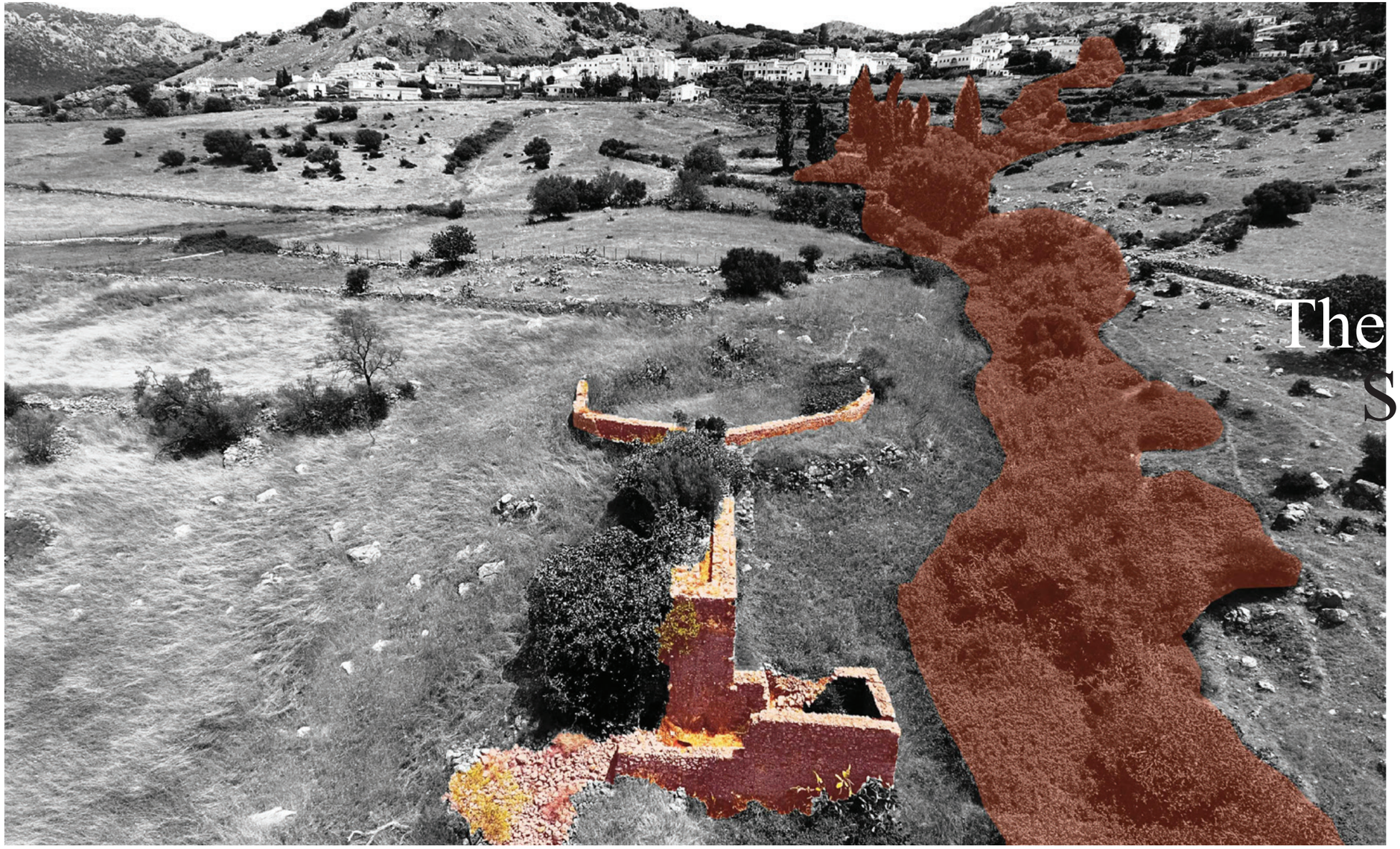


The water mills of Sierra de Cádiz

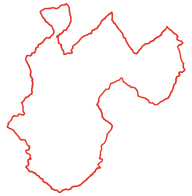
Water as a driving force in the historical production of staple food: bread.

Gloria Rivero-Lamela

Figure 1 Atmosphere of the system

Context.

The water flour mills of the Sierra de Cádiz (Andalucía, Spain) make up a network of more than 80 buildings strategically distributed throughout the region. They are architecural interventions linked to the milling of wheat and the production of flour and bread, historically related to agricultural use. They are part of *productive rural architecture*, a group considered heritage because it combines cultural relevance and tradition. However, they are now obsolete and remain inactive or in ruin.



Region of the Sierra de Cádiz

Municipalities

Hydrographic network and reservoirs

Watershed Divide

23 △ Peak El Torreón (1648 m)

24 △ Peak San Cristóbal (1554 m)

