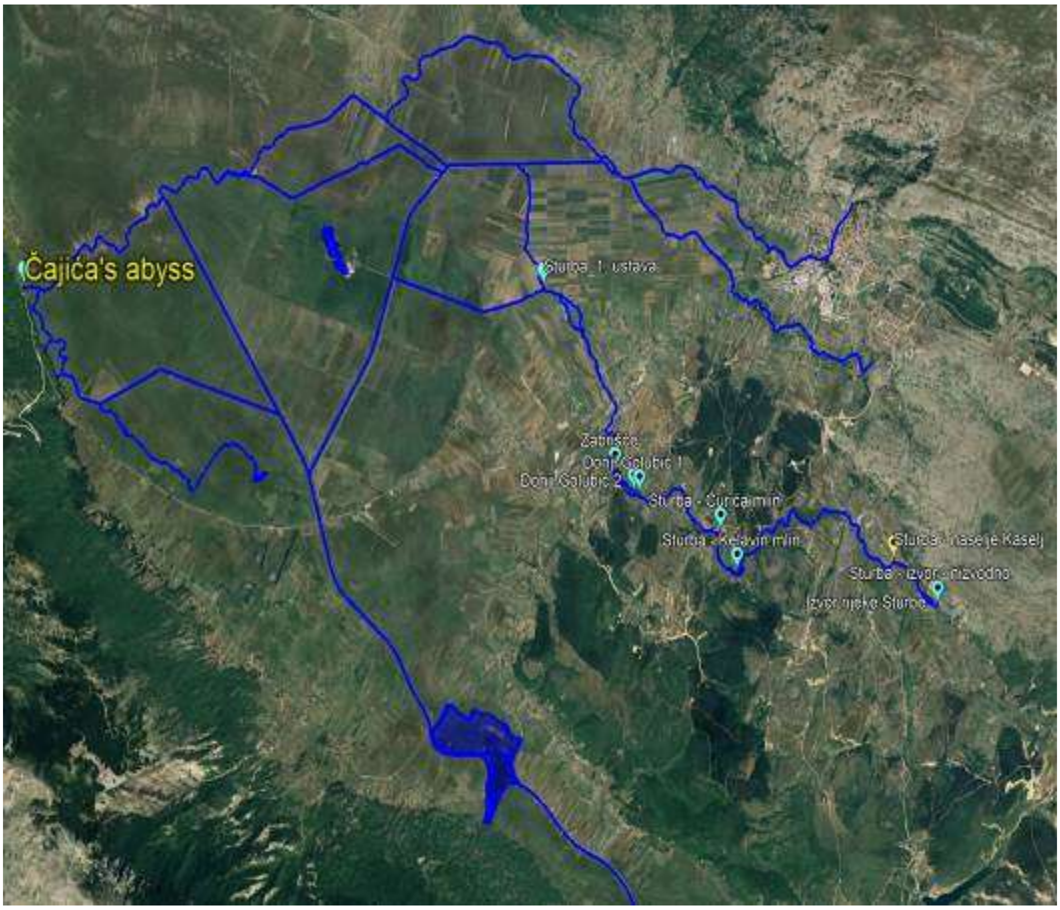

NGO “DINARICA” Final Report of Experts on the Project: „Towards the first removal of barriers /dams (on watercourses) in Bosnia and Herzegovina: Livanjsko polje case study“

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Content

GEOGRAPHICAL CHARACTERISTICS OF LIVANJSKO POLJE

GEOGRAPHICAL POSITION

Livanjsko Polje occupies the extreme southwestern part of Bosnia and Herzegovina, specifically (in the defined scope) within the following astro-geographical coordinates:

- Northernmost point: ϕ = 44° 06’ 15” N; λ = 16° 36’ 25” E (southwest of the inhabited place Zadraga);
- Southernmost point: ϕ = 43° 45’ 25” N; λ = 16° 53’ 40” E (north of the inhabited place Miškovići);
- Westernmost point: ϕ = 44° 05’ 20” N; λ = 16° 34’ 15” E (south of the inhabited place Nenadići);
- Easternmost point: ϕ = 43° 49’ 40” N; λ = 17° 00’ 08” E (north of the inhabited place Livno).

Within these coordinates, Livanjsko Polje covers an area of about 295 km² with an average altitude of approximately 710 meters. The length of the field from northwest to southeast is around 45 km, with an average width of about 7 km.

From the perspective of general physical-geographical position or zonal-explanatory type, it belongs to the southeast part of the southwestern Bosnian-Herzegovinian area, outside the Dinaric landscape region of the northern subtropical belt.

In the broader area of Livanjsko Polje, limestone-dolomite deposits of Mesozoic and Cenozoic-Paleogene, mostly flysch formations, dominate. The predominant morphosculpture types include karst, fluvio-karst, and fluvio-denudational destructive types formed on the prevailing mountainous (hill-valley) morphostructures. Significant accumulative relief forms, primarily fluvial, are formed at the bottom of the field due to reduced relief energy.

Due to its geographical location and relief specificities in the broader environment, Livanjsko Polje experiences a moderate thermal regime with annual isotherm values ranging from 9.0 °C to 3.0 °C. Its precipitation regime displays modified Mediterranean characteristics with annual isohyet values ranging from 1150 mm to 1750 mm in the areas of mountain peaks of the Dinara mountain. Analogous to these values of the precipitation-thermal regime, the broader area of Livanjsko Polje experiences a modified Mediterranean, pre-mountainous, and mountainous climate type with mixed maritime and continental influences.

The entire area belongs to the Cetina River basin, i.e., the Adriatic basin. Due to the predominant limestone-dolomite bedrock structure, the surface river network is poorly developed, except at the bottom of the field, which is composed of clastic sediments. The existing hydrogeological relations are quite complex, although the entire underground drainage belongs to the Cetina River basin.

In most parts of the area, hydromorphic soil division predominates, especially marsh soils, red soils, and calcocambisols. Hydromorphic soils, especially fluvisols, are developed along the bottoms of river valleys and basins.

The biogeographical characteristics of the broader area of Livanjsko Polje result from the values of all the mentioned elements. Contact mountain morphostructures, within the mid-mountainous elevation belt, are biogeographically represented by the biome of supra-Mediterranean forests and shrubs of evergreen oak, downy oak, and black hornbeam of the Mediterranean subregion. This biome is connected to beech and beech-fir forests of the mezic beech from the Euro-Siberian subregion towards the high-mountain zone. The highest peaks in the Dinara mountain zone belong to the biome of mountain rocks and high-mountain tundra of the Alpine high-Dinaric subregion. In the area of the field's bottom, the biome of moist forests of pedunculate oak and field ash dominates.

Map 1. Regional-Geographical Position of Livanjsko Polje

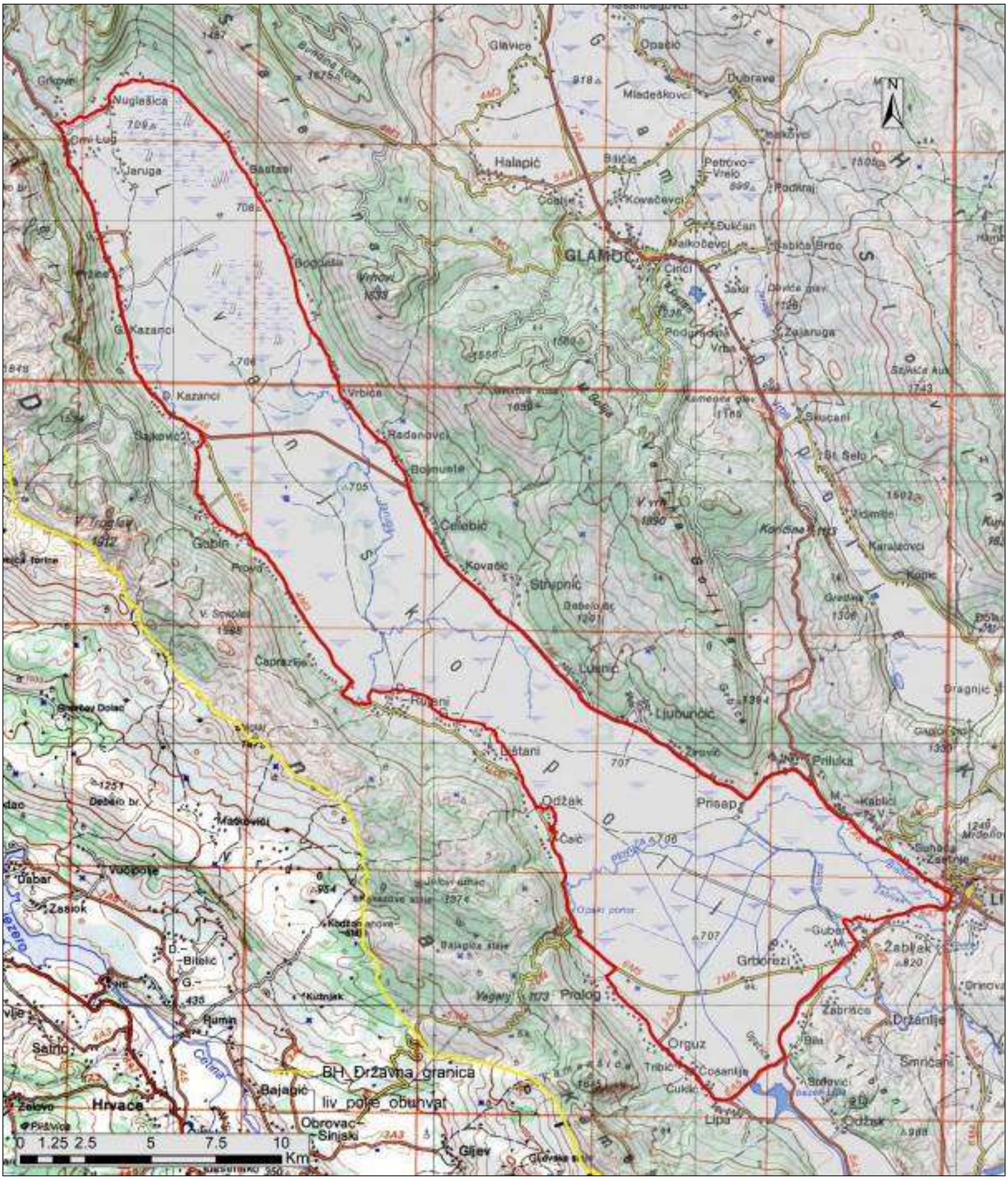
1.1. GENERAL HYDROLOGICAL CHARACTERISTICS OF LIVANJSKO POLJE

The entire river network in the broader area of Livanjsko Polje belongs to the Cetina basin, namely the Adriatic basin. The field bottom is covered with a series of clayey-sandy-lapillaceous, occasionally gravelly Neogene fractions. Their thickness is not uniform, ranging from several meters in the peripheral segments of the field to ten meters or more in the areas of widely spread alluvial terraces in the central part. Despite the fact that the differences in field bottom elevations are practically negligible, including the morphohydrological relationship of the field bottom to high waters during the flood season, it is possible to differentiate the hydro-morphological characteristics of the field bottom into several segments.

The northern section of the field up to the narrowing at Sajkovići (up to the local road across the field towards Baroš, approximately 15 km) belongs to the smaller depression of Ždralovac or Ševarevo Blato. This area is supplied with water from numerous, mostly permanent voklia springs from the eastern and western edges of the field, as well as from several small streams that flow from the Grahovo area during the rainy season. Ševareva Jaruga collects these waters and channels them into the sinkhole zone of Kazanci, or Kazanački Ponor, at an altitude of 697 m. During the flood season, high waters reach the level of the plateau part of Kazanački

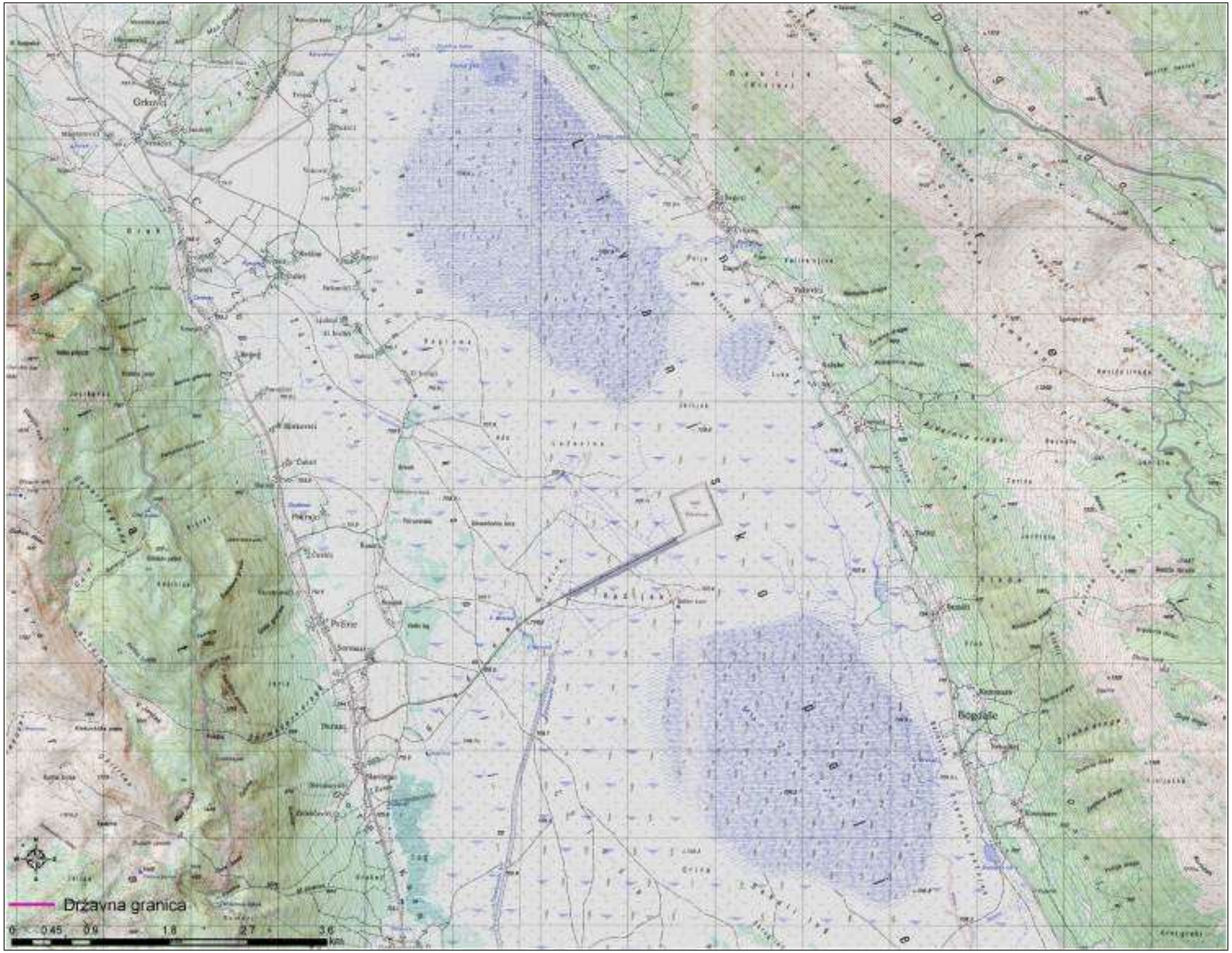
Ponor, at an altitude of around 708 m. In the northwestern part of the area, neogene morphological heads have formed, which are generally not flooded during the high-water season, such as Crni Lug and Pržina. The depth of the lapillaceous-clayey sections in this part of the field exceeds 10 m, practically submerged underwater throughout the year. Taking into account other geological-climatic elements, a very characteristic type of pedological substrate - peat - has formed in this area. Due to its physical-chemical characteristics, it has facilitated the development of very distinctive vegetation elements - marshland vegetation, which is mostly endemic, giving particular importance to this part of the field.

South of the Sajkovići narrowing (approximately 14 km in a straight line), the hydrological collector center of the second large morphological unit is formed in the area of Veliki Ponor. Although it collects water from all segments of this part of the field, it is spatially more positioned in the western part. The hydrological backbone is the course of Jaruga, which, from the extreme northern parts of the source front in the field, receives a larger number of permanent or occasional smaller streams or springs directly along its course: Virovi, Šaraica, Konjskac Spring, Jazina, Kurtovac Spring, Žarkova Bara, Crni Bunar Spring, Pandeljovac, Radića Otoka, Mrđića Bunar Spring, Otoka, etc. Waters sink into the limestone interior in the zone of Veliki Ponor, at an altitude of 696 m. This sinkhole also functions as an estavelle, so that during the flood season, high waters reach an elevation of about 708 m. As the terrain is very gently sloping towards the north, floodwaters in this area recede earlier compared to the Ždralovac unit. Springs along the eastern edge of the field in this unit are fewer in number and dry up earlier, as they are a series of springs at altitudes ranging from about 715 m to 720 m.

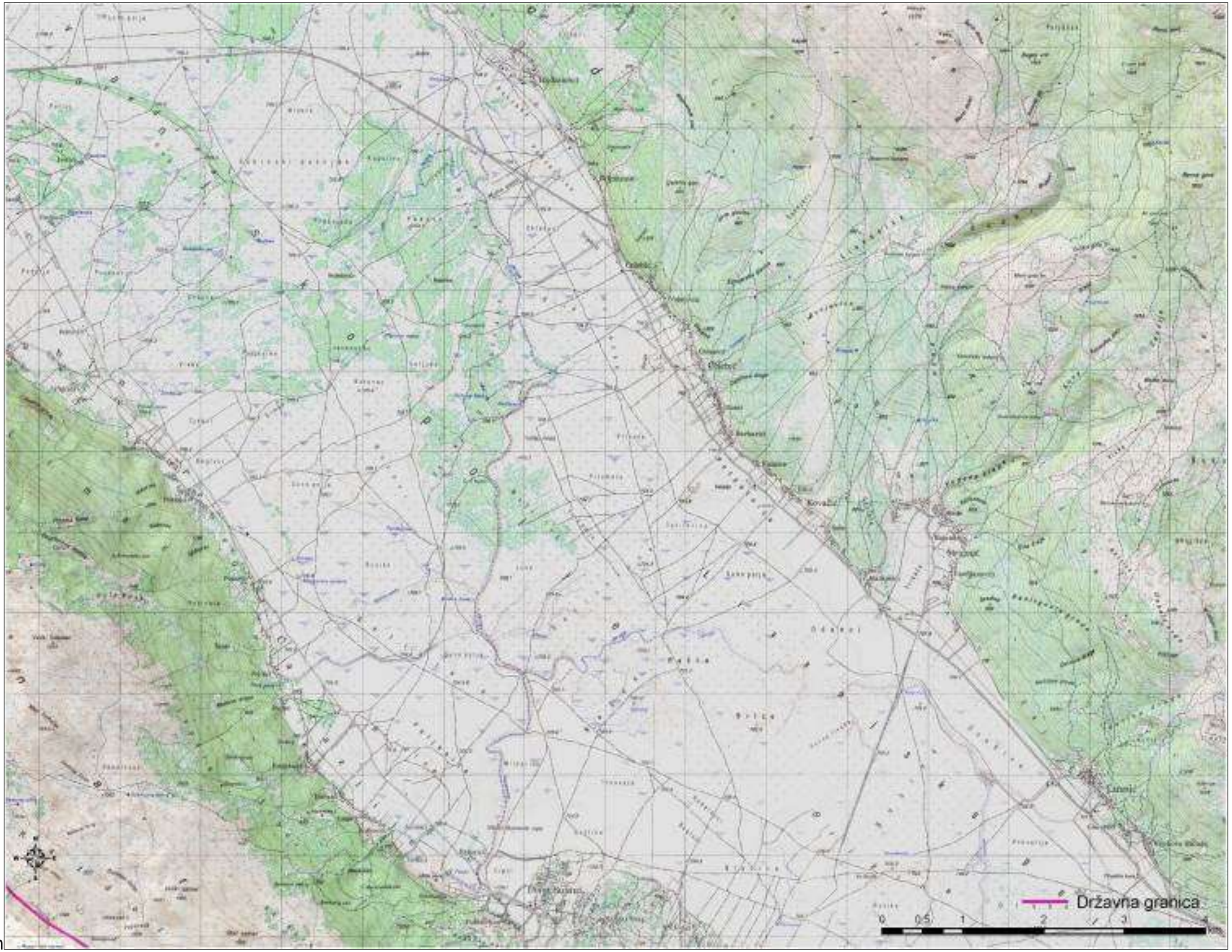


Map 2. Topographic Features of Livanjsko Polje

The next hydro-morphological unit refers to Livanjsko Polje in a narrower sense, and in relation to the previous one, it is separated by a limestone ridge in the zone south of the village of Lištani, where the width of the field (SW - SE) falls below 4 km. Immediately south of the narrowing, the field expands to an average of about 14 km, taking on a triangular shape (see map 3.). In the southeastern part of this unit, in the area of permanent and highly abundant springs, the town of Livno is developed, serving as the administrative and urban center of the entire region


Državna granica
0 0.45 0.9 1.8 2.7 3.6
km

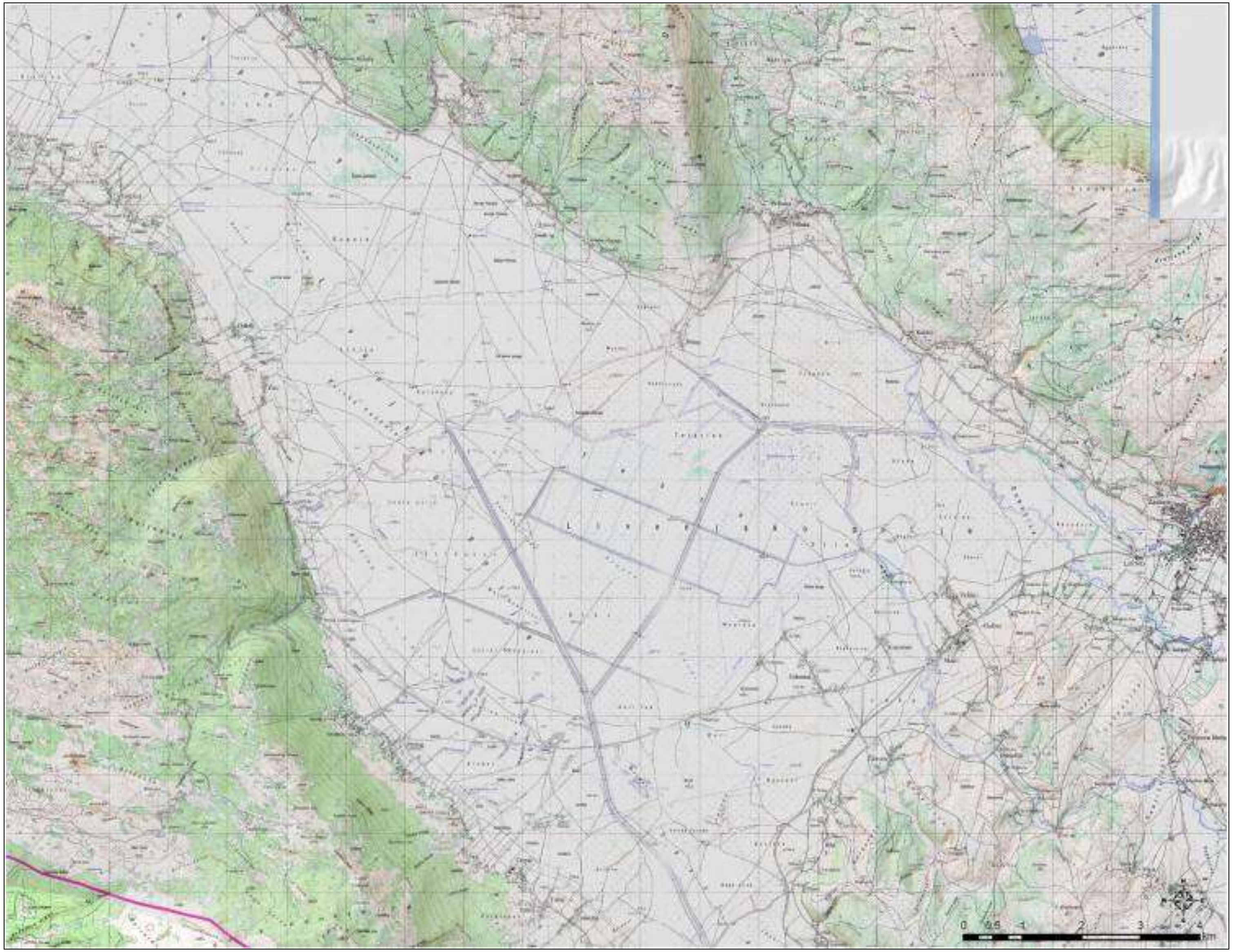
Map 3. Ždralovac Morpho-



Depression

4. Morpho-

Depression Jaruga.



