h2o Map

methodological guide

Co-funded by the Erasmus+ Programme of the European Union

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UNIVERSITAT JAUME I

UNIVERSITÀ DI PAVIA

Universitat d'Alacant

High Schools:

I.E.S. PENYAGOLOSA

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AGRUPAMENTO DE ESCOLAS Nº3 DE ELVAS

agrupamento de escolas campo maior

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- Cátedra Diputación de Castellón de Centros Históricos e Itinerarios Culturales
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Methodological Guide

Innovative educational tools for the enhancement of the hydraulic heritage through the use of new technologies. Techniques and methods for teachers, researchers and young workers.

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PART I

HYDRAULIC HERITAGE

I - Module 1
Introduction

I - 1.1 Project presentation

Promoting new forms of teaching and learning using new technologies and enhancing knowledge of the hydraulic heritage is the main objective of the “H2OMap: Innovative Learning by hydraulic heritage mapping” project funded by the European Community within the Erasmus + KA2 Project (strategic partnerships in the field of school education).

The Jaume I University of Castellon de la Plana (project coordinator), the University of Pavia, the University of Alicante, together with four secondary schools from Spain, Italy, and Portugal (Institute of Secondary Education IES of Penyagolosa, Higher Technical Institute and Training ISTF, Post Basic Training Courses AECM, and Higher Education Institute AEN3) collaborated to create innovative and suitable tools to pursue the set objectives.

H2OMap presents a tool for the analysis and cataloging of the hydraulic heritage. The target audiences are high school teachers and students, who can develop new skills in the field of information and communication technologies (ICT) and at the same time promote knowledge of the hydraulic heritage and its role in the development of the technique, of the economy and the territory.

H2O Map PROJECT OBJECTIVES

Enhance the European hydraulic heritage

Increase STEM interest (Science Technology Engineering and Mathematics);

Improve skills with ICT tools (information and communication technologies)

The richness of this project is in its interdisciplinarity; the humanistic skills related to historical heritage are combined with the technical ones of hydraulics and scientific ones for the mapping and identification of places.
The technologies developed are mainly two: a mobile application that students can use to perform data analysis (geolocation, photographic collections, etc.) and a platform to create interactive maps and historical maps of all the identified hydraulic heritage.

For the tools to be used easily in schools, the three universities involved have also developed an online course dedicated to teachers, which explores different aspects, including the value of water assets, new technologies for teaching, innovation in the educational field, use of the application and the platform.

Numerous European cities arise and develop by confronting the water, creating a relationship that blends the morphological order with the elements of the landscape and the water. Awareness of the city’s potential, if all available hydraulic resources were to be exploited, is unfortunately still too little. We believe that the realization of this innovative project will allow the recognition of what already “belongs to us” and of which we should have more awareness.

The partnership between universities and secondary schools offers a further opportunity for common growth. It brings high school students closer to the world of research and university education, allowing them to experiment with new forms of knowledge, that will help them in the future to make more informed choices for the continuation of their studies.

The project also offers high school students the opportunity to feel involved with their peers from other countries in the knowledge and protection of the natural and cultural heritage that unites us and that we share as European citizens.

In addition, this project aligns itself with the objectives of the 2030 Agenda for Sustainable Development, raising awareness, not only on a cognitive and scientific level but also on ethical and civil responsibility.

Cultural landscapes illustrate the evolution of human society and its settlement over time. Several international declarations (Council of Europe, 1975; UNESCO, 1976; ICOMOS,1987) have echoed the importance of public opinion and the need for conservation work to be socially progressive (Council of Europe, 2006: 72).

Focusing on the hydraulic heritage, this is a legacy generally forgotten, and therefore The United Nations dedicated the decade from 2005-2015 to the action "Water for Life", and the EU has launched the action "Blueprint" to protect and safeguard Europe's water resources.

In addition, in 1998, the Committee of Ministers of the Council of Europe underlined the relevance of Cultural Heritage Education indicating that educational activities in the heritage field are an ideal way of giving meaning to the future by providing a better understanding of the past. Even if no specific reference was directly made as far as the use of ICT for supporting and enhancing cultural heritage education, in the following years, the opportunity to exploit the high potential of ICT emerged, and nowadays it is fundamental to enhance the artistic and cultural heritage and its protection. In 2015 a study from the European Foundations concluded that more than 90% of Europe's heritage has not yet been digitized.
It is, therefore, a challenge to establish a digital environment for sharing community-developed data and tools, recognizing the enabling role of the ICT in the implementation of cultural heritage policies.
On the other hand, the EU warns that "employment of STEM

skilled labor in the European Union is increasing and around 7 million job openings are forecast until 2025."
However, negative attitudes and lack of interest in STEM are two of the main problems to be addressed (Fensham, 2006).
In fact, "between 50-80% of students in the EU never use digital textbooks, exercise software, simulations or learning games" (EC, 2013).
In addition, while 70% of teachers recognize the importance of training in digital-supported ways of teaching and learning, only 20-25% of students are taught by digitally confident and supportive teachers (Digital Agenda, 2012).

Finally, it is important to highlight the value of water as an essential natural element for life.
Access to water was declared a fundamental human right (UN, 2010) and is directly addressed in several Sustainable Development Objectives (SDGs), especially the 6th (clean water and sanitation). Therefore, it is essential to promote the culture of caring for the environment and the value of the environment among citizens.

H20Map, thanks to the video tutorials for teachers, the methodological guide, the database of the cards already cataloged, is open source and can be used by other European high schools using the platform created.

Improving ICT (Information and Communication Technologies) skills in the digital age is essential for new teaching models. For this reason, this intellectual production is focused on the preparation of an easy-to-use manual that helps teachers in acquiring knowledge on innovative ICT-based educational techniques and methods through the enhancement of heritage, in particular water heritage. Furthermore, this result will provide forward-looking information on these relevant aspects specific to each of the participating local regions.

I - 1.2 Topic presentation

"The presence of water confers identity to the earth "

"The presence of waterways gives geo-cultural specificity to every geographical context "

Christian Norberg Schulz

Paying attention to the freshwater network should be considered a civic duty both for the importance of water as a common good and the knowledge and protection of the tangible and intangible heritage historically connected to its functions. Natural or artificial watercourses play a great geographical role: they are capable of conditioning or promoting human activity, permeating the territory, its development, and its cultural characteristics.

The study and comparison of representations for the analysis of the hydraulic heritage, from historical maps to the most recent georeferencing systems, allows us to read the territorial processes. These are linked to the water landscape and have made it the container of important collective identities. Knowing the canals and rivers of the territory allows us to decipher its urban and rural history, in terms of defense, trade, transport, and agricultural and industrial development.
The navigable routes, internal and connecting the urban realities, have permeated the built environment, marking it with huge works of which towpaths, bridges, locks, central, and stopovers are examples. This network of elements, less known than the large rivers, has now lost part of its functions, while maintaining a high potential, in terms of extension and connection in the territory.
The value in use must also be combined with a historical and

architectural value, linked to the planning and construction of this mesh and its engineering works; as well as an artistic and social value, which places the huge system at the center of even intangible heritage. Considering the importance that these canalization works assume for the geographical context on which they insist, the need arises to know and communicate this heritage, so it is possible to have full knowledge of it and promote its common protection and enhancement.

I - 1.3 Presentation of the method

The methodological guide is a practical manual that helps teachers promote an innovative teaching activity structured to improve knowledge through specific tools. These also enhance students' ICT and STEM skills. In this way, the project also promotes learning Project-Based Learning (PBL) and Learning-by-doing methodologies.

Beneficiaries of the project are a plurality of users, including researchers who evaluate the hydraulic heritage in historical and contemporary places; the next generation of citizens; politicians and administrators in the area; conservatives, technicians, urban planners, engineers, technicians, and social scientists. The goal is to analyze the interdependencies between physical conservation, social awareness, and sustainable development of a specific heritage through digital learning tools.

H2OMap creates a new relationship between social issues such as culture and heritage with physical elements (geography, biology) through STEM and ICT.
This intellectual production offers tools to enhance heritage, meanly water heritage in Europe. Three case studies have been developed in three different countries to have a broad view.

Teachers will have access to innovative and high-quality materials. They will also contribute to the review of the material itself, ensuring the relevance of the content for workshop participants (LLTA - Learning, Teaching, Training Activities).

I - Module 2
Hydraulic heritage and its importance

WHAT IS HYDRAULIC HERITAGE?

The numerous international activities related to water do not present specific definitions for the different macrosystems that make up hydrography. First of all, it seems appropriate to consider that the term “liquid assets” is valid for fresh and saltwater systems. The H2OMap project will not deal with saltwater systems, if not through marginal comparisons. Instead, the project will investigate the freshwater system, its relationship with the city, and the relationships between the elements and sub-categories that constitute it. A further terminological distinction appears necessary to eliminate any confusion in subsequent reading: although there is no univocally recognized definition, through the reading of national /European/global laws and programs, it is possible to orient the lexical choice and consequently propose a simplified classification of the heritage inherent in water.

Water Heritage
It includes all the waters of the planet, emerged or underground, fresh, and salty. It is used talking about sustainability, climate, and resource depletion.

Hydraulic Heritage
It includes all the artifacts and artificial works closely related to water: therefore, the architectural, mechanical and engineering systems relating to the water resource, but not the water itself, are part of the hydraulic heritage.

I - 2.1 The definition of heritage

The choice of the project is to focus attention on artificial artworks and artifacts associated with the use and control of water, as defined by the English term Hydraulic Heritage.
The term "heritage" indicates the complexity of assets, which are of public interest due to their historical, cultural, and aesthetic importance. There are two types of heritage: tangible and intangible., they constitute the wealth of a place and its populations.
Speaking of hydraulic heritage:
the tangible hydraulic heritage is the set of engineering elements, which can differ according to places, linked to the use of canals and waterways for a community. Bridges, minor artwork, such as locks or vents, are examples of tangible hydraulic heritage. These elements perform a specific function and therefore are indicators of the current or historical use of the canal on which they stand.
Instead, all the cultural practices connected to a specific water system belong to the intangible hydraulic heritage and are identical for the surrounding community.
Cultivation techniques based on the controlled use of water (e.g., rice cultivation techniques) or methods of mechanical energy production (e.g., the study of the functioning of mills) are an example of intangible hydraulic heritage. This heritage has repercussions on the territory and the economic and social context.
Heritage, in its complexity of tangible and intangible elements, poses the challenge of its proper management and conservation. Europe and its Member States undertake to ensure its maintenance and to be able to pass it on to future generations, through a series of EU laws and treaties. An example is a Treaty on the European Union which highlights, among the priority objectives of the EU, the commitment to respect "the richness of its cultural and linguistic diversity and [to supervise] the safeguarding and development of the European cultural heritage" (article 3 European Union Treaty).

I - 2.2 Why do we preserve?

Heritage conservation practices are subject to continuous updates to ensure homogeneity, control, and efficiency of intervention methods on common goods at a European level. Artifacts, architecture, landscapes, and intangible elements (music, folklore, etc.) have a fundamental identity and historical importance for the society to which they belong. This importance justifies the many European conservation policies. Preserving heritage means recovering the memory and identity of peoples and guaranteeing their perpetuation for future generations.

The UNESCO World Heritage Convention

UNESCO, United Nations Educational, Scientific and Cultural Organization, is a United Nations Agency founded in 1945 to promote peace and understanding between nations through Education, Science, Culture, and Communication.
Among the activities promoted is the 1972 World Heritage Convention for the protection of Cultural and Natural Heritage. The Convention was born in opposition to the big and neglected construction works of the 1960s, due in many countries to the post-war economic boom. The Convention places knowledge as a necessary tool for tragedies prevention and the fruitful cultural exchange between peoples. It is the first international instrument that contains the notions of "nature protection" and "conservation of cultural heritage". These are recognized as fundamental elements for the development of societies around the world. The Convention aims to safeguard the heritage for future generations.

Why is it necessary to preserve the cultural and natural heritage?

The cultural and natural heritage undergoes different alterations over time, losing its qualities: degradation can depend on climatic, meteorological, biological, and hydrogeological phenomena, but also environmental

pollution and direct damage caused by man.
The natural or cultural sites registered on the World Heritage List meet specific requirements established by the Convention itself, which provides guidelines for their use and management. The nations that sign the Convention, Member States, have the duty to protect the assets present on their territory.

European policies for heritage conservation

European heritage policies are constantly updated to ensure the correct management of community assets, whether tangible or not. In 2017, to invite the knowledge and enhancement of heritage, the European Year of Cultural Heritage was defined (Decision (EU) 2017/864 of May 17, 2017).
All forms of heritage must be considered a shared resource, so it is necessary to promote a collective sensitivity that strengthens the sense of belonging to a common European space. To enable the achievement of the knowledge and promotion objectives, the EU arranges funds to support cultural heritage, inviting the submission of cooperation projects under the "Creative Europe", Erasmus +, Europe for Citizens, and Horizon 2020 programs.

Why safeguard the Hydraulic Heritage?

Preserving the hydraulic heritage allows, on the one hand, to guarantee its visibility (or usability if we are talking about intangible hydraulic heritage) for subsequent generations; on the other hand, to rediscover and recover the identity characteristics of a space and therefore of a people. In this sense, rivers and canals become cultural corridors. Starting from these water systems, it is possible to analyze landscapes and cities and reconstruct anthropic structures and relationships, typical of each geographical context.

I - 2.3 How do we preserve?

The quantitative and qualitative changes inherent in the management of the Heritage over time are discussed here. The growing interest in heritage conservation and census has collided in recent decades with two giants of our time: globalization and the digital revolution. The sub-paragraph intends to mention these two concepts, which will return in a more specific form in the following chapters, highlighting their positive effects and related difficulties.

The safeguarding of world heritage is today managed by decision-making, technical and advisory bodies, specially prepared. These include the General Assembly of the States Parties to the Convention, the World Heritage Committee, the World Heritage Center, the International Union for Conservation of Nature and Natural Resources, the International Center for the Study of the Preservation and Restoration of Cultural Property (ICCROM) and the International Council on Monuments and Sites (ICOMOS).

The conservation of the Water and Hydraulic Heritage is a topic widely discussed today, yet recently discussed. Water is the fundamental resource for life on the planet; its first structured use by man takes place for agriculture, using complex irrigation systems dating back to the fourth century BC. During the last fifty years, the phenomenon of globalization and the growing demand for production has led to a progressive depletion of this resource, a condition for which the World Commission, since 1987, has paid particular attention it.

Specific international orders and councils were born to raise awareness and involve governments, organizations, and companies in policy promotion for the world's water heritage protection and enhancement. The contemporary importance of waterways, also motivated by their ability to counteract the growing overbuilding, invites us to rethink them as significant spaces for the territory and its inhabitants. Among the actions aimed at the conservation, census, and re-appropriation of waterways, UNESCO endorsed the

worldwide network of water museum initiatives.
The museum water network, together with other European or global activities, aims to improve the management of water resources through knowledge dissemination relating to water and its use. To reach as many people as possible it uses websites and web platforms.
In this sense, the digital revolution we are witnessing allows us to benefit from fundamental supports, such as mass communication tools but also poses renewed challenges in terms of conservation, knowledge, representation, cataloging, and digital management of water and plumbing systems in the area.

Digitization as a preservation tool
The ability to document heritage, creating digital duplicates, is today a fundamental tool for understanding state of the art and the means of communicating it and making it accessible to all. In this regard, the European Commission in January 2021 inaugurated a European competence center that would establish a collaborative digital space for heritage conservation. According to these needs and EU values, H2OMap aims to promote the use of ICT as a driver for systemic change to increase the quality of education, highlighting the importance of hydraulic historical heritage as a tool for remembering the past, understanding the present, and building a more inclusive multicultural Europe.
To achieve this, H2OMap addresses five target groups:

-High school students (TG1)
-High school teachers (TG2)
-Project participants (TG3)
-Stakeholders (TG4)
-Citizens (TG5)

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For further information, please visit

- EU website (https://europa.eu/european-union/index_it)

- UNESCO (unesco.it)

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- Accordo di Cotonou

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- Fondo europeo per lo sviluppo - FES

- Relazione AEA 1/2012: Towards efficient use of water resources in Europe (Verso un utilizzo efficiente delle risorse idriche in Europa)

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WATER AS A RIGHT

Water is a resource that renews itself but is not infinite, and cannot be reproduced or replaced. Freshwater makes up about 2% of the planet's water resources, and it is estimated that by 2030 the global water demand may exceed actual availability by 40%.

Water is a chemical compound whose molecular formula, indicated by the acronym H2O, and is the bond between two hydrogen atoms with an oxygen atom. This compound in nature occurs in three different forms, liquid, gaseous, and solid, depending on the temperature and pressure conditions. Commonly, the term "water" refers to the element in its liquid state, the origin of life on our planet, the fulcrum of natural ecosystems and climate regulation, and an essential resource for humanity from the civil, social, agricultural, and industrial development.

The Resolution of the United Nations Assembly 64/92 of 28 July 2010 recognized that the "right to drinking water and sanitation is an essential human right to the quality of life and the exercise of all the rights of man".

I - 2.4 The value of water

Historically, the first human settlements arose near rivers and freshwater sources, essential for survival. With the development of societies and cultures, we saw the definition of specific construction processes for the organization and management of the collective water resource. From agricultural channels in Egypt and Mesopotamia to Roman aqueducts in Europe, the architectural and engineering works of water control and transport have made it possible to establish residential areas even at a distance from primary water sources.
To date, the diffusion of water networks in the world has different capillarity in different continents. In Europe in the thirties of the twentieth century, the need to guarantee universal access to water resources became a priority, for hygienic and humanitarian reasons. The same cannot be said in developing countries. In the latter, the lack of public economic resources does not allow the right to water to be effective as a fundamental human right.

I - 2.5 The government of water

European State of Art

The use of water resources by man extends to an areas wide variety, from agriculture to transport to industry. Population growth and the response to the needs of production sectors progressively increase water use, reducing the resource quality. To cope with this condition, Europe has worked over the years by implementing multiple long-term strategies for water resources protection. The European water policy is updated and improved over time, considering the accounting, and therefore the census, of water resources and water efficiency, concerning precise standards for water reuse, to ensure an adequate water supply from a qualitative and sustainable point of view.

In this sense, following the European Framework Directive on Water (Directive 2000/60 / EC - Framework Directive on Water -

WFD), governed by international agreements and integrated with specific rules, the Plan for the protection of European water resources was presented (Brussels, 14.11.2012 - COM (2012) 673 final). The Plan highlights the characteristics relating to the different aquatic environments within the European Union, promoting, at the management and safeguard level, an improvement methodology which considers the peculiarities of each situation. The different water resources management problems concern ecological, chemical, pollution, and water efficiency aspects, often intersecting each other. For this reason, the European objective of achieving a “good state of water” (Plan for the protection of European water resources, Brussels, 14.11.2012 - COM (2012) 673 final) favors solutions capable of consequently solving more difficulties simultaneously.
The particular attention paid by the European Commission to freshwater is motivated, proven by statistics and monitoring developed within the Member States, in the evidence of increasing exploitation, due to urbanization, economic activities, and population growth, to which these are subjected.

Water in UN strategies

Today, 76 years after its foundation, there are 193 member countries of the United Nations which, in compliance with the statute, are committed to activating fruitful cooperation to solve international problems and promote respect for human rights. The objective of the United Nations is to provide strategies and means to support conflict resolution and the development of suitable policies on issues of global interest. In this sense, in 2015 a program was drawn up for the prosperity of the planet and the promotion of sustainable practices to be adopted in the conduct of human activities: the 2030 Agenda.

The 2030 Agenda sets 17 Sustainable Development Goals launched in 2016 and to be achieved within the next 15 years. As evidence of the importance of water resources for the planet, six of the 17 total objectives concern water. Objectives 6 and 14 are specific on the topic:

GOAL 6: CLEAN WATER AND SANITATION. *Ensure the availability and sustainable management of water and sanitation facilities for everyone.*

GOAL 11: SUSTAINABLE CITIES AND COMMUNITIES. *Spreading a more sustainable culture and replacing current energy sources with green alternatives.*

GOAL 14: LIFE BELOW WATER. *Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.*

The additional objectives that promote good practices for water management are goal 1 for natural resources, goal 3 for the abatement of pollution on air, water, and soil, goal 7 for clean energy, and goal 13 for combat climate change and its consequences. Despite efforts to achieve universal access to water as a human right, economic difficulties, legal shortcomings, and an appropriate cultural approach remain between the will and the actual realization of the process at a global level.

THE CHARACTERS OF HYDRAULIC SCIENCE

LEONARDO DA VINCI

«This (the water) is never quiet until it reaches the sea, where, no longer disturbed by the winds, it stands still and rests with its surface equidistant to the center of the world».

Leonardo began to devote himself to hydraulics studies during his stay in Milan. He studied the San Marco Naviglio area, creating a project to connect the Martesana Naviglio to the internal canals through two locks. This project would have made it possible to cross Milan by boat and connect the Adda river with the Ticino river. Leonardo contributed to the technical evolution of the navigation locks by inserting a lower maneuverable hatch inside them, to manage water flow. During the Milanese period, he developed in the agricultural field the irrigation technique of the water meadows. This technique allows a greater number of crops.

Even during his short stay in Venice, Leonardo collaborated with the Republic of Venice to make the Brenta river navigable and avoid flooding.

Some of Leonardo's hydraulic projects consisted of diverting rivers and were particularly ambitious and futuristic, as evidenced by his writings.

Leonardo studied the true nature of water, its origin, dynamics, optical effects on the surface, and other peculiarities. He designed machines for hydraulic energy exploitation, lifting of water, and drainage of marshy land. Studying the motion of water, Leonardo concluded that, over time, the earth would be submerged by the sea, becoming uninhabitable.

The continuous research on the subject led Leonardo to the first studies on fossils. These analyzes allowed him to theorize the impossibility of the Great Flood.

THE CHARACTERS OF HYDRAULIC SCIENCE

JERÓNIMO DE AYANZ

Jerónimo de Ayanz is called the Leonardo Da Vinci of Spain. Da Vinci was born in the middle of the 15th century and Ayanz a century later. There is no evidence that Ayanz knew about Leonardo's manuscripts. However, Ayanz stayed in Milan for a long time during his military career, and he resolved with originality some questions that Leonardo had left open.

Different from Leonardo's time, Jerónimo could patent his inventions after having tested them. He has produced many drawings that deepen his studies with high level and detail elaborates.

He invented many tools: a pump for draining ships; a precedent of the submarine; the compass that established the magnetic declination; an oven for the distillation of seawater; irrigation pumps; the arch structure for the reservoir dams; a movement transformation mechanism to measure "motor torque".

THE CHARACTERS OF HYDRAULIC SCIENCE

HENRY GASPARD DARCY

Henry Philibert Gaspard Darcy was a French engineer who made important contributions to hydraulics.
Among his works is the impressive, pressurized water distribution system for freshwater supply in the city of Dijon. The system allowed water to be transported from the Rosoir spring 12.7 kilometers away through a covered aqueduct to the basins near the city.

Darcy was principal director of Water and Pavements in Paris, where he developed his hydraulic research. In particular, he studied flow and friction losses in pipes. Between 1855 and 1856, following various experiments, he established what is now known as Darcy's law. The law, originally developed to describe the flow of water through sand, has been replicated in a lot of situations and is now used to calculate the resistance of any flow in porous media.

WILHELM EDUARD WEBER

"The speed of the waves in no way depends only on the width as Newton, Gravensande, D'Alembert and recently Gerstner stated, but also on their size, that is their height and width together ... According to our experiments, the speed of the waves decreases as the depth of the fluid decreases."

The weber is, in his honor, the unit of measurement in the International System, with the symbol Wb, of the magnetic flux.
The German scientist was able to calculate the proportionality factor between the electromagnetic and electrostatic units, demonstrating it close to the value of the speed of light, from which J. C. Maxwell took inspiration to formulate the theory of electromagnetic waves.
From this description of Weber's activity it does not seem possible to grasp connections with the themes of hydraulics, and his book is in fact little known in the hydraulic literature, although it contains a detailed account of what had hitherto been written on the motion of wave and a broad panorama of new observations.

Weber, in many experiments on the behavior of waves, used a tank with glass walls, very long and narrow, which allowed to investigate the phenomena of reflection, interference,
orbital motion and shape of the profile, using, in addition to water, mercury and brandy!
For lack of precedent, many of Weber's experimental techniques were as ingenious as they were absolutely novel; for example, he used to sprinkle flour on the free surface of the fluid by applying a thin slate to the edge of the tub, or he sprinkled the slate itself with poor white powder which was then removed by the wave motion; in this way he could examine the traces of the wave behavior in the different experiments, 'photographing' the continuity of the motion.

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I - Modulo 3: Anthropogenic action and water: past, present and future

In book VII of Aristotle's Politics, the author describes the ideal city according to his thought and analyzes the best conditions for choosing the place to place it. One of the 4 conditions it identifies is linked to the presence of water:

"Sources and streams of water in large numbers would also be extremely opportune, the lack of which can be remedied by building innumerable and capable basins for the collection of rainwater, so that water is never lacking even when the territory metropolitan is isolated from the rest of the region by a war. Because you have to think about the health of the inhabitants, for which the first condition is that the locality is in a healthy and well oriented place, the second that there are healthy waters, even this matter must be taken care of with care. "

(Aristotle, Politics, Book VII)

NUMBERS

4 billions
of people live in areas characterized by severe water scarcity for at least one month a year

1,6 billions
di people face a shortage of "cheap" water (water is there but infrastructure is lacking)

*Over **2 billions** people live in water-stressed places*

3 billions
people don't have adequate access to hand hygiene facilities

I - 3.1 Why water?

Water is straight. Source of life, water is a good that belongs without discrimination to all living beings on Earth. Its limitation presupposes its safeguarding and recognition of its value as an essential natural resource for the survival of our planet. Universal access to water is a social right and is an essential condition for the enjoyment of human rights. (A, 2010)
Water is democracy and participation. Water management must aim at interventions that are inclusive and participatory. Water is an opportunity to rethink urban places, territories and infrastructures. Its artistic and design dimension can trigger urban regeneration processes based on the themes of sustainability, protection and social inclusion. (EU, 2000)
Water is the future. The scarcity of water resources on a global level is the main threat of our century, in which climate change and the constant increase in population represent the aggravating circumstance. The future of the entire planet depends on responsible management of this resource. The first step is awareness, the second is action.
It is time to act.

80% of industrial and municipal wastewater worldwide it is released into the environment without prior treatment

230 million people they take ***over 30 minutes*** per trip to collect water from sources far from their homes

30% of the main aquifers are in a state of decay

829 million people die each year from diarrhea after using unsafe water and sanitation facilities

Source : Corriere della Sera, March 22, 2021

I - 3.2 The culture of water

In ancient Egypt, the intermittent floods caused by the Nile River represented a divine event (Hapi - god of the annual floods of the Nile). The water that crossed the riverbed bathed the neighboring territories, ensuring the life of the inhabitants and making the soil fertile for cultivation. The population, in recognition of that gift, offered him hymns and prayers. It was not just a source of life and transportation, but also it was a sacred resource. The Ganges River in India is still sacred to Hindus today. Bathing in the Ganges grants forgiveness for one's sins and leads to salvation. It, therefore, represents an important place for the inhabitants where sacred buildings overlook and many activities related to water take place. Water is an object of narration and mythology in many sacred texts, such as the story of the universal flood described in the biblical text, in which Noah's Ark takes on a saving value, thanks to which Noah manages to save himself from the flood. And again, Poseidon, god of the waters, is a mythological figure narrated in Homeric poems, characterized by the trident as a symbol of his power over the waters. Water is an indispensable element for the birth of a city, and pleasure and benefit, as in ancient Greece. But it was also the case of the Romans who built aqueducts to bring water to the cities (for example, about 800 km of pipelines were built to feed the city of Rome) and who introduced elements of well-being, environmental quality, and health such as fountains, spas, and public churches. The baths represented the maximum place of the sociality of Roman culture, where people met, discussed, and did business in an environment of well-being.

Many of the river and coastal cities find their location thanks to the presence of this resource. The sea or waterways allowed the transport of goods, the defense of the city, and survival. From the great Greek and Roman ports to the inhabited bridges of Venice to small artifacts, water places often evoke their public vocation. Water represents, therefore, an area of profound cultural reflection, as a natural element that has always accompanied man's life and has outlined his lifestyle. The water factor was predominant in the settlement processes of the past, and although in a different form it still is today. In maritime and river civilizations, fishing, trade, and defense have defined an urban structure developed along the coast and rivers, thus remodeling the water-land border, which has generated a new landscape of relationship between artifice and natural landscape in which the water is the protagonist. For protection or supply, humans have had to develop various precautions over time: from the conveyance of rainwater into crops, drainage systems, canalizations, reclamations, deviations of natural courses to dams, and so on, up to the roof of your home. Systems and artifacts, first in wood, and stone, then in concrete, metal, and plastic, have characterized the places to live. Between threat and resource, water has always been an element of fear and blessing at the same time, but man has always been able to recognize and grasp its indispensability by translating it into different symbolic connotations, becoming a source of inspiration for art, literature, and architecture.

WATER IN THE OLD TESTAMENT

In the beginning, the book of Genesis tells us how water was omnipresent before the creation of the universe. Originally hostile to God, it had to be tamed. God created the firmament, thus dividing the waters, thus the dry land appeared. The dry land he called it Earth, the waters, the sea. In the "passage" of the Red Sea, God saves his people from the Egyptians by exercising his power over the waters. Water as rain takes on a double meaning in the Bible: sometimes a sign of divine punishment, as in the universal flood, sometimes a sign of blessing. Rain of blessing that at the right time irrigates the ground. On the contrary, lack of rain is divine punishment, as Solomon reminds us in prayer. Water like dew is also a blessing. Water like hail rages against God's enemies. Hail was the seventh plague with which God punished Egypt, devastating the vineyards.

According to the sacred text, water is a purifying resource, it heals from disease and impurity, it is a fundamental tool for cleaning and hygiene. We are reminded of the episode of King Naaman, who, ill with leprosy, under the advice of Elisha, bathed seven times in the Jordan. It was thanks to these baths that the Armenian king healed, his body was purified.

Finally, the Bible reminds us how water is an essential resource for human and animal life, thus representing a right for everyone and which morally commits us to supply the neediest, but not only, even enemies.

I - 3.3 Conflicts with water

On 9 October 1963, between the regions of Veneto and Friuli Venezia Giulia in Italy, more precisely in the Vajont valley, millions of cubic meters of the mountain fell into a basin of water at 100km an hour. Overcoming the dam, a wave 250 meters high overlooked the territory destroying entire villages. The “Vajont disaster” lasted 4 minutes. One of the mountains on which the dam rested, Mount Toc, presented an ancient landslide that was kilometers wide: the slopes of the basin built by the SADE (private electricity company) were not suitable because they were at hydrogeological risk. It is in the Vajont area that water takes on a significance related to a precise historical moment. The water, tragically sweeping entire villages, created a link between the event and the memory of the place.

Many times the power of water has fallen upon humanity from the myth of Noah to the great floods and floods, water has recaptured the territories, swallowing cities and inhabited landscapes. Water, as in the case of Vajont, represents a fundamental element in the relationship between man and nature. Man must continually seek. Today, climate change, mainly due to human behavior, poses enormous challenges, such as stemming the rise of oceans and desertification, processes that are already underway and put our security at risk. The greater vulnerability of diversified territories is worrying: variations in rainfall will have repercussions on agriculture, increasing hunger in countries already at risk of malnutrition; in southern countries, there will be a shortage of water and in the nordic countries an excess. The increase in the temperature of the water flowing on hot surfaces is destructive to aquatic flora and fauna. The high waterproofing of the soil leads to more and more frequent flooding in our cities, causing economic repercussions.

The increasingly strong heat island effect in cities causes a significant rise in temperatures with direct and indirect consequences, both the health of people and the balance

of the natural environment by altering the natural growth cycle of vegetation in urban areas.
The repercussions that climate change has on the territories are transforming the water issue into urgency. The challenges of our time are to understand the value of water for territory and our life and restore a new balance between nature and artifice, between water and anthropogenic action.

I - 3.4 Return to the water

The functionalist approach of the last century has had repercussions in the urban environment, fragmenting cities and stripping away the identities of places, and in the water resources management, introducing merely practical concepts, unable to make territories and cities resilient, unsustainable practices at any latitude. From the renewed environmental awareness, contemporary approaches provide urban regeneration processes that can be activated through natural resources intended as opportunities for relaunching, socializing, and protecting the environment. Examples of canal restoration and waterfront redesign of the last ten years demonstrate the desire to promote sustainable forms of development in which the theme of water is central. The water resource becomes a project theme belonging to a wider system capable of improving the use of the collective space. So water today represents an opportunity to rethink the places to live and raise awareness of the community on environmental and ecological issues.

