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Assessment of two hydraulic models of canal of Calais regarding the control issue

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Introduction

Hydrographical systems which are mainly comprised of dams, rivers, channels, etc. are in the category of large-scale networks. For answering these networks' demands, it is important to apply a competent control which the case of modeling and simulations should come prior to. By having a hydraulic model available, the discharges and levels can be estimated. By connecting the hydraulic model to software such as Matlab, the control strategies could be implemented and tuned.

In the domain of water systems, model predictive control (MPC) has been widely used and has become so popular. MPC can well handle with constraints and is compatible with various hydraulic models of the open-flow channels which basically work with Saint Venant equations. In the matter of hydraulic modeling, there are some solutions such as SIC², Hydra, Mike11, SWMM, HEC-RAS, etc. Among these solutions which most of them can link to GIS (Geographic Information System), few of them are linked to Automatic software like Matlab.

Based on simulation architectures, the objective of the presented paper is to define the main differences in the application of two software of SIC² and HEC-RAS in the real-data based simulation of the canal of Calais regarding using MPC for controlling over the canal.

Methodology

Since the main issue of this paper is assessing the two controllers based on two different hydraulic models, the HEC-RAS and SIC modeling software are explained in the following. HEC-RAS is mainly a software for one-dimension or two-dimensions simulations of the evolution of a flood, which could have a stable or an unstable flow rate, sediment transport, change of the river bed, etc. The software contains analysis of the constant flow rate at the surface of a considered river profile; simulation of an unsteady flow of water; calculations of the sediment transport and modifications of the river bed; and also the assessment of the water quality. When using the HEC-GeoRAS extension, the data can be easily inserted into the equation, and the results can be illustrated in the hydrological maps. In this regard, it is possible to use this software for other water distribution networks such as irrigation canals. HEC-RAS projects can always be edited using plain text files which are easy to manage and deal with. Moreover, the parameters that the user might be interested in modifying are usually stored in plain text files. Thus, reading and editing HEC-RAS projects from MATLAB can be performed in a straightforward manner in order to satisfy the issue of control.

SIC software is mainly attributed to irrigation canals. It is able to model cross and lateral devices encountered usually on such systems. It is also possible in SIC to simulate operations rules at any of these cross or lateral devices. Within the software, there are several measurement points (Z), control points (Y), control action points (U) and an algorithm calculating the control action points U (e.g.: a gate position) from the measurements Z (e.g.: water levels along the canal). The algorithm can be written in Matlab through a $U=f(Z)$ function. Also, there are a series of performance indicators that are calculated in particular at lateral offtakes. These indicators allow to assess if the simulated operational rules are satisfactory compared to canal managers objectives. The performance indicators calculated in SIC include volume and time. They define if the operational rules could provide the accurate amount of water at the correct time at the different offtakes along the irrigation canal.

Case study

The Calais canal is a navigation canal located in the north of France. The excess of water is pumped to the navigation canals and then released into the sea. The main canal's system is supplied by three secondary canals. (See Figure 1)