Karta 5.. Morpho-Depression narrower area of Livanjsko Polje

The most important voklia springs in this area are Bistrica, Sturdba, and Žabljak, which are sufficiently abundant in water to form distinct surface streams in this part of the field. The Bistrica River originates from the voklia spring Veliki Duman, along the northern mountainous edge of the town of Livno, at an altitude of about 860 meters. From there, it flows through the town of Livno and in a northwest direction until south of the village of Hajdukovići, where it merges with the smaller Žabljak River to form the course of Jaruga. Žabljak originates from a strong voklia spring northwest of the settlement of Gornji Žabljak, where, as a stream with a constant hydrological function, it flows to the mentioned confluence, at an altitude of about 711 meters. Through hydro-melioration measures, downstream of the confluence, a canal called 'Prokop' has been dug, diverting the flow of these two streams towards the central part of the field. Approximately 1.7 km from the beginning of the Prokop canal, the Sturdba stream joins in, originating from a powerful voklia spring in the zone of the eponymous village, in the southeastern edge of the field, at about 740 meters altitude. The common outflow of these three streams is the Plovuća River, which flows through the central part of the field in an east-west direction towards the sinkhole zone of the Vaganj Canyon – from Veliki Ponor, through Opaki and Kameniti Ponor, to Prolog. During the rainy season, the mentioned sinkhole zone does not have sufficient capacity to accommodate high waters, causing the flood zone to reach an altitude of 710 meters and may last for up to two months.

The fourth hydro-morphological unit covers Bijelo Polje, representing a morphological narrowing from the previous hydro-morphological expansion into the extreme southwestern part of Livanjsko Polje – Buško Blato. The average width of Bijelo Polje is 2 km – 3 km with an average length of about 12 km. As the field is quite narrow and the slopes are developed and composed of limestone-dolomite conglomerates, denudational slope processes are quite intensive, resulting in the more intense deposition of destroyed slope material at the bottom of the field. As a result of these conditions, parts of the individual bottom areas of Bijelo Polje are slightly elevated, and there is no continuous flood zone; instead, it is limited to spaces between elevated areas – morphological heads. These are constructed from proluvial deposits carried by torrents during the rainy season into the field's bottom zone. They are usually flat and inclined towards the sinkhole zones of the streams that formed them. Rural settlements developed on these raised parts, which were not flooded. Buško Blato represents the final southern part of Livanjsko Polje, at altitudes ranging from 690 m to 700 m. It is supplied by several voklia springs that dry up in the summer. The most significant tributary is Ričina, which, over a length of about 5 km, flows from the northeastern side into the lake. Most sinkholes are located on the western side of the lake basin. In the 1970s, Buško Blato was transformed by hydroengineering measures into an artificial - techno-aquatic complex for the production of electricity and intensification of agricultural production.

1. OVERVIEW OF OBSTACLES FOR REMOVAL

1.1. LOCATION 1. ČAJIĆA SINKHOLE

Čajića Sinkhole represents the zone where the waters of the Plovuća River sink, in the contact zone between Eocene clastic rocks covering the bottom of the field and the limestone collectors that form the Dinara massif. The Plovuća watercourse is formed in the central part of Livanjsko Polje, by the confluence of two streams: Okolica and Jaz. The natural stream bed is dammed 4.2 km upstream from the sinking zone by a dam, controlling the river water that flows from an artificial drainage canal into the natural bed of the Plovuća

River

Picture 1. River plovuća upstream of Čajić ponor(sinkhole) (February 2023.)

In the bed of the Plovuća River, two structures have been identified, recognized as two barriers that do not serve any hydraulic function and are planned for demolition.

Coordinates of the centroid of the first barrier:

ϕ=43°49'47.56"N; λ=16°48'50.48"E; H = 703 m above sea level.

The structure of the old mill (Duića mill) in recent times does not serve any economic or residential function. Considering the complete devastation of the structure, it can be stated that it does not serve any tourist function. The structure was made of concrete during the early 1960s and is located directly adjacent to the stream bed to harness the power of running water for milling wheat and corn. The structure is approximately square-shaped, with a total perimeter of about 105 meters, indicating that each side is approximately 10 meters

long

Picture 2. Ponor zone of Plovuća river (Veliki ponor or Čajić ponor).

The average height of the walls is approximately 3 meters, with the wall height along the stream being around 8 meters. The average wall thickness is about 50 cm. The structure comprises two main rooms separated by a partition wall, along with a small entrance area providing access to these rooms. There are no remnants of installations or equipment from the former mill, further indicating that the structure has been completely abandoned. An important aspect defining the operational capabilities of the mill is related to hydrological seasons. It can be noted that the structure could not operate during the summer period when the Plovuća River (like most surface watercourses in Livanjsko Polje) completely dries up. Consequently, the structure could only function during the colder (winter) period of the year when this part of Bosnia and Herzegovina experiences the main hydrological peak season

Picture 3. The abandoned mill structure is located directly adjacent to the sinking zone of the Plovuća River.

The second structure is located approximately 100 meters upstream from the mill. Coordinates of the centroid of the second barrier:

$\phi =$ 43°49'47.46"N; $\lambda =$ 16°48'56.05"E; H = 703 m n.v.

Karta 6. Geografski položaj lokaliteta Čajića ponora i objekata na rijeci Plovući.

Karta 7. Morfološki položaj lokaliteta Čajića ponora i barijera za uklanjanje

The structure is built directly on the course of the Plovuća River and consists of two parts: a mill structure with a dam and a regulating flap to control the water flow, and a concrete basin, likely used as a fishpond. The structure is in a dilapidated state with visibly destroyed and damaged walls. The roof is completely demolished. The dimensions of the structure are 8 m x 3 m, with an average wall height of 3.5 m. The walls are constructed from masonry stone and significantly damaged. The wooden roof structure of the building is completely destroyed (see Image
4)

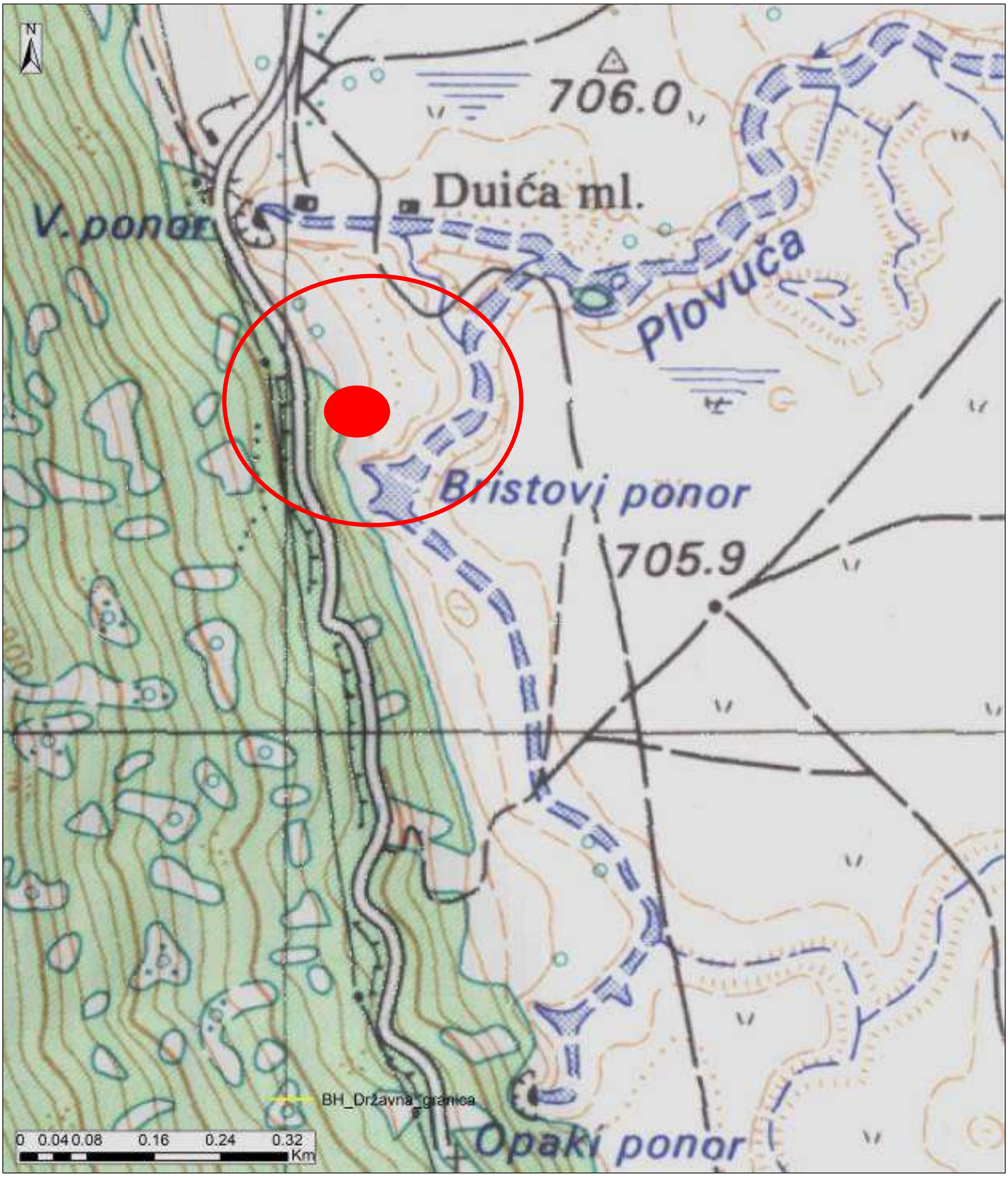
Picture 4. The abandoned structure - a mill along the course of the Plovuća River

The structure has one room which housed the dam controlled by a flap to regulate the water flow passing through the mill and into the additional concrete basin. Besides this, a smaller entrance room was also registered within the structure. The walls of the structure have varying thicknesses – from 70 cm (outer walls) to 50 cm (inner partitions).

The water passing through the mill was controlled by a flap allowing a flow of approximately 3 m3 and was directly diverted into the pool, whose external walls are also made of masonry stone. The pool is rectangular in shape, with sides measuring 20 m x 10 m, and the wall height is approximately 3.5 m. The basin likely served as a watering hole for livestock. However, the structure has long lost this function due to the construction of the hydropower plant system, which deprived it of water during the summer months when livestock grazing occurs in the field. This is evident from the very poor condition of the walls and the basin's base, which are severely deteriorated. Part of the barrier comprises the foundation of fishponds embedded in the riverbed at a depth of about 1 m. Water from the basin is regulated and released into the downstream part of the Plovuća
River.

Picture 5. The removal of the planned pool structure.

After subsequent engagement with speleologists, two more barriers were found downstream from the described structures (further detailed in the ichthyologist's report). These barriers were constructed around 1880 by the Austro-Hungarian Empire to expedite the drainage from the field into sinkholes. However, with the construction of the hydropower plant system in the 1970s, they lost their function and purpose. Consequently, it can be noted that the structures built in the course of the Plovuća River are completely devastated and serve no economic or touristic purpose. These structures have been entirely ruined both in terms of their construction and the infrastructure previously used for mechanically grinding wheat and corn. Given that the Livno area has been characterized as a highly depopulated area over the last two decades, there is a need for the restoration of these mentioned mills



Map 8. Topographic position of the Čajića ponor site and barriers for removal

2.2. SITE 2. STURBA RIVER NEAR THE FIRST DAM

The Sturba River originates from the spring in the village of Sturba, sharing the same name. The altitude of the spring is 746 meters above sea level. Sturba is the longest watercourse in the Livno field, with a total length of approximately 14.5 kilometers. The river's course is rich in aquatic and semi-aquatic flora, along with freshwater fauna (notably including the white-clawed crayfish and brown trout). The mouth of the Sturba River is at 710 meters above sea level, indicating very slight riverbed gradients. The river's mouth represents an artificially excavated channel - the Prokop - through which the waters of the Sturba, Bistrica, and Žabljak rivers are diverted into the central part of the field. Specifically, as part of planned hydraulic reclamation activities, an artificial channel was excavated about 240 meters downstream from the confluence of the Žabljak and Bistrica rivers, redirecting the waters of these two rivers, as well as those of the Sturba, into the Plovuća River.

Picture 6. Flow of the Sturba River, immediately downstream from the barrier for removal.

Picture 7. Part of the left drainage channel of the Sturba River, whose flow is regulated by the dam.

According to the existing hydroelectric power concept of water usage, most of the collected water is directed through this channel to Lake Livanjsko and further to the Buško Blato reservoir. Any potential excess water (occurring during high water periods) is redirected through the dam on the Prokop channel into the natural channel of the Plovuća River, where the waters flow towards the sinkhole zone of the Vaganjski klanac – from Veliki ponor, through Opaki and Kameniti ponor to Prolog. During the rainy season, this sinkhole zone does not have sufficient capacity to accept high water levels, causing the flood zone to reach up to 710 meters in height and can last up to 2 months. The removal barrier extends along the entire cross-sectional profile of the riverbed with a total area in plan of 575 square meters. The total length of the riverbed along which the obstacle is constructed is 52 meters, while the surface perimeter of the entire structure is around 135 meters.

Coordinates of the barrier's centroid: ϕ= 43°49'26.14"N; λ= 16°56'7.45"E; H = 710 m above sea
level

Slika 8. Segments of the drainage channel where small bridges with weirs are constructed.

Considering that the supporting elements of the weir are installed in the channel bed, they represent an obstacle that also needs to be removed. Although constituting a single construction unit, the barrier consists of two separate structures: 1. a concrete weir for water regulation 2. a dam for forming a reservoir.

1. Concrete weir for water regulation

This weir is built in the left part of the channel, with a length of approximately 6 meters. The weir comprises a metal frame about 50 centimeters thick, with a flap used to raise or lower, thereby controlling the size of the opening for water flow. The weir serves the function of regulating the water flow of the Sturba River into the left artificial channel or redirecting a part of its water into a canal for hydro-improvement activities (see map 9.)

Map 9. The geographical position of the Sturba weir.

Map 10. The morphological position of the Sturba weir site.

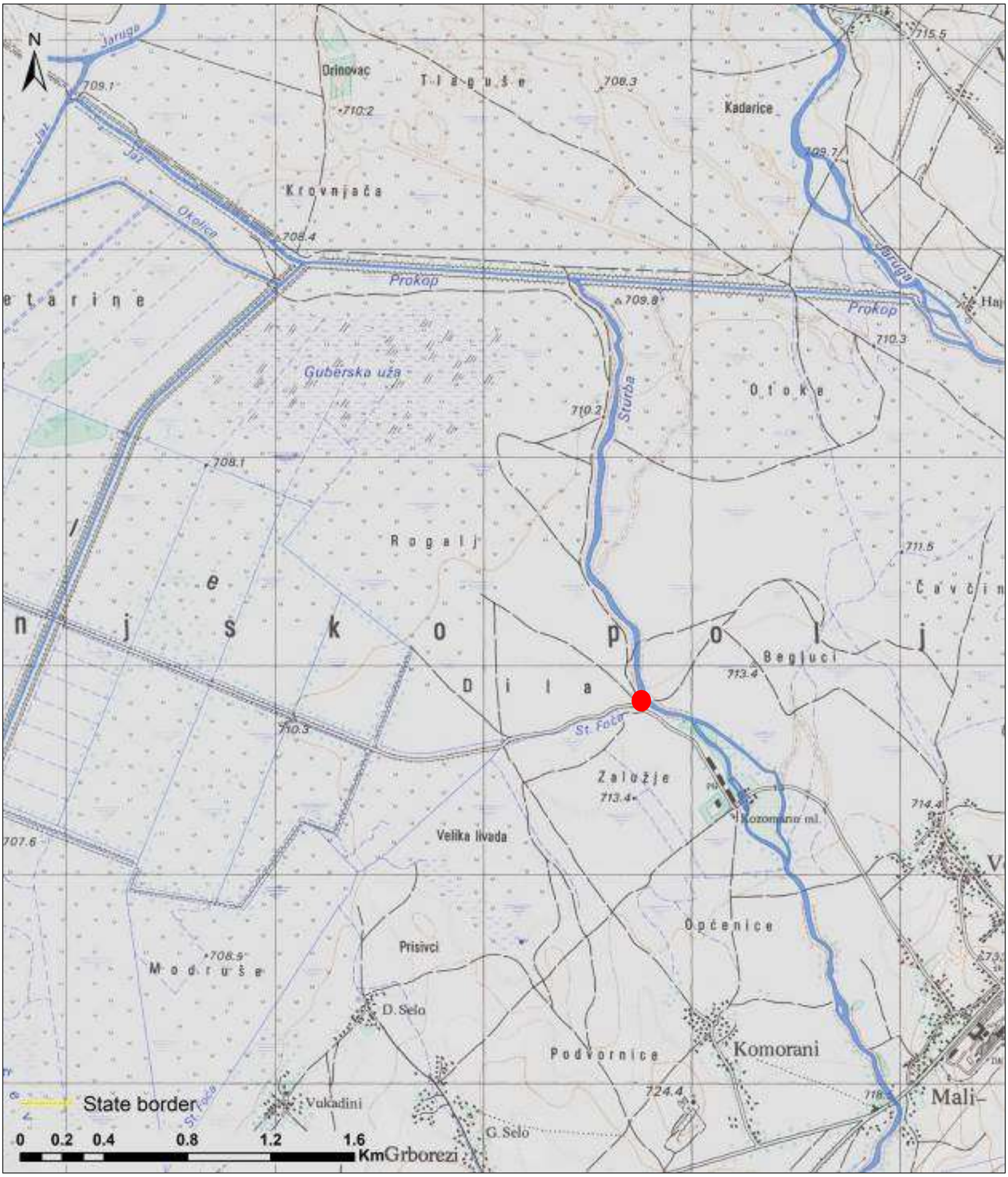
Picture 9. The weir along the left bank of the riverbed no longer serves any hydrological function and therefore requires removal

2. Dam for forming an accumulation lake.

The dam structure represents a concrete barrier built along the entire cross-section profile of the Sturba River's riverbed, with a length of about 50 meters. When observed from a plan view, the barrier has a ribbed structure that serves to create water jets, thereby increasing their kinetic energy. This was intended to generate greater power to turn the blades of watermills that operated the mills. The structure is in a completely dilapidated state and lacks any hydraulic or economic function. The dimensions of this part of the structure are: 50 meters x 12 meters. The height of the structure is approximately 1 meter, with foundations about 1 meter deep. The walls' thickness measures around 80 centimeters. The surface area of this structure is about 490 square meters. The riverbed obstruction led to the formation of a small accumulation lake of overflow type, given that the mentioned barrier is insufficiently high to form a larger accumulation lake.

Picture 10. The Sturba Dam intended for removal.

A specific part of the structure comprises a longitudinal supporting wall used as an access point to the dam, serving the regulatory redirection of Sturba River water when the gate on the dam was fully raised. During that period, this part of the water belonged to the flow of the Sturba River. The supporting wall is built of masonry, measuring 3 m x 1 m, with a height of approximately 2 m. Due to the gentle water flow, favorable conditions have been created for the migration of riparian vegetation along the dam itself, resulting in the formation of willow vegetation in this area. However, before making a final decision, further research is necessary regarding the function of the dam during low water levels. During this project period, it was impossible to determine its role in diverting part of the water during the dry period towards agricultural areas and peatlands



Map 11 The topographic position of the Sturba site and the barrier for removal.