I - 3.5 Towards ecological cities: water for urban quality

The high population density and the productive activities of the cities exert pressure on the environment, raising concerns for the European and international communities. But it is precisely in the more urbanized areas that the environment interaction takes place, where artifice and nature interact. The city then represents the right place and from which it is necessary to start to guide sustainable development. It represents a paradigmatic area of sustainable experimentation, that can be replicated on a global scale, capable of generating mechanisms to improve the quality of the environment and people's lives. European and international policies, therefore, focus in particular on the urban environment to rethink and develop resilient cities that adequately respond to the urgent ecological, economic, social, and protection, and health needs. A reversal of the trend, therefore, in which the protagonist is sustainability, as an indispensable tool for the city's growth and development.

In this context of awareness of the need to re-establish a sustainable balance in cities, international politics address the water issue management for increasingly "water sensitive" planning. Many "water-oriented" strategies have already been implemented and focus on two objectives: the sustainable use of water resources and the conservation of the hydraulic heritage. Water is a fundamental resource not only to be conserved for the survival of the planet, and therefore necessary to combat the effects caused by climate change and essential for people's health. Several adopted strategies integrate the theme of water within the cities, among these, we find several themes including waterfront and riverfront, wetlands and phytoremediation, recovery of canals and basins, water cycleways.

Figure 1 - Piscina das Marés, Alvaro Siza,1959-1973. Series of terraces and pools that allow you to enjoy the waters of the Atlantic.
Source: Laura Menéndez Monzonís, UJI university

Figure 2 - Passeo Carlos do Carmo, Lisbon (Portugal)
Source: Gaia Nerea Terlicher, Pavia University

Figura 3 - Cankarjevo nabrežje, Lubiana (Slovenia)
Source: Margherita Capotorto, Pavia University

Waterfront & rivefront

Strategies for the conservation of the hydraulic heritage are a central theme in the regeneration of water cities. Urban areas characterized by the presence of the sea or river are particularly vulnerable territories, often subject to floods that cause economic and social hardships. However, the water is a resource that can turn into an opportunity to relaunch by counteracting the vulnerability of these territories and regenerating urban spaces. Furthermore, waterfront and riverfront are areas full of cultural stratifications and relationships, places between water and land, constitute fluid spaces, for visions of the future of cities and for experimenting with new sustainable and inclusive urban forms. Water as a structuring element of the urban layout does not constitute a line in the city. It is a permeable network capable of dialoguing and actively interacting with the existing fabric by mending up the different urban areas. Thus, the water actives the spaces that it laps. They become playful and leisure places, to carry out sports activities, healthy places, that can be used to stimulate the citizen’s life in the open air. Sometimes even the water becomes usable, becoming a natural swimming pool in the open air.

The permeability of the soil and the water cycle

The contemporary challenge is to reconcile the development of cities with the protection of the environment. For this reason, it is necessary to introduce a reflection on the interactions between water and human activity. This reflection has to include the themes of soil defense and natural ecosystems. The progressive overbuilding of the soil and the continuous withdrawals of water are compromising the ability of water resilience and, consequently, the ability of water to ensure the survival of the population. Wetlands within cities can guarantee, on the one hand, a resource in the management of the growing water demand and, on the other hand, the purification of wastewater. By returning permeable soil within urban areas, wetlands improve water quality and constitute the habitat for many animal and vegetative species, guaranteeing biodiversity. In fact, by removing the contaminants present in wastewater, they act as natural filters. A similar system is the one provided by phytodepuration plants which, by reproducing the self-purification processes of wetlands, help in the treatment of wastewater. The introduction of these systems also provides places that can be used by the population, such as parks and green oases in the heart of cities for leisure, while at the same time mitigating the phenomenon of heat islands.

Recovery of canals and basins

The reopening and recovery of ancient canals and water basins is an increasingly widespread theme within the European urban context. On the one hand, an opportunity to rediscover the values of water and recover the historical image of the city, and on the other, a chance to regenerate degraded urban areas, transforming them into attractive poles for leisure and tourism. They represent renewal interventions necessary to create new pedestrian areas along the waterways that lap the existing fabric. Water becomes an aesthetic and playful element, to be admired and which allows the use of the space that borders or surrounds it, but sometimes also navigable or even bathing, as in the case of some canals.

Cycling and water routes

Among the determining factors for the urban quality of public spaces, there is the mobility system, with a fundamental role in the quality of inhabitants' life. In contrast to the more traditional form of mobility, with a significant impact on the environment, soft mobility represents the transport system necessary for the development of sustainable cities, helping to make them even more attractive. For years, many European countries have been investing in the creation of cycle networks along the waterways. This type of mobility has generated recovery strategies for rivers, streams, lakes, and canals, enhancing the territory and the artifacts that intersect it. Enhancing the water heritage through "waterways" not only provides the population with a sustainable urban connection system but also encourages people to adopt habits that can promote and improve health. Nonetheless, linking cycle paths with waterways can foster the development of slow and sustainable tourism.

Figure 4 - TURIA'S GARDEN
The Turia park was born on the bed of the ancient river Turia that ran through the city of Valencia, and which after being drained, was diverted as a prevention to the continuous floods that took place during the last century, causing serious inconvenience to the city and its inhabitants over the years. So today the park has become a symbol of the city by modifying its image and revitalizing the neighborhoods facing it.

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PART II

INNOVATIVE EDUCATIONAL TOOLS IN SCHOOLS

II - Module 4: Innovative educational tools in schools

II- 4.1 Approach to current teaching innovation:

Today, technology permeates society at all levels, and these resources include not only communication media but also the tools we use for exchanging knowledge and learning (Zaragoza-Martí, in press).

On our globalised planet, anyone can connect with anyone, from all corners of the world, at a single click. In such a world, knowledge and learning need to be more accessible, personal and direct. Our daily use of Information and Communication Technology (ICT) provides us with immediate access to an abundance of contents and tools that allow us to learn in different ways (Zaragoza-Martí, 2019). As a result, new teaching-learning dynamics, with an understanding of technology at their heart, must be generated to reflect this reality (Martí, Heydrich, Rojas and Hernández, 2010).

The context of Agenda 2030:

the educational model imposed by the European Higher Education Area centres on students' autonomous learning under the supervision of university professors. Such a focus raises the need to rethink traditional teaching and learning activities: we must reflect on how to replace them with truly useful teaching tools for the elaboration, acquisition and transfer of knowledge within the new educational model we are immersed in (Garrido Carrillo, 2012).

Specifically, the issue at play is not only that of transmitting knowledge, but as commented by Pérez Albadalejo (2017), of being able to expand and acquire skills from a small core of knowledge.

Therefore, teachers need to leave their instructor role behind and turn into drivers of the knowledge-generation process itself. Reflections are currently being undertaken at the University on its own role in addressing, among others, the global challenges posed by the United Nations 2030 Agenda. Noteworthy among them is the role of catalyst that technology and ICT have in achieving the Sustainable Development

Goals at University (Sancho Gil, Ornellas & Arrazola Carballo, 2018).
In this regard, the UNESCO report 'Education 2030' (2015) insists on the importance of these technologies in such innovative aspects as:

a) The dissemination of knowledge.

b) Access to information.

c) Effective and quality learning.

d) And the efficient provision of services.

Through this prism, reflections on educationaltechnological innovations focus on the significant transformations and changes in the concession of teaching that are being generated, together with the impact on educational practice, the ultimate aim being to improve the quality of learning (Carrizo Aguado and Alonso García, 2019).

The importance of ICT at the academic level:
technological omnipresence in young people's daily lives has disrupted patterns and practices of social and cultural behaviour (Area Moreira, 2018), as well as how young people relate to their environment.

Consequently, the existence and use of digital services and devices in the classroom, such as teaching resources, leads to drastic alterations in the way teaching is conducted. Indeed, not only have students changed, but also the teachers and the means through which knowledge is generated and shared.

It is clear that today, this teaching innovation is intrinsically linked to the mastery of ICT (Pérez de la Fuente, 2013) since using ICT in the classroom enables the generation of more open, flexible and diverse educational and learning environments, leading to more significant results. In this way, educational realities are being brought closer to social realities. The goals pursued are 'learning to learn' or the 'know-how' referred to by Miranda Vázquez (2015), rather than simply memorising content and passing exams without perfecting the skills or competences necessary for professional life (Zaragoza-Martí, 2018).

Beltran and Bueno (1995) hold that we learn while thinking, so the best strategies are those that have the greatest impact on thinking processes.

New technologies must thus become a facilitator, empowering students to explore their environment through cooperation, allowing them to gain responsibilities within the structure of their learning (Zaragoza-Martí & Pardo Beneyto, pending publication). Portillo (2017) similarly comments that the challenge of ICT adoption can be oriented towards synergies, which could represent an excellent opportunity to foster a culture of students sharing the spotlight and responsibilities.

Consequently, learning processes should no longer be teacher-centred and dominated by a one-way teacher discourse. Instead, the classroom should become a 'laboratory': a space where knowledge is created and shared, through two-way teacher-student learning, as well as student cooperation methods.

In this way, a symbiosis would be achieved, improving the teaching and learning not only of those who excel following traditional methods, but of all students, who, through cooperative, multimodal, plural, diverse, flexible, universal as well as individual work, can advance and modulate their learning (Zaragoza-Martí, 2019).

It is not only a matter, however, of providing students with comprehensive and versatile education in order to achieve the required academic and interdisciplinary rigour. It is also about using the necessary tools and making them available to the educational community, thus enabling the exploration of new ways of working, derived from the intensive use of the information and knowledge technologies we have today (Martín, 2016).

This is undeniably what the new generation of students demands: a university that accompanies them in their learning process, with modern, technologically advanced teaching

methods, free of temporal or physical boundaries. Students indeed have learning skills, yet they require motivation, confidence, mutual support and accompaniment in a language they are familiar with.
University knowledge centres cannot remain anchored only in traditional methodologies or in pseudo-digital techniques. It is necessary to understand students, their needs, their diversity and their different degrees of learning, in order to offer modular and on-going academic knowledge of quality, in accordance with the UNESCO’s goal of Universities as lifelong learning centres (Zaragoza-Martí, in press).

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II - 4.2 Geotechnologies, attractive way ICT:

Information and Communication Technology (ICT) can be defined as an extension of the term information technology (IT) which emphasises the importance of digital communications over the Internet, beyond the digital nature of information itself (Murray, 2011). It consists of the integration of telecommunications (telephone lines and wireless signals), computers, programmes, middleware, storage systems and visualisation resources, thus allowing users to access, store, transmit and manipulate information.

The sizing of information content and its required electronic-digital processing require a very different management capacity than what was known until a few years ago. It would be reductive to call it a simple technological phenomenon. Geographic information is essential today because it plays a strategic role in many domains that are now collective concerns, such as environmental processes, natural risks, economic development or inequality. However, along with major environmental or social problems, there are other spheres, relating to leisure or hobbies, in which the use of geographic information is also having a huge impact on a technified society with free time to enjoy it.

The Internet Age was heralded by some as the end of Geography, on the assumption that telematics would make it possible to overcome physical barriers. Yet the truth is that our new society, which is both global and local, or "Glocal" (Castells, 2001), is undergoing notable geographical transformations. Geographical location is today more important than ever for the study of human behaviour (Geomarketing or mobility are strategic issues from an economic or social viewpoint) thanks to how ICT facilitates the strategic use geographical information in terms of timing and form (immediacy).

Social phenomenon of Neogeography:

Twenty-first century mapping has succeeded in exploiting the value of information and communication.

Specific databases have been created making it possible to transform old paper maps into digital maps. Air and space devices have been created that capture a large amount of data about our planet (satellites, drones, etc.). A huge amount of digital information thus needs to be processed by these new geographic databases. But within the ICT phenomenon, the key to the success of geographical information has been its widespread use as well as its massive and daily consumption. The latter is constantly on the rise. Data is being updated from the mobile devices of users themselves, who are get together in virtual communities or social networks.

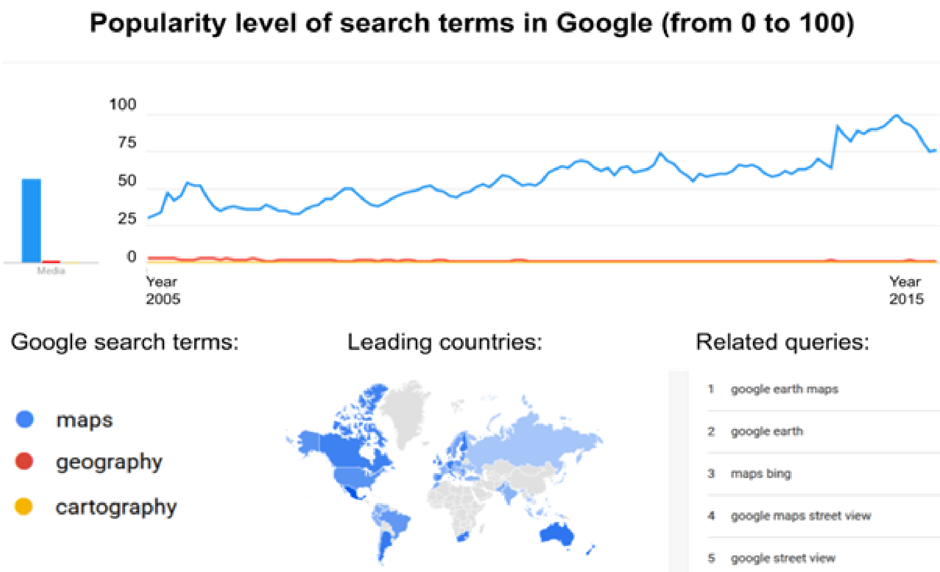

Figure 1 - Upward trend in searches for the term Maps on Google, demonstrating the interest in web map services or Web Mapping, such as Google Maps, Google Earth, or Bing Maps

Source: Google Trends. Accessed: 09/03/2021

The circulation of data over the Internet and the Web is weaving a “huge, globally connected village, that is very active locally” (Castells, 2000). Geographic information is meeting this social requirement, thanks to the effective dissemination of geographical information. Figure 1 shows recent trends in the worldwide interest for terms such as maps, geography and cartography, clearly highlighting the popularity of the term maps compared to more “academic” ones, linked to map servers on the web, such as Google Maps, Google Earth or Bing Maps.
This viral process in technified countries has rapidly spread to the rest of the world, with the exception of areas on the other side of the digital divide.

Web 2.0 and Web mapping 2.0:
We are currently witnessing a new social behaviour: WEB 2.0, a phenomenon that has introduced Internet databases to the general public.
Citizens have entered the world of digital
information and have found cyberspace very convenient indeed. The human element has turned digital technology into a medium that provides new and more effective relationship formulas, offering a range of strategies to achieve success, business, prestige and even fame.

The web revolution is happening so fast that we need to break down the different stages that have successively unfolded on the short-term: Web 1.0, or the static web of the end of the twentieth century; the dynamic and social Web 2.0, since the beginning of this century; and lastly, the multimedia, semantic and intelligent Web 3.0 (Ramon-Morte, A. 2017).
Web 1.0 was called static, because it resembled a text advertisement (HTML), capable of travelling over the internet with sound and images, but little else. Despite this, maps could be visualised online for the first time, with global satelliteweather conditions or geographical or environmental

phenomena. The most commonly used technique was "image maps", in which users could navigate by clicking on an area of the map that was linked to a web address.

When it became possible to connect web documents to databases, company data could be synchronised to their web pages, turning them into a dynamic window for communication. The added advantage was that changes were automatically updated.
Thanks to databases, the Web was no longer static. The Internet Information Service (IIS) turned personal computers into web and database servers, thanks to the classic ASPlanguage or ASP.NET popularised by Microsoft, along with other more powerful and evolved languages, such as PHP, Perl, or JAVA.

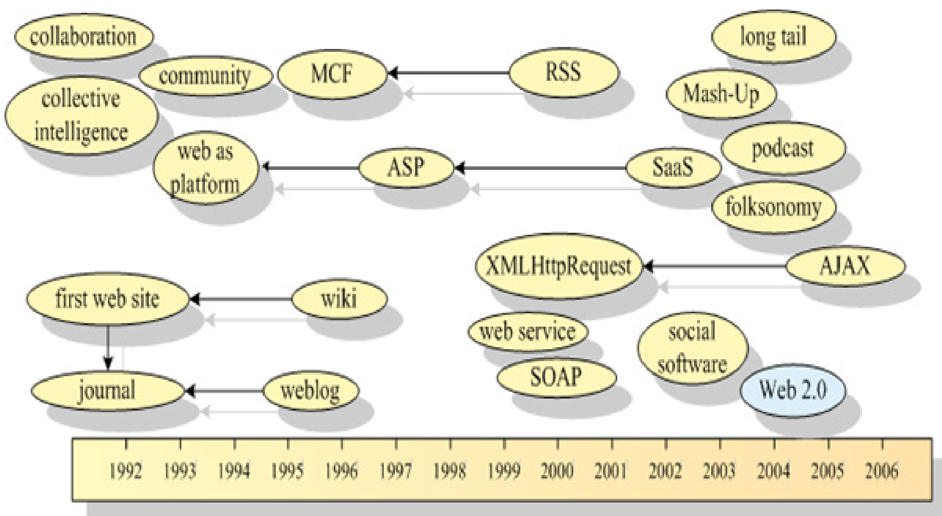

Figure. 2 - Emergence of Web 2.0 and the combination of different technological and social factors that have made it possible over time. Diagram retrieved from the Blog of J. Schiller: "Web 2.0 Buzz Time Bar". Accessed: 09/03/2021.

Thanks to this, it became possible to view updated geographic data on the web in real time, follow satellite information, or see maps change at a
"mouse-click" as they were loaded from geodatabases in real time.
The evolution of the HTML language and the emergence of the XML language enabled interoperability between different databases.
Requests to external or AJAX services (JavaScript and XML) to run applications from the browser, brought about a more dynamic behaviour, feeding on the data of the corporations themselves and those that users themselves generated via their mobile applications. Web 2.0 offered dynamic, user-centred content management to work collaboratively with information. Cloud Computing began. Figure 2 below illustrates the complex panorama of all the elements involved in the evolution of this new phase of the Internet, within such a short number of years.Web 2.0 is the development scenario of a more specific phenomenon: Web Mapping 2.0, the result of the technological evolution of Geography and Cartography to adapt geographic information to the new digital realities. Web Mapping has exceeded all expectations thanks to the standardisation of geographic data and communication standards for web access from Geographic Information Systems (GIS) or geodatabases.

The active incorporation of millions of users was triggered thanks to the convergence of three main processes in the field of technology and geographic data: the production of a huge amount of content, great processing capacity and mass dissemination (Ramón-Morte, A. 2017). Regarding the first process, the production of geographic data, geographical information has been increasing exponentially since the second half of the twentieth century, thanks to new technological devices capable of capturing this type of data more effectively. To this end, a vast constellation of satellites

specialised in obtaining digital data and locations has been set up, together with flights to produce digital images of the Earth's surface, as well as drones and mobile devices geo-positioned by satellite. Together, they provide a true universe of information about our planet, at the service of human activities and social relations.
To manage this huge amount of geographical content, it has been necessary to use the appropriate tools. And this is where the hard core of the process comes in: Geographic Information Systems (GIS). This software appeared in the second half of the twentieth century and evolved as a hybrid between computer-aided design (CAD) programmes and relational databases.
These applications made it possible to digitise analogue (paper) maps and geographic information generally. The next step was then to convert this digital information into raster images composed of pixels or sets of geometries, consisting of Cartesian coordinates stored in databases of points (locations), lines (lengths), and polygonal areas (surfaces). These early GIS applications managed geographic information in databases and could use Web 2.0 to connect spatial properties to a variety of thematic information (see Figure 3).

Figure 3 - Geographical Information System (GIS): geographical data core.
Elaborated by the authors using free sources: Wikimedia Commons and Pixabay License1

To understand how GIS have succeeded in processing spatial information, we must consider two components: the spatial/geometric element and the thematic component, i.e. attributes of other types of information: numeric, text, multimedia, date/time, etc.
The digitisation of spatial or geometric information follows, in turn two other types of models (Figure 4):

1. The raster model:
the information is continuous and structured in a grid of rows and columns; the minimum unit is the pixel,which will have a spatial resolution (the real pixel size)

2. The vector model:
the information is discrete and compiled into any of these three geometric primitives: points, lines or polygons.The way we physically store and manage data is
usually either:

• File-based: in a single file (e.g. GeoJSON), in several files (ESRI Shapefile) or contained in a directory, often in the local storage unit.
• Structured: in a spatial database, such as a single database file (e.g. GPKG, or MDB) or a cluster of a relational database manager, hosted locally or on a network.

File-based projects are used for teaching or small GIS projects,such as the ones implemented in consulting firms or local administrations. Spatial databases, for their part, tend to be used for extensive professional projects or projects led by the technical services of public administrations or large consultancy firms in which the information must be robust, stable and consistent.

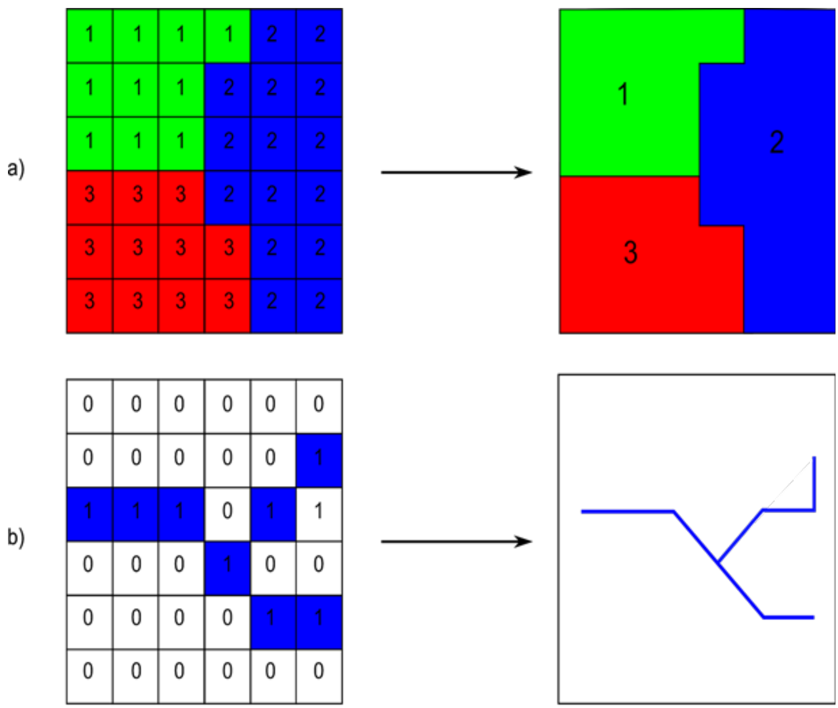

Figure 4 - Raster (left) and vector (right) models. Elaborated by the authors.

In spatial databases, added to the two graphical components and thematic attributes, one may optionally insert behaviours based on events (triggers) or properties that make the spatial data try to imitate reality (Drake et al, 2002). Triggers occur each time data is created (INSERT), modified (UPDATE), or deleted (DELETE). They launch a process that can perform several basic tasks, such as verifying that all alphanumeric fields have been recorded according to the domains created (e.g. date range, minimum and maximum values), as well as the most complex tasks (e.g. comparing that an item's digitisation is compatible with some type of legal, environmental standard, etc.).

Naturally, GIS has evolved, from simple desktop applications to databases that are better designed to manage geographic information. Current geographic databases include Oracle Spatial, PostgreSQL/PostGIS, or SQLite/SpatiaLite. Today, programmes based on modern programming languages are capable of operate directly with geographic data and other types of non-geographical databases, web servers, desktop GIS programmes, web map servers (GeoServer, MapServer, GeoNetwork, etc.), programming libraries and web applications.

In this sense, geographical information has met the challenge of producing and managing content with specialised databases. Nevertheless, the trigger for its success in the twenty-first century has been the effectiveness of Web Mapping, due to its role in the dissemination and mass use of this type of data. It has thus led to genuinely democratising geographical information, which was previously limited to a select group of specialised users.

It is worth highlighting some elements that have helped in the process, such as the founding in 1994 of the Open Geospatial Consortium (OGC), an agency that coordinates international efforts to standardise geographic data, formats and the specification of open standards for users of geodata and web applications.The aggregate of open standards (accessible geographic data) and their structuring in geodatabases on specialised servers are the foundations on which spatial data infrastructures (SDI) of the world's leading geoinformation companies and official mapping institutions in all modern countries have been developed. And it has facilitated the creation of the geographic open data of private and public institutions. Thus, for example, Italy has its Geoportale Nazionale2; in Spain, the Spanish SDI (IDEE)3is to be created and Portugal disposes of its National Geographic Information System (SNIG)—the world's first SDI4.

Added to this is a large number of data infrastructures or web geoportals belonging to regional, public and private institutions, including local entities and companies.In Europe, the INSPIRE European Directive (Directive 2007/2/EC) has coordinated the efforts of all European Community member countries to provide citizens with free access to geographical information anywhere in Europe, as a fundamental right, especially with regard to safety, health and the environment—as set out in the INSPIRE5 Geoportal which centralises all the European Union's geoinformation.

Web Mapping services developed by Google (Google Maps), Microsoft (Bing Maps) or Apple Inc. (Apple Maps) have exploited this type of information and become the geographic reference (basemap) underlying a large part of the Where 2.0 initiatives. It is worth mentioning the case of the OpenStreetMaps Foundation (OSM), one of the most illustrious collaborative, free and open global mapping projects.

It has brought together almost 2 million users since 2004. Today, OSM has attracted countless world-renowned projects, based on the social network itself, that acts as a filter ensuring its adequate and continuous updating. The data it offers is free of charge and under an open license that makes it a good alternative to other large international corporations. Indeed, this allows many companies and institutions that are part of the social panorama of geographic information to reuse the data, such as Foursquare, Moovit, Wikiloc or Wikipedia itself.

The incorporation of geotechnology into everyday life thus supports the democratisation of geographical data, which is now standardised and open, giving society the ability to georeference locations. There are a range of geolocation applications, such as: geotagging, search games, or geocaching games, or Mapping Parties, in which groups of people get together to update and expand map data of an area of interest. Worthy of note are international cooperation initiatives, such as the Openstreetmap Foundation's Humanitarian OSM Team. The latter promotes the collaborative, free and fast creation of the mapping required to meet the needs of developing countries or disaster-affected areas.

In these cases, and others, technology has played a major role in facilitating a simple integration of open applications and services into web environments.

All this is possible thanks to the daily use of global positioning systems, through satellites and telephony networks, with portable, interactive devices that have geographical positioning capabilities (GPS receivers, smartphones, laptops or tablets) and the Internet of Things (IoT), together with the creation of smart objects that will dialogue with each other through the Network. Geographic information and geolocation are fundamental In all these cases.

Neogeography:
The interest in geographic information over social networks or virtual communities has been so huge that it has led to the emergence of a new term: Neogeography or the mass use of digital maps by non-expert users in Earth Sciences or Geography. Indeed, the initial purpose of use is of an informal nature, or even simply for leisure and fun, as opposed to more analytical or academic approaches to geography (Turner, 2006).

In scientific spheres, some geoinformation experts have expressed reservations about the Neogeography phenomenon, thus differentiating it from Geography as an academic discipline (Goodchild, 2007). They express a preference for the term Volunteered Geographic Information. Therefore, Neogeography is a social movement made up of aficionados who meet up in virtual communities in order to share information and join their efforts. They follow three clear objectives: the socialisation of the means of cartographic production; the availability of geographic information data; and the need to geolocate."Participatory maps are often a socially or culturally distinct way of understanding the landscape and contain information that does not exist in ordinary maps" (Delgado, 2015).

Barrera (2009) defines concepts such as Participatory Geographic Information Systems (PGIS) and social mapping. They differ from institutional mapping, in line with a concept that reminds us of the "experienced and felt space", proper to the Social Geography of the mid-twentieth century.

Thus, the author distinguishes between container space, understood as "the space that is unaffected by the relations of the human beings who inhabit it", and a socially constructed space in which the inhabitants of that space are constantly interrelating with the inhabited space.

The first of the spaces would be represented by institutional mapping, while the second would be represented by social mapping. And this is where we encounter the benefits of using voluntary and participatory mapping to value cultural heritage, hydraulic heritage in this case.

With the phenomenon of open geographic data, the productionofnewinformation,generatedbyneogeographers, has begun to be massive and the results are shared over the network.
t is impossible to describe here a representative sample of the plethora of cases, but it is worth noting the initial role of Google Maps or Google Earth applications and services, the geo wikis of reference maps such as OpenStreetMaps (OSM), as well as other thematic map wikis such as Geonames, WikiLoc, etc.
In the latter, user communities employ mashups to combine different web information resources on which to share and publish geographic information for various purposes, such as routes,active tourism, gastronomy or maps of all kinds.

Today, the key is the instant sharing of ready-to-use information among user communities. This is what the term wikiwiki (meaning “quick” in Hawaiian) signifies, and of all the space wikis, OpenStreetMap (OSM) is worthy of note as the
map wikipedia or the open digital street map. Despite its digital street map thematic approach, its user community has remarkably grown: droves of uses and applications have been found for this huge amount of information, as illustrated in Figure 5 .

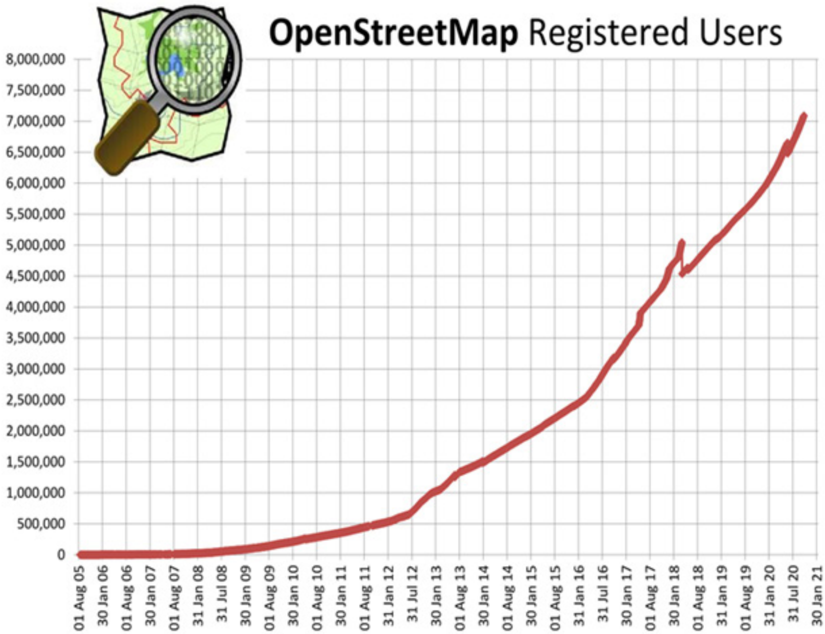

Figure 5 - Evolution of OSM registered users.
Source: OSM Wiki6.

The quality and veracity of the information are guaranteed by users' continuous reviews of users. These organised data update tasks are encouraged by the constant use of data, the development of applications based on the data, and the holding of social or humanitarian events, such as local Mapping parties or global meetings over the Internet.

Its very use guarantees the quality of the information and the ability to meet the needs for maps. It even supports rescue and emergency management tasks during catastrophic events due to natural disasters (Humanitarian OSM Team - HOT), based on the Voluntary Geographical Information (Prieto et al, 2014) phenomenon commented on earlier. Thanks to this community effort, the degree of detail of the attributes and positional accuracy are now ideal for generating Webgis portals or their use in desktop GIS programmes (Niño, 2019), as a free alternative to the Google Maps phenomenon.

The project's open nature is defined in its very slogan: "OpenStreetMap isn't just open data - it's also open source, and you can help!". This has led not only to the exponential increase in the number of collaborators in Figure __, but has become a laboratory for experimenting with many free projects associated with its data7. Among the beneficiaries of this movement are open-source GIS programmes that allow free access to cartographic data, and additional services (e.g. Nominatim Search).

Nevertheless, Neogeography is more than just accessible mapping (Buzai, 2014a), it epitomises a new vision of reality by a social contingent of amateur geographers who have implemented spatial data, bypassing the academic paradigms of Geography or Cartography.

But this social phenomenon, far from representing a confrontation between academic and amateur versus what is official, has helped to significantly enrich the world of geographic information, incorporating new approaches and functionality. It has also brought about the emergence of new geospatial companies, such as Carto or Mapbox.

Geotechnologies for learning and knowledge and hydraulic heritage

Social interest and ease of use of geographic information are the key factors enabling the use of Geotechnologies as an instrument for learning and knowledge management. Cartography already has and ingredient of success: its graphic dimension. Its visual appeal and power (combinations of shapes and colours) facilitates the understanding of many phenomena that occur on the Earth's surface. But from an educational viewpoint, added to visualisation, geotechnologies have the power to synchronise time and space, providing immediacy.

