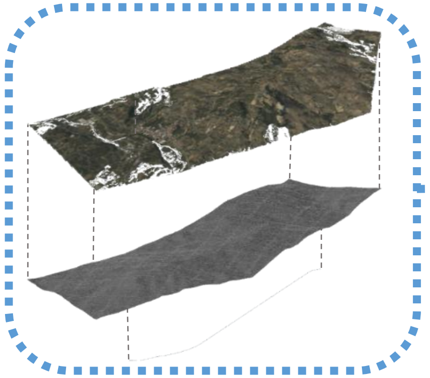
Visual Programming Language for hydropower plants Facility Management

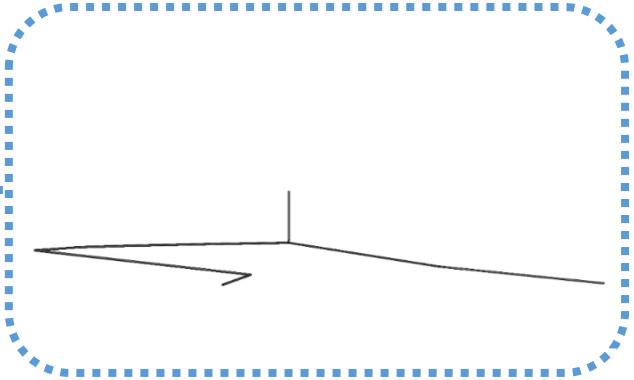
Anna Osello, Francesco Loddo
Politecnico di Torino

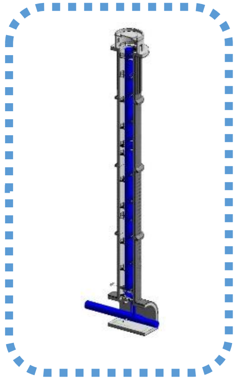
Key concepts

Real environment

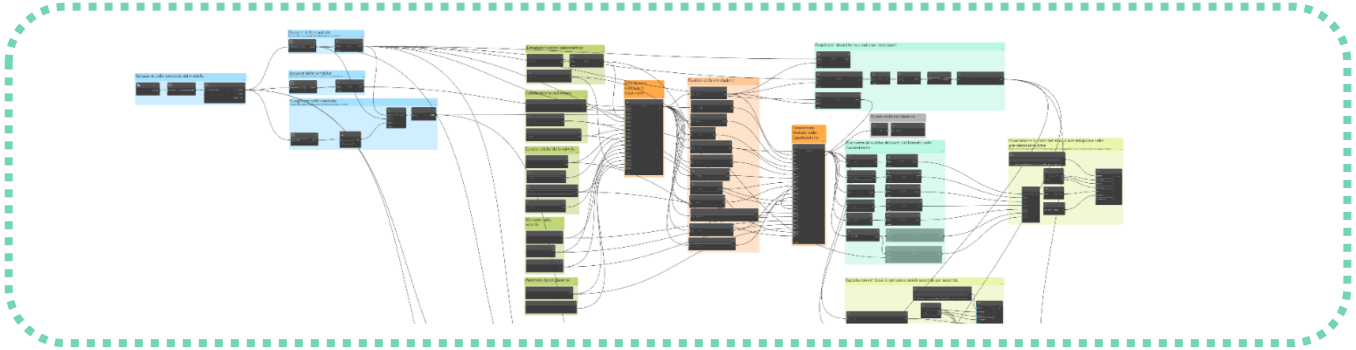
Building information modeling (BIM)







Visual Programming Language (VPL) data processing



Hydropower plants characteristics

Important role in the energy transition process

Hydroelectric energy is the only fully programmable renewable source and can be stored through pumped storage power plants

Well established in many countries

Since its first applications in the late 1800s, in many countries hydroelectric energy supported the industrial development

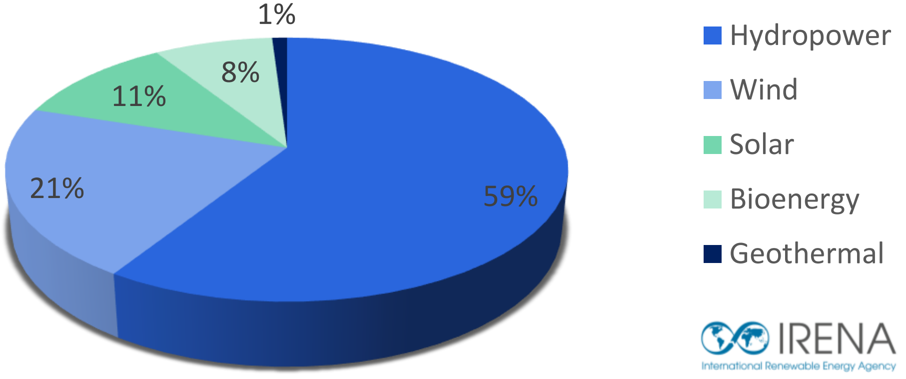
High installation costs but long lifespan

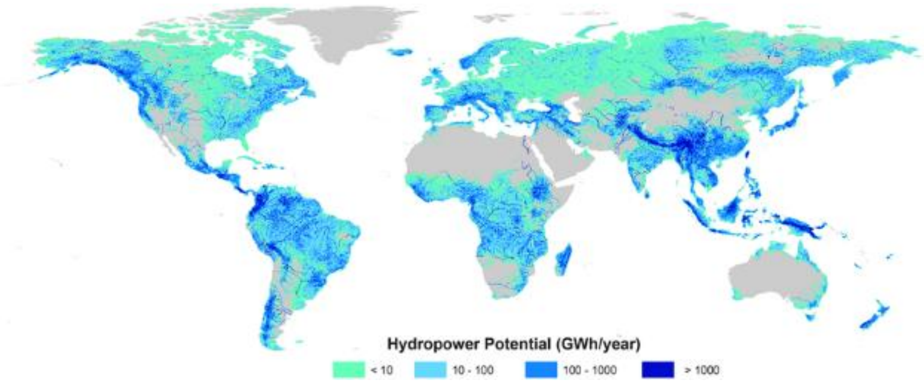
Hydropower plants are characterized by long lifespan (over 200 years) and relatively short payback period (5-10 years)

Essential scheduled maintenance activities

During operational phases, hydroelectric power plants may encounter bearing failures, unbalance, stator winding short circuits, excessive cavitation. These issues can cause severe damage to turbine-generator units