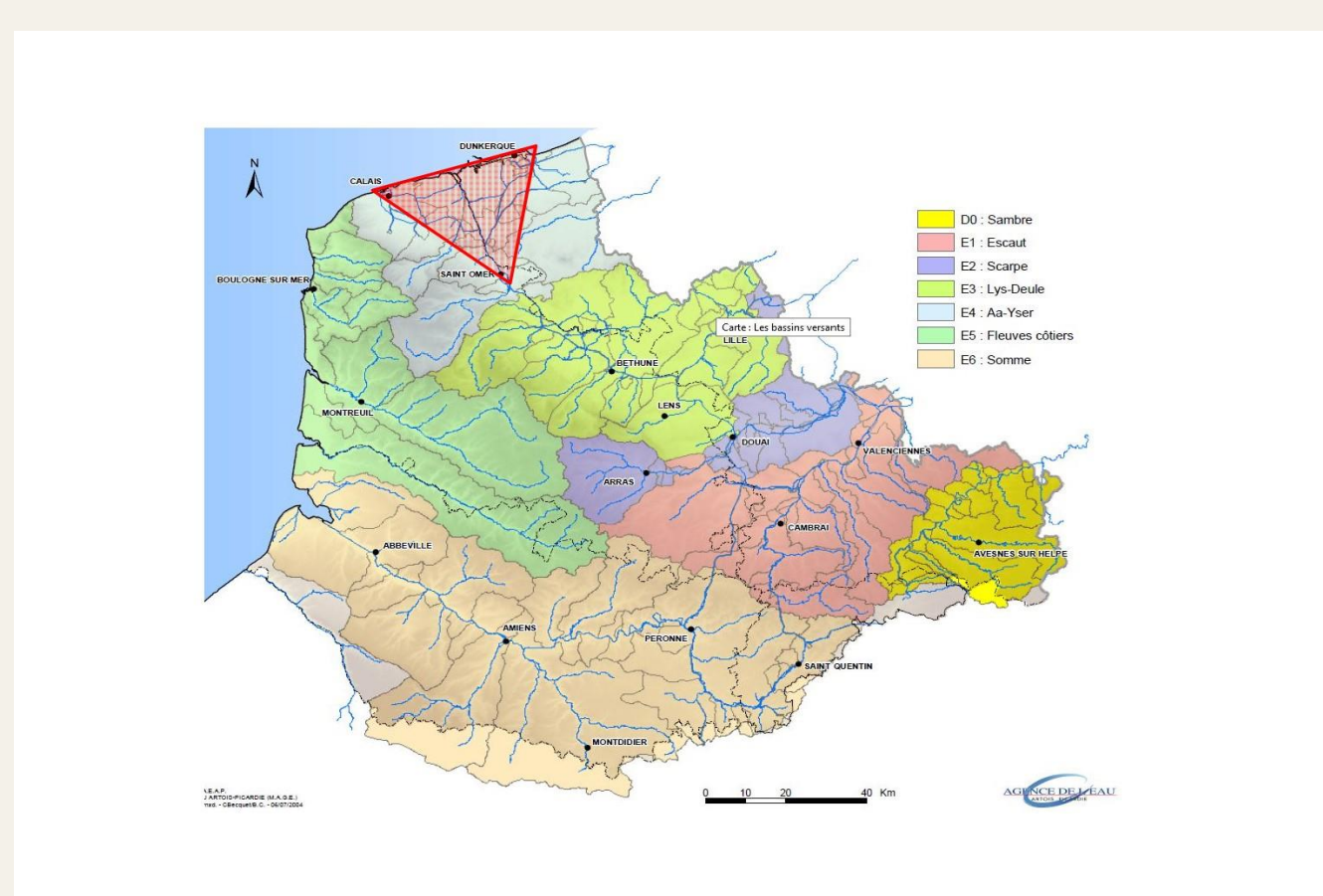


Figure 1. Canal of Calais

HEC-RAS Controller

While HEC-RAS presents an accurate simulation of the dynamics of water systems, MATLAB lets us to implement the advanced control algorithms. Thus, the performance of closed-loop control algorithms can be tested on a simulator while considering the real dynamics. It is therefore necessary that HEC-RAS sends the values of certain variables, like the water levels, at regular intervals to MATLAB. Then, based on this information, the control algorithm can highlight the suitable actions to be taken through the available hydraulic devices, e.g., gates and pumps, in HEC-RAS, taking into account the control frequency. The software tools run in parallel and exchange the information at fixed time intervals. (See Figure 2)