0 5 10 15 20 km N

Figure 2
Country scale: Spain

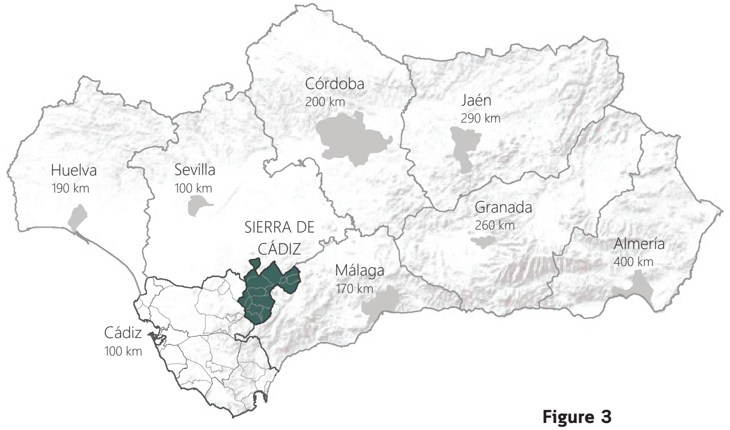


Figure 3
Regional scale: Andalucia

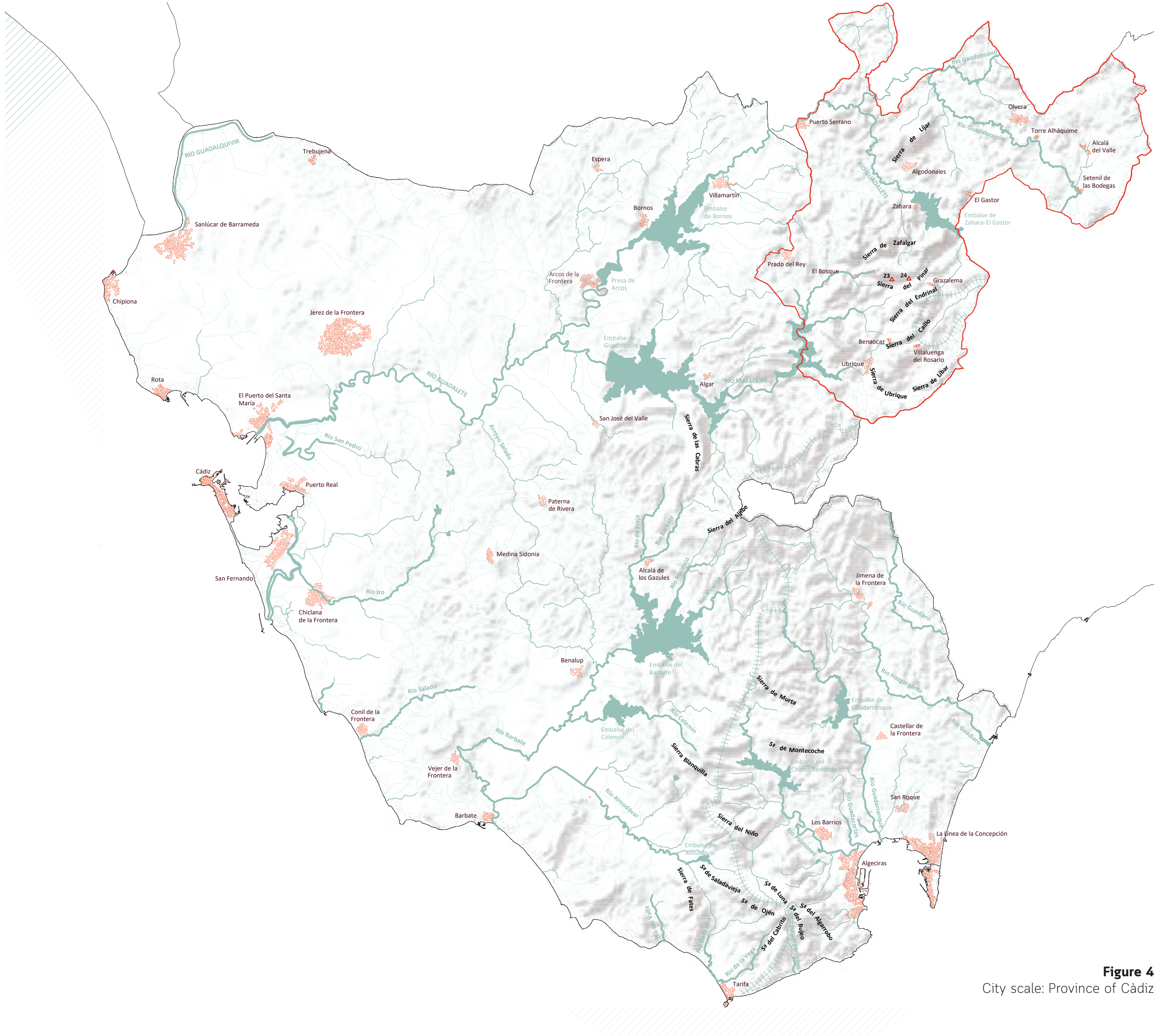
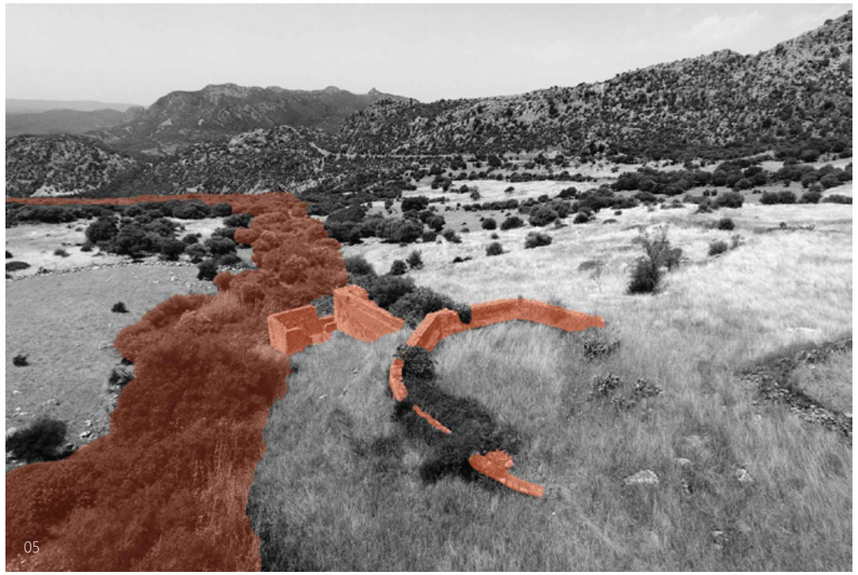
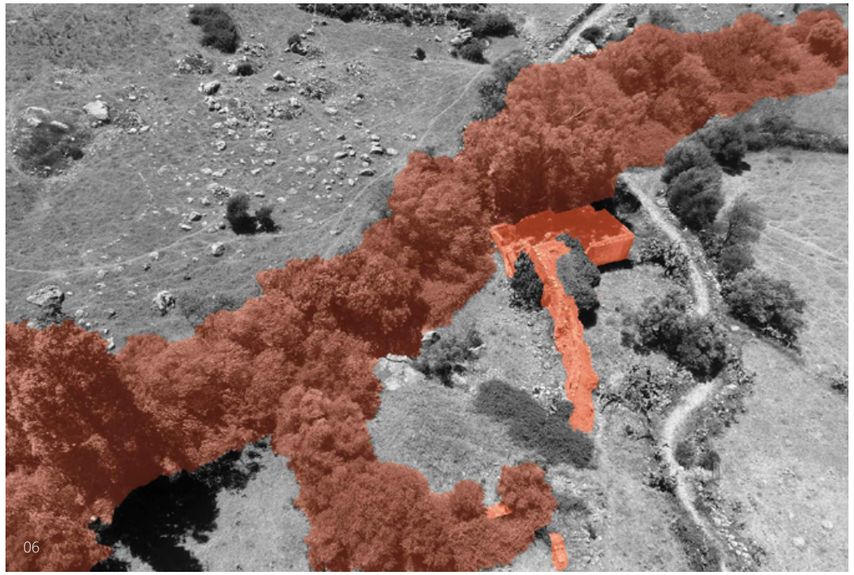


Figure 4
City scale: Province of Cádiz

Archaeological ruins of mills.