Renewable electricity generation by energy source in 2020

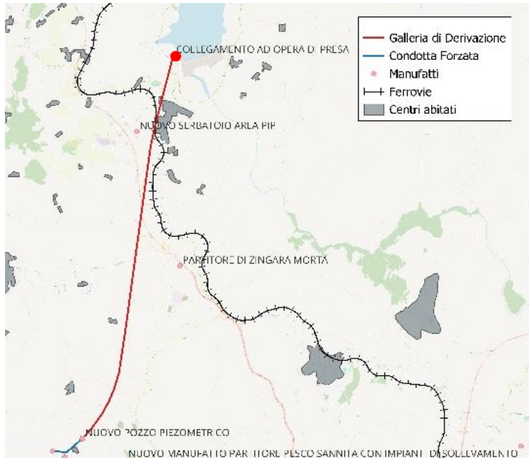


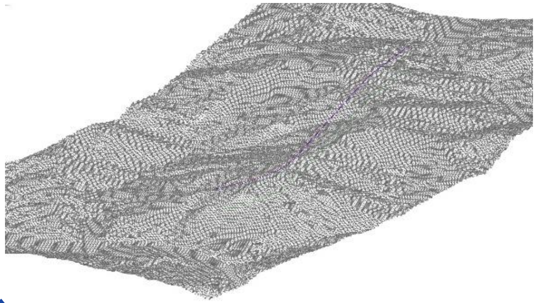


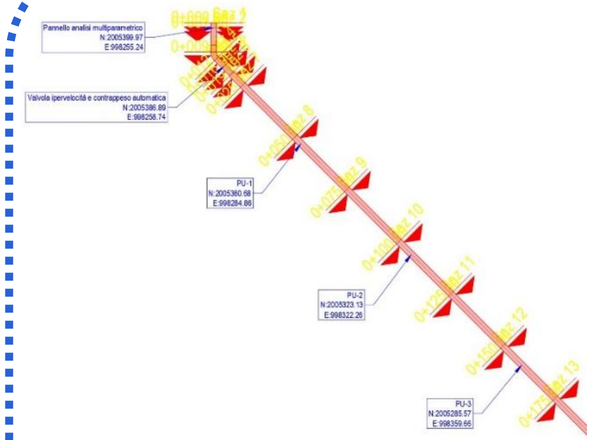
Hoes, O., et al.: Systematic high-resolution assessment of global hydropower potential (2017)

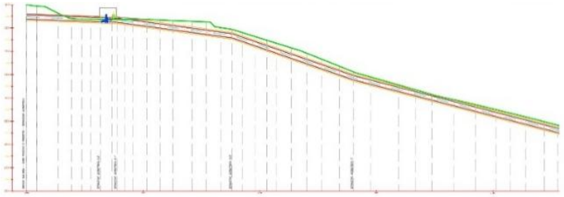
BIM workflow for linear infrastructures

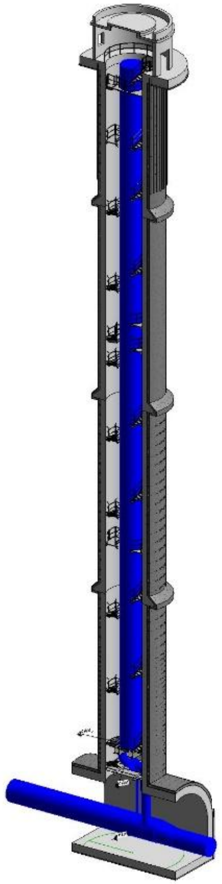
Topographical data → Alignments and profile design → 3D geometries modeling → Data integration