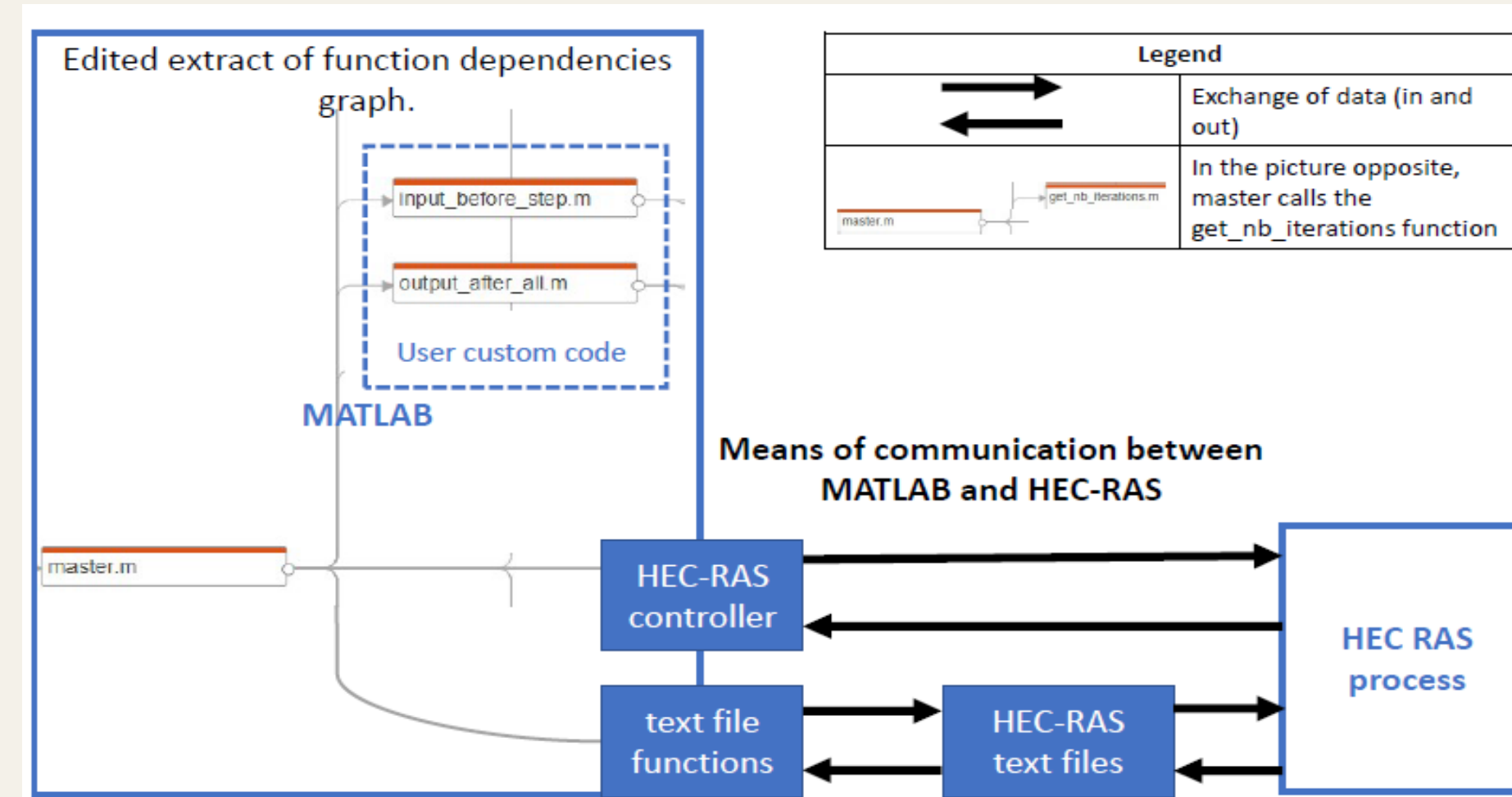


Figure 2. Diagram of the MATLAB HEC-RAS Interface operation.

The MATLAB HEC-RAS interface is tested first on the rectangular canal (see Figure 3) with the goal of showing that the automated start and stop simulations performed thanks to the designed interface lead to the same results. And then applied to a model of Beaver Creek (see Figure 4) to define a closed-loop control rules for gates using the automated start and stop simulation to validate the approach. Indeed, HEC-RAS performs linear interpolation between the two values. Thus, the resulting control strategies are true to reality, and are implemented in the custom user scripts.