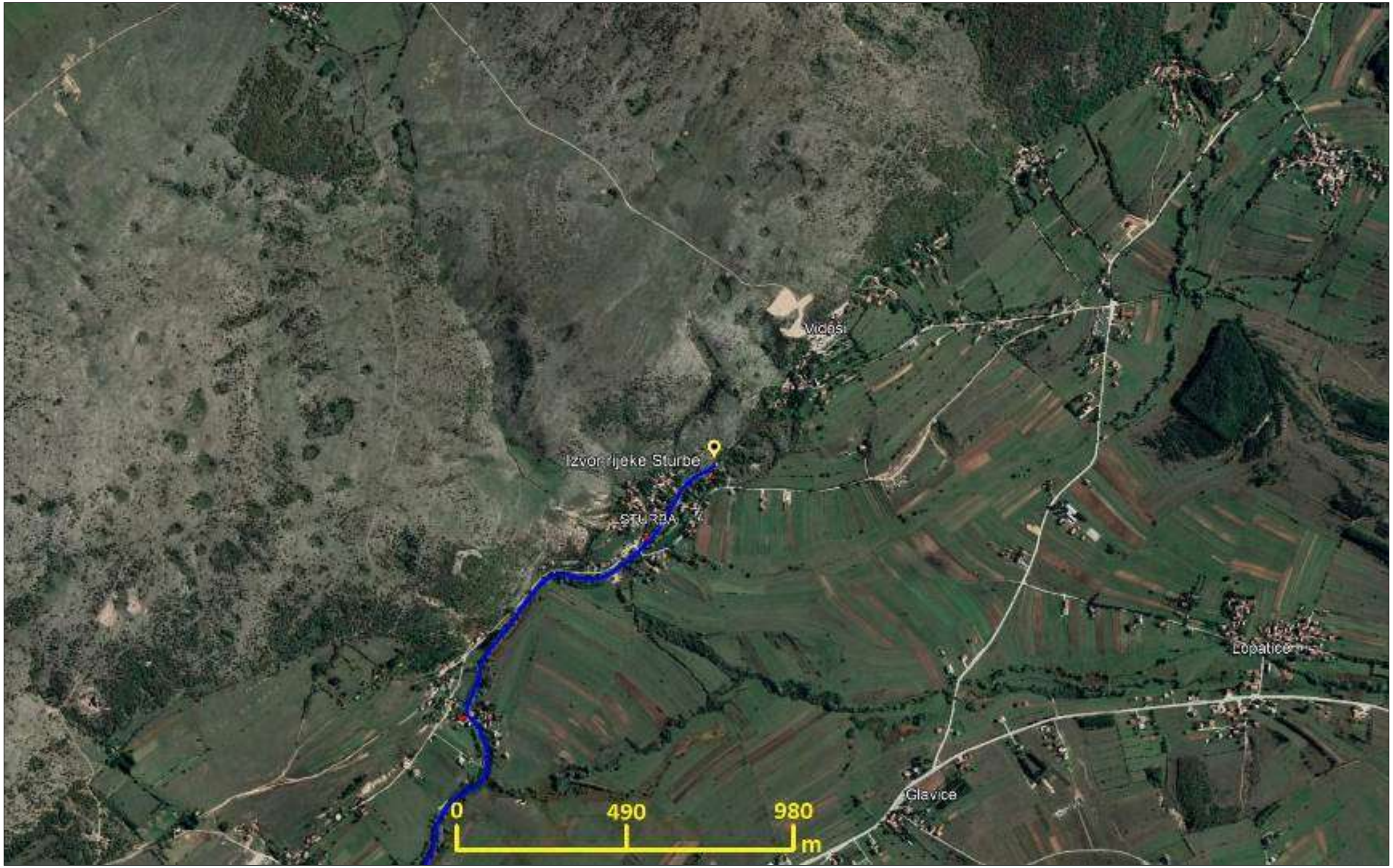
2.3. RIJEKA STURBA – Source:

The source of the Sturba River is a very powerful contact spring of the Vrelo-type, originating along a relatively shallow underground contact formed by the subsoil-layered limestones (hydrogeological collectors) of the Lower Cretaceous (K11) and the Miocene roof conglomerates, sandstones, and tuffs (hydrogeological insulators). The average water yield of the mentioned Vrelo-type spring of the Sturba River ranges from 8.0 to 9.5 m3/sec. Unfortunately, with the resources of the Federal Environmental Protection Fund, during the year 2018, the source and its immediate zone underwent construction, resulting in the permanent loss of one of the regional fundamental natural hydrogeological phenomena othe subtropical karst (see figure 11).


)

Picture 11. Izvor rijeke Sturbe: a) prije uređenja, i b) nakon uređenja

Barrier for removal is constructed in the left branch of the source stream, approximately 36 meters away from the concrete wall of the spring (see Figure 12.). The barrier consists of a concrete beam about 50 centimeters wide and approximately 1.5 meters high. The width of the stream and therefore the barrier is around 5 meters. The barrier remains underwater throughout the entire season of hydrological maximum (the entire colder period of the year, from November to May), while during the summer, when water levels are at a minimum, the upper part of it is above the water surface. In such situations, a small accumulation is formed, which, due to high water temperatures, becomes eutrophic, producing unpleasant odors emitted into the immediate surroundings. Additionally, the increased amount of accumulated heat from the reservoir affects the rise in water temperature both upstream and downstream, further contributing to the modification of the general ecological conditions in this part of the Sturba River."



Map 12. Geographical position of the Sturba - source barrier.

Karta 13. Geographical position of the Sturba - source barrier

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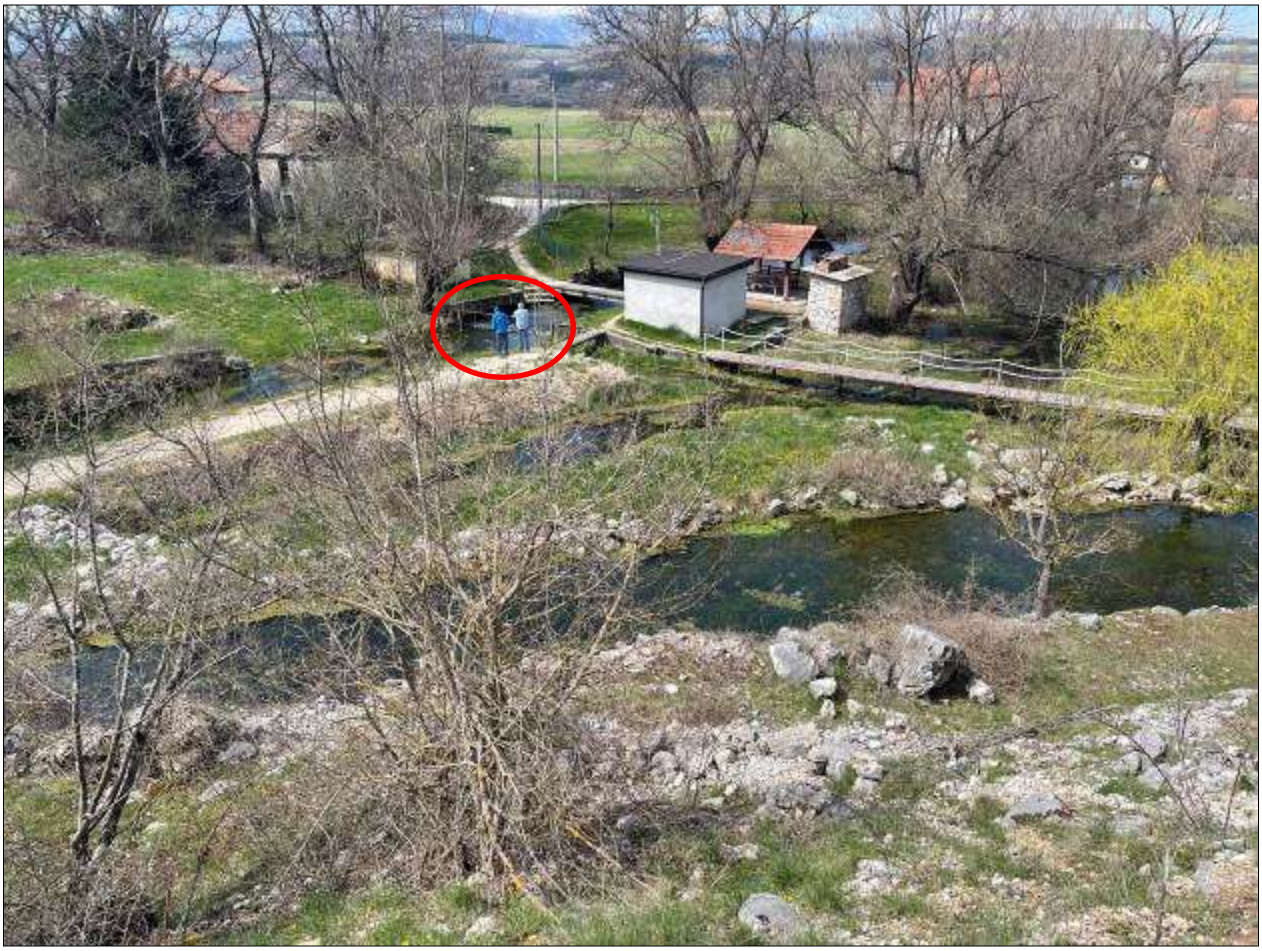


Picture 12. The position of the barrier at the source of the Sturba River (marked by a red circle)

The barrier is made of concrete with foundations buried about 1 meter deep into the riverbed, while the remaining part, around 0.5 meters, is above the streambed.
During field surveys conducted as part of the project research in April 2022, it was determined that the mentioned barrier does not serve any hydrological or other functional purpose. The immediate surroundings around the barrier consist of several individual residential structures along with several smaller auxiliary buildings. These structures are inhabited by the local population from the village of Sturba.
The vegetation in the riparian zone of all three branches of the Sturba stream consists of sub-Mediterranean species such as pedunculate oak, white hornbeam, black ash, and sporadically, white willow. The mentioned woody vegetation, in association with meadow communities, is widespread across the entire Livanjsko Polje (Livanjsko Field), and no endemic, rare, or endangered plant species have been recorded in this area. Continuous

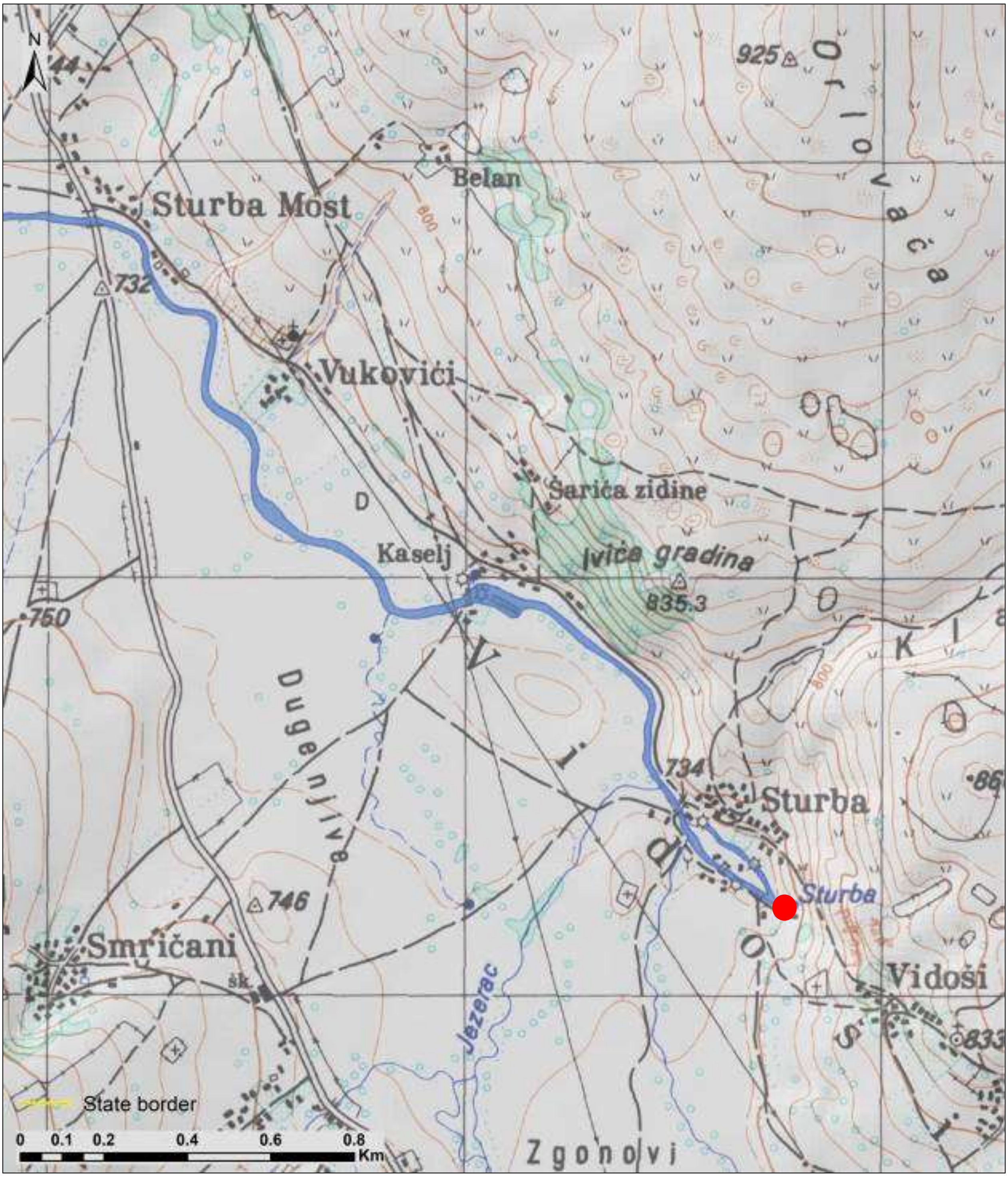
aquatic and semi-aquatic macrophyte and microphyte communities have not been registered in the riverbed, and there are no recorded valuable plant species or habitat types in this vegetation
segment

Picture 13. Location of the barrier in the left branch of the Sturba River

Considering the above, the expert research project team has proposed the necessity of removing the mentioned barrier. Its removal should be executed using construction machinery, specifically excavators. Construction work to remove it should be carried out during the summer months, during the hydrological minimum season.

Coordinates of the barrier centroid:

ϕ= 43°46'27.71"N; λ= 17° 01'22.09"E; H = 742 m above sea level

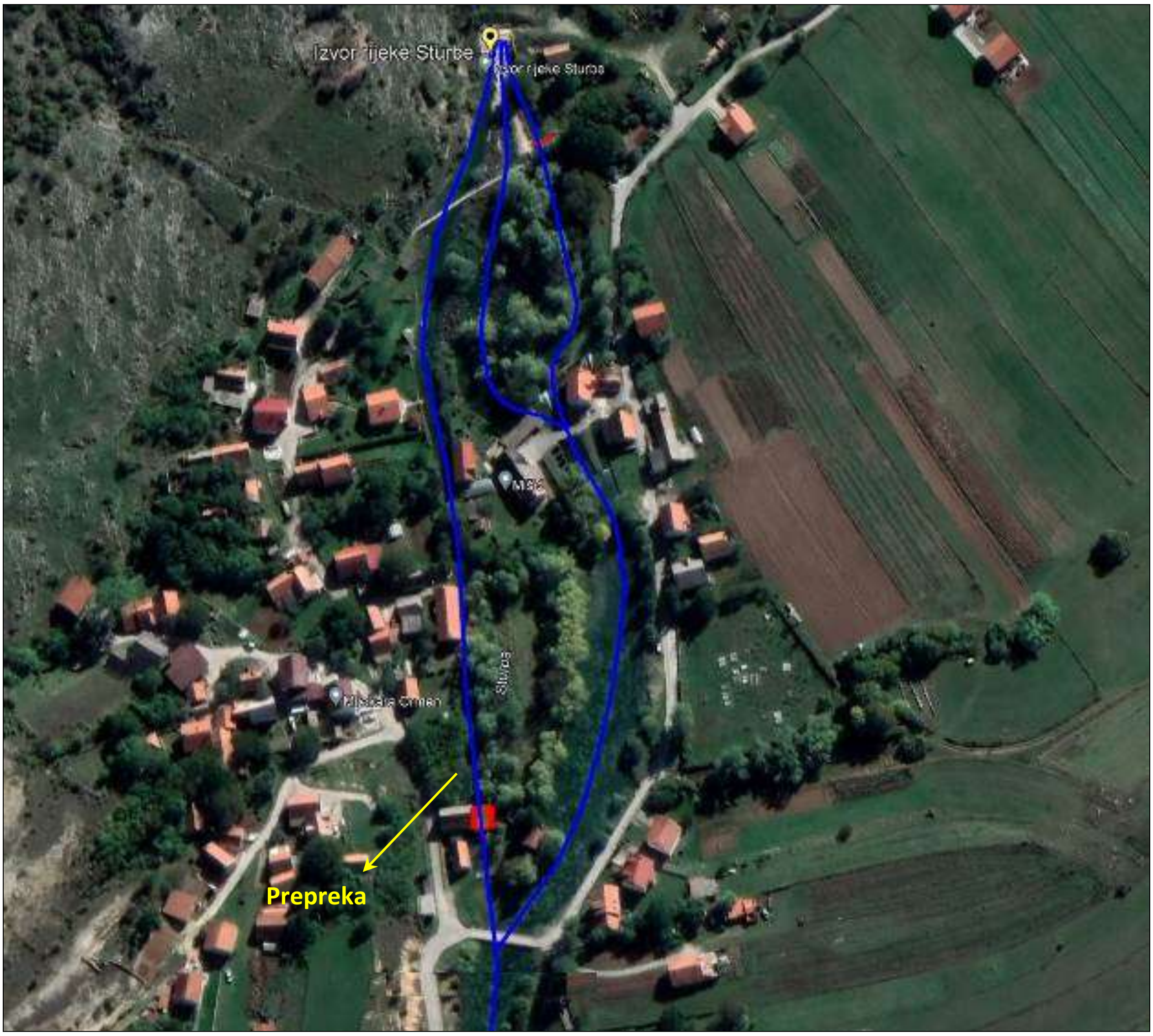


Map 14. opographic position of the Sturba-source site and the barriers for removal

2.4. Site 4. Sturba River - Near Mljekara Orman

The barrier near Mljekara Orman is located approximately 310 meters downstream from the source of the Sturba River (picture15.). The site is situated immediately upstream from the road bridge, on the aforementioned right branch of the source stream of the Sturba River,

which confluences with the left stream branch in the area of the concrete road bridge (see figure
14.)



Slika 14. The spatial position of the confluence of the three stream branches of the Sturba River in the immediate downstream area (in the Mljekara Orman zone)

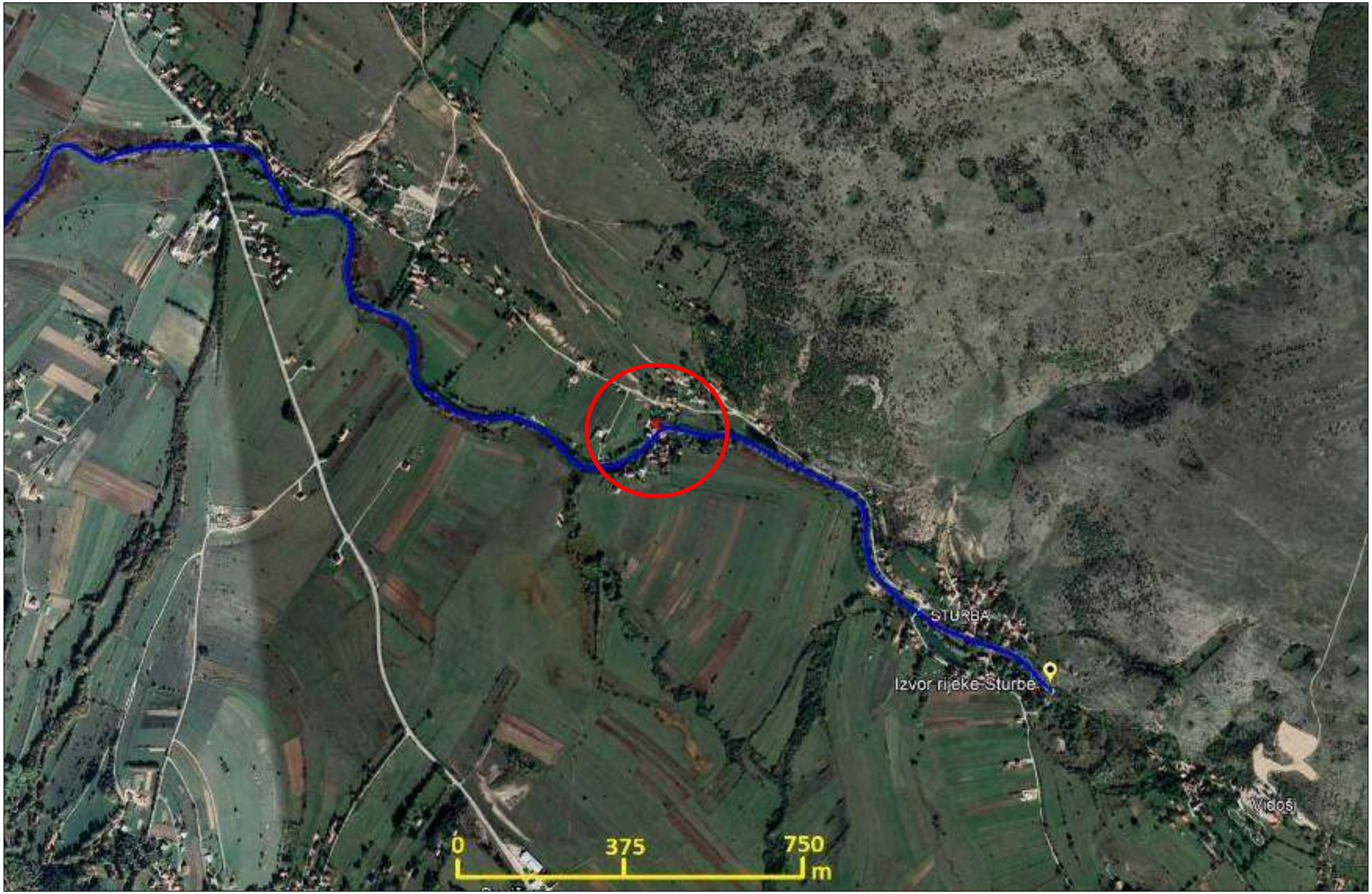
The wider area of the Sturba River around the Mljekara Orman barrier has a similar geological structure to the source zone. In this area, surface distribution is dominated by Miocene conglomerates, tuffs, and sandstones (4M), which function as hydrogeological insulators. This geological composition enables the formation of a surface river network within the surface area of the Livanjsko Polje. Subsoil contact sediments consist of layered limestones of the Lower Cretaceous (K11), which serve as hydrogeological collectors, allowing surface water to percolate into the limestone underground of the Cetina River basin

Picture 15. Spatial position of the group of objects obstructing the right branch of the Sturba River in the area of Mljekara Orman. The obstacle in the area of the right branch of the Sturba River belongs to a group of constructed objects with residential function (SO1, SO2). Essentially, these are two buildings that have been reconstructed and adapted for habitation. The first building is single-story, while the second one has two floors, with the ground floor adapted for milling operations and the first floor serving a residential purpose. Apart from residential structures, the group of constructed objects also includes two smaller ground-floor auxiliary buildings (PO1 and PO2), likely used previously as storage spaces for food products produced in conjunction with the milling operations (see figure

16.).