People with shared interests get together and form groups around a common theme, such as hydraulic heritage or any other issue in which it is important to share geolocations in a simple and useful way. For information processing specialists, geographical referencing is the opportunity to participate, together with other specialists, in a means of communication that is highly attractive to society, thanks to the power of image.
It embodies an ideal means of addressing valuable strategic questions about the territory, such as the historical, landscape, or natural heritage, the environmental value, natural risks, communications, mobility or economic development.

But it also represents a major educational resource, since without these types of resources, explaining such phenomena in a classroom context is a complex undertaking.

Geotechnologies, like any digital technology, allow students to build computer skills that will be particularly important in their professional lives, such as the use and management of databases, office, web applications and the management of mobile devices with GPS.
But the skills acquired go beyond technological abilities, as in the case of fieldwork for on-site data acquisition, which often centres on environmental or cultural issues in an active and attractive way.

They help us perceive the real world, while fostering social relations, so they represent a great ally when performing tasks that involve fieldwork and group learning (Ramón-Morte, A. 2017).

Unsurprisingly, geospatial competencies have come to cut across many disciplines, not only those related to Earth sciences.
Geolocation allows a better assessment and awareness of historical, environmental or cultural heritage, helping us to reveal it through with images, routes, maps and making it affordable.

In addition, there is no age for learning with geoentertainment, as evidenced by the incorporation of senior-age groups into the GIT, during the initiatives launched by the Permanent University of the University of Alicante and other international associations for the university education of the elderly (Delgado, 2013).

The image of the iceberg helps to explain many theories based on the composition of a very simple visible part that depends on an extensive, complex and hidden foundation that keeps it afloat (such as Hemingway's theory of omission, business success, clinical psychology, or some aspects of marketing, among others). We can apply it to the case of the success of geospatial teaching skills.
Figure 6 illustrates a Geotechnologies Icebergwhich shows how behind an easy-to-use technology lies a complex invisible fabric, under the waterline, that is responsible for making what is actually very complex appear simple.

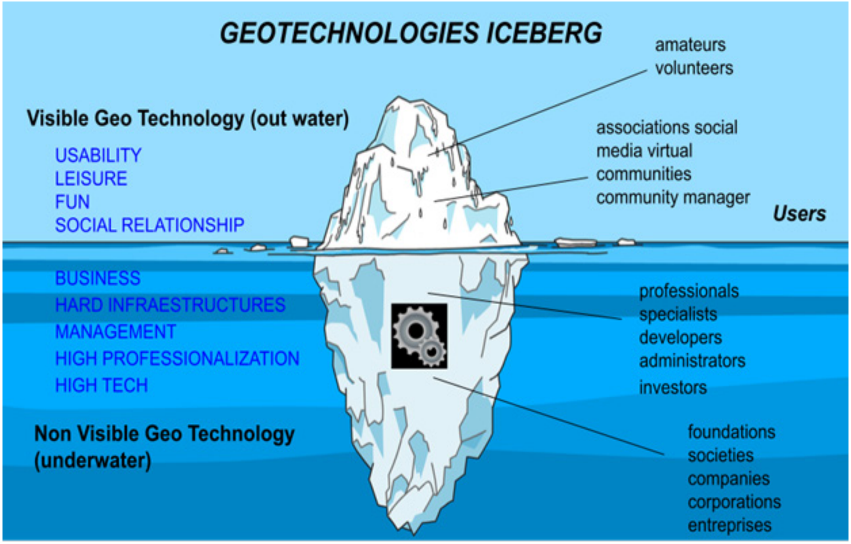

Figure 6 - The Iceberg image applied to Geotechnologies helps to understand the key to Neogeography's success for learning: the ease of using what was originally very complex. Elaborated by the authors, source of background iceberg image: Pixabay Lisence8.

Highly specialised companies and professions maintain large global databases; cartographic institutions update country information, complex software, hundreds of GPS and telecommunications satellites, innovative technology tools and astronomical budgets.

The sector of users is oblivious to this. It can even be invisible to a large part of the professional user sector.

The system allows you to immediately capitalise on the time spent during the learning curve. Getting something done with geotechnologies is easy and little timeconsuming. It can be a daily and enjoyable activity.
This logic applies to many aspects of the information society, its success stories and to teaching. The abundance of technological resources is generating a different mode

of learning that takes place physically beyond the classroom and beyond the duration of academic courses; technology and access to information are leading to the building of our own electronic learning spaces, i.e. our Personal Learning Environments (PLE) (ADELL, J. 2014).

The amount of information is growing, and it is continually being updated as well. This leads to a constant, lifelong learning process that requires the support of a specified series of digital resource.
In this way, teacher figure embodies the mediator between those who learn and the digital resources that allow the learning to take place (a link in the bibliography brings you to schemes and graphs illustrating a PLE's building blocks).

Figure 7 - My Personal Learning Environment (PLE) by Dinka Cherkezova Source: Flickr Creative Commons9

Digital natives and millennials are increasingly assuming their role of digital residents. They constantly use the Internet to obtain information, learn and share knowledge in the Cloud, and customise their own learning and professional work scenarios.
The relationships and processes they forge in the information flows are so dynamic, we could call them liquid, due to the fluidity of their behaviour (i.e. difficult to contain).

The term liquid has been taken from the world of marketing and is now applied to Networked learning.

Indeed, the variety of changing behaviours, resources and scenarios is such that they are difficult to manage from a traditional viewpoint with analogue professors.
Geographic information is no exception. The use of digital maps and the geolocation of content (images, comments, points of interest, etc.) has become a daily mechanism. They are part of many young people's personal learning environment, as illustrated by the icons of some digital tools in Figure 8, highlighted in red: Google Maps or Google Earth. PLEs do not imply access to information only, they include the activities of generating and sharing information, leading to an enriching and active process that fits perfectly with the social realities of twenty-first century youth.

At the beginning of the millennium, geotechnologies were already to geographers the new eyes that the microscope or telescope were to biologists or astronomers, whenever we the right questions were asked (GÓMEZ MENDOZA, J. 2000).

Geography itself has gained a new epistemological dimension. And the latter can be equated to a new paradigm that integrates techniques and technologies beyond their mere instrumentality and generates a new understanding of geographical scientificity and praxis (MORENO JIMENEZ, A.

2013).

In secondary education, geotechnologies have become technologies for learning geography; they are very effective to understand and evaluate geographical phenomena in a more active and participatory way in the classroom (López Fernández, J.A. 2016).

The digital skills and technological resources needed to use geotechnologies are largely the same as those already used with ICT and are available in classrooms. This facilitates a learning process in which students play a greater role, based on active methodological strategies in which teachers guide and help to solve problems, leaving behind their central knowledge transmitter role (Buzo Sánchez, I. 2017).

In addition, Cloud computing is facilitating the use of ICTs and Geotechnologies in the learning process, since it reduces the need for complex technical resources in the classroom. Meanwhile, mobile devices such as smartphones are gaining momentum, with increasingly intuitive interfaces and applications that almost require no specific training at all.

A good illustration of this is the ArcGIS Online platform of ESRI. This platform allows the creation of Web Mapping in the Cloud on different topics linked to agricultural landscape, pollution or geographical itineraries (Lazarus Torres, M.L. et al. 2016).

The latter are in step with other similar initiatives such as QGIS Cloud for GIS data, or EOS Earth Observing System Data Analytics for the management of satellite images the world over.
In this context, Web 3.0 and artificial intelligence are helping to solve the problem of how to use the information. In other words, a continuous learning process is generated, learning from learners in environments as personalised, dynamic

and diverse as PLEs. A relevant example is the Big Data phenomenon, which implements a methodology to generate knowledge through geo data mining (KDD).

The latter combines the use of artificial intelligence, Machine Learning, statistical analysis and databases with online analytical processing (OLAP) to learn about the human use of data. This big data boom has led to the development of tools for data visualisation and analysis that facilitate the application of KDD methods to Small data volumes. The latter could be more easily andfunctionally adapted to teaching activities that use Geo Small Data (e.g. Platfora), with tools and environments for generating and publishing new data visualisations that would be worth researching from an educational perspective (Zaragozí, B. et al. 2015).

It is highly likely that Spatial or Geo Big Data/Small Data techniques will help us to define the approaches required by teachers and researchers to learn how to use geographic information via geotechnologies.

To study the success stories of geotechnologies as a learning resource, there are a number of must-read works such as: Geography Education in the Digital World: Linking Theory and Practice (Walshe, N., & Healy, G. 2020); International perspectives on teaching and learning with GIS in secondary schools (Milson, A. et al. 2012); or the work of Kerski, J.J. et al. (2013) which analyse the status of GIS in schools in thirty-three countries and makes recommendations to advance the implementation and effectiveness of GIS in education (including experiences in Spain and Portugal).

To conclude, the main geotechnology resources for secondary education are based on the use of GIS programmes.
Indeed, they allow: the integration and analysis of global positioning systems data for mobile devices (tablets, laptop

or mobile); the visualisation of images generated by spatial remote sensing and aerial photographs; the use of web geoviewers, geoportals or SDI to access web map services and all of today's digital mapping resources.

Global positioning systems GPS, geocoding and geocaching:

GPS is probably one of the most widely used technological resources, but also one of the less understood by the general public. Only few know how it works. In this sense, the Global Satellite Navigation System (GNSS) or Global Positioning System (GPS) is a good example of the Iceberg theory discussed above.

Its success is based on a highly complex but easy-touse technology. Positioning is possible thanks to a constellation of artificial satellites that incorporate atomic clocks so they can be synchronised with each other and with the ground tracking stations on Earth. All satellites synchronously emit modulated frequency (FM) signals, which can be received by simple radio receivers on the Earth's surface.

The synchronisation of these signals' emissions allows determining the time gap they need to reach the same receiving device located at a specific spot.

The receiving device itself is equipped with a radio reception antenna and a processor to be able to make these calculations. This receiver, which today can be a car or a mobile phone, is able to process the time gaps of the arrival of each satellite's signal.
It calculates the position itself, via the trilateration1010of these pseudo distances which are determined by the time it takes for each satellite's signal to reach the receiver, depending on the propagation rate of the specific radio wave (see Figures 8 and 9.)

10 Trilateration consists in calculating the position of an element based on a method such as triangulation, but without using angular values, only distances from the position to be determined, from a minimum of three known positions.These constellations were originally set up for military purposes, such as the US Navstar, the Russian Glonass, the Chinese BeiDou or the Hindu Navic, but they have been given civil applications relating to navigation and mobility.

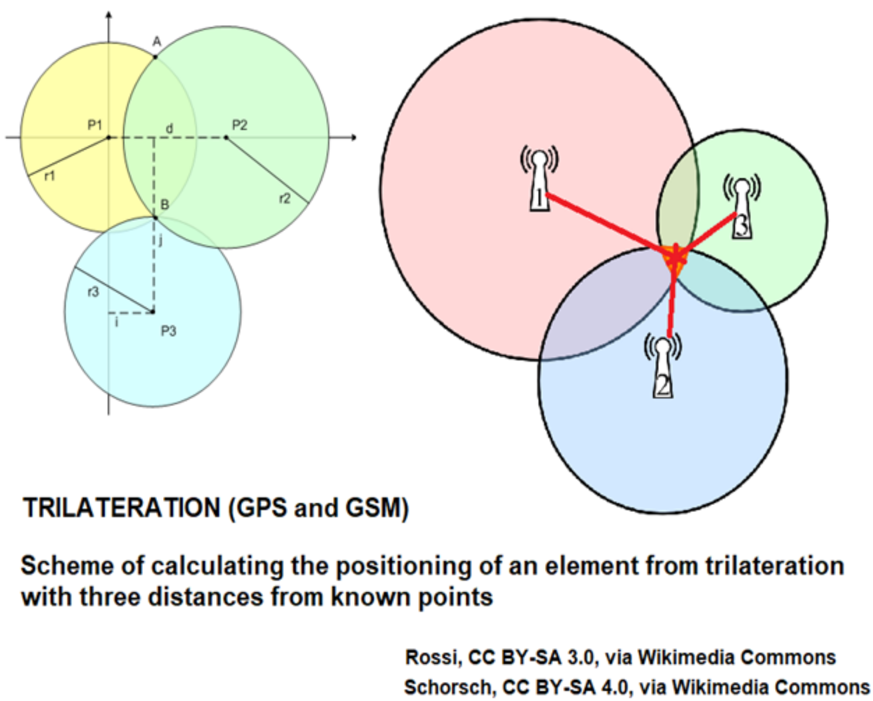

Figure 8 - TRILATERATION. Scheme showing how a position is calculated using trilateration based on three distances to the known position of three GPS satellites, three antennas of FM radio signals or mobile telephony.

This has even led the European Union to consider the need to launch the first and only non-military GPS constellation, Galileo. The Chinese and Hindu constellations are geostationary and operate only in the territorial realm of Asia and Oceania, while the rest are orbital and cover any part of the Earth, including Europe. As we can see, the system's conception is complex, but it is very easy to use, and totally transparent to the user.

These satellites' signals operate with open pit receivers, outside buildings and barrier-free zones that would hinder propagation.
But to avoid these problems, they are complemented by other communication systems based on radio or mobile telephony antennas whose positions are known and which can also communicate with the receiving
device.
They thus contribute to improving the trilateration positioning in urban areas. Satellite signals are not operational inside buildings, so the GPS are complemented with signals from wireless devices with antennas whose positions are known, such as Wifi signal emitters or by installing specific antennas for these purposes, which allow the determination of the exact position indoors. They are called IPS (indoor positioning systems).

The practical implications are that our everyday mobile devices incorporate antennas that receive FM signals from these satellites, mobile phone antenna signals or wifi signals that allow self-locating and recording our movements. Our cars, phones, tablets, laptops and ever more daily devices are equipped for locating and recording positions or movements in real time (RTLS), allowing storage and management from remote databases or in the Cloud.

From the perspective of secondary education, the functioning of GPS can be explained in the subjects of Mathematics, Technology or Physics. But in terms of possible applications, GPS can be included in didactic activities in the subjects of Geography, Cartography, Natural Sciences, Physical Education and even social sciences and language. Therefore, GPS is a multidisciplinary technological resource that lends itself to active and group learning processes.

One of the most widespread activities is open air physical exercise and sports or activities in which orientation is essential. One worth noting is Geocaching. This activity consists of using a GPS device (a specific receiver or mobile phone) to find the position of a "hidden treasure" (Cardona, 2013). It familiarises students with the use of cartographic resources (geographical reference coordinates, cardinal points, reading digital maps, determining a geographical point, etc.).

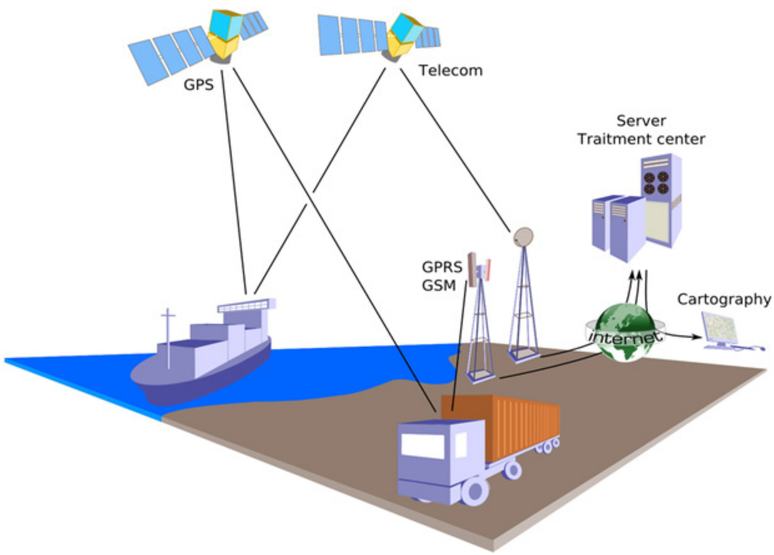

Figure 9 - GeoLOCATION Technology Environment (original illustration by Eric Chassaing, CC BY-SA 3.0, Wikimedia Commons11).

GPS is a key fieldwork instrument, whether for teaching Geography and the Earth Sciences, or for the assessment of historical heritage (or hydraulic heritage in our case). It allows the accurate positioning of the objects of study and the subsequent realisation of their cartography.

Although a stage of outdoor fieldwork is required, there are three major moments of significant learning: preparatory activities, fieldwork activities and post-processing activities.
In the preparatory activities of fieldwork, we must document the area in which we are going to carry out the activity, design the field notebook, prepare and print maps and even prepare the routes or the location of the issues of interest.

To do this, applications such as Google Earth or ArcGIS online are very useful, because they allow us to create files in standardised formats (kml) with locations, routes, to view satellite images of the work area and even upload this information to our mobile devices. GPS is used the most intensely in field activities, where it helps us to upload previous cartographic information to our receiver, in which we install the necessary applications to associate data, photos,video or sound to our geolocations (e.g. QField).

We must not forget, however, to use the field notebook to make additional notes of interest. It is recommended that students become familiar beforehand with the use of thesetechnologies through the most appropriate means: games.

There are many applications for the trivial use of Geotagging that allow users to associate geographic locations with other types of information, usually photographs, videos, texts, news or even comments on certain social networks.

Another option is Geocaching or Treasure Hunts. An event is

organised in which a group of participants compete to find a chest that encloses some type of interesting content and of which only the geographical coordinates are known.
Geocaching has attracted a huge amount of enthusiasm, with specialised associations and applications. Yet Geocaching can be set-up with nothing more than mobile phones and isa remarkable help to build students' GPS and geolocation skills.
Finally, the post-processing activities take place in a computer laboratory or computer station classroom where we download the information obtained in the field and use software (desktop GIS) to edit, correct or complete it before storing it in a remote database or on one's own storage device.

The most widely used GIS programmes are QGIS with QGIS Cloud and especially Google's ArcGIS online, Google Earth or My Maps, which make it easy to edit data obtained in the field, view it on maps and satellite images in the area, and save it to the Cloud for sharing or publishing. The educational functions of GPS have brought to light interesting initiatives related to urban studies, agricultural landscapes, pollution problems or routes in natural areas (Lazarus et al. 2016) or the most recent cultural heritage projects for the teaching and learning of Madrid Medieval History (Gómez Ruiz, M.L. et al 2021).

From the point of view of hydraulic cultural heritage, geotechnologies and mobile apps have been used for the cultural promotion of historical irrigation infrastructures in mass tourism destinations (Ricart, S. et al. 2019).

Remote Sensing:
Another major teaching resource to observe our planet's phenomena is Remote Sensing, a process of remote perception of what happens on the Earth's surface. The beginnings of the discipline date back to aerial photography in

the nineteenth century, but it truly took off in the midtwentieth century, withthe obtaining of satellite images that use active or passive sensors, producing data that goes beyond what the human eye can see, as shown in Figure 10.
Today, we are greatly accustomed to seeing satellite images in the media and on the Internet, in weather prediction applications or to simply contemplate different natural phenomena. This represents a remarkable support for learning, as there is nothing more pedagogical than images.

Satellite images allow us to build a global view of geographical phenomena beyond what the human eye can see. Since this information is continuously captured from the main spatial platforms (LANDSAT, SPOT, SENTINEL, MODIS, NOAA, etc.), we dispose of a large historical collection allowing us to explore the evolution of the phenomena under study.
The dissemination of quality and free satellite images over the Internet, on the geoportals of the world's major space agencies (NASA, ESA, etc.) has extended their application even further, along with their usual usage in the web mapping of major companies such as Google (Google Maps & Google Earth), Here Maps, Bing Maps, etc. These companies have exploited this information in a very cost-effective way for mass consumption, as it is much easier to look at an image than to read a traditional map.

The use of remote sensing in secondary education allows us to address physical aspects such as relief, hydrography or vegetation, natural hazards, along with human activities related to urban spaces, crops and different types of landscapes. To do this, didactic guides can help us locate and study these phenomena based on Remote Sensing to students' maximum benefit (Martínez Vega et al, 2010; Vivancos et al. 2005).

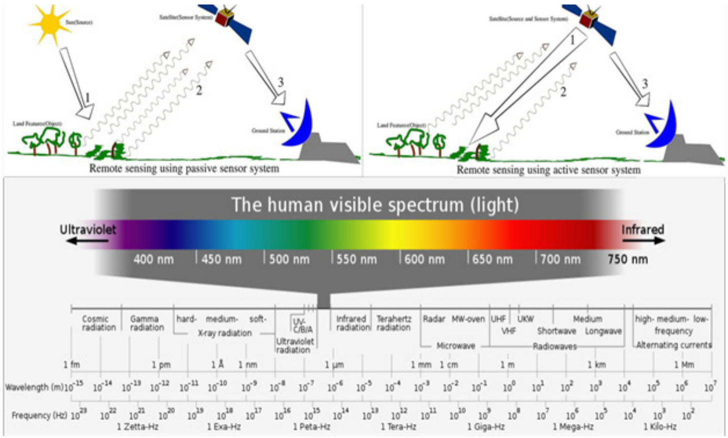

Figure 10 - Diagram showing how remote sensing operates with active and passive sensors (Source: Wikimedia Commons12) and comparison between the human visible spectrum and the information spectrum obtained through Remote Sensing Source: Wikimedia Commons13.

Further remarkable informative material of this kind is available, such as the BBC platform's Earth from Space programme, which provides a catalogue of videos on the subject with appealing titles such as: Seeing the disappearance of ice from space or Flying into the eye of a hurricane. One remote sensing teaching application is the exploitation of the evolutionary variable using specialised viewers that display the information of a same site at different times, using a progressive or sliding chronological bar that allows students to interactively compare the changes occurring over a given period of time. A good example of this is the Orthophoto Comparator of Spain's National Air Orthophotography Plan (PNOA). It provides free access to different flights photos from the beginning of the twentieth century to the present day (see Figure 11.)Geotechnologies have enriched contents and dissemination thanks to the power of image, achieved through Remote Sensing. Not only is it easier to see an image than a map, it embodies a much more powerful source of information and is a more attractive means in teaching.

Figure 11 - PNOA aerial image comparator, showing Cape Roig (in the South of the Valencian Community, Spain) between 1956 (an American flight) and 2017 (a PNOA flight).

Elaborated by the authors

SDI and Web Mapping Services:

The SDI concept was first formally adopted in the United Statesin 1994 (Robinson, 2008). According to McLeod et al. (2013), this first national SDI was incorporated into one of the most important policy documents for the coordination of geographical information in the United States, Circular A-16 of the Office of Management and Budget (OMB).

Although it was not called SDI at the time, one could argue that the Netherlands began even earlier, with the implementation, as of 1992, of its National Geographic Information Infrastructure (NGII) (now the National Georegister). Other countries among the first to adopt the SDI model include Australia (Australia's Spatial Data Infrastructure, launched in 1998), Canada (Canada's Geospatial Data Infrastructure, launched in 1999) (Hall, 2002) and Germany (Geodaten-Infrastruktur Deutschland - GDI-DE, launched in 2001).

Although further initiatives were set up in other European countries (e.g. Sweden, Denmark and the United Kingdom), the first comprehensive efforts began in most countries with the adoption of the INSPIRE Directive in May 2007, which created a mandatory requirement for the implementation of national IDEs by all Member States of the European Union (EU) (European Commission, 2007).

Just as human-to-human conversation requires a common language, to use data between two computer systems, one service provider and one requester of the computer systems, an Internet protocol and a standard are used to ensure the effectiveness of the communication between machines and software. This process is defined as: interoperability of geographic data, which is the main task of the Open Geospatial Consortium Foundation (OGC), an organisation dedicated to specifying formats and services that guarantee:

• Ease of implementation: this greatly benefits software or webgis developers, as they can learn about the specifications of a format or service and use them to their advantage.

• The neutrality of use on any device, operating system or software, programming language or browser. As mentioned above, the formalisation of OGC standards made it possible for the European INSPIRE directive to legislate and create a range of standardised geoservices that aim to:

• Avoid the redundancy or ambiguity of geographical data and mapping in Europe

• Provide a public service, offering services that enhance the use of Space Data Infrastructures (SDI) for society.

• Harmonise the European Union policies, adopting a common perspective that capitalises on the cost of maintaining these services.

This directive has led to the widespread use of SDI services at various administrative levels (local, regional and national) within the European Union and GIS users have been the main beneficiaries.

Indeed, they have gained access to geographical data via an Internet link and any desktop GIS programme that runs this standardised service.In educational settings, these structured resources are not usually used in the SDI directly, but rather indirectly by a large number of web geoportals or web geoviewers that make use of them thanks to the interoperability of OGC standardised services.

The Web Map Service WMS/WMTS is among the most widely used of these services. Nevertheless, it is a shame that other, much more complete and specialised services are underutilised, such as the Web Feature Service (WFS), the Web Coverage Service (WCS) or the Web Process Service (WPS), among others, that allow us to access the data in a more operational way.

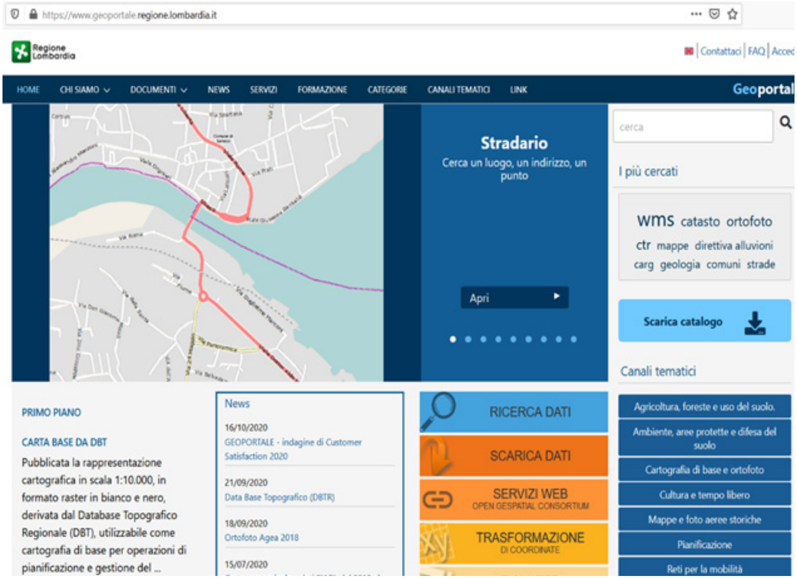

Figure 12 - Detail of the Web Geoportal of the Lombardy Region (Italy) with access to different types of topics. Elaborated by the authors

A geoportal is a web portal used to search for and access associated geographic information and services over the Internet. It thus consists of the visible face of an SDI, allowing us to work with data from one or more GIS databases in a web map viewing environment (see Figure 12). In this way, for upper secondary school students, geoportals are a good ally to search and observe phenomena in which the spatial dimension is important. The role of the SDI in the dissemination of geographical data was discussed earlier, and all the cited examples include geoportals, which facilitate the use of a wide range of open map information, coherently structured and with access to their metadata (information on how they are made and how to use the data). In this sense, open geo data is a fabulous resource that exponentially multiplies the functionality of the traditional encyclopaedia or school Atlases.

Geographical Information Systems (GIS):
GIS dates back to the early 1960s with the creation of the Canadian Geographic Information System (CGIS) to manage land occupation in the country. It was developed by Roger Tomlinson's team, which laid down the basic principles of GIS. IBM hardware succeeded in applying electronic computing methods and techniques to digital mapping for the storage, processing and evaluation of cartographic data (Tomlinson, 2013).
CGIS began a new scientific discipline that went beyond the technical and artistic aspects of mapping applied until then, giving rise to Geomatics.
Nevertheless, the need for highly sophisticated hardware restricted GIS to specialised usage by professionals in the field of research, state administration or big consultancy firms. The few GIS programmes that did exist were run by graphics stations, the most powerful hardware of the time.
Following CGIS, the GIS SYMAP of the Harvard Laboratory for Computer Graphics and Spatial Analysis (Figure 13) emerged, giving rise to the major companies in the sector, such as the Environmental Systems

Research Institute (ESRI). Thanks to these companies and research institutions, GIS software began to be widely disseminated among specialists (ESRI Arc/Info, ERDAS Imagine or Grass), leading to great advances in the field of geographic information, vector images, satellite images, and raster data, and specifically satellite data.

As from the 1980s, the proliferation of personal computers and the evolution of GIS software and new operating systems led to the spread of GIS users on desktops and their application to different scientific fields.

The multidisciplinary capacity of GIS created new approaches in all areas, yet there were great limitations due to the scarcity of accessible, standardised and structured geographic information.

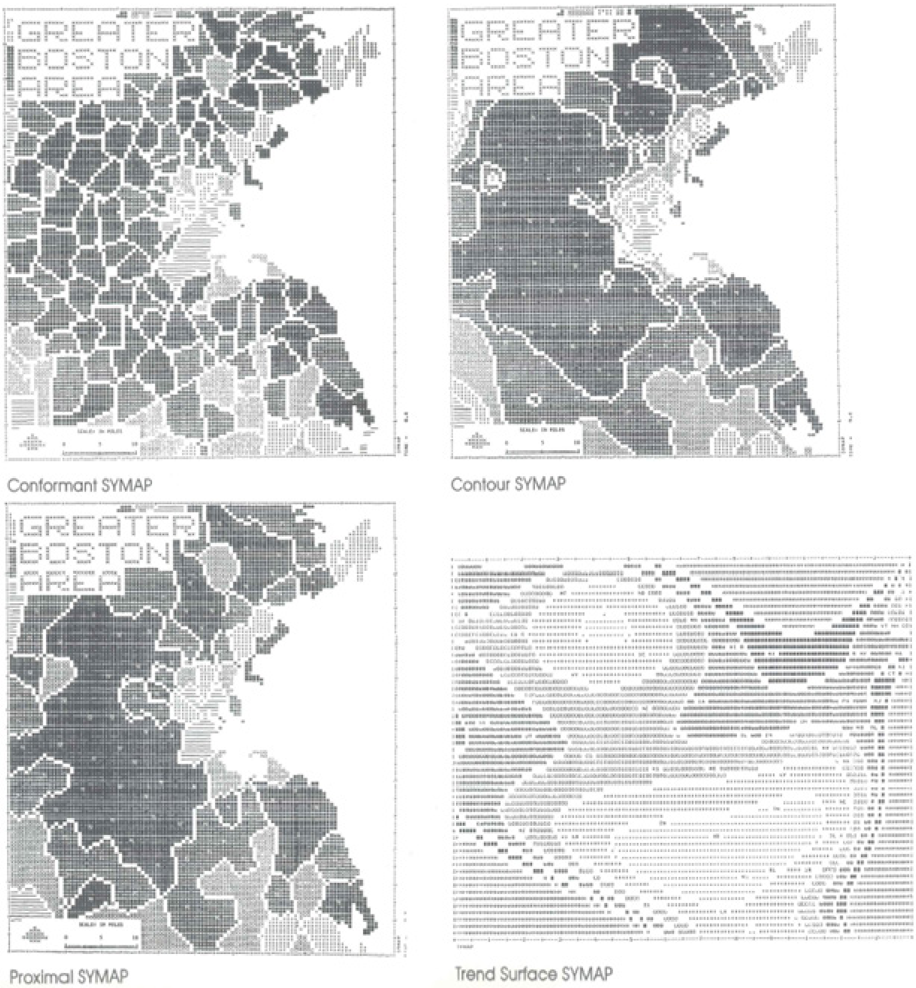

Figure 13 - Comparison of cartography, maps and trend graphics outputs elaborated in 1980 with the SYMAP GIS, from Harvard Laboratory for Computer Graphics and Spatial Analysis (1980).

Source: Open-Source Research, CC0, via Wikimedia Commons

Digital cartographic data was scarce, costly and complex for GIS users, so Geomatics remained in the domain of science, universities or public bodies (e.g. Catastro in Spain, with the emergence of the SIGCA cadastral GIS). In addition, many GIS professionals were accustomed to using local or shared physical data, often within the corporation's own networks on which they worked (intranets).
The decreasing cost of storing media naturally increased the memory capacity for a multitude of geographic data, leading to the problem of having to organise and share them. Currently, the trend is towards creating large external repositories (download centres or SDI), located in specialised Internet portals (geoportals), which contain massive data that is used via the Internet protocol, according to the following modalities:

1. Direct download of files with spatial information. This is the case with DIGITAL elevation models of NASA's SRTM and USGS.

2. GIS directly connected to the spatial repository. This is the most widespread form, and a standard communication protocol (e.g. OGC WMS) must be adopted for communication totake place.

3. Services capable of generating interoperable spatial data structures in plain text file mode. This is the case of SOAP (XML-based exchange protocol) or the simplest REST (web development architecture used in http clients), which generate data in GPX or GeoJSON formats. These services are typically prepared based on large geographic databases.