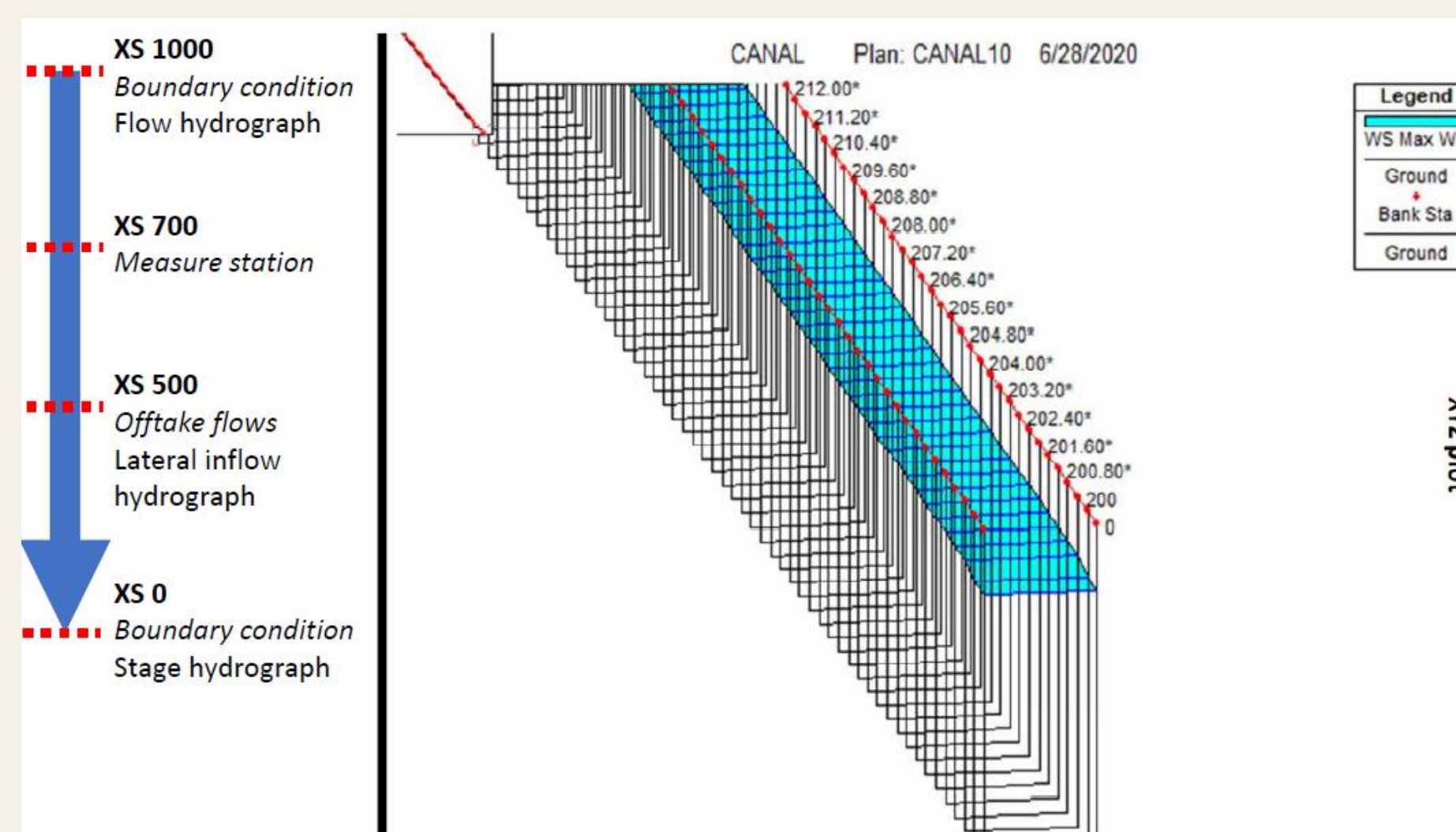


Figure 3. Schematic representation of the geometry of a simple rectangular canal.