Picture 16. Spatial position of the unreconstructed objects that obstruct the right branch of the Sturba River in the area of Mljekara Orman

The auxiliary buildings, which are built and completely devastated. The walls are approximately 70 cm thick. The first auxiliary building (PO1) has dimensions of 8 m x 7 m x 6 m. On the front side of the first auxiliary building, two smaller window openings are constructed (dimensions: 0.8 m x 1.2 m), while entrance doors are installed on the side. The building is constructed over the left branch of the Sturba River, and obstructive barriers P3 and P4 are built on the supporting walls of the building (see figure 16.). Coordinates of the barrier centroid: ϕ= 43°46'33.93"N; λ= 17° 01'13.91"E; H = 737 m a.s.l.



Map 15. Geographical position of the barrier Sturba - Mljekara Orman

Map 16. Morphological position of the barrier Sturba - Mljekara Orman.

The second auxiliary facility (PO2) is built adjacent to the right side of the previous one and has dimensions of 8 m x 4.5 m x 6 m. On the front side of this structure, there are also two smaller windows measuring 0.7 m x 1 m, along with an entrance door. The building had a ground floor and an upper floor, but the interior is completely devastated, lacking a dividing plate. Both auxiliary structures lack a roofing structure and are entirely overgrown with tertiary woody vegetation, characterizing a ruderal habitat.

The barriers on this section of the Sturba stream are constructed on the foundations of residential building 2 and auxiliary building 1. The foundations of these buildings are concrete, buried in the ground at a depth of approximately 1 m. The constructed barrier does not form a single spatial unit; rather, it divides into four separate spatial compartments through the load-bearing walls of both structures (see figure
17)

Picture 17. The spatial position of the barriers built between the load-bearing walls in part of residential building 2 (the first two barriers) and the first auxiliary structure (the remaining two barriers).

The barriers are built in the rear part of the load-bearing walls of the residential and auxiliary buildings, while there are no concrete parts for removal in their front part (see Figure 18).

Picture 18. The front part of the space on the load-bearing walls of residential building 2 and auxiliary building 1 where the removal barriers are constructed.

The barriers 1 and 2 have installed metal grilles, likely intended to prevent access to the interior space, that is, the spaces between the load-bearing walls of the buildings. The other two openings do not have any additional built-in construction elements.

The removal barriers are constructed between the rear parts of the load-bearing walls of the buildings (see Figure 19). These barriers are made of concrete and completely seal off the entire opening between the load-bearing walls. Consequently, the right branch of the Sturba River is entirely blocked, preventing natural drainage. The barriers have the following dimensions: 4 m x 8 m x 1 m. The thickness of the load-bearing concrete walls is approximately 1 m, while the foundation depth of the load-bearing walls of the barriers is around 1

m

Slika 20. View of the rear part of the load-bearing wall in auxiliary building 1, where barrier no. 4 for removal is constructed.

The removal of the mentioned barriers involves mechanized construction work to demolish the rear sections of the load-bearing walls. Their removal would create space for unobstructed water flow in the right branch of the Sturba River. A specific aspect of the activities in removing the barriers includes assessing the structural integrity of residential building 2 and auxiliary building 1, necessary to evaluate the effects resulting from the removal of the above-ground and below-ground parts of the load-bearing walls between the first and fourth barriers. The significant contribution to ensuring unimpeded flow in the right branch of the Sturba River involves demolishing both devastated auxiliary buildings. This process would completely free the left section of the Sturba River for uninterrupted natural flow of both water masses and the migration of aquatic and semi-aquatic organisms

Map 17. The topographic position of the Sturba site – Mljekar Orman and the barriers for removal

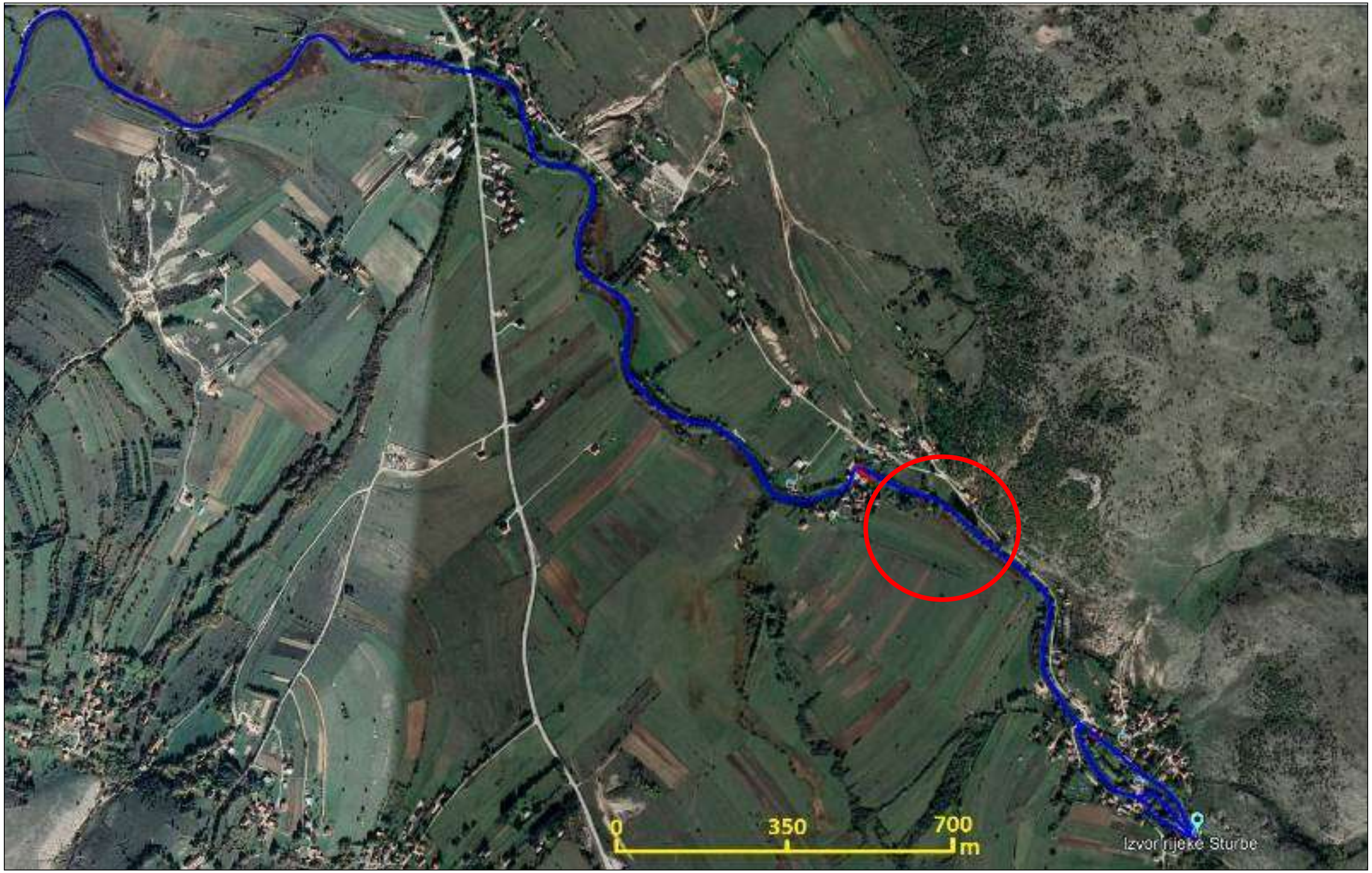
2.5. SITE 5. STURBA RIVER - KASELJ SETTLEMENT

The barrier on the Sturba River in the Kaselj settlement area is located approximately 1.3 km downstream from its source (parcel 18.). The barrier site is situated immediately upstream from the concrete road bridge, along which numerous residential buildings are constructed. Besides the residential structures in this zone, there are several auxiliary buildings – mills that utilize water energy for operation (see figure 21). The broader area of the barrier site lies within a wider contact zone, consisting of Miocene waterproof conglomerates (4M) made up of gravelly-sandy-clayey deposits. Subsoil sediments consist of waterproof Lower Cretaceous limestone layers (K11), characterized by a system of fissures, cracks, and underground channels through which percolated water from the surface flows into the limestone underground.

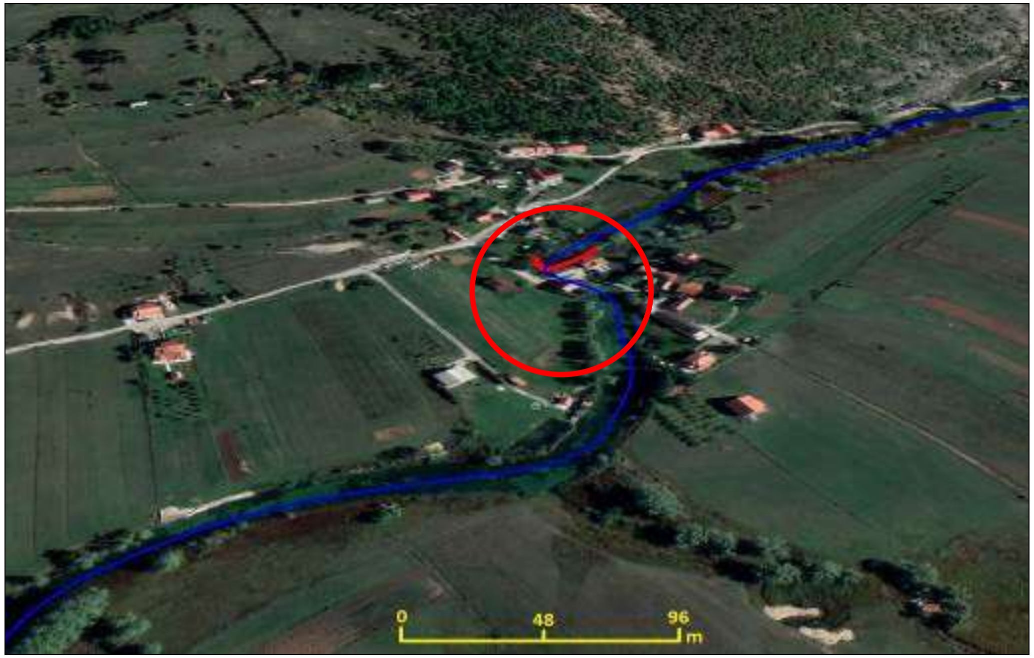
Picture 21. Spatial position and characteristics of the transverse and longitudinal barrier on the Sturba River in the Kaselj settlement area.

The barrier in this part of the Sturba River consists of two sections. The first section comprises a transverse barrier formed across the Sturba's course, while the second part is established along the left side of the riverbed. The transverse part of the barrier is, in fact, a smaller concrete-stone dam about 3 meters in height and approximately 15 meters in length. The base width of the barrier ranges from 2.0 to 2.5 meters, while its upper part is around 1 meter wide. At the central part of the transverse barrier, near its top, there is an opening that serves as an outlet for excess water accumulated during periods of high water levels in the dammed area (see figure 23). The longitudinal section of the barrier is formed along the left side of the riverbed and extends for approximately 42 meters. This part of the barrier is also constructed using concrete and masonry stones, with an average height between 1.5 to 2.0 meters (see figure 24).

Picture 22. Spatial position of the transverse barrier with the position of the overflow opening for the discharge of excess water accumulated in the dammed area.



Map 18. Geographical location of the barrier on the Sturba River in the Keselj settlement area



Map 19. The morphological position of the barrier on the Sturba River in the Keselj settlement area.

The total surface area of both barriers in the upper part is around 120 m2, with a minimum volume of the above-water part of the barrier measuring approximately 250 m3. The total amount of material used in constructing the barrier includes the material incorporated into its foundations, thereby increasing the mentioned volume of embedded material by about 1/3.

Coordinates of the barrier centroid: ϕ = 43°46'52.10"N; λ = 17° 00'49.24"E; H = 733 m above sea
level.

Figure 23. The water surface of the artificial reservoir formed by damming the flow of the Sturba River in the area of Keselj village.

The length of the artificial reservoir formed up to the spillway level is about 120 meters, covering an approximate water surface area of 0.35 hectares. The average volume of accumulated water at average water levels is around 6,000 cubic meters. The overflow of the reservoir occurs towards the lowered part of the dam, specifically along its longitudinally positioned section, directing water towards a channel formed alongside the walls of the adjacent structures. Utilizing the increased energy from a drop of about 1.5 meters, the water is used to power the mill blades installed in the structures along the channel.

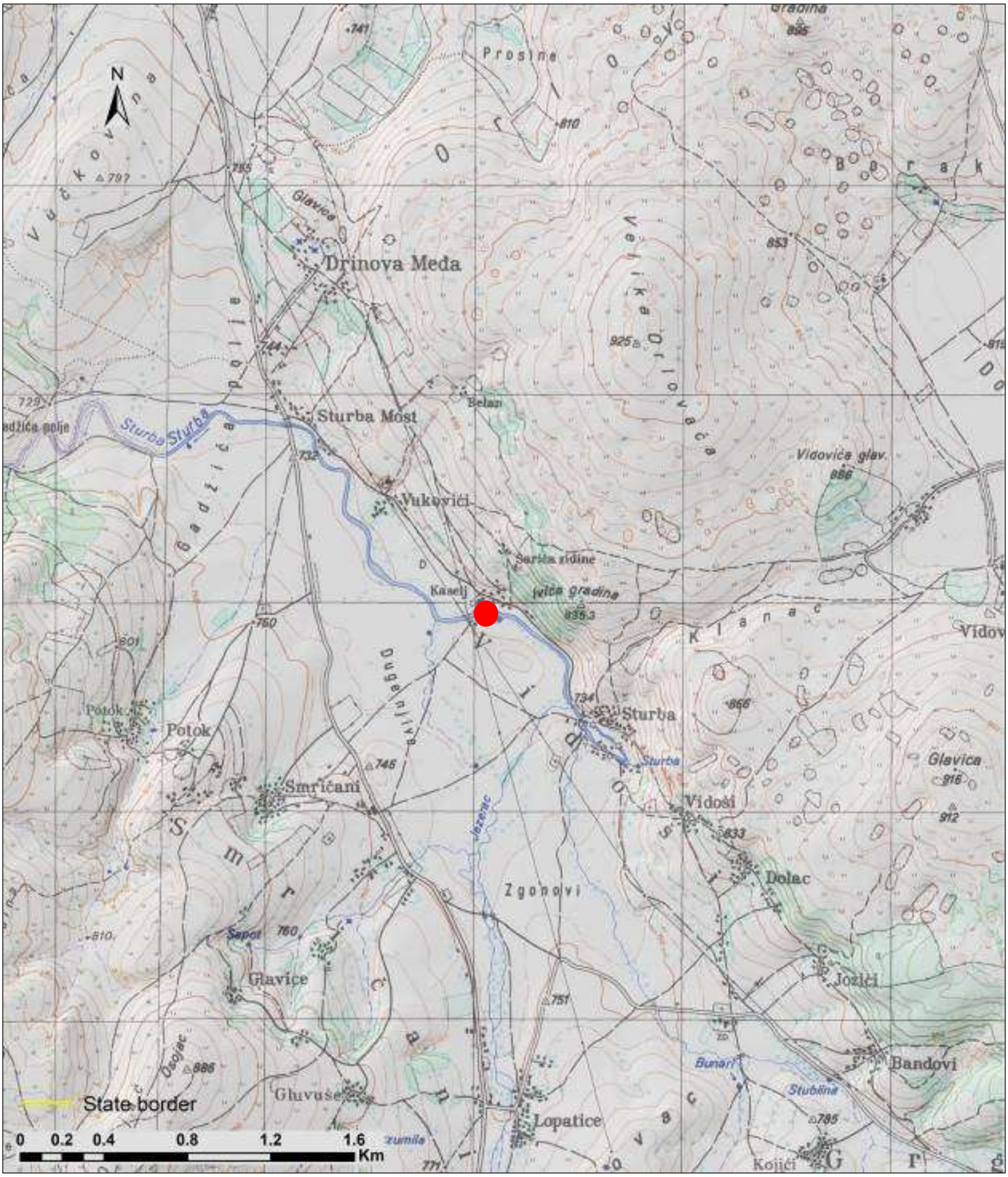
Coordinates of the dam centroid: ϕ = 43°46'52.10"N ; λ = 17° 0'49.24"E; H = 733 m above sea level Koordinate centroida dam: ϕ = 43°46'52.10"N ; λ = 17° 0'49.24"E; H = 733 m n.v.

Figure 24. The spatial position of the channel used to direct water onto the mill blades..

Field inspections have confirmed that several mills are still active, processing grains (see figure 25.). All these structures are built directly adjacent to the riverbed of the Sturba River, making this segment almost entirely human-altered. Including the constructed concrete vehicular bridge, the riverbed of the Sturba River has been developed and covered over a length of approximately 28 meters. It is important to note that these active mills are often promoted as part of the cultural and historical heritage of the Livanjsko Polje and are frequently visited by tourists. Most of these structures are privately owned, which further complicates the proposal for the removal of the mentioned barrier.

Figure 25. The grain mills used for processing are still active today, powered by the channeled water energy.

By removing the mentioned barrier, the Sturba River would be restored to its natural state, reinstating the hydrological regime of the river. Additionally, the removal of the barrier would enable unobstructed migration for ichthyofauna and other native species inhabiting the Sturba River. The restoration to its natural state would also revive its significant role as a habitat for migratory bird species during the spring and autumn migration seasons from Northern and Central Europe to North Africa and vice versa.



Map 20. The topographical position of the barrier site on the Sturba River in the Keselj settlement area

2.6. LOCATION 6. RIVER STURBA – KELAVA MILL

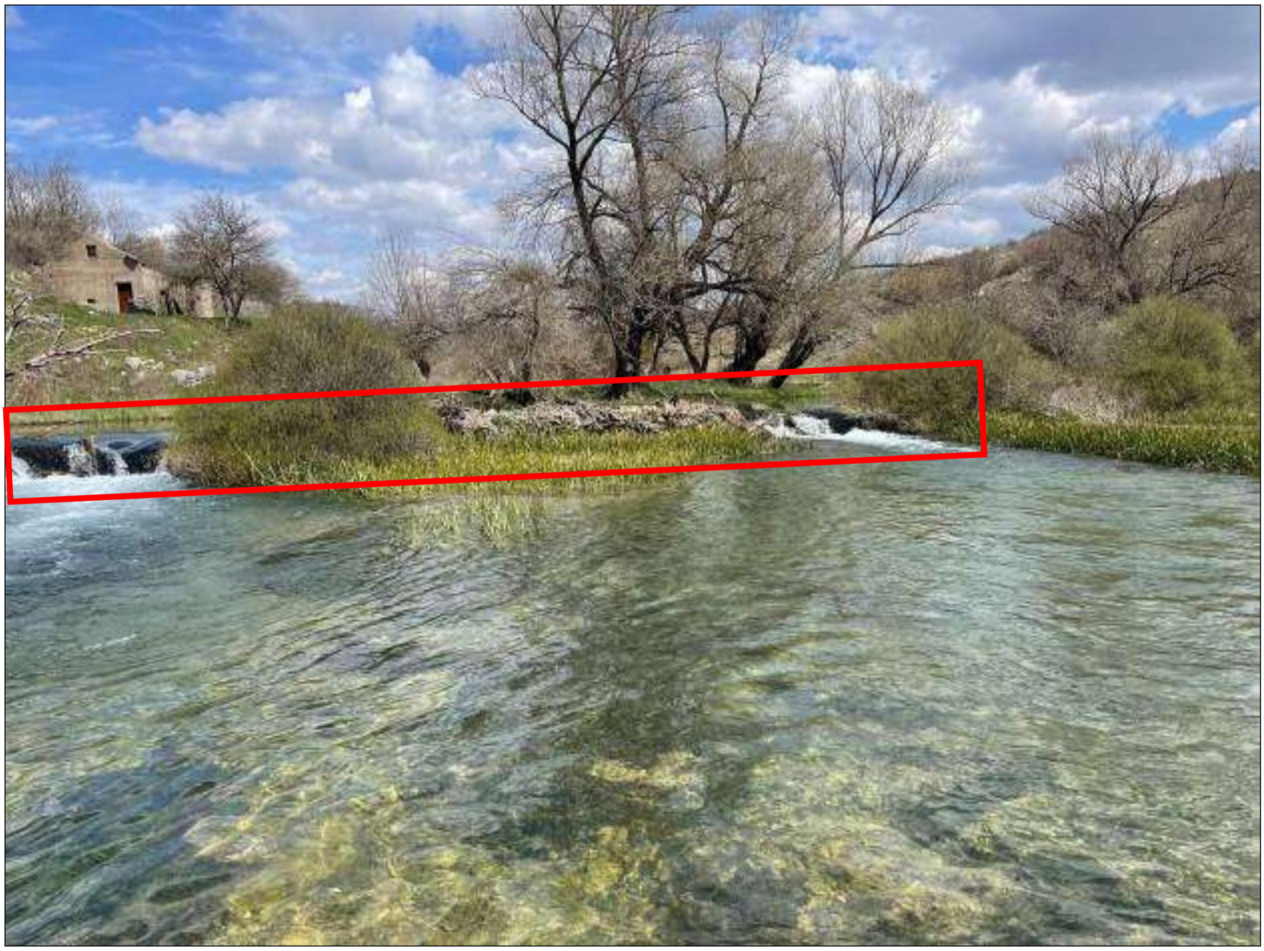
The barrier on the Sturba River at the Kelavin Mlin site is formed along the entire transverse profile of the riverbed, diagonally in relation to the river's main flow. The barrier consists of several segments covering a very long strip, starting from the pedestrian bridge along the right bank of the stream to the left bank (see Figure 26). Most of the barrier is constructed by cementing pebbles and larger stone blocks. Vegetation communities of black willow and black ash have subsequently populated the barrier, forming an additional natural obstacle. The total length of the barrier is over 91 meters. Coordinates of the barrier centroid: ϕ = 43°46'52.60"N; λ = 16°58'36.89"E; H = 732 m above sea level. Dimensions of the dam: Length 50 meters, height 2 meters (including the dam's foundations), with an average width of about 1.0 meter (approximately 1.5 meters at the dam's base). The barrier is divided into two separate structures (see Figure 27).The first barrier predominantly diagonally intersects the Sturba's course from the left bank to the mill structure (see Figure 28). The total length of the first barrier is approximately 50 meters.

