

CONSTRUCTION AND OPERATION OF 29 INFLATABLE GATES IN NORTHERN FRANCE

by

Jean-Luc Berterrotière¹, Julien Aubonnet² and Jan-Willem Lechtenberg³

ABSTRACT

Voies Navigables de France is the French navigation authority responsible for the management of the majority of France's inland waterways network and the associated facilities (towpaths, commercial and leisure ports, lock-keeper's houses and other structures). They operate more than 500 dams, including 150 manual dams.

In 2010, VNF prepared a tender to replace 29 manual dams in the North East of France (Fig. 1). The old manual dams, located on the Aisne and Meuse rivers, were installed at the end of the 19th century, to develop transport and navigation in this area. They were made of wooden needles. Although globally widespread, inflatable solutions for mobile weirs were kept confidential in France for years. Among the possible solutions, inflatable gates prove to be a technically and economically attractive solution, both in investment, operation and maintenance. After few years of studies, the inflatable technology was chosen for this project. The works started in 2015 and have to be finished before 2020. With an average gate height of 2.2 meters, the total length of the 75 rubber gates to be installed will reach around 2500 meters.

This article outlines the context of this project, which will concern more than 200 kilometers of waterways, and the feedback after three years of works. Today (March 2018), a total of 58 spans out of 75 have been installed and 13 weirs have been commissioned.

1. INTRODUCTION

In 2013, Voies Navigables de France (VNF) signed a PPP contract (Public Private Partnership) with VINCI group, VINCI Construction France subsidiaries, and EDF to replace 29 dams before 2020 and operate 31 dams for thirty years: 2 of them were already rebuilt before, using traditional flap gates. By this contract VNF entrusted VINCI the financing, the design, the construction and the operation of six new mobile weirs on the Aisne River and twenty-three on the Meuse River. In addition, each project must include a fish pass. Three of the sites that are all located on the Meuse River will be equipped with very low head hydropower plants. As a result, VINCI bears all the administrative procedures related with the environment, water, urbanism, and so on, in order to obtain the work authorizations from the state agencies to proceed.

This project takes place on 2 rivers located at more than 240 km from each other: Aisne and Meuse. On the Aisne, the inland waterway is about 48 km long and on the Meuse about 160 km long. This means that all the sites are disseminated on a large territory. Such is an important constraint both administrative and logistic procedures.

The design and build of the whole Project were assigned to a Vinci Consortium. The design and hydraulic design were awarded by VINCI to a consortium led by BRLingénierie including BRLingénierie, Faubourg 2/3/4, Hydrostadium and ISM Ingénierie.

¹ Project Leader, VINCI Construction France, jean-luc.berterrotiere@vinci-construction.fr

² Deputy Director, BRL Ingénierie France, julien.aubonnet@brl.fr

³ Dipl.-Ing. Floecksmühle Energietechnik Germany, willi.lechtenberg@floecksmuehle.com