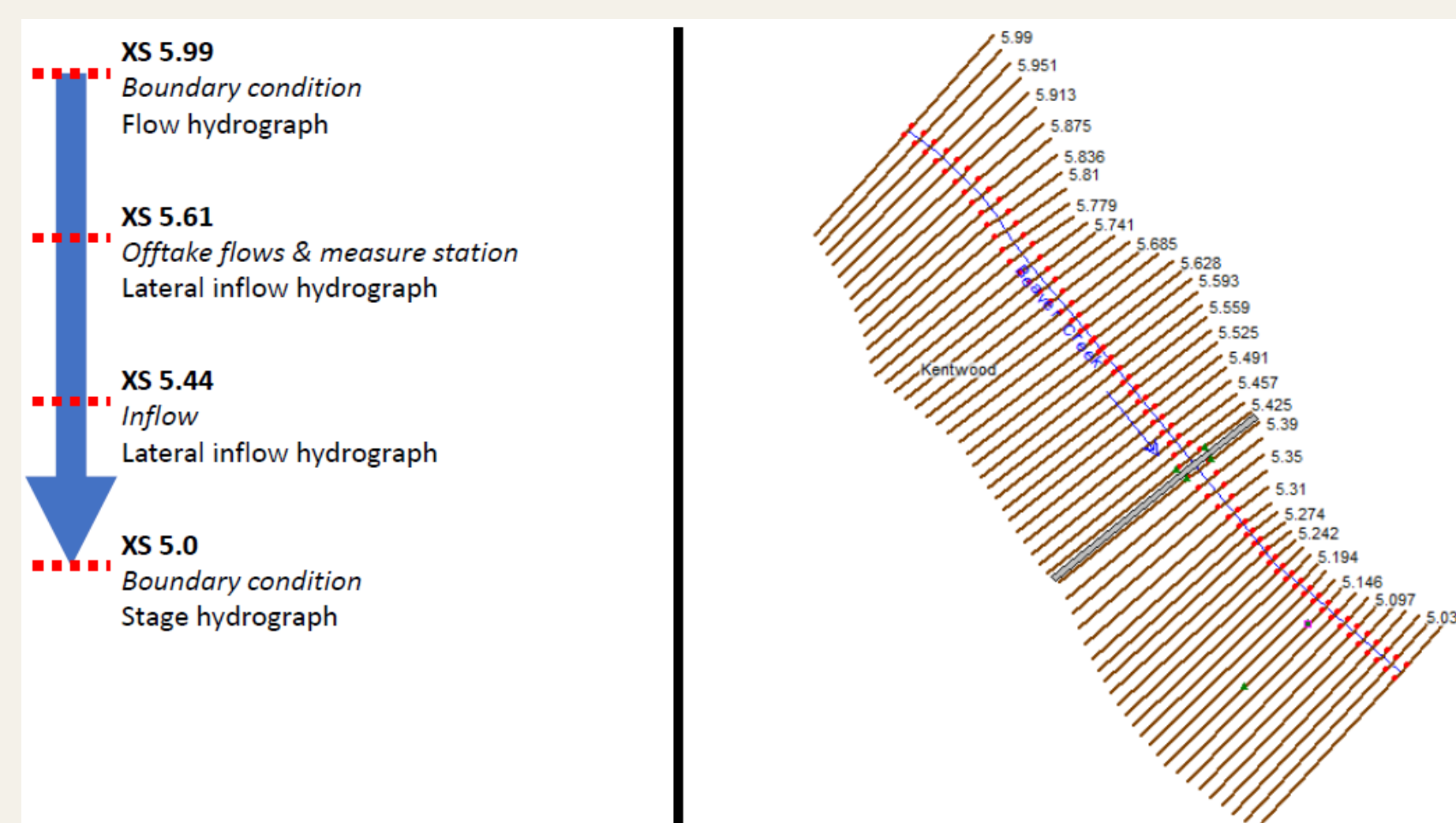


Figure 4. Geometry of the Beaver Creek case study.

SIC Controller

The schematic view of canal of Calais is shown in Figure 5.

