CHAPTER 03. **PAST, PRESENT AND FUTURE OF THE MECHANISMS OF THE CANAL DE CASTILLA**

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1. INTRODUCTION

The Canal de Castilla is one of the most important hydraulic engineering works in Spain, built during the 18th century. Its purpose was to create a communication route between the Castilian plateau and the Cantabrian coast, which was essential to unify the territory and improve transportation. Different branches were created, one of them being the Northern Branch which occupies the provinces of Palencia and Burgos. As a result, the railway network was expanded and improved, which in turn incentivized the creation of numerous roads. The main axis that connects Valladolid-Palencia-Santander was established *Gutiérrez et al. (2014)*.

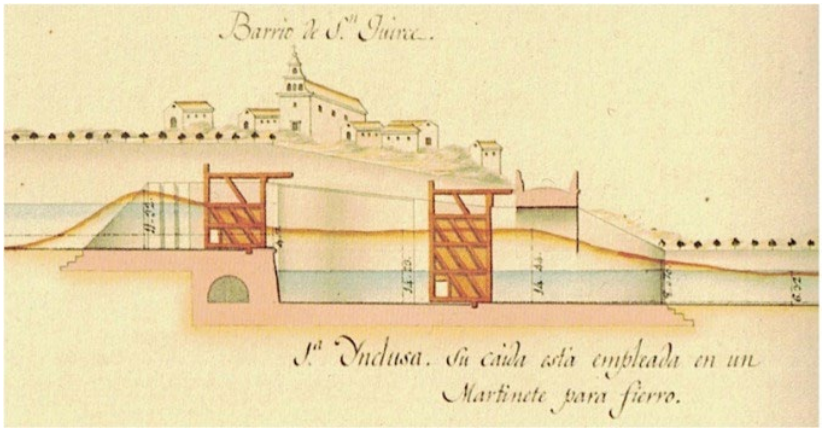
The Canal de Castilla worked by means of locks due to the unevenness of the terrain. It was governed by a system of gates that opened upon the arrival of a barge, allowing the water level to rise until it was equal to the next section. This system allowed for navigation. The Canal de Castilla was created to provide an outlet for surplus cereals and transport them to other regions. However, in practice, they encountered many difficulties, including the high cost due to the orography of the terrain. The positive effects of its construction could be appreciated in the economic realm and are still valid today *González Pena (1981)*.

Today, the main use of the canal is for irrigation and supplying water to nearby populations. All of this is managed by the Hydrographic Confederation of the Duero, which is responsible for its exploitation and maintenance *Ramírez (2020)*. However, the canal also has special importance in regional tourism as it has promoted the creation of interpretation centers, museums, and other activities such as boat trips. As a result, it has favored the opening of tourist accommodations *Pardo Abad (2022)*.

The canal was designed for the production of tools for the canal itself and for agricultural activities, as can be seen in Figure 1 from the year 1806. The

different elevations of the canal and the gates that allowed for the entry and exit of water for navigation can be appreciated in the image.

Figure 1: Graphical representation of First lock of the Canal de Castilla. Source: Juan de Homar, Archive of the Royal Palace of Madrid (1806)



Source. Geijo (2022)

Numerous studies have been conducted demonstrating the negative impact that the installation of a hydroelectric power plant on the Canal de Castilla would have on the historical and cultural heritage as well as the environment. Therefore, any intervention must be evaluated to ensure its conservation. It is mentioned that the construction of the hydroelectric power plant could have negative impacts on the river regime, as well as on the fauna and flora, affecting the quality of the water and soil. These works conclude that measures must be taken to minimize the negative impacts of the hydroelectric plant installation and studies must be conducted for its viability *Canal de Castilla. (2018) y Vela (2018)*.

The placement of turbines has been a topic of controversy and has been analyzed by different experts and researchers in the field of renewable energy. There are studies that examine the potential use of the Canal de Castilla for the generation of hydroelectric energy through the installation of small turbines in selected sections of the canal. A technical and economic analysis was conducted, stating that it could generate up to 11.5 MW with an investment of 9 million euros. However, the importance of preserving the environment and the historical and cultural heritage is also emphasized.