4. GIS-Cloud: "Cloud computing Geographic Information systems (GIS Cloud) constitute the natural development of cloud computing for geographic information (cloud computing) (Valencia Martínez de Antoñana, 2013). This modality will be the one to grow the most in the future,

especially in non-specialised or educational environments. Mature and reputed projects already exist, such as ArcGIS Online, Carto or GIS Cloud. GIS Cloud, like any cloud computing service, can be broken down, in turn, into three categories:

1. Infrastructure as a Service (IaaS): that is, virtualised hardware (e.g. Amazon EC2)
2. Platform as a Service (PaaS): Allows the user with a software platform to operate (geoprocesses) over the Internet (e.g. ArcGis Server)
3. Software as a Service (SaaS). the most widely used, generally via a web browser to access services and data (e.g. Carto, ArcGis Online). Currently, there is major technological competition between GIS programmes, although ESRI, which has positioned its software very well in the different user market sectors (cartographic production, web publishing, etc.) is the undisputed leader. Products like ArcGIS are synonymous with quality. They offer a welldesigned graphical interface (UI) and above all, a satisfactory user experience. It even offers Arcgis online as a cloud-based mapping solution. Looking towards the future, while geodatabases, the GIS Web and desktop GIS are the best choice for the most ambitious, demanding and stable projects, they are subject to the serious competition of GIS Cloud, especially since the Turj.js javascript library appeared in 2013 with advanced spatial analysis features for the web, along with other map display libraries such as OpenLayers, LeafletJS, Mapbox GL JS and D3.js.

The latter are capable of meeting the demands of many users who require ease of use for non-bulky data and quick results on a thematic map background, provided by cloud services, such as OpenStreetMap or Google Maps data.

In practical terms, in the context of the integration of European secondary education, GIS training is a crossdisciplinary technological resource used for teaching subjects related to Earth sciences, thanks to its interdisciplinary nature. The picture in secondary education is very promising (Kerski et al, 2013), although some matters need to be reviewed in this regard.

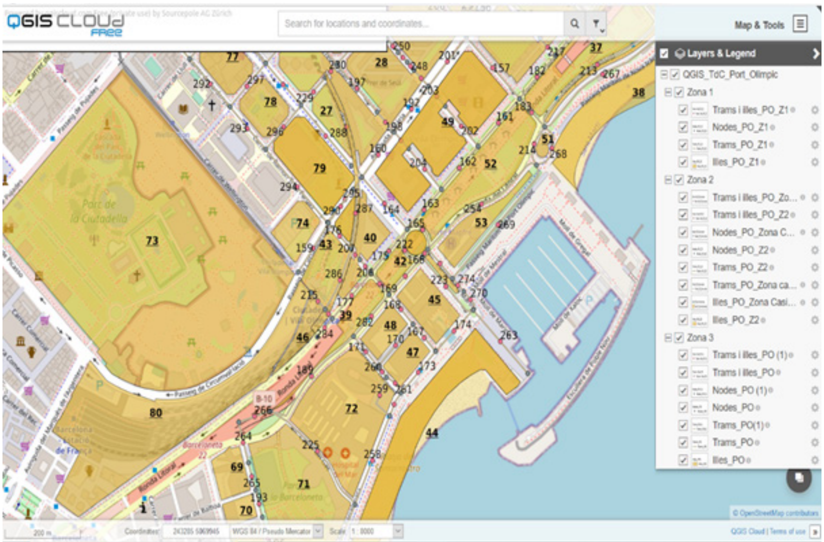

Figure 14 - Example of QGIS Cloud work on the city of Barcelona by an anonymous user.
Elaborated by the authors.

There are some inherent problems to the application of GIS technology to secondary education. The latter include the need to update the computer equipment, insufficient teacher training, and the imbalanced student-teacher ratio in the classroom (Martín et al, 2016). There are also some other specific problems (Oller and Villanueva, 2007):

• There is a notorious dearth of geographer teachers. Instead, history teachers or environmental science teachers are imparting geography subject contents.

• ICT is barely used in geography classes and few teachers show interest in their Master degree in Education, leading to limited use of GIS in the teachers' practices (Bouza, 2015)

• Educational resources come in analogue (maps) or audiovisual formats, limiting student interactions.

• The use of GIS is more the result of a teacher's personal—and exceptional—initiative, rather than a standardised academic resource. Despite all these adverse circumstances, the contributions of Congresses on the Teaching of Geography reveal a growing trend in specific and isolated didactic initiatives that focus on geotechnologies, such as:

• Introducing activities around modules that use WebGIS resources (Iberpix, viewers of regional mapping institutions), or GIS-CLOUD (Arcgis online, Google Earth). The fact that tools reside on a thirdparty server or in the cloud makes it easier for teachers to install and maintain programmes in computer classrooms.

• The tendency to use local data to motivate students leading them to learn through immersion (Zaragozí et al, 2016).

• The use of technological devices such as whiteboards, mobiles for data capture or photo geolocation, although tablets are also used for joint activities, and even GPS field receivers,

• ESRI's online Arcgis has become a major resource to produce teaching materials thanks to:

- its ease of use and low requirements: a browser and the internet.
- the fact that it is free of charge for schools and students.
- its ability to incorporate data in the form of tables with positional information (CSV files) that are then translated into GIS layers and graphics.
- multimedia resources, which are eventually incorporated into an interactive thematic map or "story map".
- ESRI's support for providing background layers in the cloud with spatial instruments (topographic cross-sections)
- And last, the fact of being able to share these teaching units in the cloud itself so they can be reused by other schools is of great interest.

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II - Module 5:
Techniques of heritage cataloguing and examples

II - 5.1 Systems identification

The hydraulic heritage concerns a complexity of elements of different nature and origin; for this reason, it is necessary to narrow the field of investigation to obtain a result that has a significant impact and returns an overall picture within which the different mapped artifacts take on a specific meaning.

The presence of different territories in geography, orography, and cultural context, for which a generalization is impossible, characterized the European landscape. Territories rich in surface water, arid areas, mountain localities, and lowland areas, do not allow to study of the local hydraulic heritage uniformly.

For these reasons, a system for the territory must be identified in preparation for the mapping activity, starting from the knowledge of the history, human activities, and characteristics of the place to return at the end of the mapping activity a result that can have the greatest possible impact for the local community.

Identify the system on which to operate will be the task of the teachers, or of the people who will guide the mapping activities.

The choice of the system is also important because it allows you to better specify the role of an artifact within a more complex human practice. It is necessary to consider that a hydraulic heritage artifact belongs to several systems connected. If we think, for example, of an artificial canal such as the canals around Milan, we realize that they were built with different purposes, each linked to different systems such as defense works, navigation, irrigation, and the production of energy. Each of these systems, if correctly identified, intercepts artifacts of different hydraulic heritage.

From a methodological point of view, it is therefore very complex to map the hydraulic heritage without referring to an identified system to not waste energy and give a deep and cultural meaning to the activity promoted.

In a non-exhaustive way, we proposed four categories to

identify hydraulic systems in different local contexts: the geographical one; the water networks, the historical era, the itinerary.
For their identification, it may also be useful to involve territorial institutions to support mapping and dissemination operations. The involvement of a city, for example, can guarantee a high level of knowledge on a limited area, or that of an entity that manages a watercourse can help identify the notable elements. Furthermore, in some cases, the assets or soils are private, such as agricultural fields and mills. The involvement of territorial institutions, foundations, or cooperatives can allow access to areas and assets, obtaining documents such as drawings or archival photographs.
The proposed categories, specified in the following pages, can be expanded and intersected. For example, we can talk about water irrigation canals network in a specific period or the artifacts along a tourist itinerary linked to a certain human activity.

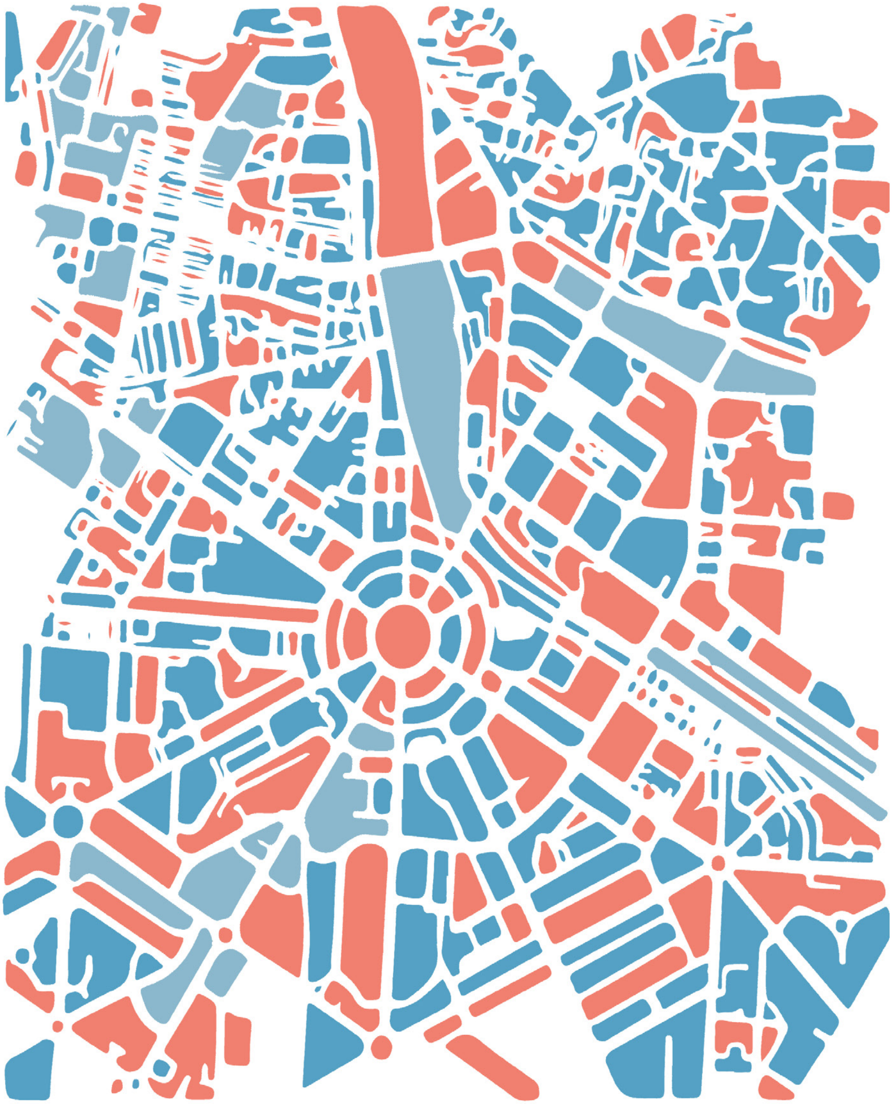
GEOGRAPHICAL CONTEXT

Simple categories are useful for defining the geographical context, such as a municipality, a region, or a park.

Different systems coexist within each category. For this reason, contexts in which water artifacts or hydraulic heritage are limited, and it is difficult to resort to specific systems, are important.

Operationally, it is necessary to indicate a portion of the territory on which to operate and to select, within this, the elements even very different from each other.

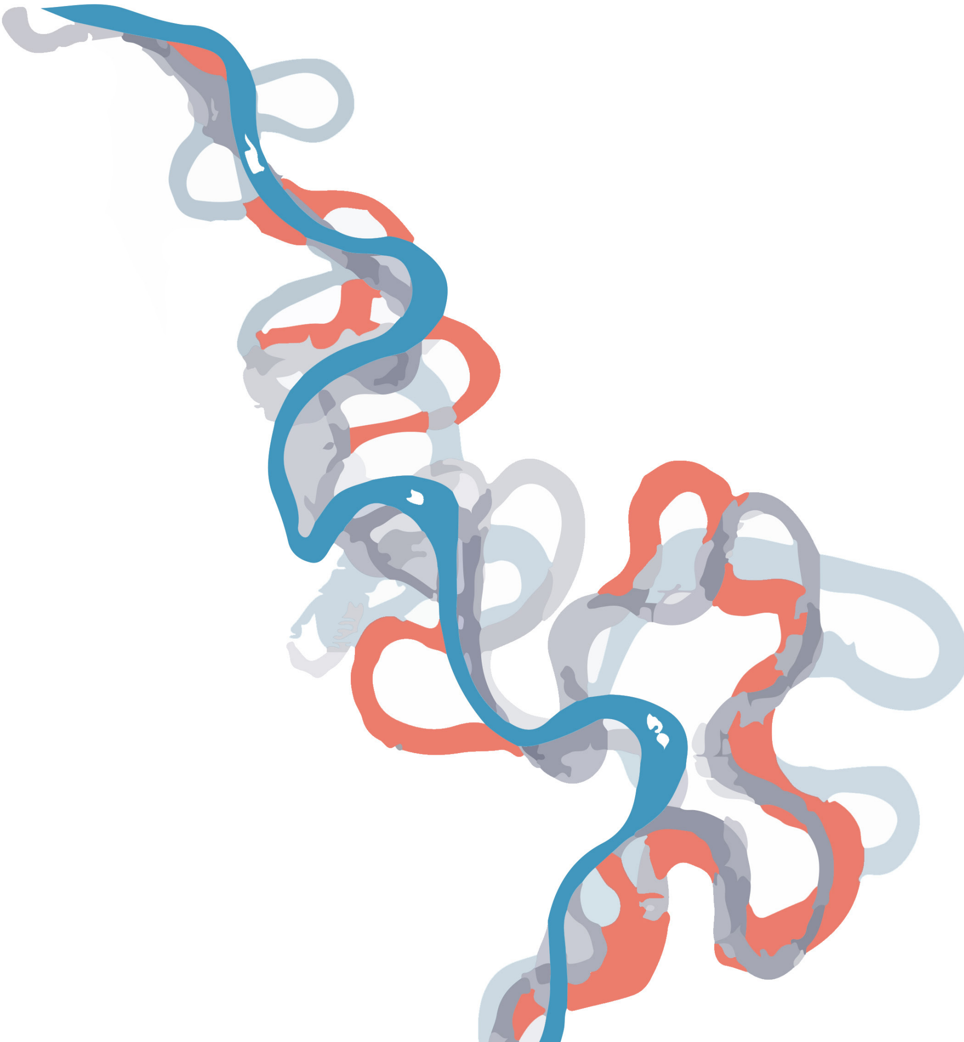
"*An example can be the mapping of hydraulic artifacts included within the territory of a city, considering the administrative limits as the boundaries of the survey field, and involving the Municipality to obtain documents and promote it.*"



IDRIC NET

In many contexts, there are extensive water networks around which have generated artifacts of the hydraulic heritage.
This is the case, for example, of the irrigation canal system often well identified by extension and characteristics. In these cases, it is also often possible to understand the extent by going back to the ownership and management of the water. Within a system, there are recurring elements, such as water intakes, mills, or bridges, which have to identify and recognizable characteristics.

"An example can be a navigable artificial canal with all the artifacts that allow its use such as moorings, navigation locks, water diversion points."



HISTORICAL ERA

Particularly significant historical periods influenced some cities in their shape and their society. Just think of the medieval villages, cities of Roman origin, or the centers born with the industrial revolution. In this case, it is possible to concentrate the research on those hydraulic artifacts that date back to this period.

"An example can be to map all the artifacts dating back to a limited period or an architectural style, contributing to the identity of a historically characterized place."

ITINERARY

There are some itineraries, especially cultural or tourist ones, interconnected with the material and intangible heritage of a place. Pilgrimage routes, paths that follow rivers or coasts, or historical routes, such as roads of Roman origin, are examples of this. Often, they are already consolidated itineraries in the tourist use, which are intertwined with a path of hydraulic artifacts, even from different eras, which contribute to the story of the territory and its history.

"In many European countries, along the ancient railway tracks, paths and canals, cycle paths have recently been created for tourist use. They can be a possible route on which to set the search for hydraulic products. "

II - 5.2 Cataloging elements

A cataloging tool must be able to give as much information as necessary to understand the characteristics of the artifact to be cataloged, and at the same time, it must be sufficiently generic to be able to include different cases. For example, if I register a bridge, I must be able to say the materials with which it is built, the techniques, the formal characteristics, the age, and use; but the same card must be able to describe an artificial canal, a water intake, or a mill. To define the scheme to be adopted, the cataloging models used by the entities responsible for the protection of Italy and Spain (ministries, regions, communities, etc.) which are based on international standards, were compared. The models have been reformulated to meet the specific needs of the artifacts attributable to the hydraulic heritage by eliminating and adding the necessary items. A series of mandatory items, common to all the identified heritage, and specific items for individual types of artifacts, made up the final cataloging tool.

The cataloging is structured in **4 areas**:

1) IDENTIFICATION OF THE HYDRAULIC ELEMENT

containing the name and information relating to the specific geographical location of the element;

2) CONTEXT

containing information relating to the membership system and context;

3) DESCRIPTION

characteristics relating to the use of the property, ownership, management, state of conservation and more specific qualities;

4) DOCUMENTS

containing the history of the item, photos, videos, websites, bibliography.

Below is an example of a standard form that can be filled in during the study or workshop:

SHEET
HYDRAULIC ELEMENT IDENTIFICATION
ID (GIS)
Longitude (coord X)
Latitude (coord Y)
Height (coord Z)
Name
Other names
Country
Province
City
CONTEXT
System
Itinerary
Landscape
Access
DESCRIZIONE
Original use
Actual use
Height
Lenght
Widht
Age
Etnology
State of conservation
Nature of good
Materials
Type of element
Features
DOCUMENT
History
Foto
Video
Website
Bibliography
Sheet Author
Date

The representation by points

If we depict the real world on a cartographic basis, specifically freshwaters and their relevance - both natural and artificial - we must consider that each element will be simplified to easily identify it concerning the others. The fundamental entities of geometry, the point, the line, and the plane, are the most effective forms of synthesis of the elements of reality. It, therefore, happens that, by natural association, the plots of land become flat, streams become lines, and artificial artifacts (from the hydroelectric power station to the fountain) become points. This type of representation is the most immediate to understand the landscape from a distance. The cartographic restitution, through these three signs,

allows the reader to get a first quick understanding of the aquatic landscape to be analyzed.

The use of only three geometric shapes facilitates the reading of the territory, but all the surfaces represented must have their spatial coordinates.

It is, therefore, necessary to associate a coordinate to each element. We should also locate the planes and lines through a single point of the infinities that constitute them. A precise spatial coordinate will correspond to the chosen point, which will make it traceable to anyone who wants to know its position.

So how to choose that particular point, for example, within a cultivated field, an irrigation canal, or even an architectural system linked to the hydraulic heritage?

This guide provides a geometric method, applicable to different contexts, to allow you to select the correct point to associate the desired spatial coordinate with.

The operator who will carry out this type of analysis must always consider the morphology of the elements in front of him. This method is generically recognized and also used by google maps. The method is simple and understandable even by those who, outside the project, read analysis data produced.

POINT *- Shapes similar to dot*

The operator will have to choose all elements similar to a point on a map, even if some of these have extended dimensions in real life (e.g., power plant).
Here are some examples of elements with the relative position in which to take the photo for georeferencing:

Disembarkation: in a central position;
"Mouth in frieze": positioning itself on the embankment, above the element;
Cascina: in front of the main entrance;
Hydroelectric Plant: in front of the main entrance;
Closed: lateral to the element;
Conca: on the pedestrian passage (always present) central to the element;
Fontana: in front of the element;
Mill: at the entrance;
Noria - in front of the element; Pedestrian / cycle bridge: in the center of the element;
Driveway / railway bridge: lateral at the end of the element;
Cleat: in front of the element;
Rope guide roller: in front of the element;
Command station: in the center of the long side of the station.

LINE **-** *Shapes similar to the line*

If the operator must define the position of a watercourse (geometrically similar to the line) for example of an irrigation canal of limited size or of a large flow river, he/she must position him/herself near the embankment, possibly central to the length of the element included in the portion under analysis, and position the georeferencing photo at that point. If the membership system is limited, the forms similar to the line can also be represented by an access point or a particularly significant one.

PLAN *- Forms similar to the plan*

For extended forms, geometrically similar to the plane, the pic must be placed in a central position for these. For example, if the operator wants to locate a rectangular piece of land, he/she will have to place him/herself almost in the center of the imaginary diagonals of the rectangle and select that point for georeferencing.

Introduction to the sheets of the hydraulic elements

This chapter presents sheets on the recurring hydraulic heritage elements. The cards specify the characteristics to highlight during catalogings, such as operation and use. They are not exhaustive, and their number can grow up in the future to allow the inclusion of other assets.

Sometimes the system identified for cataloging refers to specific assets linked to the local context. In these cases, it will usefully identify main elements and characteristics and analyze them in another specific sheet.

Index of cataloged hydraulic elements:

1) Lock
2) Water trough
3) Irrigation canal
4)Noria
5) Water jump
6) River front
7) Mill
8) Dam
9) Irrigation raft
10) Well
11) Sink
12) Artificial basin
13) Embankment
14) Crusher
15) Factory
16) Hydroelectric power plant
17) Bridge
18) Aqueduct
19) Paddy field
20) Landing
21) Water intake
22) Ripa
23) Towpath
24) Service building
25) Irrigation tank

1 LOCK

General description:
A lock on a canal is a door, which usually is in a system with another, for the water containment in a basin. The lock system (two side doors and a central basin) is used to house a boat that must pass from one water level to another higher or lower. The lock can be single or, to overcome a high-water level, there may be several locks, one after the other, for a gradual ascent or descent. Locks are engineering works built on artificial canals characterized by a large difference in height to allow boats to overcome them.

Types of lock:
- Single
- Double or multiple jumps

Part of lock:
- 2 doors, called "Vinciane" (one upstream and one downstream) with holes in the lower part
- Basin

Functioning of the lock:
While the first door remains closed as a barrier or support between two different water levels, the boat enters through the other door.
After the boat entered in the basin, the second door also closed, and small openings are opened in the lower part of the doors: through these openings, the water enters (if the boat must level up) or exits (if the boat is going down) from the basin.
When the internal water level of the tank chamber is equal to the external one, the door between the two water levels opens, and the boat exits the tank.

History and bibliography

Navigating in shallow canals or going upstream, the boats were pulled by horses, led by riders, or by the boatmen themselves who travelled the embankment, on the banks called towpaths.

To facilitate navigation, basins were built, also called Chiuse or Porte, real water elevators that joined streams of different heights and allowed boats to go up or down the stream.

Figure 1 – Lock in Borgarello, Pavia
Source : Silvia La Placa, Pavia University

2

WATER TROUGHT

General description:

The term water trough refers to any container used to quench the thirst of domestic animals, usually a container or tank, consisting of a simple channel of wooden boards or tree trunks, or a stone, concrete, or masonry plant.

Types of trought:

As a very generic term, we can identify different types of water troughs, which are distinguished by size and construction material. Typical rural environments are water troughs consisting of large tanks in stone, concrete, or wood, used to quench several animals at the same time.

Figure 2 – Stone water trough, Spain
Source : Pablo Altaba Tena, Uji University

3

IRRIGATION CANAL

General description:

Water flow center, created artificially to serve irrigation.
The channels can be obtained, by digging on the surface, with sides and bottom left in the natural state or covered with a layer of walls.

Types of irrigation canal:

- underground
- in tunnels
- elevated areas

Functioning of the irrigation canal:

The work can be controlled manually using small locks, water intakes, and regulation/discharge. Otherwise, it can be monitored with remote control and transmission systems, that are part of the corresponding operational center.

Figure 3 – Canal du Midi, France
Source: Luca Trabattoni, Università di Pavia

4 NORIA

General description:
Machine for lifting water and inert materials (such as sand, seeds, and the like). Noria transforms the potential or kinetic energy of small streams into mechanical energy in the form of rotary motion.

Types of noria:
- rosary
- with the side wheel
- with the wheel from above
- With the wheel from below
- with the kinetic wheel

Part of noria:
- wheel with shovels
- pulleys
- series of buckets fixed at equal distances on a chain or endless belt, moved and guided by pulleys.

Functioning of the noria:
The noria consists of a large wheel, a few meters in diameter, with the lower part immersed in a river or canal. On the wheel, there are blades, which lap the current and allow rotation, and buckets, which are filled with water. When the buckets reach the top of the wheel, they empty their contents into a collection tank. The cups are filled at the bottom, fishing in the water (or plowing the pile of material) and, passing on the upper pulley, pour the contents into a hopper that collects it. In particular, the lifting of the liquid is obtained using a series of steel discs, with rubber seals on the edges, which, dragged by a chain, move inside a tube immersed in the liquid.

History and bibliography

The origin of noria seems to be in Mesopotamia in a period dating back to around 2000 BC., and it has been spread and improved in the Islamic world by mechanical engineers. The Versailles Palace fountains were once fed by a noria plant on the Seine, called the “Marly Machine”, named after the place on the Seine near which the machine was installed.

The water wheel was the ancestor of the so-called first motors that directly transform the energy available in nature into mechanical energy. Its first applications are very ancient, probably linked to the milling of cereals. The first wheels were likely of the “bottom-up” type.

The development took place in the eighteenth century, before the steam engine and the construction of hydraulic turbines, which are its natural evolution. In this sense, the water wheel allowed the start of the industrial revolution, which was then powered by engines of greater power.

Figure 4 – Noria in Castellón de la Plana, Spain
Source: Pablo Altaba Tena, Uji University

5

WATER JUMP

General description:

The difference in height between the amount at which the mass of water is available and the level at which it is returned after the passage in the turbine, and the flow rate, or the amount of water that flows through the turbine per unit of time.

Figure 5 – Jump of water in Borgo Calvenzano, Pavia Italy
Source : Silvia La Placa, Pavia University

6 RIVER FRONT

General description:
The road in a town that follows the bank of a river and, therefore, has a side free of buildings.
The main feature of a long river is the asymmetry of the section. The construction of such roads is limited only along the opposite riverside (towards the ground), while the riverside remains open. Therefore, usually, while towards the ground there are roadways and sidewalks similar to those of any other urban road, towards the river the sidewalk, often tree-lined or adorned with gardens, usually form walks and meeting places.
The long river may take a local name, joining the “long-prefix” as the proper name of the river bordered.

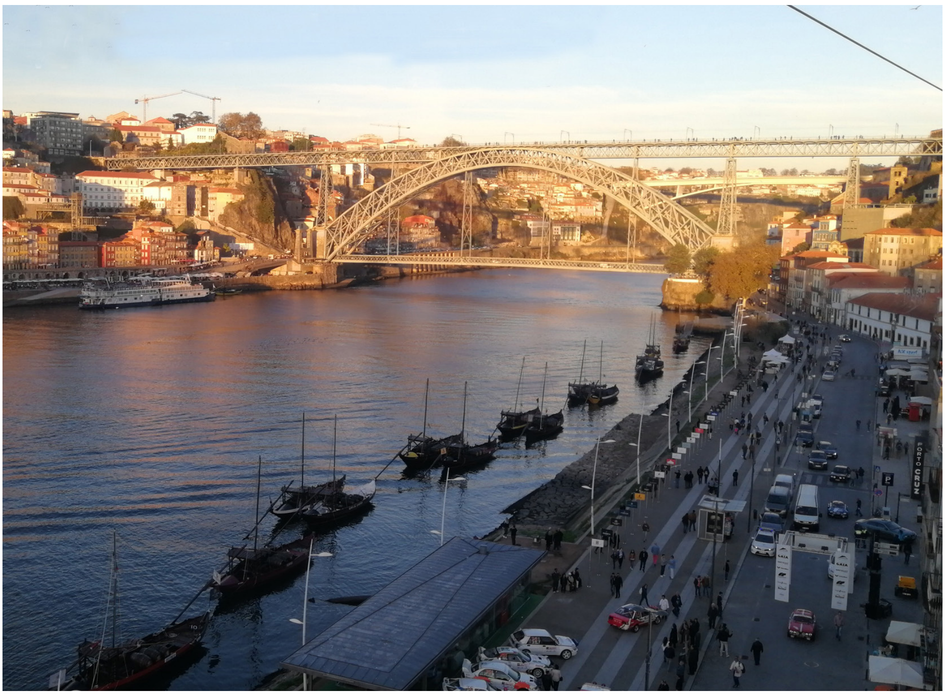


Figure 6 – Duero river front, Portugal
Source: Federico Mezzadra, Pavia University

7 MILL

General description:

The evolution of the mills places them, like the farmhouses, between homes and workplaces. They are usually two-story buildings: the ground floor contained the milling room and a fence. Although the main mill function was to grind, the owners were also farmers and needed a place to keep work animals. The upper floor was the miller's house. The external parts of a mill vary depending on the needs, location, and ease of bringing water. They are solid buildings made of ashlar and with very thick walls. The explanation is quite simple: the construction had to resist the force and pressure exerted by the water on the walls.

Parts of the mill:

- The barrier, also known as the lock, is nothing more than an obstacle in the river bed to divert the current and transfer water into a ditch.
- The ditch was a conduit that transferred water from the dam to the pond.
- The raft is a tank where water was stored so that the grinding process was uniform.
- The vertical storage bucket, generally of great height where the water increases pressure into the wheel. (In some cases, the mills have no tank and the ditch deposits the water directly into the bucket.)

Functioning of the mill

The path of the wheat and the flour, represented by points (fig. 11), begins in the hopper (1) from where it passes to the channel (2) that brings the grain to the eye of the grinding wheel, where it falls to the center of the sliding wheel (3) and of the wheel of the hearth (4). Once ground, the grain comes out of the flour (5) and falls into the mill (6). The water path is represented by black arrows. The water in the basin or bucket comes out under pressure through the canal (9) and hits the wheel (8), the shaft (7) and the wheel (3) are the only pieces that rotate simultaneously in the mill (Barberà I Miralles, 2002)

Figure 8/9 – Machinery for the preparation of the mill
Souce: Pablo Altaba Tena, Uji University

Figure 10 – Mill Joaquín, Villahermosa Spain
Souce: Pablo Altaba Tena,
Uji University

Figure 11 – Molí de Xodos, Spain
Souce: Pablo Altaba Tena,
Uji University

History and bibliography

As Gonzalo Morís (1995) writes in the magazine Ingeniería del Agua. Vol 2. N. 4 (p. 28-29) "Around and on the basis of the mills were created a multitude of legends and funny couplets, the mills were meeting places for people, old and young. They spoke of daily events, gossip and stories, sometimes real and other times, the result of the imagination of members of the public, questioned in the mills all the way to the nearby parishes. Moreover, since they are generally far from the rest of the population, the imagination and malice of people have given them a reputation that is little less than sinful and there are many popular songs that allude to this ". (Morís Menendez-Valdés, 1995) There are two variants of the modern mill: the private and the common.

The particular variant, as the name suggests, was for private use. He had an owner who was the one who worked the mill, to whom they brought the grain and he grinded it, making him pay. His house was adjacent to the mill and had a shape similar to farmhouses. The miller's trade involved an artisanal work of grinding the millstones. Rafael Miralles, visiting his mill, explained the difference between French and Catalan millstones:

- French mill: the stone contained flint and was harder, it had straight grooves and the product was finer. It was used to bake flour and to make bread.

- Catalan mill: it was the most common and had curved grooves. It also served the uses of the French, although the product was coarser. It was used to grind grain for animal consumption.

The communal mills, to which the quotation refers, had an owner or were of communal property, these were paid in the product that had to be ground according to the quantity that was worked. The same person who carried the grain would grind it, make good use of the plants and leave them as they were. So the mills were a meeting place, the harvest seasons were the same for the whole area, so also the milling seasons.

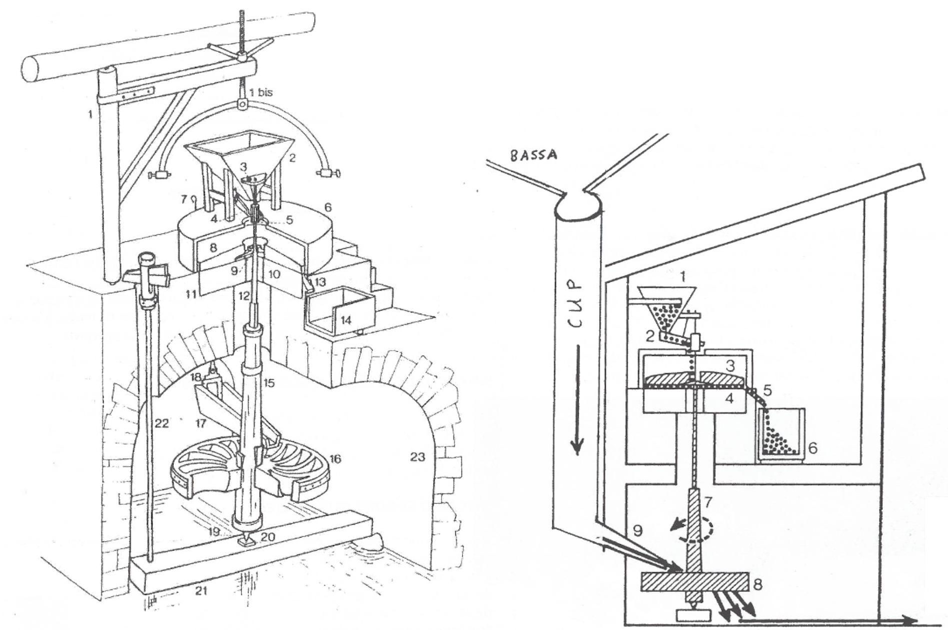


Figure 12/13: Diagrams of the parts and operation of a mill. Extract from the book Catàleg dels molins fariners d'aigua of the province of Castelló. Barberà, B.