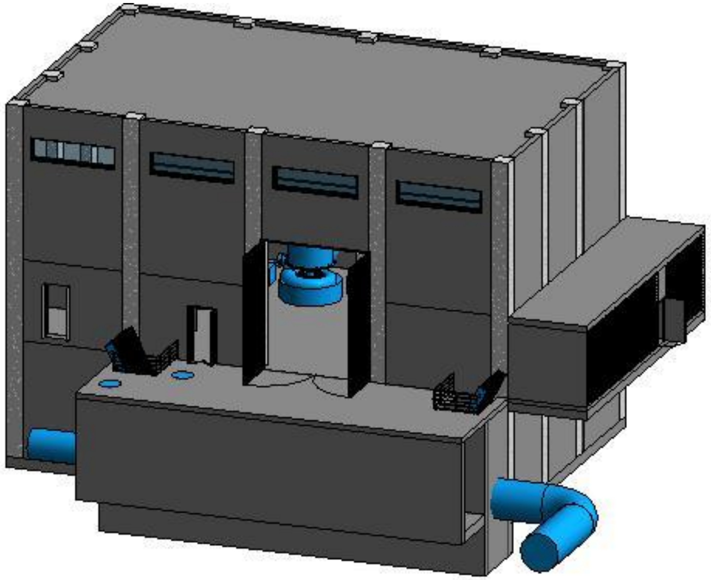






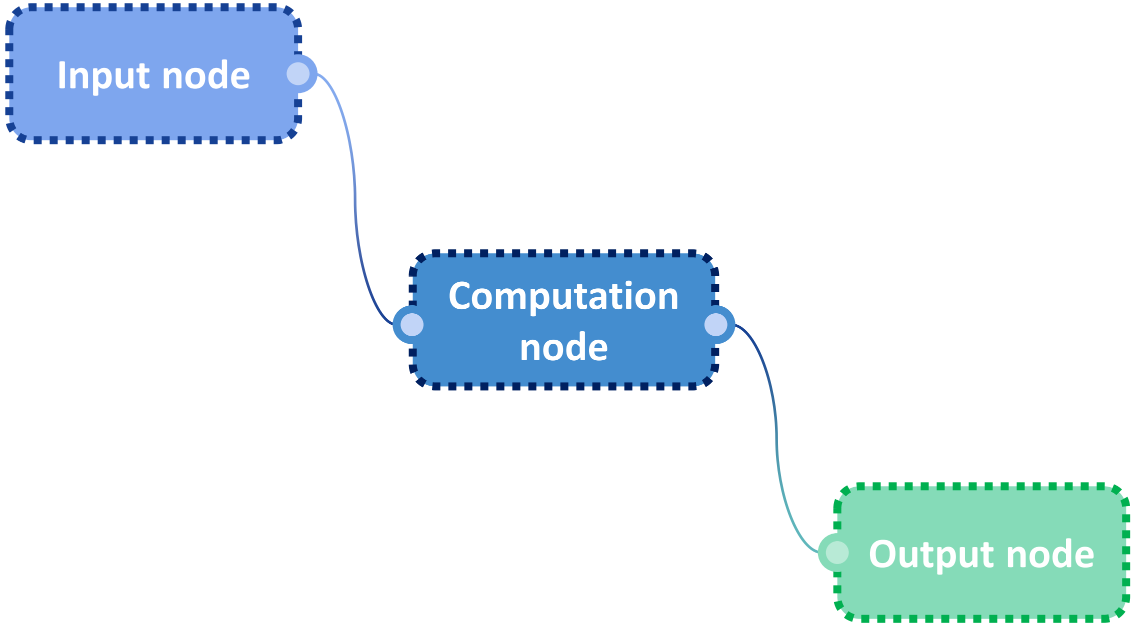




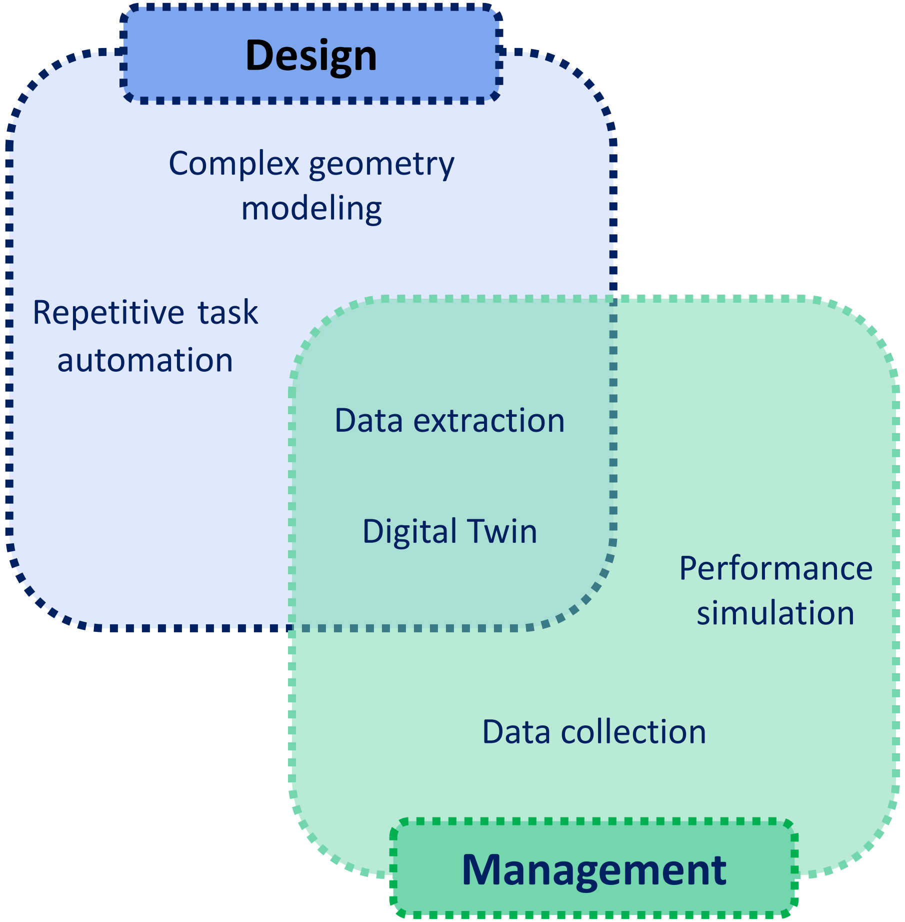


Visual Programming Language

Type of programming language that allows users to create programs by manipulating **graphical elements**



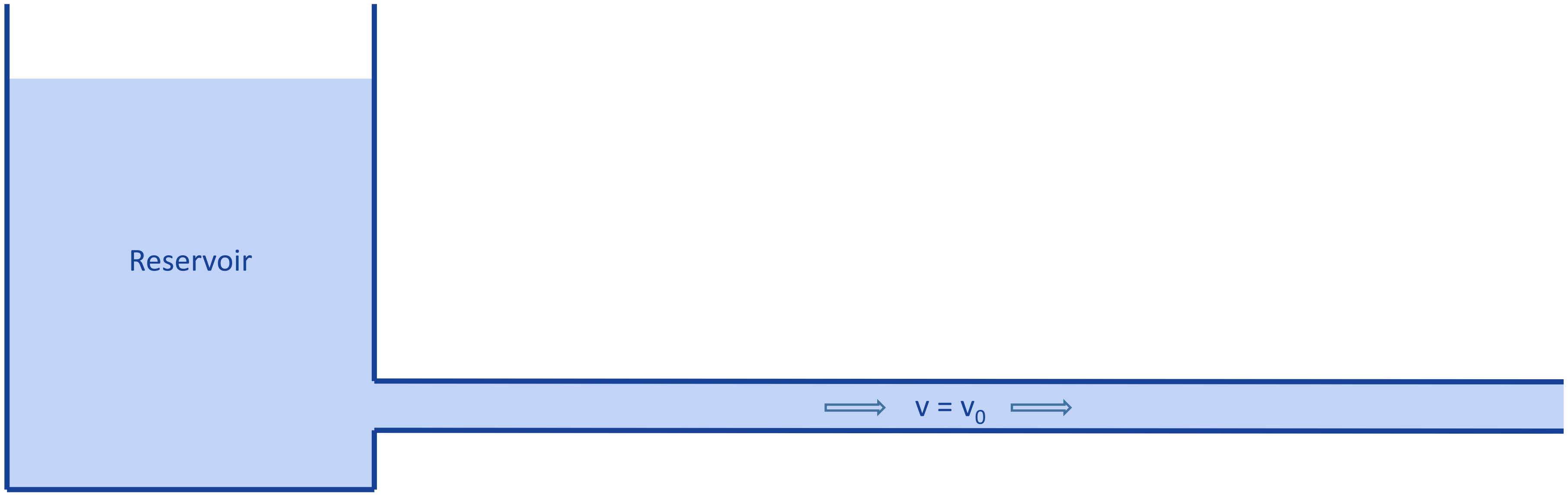
Common uses in literature



Transient flow phenomena

1 **Steady-state flow**

Constant flow out of a reservoir.