Slika 26. Spatial position of the barrier on the Sturba River at the Kelavin Mlin site

Figure 27. Spatial position of barriers for removal on the Sturba River in the Kelavin Mlin area

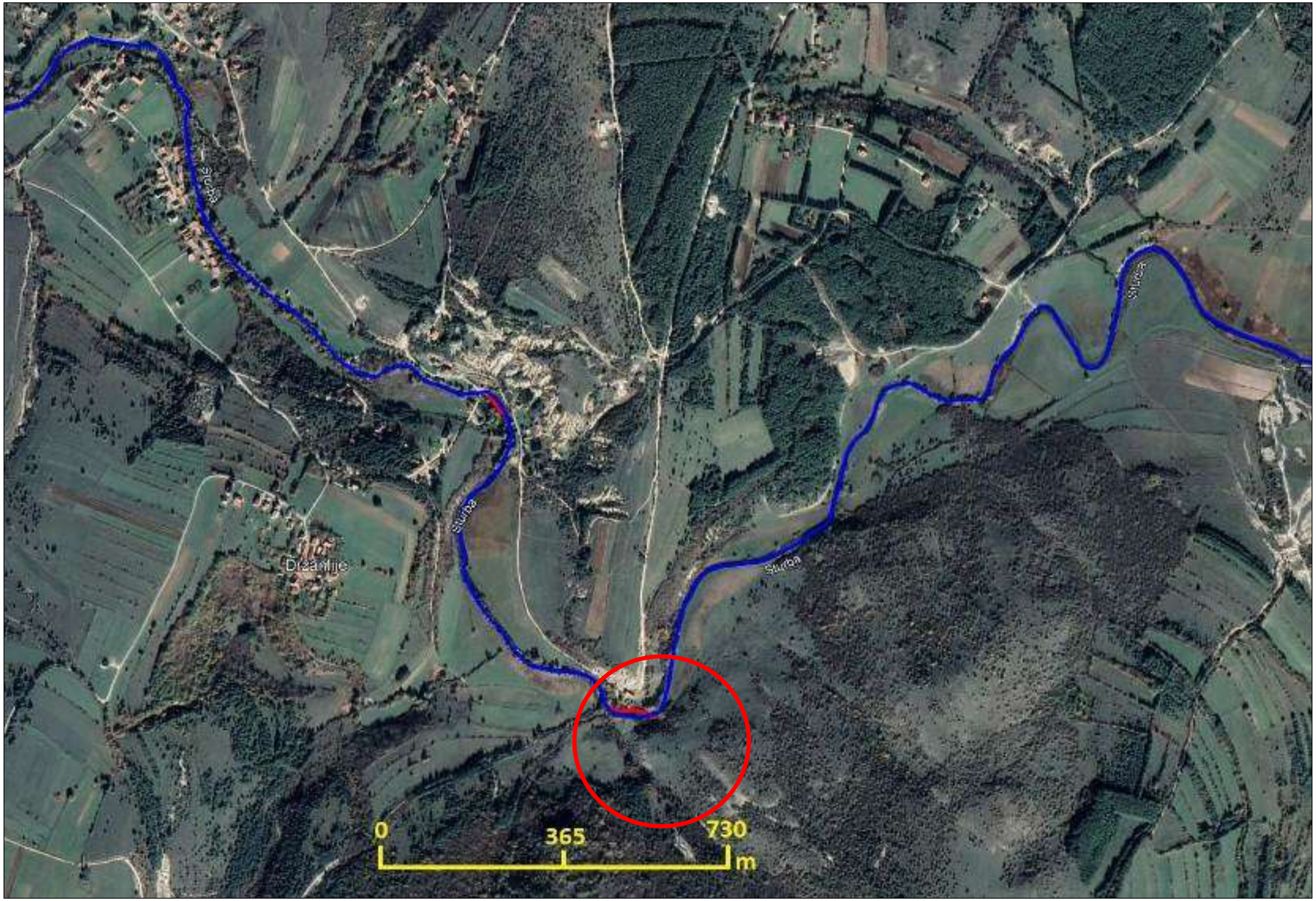
Figure 28. Spatial position of the first part of the barrier on the Sturba River (next to Kelavin Mill)

The first barrier diverts part of the Sturba River's water towards a smaller constructed channel where the mill building is located. The channel is approximately 5 meters wide, increasing the speed of the water mass and its kinetic energy, which propels the mill wheel blades. With the first barrier, a small accumulation is formed, allowing excess water (during periods of maximum rainfall) to overflow into the natural riverbed. During periods of minimal rainfall (July - September), much of the natural flow is redirected by the barrier into the channel for the mills. During this period, the Sturba River in the accumulation area flows very slowly, creating necessary conditions for eutrophication and the development of semi-aquatic vegetation. This is one of the main reasons why woody vegetation such as black willow and black alder subsequently grew around the barrier. Among the woody vegetation, tertiary vegetation comprising shrubs (in their early developmental stages) and tall grasses from the mesophilic meadow communities of the Livanjsko Polje have developed..



Slika 29. Spatial position of the right part of the first barrier overgrown by successions of black willow and black alder communities and their early developmental stages of shrubs.

In the central and left part of the first barrier, outlets have been built through which the excess water from the accumulation spills into the downstream section of the Sturba streambed. The second barrier is constructed in the right section of the riverbed, encompassing the stretch from Kelavin's mill to the pedestrian bridge. With this barrier, the inflow channel is separated from the Sturba stream, from Kelavin's mill to the bridge (where the channel reconnects to the river - see Figure 30). The length of the second barrier exceeds 40 meters. It is also constructed from larger stones with cement binding, with an above-water part height of about 1.0 meter. The foundation depth of the second barrier reaches up to 1.0 meter while its width extends up to 1.5 meters.



Map 21. Geographical position of the barrier on the Sturba River in the area of Kelavin's Mill.

Karta 22. The morphological position of the barrier on the Sturba River in the area of Kelavin's Mill.

Figure 30. The part of the canal downstream from Kelavin's Mill with the initial section of the second barrier planned for removal

The part of this barrier has also been overgrown by the vegetation succession of black willow and black alder communities along with their early developmental stages of shrubs (see Figure 31). Herbaceous vegetation of tall grasses also inhabits the area along the entire barrier, halting the natural filtration process of water from the canal almost entirely.

During an external inspection of the mill, four barriers or mini-turbines that power the millstones within the mill building were identified. These concrete barriers also slow down the water flow, contributing to changes in its fundamental physical and chemical characteristics, significantly reducing the ecological status and ecological category of the Sturba river in this section. Specifically, the formed mini-accumulation and ponding of water during the summer months induce the development of eutrophication conditions, altering the qualitative and quantitative composition of natural aquatic and semi-aquatic ecosystems that exist under unchanged hydrological regimes. Additionally, eutrophication conditions spread both upstream and downstream during the summer months, negatively impacting the state of the natural biodiversity of highly sensitive karst water ecosystems of the Sturba river

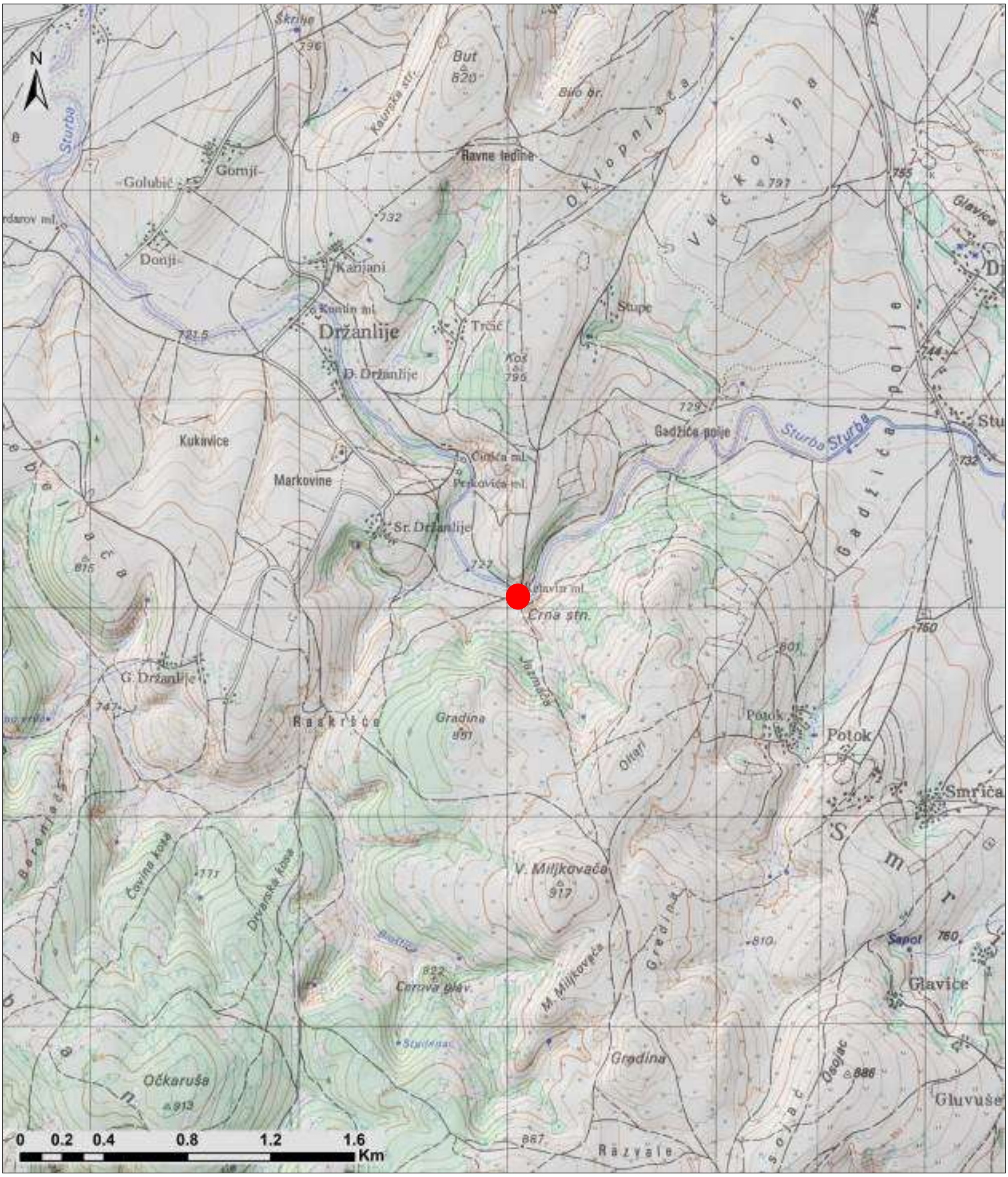
Figure 31. The spatial position of the second barrier, also overgrown by the successions of communities of black willow and black alder in their early developmental stages as shrubs..

Removing obstacles would also mitigate the negative impact of residential and economic facilities directing most of their wastewater into the Sturba River. The structure of wastewater mainly comprises organic waste, significantly increasing the share of phosphorus, ammonia, and nitrogen, as well as chemical elements and compounds that significantly contribute to increased water eutrophication in conditions of elevated temperatures in slow-flowing water

Figure 32. The natural part of the Sturba River exhibits reduced water levels due to diverting a significant portion of the water into the channel towards the Kelavin mill. This situation creates favorable conditions for the development of eutrophication and associated types of herbaceous semi-bog vegetation..

During field research, it was noted that the mills do not have a consistent economic function, providing the necessary conditions for the comprehensive removal of the built obstruction, which has dammed the Sturba River bed and significantly altered the natural hydrological regime in this section of the watercourse. This area is managed by a fishing association that uses this part of the river as a fishing ground.

Moreover, the mill is a concrete structure whose architecture and appearance significantly contrast with the original natural ambiance of the Sturba valley in this part of the stream. As such, it lacks specific tourist appeal, and the entire Kelavin mill site is not suitable for incorporation into the ecotourism offerings of the Livanjsko Polje region



Map 23. Topographic position of the dam site on the Sturba River in the area of Kelavin's Mill.

2.7. LOCATION 7. RIVER STURBA – ĆURIĆA MLIN (Mill)

Pregrada u zoni Ćurića mlina je locirana na rijeci Sturbi, na oko 870 m nizvodno od pregrade uz Kelavin mlin. Pregrada je locirana neposredno uz objekat Ćurića mlina, u proširenom dijelu riječnog korita, formiranog duž laktastog skretanja rijeke Sturbe. Prosječna širina riječnog korita u ovom dijelu toka Sturbe iznosi oko 30 m.

Slika 33. Dio pregrade na toku rijeke Sturbe u zoni Ćurića mlina.

The length of the dam is about 53 meters, its width approximately 2 meters, covering a total area of around 150 square meters of the riverbed. The height of the dam, including its foundation, is about 3 meters, with a base height of around 1.5 meters. The dam is constructed from concrete in combination with stone (see images 34 and 35).

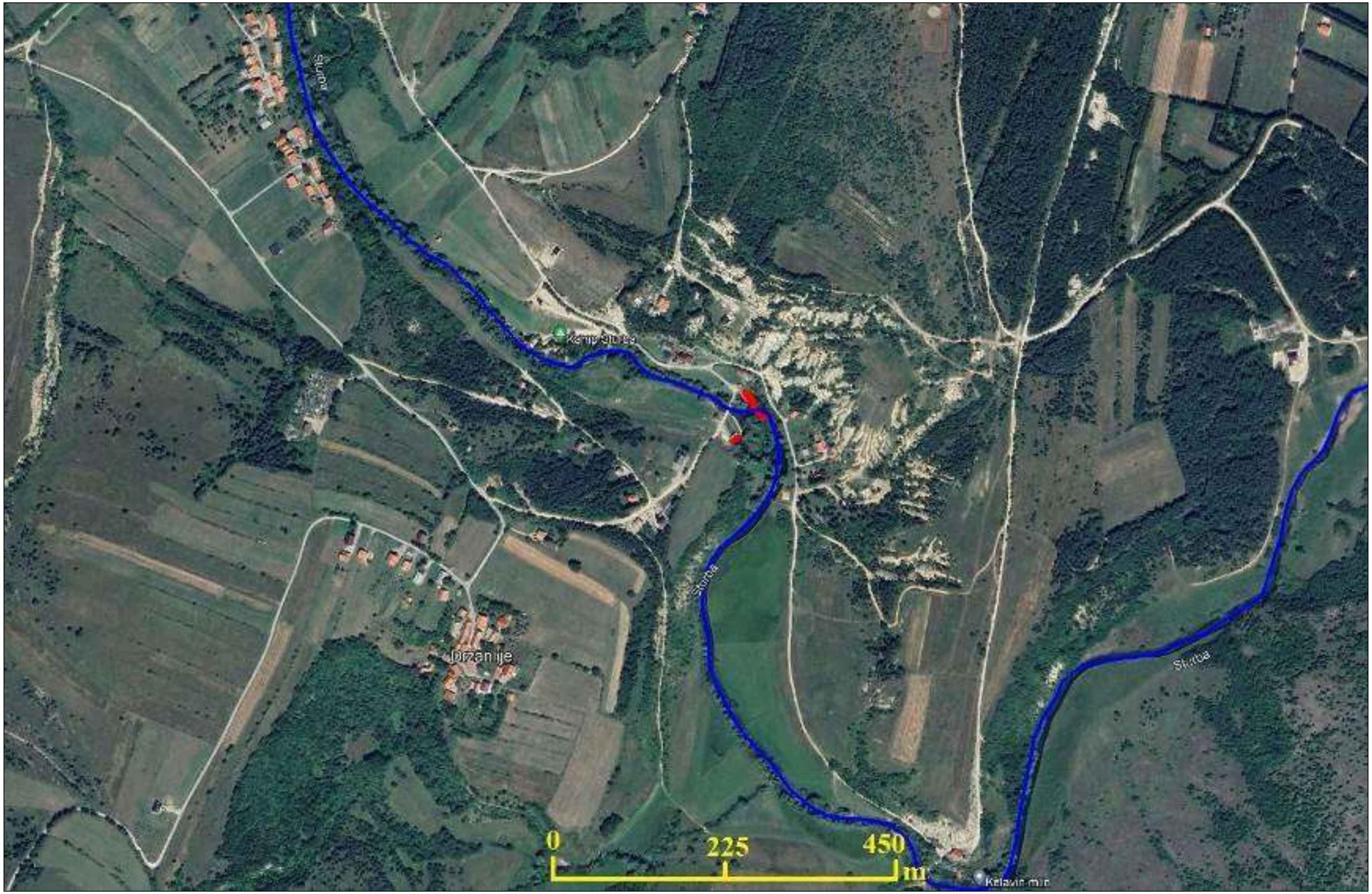
Coordinates for the centroid of the first dam: ϕ = 43°47'13.64"N; λ = 16°58'24.83"E; H = 730 m above sea level. The dam obstructs the flow of the Sturba River perpendicular to its main course. The nearby mills, one on the left side and the other on the right, are operational, which likely renders the dam site unsuitable for demolition.

Map 34. The spatial position of the barriers on the River Sturba in the Ćurića mill area.

The first barrier obstructs the flow of the Sturba River in the widest part of the channel, directing a portion of the water towards the mills constructed at the Ćurića mill. The average width of the initial obstructed section of the Sturba River measures over 7 meters and is directed towards three separate openings built at the ground level of the facility. Behind these mill openings, there is a pond specifically designated for the cultivation of consumable fish. To be more precise, the water that passes through the mill openings accumulates in three distinct basins used for the breeding of consumable fish. Based on these highlighted facts, it can be noted that the first barrier provides water for two active commercial functions of this facility.

Figure 34. Panoramski view on the barriers.

Figure 35.



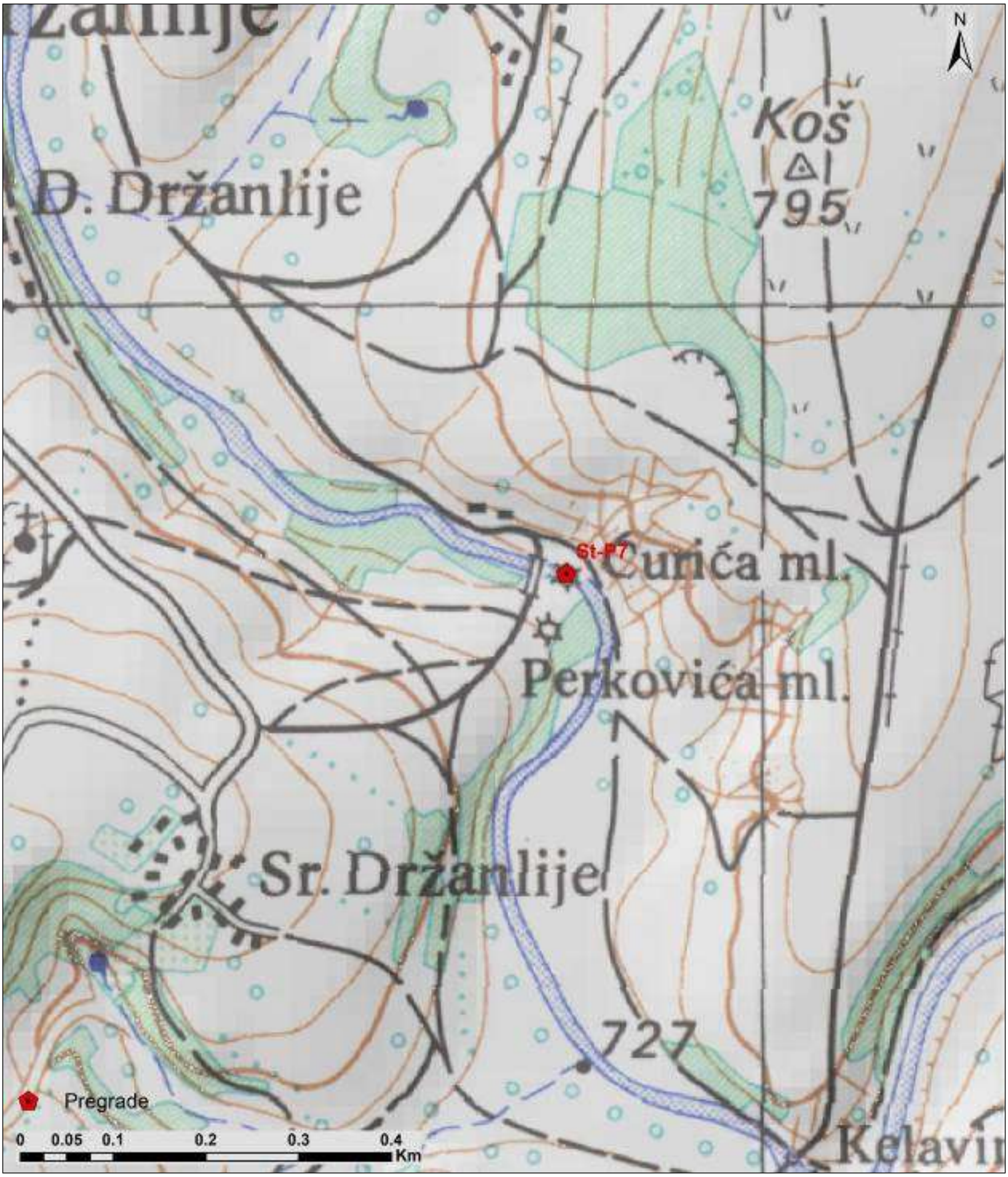
Map 23. The geographic location of the barrier on the Sturba River in the area of the Ćurića mill.

Map 24. Morphological location of the barrier on the Sturba River in the area of the Ćurića mill.