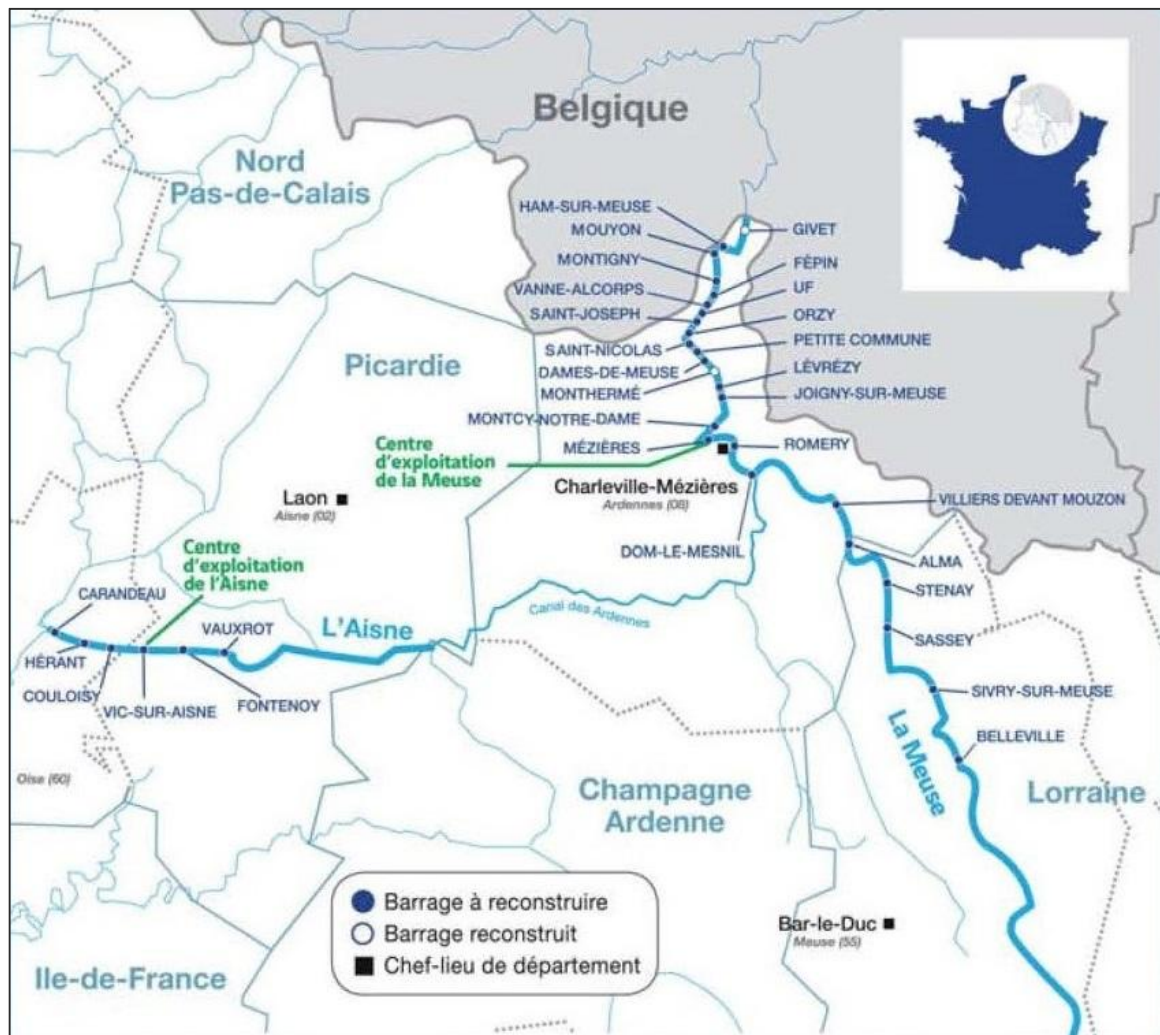


Figure 1: Location of the 29 projects on Meuse and Aisne Rivers

VNF requested very high performances with regards to regulation: the dam upgrades must allow for very low water level variation. The designer must ensure that the performance criteria are reached with the selected technology. The automated system of these dynamics structures, regulating a navigation level with very low tolerances is a critical point of the project. The supply and installation of the equipment was awarded to Vinci Energies, partner of Vinci Construction France from the beginning of the bid.

The global cost for the Aisne and Meuse project is 312 million euros, including an operation and maintenance period of 30 years.

2. MAIN HYDRAULIC CONDITIONS

This complex project requires from start to end strong hydraulics analysis. Feasibility studies allow to design the works, and to validate major strategic orientations with regards to construction stages. This enables to reduce the financial risk of the project.

During draft and environmental studies, hydraulics studies are required to check that the project, taken as a whole, will not increase the flood risk, during and after works. To achieve this, it is necessary to implement a more complex modelling tool which represents minor bed and floodplain, and to introduce two-dimensional model, which determine with precision the back water generated by the new structures, at final state or during the works. During detail design studies, those hydraulic studies allow to answer new specific questions and to optimize the works stages and the project itself.

On the river Meuse, the typical minimum discharge during summer is less than 10 m³/s upstream from the river to 50 m³/s close to the Belgium border. Each dam (the total width of the weirs vary from 40 to 130 meters) has to be fully lowered during floods approximately 1 or 2 times per year. For a 100 years return period floods, the flow can reach between 900 and 1900 m³/s.