They are, in addition, functional architectural interventions: for its industrial use and for the required productive profitability, water was necessary for its operation. Therefore, these mills were built with the precision and logic of the small hydraulic engineering works that, together with other minor and usual works in these places, such as ditches, canals, ponds, etc., make up a network of constructions aimed at control and management of hydrological resources that the artisanal industries of the Sierra de Cádiz region require.





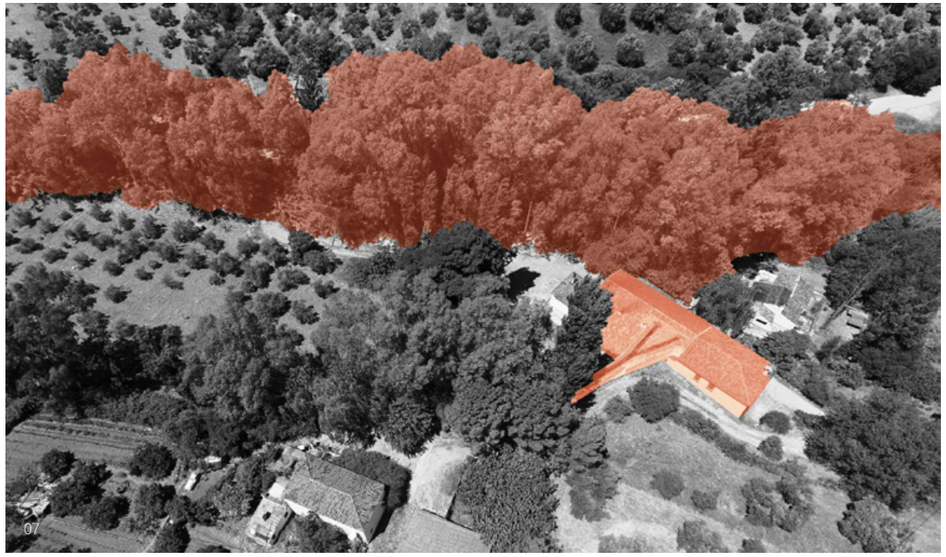


Figure 5 - Water mill "Segundo". Riverside of Arroyo Seco, Benaocaz.
Figure 6 - Water mill "Primero". Riverside of Arroyo Seco, Benaocaz.
Figure 7 - Water mill "Alto". Riverside of Arroyomolinos, Zahara de la Sierra.
Figure 8 - Water mill "El Caballo". Riverside of Gaidovar, ZGrazalema.

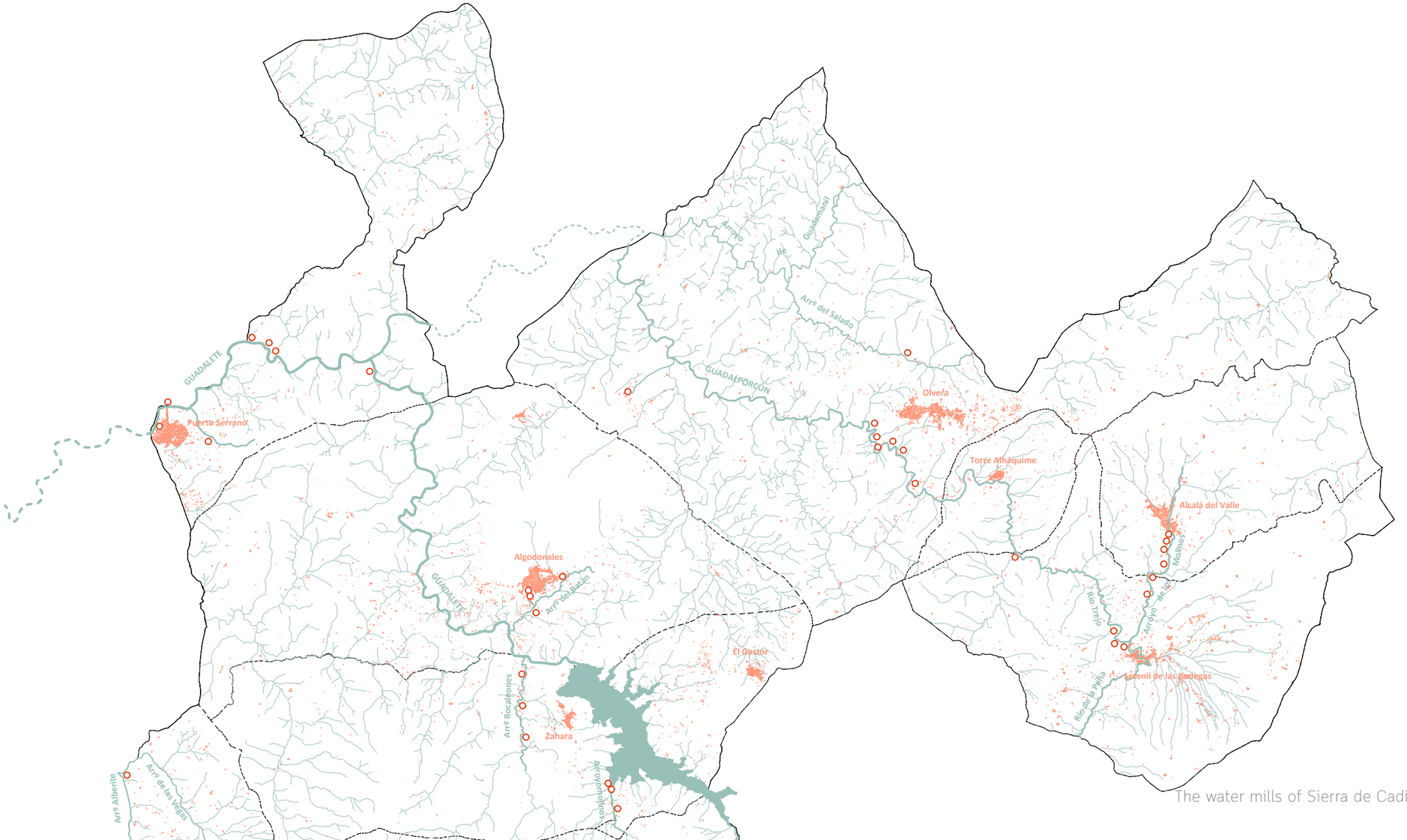
Catchment area.