The second barrier is smaller in size and is situated on the left, secondary branch of the Sturba River. This particular branch has naturally formed along the left side of the river's meandering section. The island's surface measures approximately 1,750 square meters and is covered with hydrophilic vegetation consisting of willows and green alder. The average width of this branch of the Sturba River is around 15 meters, and the water flow is directed towards two separate openings, where two shafts with blades for operating the mills are installed on the ground floor of the structure. The obstructed part of the structure consists of a concrete barrier measuring 13.5 meters x 2.5 meters x 0.8 meters (see figure 36)

Figure 36.

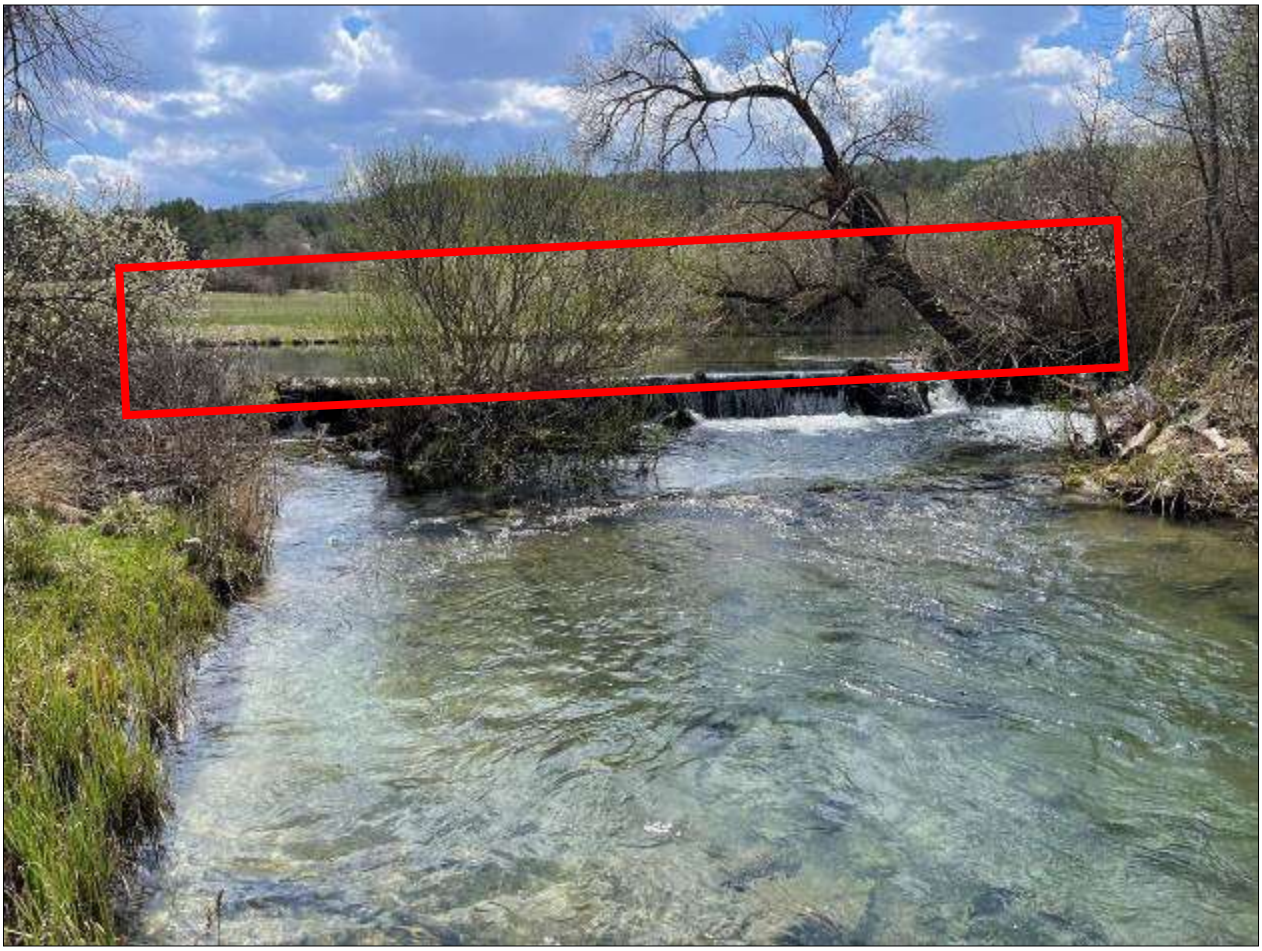
Voda se nakon prolaska kroz otvore za mlinice akumulira u betonirani rezervoar u kojem se također nalazi ribogojilište. S obzirom da su objekat mlinice te glavni objekat renovirani može se zaključiti da se radi o objektu koji ima aktivnu ugostiteljsko-turističku funkciju, te se može zaključiti da uklanjanje ove barijere nije prihvatljivo.



Map 25. Topographic position of the barrier site on the Sturba River in the area of Ćurić's Mill.

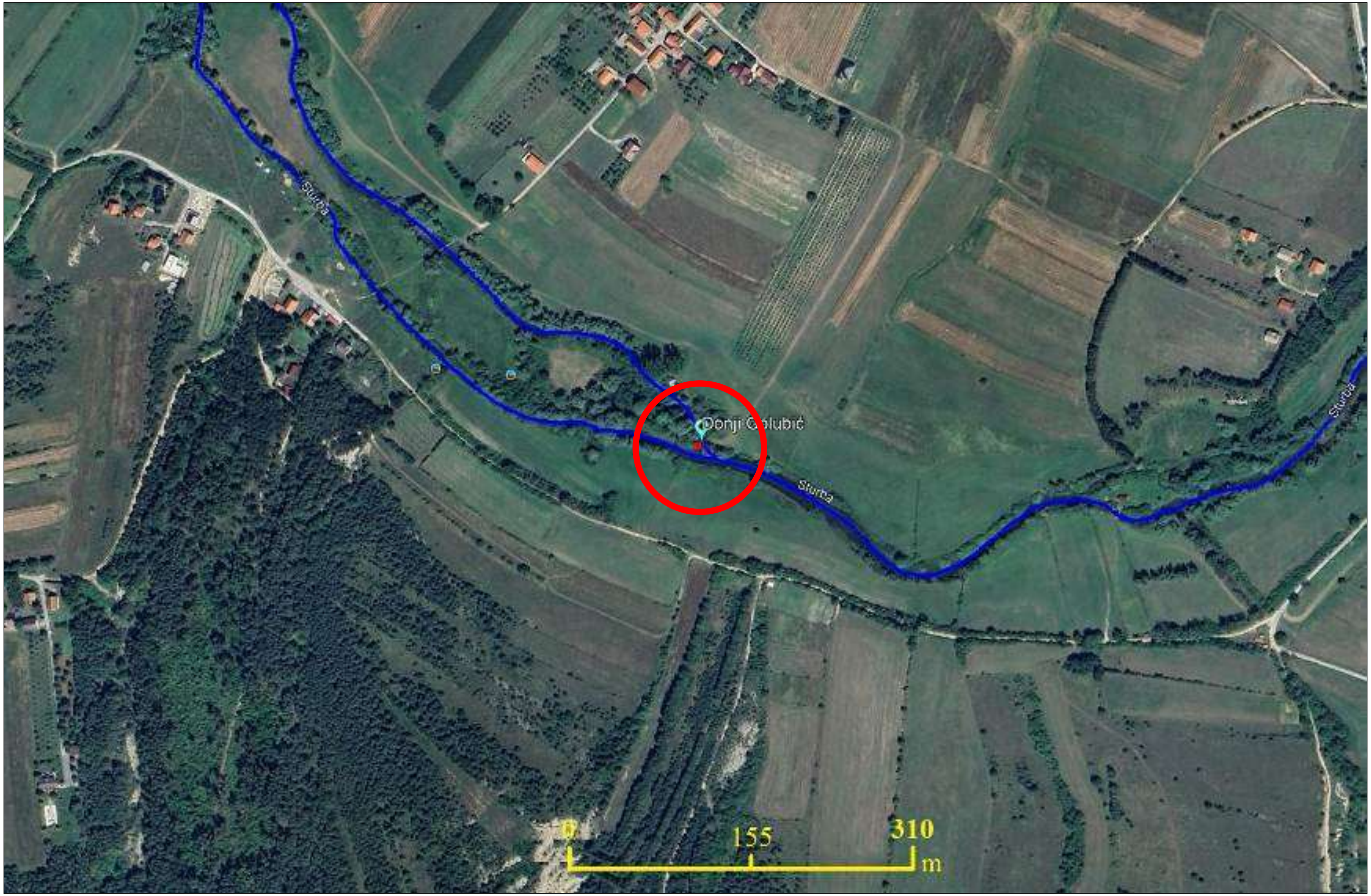
2.8. Location 8. RIVER STURBA – DONJI GOLUBIĆ 1.

The barrier at site number 8 on the Sturba River is located in the broader area of the populated place of Donji Golubić. The barrier is situated on the right branch of the Sturba River, which is formed immediately upstream of its location. Specifically, a natural right branch has been formed on the main course of the Sturba River, which extends for about 0.7 km before rejoining the Sturba River. The barrier is positioned at the site where a portion of the water from the Sturba River is redirected into the right branch (see image 37).

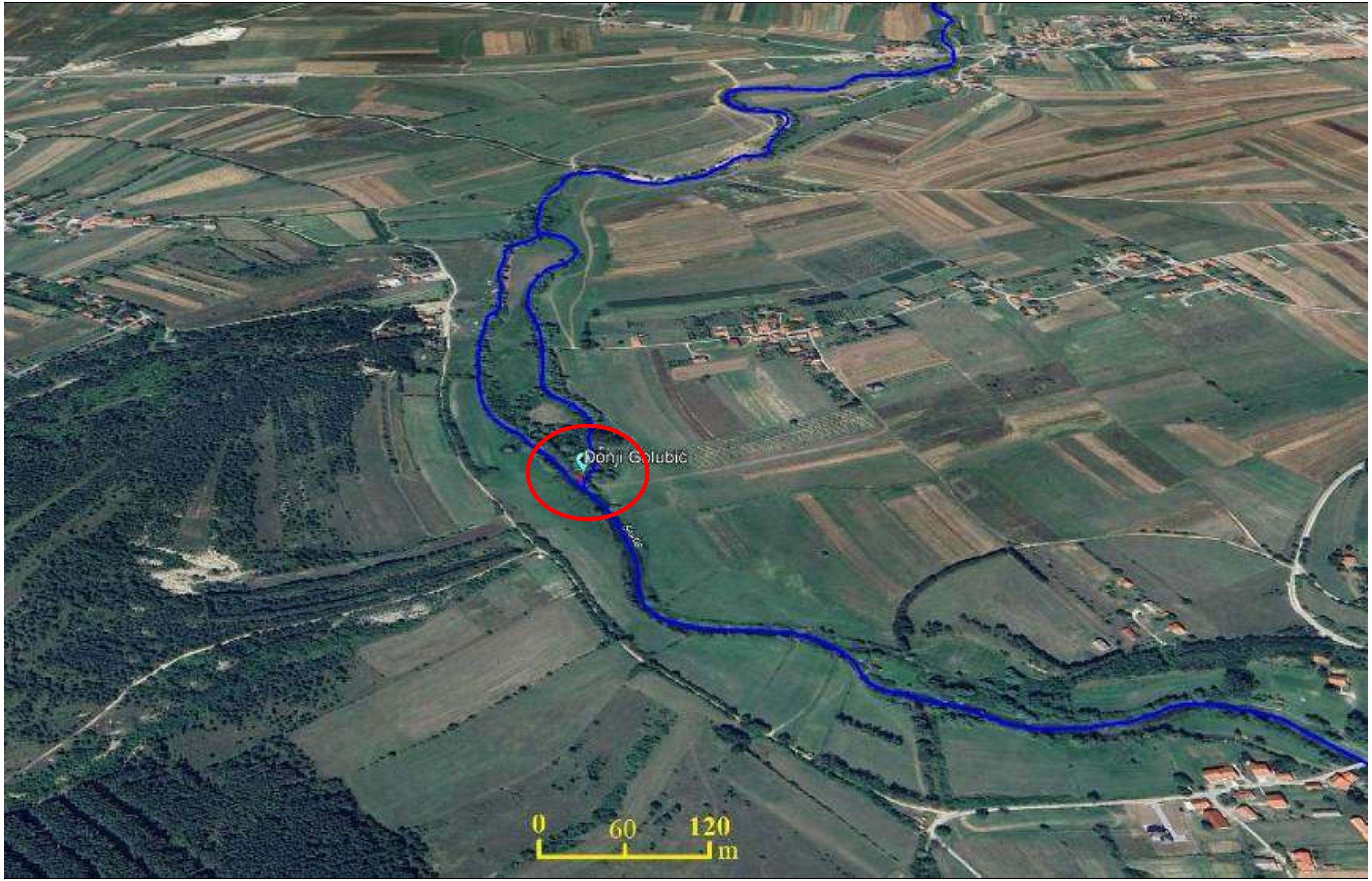


Figur 37..

The barrier is formed within the wider area of Miocene-Pliocene (M, Pl) white, porous sedimentary rocks that have filled the Neogene basin in this part of the Livanjsko Polje. Consequently, various phenomena of underground hydrography dominate the broader area of this segment of the Sturba River, such as percolating types of springs formed in the mentioned loose series of porous sedimentary rocks.



Map 26. The geographical location of the barrier on the Sturba River in the area of Donji Golubić 1.

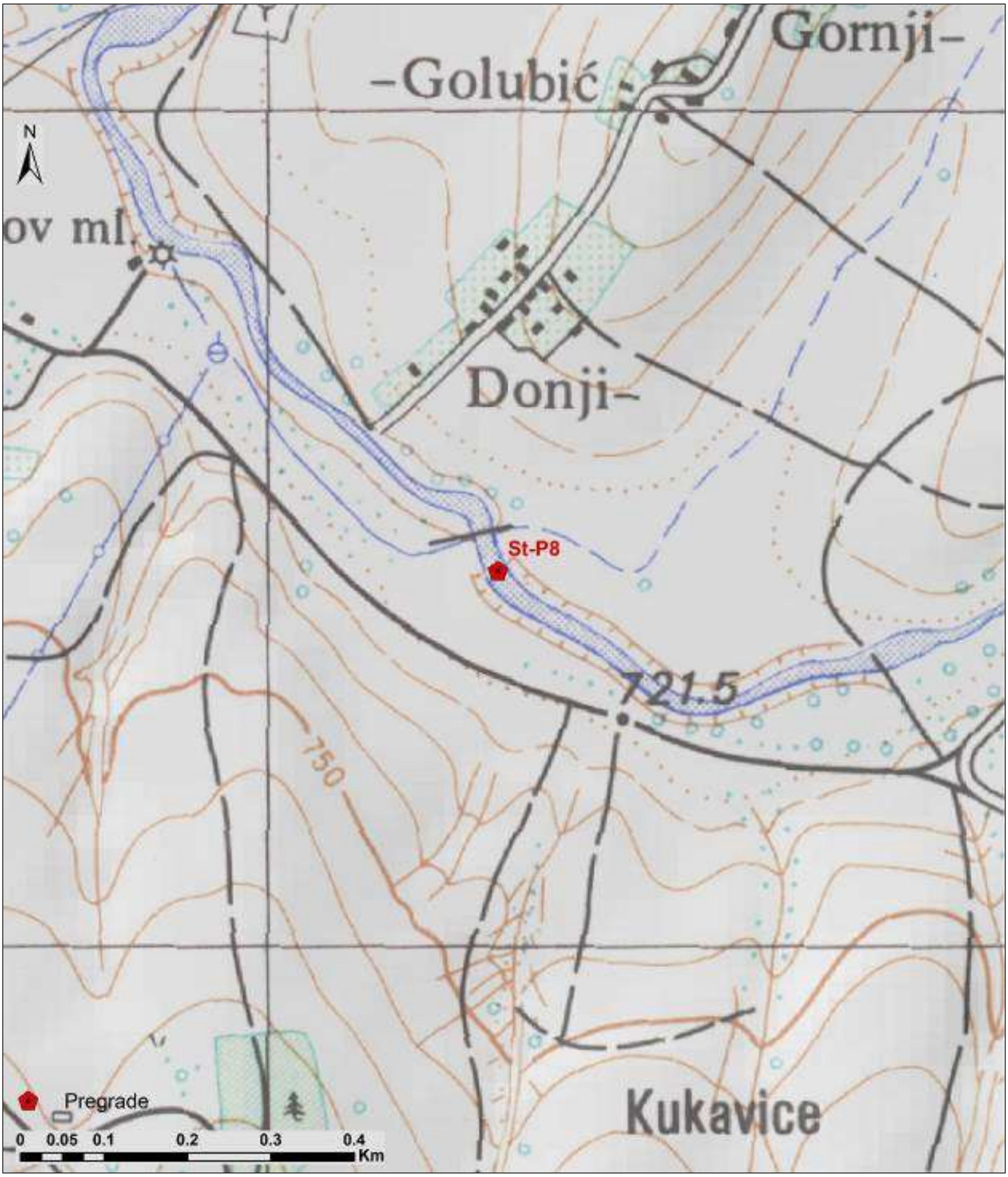


Map 27. Morphological position of the barrier on the Sturba River in the area of Donji Golubić 1..

The mentioned occurrences further enrich the natural values of this area, making it more attractive in terms of the natural diversity of the entire field. The barrier is constructed using a combination of reinforced concrete and stones of varying sizes. The dimensions of the barrier are 13 m x 3 m x 0.8 m. The thickness of the barrier at the base is approximately 1.5 m, while the above-water part ranges from 1.2 m to 0.8 m. Under the influence of microseismic tremors and lateral pressure from the water mass, the barrier is inclined by about 5 degrees in the direction of the water overflow.

Figure 38.

The coordinates of the barrier's centroid are: ϕ = 43°47'36.21"N; λ = 16°57'18.38"E; H = 720 m above sea level. Taking into account that the analyzed barrier does not support specific active commercial functions of downstream objects, its demolition and removal would significantly contribute to the restoration of the primary natural values of this part of the Sturba River valley



Map 28. Topographic position Donji Golubić 1.

2.9. LOCATION 9. RIVER STURBA – DONJI GOLUBIĆ 2.

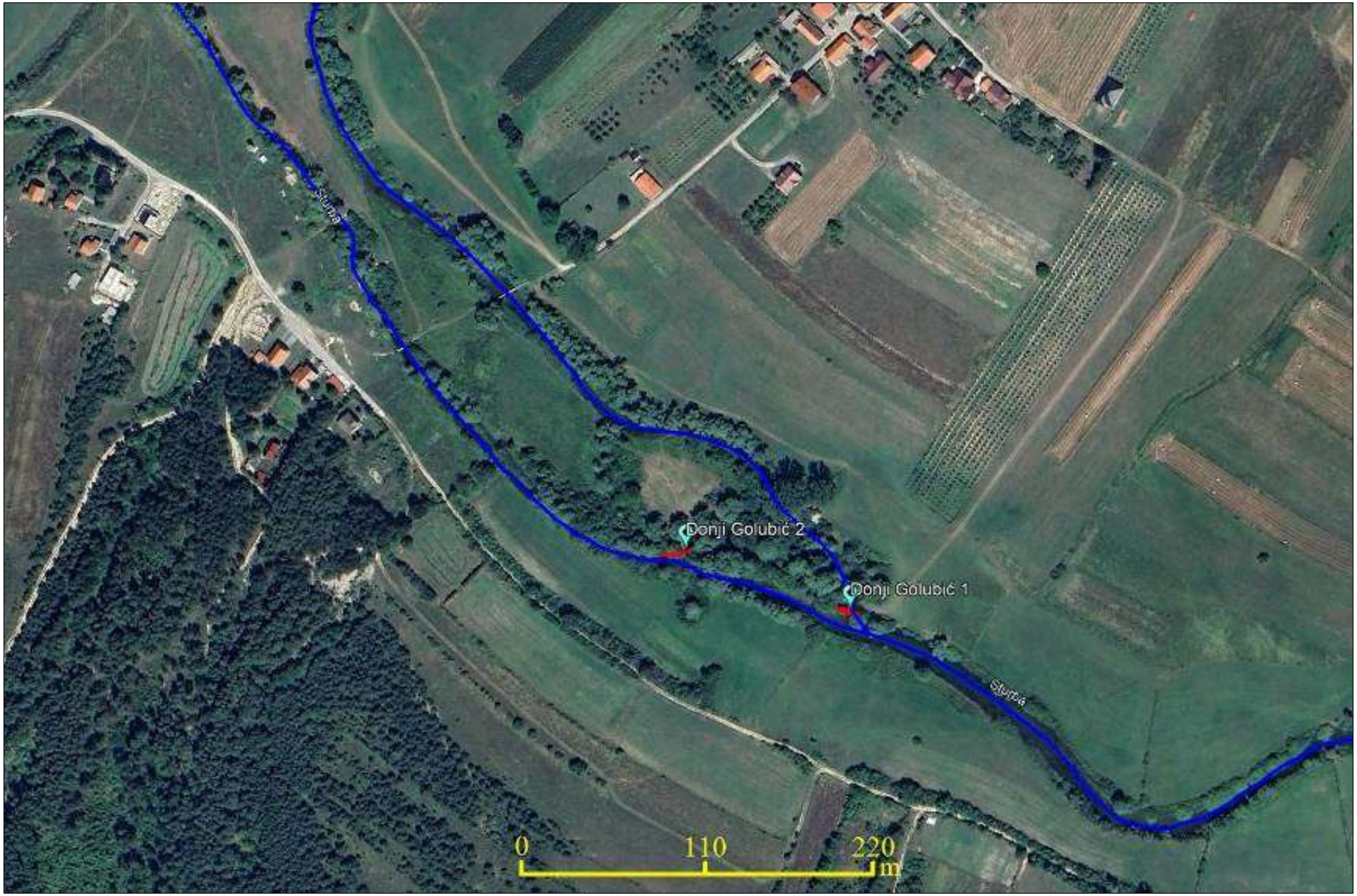
The barrier at the Donji Golubić 2 site is located immediately downstream from the previously mentioned Donji Golubić 1 site. Accordingly, the barrier is situated on the described part of the Sturba River but on the left channel of the stream. Specifically, the barrier is located adjacent to the contact area with the extensive alluvial plain, formed between the two aforementioned channels (see figure 37). The immediate vicinity around the barrier is covered with woody vegetation of willow and alder that developed along the embankment formed along the right bank of the mentioned channel. It consists of earth material obtained by digging out this channel, which was carried out to redirect a part of the Sturba River's water to the mills built in the downstream segment of the channel. The earth embankment is approximately 2 meters high and has an average width of about 1.5 meters. It is assumed that the embankment was constructed during the 1950s