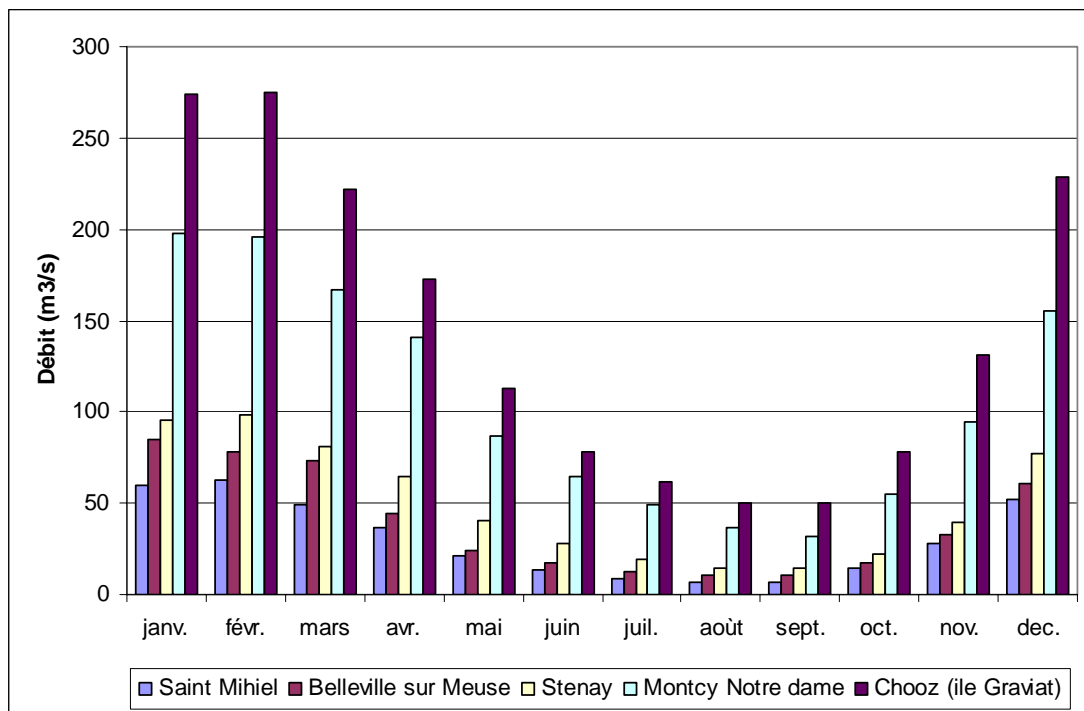


Figure 2: Monthly average discharge (m³/s) varies on Meuse river following season and location

3. DESIGN AND WORKS

After environmental and technical studies, the works started in 2015. The design of the new weirs took advantage of the similarity of the single projects and introduced a standardization approach. The new weirs were divided into different classes concerning the width and height of the rubber gates. The width of the gates ranges from 17 m to 35 m and the height from 1.8 m to 2.9 m. For hydraulic

and maintenance reasons, all new weirs consist of at least two spans up to 4 spans. Each new weir is built upstream or downstream from the dam to be replaced, depending on the site conditions. This means that the construction of a new weir has to be completed without reusing any piers or any abutments (Fig. 3).



Figure 3: Montigny existing weir on Meuse river (left) and construction of Mézières dam on Meuse river, without reusing piers and abutments (right)

The contract fixed severe conditions for the duration of the works which cannot exceed 5 years. Due to flood risks, the works in the riverbed are allowed every year from the beginning of April to the end of October (Fig. 2). With only 7 months of works for 5 years, this means that the works in the river bed have to be completed after only 35 months.

Every year, works are undertaken on several sites simultaneously, knowing that the modifications carried out on a weir can influence the level of water on the weir located in its upstream. The completion of each span involves the establishment of a cofferdam, which blocks the flow. Specifically, for a given work phase, the section of the watercourse is reduced by about one-third where the new weir has to be built. Therefore, each dam is built gradually, i.e. span by span, to maintain a normal discharge and level in the river. In order to keep the overall time limit, it is necessary to determine each year the maximum number of spans that can be under works simultaneously, while ensuring an acceptable level of risk.

The designer-builder group estimated that to build all the dams, a maximum of 7 dams on Meuse river and 3 dams on Aisne river would have to be built in parallel. In practice, however, up to 14 sites were under construction simultaneously. Works proceed from downstream to upstream because the fluvial flow is mainly controlled at the downstream dams and the new mobile gates are more efficient than the old ones.

Basically, the phasing of works is always the same. Beginning of April, as soon as it is permitted to start working in the rivers, the construction teams start to put the sheet piles for the first span. These works normally take three weeks. However, the duration strongly depends on the geological site conditions and can increase rapidly on rocky ground. Then, the construction pit is pumped dry, excavated and a layer of binding concrete is poured. In addition, a lower layer of reinforcement and connecting pieces are installed, which altogether takes another 3 weeks in average.

The pipes as well as the fixing system for the rubber gate are installed on adjustable supports (Fig.3). Including the installation of the remaining reinforcement of the bottom slab these works require roundabout two weeks. Following this installation step, the concrete of the bottom slab has to be poured, which takes less than one week including finishing works. In order to better standardize the installation phasing and due to the limited capacity of the concrete works, the piers are constructed in a separate step during one additional week.