The Sierra de Cádiz is located in the north-eastern end of the province of Cádiz; within Andalusia, in Spain. It has an area of 105,435 ha (14.2% of the provincial area) and is administratively composed of 14 municipalities. It comprises a large part of the Sierra de Grazalema Natural Park, declared a Biosphere Reserve in January 1977 and a Natural Park in December 1984.

It presents a rugged orography of steep slopes, resulting in average altitudes that vary between 285 and 1,072 m with slopes that exceed 18%. This causes the Sierra de Cádiz to be the area where the provincial hydrographic network springs. The Majaceite, Guadalete, Guadalporcún and the Zahara and Hurones reservoirs stand out.

In addition to these physical issues, it is a cultural region, since it has been an isolated area (Hispanic-Muslim border during more than two centuries) that has generated among its inhabitants the awareness of sharing a common history and a cultural past.

Figure 9 Catchment area of Sierra de Cadiz



Water mill

Municipalities

Hydrographic network

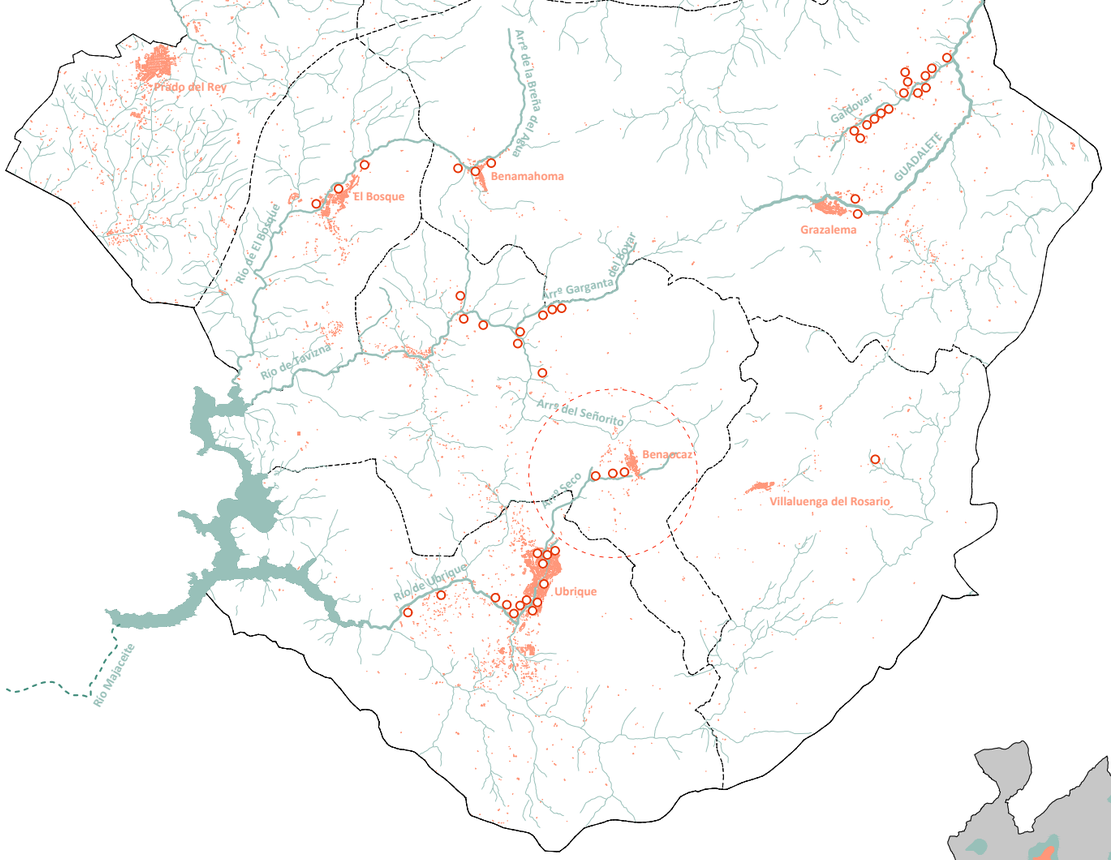
Reservoir Zahara - El Gasor

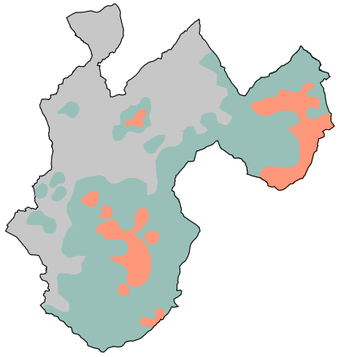
Reservoir Los Hurones

Climate.

With respect to the province's climatology, it is classified within the Mediterranean type, although there are contrasts due to its littoral condition, its contact with the great Atlantic mass, its southern position and its proximity to Africa (influence on the wind regime). Thus, the Sierra de Cádiz is the area within the province with the highest rainfall and with a thermal regime more markedly continental, with a marked seasonal character. This determines the great importance of its hydrographic network and the greater presence of hydraulic works. Grazalema, one of the municipalities of the Sierra de Cádiz, is the rainiest places on Spain, with an average annual rainfall of over 2000 mm.

The Sierra de Cádiz presents a cold or frost period of 5 and 6 months; a warm period that varies from 0 to 3 months and a dry or arid period, with water deficit, of between 2 to 4 months. According to the agroclimatic classification of Papadakis, the region can be divided into three zones according to the climatic type. The north-western half presents a *subtropical Mediterranean* type, the southeast half a *maritime Mediterranean* type, and the higher altitude zones of the sierras, the *continental Mediterranean* climate type.