Other studies evaluate the technical and economic viability of the installation of hydraulic turbines in the Canal de Castilla. An analysis was made of the benefits and costs, considering aspects such as operational costs, initial investment, maintenance costs, and profitability. Therefore, the installation of turbines is a feasible option from a technical and economic perspective. Various tests have been conducted to measure the flow and speed of water in each section of the canal, and it has been concluded that it is viable from a technical

standpoint, although a study must still be carried out to ensure its profitability *González (2016) y García (2014)*.

The objective of installing hydraulic turbines in the Canal de Castilla for the production of hydroelectric energy is to contribute to one of the future options of the canal being the generation of clean and renewable energy, always respecting that the canal is a cultural heritage asset due to its historical significance.

2. MATERIALS Y METHODS

The Canal de Castilla is an impressive system of water canals located in northern Spain, built in the 18th century for the transportation of goods and irrigation of farmland. If you look at the Canal de Castilla map, you can see a network of canals winding through the countryside, connecting towns and cities along its path.

Figura 2: Draw of the three branches which compose the Canal de Castilla

Source. Rivero (2000).

As shown in Figure 2, the Canal de Castilla map displays a network of canals branching and merging at several points along its route, like the veins of a leaf. The canals are surrounded by a green and fertile landscape, with fields and trees

lining their banks. There are also stone bridges that cross the canals and small locks that control the water flow.

The Canal de Castilla is composed of three main branches:

Northern Branch: This branch extends from Alar del Rey to Ribas de Campos, in the province of Palencia. It is the longest branch and was built first to transport wheat and other agricultural products from the Castilian plateau to the northern coast.

Campos Branch: This branch begins in the town of Ribas de Campos and ends in Medina de Rioseco, in the province of Valladolid. It was mainly built to transport wheat and other cereals from the fertile lands of the Campos region to the markets of Castilla y León.

Figure 3: Locks along the Canal de Castilla

Source. Moisén Gutiérrez (2013)

Southern Branch: This branch extends from the municipality of Grijota, in the province of Palencia, to Valladolid. It was built to irrigate farmland and orchards in the area, as well as to transport agricultural products such as grapes and other fruits from the production areas to local markets.

However, the installation of turbines in the Canal de Castilla poses several challenges and limitations that must be taken into account. One of them is the fact that the Canal de Castilla is a cultural heritage site that needs to be protected and preserved. Consequently, any turbine installation project must be done in a sustainable manner.

The placement of turbines involves a high economic investment as well as a specific study of the technical and economic feasibility of the project. Additionally, the activation of the turbines must be communicated to local authorities for subsequent acceptance.

3. RESULTS AND DISCUSSIONS

The Canal de Castilla is an important source of water and hydroelectric power, and there are several suitable locations along its branches to install turbines and generate electricity *Arranz (2001) y Linaje (1985)*. The ideal places where turbines could be placed on the Canal de Castilla are:

Locks: Locks are areas where water is raised or lowered to navigate different levels of the canal. These areas can be ideal places to install turbines, as water flows forcefully through them and can generate energy.

As we can see in figure 2, the Canal de Castilla is divided into three branches: the northern branch, the Campos branch, and the southern branch. In each branch, we can find the following number of locks:

Northern branch: This branch has a total of 24 locks, from Alar del Rey to Ribas de Campos.

Campos branch: This branch has a total of 7 locks, from Ribas de Campos to Medina de Rioseco.

Southern branch: This branch has a total of 18 locks, from Grijota to Valladolid.

In total, the Canal de Castilla has 49 locks, as the remaining three are located in the section from Frómista to Alar del Rey, which does not belong to any of the three main branches. The most important locks where turbines could be placed are:

San Llorente Lock: This lock is located on the northern branch, with a drop height of 13.67 meters and a maximum flow rate of 22.4 m^3/s. It is located near the town of Melgar de Fernamental in the province of Burgos.

Herrera de Pisuerga Lock: Located on the northern branch of the Canal de Castilla, with a drop height of 11.60 meters and a maximum flow rate of 13.2 m^3/s. It is located near Herrera de Pisuerga in the province of Palencia.

Saldaña Lock: This lock is located on the Campos branch, with a drop height of 11.22 meters and a maximum flow rate of 11.9 m^3/s. It is located near the town of Saldaña in the province of Palencia.

Calahorra de Ribas Lock: Located on the northern branch of the Canal de Castilla, with a drop height of 10.80 meters and a maximum flow rate of 13.2

m³/s. It is located near the town of Calahorra de Ribas in the province of Palencia.