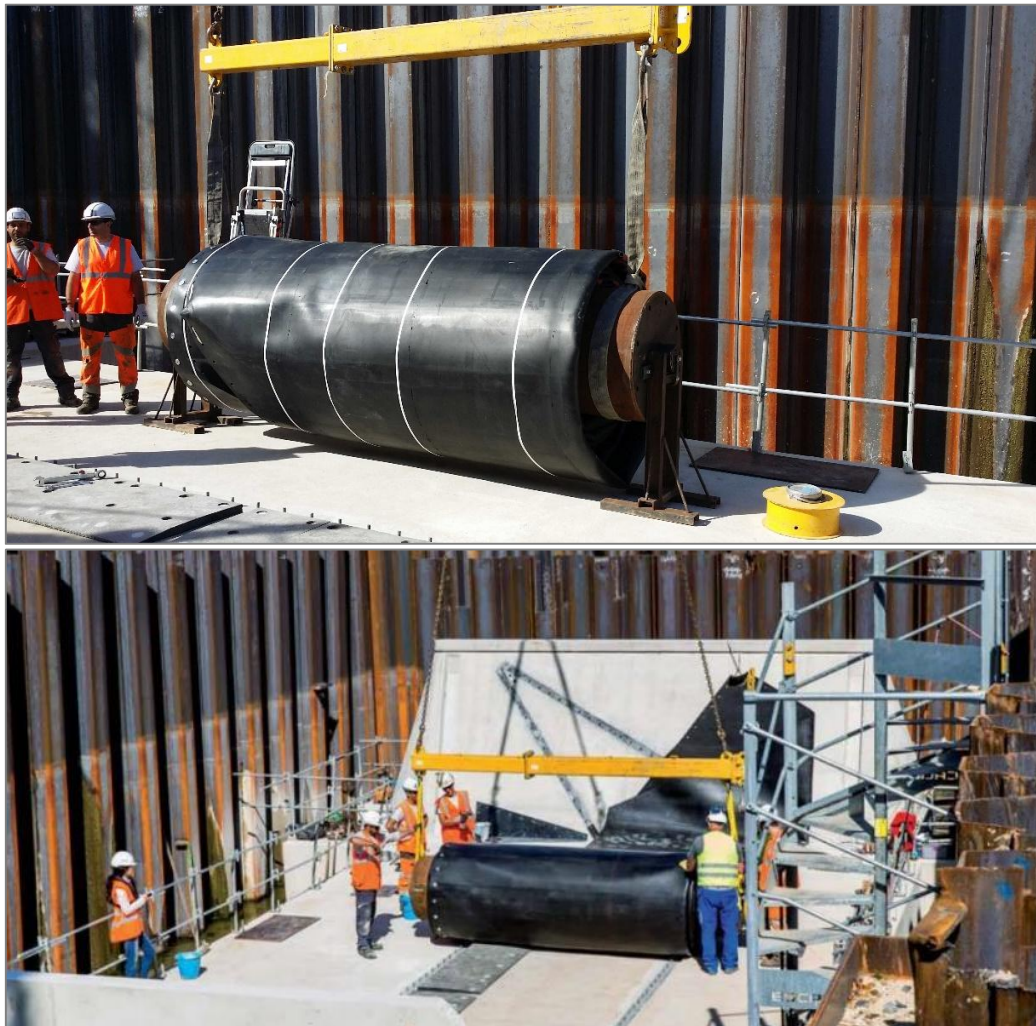


Figure 4: Vic sur Aisne site (Aisne river) installation of the first membrane in 2015

Finally, the membrane of the rubber gate is installed (Fig.4). Including preparation and finishing works this step requires two to three weeks on the average. As soon as the weir span has passed several checks and tests, the sheet piles can be pulled and put for the next span. In total, the construction works for each span take roundabout 3 to 4 month, which allows for installing two spans per year. However, at some sites the construction teams were able to install three spans in just one year.

All construction and installation works are executed by the civil contractor. Only during the installation of the rubber gate equipment, i.e. pipes, fixing system and membrane, one experienced technician of the gate supplier (Floeksmühle Energietechnik GmbH) is on site to advise the construction teams.

During winter, the civil contractor is able to work on the fish pass and the control house which are located outside the main course of the river (fig. 5 and fig 6). The control equipment is typically installed following the construction of the weir spans.



Figure 5: Carandeau two-span weir (Aisne) the old weir and its piers have to be demolished



Figure 6: Montigny three-span weir (Meuse) and its new control house

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Today (March 2018) after three and a half years of works, a total of 58 spans out of 75 have been installed and 13 weirs have been commissioned. In total, the whole project will necessitate 1 million workman hours, 15,000 tons of sheet piles, 200,000 m³ of earthworks, 100,000 m³ of concrete and 6,000 tons of reinforcement bars.

References

PIANC (2018). Report of Working Group 166: Inflatable Structures in Hydraulic Engineering. PIANC, Brussels.