8 DAM

General description:

A barrier built to obstruct or divert a river course and collect its waters in an artificial basin. Generally, dams are built to concentrate the natural water jump of a river, to exploit it to generate electricity, feed channels, and irrigation systems and water supply, to raise the water level of the river to make it navigable, to control its level during periods of flood and drought, or to create artificial lakes for recreational purposes. Often dams perform many of these functions at the same time.

Types of dam:

A) Dams of walls:
A) Dams of walls:
- a) to gravity;
  - 1) ordinary ones;
  - 2) spurs and internal compartments;
- b) in turn;
  - 1) with an arc;
  - 2) arc to gravity;
  - 3) a cupola;
- c) sometimes or only, supported by buttresses.

B) Dams of loose materials
- a) homogeneous earth;

b) land and/or stone, zoned, with a core of land for the estate;

c) Of permeable earth or rock, with a covering or diaphragm sealing of artificial materials.

C) Various types of barrier

D) River sleepers

Dams, according to their use, are classified (ref. 1987, USBR, Design of small dams) in:

A) Dams for RESERVOIRS (storage dams):
- for IRRIGATION
- for DISTRIBUTION of drinking and non-drinking water,
- for ENVIRONMENTAL PROTECTION of endemic fauna and flora,
- for RECREATIONAL and SPORTS USE,
- TO GENERATE ELECTRICITY

B) DEVIATION dams (diversion dams)

C) Dams (retention dams)

Dams are classified, for the MATERIALS with which they are built, in:
A) EARTH DAMS (earthfill dams)
B) Dams in PIETRAME (rockfill dams)
C) CONCRETE DAMS (concrete dams and RCC dams)

Functioning of the dam:
Hydroelectric dams create vast reservoirs of hydrostatic potential, move large quantities of water through turbines and run generators that produce electricity.

History and bibliography
Dams in earth and rubble are the easiest to build and, therefore, the oldest. Some Roman dams have remained standing to this day.
The first concrete dam in Europe was built in Switzerland in 1872.
In the last 20 years, gravity dams, on the other hand, have undergone great development thanks to the invention of COMPACTED ROLLED CONCRETE (RCC), a technology that allows reducing the costs and the times of realization of these dams. This technology was also designed by the Italians, for the dam of Alpe Gera in the sixties, and resumed 20 years later in the United States and now widely spread.

Figure 14 – Diga del Molato, Val Tidone
Fonte: Luca Trabattoni, Università di Pavia

9 IRRIGATION RAFT

General description:

Tanks of variable size for the collection of water necessary for irrigation. Irrigation rafts are artificial basins made with different techniques and always placed close to the fields and equipped with instruments for water distribution.

Figure 15 – Irrigation raft
Copyright free

10 WATER WELL

General description:
A water well is an artificial work for the extraction of groundwater. The geological structure from which draw the water is called the aquifer.
In the past, men dug water wells by hand, with diameters large enough for the digger to descend inside. Today water wells are made with mechanical means, which penetrate to great depths while keeping the diameter limited.
Water wells have one or more openings to let the water that saturates the surrounding soil penetrate.
Water well gives the possibility of acquiring univocal information (stratigraphic and about the quality of the water) on the characteristics of the subsoil in which it is located.
This information is essential to determine the flow directions, and therefore to reconstruct the groundwater feeding mechanisms.
A water well, if not properly built and managed, can also be a source of danger for the aquifer's pollution. The water well connects the soil surface with the deep aquifer, bypassing the filter action of the soil.
A water well can also be a dangerous point of communication between separate aquifers.

Types of wells:
- ordinary, in which the water never rises above surrounding natural soil level;
- artesian or Modena, where the water always rises inside the water well, and sometimes its upward force is such that it also gushes from the ground.

The construction methods distinguish two categories: dug water wells, with masonry or other material linings, and bored water wells, with or without metal lining.

History and bibliography:

The oldest known wells date back to the Neolithic. A water well dating from 8100-7500 BC was found in Atlit Yam in Israel.

Figure 16 – Stone water well, Spain
Souce: Pablo Altaba Tena, Uji University

11 LAUNDRY/WASH-HOUSE

General description:
The laundry is a handwashing facility for linen and other articles of fabric. In the forms of domestic use, it consists of a tank, usually of concrete with an inclined plane for the soaping of the washing items. Generally, it is a public place, sometimes covered by a shelter, now in disuse.

Figure 17 – Laudry, Spain
Source: Pablo Altaba Tena, Uji University

12 ARTIFICIAL BASIN

General description:
The artificial basin is a structure containing a considerable mass of water.

Types of artificial basin:
- loading dock
- calm pelvis
- drainage basin
- expansion basin (emergency tank).

Functioning of the artificial basin:
The purpose of the basin is to collect large quantities of water to have it available for use in both industry and agriculture. There are also cases in which the basin is kept empty to collect large quantities of water during exceptional events, such as floods; the latter type of basin is called an expansion basin or an emergency basin.

Figure 18 – XXV Aprile park basin, Rimini
Source: Tiziano Cattaneo, Pavia University

13

EMBANKMENT

General description:
The embankment is a barrier designed to protect the territory from flooding phenomena. Embankment can be a natural or artificial rise.

Types of embankment:
- Golean embankment
- master embankment

Functioning of the embankment:
Its banks have a slope between 2/3 and 1/3 depending on the characteristics of the material used. The height of the embankment is defined based on hydraulic criteria (hydraulics, installations). The height of the bank summit is usually fixed equal to the water height, increased by an appropriate safety margin. The bank located on the riverside can be covered with blocks of quarry or concrete to protect it from the erosive action of the current. In complex systems (such as the Po River), there are several embankments' orders to prevent a single embankment route from causing the flooding of large parts of the territory.

Figure 19 – Ticino embankment, Pavia Italy
Fonte: Lorenzo Quaglini, Pavia University

14

OIL MILL

General description:
instrument or apparatus for crushing solid materials.
Also the place, that is the room, the building, the plant where the crushing takes place.

Types of oil mill:
- grinder
- cylindrical oil mill, for the processing of olives
- mill with jaws
- cone oil mill, for hard materials (stones)
- hammer oil mill for soft materials (coal, gypsum, shale)

Figure 20 – Ostuni Oil mill, Italy
Copyright free

15 FACTORY

General description:

A factory is a set of buildings intended for industrial production. Technological development has led to the birth of increasingly automated structures whose maximum expression is the automatic factory. Generally, raw or semi-processed materials are transformed into finished products.

Very often, factories are near water resources (rivers, lakes, streams.), which actively participate in the activities within the factory.

Figure 21 – Factory in Duisburg, Germany– Copyright free

16

HYDROPOWER PLANTS

General description:
Hydroelectric power plants convert the hydraulic energy of a watercourse into electricity.

The power of a hydraulic system depends on the head and flow rate.
In the case of several plants in series, the water is collected at the exit of the production plant and sent back to the next plant to a new head.
The water is then used several times inside the plants to make the most of all the energy content.

Types of hydroelectric power plants:
- Hydroelectric power station in the basin
- Run-of-the-river hydroelectric power station
- hydroelectric pumping plant
- hydroelectric power plant with artificial basin

Functioning of the hydropower plants:
Generally, the water intake takes place through a watercourse dam and hydraulic works for the water withdrawal.

The transport of water inside the system takes place through hydraulic channels in the tunnel or outdoors. Finally, the water is conveyed into loading tanks and, through penstocks, into the turbines of the hydroelectric power plant.

The electricity is obtained from the water coming from the forced pipe at the foot of the jump. The flow impacts with the turbine blades which, connected to the alternator, allows the generation of energy.

History and bibliography:

For thousands of years, water has been the main source of energy to manage grain milling systems, irrigation of fields, and wood processing. In the late 1800s, people started using waterpower to generate electricity. The first large Italian hydroelectric plant was activated in 1895 in Paderno. The power plant was built on the Adda by Edison, a company.

Figure 22 – Semenza Hydraulic factory, Calusco d'Adda
Copyright free

17

BRIDGE

General description:
The bridge is an engineering work in masonry, reinforced concrete, iron, wood, or other materials, that allow the overcoming of natural or artificial obstacles.

Types of bridge:
- Truss bridge
- Suspended bridge
- Arch bridge
- Mobile bridge

Parts of the bridge:
- superstructure (roadbed, deck, and beams)
- substructure (trusses or abutments) and supporting foundations.

Bridges typology:
- Truss bridge:
A first elementary type is that of the simply supported beam, which can be made with any material, but with different spans according to the characteristics of the material used (e.g., stone bridge over the Leach, England; iron bridge over the Tennessee, USA; Montesi viaduct in reinforced concrete, near Genoa).
There are bridges with continuous beams on several supports to obtain greater rigidity and lightening of the sections and increase the light of the individual spans (e.g., Gardiol Reinforced Concrete Bridge, Switzerland, with 14 m spans; iron bridge on the Reservoir Fountain, North Carolina, 70 m of light; Waterloo Reinforced Concrete Bridge, London, with 73 m of light).

- Cantilever bridges:
This type consists of two protruding beams joined by another suspended beam. The system, giving maximum rigidity, allows

a further reduction of the sections (e.g., Dry Creek Reinforced Concrete Bridge, Kansas, 1941, 20 m of span).

The prestressed concrete also allowed the use of prefabricated elements to overcome spans of the order of 100 m. The beam, accompanied by other structural elements (e.g., tie rods), allows even wider spans to be reached (e.g., Maracaibo bridge, Venezuela, 1962, with a 235 m span m).

- Arch bridge:
This structural typology can have different static schemes and architectural solutions.
There is a wedge arch, such as the Freyssinet Bridge in Saint Pierre de Vauvray, 1928, with a span of 131 m; the two-hinged arch, like the Garabit viaduct, Eiffel, 1884, with a span of 166 m); the three-hinged arch such as the metal bridge at La Roche-Bernard over the Vilaine, 1912, with a span of 200 m, or the reinforced concrete bridge at Maillart, over the Aare, with a span of 132 m).
The advent of iron and reinforced concrete has given the arch new proportions, enhancing its expressive abilities.

An intermediate static scheme between arch and beam was created in the bridges called "Risorgimento type" (from the first built in Rome, in 1911, by Hennebique) in reinforced concrete with a hollow diaphragm section.

- Suspended bridge:
The structural typology of the suspension bridges allows them to reach the greatest spans, thanks to the tie rods.
Steel ropes have allowed the creation of ever more daring works, from the Brooklyn Bridge (New York, 1883), to the G. Washington Bridge (New York, 1931), to the Golden Gate (San Francisco, 1937).

- Mobile bridge:
In some situations, particular technical solutions are necessary, for example, when the free height below the road level of a bridge (on a navigable canal) does not allow easy navigation on the underlying watercourse, mobile bridges are used (e.g., drawbridges, swing bridges, sliding bridges, lifting bridges).

- Temporary bridges: boats, barges, and self-supporting structures (bridge cranes) or demountable elements are connected and used in emergencies.

History and bibliography:
The need for work that allows the stable and continuous overcoming of natural obstacles has been addressed since prehistoric times. Among the first architectural expressions of man, there are the suspension bridge (in lianas) and the leaning one (in wooden trunks). These structures are always strongly linked to the characteristics of the different civilizations, becoming experimental technical works and, at the same time, works of art.

Among the best-known bridges of the first-millennium a. C. there is the one on the Euphrates, near Babylon, mentioned by Herodotus and Diodorus, and the Ponte Sublicius, in Rome in 621 BC. The Etruscans were the first to build masonry bridges, and the Romans obtained the technique from them, becoming the greatest builders of antiquity.

In the sec. XII, the brotherhoods of the Fratres Pontifices began a period of rediscovery and restoration that led to the construction of new bridges inspired by Roman types.

From about 1700, the technological development of bridges took an ever-faster course, also linked to the appearance of new building materials (e.g., iron, steel, reinforced concrete, and prestressed concrete).

The evolution of bridge construction technology has allowed new works in highly seismic areas or unfavorable environmental conditions, such as in Japan, or even to overcome large stretches of the sea with hybrid systems (submarine bridge-tunnel).

Figure 23 – Castelvecchio Bridge,Verona
Source : Margherita Capotorto, Pavia University

18 AQUEDUCT

General description:

From the Latin "aquae" and "ductus", water conduit, the aqueduct is the set of works that serve to lead water from a place of withdrawal (source or basin) to one of use.
Generally, an aqueduct consists of an intake structure, a pipeline with buildings useful for maintenance along the route, and collection, treatment, and distribution work in the place of arrival.

Constructively, the aqueduct can be built with artificial canals, pipes, or mixed solutions. In the case of channels, the operation can only be free-surface, in the case of pipes also under pressure.

Parts of the aqueduct:
The aqueduct system consists of all the pipes, plants, manufactured products, equipment and instruments for the collection, treatment and distribution of water from the collection points to the end users.

Functioning of the aqueduct:
The water intake works are different depending on the type of resource from which it is drawn (e.g., wells and trenches, transfer tunnels, pumping stations, etc.). The supply works (oil pipelines) can be free-surface or under pressure.
The ducts on the surface operate by gravity: the water only partially fills the duct and moves, due to the difference, in level between the outlet and the point of arrival. In the case of pipelines under pressure, on the other hand, the energy for moving the water is supplied by pumps located in pushing stations. In general, the aqueduct follows a road layout to reduce the exploitation of bridges and tunnels.
At the end of the pipeline, there is a tank in which the water is stored.

The approach line starts from the tank and connects to a ring pipe from which the distribution lines depart, which in turn connect to the user connection pipes.

History and bibliography:

The oldest known remains of an aqueduct are found in Mesopotamia (first half of the fourth millennium BC). Eastern kingdoms have used water collection and transport systems since the 8th century BC.. These systems are comparable to those of reclamation and collection of the Etruscans before the expansion of Rome.

The Greeks used water collection and supply systems with tunnels obtained in reliefs or surface channels with ancillary masonry works, with pipes (clay or stone), or water channels dug into the rock, with or without plaster, protected by stone slabs.

The Treaty of Frontino (97 AD) provides more detailed knowledge on the construction and management of aqueducts.

Empirical observations guided the choice of sources. The Romans withdrew water in different ways (with underground tunnels, with sockets connected to a sedimentation tank, from artificial basins with locks). The adduction took place by gravity, through a slight slope of the duct.

The aqueducts that served Rome at the time of Frontino were many some of their structures are still visible.

Aqueducts and other hydraulic works arose from the Arabs in the lands under their dominion.

From the 19th century onwards, the metallic materials increased, and the pressure system began to be favored.

Figure 24 – Roman Aqueduct, Elvas (Portugal)
Source: Carlo Berizzi, Università di Pavia

19 PADDY FIELD

General description:
The rice-growing land, permanently submerged by a layer of water, is slightly sloping, delimited, and crossed by transverse and longitudinal embankments.
Rice fields are typical of many East Asian countries, including China, Korea, the Philippines, Japan, India, Bangladesh, Indonesia, Taiwan, Thailand (where the king himself opens the rice season), and Vietnam.

Rice cultivation in Italy is mainly concentrated in the low Po Valley and the narrow belt up to the pre-Alps between Lombardy and Piedmont. In particular, the laughter is in the areas of Lomellina, in the lower province of Milan, in the Novara area, and the Vercellese area in Piedmont.
From a naturalistic point of view, the rice paddy area was very important because it housed a large part of the European heron population, concentrated in nesting areas called heronry. In recent years, following the modification of the water cycle management technique and the spread of "dry rice fields", the naturalistic value of rice fields has significantly decreased due to ecological imbalances, including the enormous proliferation of mosquitoes.

Figure 25 – Paddy field, Pavia
Source: Lorenzo Quaglini, Università di Pavia

20 LANDING

General description:
Space equipped with ropes and ramps where a boat can stop to stop on the ground. There are different types of landings: some are obtained from the natural bends of a river or canal, others are, instead, equipped with walkways and systems that make them similar to small ports.

Figure 26 – Landing, Borgarello (PV)
Source: Silvia La Placa, Pavia University

21 WATER INTAKE

General description:
Water intakes for irrigation are small engineering systems located on canals, often near nodes or water exchanges. The sockets consist of two sides usually, in concrete or bricks parallel to the edges of the water channel and two other sides in wood or iron orthogonal to the water channel. The latter are mobile and are raised and lowered to control the water flow between the different reservoirs.

Figure 27 – Water intake, Pavia – Fonte : Silvia La Placa, Pavia University

22

RIPA

General description:

The term ripa indicates the shore of lakes or rivers. The ripa is a natural bank and so a significant element for the water and hydraulic landscape, as it is the habitat of bird and amphibian species that nest there

Figure 28 – Ripa Naviglio, Pavia – Source : Silvia La Placa, Pavia University

23 TOWPATH

General description:
The towpath is the road that runs along the bank of a river or canal. Towing of boats is carried out by mechanical means from the towpath. At one time, the towing took place with arms or with towed animals, and for this reason, the term towpath also indicates the tow rope.

Figure 29 – Alzaia Street, Pavia
Source : Silvia La Placa, Pavia University

24 SERVICE BUILDING

General description:

The service buildings are control cabins, as in the photo, or housing for tools for the water channel management. An example is the control cabins on the Naviglio Pavese. These “houses” contain inside levers and buttons used to mechanically control lock movements, to check that the basins were filled or emptied of water as needed

Figure 30 – Service building on Naviglio,Borgarello (PV)
Source : Silvia La Placa, Pavia University

25 IRRIGATION TANK

General description:

The irrigation tanks are constructions, generally made of concrete, used to manage the irrigation water of the cultivated fields. These cisterns are connected to the irrigation channels through small mobile lock systems. The tanks collect excess water from a canal and redistribute it to other minors, to allow irrigation even in times when the minor canals are arider.

Figure 31 – Irrigation tank, Copyright free

II - Module 6
Field information mapping

II - 6.1 Open source apps to work with spatial data:

Over the past few decades, all kinds of initiatives have flourished within the framework of Free and open-source software (FOSS). This boom is partly due to the movement that defends the Free Software Foundation paradigms, advocating the four freedoms proposed by Stallman (1989) that free software must comply with (to use, study, distribute and improve). The greatest exponent of this philosophy is the GNU/Linux operating system. We should remember that in the beginning, commercial software was omnipresent in the geospatial sector. It is thus remarkable how the contributions of the scientific community in the form of programmes of all kinds, algorithms and libraries released under one of the many open-source licenses have led to an open, free and sustainable alternative in the world of GIS. Evidence of this is the establishment of the Open-Source Geospatial Foundation (OSGeo)14. This foundation was created to provide financial, organisational and legal support to the open-source geospatial community. The mission of this non-profit organisation is to promote the global adoption of geospatial technology in a participatory manner and driven by the information society. It would be unfeasible to list here all the free and opensource projects, so we will simply name those that have had the greatest impact, classifying them into the following categories:

Geospatial libraries:

Libraries are algorithms that are used by any programme to develop from the simplest tasks to the most complicated. They are integrated into both free and commercial GIS programmes.

Some of the most widespread free GIS libraries include:

• PROJ: This is an Application Programming Interface (API) for coordinate conversion and reprojection to the many existing mapping projections. It also allows you to transform coordinates between different datums. It is a mature, stable library which is used in many free and commercial programmes.

• Geotools: a Java-programmed library that provides utilities for managing geospatial data, supporting all Open Geospatial Consortium (OGC) specifications. It can render a wide range of spatial formats.

• GDAL/OGR: Geospatial Data Abstraction Library (GDAL) is a software library for reading and writing geospatial data formats. It features a single abstract data model that allows you to communicate with all supported formats (163 raster and 69 vector). It also comes with a variety of command-line utilities for geospatial data translation and processing.

• GEOS: This library is programmed in C++, one of the most efficient languages, and is widely used in numerous free and commercial projects for geometry geoprocessing. It was originally a Java

Topology Suite (JTS) library, created by Vivid Solutions for its JUMP programme. It includes Simple OpenGIS features for SQL (SFA). It defines spatial predicate functions (Figure 2) for SQL (Standard Query Language) and spatial operators (Figure 1), as well as JTS enhanced specific topology functions. In short, GEOS allows us to know the result, in Boolean values (true or false), of operations with two spatial sets and applying an operator (they cross, touch each other, intersect, etc.). It also allows us to obtain the result of applying the overlay operation to two geometry sets (union, intersection, etc.)

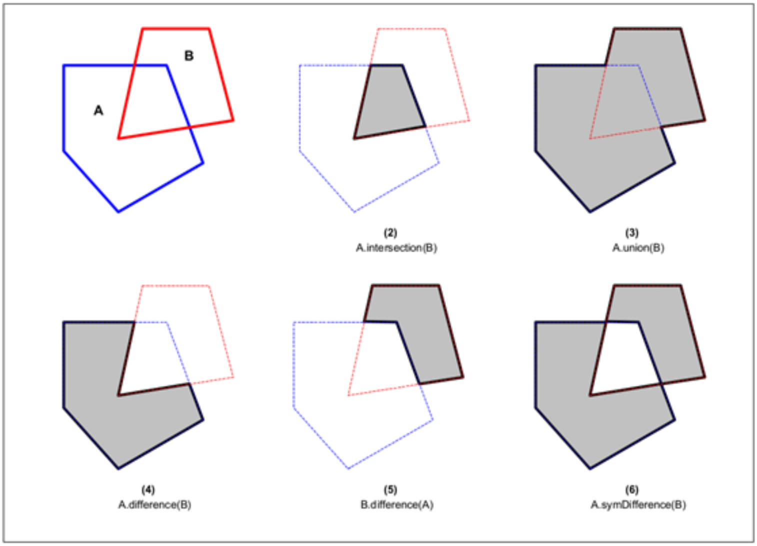


Figura 1 – Spatial analysis method– Source : internet1

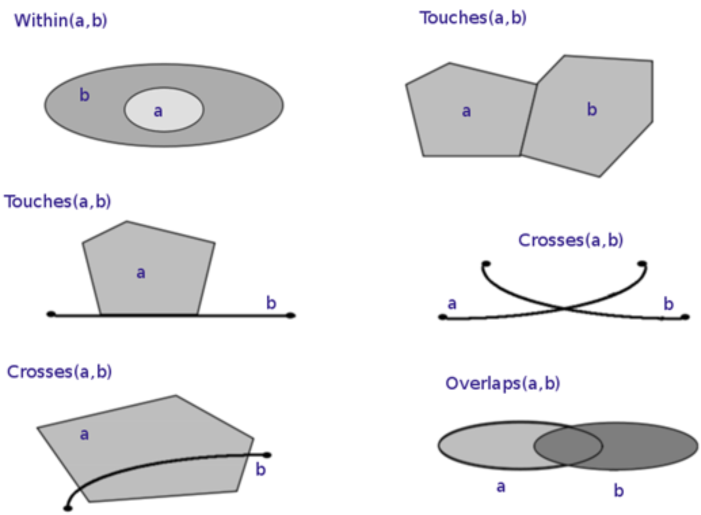


Figure 2 – Spatial Predicates– Source: internet16

• Sextante17: a set of up to 240 algorithms that was originally implemented in SAGA GIS software (Olaya, 2009). Sextante is a personal project of its creator, Victor Olaya, undoubtedly among the most visionary minds of the GIS landscape. Its contribution to GIS has been crucial in providing emerging GIS programmes with a set of remarkable features that make their use attractive in a professional environment. These libraries have been carried into other languages, allowing them to be used in other programmes (QGIS, OpenJUMP and GvSIG)

Desktop apps:
Desktop GIS programmes are the most widely used. These tools require a certain level of specialisation. Among the most widespread are the following:
• GRASS18: If we follow the chronology, in 1982, the Construction Engineering Research Laboratory of the U.S. Army Corps of Engineers (U.S./CERL) began exploring the use of GIS for environmental research, the monitoring and management of military lands (Neteler, M. & Mitasova, 2008). Since no other software package available at the time met all their requirements, they designed and developed their own. GRASS software gradually developed and was introduced into several universities. Yet it was not until October 1999 that GRASS version 5 was released under the GNU General Public License (GPL). The GIS programmes of the previous century, in line with the computer advances of the time, were used on a terminal; long commands were written that were difficult to remember, added to unfriendly graphical interfaces. GRASS has been described as a very powerful and safe software, but with a knack for non-intuitive interfaces. It could hardly compare to the friendly graphic environments of other programmes, despite the latter offering less functionality. GRASS usage thus became increasingly residual. According to Neteler and Mitasova (2008), to make the development of the tools of other GIS programmes more efficient, GRASS provides a set of libraries arranged in the form of documented

application programming interfaces (API), mainly used by QGIS.

• System for Automated Geoscientific Analyses (SAGA GIS)19: a very efficient software for the easy and effective implementation of spatial algorithms. Programmed in the C++ language, its algorithms are executed with speed, making it very popular in scientific spheres. The weak point, as in the case of GRASS GIS, is an interface that is not very intuitive for beginners.

• OpenJUMP20: This programme is very simple to use, and its greatest virtue is the extension of its functionality through external plugins. It originally derives from other JUMP software, developed by Vivid Solutions. JUMP was primarily designed to implement the spatial geoprocessing algorithms of the JTS library mentioned above.

• gvSIG21: another GIS application programmed in JAVA, with an interface that originally imitated the modus operandi of ArcView GIS, a programme owned by the ESRI company that was very popular in the first decade of this century. GvSIG emerged in 2004 and should be credited with being the first broad-spectrum, functional and friendly desktop GIS. The incorporation of advanced extensions (Anguix et al, 2008) such as topology, networks, 3D, remote sensing, OGC publication, etc. made it very popular, to the extent of becoming one of the most widely used programmes, especially in Spanish-speaking countries. Later, the incorporation of Sextante's algorithms enriched this programme with new raster and vector analysis capabilities. However incompatibility issues with inter-version extensions, their funding policy (the initial support provided by public administrations was withdrawn at the first signs of the economic crisis) led users to migrate to other more promising free solutions. Since 2010 it has been maintained by the gvSIG Association.

Worthy of note, several forks have been created from the

original code (branches of the original project).
• Cloud Compare22: This software is specialised in the processing of LIDAR data and other photogrammetry sources (3D scanner). It is crossplatform capable of moving a huge amount of data quickly and efficiently.

• QGIS Desktop23: this is the programme selected for the data entry phase, so we discuss it in another section.

Web mapping:
With the advent of web mapping, it became possible to share, view and edit geographic information using web browsers (Dorman, 2020). Without doubt, Web mapping or webGIS are among the sectors that open-source projects have focused on the most.
Currently, highly professional and mature software exists in each of the different technologies available:

- Server technologies: Mitchell (2005) describes a web map server as the engine behind the maps you see on a web page. Its objective is to provide services that are consumed by other GIS programmes or web browsers. They are usually connected to spatial databases that are given styles of symbols to create maps in image format generated uponrequest, using a, determined syntax in their web address. UMN Mapserver24: Mapserver is the oldest webGIS programme and has a large community of users. It was developed in 1999 by Steve Lime at the University of Minnesota. It is a Common Gateway Interface (CGI) application that works alongside a web server, usually Apache. It was originally designed to generate map images from shapefiles, but throughout its long development, it evolved to include a multitude of GIS formats by incorporating the GDAL library, support for OGC standards to generate map services (WMS, WFS, etc.) and advanced symbolisation. Mapserver centres entirely on the “mapfile” feature, which is a text file in which data, projection, fonts for labels, symbology, graphic output and everything related to publication are defined.

• GeoServer[25]: Another spatial data server developed in Java. It sought, from the very start, to implement almost all OGC publication standards (WMS, WFS, WCS, WPS, WMTS, etc.). It has a notably intuitive graphical interface that allows you to create map services by following a few simple wizards.

• TileServer GL[26]: This is the latest server and is based on a completely new approach. It uses the new WebGL internet standard (the library for drawing and moving 3D graphics) enabled in some browsers to generate vector tiles from geographic information. Google Maps relied on Vector tiles for its map browser. They use up very little space, which is what is sought after in a browser. The tiles offer not only geometry, but also style and alphanumeric attributes. The server is responsible for converting the tile into a geoJSON


```
{
 "type": "FeatureCollection",
 "features": [
  {
   "type": "Feature",
   "properties": {
    "marker-color": "#ff0000",
    "marker-size": "medium",
    "marker-symbol": "circle",
    "name": "University of Alicante",
    "population": 4500
   },
   "geometry": {
    "type": "Point",
    "coordinates": [
     -0.5140829086303711,
     38.38538363766151
    ]
   }
  }
 ]
}
```


Figure 3: A marker in GeoJSON format with attributes and style. Elaborated by the authors.

object (spatial exchange data based on JSON notation) that can be interpreted by the client in a browser.

- Web mapping con Javascript map Application Programming Interfaces (API): we are highly accustomed to viewing maps on the web and performing actions such as change of scale (zoom), scrolling (pan), obtaining information on a certain element (info), displaying the available layers, etc.
In the web's evolution, W3C standards such as HTML5, JavaScript and WebGL have played a key role (Zunino et al, 2020), promoting map libraries to facilitate these interactions. All these tasks are managed on the client, which interprets the Javascript language code that generally makes requests to external data, using Asynchronous JavaScript and XML (AJAX) via a PC browser, but also on mobile devices using hybrid webapp technology. The following APIs are worthy of note:
• OpenLayers27: this library is designed for spatial management. It is very complete and covers all the necessary processes for the publication of geographical information. It has long been the reference API for publishing webGIS. The approach is purely geographical.

• LeafletJS28: though more modern, this project has not inherited all the features of OpenLayers. It is very small in size and loads swiftly to a browser. Notable features include the speed at which it manages geometries and the clarity of its API architecture, making it suitable for programmers who are not very familiar with GIS.

• Mapbox GL JS: This library allows you to interact with the vector tiles mentioned above. It allows navigating in a 3D environment, with the possibility of infinite scaling, extrusion of objects and viewing from any camera optics, and to apply light and shadow effects. Native access to alphanumeric data in real time is also possible, so it is very interesting to generate thematic mapping interactively. This library offers a completely new perspective and of the three, offers the best performance (Zunino et al., 2020). It is developed by the Mapbox company that has licensed its latest version (v2) in a non-open license. Nevertheless, a fork was rapidly created of the latest open version, which is now called "MapLibre GL"[29]

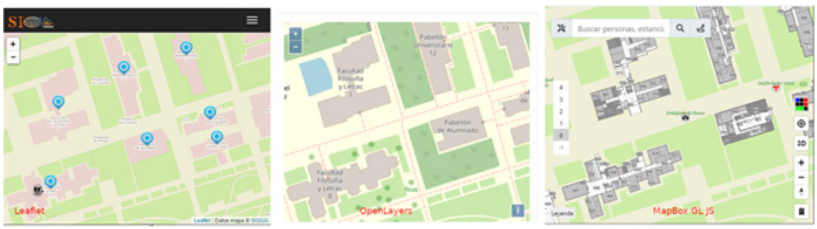


Figure 4: Comparison of Javascript Maps APIs. Elaborated by the authors.

GIS Cloud:

the GIS Cloud has come to meet the demands of companies and users who wish to avoid having to maintain all the components necessary for the publication of webGIS, both from the server viewpoint (web server, map server, database) and customer perspective. It provides web tools for the user to easily scale up their data, and design the symbolisation of geographical elements. These include:

- GeoNode[30]: a content management system (CMS) to publish geospatial information and to publish it on the web under the OGC standards umbrella. it GeoNode is not, technically speaking, a software, but a series of free tools, many of which have already been mentioned.

Notable components include: PostgreSQL/PostGIS to store geospatial information; Geoserver, to publish in the form of OGC services; and Leaflet,a library to use as a client in the browser.

• QGIS Cloud31: an add-on for QGis desktop GIS that allows you to generate OGC services and store data in a cloud PostGIS. The interesting feature is that the symbology can be performed using QGIS, making the task easier.
• Carto32: Formerly known as CartoDB, Carto is a Software as a Service (SaaS) cloud computing platform that provides GIS and web mapping tools for viewing in a web browser. The company is oriented towards a Location Intelligence platform because it offers tools that are capable of data analysis and visualisation while not requiring any prior GIS development experience.
It also uses PostgreSQL/PostGIS and Node.js.
There are two products for two different profiles: Carto Builder for non-specialised users and Carto Engine for developers.