Figure 39. Donji Golubić 2

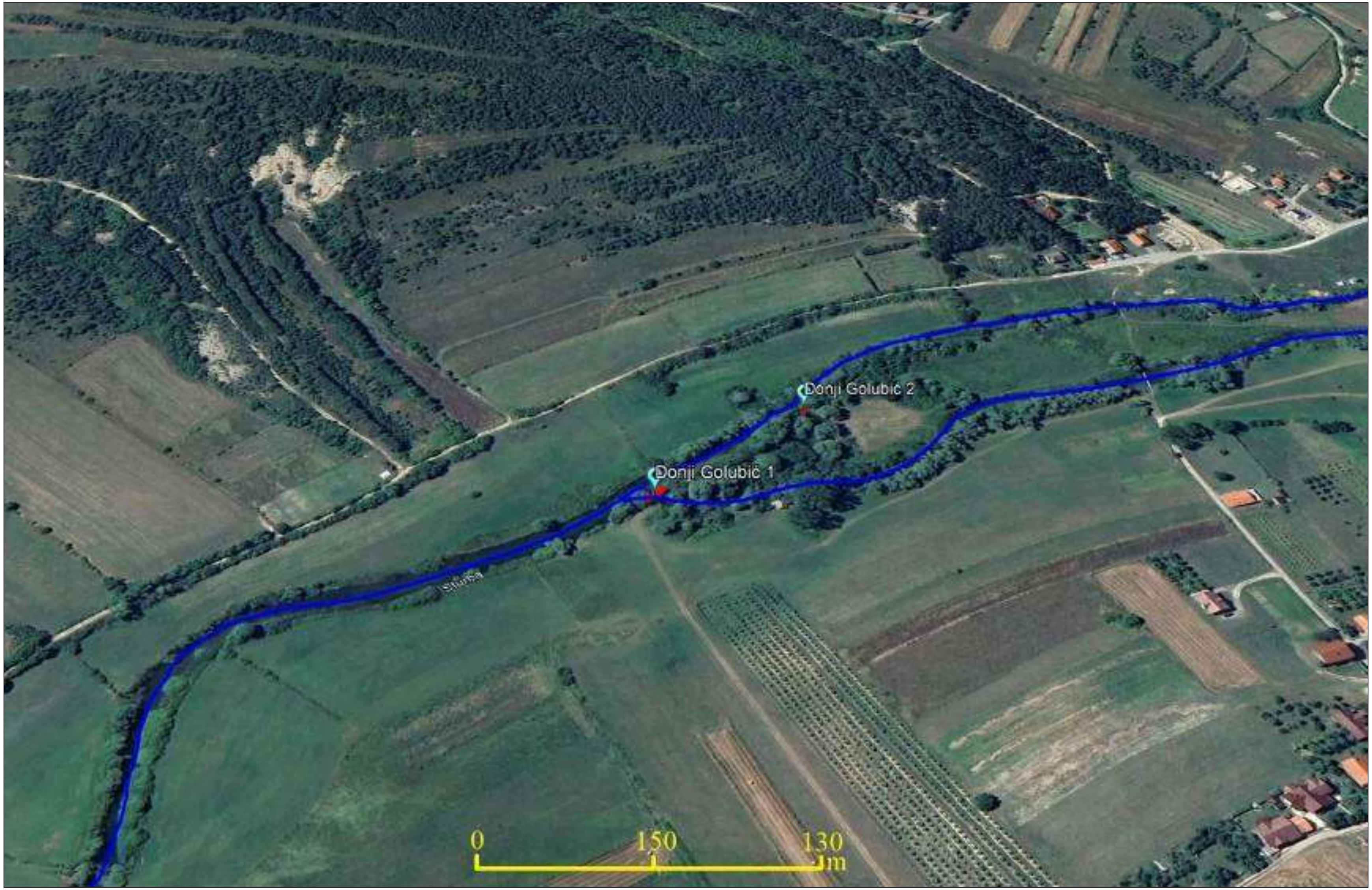
In order to reinforce the mentioned embankment, a retaining wall was built on the outer side, which, in addition to supporting the embankment's structure, serves the purpose of completely preventing water from flowing out of the riverbed. The wall is constructed from concrete blocks, which has contributed to its preservation up to the present time (see figure 40).

Slika 40. part of the walDonji Golubić 2.

Additionally, as evident in figure 40, both the sub-structure and the embankment are covered in shrub vegetation, predominantly willow and sporadic areas of dogwood, which successively alternate with grasses and other weed species. The image also highlights that due to prolonged lack of maintenance, the wall at the foundation level is indeed allowing water seepage from the riverbed. Consequently, it is realistically expected that there will be an erosion of the wall in the foreseeable future (see figure 41).Measurements taken during the field survey have determined that the total length of the concrete (masonry) barrier amounts to around 24 meters. The overall height of the wall is approximately 2.0 meters, with the foundations measuring about 0.5 meters, and the above-ground portion standing at roughly 1.5 meters.



Map 29. . The geographical location of the barrier on the Sturba River in the area of Donji Golubić 2.



Karta 30. Morpohological position of the barrier river Sturba Donji Golubić 2.

Figure 41. Donji Golubić 2.

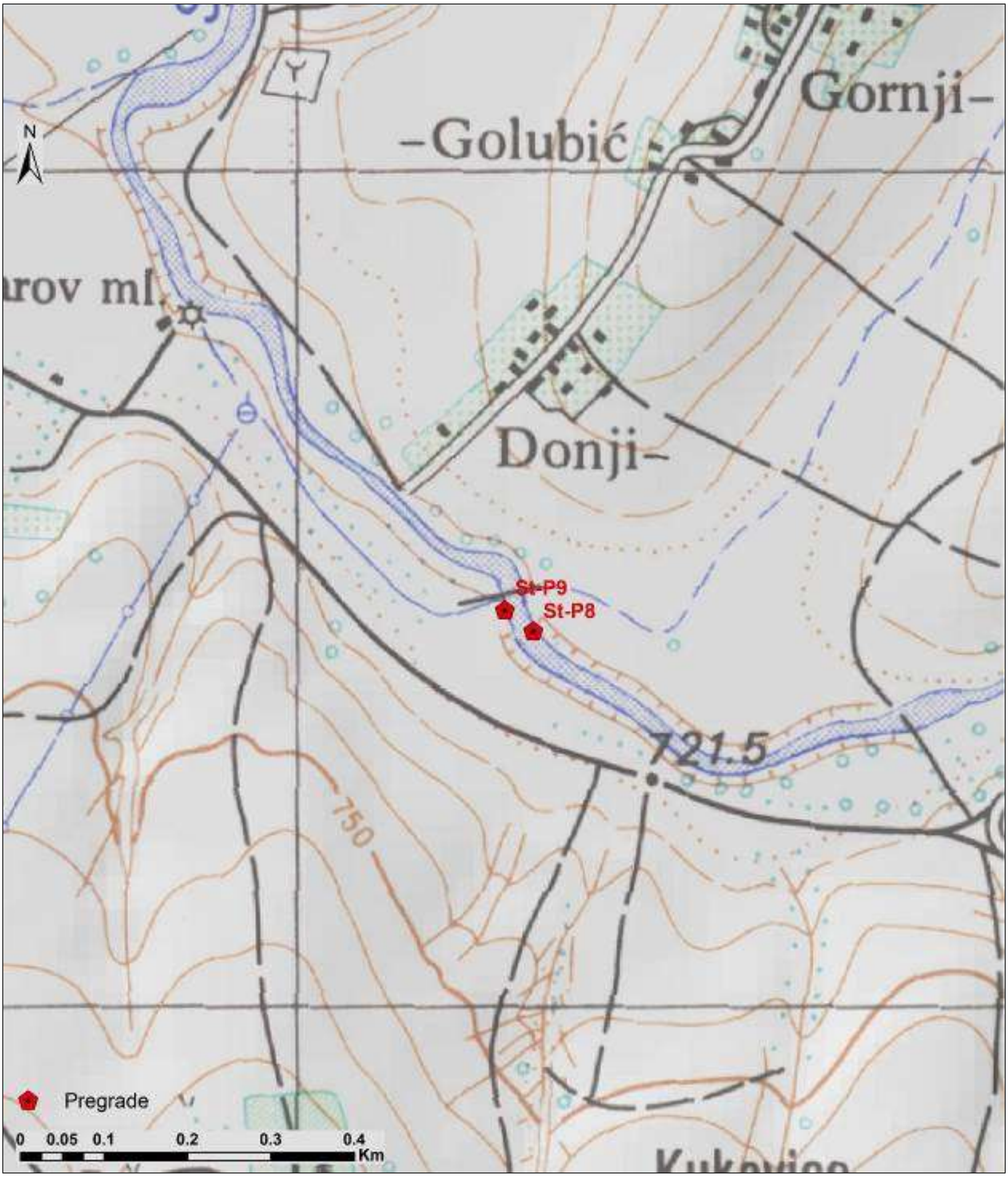
Near the initial section of the constructed wall with the embankment, a smaller barrier was built to regulate the water level in this branch of the Sturba River. Due to its intended purpose, the overall height of this barrier is lower, measuring about 1.5 meters. Initially, water release was mechanically controlled, but due to lack of maintenance, this system has been devastated and no longer operational. Consequently, water now overflows over the concrete part of the barrier, specifically its lower base. The length of the barrier is approximately 5.0 meters, with an average thickness of about 1.2 meters at the ground level and around 1.0 meter at the upper (overflow) part (see figure 42). The barrier is constructed from reinforced concrete in combination with stone material. As a result of water pressure and micro-tectonic stresses on the terrain, it has partially cracked and lost its stability.

The coordinates for the centroid of the barrier are: ϕ = 43°47'37.32"N; λ = 16°57'13.70"E; H = 719 meters above sea level.

Figure 42..

During fieldwork, it was observed that the earthen embankment and supporting wall were constructed on the left side of the barrier, extending for approximately 5 meters. Similar to the described embankment and supporting wall on the right side, these structures have also been significantly damaged and have largely lost their primary water protection function.

Considering the mentioned issues, it can be confidently stated that the entire described water protection infrastructure has suffered substantial damage and, as a result, does not fulfill its primary hydraulic function. Consequently, the research team is of the opinion that the entire constructed barrier should be removed to restore this section of the Sturba River to its natural hydrological state



Map 31. Topographic position of the barrier site on the Sturba River in the Donji Golubić 2 zone

2.10. LOCATION 10. RIVER STURBA – ZABRIŠĆE.

The location of the barrier on the Sturba River in the area of the Zbrišće settlement is also situated on the left river branch, approximately 520 meters away from the previous barrier (Donji Golubić 2). The barrier was constructed to redirect a portion of the water to the mills located immediately downstream. Specifically, the barrier diverts a part of the water into a smaller excavated channel where smaller dams were built. These dams directed water onto wooden turbines that powered the mills (see image 43).

Figure 34 The ruins of the former building (mill) with stone weirs used to direct water to the wooden turbines of the mills**.**

The water from the canal was directed to wooden turbines that powered the mills located on the ground floor using stone barriers. This method utilized water power to generate the necessary mechanical energy for the mills

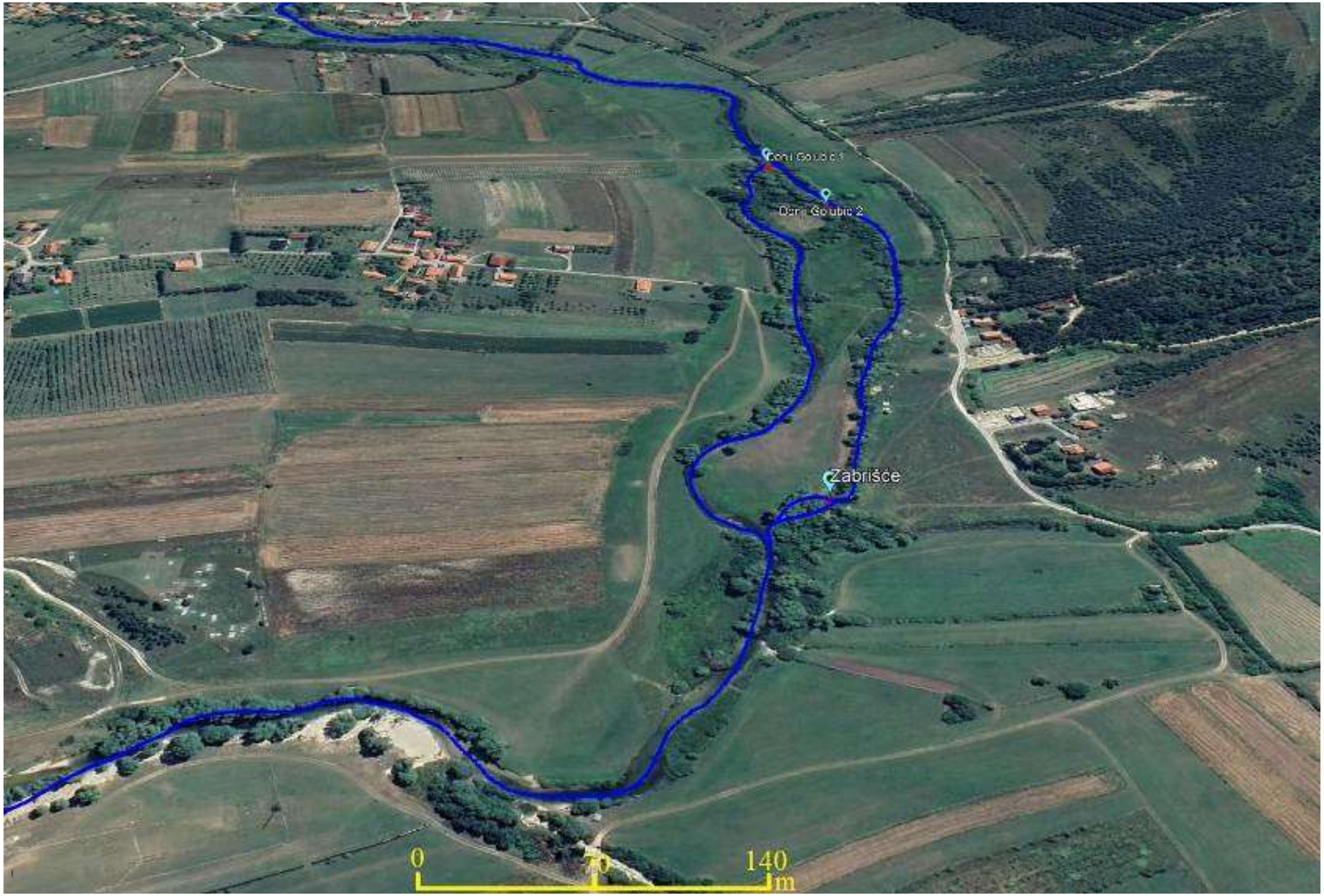
For redirecting the water flow, excavation and setting up a drainage channel were carried out. This process involved cleaning the channel bed and depositing the excavated gravelly-sandy material along its right bank. This practice led to the formation of an embankment serving as water protection, preventing the overflow of water from the drainage channel. To fortify the embankment, a concrete wall was built on its outer side, measuring approximately 8.0 meters in total length. The earthen embankment has been covered with woody vegetation such as willows, birches, and sporadic instances of oak (as shown in Figure 44).

Figure 44..

The water diversion barrier was initially built as a smaller weir capable of regulating water flow in the drainage channel through a mechanical mechanism.

Coordinates of the barrier's centroid: ɸ = 43°47'48.59"N; λ = 16°56'58.98"E; H = 718 m above sea level.

Map 32 Geographical position of the barrier on the Sturba River in the Zabrišće settlement area.

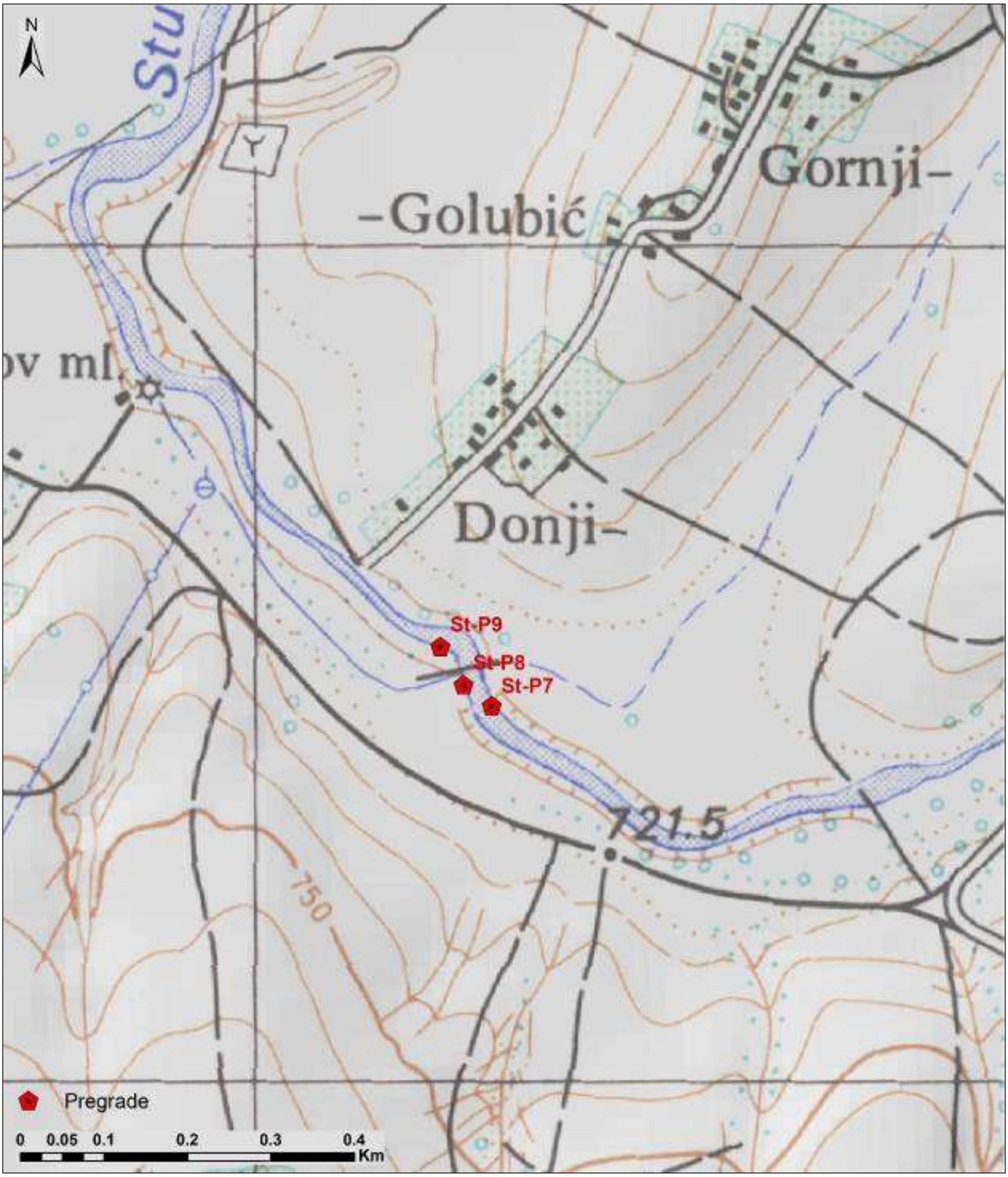


Map 33. Morphological position of the barrier on the Sturba River in the Zabrišće settlement area.

The weir, however, due to decades of disuse and the damage caused by water action, is out of operation, and water overflows over the upper base of the weir (Image 45). The length of the weir (sluice) for water level regulation is about 3.5 meters. The weir is built on a concrete base with dimensions of 3.5 meters x 1.0 meter x 2.0 meters. The height of the above-ground part of the weir is about 1.5 meters, while the foundation has a depth of about 0.5 meters

Slika 45. Prostorni položaj ustave u odnosu na odvodni kanal.

The completed field survey confirmed that the mill structure, for which the drainage channel was originally constructed, is completely demolished, and the former hydraulic infrastructure is not preserved. The weir structure with the weir itself is also entirely devastated and no longer serves the purpose of regulating water in the drainage channel. Considering these noted facts, it can be affirmed that the observed remains of the former weir structure with the weir and the supporting concrete wall should be removed to restore the course of the Sturba River in this section to its original natural state



Map 34. Topographic position of the barrier on the Sturba River in the Zabrišće settlement area.

3. Conclusion

Field research on the spatial identification and explanation of barriers in watercourses in the southern part of the Livanjsko Polje were conducted during two research periods:

- 06.03. – 07.032023.
- 20.04. – 21.04.2023.

During these timeframes, extensive field visits were conducted to numerous sites where barrier infrastructure was built during different periods and for various purposes. Specifically, the initial canal excavation and construction of the first weirs were realized during the reign of the Austro-Hungarian monarchy, aiming to improve agricultural production in the Livanjsko Polje area. These channels and weirs were established for controlled irrigation of agricultural crops (primarily cereals) and for draining excess water during rainy seasons into regulated minor morpho-depressions. Construction of new channels and renovation of existing ones continued during the period of socialist Yugoslavia, primarily focusing on establishing the hydroelectric system in Buško Blato for electricity production across numerous hydroelectric plants in Bosnia and Herzegovina and Croatia.