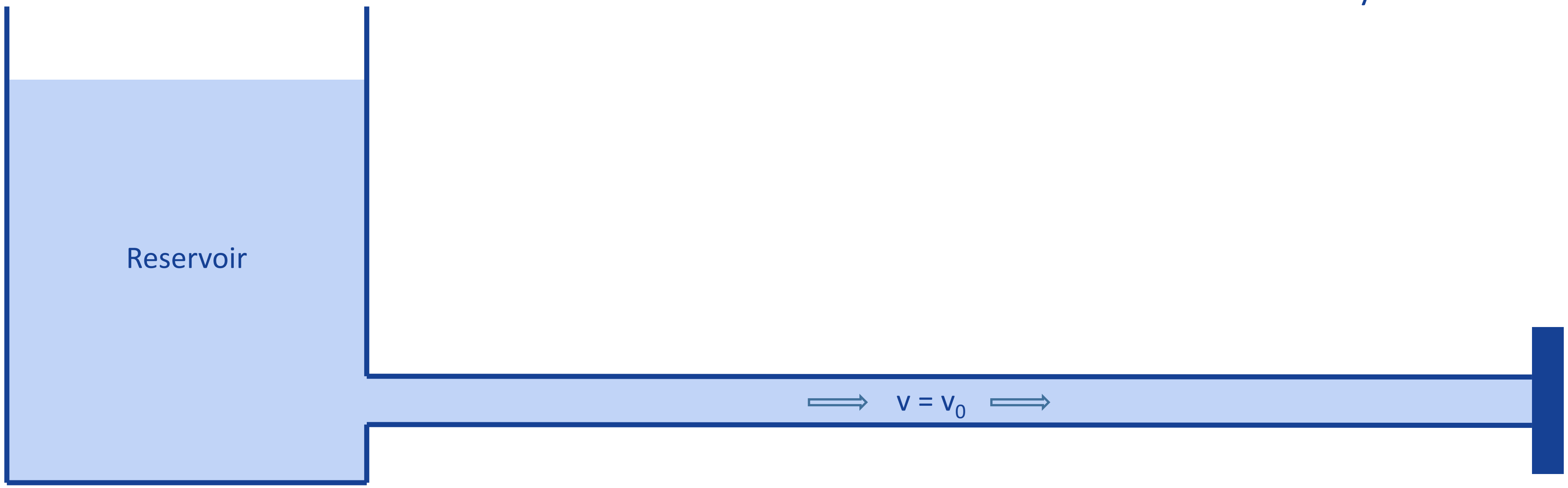


Transient flow phenomena

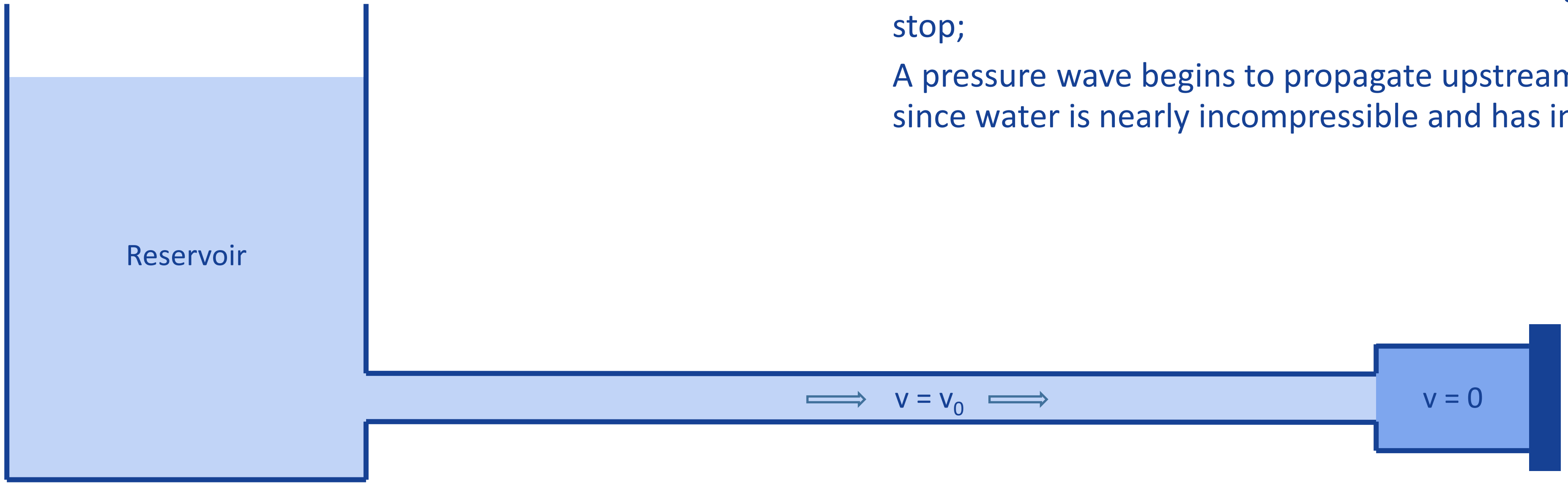
2

An occlusion interrupts the flow

Ex: a downstream valve instantly closes.



Transient flow phenomena



3 Beginning of unstady-state

The water sections closest to the occlusion begin to stop;

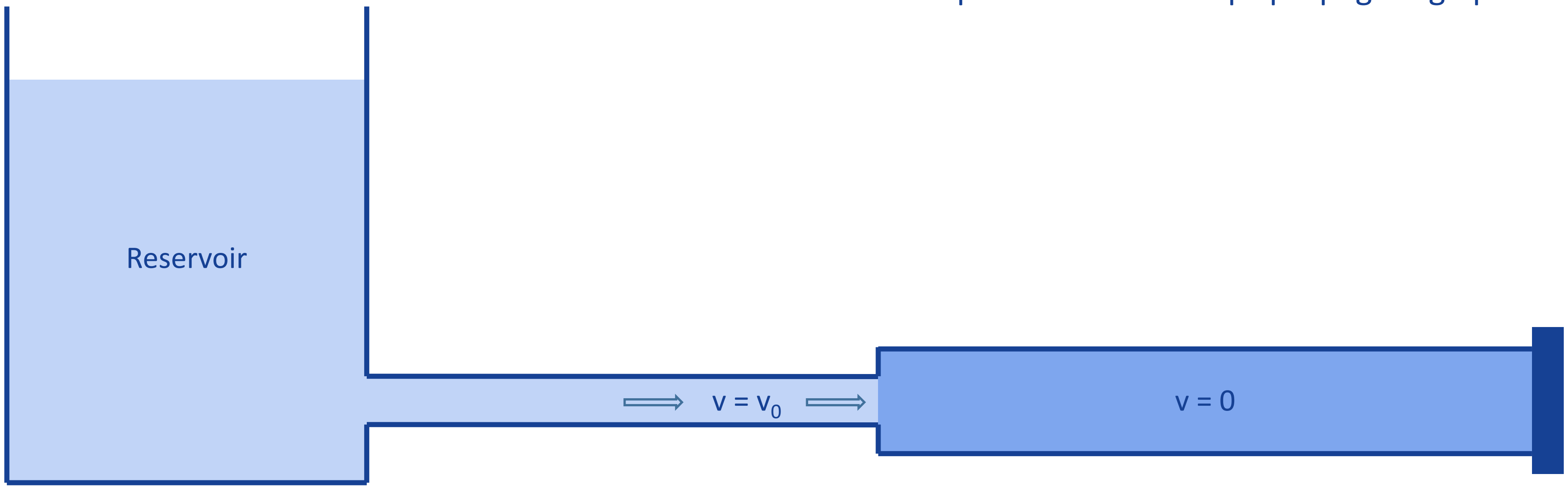
A pressure wave begins to propagate upstream, since water is nearly incompressible and has inertia.