Spatial databases:
In the database domain, we are witnessing a third generation of management systems in which spatial data represents just another type of data, like text or number (Rios, Lorentzos, Brisaboa, 2005). In GIS, the current trend is the increasing use of spatial databases to the detriment of traditional files (e.g. shapefiles). They all share SQL language. The major free databases are:
• PostGIS33: an add-on that allows storing vector geometry, and in the latest versions, raster data in a PostgreSQL relational database with a clientserver architecture. In addition to storing information, PostGIS adds a multitude of functions for geoprocessing spatial data, like any GIS, but using the SQL language of databases, which has led to popularising its use among database users who need to operate geometries. Its performance and customisation possibilities have made it the foremost relational database manager for research and commercial initiatives in the form of services (SaaS).
• SpatiaLite34: Like PostGIS, SpatiaLite is an extension to provide spatial (vector) capabilities to an SQLite database. The database resides in a single file, allowing its portability,

but obviously it loses all the power and capacity of a scalable database such as PostgreSQL. This ability allows you to include it in many mobile apps that need to use an embedded database.

• Geopackage (GPKG)3535: This database is also derived from SQLite, but with the added feature of allowing you to store raster data. The format is supported by the OGC and has today become the new de facto standard in free desktop GIS to create new layers.

II - 6.2 QGIS: the open-source GIS:

QGIS, originally called Quantum GIS, was created by Gary Sherman in 2002 to provide a desktop GIS for Linux(Hugentobler, 2008). It is programmed in C++ (high-level language and performance), which uses the Qt library (the same as Google Earth Pro) to deploy the graphicalinterface (Khan and Mohiuddin, 2018). Its first version offered merely one viewer to visualise PostGIS tables and shapefiles, with very limited functionalities.

Today, QGIS is a product ecosystem for various uses: QGIS Desktop as desktop GIS and the most widely used, QGIS Server as web map service; QGIS client to display mapping in a browser; and QField (Figure 15) for data capture on mobile devices.

QGIS is therefore a 100% free desktop GIS, which, as its namesakes, allows to add geographic information from many providers and formats, whether local or online, and is closely linked to them because it consumes interoperable OGC services. One of the programme's highlights is its ability to apply quality symbology, along with an excellent composition editor for printing or publishing maps (Graser and Peterson, 2016).

Cross-platform: Strategically, almost all GIS programmes were (and are) almost exclusively centred on use over Windows. However, as QGIS uses standard libraries available on other operating systems, it has allowed the portability of QGIS to

Windows, Apple iOS, in addition to Linux, and even Android, which gives it an added advantage because it can thus increase the number of GIS users on platforms where there was no niche market.
As commented above, in the first decade of this century, Java-based desktop GIS (gvSIG, KOSMO, uDIG) have become widespread. Despite their unquestionable functionality, the installation of these programmes, which depend on a Java compiler (JRE) and additional libraries for managing images, represents an added difficulty for some less experienced users, and leave us powerless in the case of some difficult-to-resolve errors. In this sense, QGIS is much more user-friendly and intuitive, though not totally devoid of difficulty, as is usually the case with GIS programmes.
QGIS is usually compared with other business solutions36. Yet in our view this competition, far from being an impediment, greatly benefits the industry and especially the end user. In addition, it represents a challenge for programmers, who add more functionalities at each new version, improve existing ones, and facilitate tasks with rich and user-friendly interfaces. The conception of QGIS as a pure open-source project with a GPL license has allowed, on the one hand, to build a mass of users, who are often attracted by the fact that the software is completely free of charge. On the other, it has thus gained the support of the community of developers, who are interested in having their developments included in the QGIS core. The philosophy of open-source software itself allows developers to share their code with others to extend or improve their functionality. In this way, some institutions have preferred to develop add-ons in QGIS to incorporate their own tasks into a GIS environment, while using the opportunity to showcase their technological innovations. The undeniable success of this policy is demonstrated by the fact that new product versions are issued every six months or so. Indeed, up to three related products are released: a Long Time Release (LTR) focused on ensuring system stability; an advanced version that includes

new features; and an experimental version for those wishing to test new experiences at the cost of greater instability.
In this sense, the highlights of QGIS are as follow:

Customisation and programming (add-ons):
QGIS
has always intended to extend its functionality with input from external programmers. In fact, the broad acceptance of this software has been largely due to the quality and quantity of the new functionalities that are incorporated in each new version. To facilitate this work, QGIS disposes of a library named PyQGIS (Sherman, 2014), which is capable of calling all QGIS objects, methods and properties (project, view, layers, tables, compositions, etc.). As it is programmed in the interpreted Python language, and has no usage restrictions, many programmers have chosen QGIS to develop their applications, thus taking advantage of the full power of the QGIS application. It allows the creation of the following utilities:

• Standalone applications. These are standalone applications that use the QGIS kernel. It uses PyQt to generate graphical interfaces and present the advantage of being capable of generating specific stand-alone applications for personnel that do not usually work with QGIS.

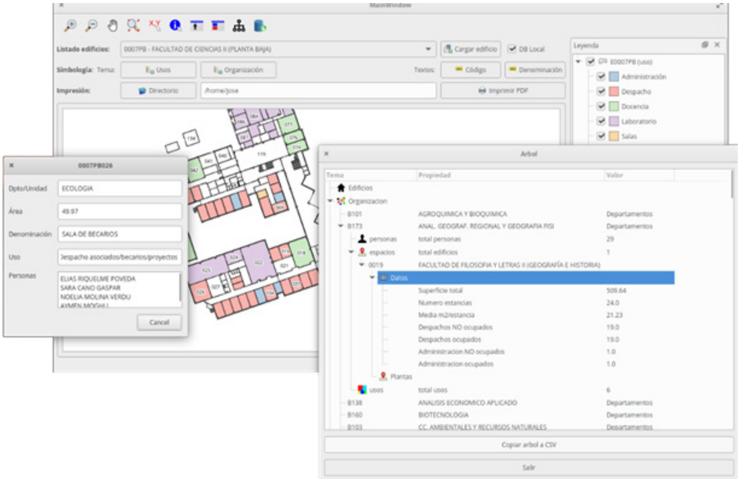


Figure 5: Standalone application for Campus management (SIGUA). Elaborated by the authors.

• PyQgis scripts: These are simple files that are used within Qgis to automate tasks or solve daily tasks.

• Qgis add-ons: The add-on architecture allows to extend the program's functionality in the form of small, and not so small, applications that solve different themes. These applications are relatively easy to create and have made Qgis the most plug-in GIS software. There are currently 1041 add-ons in the stable branch37. You have to think that Qgis offers all the necessary ingredients for developers to value their knowledge. Many institutions have chosen QGis as a platform to offer their services in the form of accessories. In this way it is guaranteed that they are used as it is a free platform, and capable of being constantly improved as the source code is available.

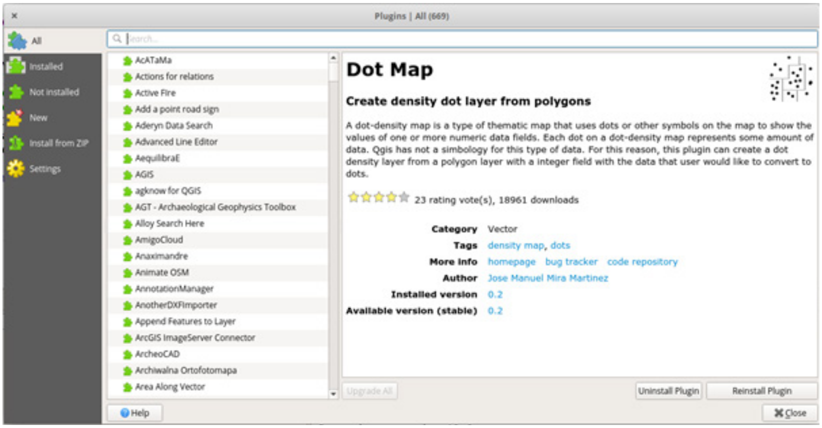


Figure 6: Plugin installer.
Elaborated by the authors.

Frameworks integration:

QGIS has an integration environment that allows the hosting of native algorithms and third-party libraries, extending the range of spatial analysis tools38. This enables you to integrate geoprocessing functions available in other GIS programmes into QGIS. In short, all the programmes that incorporate a bridge to work with Python can also be called from QGIS. This has permitted the integration of high-quality programmes such as:

• those mentioned above: GRASS, GDAL/OGR, Sextante and SAGA GIS.
• LasTools: a set of tools for working with LIDAR data.
• Terrain Analysis Using Digital Elevation Models (TaudDEM)39: a set of digital elevation model (DEM) tools for the extraction and analysis of hydrological information based on the topography represented by a DEM.
• Cran-R40: the most widely used free statistics library in scientific environments.
• Orfeo Toolbox (OTB)41: a next-generation library for remote sensing. It allows you to process highresolution optical, multispectral, and radar images at a terabyte scale. There

are a wide
variety of applications: from orthorectification or sharpening, to classification, SAR processing and much more.

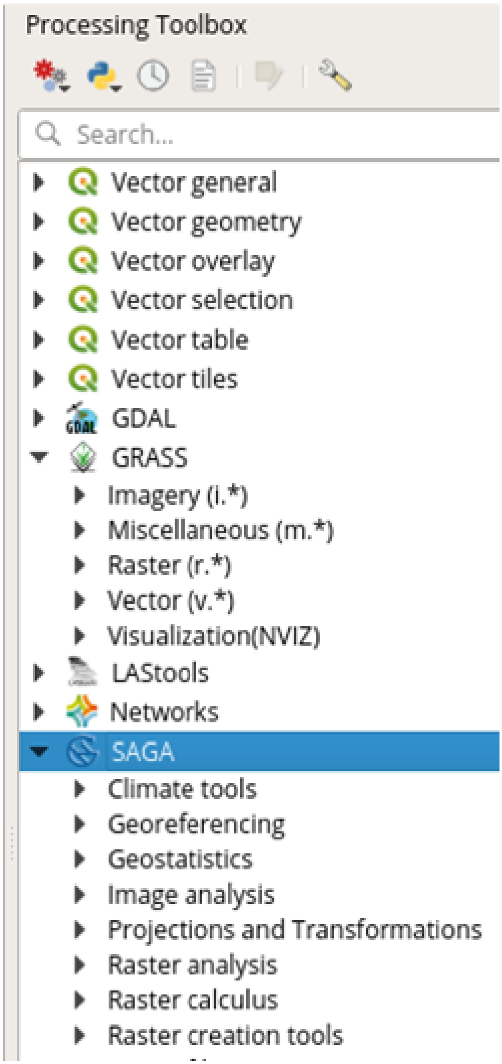


Figure 7: Qgis Framework integration

II - 6.3 Elements in a geodatabase for H2O maps :

As indicated above, layers of information can be added in a project, and among the various data providers, QGIS has a close relationship with the PostgreSQL/PostGIS spatial database, which was in fact the source of this programme. PostgreSQL/PostGIS is a relational database with a clientserver architecture. In other words, it is hosted on a server and is accessed, via an Internet connection, from a clientprogramme (web browser, QGIS, etc.) that points to the database name, IP address or domain name, a user and password with permission to access the database. This structure is of great relevance for a GIS project with simultaneous access from various positions in a multidisciplinary environment. Indeed, it allows to relocate the server that is hosting the data software, and the remote data can be accessed by simply opening the project.

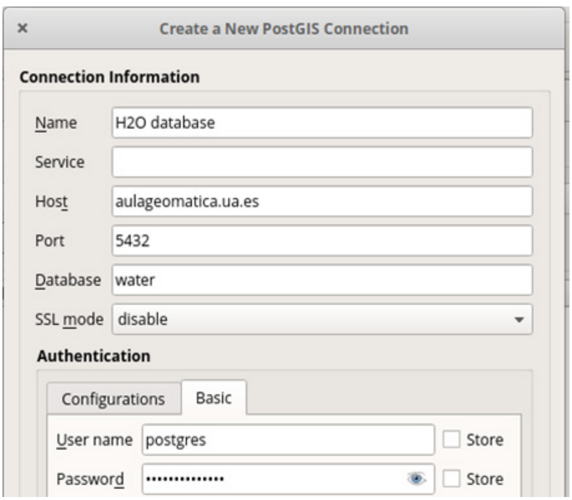


Figure 8: Dialogue box in QGIS to connect to the database. Elaborated by the authors.

Like all relational databases, tables connect to each other via shared table columns, forming a model known as an entity-relationship diagram (see figure 9). This prevents data redundancy and ensures information integrity.

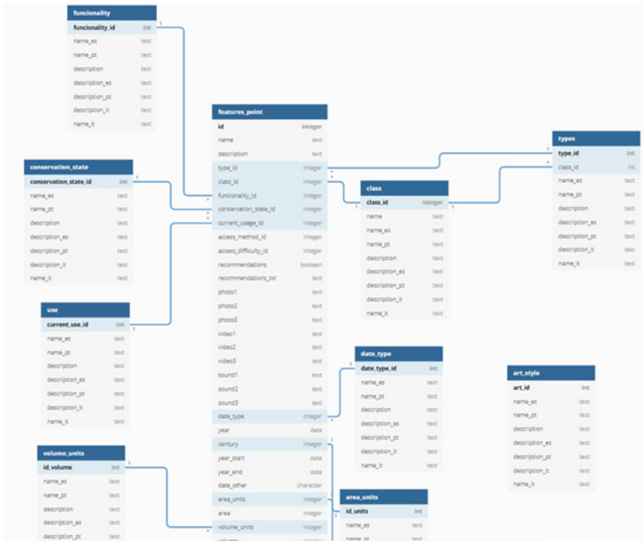


Figure 9: Entity-Relationship model of the "public" schema of the H2O database

Source: elaborated by the authors42.

The advantage of relational databases is that to manage them, you only need to know the language in which they are all based, i.e. the Structured Query Language (Beaulieu, 2009), known by its acronym SQL, originally developed by IBM. Since 1986, SQL is an ISO standard for algebra of sets and data manipulation. In short, it allows you to define phrases or statements to manage a database: create tables (CREATE), insert (INSERT) and delete (DELETE) rows from a table, and the most widely used, query (SELECT) data applying logical requirements.

Some databases, such as PostgreSQL, Oracle, or MSSQL have incorporated the OGC SFA specifications in the form of extensions (PostGIS in PostgreSQL) that provide GIS functionality to the database (MARTINEZ, 2020), using the SQL language itself. PostGIS allows PostgreSQL to use a new data type (geometry) to store geometry in one table as one more column, and other manipulation and analysis functions.In the context of non-geographic relational tables, in order to obtain information from two relational tables, we need to establish the relationship between tables (join them), while if the tables are geographic, we have the advantage that queries can be sent based on basic spatial overlap or proximity operators. For example, geodesic vertices (geotable of points) can be listed that belong to a particular municipality (geotable of polygons). This way, when you digitise in GIS or insert spatial records with SQL, you do not need to add information about the related administrative unit or river basin context, since it can always be obtained by overlay operations. To query the geometry, we can use a client such as a desktop GIS to graphically visualise in the form of a map, either raw data (query a table), or in combination with a relational query to multiple tables or a view. In either case, SQL code is always used, even within a GIS, and despite not being visible. This has brought database specialists closer to the world of GIS and vice versa.

Today, many institutions use PostgreSQL/PostGIS as a data repository. There is also a business sector based on the rental and services of this database, using SaaS services to launch GIS-Cloud applications. Scarce interest in SQL programming among some geographers, despite the language being regarded as the fourth-best for data science43, has resulted in a spatial database being considered as a data repository in which to store all kinds of vector, raster as well as spatial data. In these cases, the least important feature is the relationship between tables, and the statistical analysis provided by SQL language itself. A lot of functionality is thus lost. This explains why many users prefer to use spatial databases compiled in a single, locally-hosted file in their GIS programmes. Indeed,

they are easier to manage since there are no permissions, authorisations, etc. This is why file-type databases have been so popular, such as Access MDB used in ArcGIS, or, recently, GeoPackage (GPKG) files adopted as a standard in QGIS, to the detriment of the outdated shapefile format.
A PostgreSQL/PostGIS database was created for the H20 Maps project. It includes the following data repositories, or schemas (Figure 10), to use the database terminology:
• public: This dataset consists of geotables with the spatial elements that students will need to introduce: wells, fountains, etc., and all related tables.
• hydro: Set of spatial tables related to hydrology: basin boundaries, sub-basins, swamps, lakes and reservoirs, rivers and watercourses, etc.

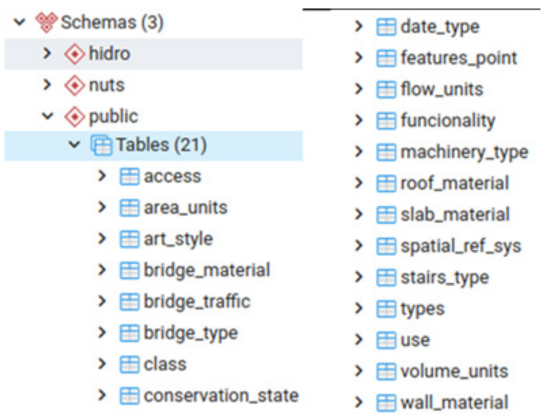


Figure 10: Tables in public schema.
Elaborated by trhe authors.

Nomenclature of the Statistical Territorial Units or NUTS
(derived from the French acronym of Nomenclature des Unités Territoriales Statistiques), is a hierarchical system for dividing the economic territory of the European Union for statistical purposes. The portal provides the updated map of these administrative limits.

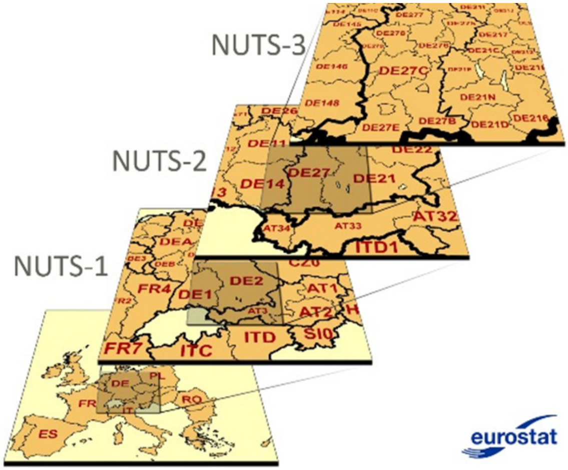


Figura 11: Nuts levels.
Source: Internet

In addition to the tables, the following elements are included:
Views: These are very frequent queries to one or more tables, so for simplicity, they are given a name. They are often used for reporting or publishing on Internet geoportals with specific layers. For example: lists of hydrological elements of a municipality, or of an author, or close to a river, etc.

Programming of functions: Functions are small utilities programmed to obtain certain functionality. In fact, database extensions such as PostGIS consist of many functions (about 700) ranging from the most basic, such as calculating a polygon's area or perimeter, to more complex ones (Voronoi, interpolations, clustering, etc.). We sought to make the most of PostgreSQL's ability to define functions to create those that may be of interest to our project. For example, the "river_distance" function produces the name and distance of the river closest to a given point (a well, waterwheel, etc.). The

functions can also be used as quality controls in digitisation, e.g. to insert points that overlap with administrative boundaries or areas of influence.
Finally, multiple users access a database at the same time, so it is necessary to manage them. It is common practice to assign users to groups, with different privileges and limitations according to each profile: administrator, teachers, students and visitors.

II - 6.4 H2O maps in QGIS:

QGIS, like other similar programmes, is based on the "project" feature, which is ultimately a file where the specialist's ability to process spatial information is given meaning.
The project defines:
• Both the spatial and alphanumeric information layers (tables) that are used.
• Links to online data providers: a spatial database located on a server, OGC services, etc.
• The 216ymbolization of layers with their cartographic semiology adapted to work scales.
• Map compositions for printing.Naturally, all projects share the ability of GIS to query information, relate (join) it to other data, process it using spatial algorithms for a layer (e.g. buffer), or for sets, and extend functionality using scripts or plug-ins.
In the context of the H2O Map project, work is under way on a QGIS pilot project capable of meeting the tasks to be performed by the project's main users. This project can be opened from any computer that has an updated version (currently 3.16 LTR) and an Internet connection), and consists of the following features:
• Links to all online spatial data resources, so that the user does not have to worry about defining links to online data sources. The theme structure (layers) are as follow:
- Editable Vector Layers (from the database) with the elements to be scanned.
- Non-editable vector support layers (from the database):

administrative divisions (municipalities) and river basins (basins and sub-basins).

- Raster layers from SDI OGC services ready to be viewed when disconnected from the Internet.

• Symbolisation of vector layers, and in a very special way, that of the water basin elements, with their semiology depending on the scale and labelling.

• Templates of map compositions ready for direct printing or the generation of map files in PDF or image format. They can be useful for defining work zones, printing detail zones for each workgroup, etc.

• Specific forms applied to editable layers to facilitate the entry of data in an assisted manner in scanning.

• Project configuration to allow portability to the application that collects the field data.

• Supports project internationalisation, with interfaces translated into English, Portuguese, Italian and Spanish.

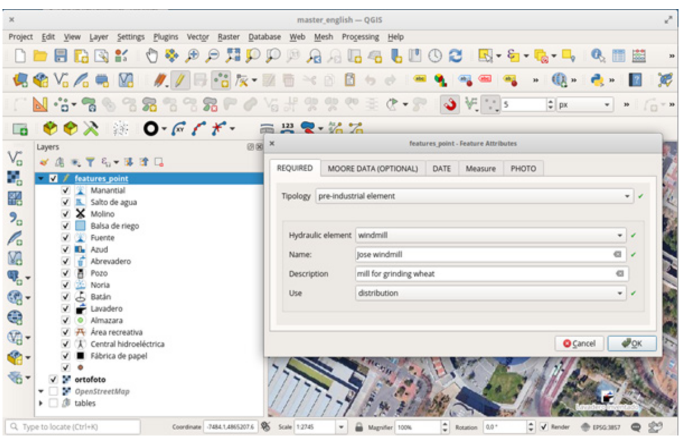


Figure 12. Project prepared for digitisation with form and aerial orthophotograph of background

II - 6.5 Data capture in field mapping:

The emergence of increasingly powerful smartphones and tablets, equipped with mixed satellite positioning (GPS) receivers, has allowed non-specialised users to collect spatial information at a low cost. To use them, the (APP) software must be installed, allowing you to capture spatial data, i.e. to perform a real-time digitisation, and complete information as needed. Applications can be classified as:

a) Generic applications: many applications exist for data capture, but the vast majority focus on sporadic and personal use, where you only need to capture spatial information and associate it with a name and then view it on your PC or upload it to specific wikis (e.g. Wikilocs, OpenStreetMap). They are not related to any GIS programme, even if you work with formats that are supported by them. In this regard, the OGC has promoted international standards for working with data collected in the field. These standards consist of the GPX exchange format, (GPS eXchange Format), and the KML/KMZ, better known for being used with Google Earth and Maps. Worthy of note, within this category, is the excellent OruxMaps45 application focused on capturing waypoints, tracks (recording a route), routes (set of waypoints and tracks for tracking a route). When connected to the Internet, it is possible to generate a database before leaving the programme, with raster images from various WMS resources, which are later displayed in the field offline, facilitating the interpretation of the terrain. Another interesting application is CartoDruid46, focused on offline data capture. It is closely related to further integration into a generic GIS.

b) Apps connected to a GIS: there are also some mobile applications that allow the capturing of data associated with a GIS programme. These are the ones that interest us the most since we aim at integrating fieldwork into the GIS project, and this application acts, in turn, as an intermediary with the

database. These tools focus on maximising data collection and are designed for teamwork. They seek to offer trauma-free integration of the collected data with the SIG project of the matrix application. Notable applications include:
Collector Classic for ArcGIS, gvSIG mobile for gvSig, Input or QField for QGIS.

Field mapping planning:
Good planning is the best way to guarantee satisfactory fieldwork or mapping. Moreover, in a work environment that involves many people, spatial overlaps or the duplication of digitised elements should be avoided. Mobilising a group of people is no trivial task either. We need to dispose of the most up-to-date maps of the area under study in advance, both in map format and aerial orthophotograph.
The initiator of the mapping project must attend to the following tasks:
• Know in advance the team of people who will participate
• Indicate the day and time of execution
• Plan the number of sessions required, including training and the sharing of the collected data
• Train staff on matters related to the capture, programme installation, operation, download and
transfer of data, etc.
• Advise on the type of terrain that will be encountered, as well as the necessary clothing, footwear or food and water supply depending on the duration of the session.
• Specify the objectives, clearly defining the elements to be digitised, their spatial nature points, lines or polygons), and the attributes to be collected for each element.
In relation to spatial planning, the following points must be considered:
• Zoning of the study area according to the teams involved, as well as the daily schedule.
• Assignment of staff to each area, as well as individual tasks or roles.

• Preparation of the necessary computer equipment, mainly smartphones or tablets, and related accessories to ensure that the working session is covered: wiring for data charging and transfer, portable power bank for charging batteries.
• Printing of paper maps of the assigned areas for each area or group.
• Make sure an office area is set up, equipped with computers, or personal laptops with the necessary software.
• Set up an Internet connection in the meeting area to be able to install or download necessary data or programmes.
• Optionally, prepare rulers for calculating distances, calculators, pencils/pens, notebooks, compasses, etc.

In this way, it is recommended to learn from social events such as the "mapping party" associated with OpenStreetMap, which allows working with multidisciplinary teams using a variety of techniques: GPS trace processing, Paper map scanner with QR codes created thanks to the Walking papers application (Prieto Cerdá et al. 2014), direct digitisation of satellite images licensed for OpenStreetMap, etc.

II - 6.6 Project prototype for the collaborative mapping of hydraulic heritage:

It has been enriching to learn from similar hydraulic management initiatives when developing a project based on field data collection. In this regard, we should highlight "the case study of data collection and data sharing for rural water supply in Rwanda". The conditions of the study are similar to those raised in the H2O Map project, with work teams collecting hydraulic information in the field using QField to transfer it to a PostGIS database.
We considered some of the criteria that conditioned the selection of QField software. The initial assumption was that this data capture project should be conducted by upper secondary school students, operating with their own means

(smartphones or tablets). The field software thus needed to meet the following specific conditions:

• Cost-free: there are many solutions today, but we wanted free and open software, since this would permit making any necessary future modifications, and/or benefiting from future versions.

• Intuitive: The user interface is very simple and requiresminimal instructions. In addition, staff who have worked with GIS must be somewhat familiar with it (layer-based system).

• Integrated into the GIS project: the QField developers have created an add-on for use within QGIS that facilitates the operations necessary to integrate the field work successfully (Figure 13).

• Offline capture: The most efficient way to keep the spatial database in QField is to have an internetconnected layer inQField, so that the spatial data passes directly to the database as it is digitised in the field. Nevertheless, this is not how the process usually unfolds in practice: there is not always an Internet connection in the field, and it does not make much sense either to indicate all the attributes that belong to an element in the field. It is more convenient to fill them out during the postprocess in the office.

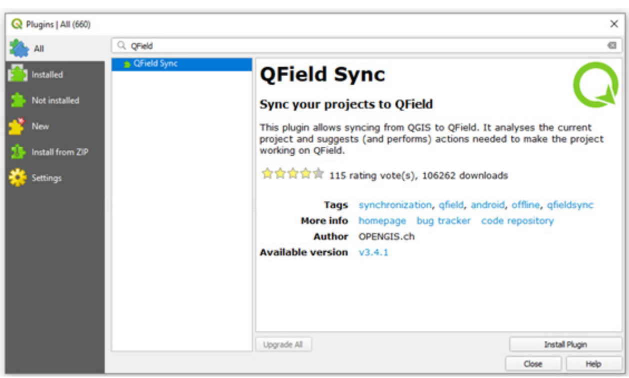


Figure13: QField plugin. Elaborated by the authors.

QField is an Android application for mobile devices that uses the same libraries as QGIS in its programming. As a result, the modus operandis is the same: it is opened and digitised based on a QGIS project, sharing the same layer structure and symbology. Functionality is naturally reduced in favour of operability. In fact, QField cannot create projects, and can only open those that have been created with QGIS. The only difference is the user interface (the rendering) designed to adapt to the mobile device's screen and events, thus removing all the complexity of a desktop application and focusing on digitisation productivity. The more the QGIS project is optimised at the level of symbology, based on scales, form customisation. etc., the higher the data capture productivity with QField.

Synchronisation with QField uses an add-on in QGIS, QField Sync (Figure 16), designed to ensure the input and output processes of the GIS project:

• Output: Generate a "portable" QGIS project tailored to work in the field with the QField application.

• Input: Incorporate the projects generated with QField with the digitised data, and that must be incorporated into the online database.

Field mapping phases :

Each agent involved in spatial management plays a role. Thus, the GIS specialist is responsible for providing teachers with the QGIS "master project", which offers the mechanisms to ensure the data's traceability; the teacher will assign the working groups and create a portable project for students to work on.

Whether individually or as a group, students will be responsible for digitising the hydraulic heritage elements in the field in the areas assigned to them by the teacher. To facilitate data collection, only certain point layers that were less complex than lines or polygons were digitised. The latter could be incorporated later using QGIS on the PC with the help of orthoimages and/or maps. The stages of the QField workflow are detailed in the figure below:

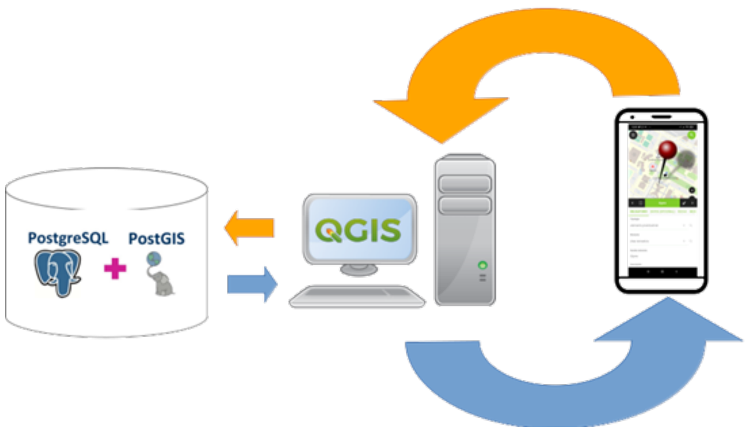


Figure 14: Diagram of the Qgis-QField synchronisation operations. Elaborated by the authors.

Developing a QGIS project:
this task is performed by GIS specialists and must be connected to the generated PostgreSQL/PostGIS database. Its function is threefold:

• It acts as the parent project that integrates all the cartographic resources.

• It is the basic support on which the projects will be generated to work in the field using QField.

• It is the means to synchronise the field work executed with QField that will be incorporated into the main database.The project must use suitable symbology for its representation on mobile devices, with labels (toponymy) and templates for printing map compositions. It must also include a layer with raster mapping for the study area's background, which will come from an aerial orthophotograph in formats suitable for fieldwork (MBTiles, GPKG), or a layer with an OGC map service on the Internet such as WMS or Tile Map Services (TMS)like OpenStreetMap. Items that will be digitised in the field mustbe pre-customised with intelligent forms that prevent errors and facilitate data entry, using controls such as drop-down lists, validation fields, sliders, calendars for dates, etc. These forms to fill out are the same as those used in the fieldwith the QField app, except that they are adapted to mobile devices.

Export QGIS project to mobile device:
this means applying the QField plug-in to build the project to be used in the QField app. This process involves converting project data that is present online, such as the database, to physical "portable" database files in geopackage format. In the case of this project, this task is performed by the teacher responsible for a group of students. Currently, the portable project is transferred via a physical cable that connects the PC to the mobile device.
We know, however, that the same company that developed QField is working on a version that allows all these processes to be done in the cloud (QFieldCloud47)

Field mapping with QField:
This task is performed by each student, or group, in the study area, using their mobile device with the pre-installed QField app and the project provided by the teacher. The sequence of actions is as follows:
1. Activate the positioning sensor on the mobile device
2. Open the QField application. Select the QGIS project
that will be customised with background images from the study area (map or orthophoto).
4. Digitise elements in the geographic layers that allow it, filling out all known attributes with the help of forms designed in QGIS. In addition, photographs or other multimedia resources in the gallery can be attached to each digitised item. Digitisation can be run using the GPS positioning or drawing on top of the

map, just as one would do so in QGIS using the mouse.
5. Once the digitisation is completed, transfer the project to the PC. This process is carried out by students, who locate the project folder in the directory indicated by teacher.

Figure 15: Capturing the QField app on a mobile device on an OpenStreetMap background. Elaborated by the authors.