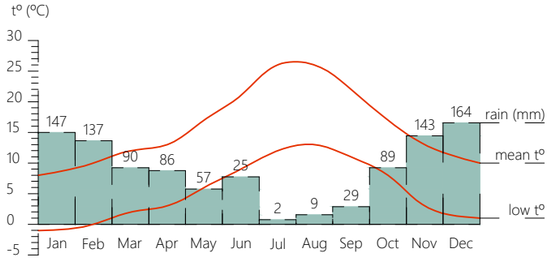


subtropical Mediterranean type
maritime Mediterranean type
continental Mediterranean type

0 5 10 km N

Climate zone: *Mediterranean*
Sub-climate:
The north-western half: *subtropical Mediterranean* type
the southeast half: *maritime Mediterranean* type
the higher altitude zones: *continental Mediterranean* type

Climate & Weather averages of Sierra de Cádiz



Annual climatological data of the municipalities of the region

Municipality	Altitude	Rainfall (mm)	Mean/High/Low t°(°C)
Alcalá del Valle	714	762	3,1/14,6/32,4
Algodonales	738	752	4,4/16,8/33,8
Benaocaz	647	1.222	4,3/16,4/32,3
El Bosque	363	970	5,1/17,4/33,5
El Gastor	501	868	4,2/16,5/33,1
Grazalema	858	1.969	3,5/15,2/31,7
Olvera	456	681	4,1/16,3/33,7
Prado del Rey	368	866	5,0/17,2/33,8
Puerto Serrano	274	644	4,6/17,1/34,7
Setenil	653	699	3,4/15,1/32,3
Torre Alháquime	542	624	3,9/16,1/33,2
Ubrique	452	624	3,9/16,1/33,2