Transient flow phenomena

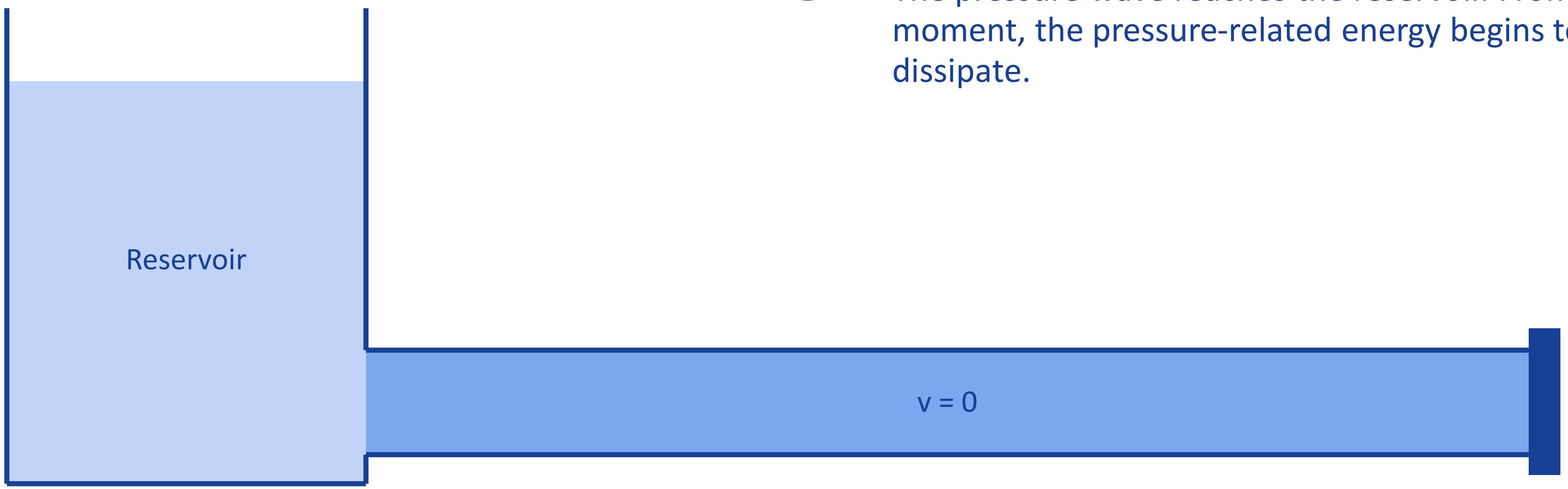
4

Pressure wave propagation

The pressure wave keeps propagating upstream.



Transient flow phenomena



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Pressure wave propagation

The pressure wave reaches the reservoir. From this moment, the pressure-related energy begins to dissipate.

Transient flow phenomena

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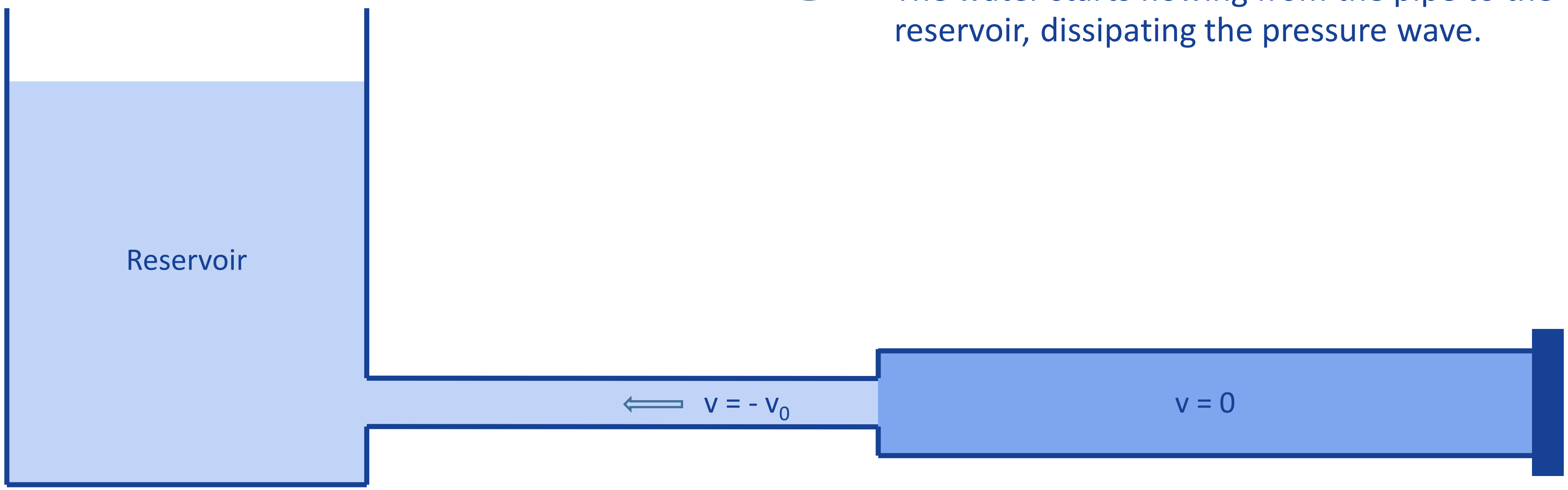
Pressure wave dissipation

The water starts flowing from the pipe to the reservoir, dissipating the pressure wave.

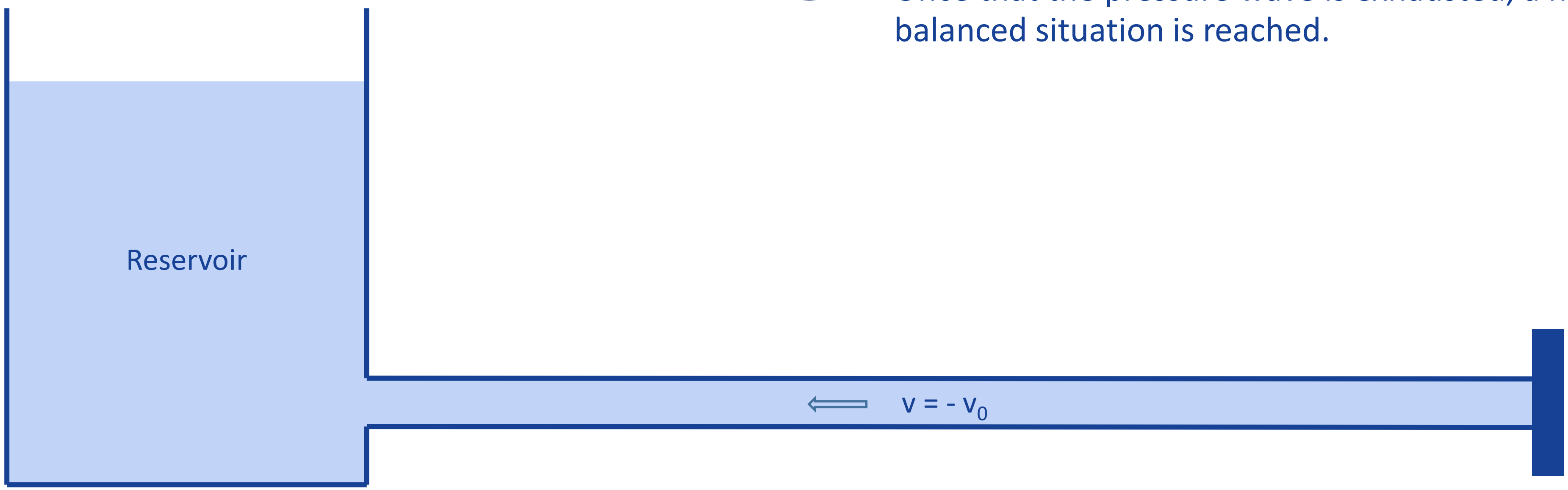


Transient flow phenomena

7

Pressure wave dissipation

Once that the pressure wave is exhausted, a non-balanced situation is reached.