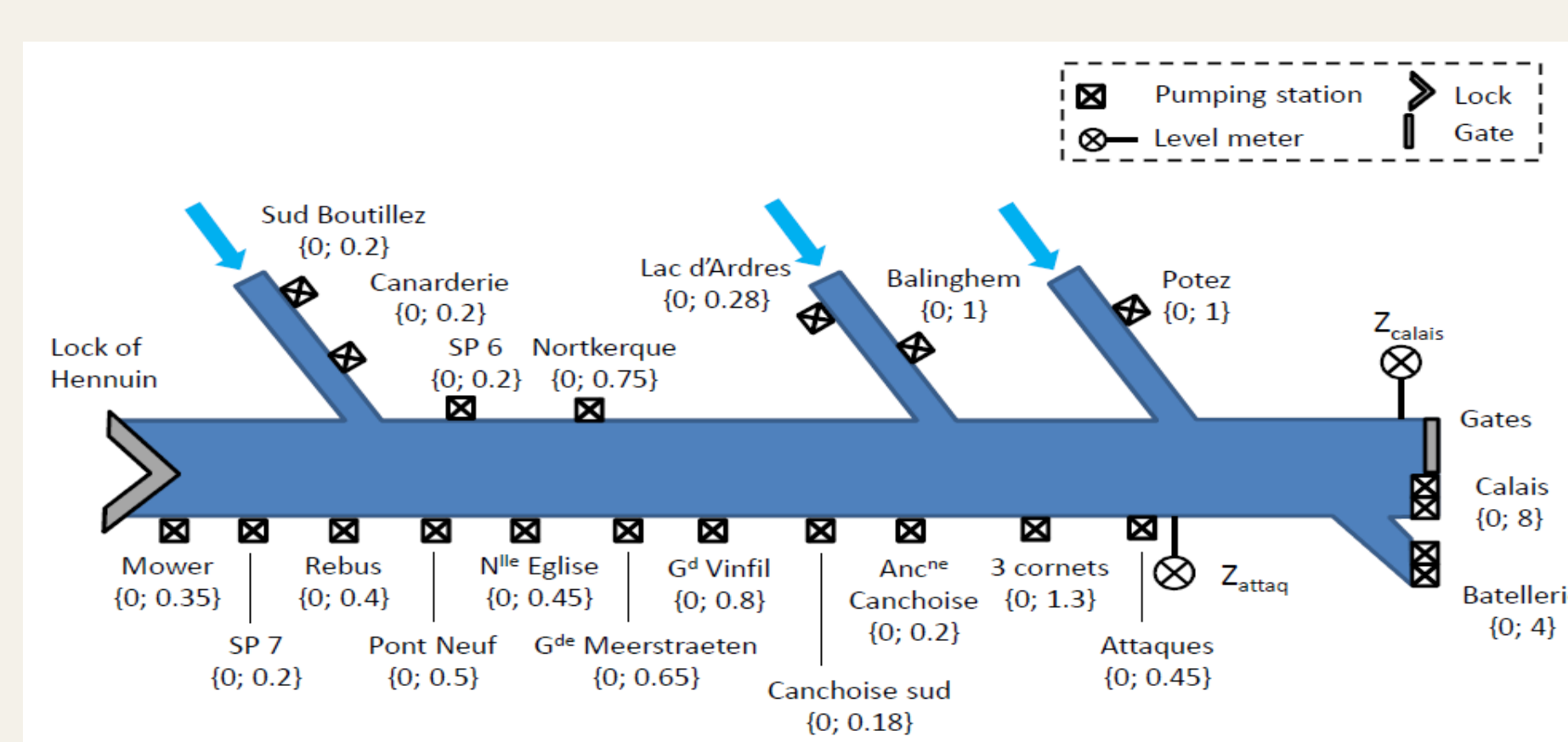


Figure 5. Schematic view of canal of Calais

SIC Controller

It is necessary to calibrate the model from available data. In this regard, some data is missing such as the flows of the Audruicq, Ardres and Guines canals. In the presumed absence of pumping, the flow rates of the Audruicq, Ardres and Guines canals are used as adjustment variables. Whole these assumptions would reduce the accuracy of the model, however.

The simulation platform between SIC and Matlab is illustrated in figure 6 along the capability to insert different scenarios. At this time, like HEC-RAS, SIC sends the values of water levels, etc. at regular intervals to MATLAB