Villaluenga	940	1.442	3,4/14,1/30,9
Zahara	506	955	4,4/16,6/33,3

Water System near Benaocaz village.

The riverside of "Arroyo Seco" (it would be translated as a "dry stream") is drawn on this map as a representative example of the 21 milling banks existing in the Sierra de Cádiz. It is located in the municipality of Benaocaz, and has three hydraulic flour mills. This scale is very important, since mills should not be considered as autonomous buildings, but inseparably connected to the streams that activated their mechanism.

Regarding the factors conditioning mills' location, the first thing is the fundamental dependence of the presence of water courses. Second, there is a tendency to locate the mills as close as possible to the villages, main flour consumption centres, or in more remote areas to supply other rural constructions.

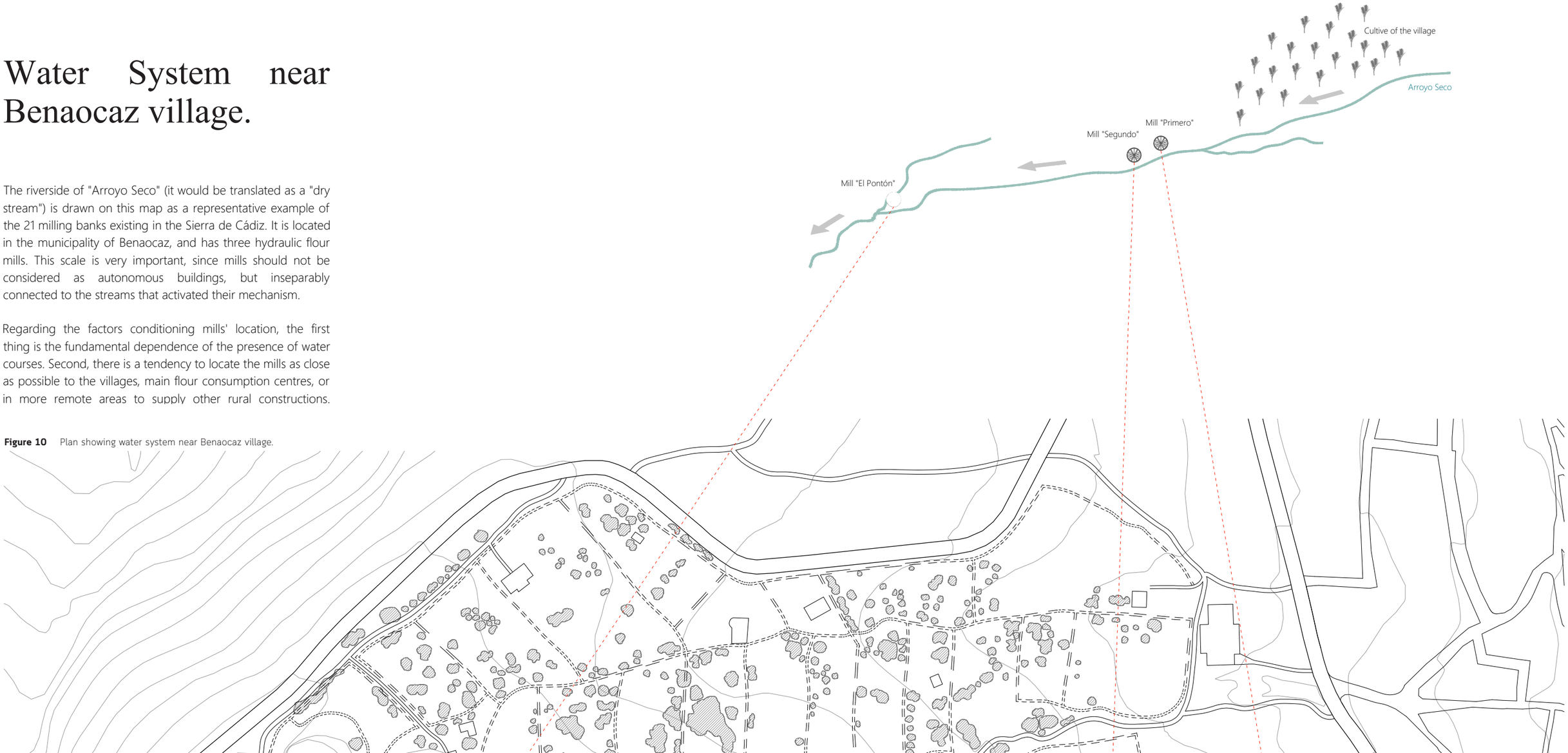
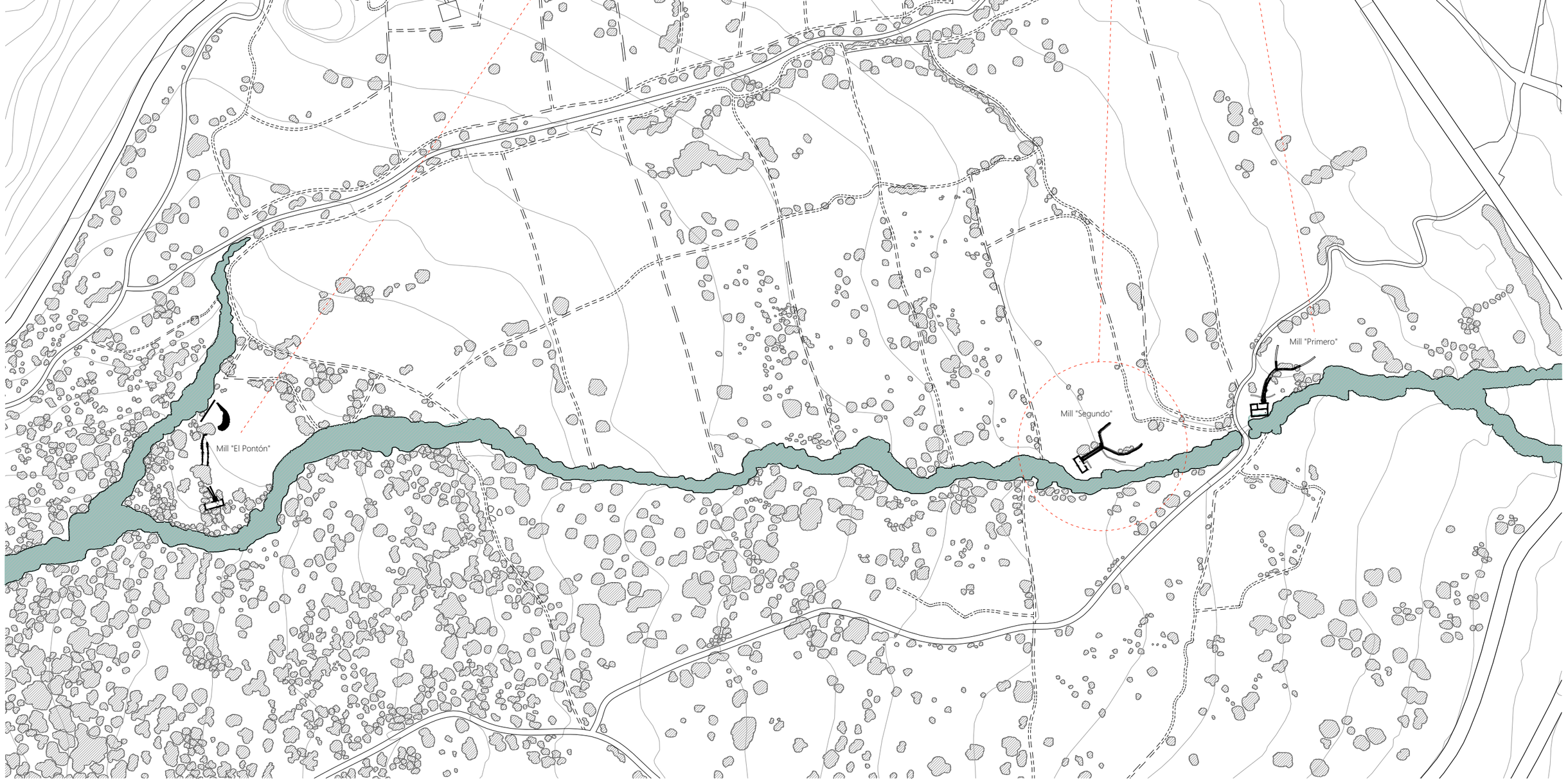