Synchronisation field mapping in GIS project:

This phase consists of incorporating the data captured in the field into the PostgreSQL/PostGIS database. To do this, the teacher opens the main project in QGIS and with the help of the above-mentioned QField sync plugin, selects the folder with the student's QField fieldwork. After being synchronised, the data is transferred to the PostgreSQL/PostGIS database. Once transferred, the teacher can review the synchronised content and modify the attributes, change the position, or delete the item.

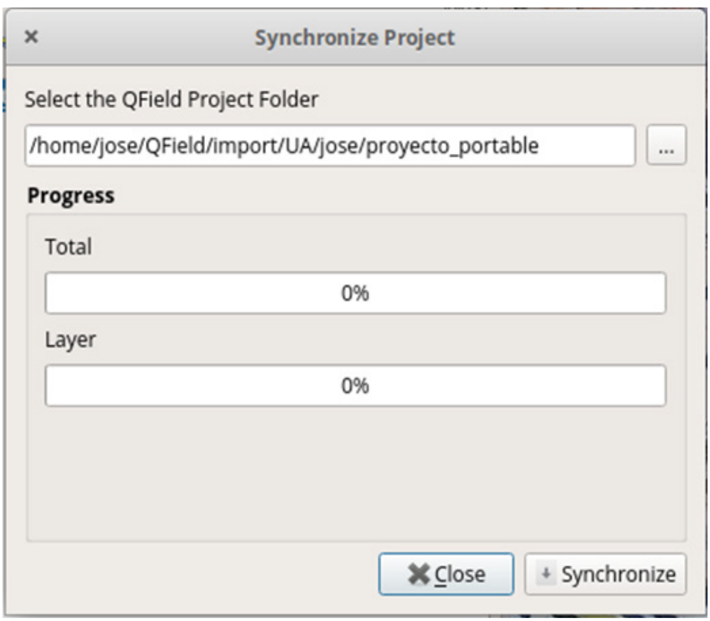


Figure 16: Screen capture of the QField app on a mobile device. Elaborated by the authors.

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PART III

MAPPING HYDRAULIC HERITAGE

III - Module 7
Creation and visualization of interactive maps

III - Module 7. Creation and visualization of interactive maps:

A web map is an interactive visualization of geographic information that you can use to tell stories and answer questions. For example, you can find or create a map that answers the question: Where are the hydraulic heritage infrastructures in Europe? Then, this map would have layers showing what kind of hydraulic heritage is in Spain, Italy, and Portugal, and for contextualization, the map would also have a topographic base map that includes cities, roads and buildings overlaid with images of land cover and shaded relief.
Typically, web maps contain a base map, a set of data layers (many of which include interactive pop-ups with information about the data), an extension, and navigation tools for scrolling and zooming. Primarily, the base map and layers are hosted and shared across the web. Many maps also contain scaled symbols and other intelligent styles that reveal data and patterns as you interact with them.
There are many different commercial platforms to create or visualize web maps. One of the most known is the map viewer of ArcGIS Online which has an intuitive design that enables you to customize and configure your map in one area while seeing and managing your content in a separate area.

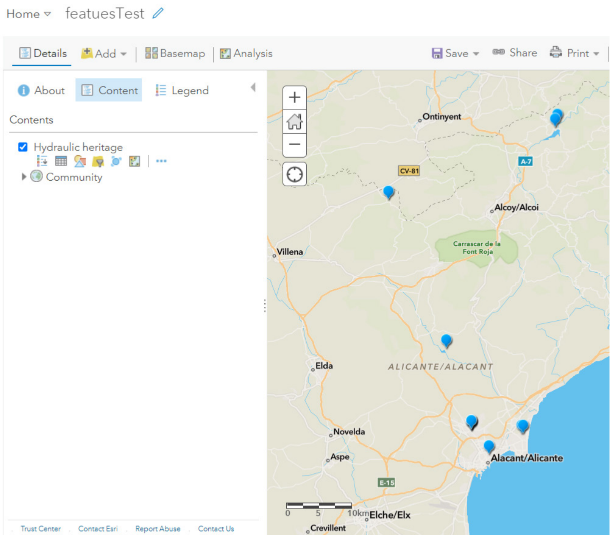

Figure 1: ArcGIS Online Map Viewer.
Elaborated by the authors.

III - 7.1 Creating a Web Map

You can create maps in a few basic steps and open them in standard web browsers, mobile devices, and desktop geographic software. You can share them via links or embed them in websites and use them to create map-based web applications. When a map is shared, the author decides what to include in it. For example, when the map is shared with a general public through a map viewer, many times, the map includes options to change basemaps; view a legend (if the map contains one); view details about the map; share, print, and make measurements; and find locations on the map. Maps embedded in websites and shared through applications typically contain a set of tools focused on a specific purpose, such as gathering information, editing features, or comparing two maps side-by-side.

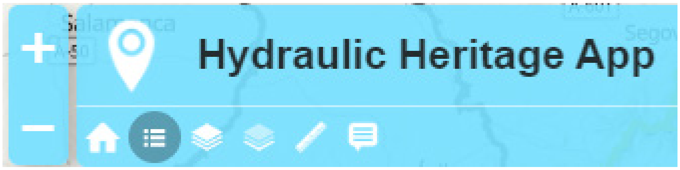

Figure 2: ArcGIS Online Default Interactive Widgets.
Elaborated by the authors.

As a conclusion, web maps are online maps created that provide a way to work and interact with geographic content organized in the form of layers. They are shared on the web and through smartphones and tablets. Each web map contains a reference base map along with a set of additional data layers, plus tools that work on these layers.

III - 7.2 Adding Information

Layers, also called web layers, are logical collections of geographic data that are used to create maps; they are also the basis for geographic analysis. For example, a heritage layer could represent a collection of hydraulic heritage and include attributes that describe the properties of each infrastructure, such as name, what type it is, size, and other possible attributes. Other examples of layers are historical traffic patterns, terrain, 3D buildings, and parcels.

The type of layer determines how you can interact with the layer data. For example, you can view and query the data in a feature layer to see the attributes of a feature. You can also edit the data represented by the feature layer. In the case of tiled layers, you see only tiled images of the features.

The following are the types of web layers you can publish or add to a GIS portal as a feature:

- Map Image, Images, Mosaic, Elevation, Feature Layer, and Scene, also Tables.

III - 7.3 Modifying Symbology

Maps are powerful because they allow you to visualize your data in a variety of ways. For example, population data for countries can be visualized as a sequence of colours, such as from light to dark, or as proportional circles, such as from small to large. This flexibility allows you to tell different stories and discover hidden patterns depending on how the data is presented. But because map making is so flexible, it requires making decisions when there is not always a single best answer.

Fortunately, web maps allow you to explore different styling options using smart mapping defaults. In addition, you can make changes to its appearance that are immediately reflected on the map, having the control over graphic elements such as colour ramps, line weights, transparency, and symbols.

Figure 3: Different geographic data.
Documents, charts, layers, tables, collections.
Elaborated by the authors.

The styling options provided for a layer are based on the type of data you are mapping. You will see different choices depending on whether your layer is composed of point, line, or polygon features. The options offered are also influenced by the type of data associated with your features. For example, a point feature might only have location information such as geographic coordinates but could also have categorical information such as type of hydraulic heritage. Styling options also vary depending on whether you want to show one or two attributes, such as type or built year. Not every styling option can be used for every type of data.

III - 7.4 Saving and Sharing the Map

When you initially save a map or save a copy of a map, a new web item is created by you. Depending on the platform, you will be able to share your map with your organization or make it public for everyone to see.

You can share any map you find on the website by sending an email with the link, posting it to your Facebook or Twitter account, embedding it in a website or blog, or creating an app that includes the map.

Considerations using ArcGIS Online as platform of sharing maps:

- If you want your map to be accessible to the public (and your organization allows sharing outside the organization), you need to select share it with everyone option.
- When you share a map through a link or embed it in a website, the extent you last viewed is automatically captured and included in the link or embedded map. When the map is opened, it shows the extent you were viewing when you shared it. This allows you to share and embed maps that open at specific locations.

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- https://www.esri.com/arcgis-blog/products/product/uncategorized/webmapping-101/
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III - Module 8
Story maps: an innovative educational tool to value water heritage

III - Module 8. Story maps: an innovative educational tool to value water heritage

Everyone loves a good story. Put simply, a story is an account of an incident or series of events, and the story can be real or imaginary. Stories can be interesting, amusing, or instructive.
Most stories are told with words—either spoken or written. Stories can include other forms of communication, too, such as pictures, gestures, or music. Often, pictures provide details about characters or events that are difficult to convey with words. Think of a children's book, a comic book, or a movie that you are familiar with.
When telling stories, a map is a special type of picture. A map can help you visualize where events happen, how far a character travels, or what a country or landscape is like. A map might give your insight into why certain events happened where they did or why the hero of the story made a particular decision.

III - 8.1 Building your Narrative

Sharing your results or discoveries is essential for demonstrating the value of any research effort. But communication can be tricky, especially if you're trying to connect with people who aren't experts in your area of study. The key to success is keeping your audience interested from start to finish.
Tips using StoryMaps application to create a story:

- It's helpful to have the story written and multimedia elements organized before you start putting the content into the StoryMaps builder.
- With your content inventory complete, you'll start thinking about how you might weave all these pieces together into an outline. Outlines can take a variety of formats, from a simple bulleted list to an entire storyboard, a slide deck, or even a collection of index cards you shuffle around on your desk.

III - 8.2 Adding Immersive and Multimedia Blocks

Now that you have the story text and media, you'll start building the story using content blocks. Each title, paragraph, image, and media type is added as a separate block from the block palette.

There are a few types of blocks you can choose from. There are of course text blocks—paragraph, heading, quote, and so on—and there are also a few options for adding small visual accents, such as a separator or a button.

Immersive blocks are unique in that they become full-screen takeovers of your story, providing different, interactive reading experiences. For example, may recognize the split-screen feel of sidecar, where a fixed media panel displays visual content while a smaller narrative panel scrolls by.

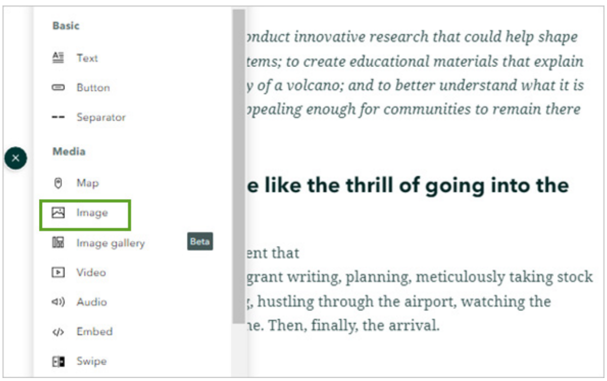

Figure 1: ArcGIS StoryMaps Objects.
Elaborated by the authors.

Once you have added your text, you can start adding and adjusting media to bring your expedition to life. Images, video, and other media are important because they break up a long narrative and provide context. For example, you can add both individual images and an immersive sidecar to the story and change their appearance to best fit the story.

Also, you can add alternative text, that describes the image so that anyone consuming your story with a screen reader can still experience your work in its entirety.

Tip creating stories:

- As you go, be sure to pause and ask yourself if this is working the way you expected. While having a plan for your story is important, it's okay to iterate and adapt as you go; some things that seem good as a concept do not work out as expected in practice.

III - 8.3 Adjusting the Design

One of the snazziest things about ArcGIS StoryMaps is the ability to make lots of design refinements.

The first design option is to change the cover layout for your story. There are three choices: full, side-by-side, and minimal. The minimal option gives you the option of including horizontal-format image above the title, or no image at all.

Additionally, you can change the theme look and feel of your whole story. It also changes the fonts and the accent colour. You'll notice that it changes your express maps, too, utilizing a darker basemap to complement the story background.

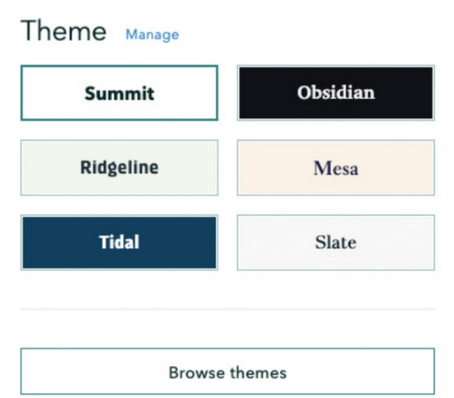

Figure 2: ArcGIS StoryMaps Theme Types.
Elaborated by the authors.

Better yet, try creating your own custom theme. The theme builder gives you lots of options to customize colour palettes, fonts, quote blocks, separators, and buttons, and even add a logo.

III - 8.4 Publishing and Sharing your Results

When you are ready to publish, you see these sharing options. Private means it visible only to you; My organization makes it accessible to other people in your ArcGIS organization; Everyone makes your story public.
As part of the publishing process, the story checker will look for permissions issues with the maps in your story and flag any maps or layers whose sharing permissions are more restrictive than that of your story. Once you have published, you can return to editing the story at any time.
If your published story is available to the public, you might want to promote it through platforms like Twitter or Facebook. A key part of successful sharing is having an attractive card (or link preview) for your content. ArcGIS StoryMaps generates those cards automatically.
On the back end, the builder takes your story's title, subtitle, and cover image, bringing them together in a card to the social media feeds. You can also change the information referenced by the social card from your story, the card will automatically update to show whatever image you swapped in.

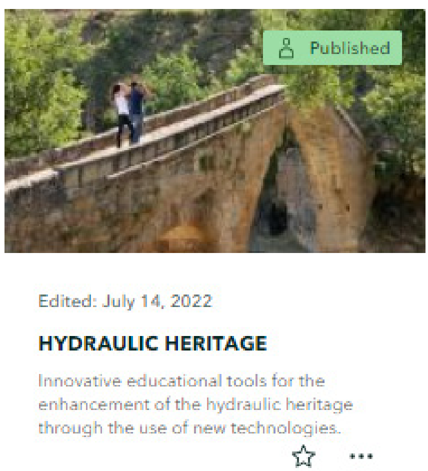

Figure 3: ArcGIS StoryMaps Card for Social Media Feeds. Elaborated by the authors.

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PART IV

PRACTICES LEARNING-BY-DOING: CASE OF STUDIES

IV - Module 9
Castellón (Spain)

IV - Module 9. History of the Hydraulic Heritage of Castellón de la Plana

9.1 The context

Innovative educational tools for the valorisation of hydraulic heritage through the use of new technologies.

The context

The project "H2OMap: innovative learning through mapping of hydraulic heritage" is funded by the European Community through the Erasmus + K2 project (strategic partnership in the field of school education).

The main objective of the project is to promote new ways of teaching and learning with the use of new technologies and to enhance the knowledge of hydraulic heritage.

The Jaume I University of Castellón (project coordinator), the University of Pavia, the University of Alicante, and four secondary schools in Spain, Italy and Portugal (IES Penyagolosa, Istituto Superiore Taramelli Foscolo, Agrupamento Escolas de Campo Mayor and Agrupamento de Escolas No. 3 de Elvas) are collaborating to create innovative and appropriate tools for the analysis and cataloguing of hydraulic heritage. The target audience is teachers and students of secondary schools, who can develop new skills in the field of information and communication technologies (ICT) and, at the same time, promote the knowledge of hydraulic heritage and its role in the development of technology, economy and territory.

The purpose of the Storymap

The storymap on heritage and hydraulic spaces that we can see below aims to show a process over time of construction, destruction, improvement, expansion, and maintenance of a complex network of infrastructure and water landscapes unique to the municipality of Castellón de la Plana.

Water landscapes that carefully reflect what different societies and cultures have been bequeathing us over more than

1000 years of history. The ways of using water, the relationship with the environment, the use or abuse that has been made in the exploitation of available resources, as well as the need to build constructions and works that allowed the collection, conduction, distribution, storage, or energy transformation of water flows are present everywhere.
We just have to open our eyes and begin to identify them in our daily landscapes, in the fields or in the city. It is an experience to meet again with our ancestors, with the people who built them and to find out at the same time the historical reason for their existence. We invite you to make a unique journey, to participate in some great discoveries.
Let's go.

Historic Evolution
The following interactive map shows the historical evolution of the hydraulic heritage in Castellón de la Plana. In the corners there are some buttons that allow to extend the map in full window, to change the scale of visualization and to display the legend of the heritage elements. In the same way, by clicking on the catalogued elements you can see their description and other multimedia information.

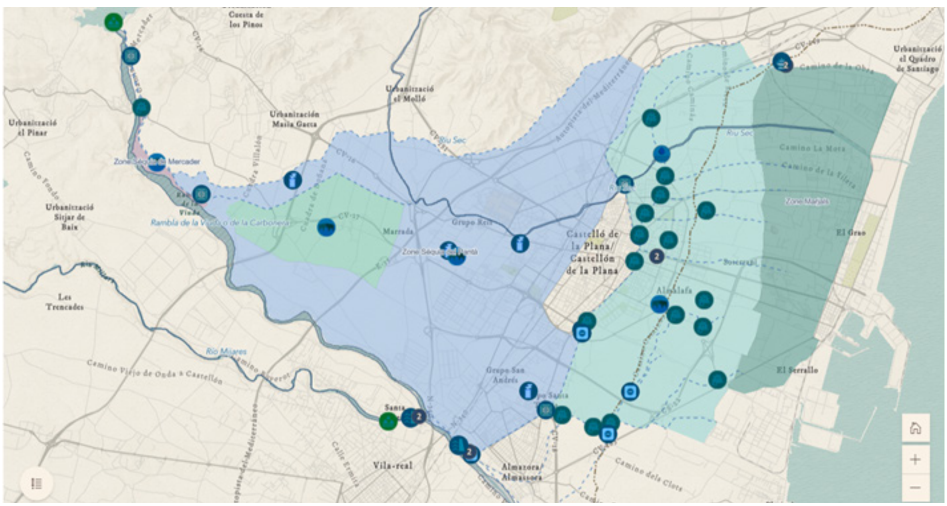

Figure 1: Hydraulic Heritage in Castellon de la Plana Area. Elaborated by the authors.

- **Before Changes**

The current municipality of Castellón de la Plana had an extensive wetland lake area located along the coastline extending from the foot of the Desert de les Palmes Mountain range to the Grau area. It is a space separated from the sea by a natural barrier that prevents the mixing of salt water from the sea with the fresh water provided by the different springs and springs, such as Fuente la Reina, or also the occasional contributions of the different ravines that drain the mountains, or the same Río Seco that drained into this marshy area.
The use and human exploitation of the wetland area, rich in biodiversity and abundant in natural resources, is ancient, as evidenced by a dense occupation of prehistoric settlements in their environment, as well as the presence of an ancient communication channel as the Anduviera that borders this space by the west side, from north to south.

Figure 2: Natural landscape
Elaborated by the authors.

- **Century X**

The conquest and incorporation of these lands to the Àndalus, from the 8th century onwards, led to the progressive installation of Berber human groups of North African origin who resorted to irrigation as a significant way of transforming the immediate environment. But it was from the 10th century, with the Caliphate of Cordoba, that a singular growth of large-scale hydraulic infrastructures took place. One of these was the water catchment of the Río Millares and the transformation of the agricultural area on the northern bank of the river thanks to a diversion with two branches or mother ditches: one that circulates at lower altitudes, the Almalafa ditch, and the other that circulates at the highest altitude, the mayor ditch.

Both ditches and their branches embrace an important arc of land between the Río Millares in the south and the foot of the Desert Mountain range in the north. The hydraulic infrastructure allowed the irrigation of the constructed fields, but also made contributions and recharges to the natural aquifers and in the lake areas. The human settlements follow the route of the main irrigation ditches or are linked to other derived irrigation ditches that usually bear the same name. Despite the construction of conduction infrastructures, only the stands closest to the farmsteads or human settlements of the time were transformed.

The most singular and representative hydraulic element of the time is the divider that allowed dividing a flow of water that circulated continuously in two others proportionally.

Figure 3: Partitor
Elaborated by the authors.

- **Centuries XIII – XVI**

The feudal conquest of these lands in the 13th century led to the incorporation of the left bank of the Río Millares plain into two new feudal lordships. The conquest of an agricultural area with a powerful and highly structured irrigation system allowed the new settler population and their lordships to intensify the transformation of the fields to the maximum and to extend as much as possible the area irrigated with the waters of the Río Millares.

At the end of the 13th century and the beginning of the 14th century, the extension of the historical cultivated area of Castellón de la Plana reached the same surface as the current one. All the previous interstices existing between the cultivated stands of the different Andalusian farmhouses were transformed, some areas of Alters were transformed that were difficult to irrigate and a process of draining of wetlands from the Donación road towards the sea began. The great transformation also affected the settlement and its places of residence that now happened to be concentrated in only one: the medieval villa of new plant that was raised bordering the Major irrigation ditch.

The main transformations in the irrigation system occurred in the distribution and allocation of water. Now there is the same water to irrigate more land, which forced to make water batches, irrigation shifts, and alter the proportions that made the old partidores. The other great change in hydraulic infrastructures is the proliferation of flour mills between the 14th and 15th centuries, reaching a figure of twelve mills, half on the acequia Mayor and the other half on the rows. Almost all of them were flour mills, except for one that worked as a rice mill. Some of these mills survived until the 20th century, but almost half of them were abandoned around 1500.

Figure 4: Irrigation canals
Elaborated by the authors.

- **Centuries XVII – XVIII**

The irrigated agricultural area remained almost the same, without any growth, but with much use of water flows as a source of energy with the consequent construction of new mills. Three important milestones characterize the period. Firstly, in the 17th century, the construction of the new weir upstream of the river, beyond the confluence of the Rambla de la Viuda; and at the end of the 18th century, on the one hand, the separation of water between Almassora and Castellón de la Plana with the new hydraulic infrastructures derived; and on the other hand, the development of Salvador Catalán's project to build an agricultural colony in the Benadressa district and transform a whole set of dry land into irrigated land. Unfortunately, the project of the agrarian colony did not come to fruition and of the 700 bushels of unirrigated land that it was foreseen to transform, only a hundred ended up being irrigated. The important thing, however, is that the bases and foundations were established for future hydraulic works in the municipality.

Figure 5: Hydraulic Infrastructure
Elaborated by the authors.

- **Century XIX**

A consequence of the separation of waters between the towns of Almassora and Castellón de la Plana, at the end of the previous century was the concentration of a greater flow of water to the initial section of the new irrigation channel and the construction of up to six new flour mills, one of them later converted into the Estrassa paper mill. In this way, the municipality once again had a maximum number of mills, with a total of thirteen.

But the most significant hydraulic transformation will be the construction of the Fomento irrigation channel, with the aim of continuing and significantly extending Salvador Catalán's project to the Benadressa district. To the project of transforming 400 hectares of dry land into irrigated land was added that of providing drinking water to the city of Castellón de la Plana, which led to the constitution of the company "Fomento Agrícola Castellonense", which became a public limited company and FACSA.

Despite building a spectacular infrastructure, only a little more than a quarter of the initially planned area was transformed into irrigated land.

Figure 6: Fomento Agrícola Castellonense.
Elaborated by the authors.

- **Century XX**

The century is characterized by two phenomena linked to obtaining more and greater water resources for irrigation. On the one hand, there is the capture of underground flows and, consequently, the proliferation of steam engines to raise water from the subsoil that left in the landscape the slender silhouettes of the tiled chimneys. On the other hand, the construction of the Maria Cristina reservoir and the irrigation channel of the reservoir allowed the transformation of a quantity of dry land into irrigated land of more than 2,000 hectares, which represented almost an extension similar to that of the historical cultivated area of the Río Millares. The agricultural landscape of the municipality changed radically.

Figure 7: Hydraulic Mapping.
Elaborated by the authors.

Inventory

The inventory shows the registered hydraulic heritage along with the description and location associated with them.

Almalafa/Valero Partitioner

The partidor of tongues of the ditches Almalafa/Valero consists of a tajamar, with stone edge in the bottom and with a rounded frontal. It is located inside the new Almalafa irrigation channel, built in 1789, and distributes the water flow between the two new irrigation channels, the Almalafa channel itself with more volume on the left, and the Valero channel a little less on the right. The latter, after a short distance, reaches the Salt de la Novia mill and then continues on, taking advantage of the Barranquet, which is canalized. The partition adopts a curved shape by drawing a 90° turn, coinciding with the turn made by the Almalafa irrigation channel only after crossing the Anduviera and running parallel to it in a northerly direction.

Figure 8: Almalafa/Valero Partitioner
Elaborated by the authors.

Aqueduct Sec River

The irrigation channel of Coscollosa draws an almost perfect arc from its source on the edge of the wall until it reaches the ravine of the Magdalena. In its layout it crosses the Seco river by a wide point and with a great unevenness where always there was an aqueduct that allowed the passage of the water. Its initial form was of pillars that supported wooden channels, although the successive floods left only small traces. The last aqueduct that existed was a construction that used concrete as a base material. Supports were built on the margins, in the form of pilasters, and two rounded central pillars. Above them was a prefabricated concrete channel that was covered, thus allowing passage over it. It was 1.4 meters wide and 42 meters long. The height of the aqueduct with respect to the bottom of the Seco River exceeded 6.5 meters. The works of canalization of the Seco river at the beginning of the 21st century have eliminated any trace of the hydraulic element and have deeply transformed the area.

Figure 9: Aqueduct Sec River
Elaborated by the authors.

Babiloni Mill

The building of the flour mill is located in Fadrell. It was built in the first decades of the 19th century and had three floors and a gable roof. It is an elongated construction made with masonry that is located perpendicular above the layout of the irrigation ditch of Valero, bordering the Anduviera. Around it there are a series of bodies added in successive stages because it was also a house. Inside the building nothing has been preserved of the machinery, the millstones or the reels, although the place was not abandoned. The most recent works affected the hydraulic part of the mill, specifically the arrival of the water through the irrigation channel that, after cancelling its passage through the interior of the carcau, runs through the old spillway converted into a normal passage of the irrigation channel, pouring the entire flow into the channelled ravine.

Figure 10: Babiloni Mill
Elaborated by the authors.

Barranc del Malvestit Aqueduct

The aqueduct was built at the end of the 19th century for the Fomento irrigation channel to cross the Malvestit ravine. The construction presents a very solid craftmanship of a single arch of average point that has a light of 3,95 m and the intrados makes 2 m. It is built on abutments to the bed of the ravine that are of ashlars and the arcade of tile, while the rest of factories of the structure is of masonry locked with mortar. The total height of the aqueduct is 9.55 m and an approximate length of 202 m. The channel has an exterior width of 1.9 m, of which 110 cm correspond to the casing, with a depth of 86 cm. Currently the aqueduct does not perform its original function. The only significant alteration it underwent was the covering of the channel, originally uncovered, by means of the construction of a lowered tiled lap. In the area of the aqueduct, the covering was made of long stoneware slabs laid on the plain.

Figure 11: Barranc del Malvestit Aqueduct
Elaborated by the authors.

Barranc d'Almela Aqueduct

The aqueduct was built at the end of the 18th century for the Mercader irrigation channel to cross the Almela ravine. The construction presents a very solid construction of a single semicircular arch. The eye of the arch has a span of 5.75 m on abutments of 1.65 meters above the bed of the ravine. The entire arch is built with stones bonded with mortar. The channel has an exterior width of 1.76 m, of which 98 cm correspond to the ditch box, with a depth of 68 cm. The total height of the aqueduct is 6.88 m and the length is 16.5 m, with a straight section in the center and two small inflections at the edges of the ravine to enter the ditch. On the downstream side, in the west, it has an imposing buttress, which covers all the elevation of the work. Currently the aqueduct is out of service. The only significant reform that can be observed was the raising of the channel as it passes through the aqueduct to make it possible to increase the water level, most probably at the end of the 19th century when the Fomento irrigation ditch was built.

Figure 12: Barranc d'Almela Aqueduct
Elaborated by the authors.

Barranc Mill

The mill was built at the beginning of the 19th century in the Fadrell district, on the outlet of the new Almalafa irrigation channel that was built after the definitive division of water between Castelló and Almassora. The mill building, which was still standing at the beginning of the 21st century, had a rectangular ground plan, was situated transversally to the water flow and had three floors with a gabled roof. In the milling room there were two pairs to make flour, although in the 1920s and the 1930 it also milled rice, and in the second half of the 20th century it manufactured ice, hence the name of the Ice Mill. The building was completely destroyed at the beginning of the 21st century and nowadays only traces of the old construction remain.

Figure 13: Barranc Mill
Elaborated by the authors.

Barranquet Aqueduct

The main irrigation channel of Castelló overcomes the Almassora ravine through a narrow and steeply sloping point by means of the construction of an aqueduct. The work presents a very solid craftmanship of a single lowered arch, the eye of which is 2 meters high and 6.40 m wide. The whole is built with ashlars. The total height of the aqueduct is 5.40 meters and its length exceeds 35 meters. In the part of the current it has two cutwaters of more than two meters of length that are constructed with ashlars to canalize the waters. At the end of the 18th century reforms and improvements were made to the aqueduct that involved reinforcing this area with buttress walls that left the cutwaters almost hidden. At the top of the aqueduct is the canal, which was initially uncovered, but now has a concrete cover. The aqueduct has an exterior width of 3.30 m, of which 2.20 m correspond to the ditch box. The lateral walls were topped with worked ashlars that belong to the improvements made at the end of the 18th century.

Figure 14: Barranquet Aqueduct
Elaborated by the authors.

Casalduch Mill

The origin of the mill is medieval, but it has undergone numerous modifications that have altered both the original building and the hydraulic part. The architectural basis of the present building dates back to the end of the 19th century. It is a building of large proportions, arranged transversally to the route of the Major de Castelló irrigation channel, with three floors and a gabled roof. The masonry of the mill contrasts markedly with the rest of the attached buildings that have been built during the second half of the 20th century. The latter are large open spaces made with modern materials and with few openings to the outside, used as storage and to install industrial machinery. The mill had three millstones and, therefore, three water inlets as well as a spillway for water circulation, the cutwaters of which are built with ashlars of worked stone. The mill has been growing by the sides adjusting itself to the limits of the Street of Vinamargo or to the drawer of the Major irrigation ditch.

Figure 15: Casalduch Mill
Elaborated by the authors.

Castelló/Almassora New Weir

The 1618 weir of Castelló and Almassora only conserves a small part of its dike, built with large stone slabs and mortar to hold them to the conglomerate of the riverbed. Its layout also points to a rectilinear shape that channelled the water to the same point as today, where the gorges were. The surface of the wall presents a slight inclination towards the side that receives the current. It is located just 20 meters from the new 19th-century dam.

Figure 16: Castelló/Almassora New Weir
Elaborated by the authors.

Castelló/Almassora Weir

The current Castelló/Almassora weir is a rectilinear construction that is arranged obliquely to the riverbed. It is made of ashlars and mortar and consists of a dam or wall 2.75 meters high and 106 meters long, with a base that exceeds 5 meters, reduced to 1.5 meters at the top. The longitudinal arrangement of the weir allowed the entire sheet of water to be channeled to the left side of the Río Millares, where the new gorges or water dams of the late 19th century are located. These are arranged parallel to the riverbed, so the water inflow is never direct. The water dams are part of a larger joint construction that includes, in addition to the three gorges, three other gates for cleaning the bottom of the weir. There are three flow regulation gates and three cleaning gates to let the gravel and mud pass through. The set was built between 1886 and 1895.

Figure 17: Castelló/Almassora Weir
Elaborated by the authors.

Catx Mill

The built-up mill complex is located in the Fadrell district, on the new section of the Almalafa irrigation channel that crosses through the middle. The construction is of the first half of the 19th century and presents a simple body to the front part with a series of big, closed patios behind that were used as warehouse and pictures. The facade of the complex faces east and is formed by two elongated and attached buildings. The one on the left has only one floor with a terrabasal that served as a residence, while the one on the right has two floors and corresponds to the milling room and the miller family's dwelling. The mill room conserves the two fixed millstones, but the upper ones and any type of mechanism of the mill are missing. The arrival and the water jumps are the areas that have suffered more alterations. Hooked to the walls there are remains of the numerous pulleys that allowed to drive the different cleaning and sifting machines installed on the upper floor. Before 1887 it functioned as a paper mill, and there are still traces of this activity, although from then on it functioned as a flour mill.

Figure 18: Catx Mill
Elaborated by the authors.

Censal Chimney

It is a tiled chimney related to a water extraction well for irrigation located in the Censal area, between the Almassora road and the main irrigation ditch, near the old Ribelsalbes road, from the beginning of the 20th century. Associated to the chimney there was a farmhouse and other facilities that conform the hydraulic set as the well, the hut destined to lodge the motor, the wheel of shovels that elevate the underground waters and the raft of storage and regulation of the irrigation capital. The chimney remains complete despite its poor state of preservation. It is square in plan with pedestal, pipe and paddling. The element is a typical example of the first chimneys that appeared in the middle of the 19th century (of the type "truncated pyramid") and very frequent in our country in well engines during the decades of 1920-1930.