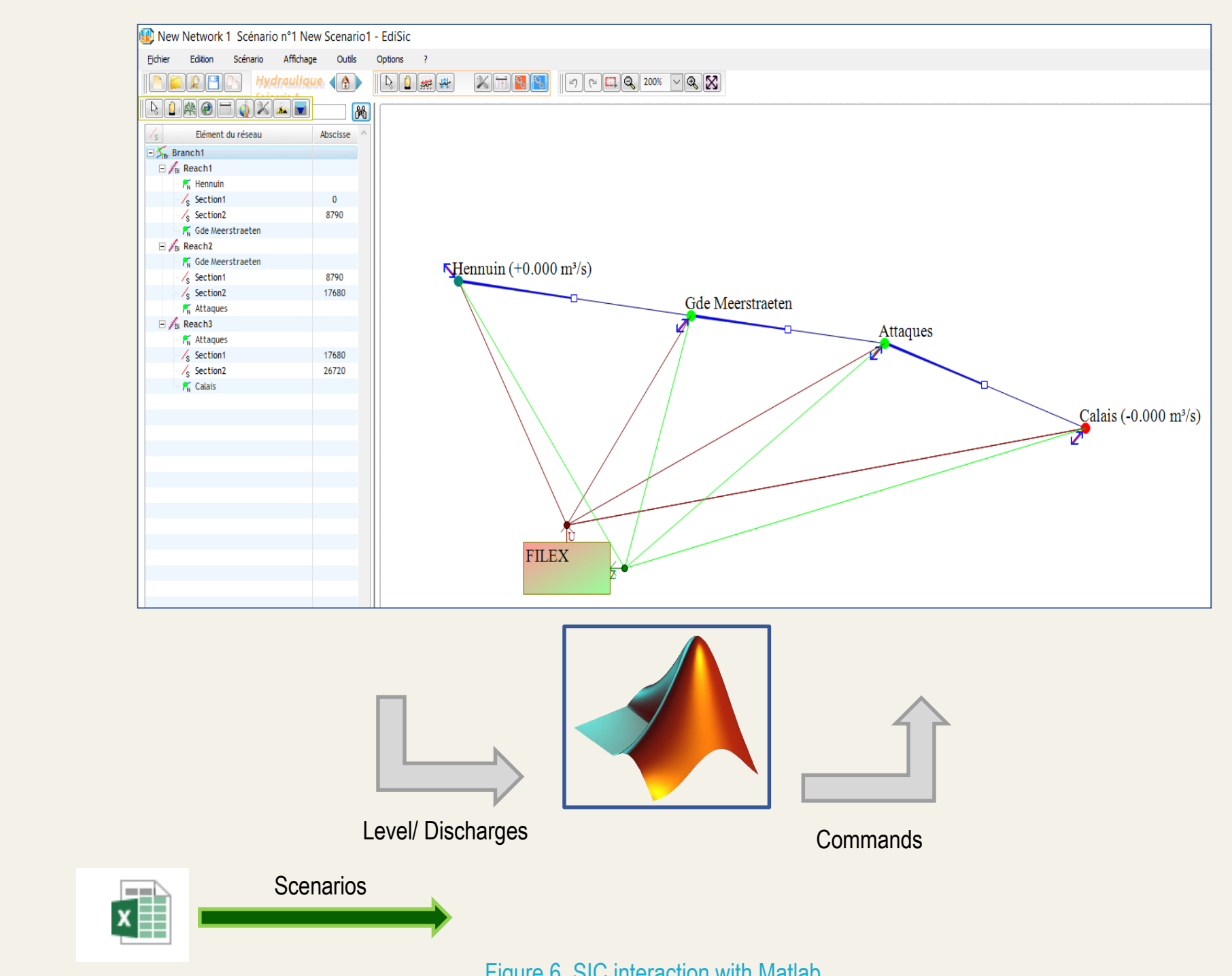


Figure 6. SIC interaction with Matlab

Conclusion

In case of controlling the management over the canal of Calais, the implementation of HEC-RAS leads to an accurate models which are based on precise geographic information systems (GIS). In doing so, it will be possible to assess the performance of the MPC with a more realistic model. However, it should be noticed that, an excess of detail in modeling might cause another challenge which is the computational time. This one shouldn't exceed the sampling time and could allow for a real-time application.

On the other hand, by applying SIC, it is an efficient tool that allows canal managers as well as researchers to simulate quickly a large number of hydraulic design or management configurations. The software is menu driven in order to be easily used. Thus, the model might not be so much accurate to provide a high efficient decision tool when it is connected to Matlab.

Thus, for designing decision tools and control architecture, it is necessary to define a trade-off between the level of modeling detail (so its accuracy) and the computation time.

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