Figure 10 Plan showing water system near Benaocaz village.



The water mills of Sierra de Cadiz

Functional diagram of the mills.

The function of the mills determines its design. On a small scale, the mill is distinguished by its location close to the rivers and by the external infrastructure works that channel the water to its interior: the millrace, the well and the wheelhouse.

All the water mills of the Sierra de Cádiz have a horizontal wheel and a well, one or two at most, and they may or may not have a pond. They were built when the water courses had no speed or sufficient flow.

Almost all the mills had a mixed structure with masonry load-bearing walls of irregular stone, taken with mortar of sand and lime, 60-80 cm thick, plastered with lime and wooden beams. Most of the roofs had one or two water structures, also made with wooden structure, thatched and Arab tile. The main space that articulates the building is the grinding room, located above the wheelhouse.

If it exists, the pond is built where the slope of the land is not excessive to achieve, with minimal construction resources, store as much water as possible. The water is conducted from the pond to the well by the millrace, which bypasses the topography. The well is located in the area of greatest slope so that the waterfall generates enough force to move the horizontal wheel. The position and length of the millrace result from the position of the pond and the well according to the topography. The system is further optimized with the mill's proximity to the river for the immediate return of the water to the natural course.

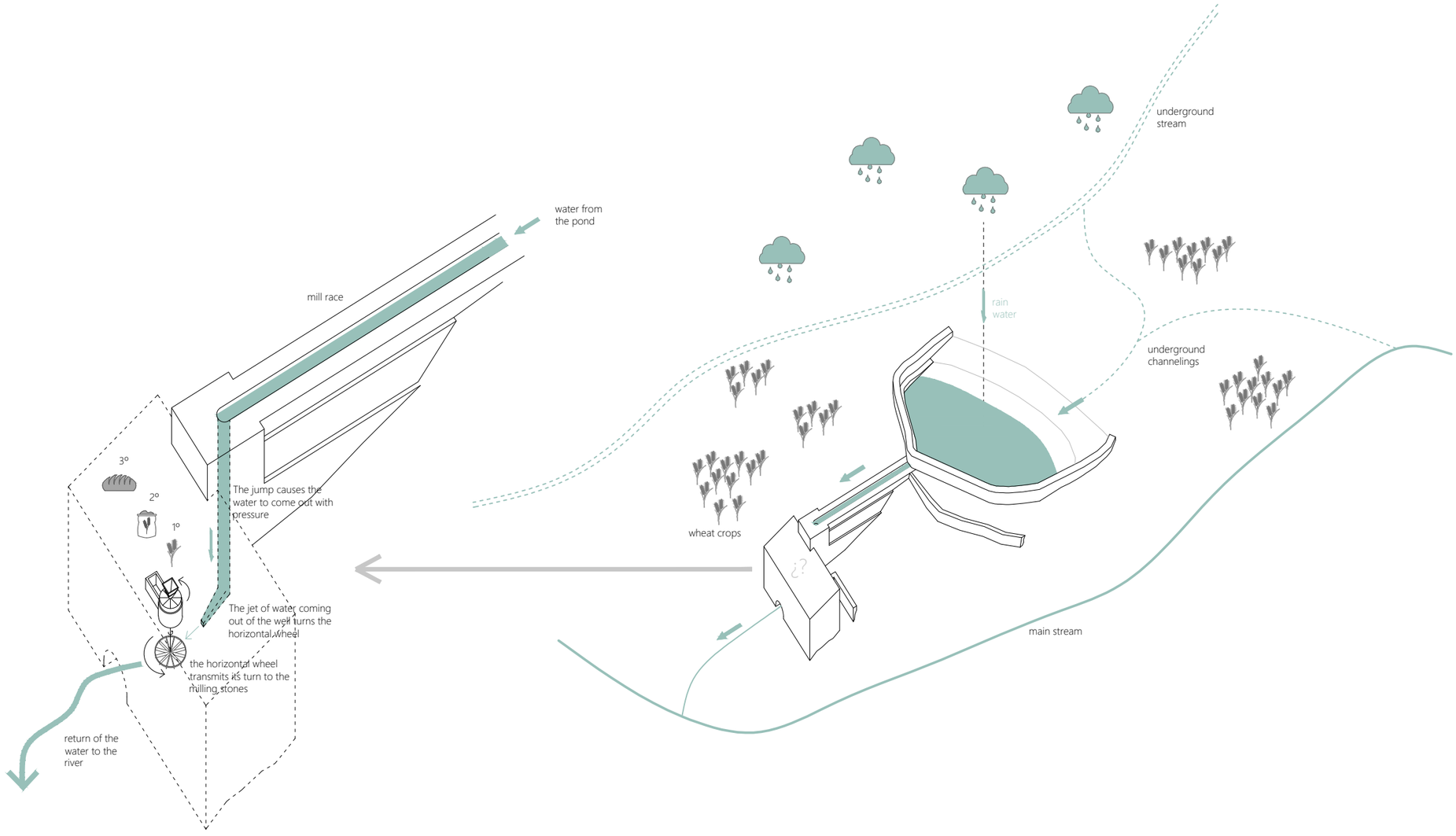
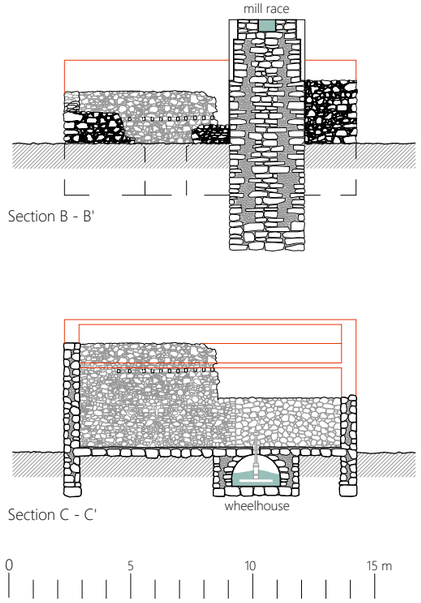


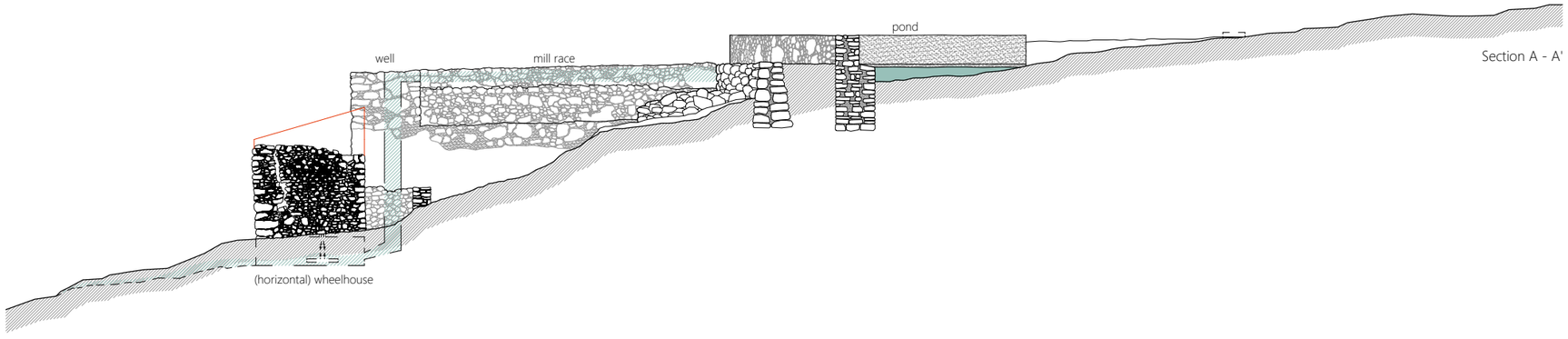
Figure 11 Functional diagram of the mills.