Figure 19: Censal Chimney
Elaborated by the authors.

Cervera Mill
The name of the mill is due to the surname of its constructor, the neighbour of Castelló Pedro Cervera. The mill was built at the beginning of the 19th century on the Rafalafena row, in the rural district of the same name and next to the Hondo Road. In the middle of the 19th century its production was the third of all the mills of Castelló and at the end of that century two families lived in the mill. Its activity did not last beyond the first decades of the 20th century, and it was later abandoned and demolished.

Figure 20: Cervera Mill
Elaborated by the authors.

Darrer Mill
Mill located downstream of the three built in the fourteenth century in the section between the partidor of Coscollosa and Seco river. The name Masquefa is the surname of its owner in the 16th century. It was built on the outlet of the Major de Castelló irrigation channel, in the Ramo district. The mill continued to operate during the 19th century but ceased its activity as a flour mill at the beginning of the 20th century. The last industrial activity was to grind gypsum, also with a short duration during the first decades of that century. The mill was for the last decades a farmhouse until 1993 when it was completely overthrown. The mill had a single nave with an elongated floor plan, arranged transversely over the irrigation ditch with a gabled roof and was two stories high. Access to the building was through the side façade facing the Molins road. Later, other smaller outbuildings were added at the north and south ends. The mill had two sets of millstones.

Figure 21: Darrer Mill
Elaborated by the authors.

Ditch of the Pantà

The irrigation ditch of the reservoir is a hydraulic infrastructure formed by an extensive network of canals and ditches. The diversion channel was 14 kilometers long, from the dam of Maria Cristina to overcome the Torreta ravine and reach the path or path of La Paja, on the northern side of the municipality. A total of five distribution ditches (called irrigation ditches number 1, 2, 3, 4 and 5 respectively from south to north) were born from the diversion channel, which together totalled 34 kilometres in length. The first distribution ditch appears when the canal has already covered a distance of 5.5 km, at the height of Cuadra de Villalón, and the five take an easterly direction until they reach almost perpendicular to the Major de Castelló ditch, in the southern part of the municipal district, or to the Coscollosa ditch, at the northernmost end. The water from the reservoir irrigates more than 2,000 hectares of land (24,000 fanegadas) in the districts of Benadressa, Estepar, Rodeo and Boalar, which were previously rainfed. The construction of this infrastructure between 1913 and 1925 had a radical impact on the agricultural landscape of Castelló de la Plana because it almost equaled the area that represented the historical cultivated area of the irrigation ditch of the Río Millares.

Figure 22: Ditch of the Pantà
Elaborated by the authors.

Foment Ditch

The starting point of this infrastructure was in 1872, when Antonio Barrachina obtained a water concession for the water flowing through the Viuda watercourse to irrigate 400 hectares of dry land in the Benadressa district. The project recovered Mercader's proposal and extended it notably. The irrigation channel now crossed the Malvestit ravine and reached the Seco river and the Ros stable. To the project was later added the objective of providing drinking water to the city of Castelló de la Plana, which led to the constitution of the company "Fomento Agrícola Castellonense" that same year. In spite of having the infrastructures built, the project of transformation into irrigated land did not achieve the planned objectives and of the four hundred hectares only 117 were transformed, the others continued to be unirrigated land. In the end, at the beginning of the 20th century, some 1,500 bushels of unirrigated land had been converted into irrigated land in the Benadressa area.

Figure 23: Foment Ditch
Elaborated by the authors.

Font de la Reina

Fuente la Reina is a natural freshwater spring, which gives an irregular flow but always less than 1 m3/s. Its location corresponds to its point of spoil of the mountain range of the Desert, and line of connection between the dry land and the traditional cultivated area, just where the route of the Major irrigation channel of Castelló ends. The fountain has a underground part, a gallery excavated to the natural ground to find the point where the water springs. Along its route a series of wells of aeration or ventilation can be found that also served to extract the sediments excavated from the gallery. Most of the wells are sealed but a couple are still visible.

Figure 24: Font de la Reina
Elaborated by the authors.

Font Mill

The mill was built just where the route of the Major irrigation channel ends, in the area of Fuente la Reina. The construction that is still standing today corresponds to a building that has been enlarged and retouched in the last centuries, with outbuildings built to house the mill's new motor mechanisms. The oldest space corresponds to an elongated nave arranged transversally over the main irrigation channel. The mill has a single floor with a gabled roof and its construction combines masonry with the use of tiles. In the interior there are no remains of the millstones or of the complementary machinery, nor of the reels.

Figure 25: Font Mill
Elaborated by the authors.

Former Royal Partitioners
The partition is resolved with a central cutwater and lateral ashlars, with a recess to slide wooden gates. These are the old royal dividers that divided the water between the Molino irrigation channel -formerly from Almassora- and the Mayor irrigation channel -formerly from Castelló- and that were adjusted to the new internal water partition between Almassora and Castelló after the waters were separated at the end of the 18th century. The intervention consisted of dismantling the left side in order to narrow the water passage in the direction of the town. The current proportions reflected in the ordinances are 8.5 parts for the Molino irrigation ditch and only 1.5 for the Mayor irrigation ditch, when in the past they divided 14.5 rows for Castelló and 12.5 rows for Almassora. A few decades ago, the ditches were lined with concrete while respecting the partition.

Figure 26: Former Royal Partitioners
Elaborated by the authors.

Forn de Vidre Mill

In medieval documentation there is a reference to a mill located in a place called the glass furnace, a very suggestive appellation about a possible industrial use. Its location could correspond to a site that still maintains the toponym currently next to the irrigation channel de la Obra, in the surroundings of Fuente la Reina and close to the area of marshes. The oldest reference is from 1486, to indicate that it is in ruins. In 1502 it is called for the first time "el Molinàs", being used the term at least until 1566 when it is insisted that the place was abandoned for more than thirty years. Corresponding to the ruins of the Molinàs, all that remains are a few standing walls of a rectangular building with a gabled roof.

Figure 27: Forn de Vidre Mill
Elaborated by the authors.

Final product

The entire inventory is presented in the final storymap on: https://storymaps.arcgis.com/stories/c6f249ec49904a-428def1d5faf9ae688

IV - Module 10
Pavia (Italy)

IV Module 10. Origins of the Project: Why H2OMap

IV - 10.1 The Taramelli-Foscolo Higher Institute in Pavia

The Taramelli-Foscolo Higher Institute (hereinafter referred to as ISTF) was established in 2015 through the merger of two of the oldest high schools in the city of Pavia: the Torquato Taramelli Scientific High School and the Ugo Foscolo Classical High School. Both schools emphasize the relationship between the humanistic tradition and scientific culture in their curriculum, offering a wide range of disciplines, including Italian language and literature, Latin language and literature, mathematics, physics, chemistry, biology, natural sciences, geography, history, philosophy, English language and culture, art history, physical education, ancient Greek language and literature (specific to the Classical High School), and technical drawing (specific to the Scientific High School).

The mission of the Institute is to equip students, who attend school for five years (from 14 to 18 years old), with the necessary skills to access any university or higher education institution. The Ugo Foscolo Classical High School, founded in 1859, has its home in the ancient monastery of Santa Maria di Canepanova (15th-16th century), after centuries as a religious college (Barnabites and Jesuits). The Torquato Taramelli Scientific High School, established in 1923, is located in an ancient Carmelite monastery (15th century), which once hosted the Normal Schools from 1799.

ISTF boasts more than 1000 students, approximately 100 teachers, and a long-standing tradition of collaboration with the University of Pavia in various orientation and enrichment projects. Notably, in 2018, a group of ISTF students had a valuable opportunity to engage with Prof. Carlo Berizzi from the Department of Civil Engineering and Architecture at the University of Pavia through one of these projects, the Archias project.

IV - 10.2 Why H2OMap

Hence, when Prof. Berizzi proposed the possibility of participating in the H2OMap project, it presented an exceedingly interesting and engaging opportunity for ISTF. The project's fundamental objectives can be summarized as follows:

Enhancement of skills in the active use and application of Information and Communication Technologies (ICT).
Cultivation of interest in science, technology, engineering, and mathematics (STEM) disciplines.
Enrichment of the hydraulic heritage from historical, artistic, geographical, and socio-economic perspectives.
The curriculum at our Institute is intentionally designed to integrate scientific disciplines with humanistic ones. Commencing with a profound historical and cultural awareness, the acquisition of knowledge and skills, ranging from scientific to digital and communicative proficiency, is firmly rooted in the past. This synergy contributes significantly to the ongoing effort to foster a shared European identity, within a framework of internationalization that strives for inclusivity. This approach is geared toward not only mitigating the impacts of socio-economic inequality and discrimination but also promoting interaction, comparison, and meaningful exchange among students from diverse backgrounds and countries. In this context, student mobility linked to Learning Teaching Training Activities (LTTA) serves as a valuable tool in the endeavor to cultivate future European citizens.

IV - 10.3 H2OMap during the Covid-19 Era

As a result, we embarked on this journey with a resolute intention to involve as many students and teachers from various disciplines as possible. The working group consisted of two coordinating teachers, one specializing in Latin and Greek, and the other in history and philosophy. They were complemented by approximately twenty teachers from class councils and external sources, including language teachers, mathe-

matics and physics instructors, science educators, and history faculty. The contingent of students involved exceeded 40, hailing from the upper three-year period, all collaborating for the second phase of LTTA. Initially planned to be conducted in Pavia in 2022, the Covid-19 pandemic necessitated a profound reassessment of our planned activities.
Fortunately, due to the concerted efforts of all parties involved, the pandemic did not result in the distortion or depletion of the project. While it did impose a slower and more cumbersome start to the project, with a shift of nearly all activities to an online format, it also made the H2OMap project a beacon of openness and hope during challenging times. This was particularly evident during the first mobility in Spain in October 2021. To facilitate the participation of all partners in this valuable experience despite pandemic-related difficulties, we restructured the second phase of LTTA. Originally slated for a collective endeavor in the spring of 2022, we decided to divide the activities into two separate periods: the first phase occurred from May 1st to May 6th, 2022, during which we hosted 17 students and 3 teachers from Castelló, Spain. The second phase took place from October 9th to October 14th, 2022, with the participation of 20 students and 6 teachers from Elvas and Campomaior, Portugal. The increased organizational effort invested in this approach proved to be highly worthwhile, as it enabled a more comprehensive and profound engagement of students. Consequently, they were able to acquire the expected skills more productively and constructively.

IV - 10.4 LTTA 2022: The Naviglio Pavese from Castello Visconteo to the Confluence with the Ticino

The city of Pavia has a time-honored tradition of a symbiotic relationship with water. It was born on the banks of the Ticino River, and this connection is evident in its name, which it retained for centuries. Ancient Ticinum, believed to be founded in 89 B.C., preserved this name until the Lombard period. Over the centuries, this special bond with the river was complemented by a complex network of canals that crisscrossed the city's territory, starting with the Naviglio Pavese. Therefore, with invaluable support from Prof. Berizzi's team, we identified the urban area of the Naviglio Pavese, from Castello Visconteo to the Confluence Basin, where the Naviglio merges with the Ticino, as our case study. This journey guides one through the city and the park, traversing Borgo Calvenzano and the pathway along the Naviglio that leads to the bank of the Ticino. Along this path, both the city's artistic heritage and the numerous historical hydraulic structures along the Naviglio come to the fore. Additionally, it offers valuable insights into water and environmental health indicators.

Figura 1. Students during mapping event.
Elaborated by the authors.

IV - 10.5 Mapping along Naviglio Pavese

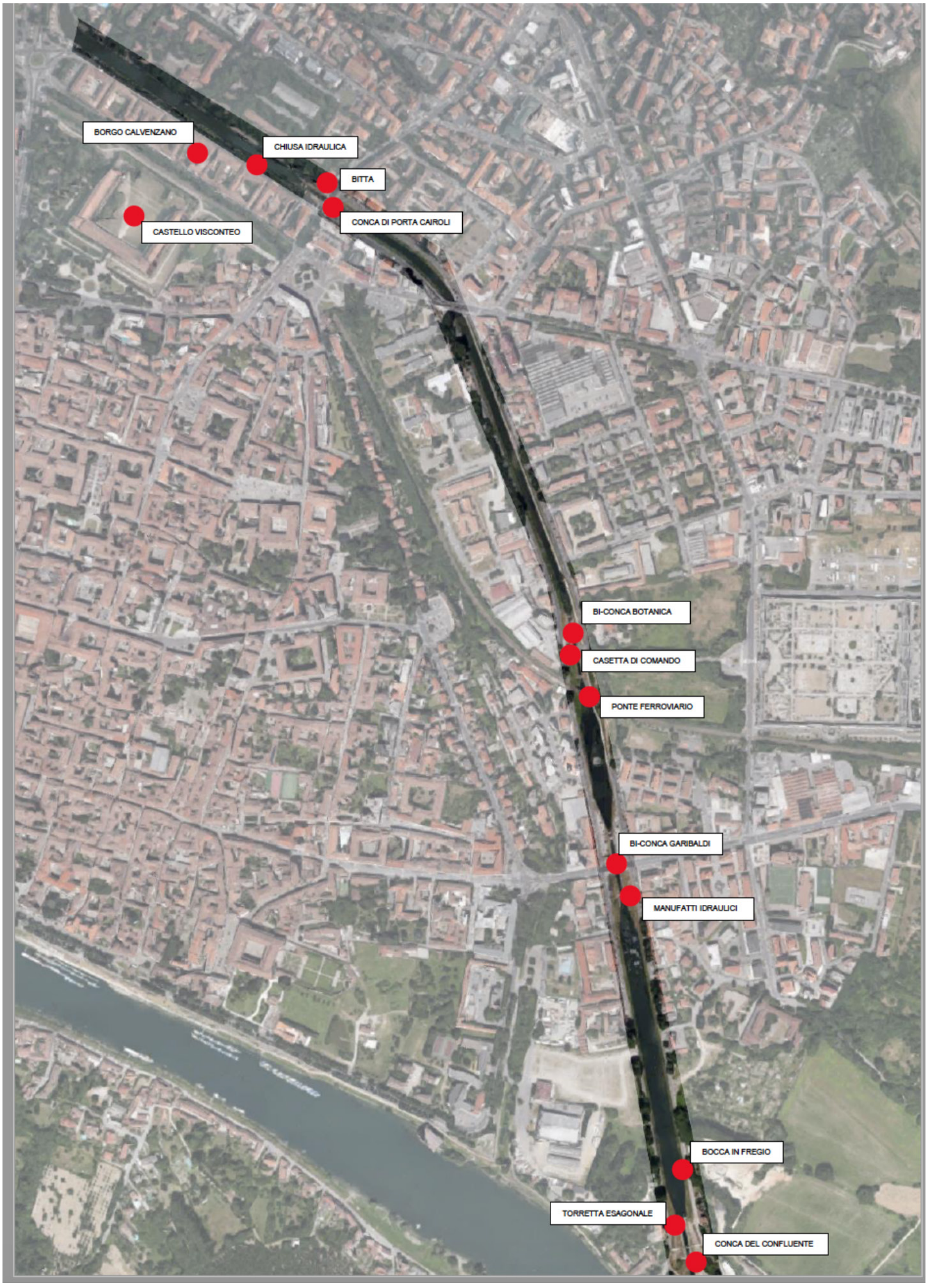

Figure 2. Mapping of the hydraulic elements along the Naviglio Pavese. Elaborated by the authors.

Among the noteworthy monuments of historical and artistic significance, Castello Visconteo, our starting point, commands attention. Its gardens in the 14th century were irrigated by the waters of the Naviglio. Subsequently, we encounter the complex of Borgo Calvenzano, constructed in 1816 with its original purpose as a commercial infrastructure. Among the hydraulic structures of utmost interest is the "hydraulic lock," built parallel to the Naviglio Pavese in the early 1800s. This lock was essential for diverting excess water and surmounting the elevation differences in the canal to facilitate navigation. Although the project was conceived by Napoleon's engineers, it was constructed during the Austro-Hungarian rule.
Additionally, there is the "bitta," which functioned to stabilize boats during the water filling process of the basin. Each bitta was associated with a noble family that donated it to the city, often bearing the family's name and/or symbol, signifying its significance. Moving forward, we encounter the "Bi-Conca Botanica," which constitutes the initial segment of the Water Stairs monument. This monument comprises two double basins (Botanica and Garibaldi) and the final basin known as the Confluence Basin. The entire structure was erected in 1819, and it also incorporates a "control cabin." This cabin served as a control center from which a technician could operate the sluice gate, facilitating the passage of boats. Notably, there is the railway bridge, constructed after the mid-1800s, marking the advent of the railway era in Pavia. The introduction of fast train transportation gradually rendered the canal obsolete.
Following these features, we encounter the "Bi-Conca Garibaldi," which constitutes the second part of the Water Stairs monument, showcasing all the hydraulic structures responsible for operating the gate. The "Bocca in fregio" is a historic hydraulic lock dating back to the early 1800s, and the "Torretta esagonale" stands as the sole surviving hexagonal brick tower in Pavia. Finally, we arrive at the "Confluence Basin," which serves as the conclusion of the Naviglio, where its waters merge with the Ticino. In the course of this journey, the

mapping activities pertaining to the hydraulic heritage were seamlessly integrated with observations of the flora, fauna, and environmental conditions. For instance, the conspicuous poor quality of both water, resulting from pollution, and the environmental context, occasionally characterized by neglect and degradation, underscored the area's limited appeal and utility, despite its proximity to the city center. These findings emphasized the social and political imperative of redevelopment proposals.

IV - 10.6 Implications and Prospects

The initiation of the H2OMap project coincided with the introduction of Civic Education in September 2020, as a cross-disciplinary subject spanning all school grades, from kindergarten to secondary school. The key thematic areas of this subject include:

CONSTITUTION, law (national and international), legality, and solidarity.

SUSTAINABLE DEVELOPMENT, encompassing environmental education, knowledge, and the preservation of heritage and territory.

DIGITAL CITIZENSHIP.

The profound alignment of the activities championed by the H2OMap project with this newly introduced discipline is readily apparent. The project promotes:

The cross-cutting nature of skills through multidisciplinarity and interdisciplinarity. Internationalization and the cultivation of European citizenship. Environmental education and sustainable development (Agenda 2030), via heightened awareness of water management issues and hydrogeological instability, particularly in the context of climate change. The cultivation of digital skills through Information and Communication Technologies. The education of informed citizens, bridging the gap from the local "small homeland" to the European "common home."

IV - Module 11
Elvas (Portugal)

IV - Module 11. Hydraulic Heritage in Elvas Population Growth and Water Needs in a Military City

IV - 11.1 Introduction

The present case study intends to briefly describe the application of the methodology described in the methodological guide, associated with the survey of the hydraulic heritage in the municipality of Elvas, district of Portalegre, Portugal. The data collecting and its organization according to descriptors, allowed the construction of a story map as a final product, through the use of the ArcGis computer program and QField application, for data collection, together with the bibliographical research.

IV - 11.2 Methodology

- Identification of the hydraulic elements by the students proximity to the students' place of residence;
- First list and use of ICT for bibliographic research;
- Introduction to the use of Geographic Information Systems (GIS);
- Use of Google Pro, for marking and identifying Points;
- Use of QField for mapping points on the ground.
- Training of teachers in the use of ArGis and Construction of Story Maps.
- Construction of the final Story Map.

IV - 11.3 Human resources

Teachers: Biology e Geology, Math and Electricity.

Students: The students who were part of the project and carried out the case study started the project in 2020, during their 10th year (2020), and finished it in the 12th year (2023). The students were part of the Professional Course in Agricultural Production and the Professional Course in Electrical Installations. In both courses, the contents of Geographic Information Systems were worked on in an integrated manner, in articulation with the curriculum of different disciplines

IV - 11.4 Story Map Construction

Link:
https://storymaps.arcgis.com/stories/05a83a95d1ca46a9965c110edd507231

Context
The geographical location of the city of Elvas in Alto Alentejo, located on top of a hill, is conducive to periods of drought, sometimes lasting longer than a year, aggravating this situation the nearest permanent watercourse (the Guadiana river) is located about 12 km.

The construction of the city, starting from the hill, a strategic position of defense against the invaders, constituted over time a challenge for the storage of water and supplying water to the population between walls, from the Islamic to the 17th century.

Elvas is now home to the largest set of bastioned fortifications in the world, the walls of Elvas, which together with the historic center of the city are a World Heritage Site, a title awarded by UNESCO on June 30, 2012.

This story map intends to show the influence of the location of Elvas as a military city and the need to supply the civilian and military population throughout different historical moments of the city, where the ex-libris is the Amoreira Aqueduct.

IV - 11.5 Route Sequence

The sequence of points, on the story map, makes it possible to start the journey from earlier times, outside the walls, to the present day, passing into locations within the walls, after the construction of the Aqueduct.

It also allows reference to the Guadiana River, with the connection of its Spanish and Portuguese banks, through the Ponte da Ajuda, highlighting the importance of these elements and the importance of their strategic management in conflict situations.

Os pontos identificados resultam de uma seleção prévia e a informação do Story Map encontra-se em aberto, podendo ser melhorada e aumentada.

IV - 11.6 Typology of identified hydraulic elements

- Aqueduct;
- Cistern;
- Source;
- Bridge;
- Mills.

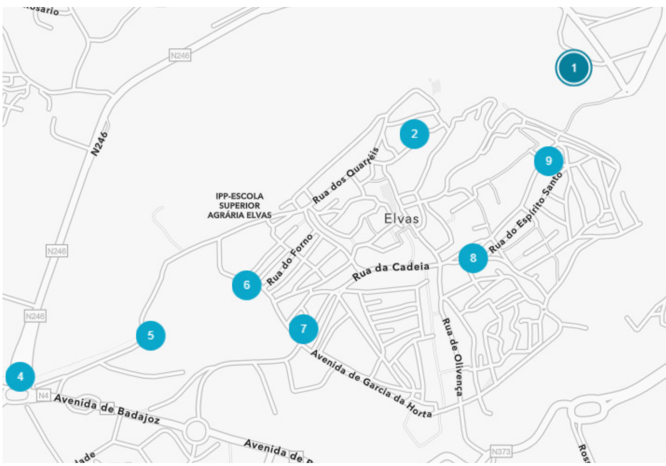

Figure 1: Identified elements map. Elaborated by the authors.

IV - 11.7 *Identified points*

1 Fonte da Prata
2 Poço de Alcalá
3 Fonte da Amoreira
4 Aqueduto
5 Chafariz da Amoreira
6 Cisterna
7 Fonte da Misericórdia
8 Fonte de São Lourenço
9 Fonte de São Vicente
10 Cisterna do Forte da nossa Senhora da Graça
11 Ponte da Ajuda
12 Moinhos do Guadiana

IV - 11.8 *Target*

Students between 11 and 18 years old. It can be used with younger students in the Portuguese version and with specific objectives.

General public that wants to know the relation of the implementation of the main fountains between walls and population growth.

IV - 11.9 *Application and use in curricular areas*

Some disciplinary areas stand out in which they will be able to use the story map for the teaching of some curricular contents: History, Foreign languages, Portuguese, Mathematics, Visual Education and Physical Education.

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IV - Module 12
Campo Maior (Portugal)

IV - Module 12. Hydraulic Heritage in Campo Maior
More than water - social life around hydraulic heritage

"We never know the worth of water till the well is dry."
Thomas Fuller

Based on Thomas Fuller's quote, we started our work around the importance of water and sources in Campo Maior society over the years.

IV - 12.1 Context

Campo Maior is located in the inland of Portugal, in the Alentejo region where summers are dry and hot and winters are very cold. Throughout the year, in general, the temperature varies from 3°C to 34 °C and is rarely below -2 °C or above 45 °C. The chance of wet days in Campo Maior varies throughout the year, however the duration of rainy days and the amount of monthly precipitation has been decreasing due to climate change. Therefore it is extremely important to preserve water and make it available to the entire population. Campo Maior has several fountains which are part of their hydraulic heritage.

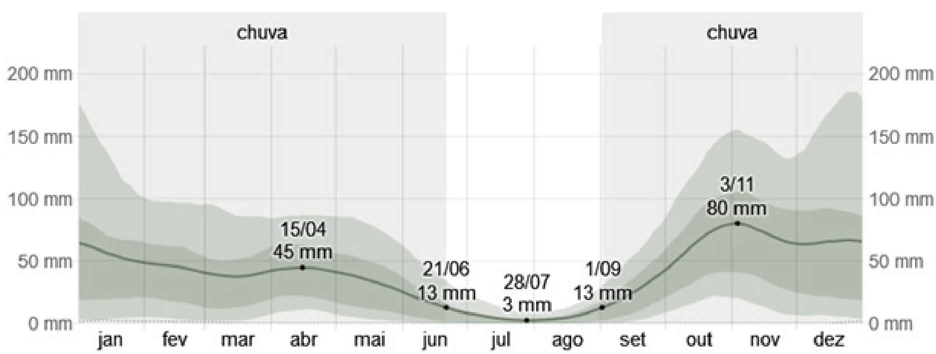

Figure 1: Diagram of the precipitation in Campo Maior.
Source: https://pt.weatherspark.com/y/32838/Clima-caracter%C3%ADstico-em-Campo-Maior-Portugal-durante-o-ano .

Campo Maior started growing from the walls of the castle. Before the 14th century the major concern was to keep the village safe from the military attacks that could come from Spain, but from that century and until the 17th century, as there were not many wars, the village could grow and extend beyond the castle walls.

That growth was determined by the existence of fountains that guaranteed the population's access to water. In this sense the village expanded towards the water sources: Towards Fonte de São Pedro (northeast from the medieval nucleus); towards Fonte Nova (northwest) and towards Fonte das Negras (east).

By building this story map we want to show the social and economic importance of some fountains in the history of Campo Maior. The fountains placed outside the castle walls had three main functions: they were sources of drinkable water for the population; they were places to give water to animals and places to wash the clothes.

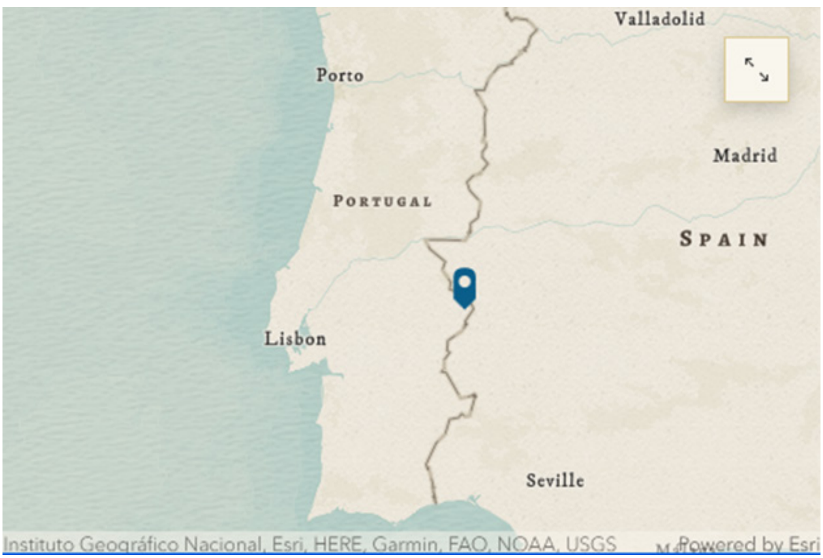

Figure 2: Localizacion of Campo Maior.
Source: Instituto Geografico Nacional, Esri.

IV - 12.2 Working process

	Meeting point	Animal water fountain	Getting a Job	Washing Tank	Leisure
Fonte Nova		x			
Fonte do Jardim					x
Fonte dos Cantos de Baixo			x		
Fonte do Largo da Casa do Povo	x				
Chafariz da Abertura		x			
Fonte de São Francisco				x	
Fonte das Negras		x		x	
Fonte da Praça Velha	x				
Fonte do Largo do Barata	x				
Fonte das Negras		x			

Table 1: Working process table with functions of water fountain.

First, we asked the students to do a survey of all the existing fountains in Campo Maior and grouped them according to the different functions performed over the years.
Then we went on a field trip to collect the geographic mapping points through the mobile application and other data such as current photographs of them.

*Figure 3 and 4: Students group during hydraulic mapping.
Elaborated by the authors.*

Back in the classroom, each student did some research on one of the fountains, completing the data that might be missing, such as the date of construction, past and present use, etc.

*Figure 5,6 and 7: Students group during working process.
Elaborated by the authors.*

With this work, we learned that no one imagines a fountain could be a social place, but it was. In very old times they were not only a water point but also a meeting point.
Taking the animals to drink some water in a fountain wasn't really a meeting and, in fact, it could be a hard task to do. As there weren't any other sources of water, one had to take the animals there to drink.

As a meeting point, it was a place where men could meet, talk about life and find some work in the fields. There was no contract, but there wasn't also any concern with illegal work as nowadays.
The public washing tanks were a local place where women met and, besides washing the family clothes, they could chat a little, or should we say gossip? In Portugal there is a saying: "lavar a roupa suja", translating you have something like "washing dirty clothes". However this saying doesn't apply particularly to clothes, but specially to that moment when someone talks about the life of others with his / her interlocutor. In a way, the washing tanks were a social meeting place.
Nowadays these fountains are decorative artifacts due to the domestic water plumbing. The washing tanks were abandoned and some even disappeared and were substituted by the washing machines. Fountains are no longer "job offices" and no one even imagines they have been like that.

Fonte Nova: drinking fountain for animals

Figure 8: Fonte Nova.
Elaborated by the authors.

It is a fountain with a tank made of marble and masonry backrest. It has the coat of arms of Portugal and two Manueline spheres. It has water but it isn't advisable to drink.

Located in one of the occurrences of the village of Campo Maior, next to the road that goes to the village of Degolados, Fonte Nova is a fountain of probable 16th century edification. The building, which is integrated into a wall, is divided into two parts, the lower part corresponding to the rectangular stone tank, one formed by the backrest .

Fonte do Largo do Barata:

Figure 9: Fonte do Largo do Barata. Old status
Elaborated by the authors.

It is a fountain placed inside the 17th century walls but, as it is located at an important entrance to the town, it had the dual function of a fountain and a drinking fountain for animals. It is not currently in use.

Figure 10: Fonte do Largo do Barata. Current status
Elaborated by the authors.

Fonte dos Cantos de Baixo:

Figure 11: Fonte dos Cantos de Baixo. Old status
Elaborated by the authors.

Figure 12: Fonte dos Cantos de Baixo. Current status
Elaborated by the authors.

It was the place where men gathered early in the morning to be chosen by the landowners to do some work. It is still a place for socializing. It has no running water

Fonte de São Francisco:

Figure 13: Fonte de São Francisco.
Elaborated by the authors.

It’s an example of Baroque architecture, built in 1766. It is located in a corner, theatrically arranged in relation to the surrounding urban space. It was classified as of municipal interest in 2014. It has no running water. It has a decorative purpose.

Chafariz da Abertura:

Figure 14: Chafariz da Abertura.
Elaborated by the authors.

Situated in Largo de Sao Francisco, this fountain was a place where animals could drink. The remaining water was channeled behind the so-called mini aqueduct for agricultural use in the nearby lands.

Fonte das negras

Figure 15: Fonte das negras.
Elaborated by the authors.

Was a public washing tank called "Tanquinhos", which ran till 1982. It was closed because it was rarely used. It was also a drinking fountain for animals. The spouts of the fountain were closed at night so that the water could be entirely used in watering the crops of the nearby farms.

Fonte do Jardim

Figure 16: Fonte do Jardim.
Elaborated by the authors.

It is a circular fountain of modern and recent construction, located in a wide main central area of Campo Maior. It is used as an ornamental place; however, it becomes the center of different activities such as fairs, parties, meetings, exhibitions and other social events, bringing beauty and freshness to this main "street" of the village.

IV - 12.3 Inventory

Figure 17: Elaborated Map of Campo Maior.
Elaborated by the authors.

When we finished all our work of collecting information and mapping geographic points, we were able to build our historical map, in which we identified the sources and their uses, highlighting the importance that each one of them had over the years for the population of Campo Maior.
Parallel to the creation of the historical map, and to enrich it, the students created three pedestrian routes to meet the fountains in Campo Maior and according to the degree of hardness of the water: soft water - four fountains; medium water - eight fountains; hard water - twelve fountains.

Water routes:
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H2O Map: Methodological Guide was developed during the Erasmus+ project “H2O MAp Innovative Learning by hydraulic heritage mapping,” funded by the European community.
This book serves as a guide and tool for the analysis and cataloging of hydraulic heritage, aimed at high school teachers and students to develop new skills in the field of information and communication technology (ICT).

The objective is to raise awareness within schools about hydraulic heritage, offering an opportunity for high school students to engage with the world of research and university education while promoting its appreciation.