Boada Lock: This lock is located on the northern branch of the Canal de Castilla, with a drop height of 10.40 meters and a maximum flow rate of 13.2 m³/s. It is located near the town of Boada de Campos in the province of Palencia.

There are several places on the Canal de Castilla where it would be possible to install turbines to generate hydroelectric power. The final choice will depend on factors such as the amount of available water, the lock height, and the capacity of the turbines used to generate electricity.

The future of the Canal de Castilla will depend on several factors, such as investment in its maintenance and improvement, its promotion as a tourist destination, and its use as a resource for renewable energy generation. Regarding its maintenance and improvement, continuous investment is required in the conservation of its infrastructure, such as dams, locks, and bridges, to ensure safe and efficient operation. In addition, restoration and improvement projects can be carried out on the canal's banks and natural surroundings, which could increase its tourist appeal. As a tourist attraction, the canal is already a popular destination for activities such as boat trips, hiking, and cycling. If the canal and its surroundings continue to be promoted as an attractive tourist destination, it could increase.

4. CONCLUSIONS

The Canal de Castilla is an important historical and cultural heritage site in Spain that requires attention and care for its conservation and sustainable use in the future. While restoring the canal as a means of river transportation presents economic and technical challenges, its conservation as a cultural and tourist resource may be a viable option for its future, generating economic and social benefits for the area.

The use of the Canal de Castilla for hydroelectric power generation, water management and agriculture, or the use of canal sections for recreational activities, can also be interesting options for the canal's future, as long as they are carried out sustainably and respecting the canal's historical and cultural significance.

The installation of hydraulic turbines in the Canal de Castilla for hydroelectric power production is an interesting option that could contribute to the generation of clean and renewable energy in the area. However, it is essential that any such project be carried out sustainably and respecting the canal's historical and cultural importance. Likewise, it is important to carry out detailed technical and economic feasibility studies, as well as involving the local community in decision-making and project management. The necessary independent sections can be included in each project.

Regarding the future of the Canal de Castilla, it depends on investment in its maintenance, its promotion as a tourist destination, and its use as a resource for renewable energy generation.

REFERENCES

Arranz, J. B. (2001). *El canal de Castilla* (Vol. 2). Editorial MAXTOR.

Canal de Castilla. (2018). *Informe de impacto ambiental de la central hidroeléctrica en el Canal de Castilla*.

García, J. y Mira, F. (2014). Estudio de la viabilidad de la instalación de turbinas hidráulicas en el Canal de Castilla para la generación de energía eléctrica. *Ingeniería Energética*, 35(1), 23-33.

Geijo, J. M., Sanchez-Lite, A., Zulueta, P., & Sampaio, A. Z. (2022). Study of an "Artefact" of the Castilla Canal: Reconstruction of the Missing Machinery. *Machines*, 10(4), 239.

González Pena, M. L. (1981). *El Canal de Castilla*.

González, R. y González, C. (2016). Estudio de la viabilidad técnica y económica de la instalación de turbinas hidráulicas en el Canal de Castilla. *Ingeniería Industrial*, 37(2), 158-168.

Gutiérrez, J. L. M., & Luis, J. (2014). El canal de Castilla y la vertebración del sistema de transporte en torno a su ramal norte (1750-1936). *Tst: Transportes, Servicios y telecomunicaciones*, (27), 12-36.

Linaje, J. L. (1985). Canal de Castilla: El recuerdo de un sueño ilustrado. *Publicaciones de la Institución Tello Téllez de Meneses*, (52), 153-171.

Moisén Gutiérrez, J. L. (2013). Patrimonio industrial y de la obra pública en el ramal norte del Canal de Castilla.

Pardo Abad, C. J., & Fernández Portela, J. (2022). El Canal de Castilla: recurso patrimonial del agua y perspectivas de uso e innovación turística.

Ramírez, M. (2020). El Canal de Castilla, el sueño de la meseta castellana por alcanzar el mar. *Técnica Industrial*, (327), 26-30.

Rivero, E. Del (2000). El Canal de Castilla, Burgos: *Diario de Burgos*.

Vela, R. y Romero, L. (2018). Análisis de la viabilidad de la generación de energía hidroeléctrica en el Canal de Castilla mediante la instalación de turbinas hidráulicas. *Revista de Investigación en Energía*, 7(1), 25-35.