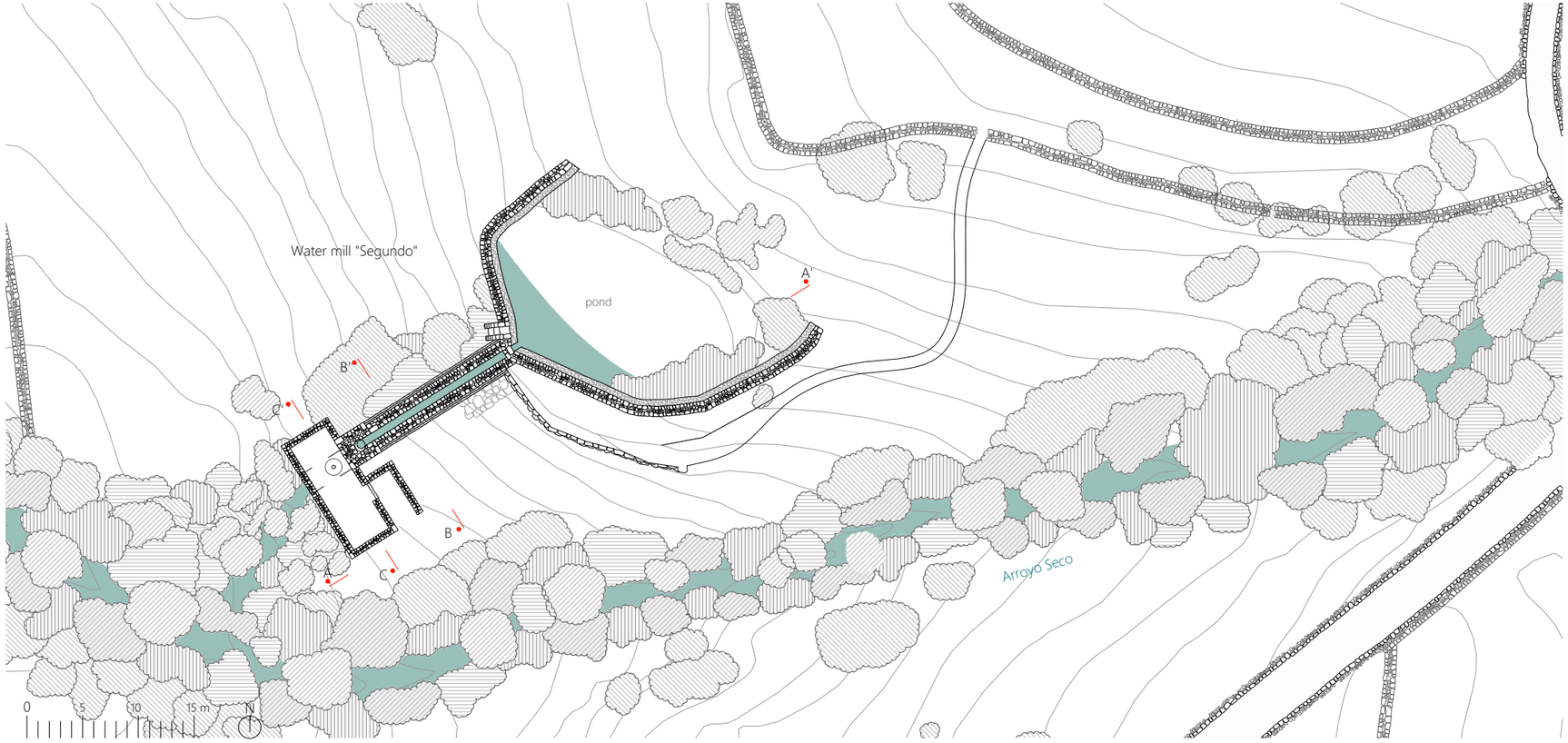
Water mill "Segundo".

This milling infrastructure works like a hydraulic dam and constitutes the necessary structural support, arranged on the ground, from which the mill is built.

Figure 12 Section of the Water mill “Segundo” (left & top)
Figure 13 Plan of the Water mill “Segundo” (right)







Conclusion.

Although these anonymous architectural interventions are not exactly dated, it is known that they already existed in the Middle Ages, when the lordships hoarded the production and transformation of crops, so the mills also served for territorial and social control. It is from the eighteenth century when the presence of mills is more pronounced in the Sierra de Cádiz, and they continued to operate in the Sierra de Cádiz until the 70s and 80s of the twentieth century, a singular fact if one takes into account that in the rest of the country, due to technological innovations (Austro-Hungarian milling system), the traditional mills were disappearing at the beginning of the 20th century.

In short, the orographic and hydro-graphic conditions of the region and its mountain character have determined a socioeconomic development supported by livestock, agriculture and grinding. Grinding or milling is a cottage industry based on the use of rivers and the circularity of water. It has a great importance and presence in the region: the architectural impact of this activity is evident in the number of buildings that existed and still exist in the region. Origin of life and culture, the mills have also generated roads and paths, and have coexisted in symbiosis with the nearby villages and with other rural constructions.
They are architectural interventions of the past, lethargic, but from which we can learn a lot because they treasure a very different set of values:

Landscape Values - The paths that connect the mills form a network of rural roads that go through the entire Sierra de Cádiz and help its route.

Strategic values - The mills reveal with its positioning the optimum enclaves to achieve maximum profitability with the minimum resources and infrastructures, by taking advantage of natural elements, topographic changes, slopes, river bends...
Functional values - Since they are architectural interventions with simple formal and constructive solutions, mills are buildings constructed with precision and logic; in them, each space serves a specific function.

Material and tangible values - The mills are a source of knowledge about traditional construction techniques and use materials from the surrounding area that adapt to our climate and lithology: masonry based on the limestone of the area, mortar, lime, wood, straw, mud...

Values of sustainability and circularity - They use elements of the surroundings and non-polluting materials. In the case of these mills, water is the driving force. It is also used to irrigate surrounding crops and gardens, and is returned to the river once the mill mechanism has been activated. In this way, a pseudo natural circuit perfectly integrated into the environment is created.

Ethnographic and identity values - The mills encompass the knowledge of what was one of the main activities of the region, grinding with water.

Lessons to Learn - This study shows how in this southern region of the Iberian Peninsula, milling was not only a way of subsistence and flour and bread production, but also of sustainable management of the region's natural resources. The number of mills and their position in the territory show the balance between demand and production that characterized the places that were self-sufficient and that lived off the surrounding lands. Although obsolete, this traditional water system preserves many lessons that can be useful for today's society and for the contemporary landscape project.

It is an example of using renewable and non-polluting energy, since the mills used the driving force of water to grind grain. In addition, they used recycled or recyclable materials from the area surrounding for their construction, as currently required by the Triple Zero® concept: Zero Energy Building, Zero Emission Building; Zero Waste Building. They show how a powerful hydrographic network can be profited, where the rugged topography did not allow other productive uses of the land. At the same time, they teach us to optimize rural infrastructures, since the ditches or ponds that were built to bring water to the mills were also used in agricultural activities, and the roads that led to the mills were also livestock trails. They are architectural interventions that dialogue with their natural support, integrating themselves in a sensitive way in the territory, and that were built in a rational and logical way to solve the needs of the society of a certain period, and that is a lesson we should not forget.

Although the mills are in ruins, their renovation could reactivate them and involve them, from a new perspective, in the development of the region; they could become space containers that would house ethnographic activities related to milling and landscape projects in the region, whose environmental values have earned them international recognition as a Biosphere Reserve by UNESCO.

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Project 2 - The water mills of Sierra de Cadiz

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