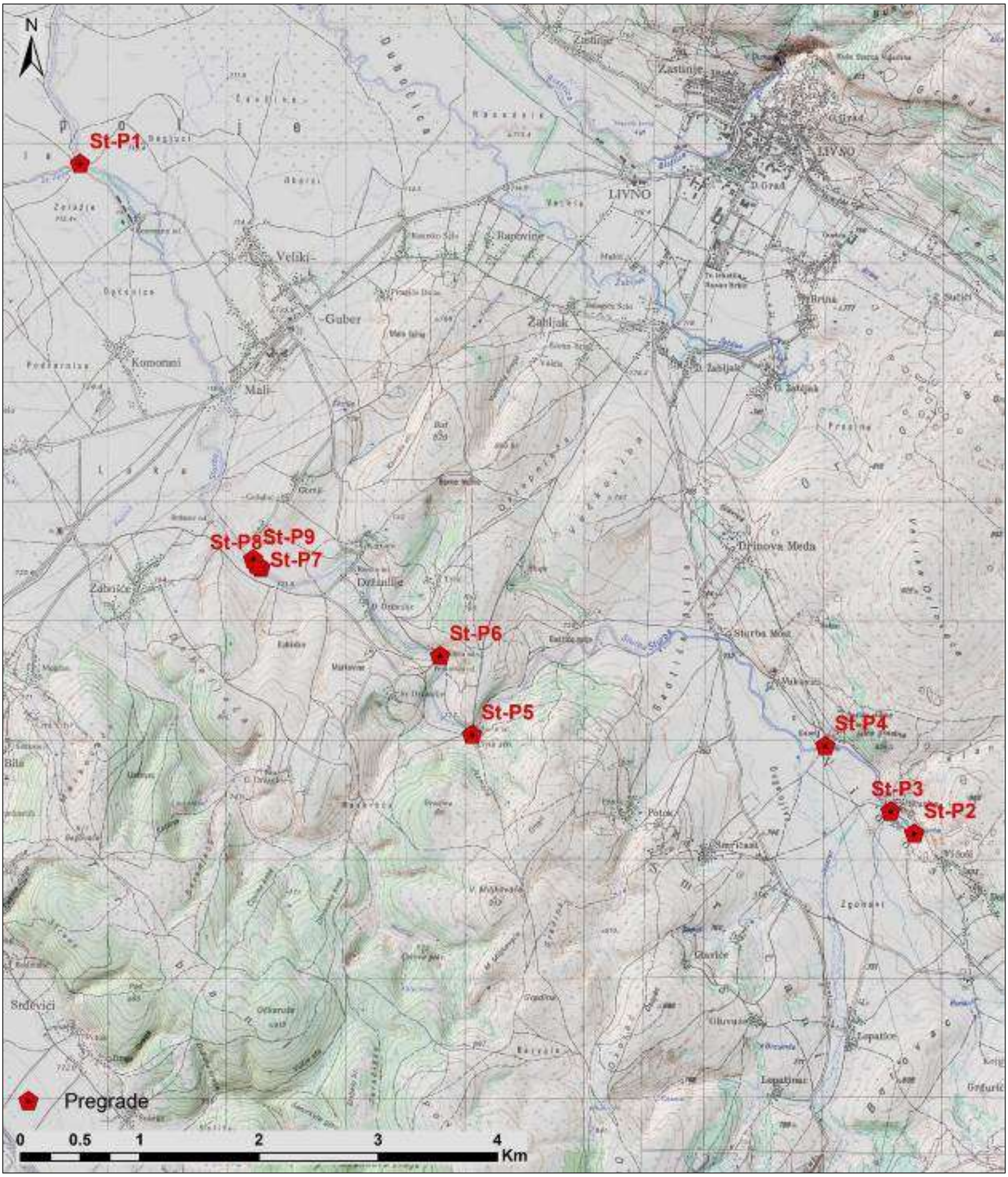
After the dissolution of the former Yugoslav state, part of the system designed for hydro-reclamation completely deteriorated, leaving behind numerous canals and weirs in the southern part of the Livanjsko Polje without hydro-technical functions.

The project aimed at removing barriers in watercourses and channels in the Livanjsko Polje aimed to identify and determine barriers in watercourses and channels in the southern part of the Livanjsko Polje, proposing potential removal of specific barriers. Literary research conducted confirmed (further confirmed by subsequent field research) that a large number of barriers were established along the course of the Sturba River and certain watercourses along the southeastern edge of the Livanjsko Polje. Accordingly, a detailed field observation program was established for this project, focusing on observing the Sturba River's course, associated channels, and the Plovuća River (along the southeastern edge of the Livanjsko Polje).

While field research detected numerous types of barriers, this report describes a total of 10 barriers that the research team evaluated as producing the greatest negative effects on the natural hydrological regime of the respective watercourses are attributed to these barriers. An overview summarizing their impacts is provided in the following Table 1

Table 1. Overview of the analyzed localities with a proposal for removal.

R.br.	*Stream /river*	Location	Coordinates	Proposal for removal
1.	*Plovuća*	Čajića ponor	ϕ=43°49'47.56"N λ=16°48'50.48"E H = 703 m n.v	YES
2.	*Sturba*	Sturba kod prve ustave	ϕ= 43°49'26.14"N λ= 16°56'7.45"E H = 710 m n.v.	YES/NO (further reaserch needed)
3.	*Sturba*	Sturba - izvor	ϕ= 43°46'27.71"N λ= 17° 01'22.09"E H = 742 m n.v.	YES
4.	*Sturba*	Sturba kod mljekare Orman	ϕ= 43°46'33.93"N λ= 17° 01'13.91"E H = 737 m n.v.	NO
5.	*Sturba*	Sturba kod naselja Kaselj	ϕ = 43°46'52.10"N λ = 17° 00'49.24"E H = 733 m n.v.	NO
6.	*Sturba*	Sturba kod Kelavinog mlina	ϕ = 43°46'52.60"N λ = 16°58'36.89"E H = 732 m n.v.	YES/NO
7.	*Sturba*	Sturba kod Ćurića mlina	ϕ = 43°47'13.64"N λ = 16°58'24.83"E H = 730 m n.v.	NO
8.	*Sturba*	Sturba – Donji Golubić 1	ϕ = 43°47'36.21"N λ = 16°57'18.38"E H = 720 m.n.v.	YES
9.	*Sturba*	Sturba – Donji Golubić 2	ϕ = 43°47'37.32"N λ = 16°57'13.70"E H = 719 m.n.v.	YES
10.	*Sturba*	Sturba kod naselja Zabrišće	ϕ = 43°47'48.59"N λ = 16°56'58.98"E H = 718 m.n.v.	YES



Map 34. Topographic position of the barrier sites in the researched (Livanjsko polje).

In light of the provided data, it can be stated that at all 10 selected locations, it has been determined that the barriers significantly degrade the natural flow regime of the watercourses on which they are built.Through field research, in addition to providing detailed descriptions of the barriers, their current economic and/or touristic function has been described. This served as the basis for proposing their potential removal. Specifically, based on the findings of the field research, the research team proposed the removal of a total of seven barriers. It was determined that these barriers do not serve an active agricultural or touristic function and were identified as structures that have significant negative impacts on freshwater ecosystems as well as on the natural hydrological regime of the analyzed watercourses.

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Final Report of the Project:

Towards Removing First Dams in Dam Removal in Bosnia and Herzegovina – Case Study Livanjsko Polje

Livanjsko Polje

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1. INTRODUCTION

Livanjsko polje is a karstic field located in the western part of Bosnia and Herzegovina, characterized by a flat landscape that stretches over an area of approximately 730 km^2. The field is surrounded by mountains and hills and contains several rivers, lakes, and wetlands that make it a unique and ecologically diverse region. Due to its geological features and hydrological regime, Livanjsko polje plays a crucial role in regulating the water balance of the area, and it is considered one of the most important sources of freshwater in the country. Additionally, the region is home to a rich biodiversity of flora and fauna, including several endemic and endangered species. However, the Livanjsko polje area has been subject to various environmental challenges, such as intensive agricultural practices and the construction of dams, which have resulted in the degradation of its natural habitats and the loss of biodiversity. As a result, several restoration initiatives have been proposed to preserve and enhance the ecological integrity of the region, including the Dam Removal project – Case Study Livanjsko polje, which aims to restore the natural flow of the rivers and wetlands in the area.

1.1. KARST AND BIODIVERSITY

Karst is a geological formation characterized by soluble rocks, such as limestone or dolomite that have been eroded by water over time. Herzegovina, which is located in the southern part of Bosnia and Herzegovina, is known for its extensive karst landscape, which covers approximately 60% of the region.

One of the most prominent features of the karst landscape in Herzegovina is the Livanjsko polje, which is one of the largest karst poljes[3] in the world. The Livanjsko polje is approximately 60 kilometers long and 7 kilometers wide, and is surrounded by the Dinaric Alps. In the southeastern part of Livanjsko polje accumulation Buško Lake is located (Figure 1). Accumulation Buško Lake is one of the largest reservoirs in Europe with an area of about 57 km^2. It was formed in the mid 1970s, with the main goal of providing water for the

[3] polje is a flat plain or depression that is typically surrounded by mountains or hills, and is formed when the roof of an underground cave collapses

production of electricity in the Orlovac hydropower plant, which is located in the Republic of Croatia.

Figure 1. Livanjsko polje and Buško Lake[4]

All the waters of the Livanjsko polje belong to the Cetina river basin and end in the sea near Omiš in the Republic of Croatia. Regarding the Buško Lake Accumulation, the main inflow of water into the reservoir is from Duvanjsko polje, which is directly connected to the reservoir via the Kovači sinkhole and a short course of the Ričina River. Smaller amounts of water flows through the streams along the northern side of the reservoir, such as the Mandek Stream.

Livanjsko polje is an **important ecological hotspot**, and it was recognized as a Ramsar site in 2008 due to its importance as a unique and biodiverse karstic wetland complex. Its role as a critical habitat for a variety of plant and animal species, such as over 260 bird species, several endemic fish species, insects, as well as a significant diversity of flora is worth mentioning.

Fish species, like Dalmatian barbel-gudgeon (*Aulopyge huegelii* Heckel, 1843), Dalmatian rudd (*Scardinius dergle* Heckel & Kner, 1858), Livno chub (*Squalius tenellus* Heckel, 1843)

[4] Source: Google Earth (https://earth.google.com/)

and Minnow nase (*Chondrostoma phoxinus* Heckel, 1843)[5] (Figure 2) that are found in the waters of Livanjsko polje, have adapted to special conditions that this karst polje provides. Considering that the polje was seasonally flooded, these endemic fish species would go underground during dry periods in the summer in order to survive.

Figure 2. Endemic fish species of Livanjsko polje, with local names[6]

However, the Livanjsko polje has been subjected to various environmental challenges, such as dam construction, habitat loss and degradation. These challenges have threatened the ecological health and biodiversity of the Livanjsko polje, as well as the long-term sustainability of the local communities that depend on it.

1.2. ENDEMIC FISH SPECIES OF LIVANJSKO POLJE

As mentioned before, four endemic fish species inhabit Livanjsko polje:

- Dalmatian barbell-gudgeon (*Aulopyge huegelii*);
- Dalmatian rudd (*Scardinius dergle*);
- Livno chub (*Squalius tenellus*);
- Minnow nase (*Chondrostoma phoxinus*).

[5] Croatian names in order: oštrulj, drlja, sitnoljuskavi klen, podbila
[6] Source: Sanja Duranović

Before the Buško blato accumulation, all four species were present in the field which seasonally flooded, but now they are only present in old mine holes or small seasonal streams such as Jaruga stream (Figure 3 and 4).

Figure 3. Flooded Jaruga stream in late spring[7]

[7] Source: Sanja Duranović

Figure 4. Jaruga stream in early fall when there is barely some water[8]

1.2.1. Biology of endemic fish species

In this chapter, biology of four mentioned endemic fish species will be briefly introduced for better understanding how certain obstacles on streams and rivers can affect their life cycle.

Dalmatian barbell-gudgeon (oštrulj, hrv.)

An endemic fish species that is characterized by its pointed head (Figure 5). The body is almost completely without scales, which is actually an adaptation to life underground. It can reach a maximum size of 20 cm.

[8] Source: Sanja Duranović

Figure 5. Dalmatian barbell-gudgeon[9]

Species lives in flocks and they inhabited rivers and sinkholes of Livanjsko, Duvanjsko and Sinjsko polje, as well as in the accumulation Buško jezero. But recent field studies shows that the species is restricted to smaller area due to introduction of invasive species. It is considered that it was introduced unintentionally into Blidinjsko and Šatorsko jezero. Inhabits watercourses with faster and cleaner water, and lakes and reservoirs on these waters. **During the dry season, it enters the groundwater**. It feeds on different algae, zooplankton, aquatic insects, larvae and others invertebrates. It tolerates the lack of food well, which appeared as an adaptation to survive the unfavourable conditions in the underground. Spawning begins at the end of April in shallow water at a temperature of 13-17°C. During spawning, the female looks for a suitable place and then, using a brooder (a specially modified tube), she lays several thousand eggs that go into hollows, cracks in the rocks and between plant roots.

Regional IUCN status - endangered (EN)

Global IUCN status - endangered (EN)

Threats affecting this endemic species are **habitat alteration**, overfishing and introduction of invasive fish species.

Minnow nase (podbila, hrv)

An endemic fish species (Figure 6) described by ichthyologist J.J. Heckel in 1843.

Widespread in the sinkholes and springs of Glamočko, Livanjsko, Duvanjsko and Sinjsko polje, as well as in the Buško lake hydroaccumulation. It can grow up to a maximum size of 15.5 cm. It feeds on algae, diatoms, but also mosquito larvae, molluscs, and water flowers. During the reproductive period, they make short migrations. Spawning takes place in late

[9] Source: Dušan Jelić

spring, from April to June. They congregate in waters that are well oxygenated, unpolluted and have a rocky bottom or gravel where they will lay their eggs. During unfavorable conditions, it enters the underground water.

Figure 6. Minnow nase[10]

Regional IUCN status - critically endangered (CR)

Global IUCN status - endangered (EN)

The population declined drastically in the 20th century due to **alteration of habitat**, pollution, overfishing and introduction of invasive species.

Dalmatian rudd (drlja, hrv.)

Not much is known about the biology of this species. The maximum size they reach is 15 cm (Figure 7). It is widespread in karst rivers in Livanjsko polje and in Lake Buško and Lake Mandek. It inhabits slow-flowing and stagnant waters and lakes. They prefer calmer streams, river backwaters and flood zones with aquatic vegetation. They tolerate low oxygen levels and high temperatures well. They stay in flocks next to aquatic vegetation. During dry seasons, they enter underground.

[10] Source: Dušan Jelić

Figure 7. Dalmatian rudd[11]

Spawning takes place in the spring, in shallows overgrown with aquatic vegetation. Females lay eggs among aquatic plants, and several males then fertilize them. They can spawn several times. They feed on plankton, aquatic plants, invertebrates and especially terrestrial insects that accidentally get into the water.

Regional IUCN status - near threatened (NT)

Global IUCN status - Near Threatened (NT)

Livno chub (sitnoljuskavi klen, hrv.)

Livno chub is an endemic fish species that has a narrow area of distribution. It has a spindle-shaped body, and the scales on the body are particularly small - these are the smallest scales of all chubs, which is why it got its name. The maximum size it reaches is 40 cm (Figure 8).

Figure 8. Livno chub[12]

It is widespread in the Cetina River, as well as karst streams and rivers in Livanjsko Polje, Lake Buško and Lake Mandek. It was potentially introduced into Lake Blidinje. It inhabits lakes and slow-flowing rivers and lakes. It enters the groundwater during winter and during

[11] Source: Dušan Jelić

[12] Source: Dušan Jelić

summer droughts. It feeds on planktonic shrimps and insect larvae. In lakes, adults feed on smaller fish. It spawns from April to June.

Regional IUCN status - critically endangered (CR)

Global IUCN status - endangered (EN)

It is endangered due to the pollution of watercourses and introduction of invasive fish species. The sharp decline in population in the 20th century was caused by **habitat loss** and pollution.

Each of these species enter underground in some point in order to survive. Due to significant alteration of habitat in the past century their life cycle is endangered. Some obstacles were identified and closely examined during this project.

2. METHODOLOGY

With the aim of realizing the project "Towards removing first dams in Dam Removal in Bosnia and Herzegovina – Case Study Livanjsko Polje", a literature review of the current data on the state of biodiversity in the area of Livanjsko Polje was carried out, mostly focusing on endemic fish species, as well as a fieldwork.

In this second phase of the project, fieldwork was conducted together with the members of Speleological Society Mijatovi Dvori, Tomislavgrad. We thoroughly examined and assessed one of major abysses that are located in southern west part of Livanjsko polje, **Čaića ponor**.

3. ČAIĆA PONOR

Čaića ponor is located in southern west part of Livanjsko polje (Figure 9) and it collects water from the River Plovuča. River Plovuča is formed by the joining rivers Sturba, Bistrica and Žabljak. It flowes through the Livanjsko polje and then sinks in the location of Čaića ponor.

In front of the Čaića ponor there is a barrier in the form of the cattle pool (Figure 10) which is always filled with water. Beside the cattle pool there is a narrow part of the River Plovuča that goes directly to the abyss. During summer, that part of the river is dry and thus no water is coming to the abyss.

Figure 9. Čaića ponor[13]

Due to this barrier and what it represents in space endemic fish species that were described earlier in the report have an obstacle to migrate underground to survive during hard conditions such as drought and lack of water in their natural habitat.

In the appendix of this report, thorough view of the Čaića ponor from speleological side is given by the members of Speleological Society Mijatovi Dvori.

Figure 10. Barrier in the form of cattle pool near Čaića ponor[14]

[13] Source: Sanja Duranović

At the very entrance to the abyss we identified one more barrier (Figure 11) that looks like concrete wall. It is assumed that the barrier dates back to Austro-Hungarian era. By the look of it from biological side, this barrier prevents fish to migrate back to the surface waters unless the level of water is very high. In low levels of water fish species are forced to stay in this small area on the entrance of the abyss.

Figure 11. Barrier in the very entrance of the Čaića ponor[15]

[14] Source: Sanja Duranović
[15] Source: Sanja Duranović

4. CONCLUSION

Recognizing barriers like these that were identified through field research during the project is important for determining threats to plant and animal species, especially to those that are already endangered.

There are many advantages that favours dam removal such as increased possibility of movement for all species in the habitat and between habitats, easier access to resources, increased ability of species to reproduce, better flow of gene material, decreased possibility of disease developing, et cetera.

In addition, the removal of barriers could be a turning point for the implementation of many extensive researches in the area of Livanjsko polje, which does not necessarily have to include freshwater ecosystems, but also land habitats.

We focused on Čaića ponor because we recognized its great significance from both biological view as well as from speleological side. Returning this location to its natural form will significantly improve biodiversity in this area, especially if the fact that in the River Plovuča there are no big predators for endemic fish species is taken in mind.

5. LITERATURE

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6. APPENDIX – Čaića ponor, Speleological Society Mijatovi Dvori

The field survey covered the Čaića ponor with the aim of determining its speleological potential and its valorisation. A field survey is one of the basic speleological methods by which all data on the observed area is recorded and the speleological potential of a certain area is determined. It serves us to observe and record speleological objects and their representation and density in the observed space, then to collect data on flora and fauna, to identify all human activities that had any impact on speleological objects both today and in the past and to document all other changes in order to better understand and correctly interpret all speleological indicators for their protection.

Čaića ponor was the research focus of older studies, especially during the Austro-Hungarian era and during the construction of the Buško lake accumulation. A big problem during those older researches that were carried out is its lack of documentation, and in one that got published, in most cases, the speleological and spatial context was absent or completely simplified. The context is a set of different geological, geomorphological and human activities accumulated during the formation of the object. Due to the absence of context, there is a lack of data on all natural and human transformation processes that influenced the formation of the speleological object.

In order to determine the condition of the observed locality, it was necessary to carry out a fielwork of the terrain. During the visit to the site, an extensive speleological examination was carried out with an emphasis on recording all observations on the ground. This inspection serves primarily to determine the speleological potential of the locality, then to determine the state in which the locality is located and whether there are real dangers for the entry of people and bringing equipment into the locality. It then serves to determine the methodology of speleological research and the methods of scientific research. During this fieldwork, all observations were recorded and documented, and all information about the situation on the ground was collected, and it was determined whether there was any pollution. In addition to the above, photographs of the locality were also taken during this fieldwork.

Through fieldwork, it was established that access to the site is not complex and that the entire bed of the dried-up stream is generally passable. In some places it is necessary to pass through low vegetation, but this will also not be the issue. This area is not too polluted with waste, which is present in smaller quantities as a result of irresponsible human activities. It is not necessary to organize a special cleaning campaign, but the garbage will be picked up during future research campaigns. The access through the river bed has the most fallen trees from the surrounding vegetation.

Before the main entrance, you can see a brick structure from the time of the Austro-Hungarian Monarchy, which in no way presents an obstacle to speleologists and does not threaten the entry of the speleological team into the main entrance. A few meters before this main entrance, on the left side there is also a smaller opening that should be included in future research.

After this fieldwork, a cabinet analysis of the collected data and consultations with other members of the Speleological Society Mijatovi Dvori Tomislavgrad were carried out, on the basis of which the future field approach was clearly defined and it was determined which research methods would be implemented.

In order to properly investigate this locality and to determine all the speleological aspects of the locality, it is necessary to conduct several research campaigns and field trips. The first tour of the underground system would entail the beginning of the creation of a topographical plan and a preliminary inspection of the underground system. Depending on the complexity of the building, on that occasion an approximate assessment of what is necessary to create a blueprint would be made. Since it is an abyss, there is a strong possibility that it will be necessary to carry out speleo-diving expeditions to create the overall plan.

After that, an intensive speleological examination will be carried out, which examines the observed area in detail. The basis of the intensive field inspection is a detailed interdisciplinary inspection of the entrance and the underground system during which various samples and surface findings are collected. This research would determine the geological, geomorphological, hydrological, biological, paleontological and archaeological potential of the locality.

The methodological approach to this type of inspection implies, above all, the division of the object into zones for simpler and more efficient data collection. Based on the configuration of the terrain, the facility will be divided into several zones of different dimensions, in principle arbitrarily determined depending on the accessibility within the system. When determining the zones, coverage is only thing to ensure in order to collect a sufficient amount of data for a valid interpretation. Certain zones are marked with Roman numerals, and separate spaces within the zones with ordinal numbers. All findings within one zone are also marked with ordinal numbers and are mapped on the speleological plan on which the zones are applied. In this way, the most detailed and precise concentration and distribution of findings and samples will be obtained. Only a sufficiently large number of inspected units gives an insight into the entire observed area. All findings are collected and mapped, regardless of the scientific disciplines involved. The mapping of this data is primarily due to the spatial distribution of findings and samples and other phenomena. Detailed documentation and photo documentation will be kept during the research.

After the conducted research, a cabinet analysis of the findings follows. This includes computer processing of data and the creation of a digital topographical plan, as well as the entry of spatial data into the Geographical Information System (GIS) and a detailed description of the morphology of the locality. Then follows the analysis of the found fauna in order to determine further monitoring of the object. If the paleontological and archaeological potential of the locality is determined, then analyses of that material will be carried out. Ultimately, all data obtained at the locality will be compared with data obtained at other investigated localities of a wider area in order to obtain a spatial picture of the area.