Transient flow phenomena

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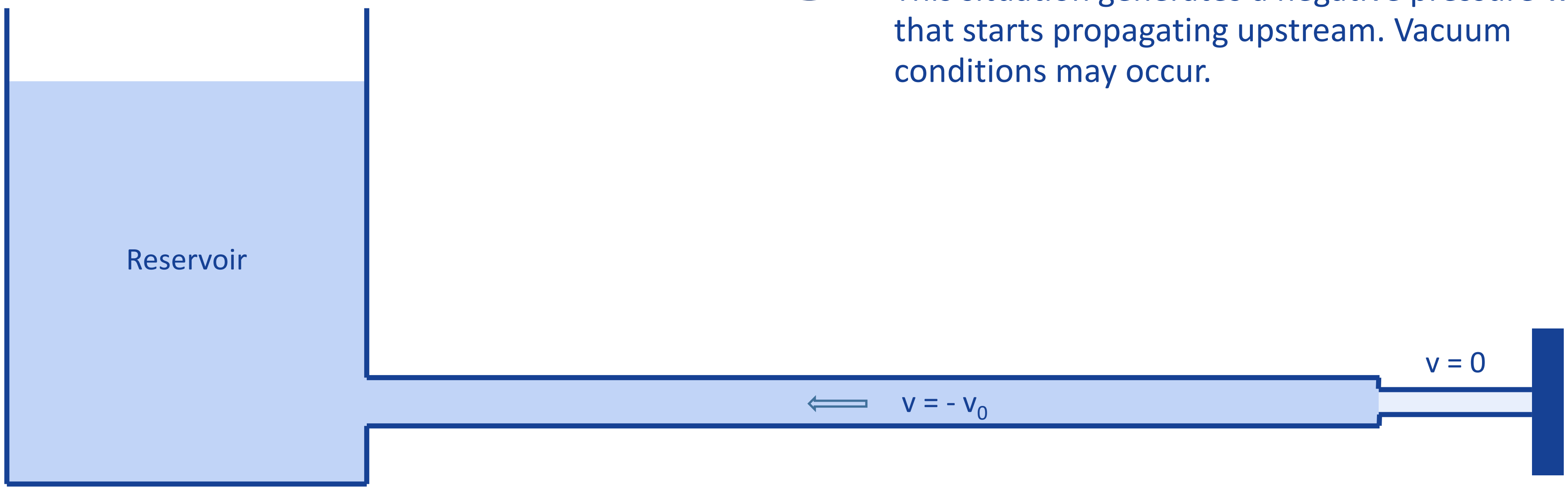
Negative pressure wave propagation

This situation generates a negative pressure wave, that starts propagating upstream. Vacuum conditions may occur.

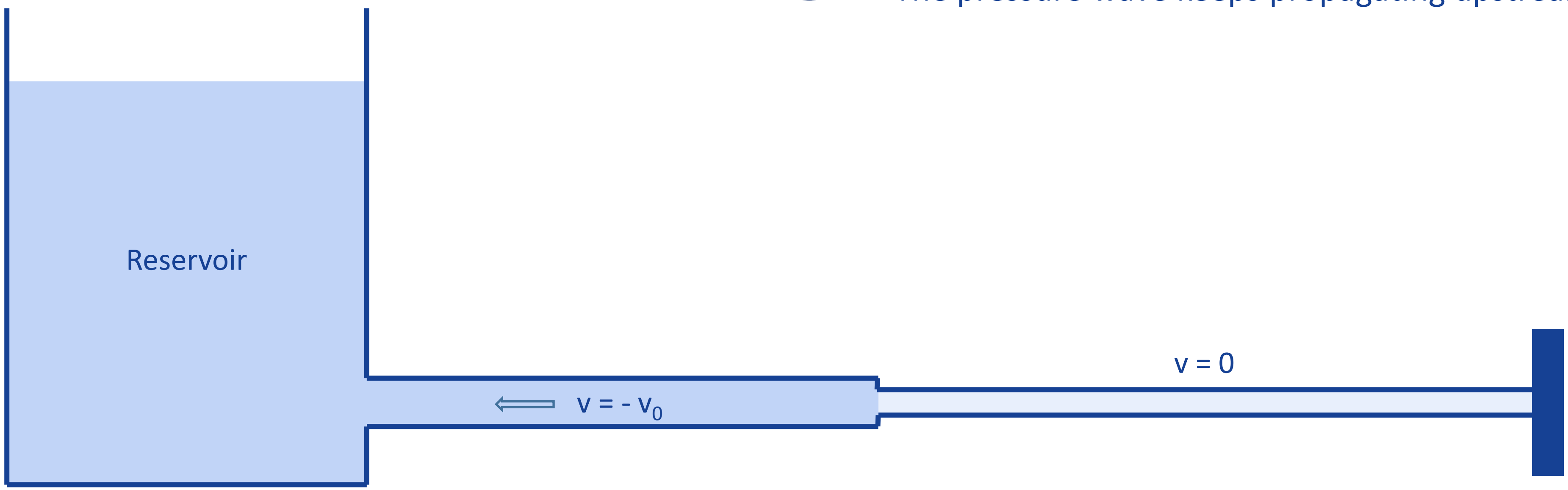


Transient flow phenomena

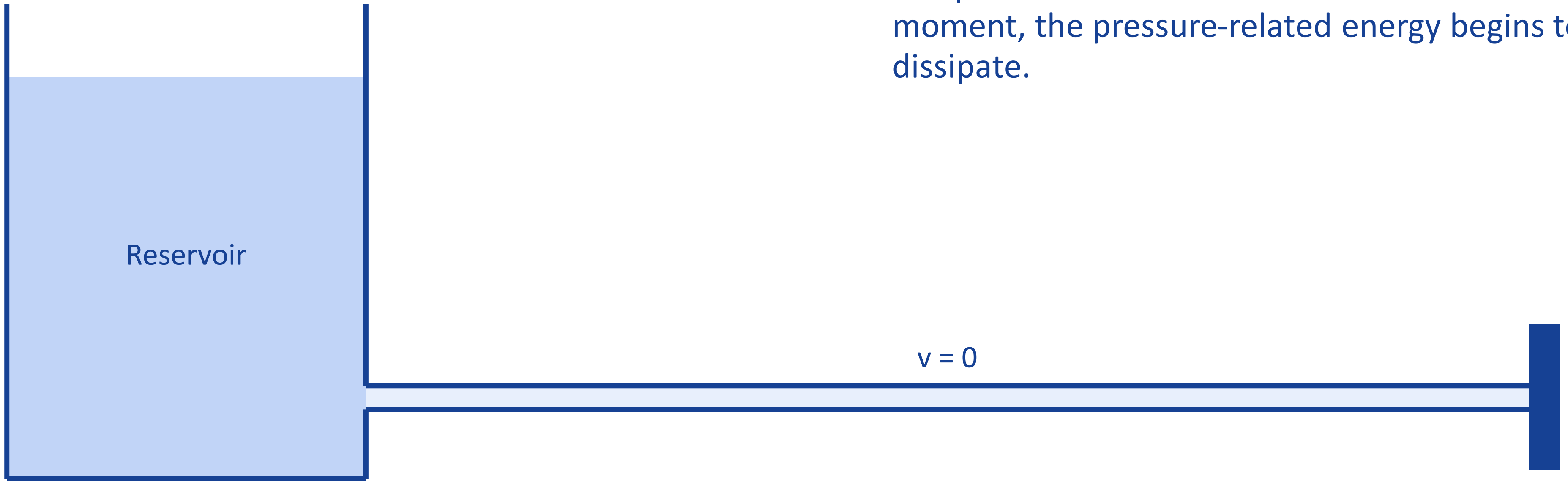
9

Negative pressure wave propagation

The pressure wave keeps propagating upstream.



Transient flow phenomena



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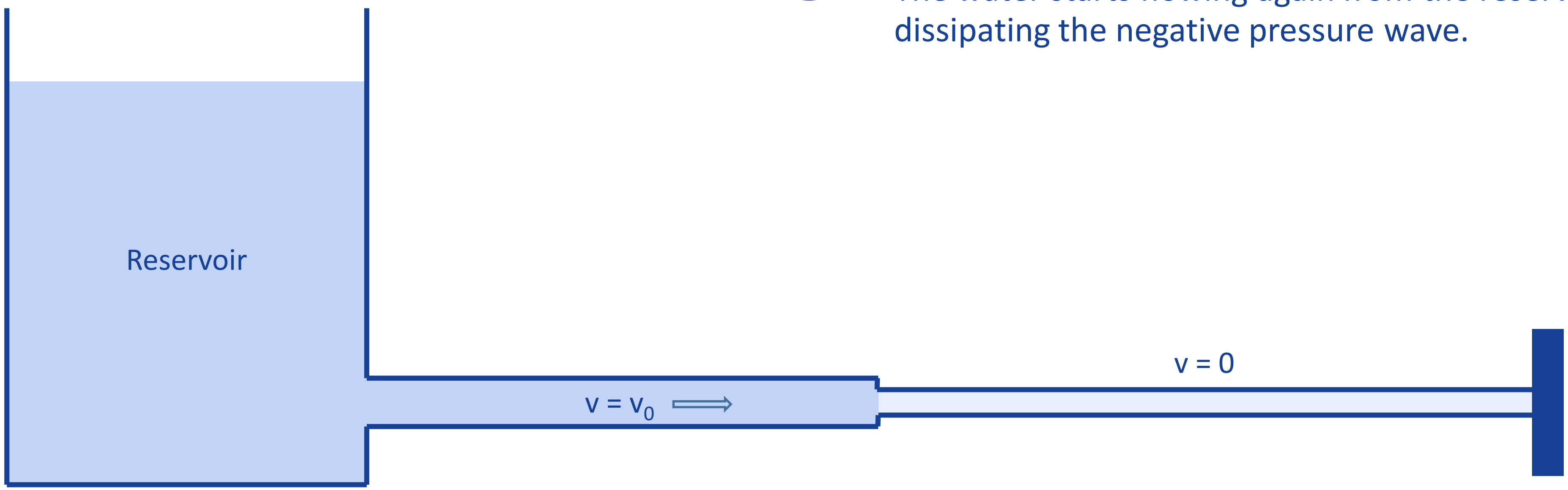
Pressure wave propagation

The pressure wave reaches the reservoir. From this moment, the pressure-related energy begins to dissipate.

Transient flow phenomena



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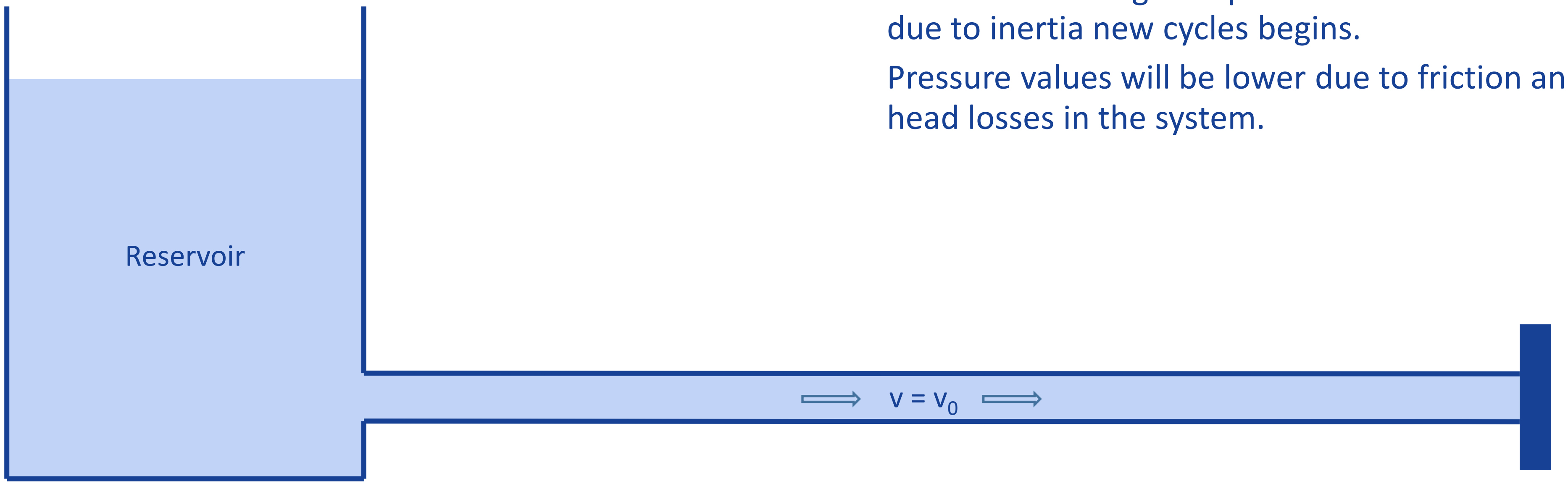
Negative pressure wave dissipation

The water starts flowing again from the reservoir, dissipating the negative pressure wave.

Transient flow phenomena



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Negative pressure wave dissipation

Once that the negative pressure wave is exhausted, due to inertia new cycles begins.

Pressure values will be lower due to friction and head losses in the system.

Mathematical model - Method of Characteristics

Transient flows are governed by the continuity and momentum partial differential equations (**PDE**)

$$\frac{\delta H}{\delta t} + \frac{a^2}{gA}\frac{\delta Q}{\delta x} = 0$$

$$\frac{\delta Q}{\delta t} + gA\frac{\delta H}{\delta t} + RQ|Q| = 0$$

Transformation in ordinary differential equations (**ODE**) through the Method of Characteristics (**MoC**)

MoC calculation grid

Horizontal axis: spatial discretization (dx)

Vertical axis: temporal discretization (dt)

Initial conditions

Flow and Head values in steady state conditions, considering minor and distributed head losses along the system

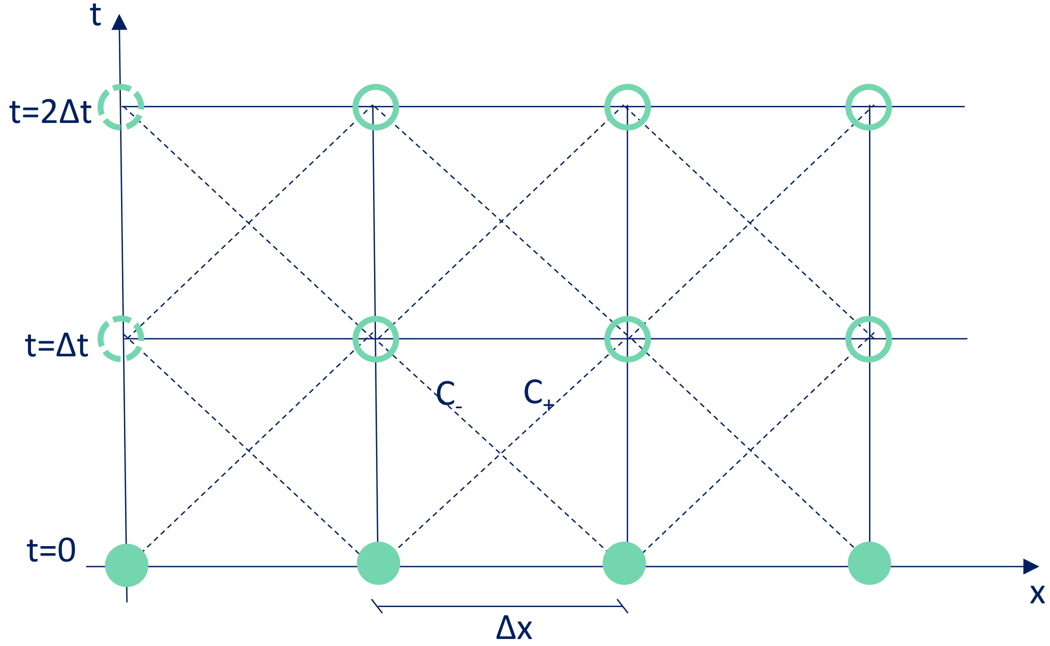
Boundary conditions

Conditions in discontinuity sections or specific points within the system (ex: reservoir, downstream valve)

Calculation nodes

Positive and Negative Characteristics computation in every central node

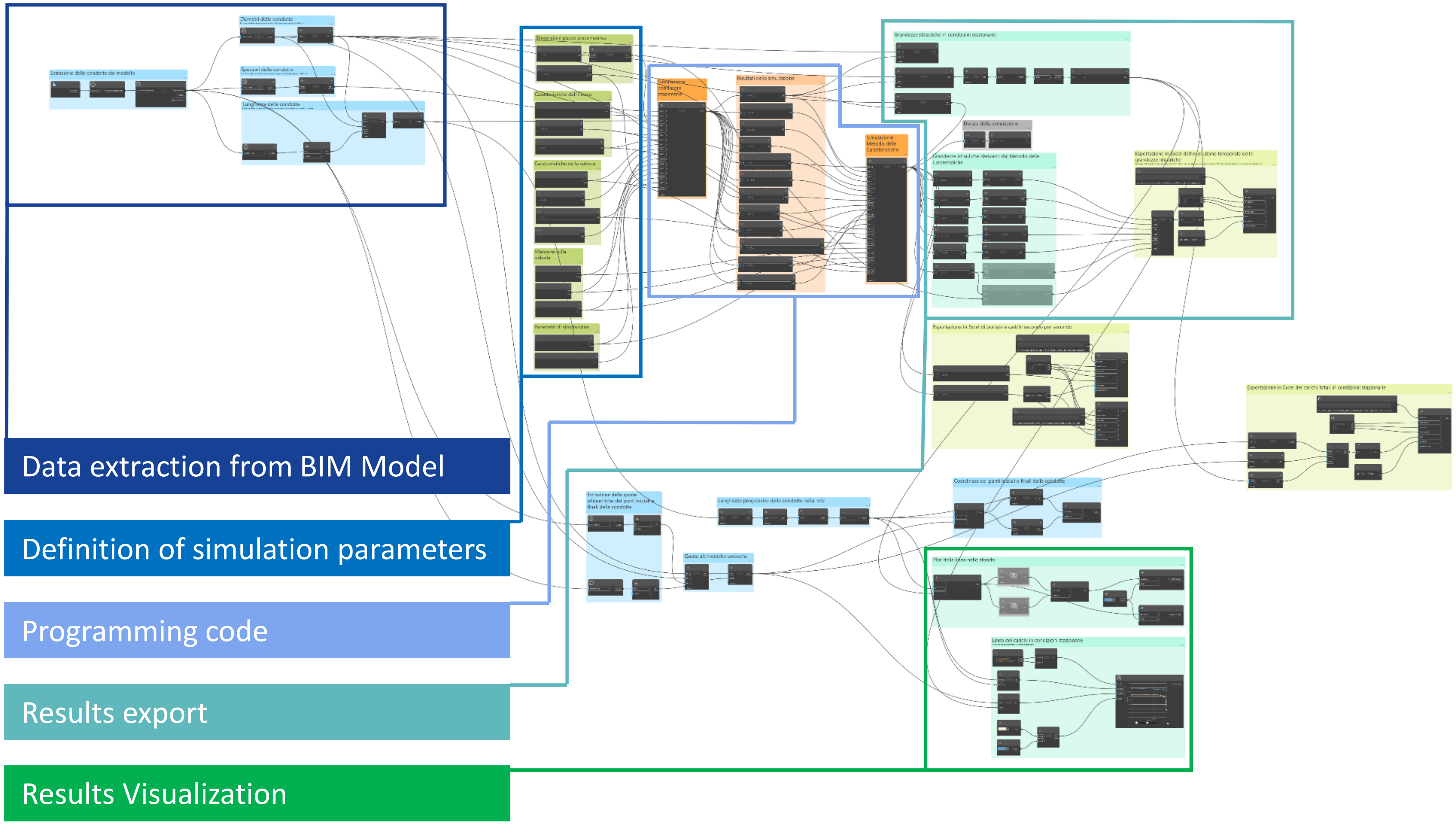
$$\frac{dx}{dt} = \pm a$$ (a = wave speed in circular pipes)



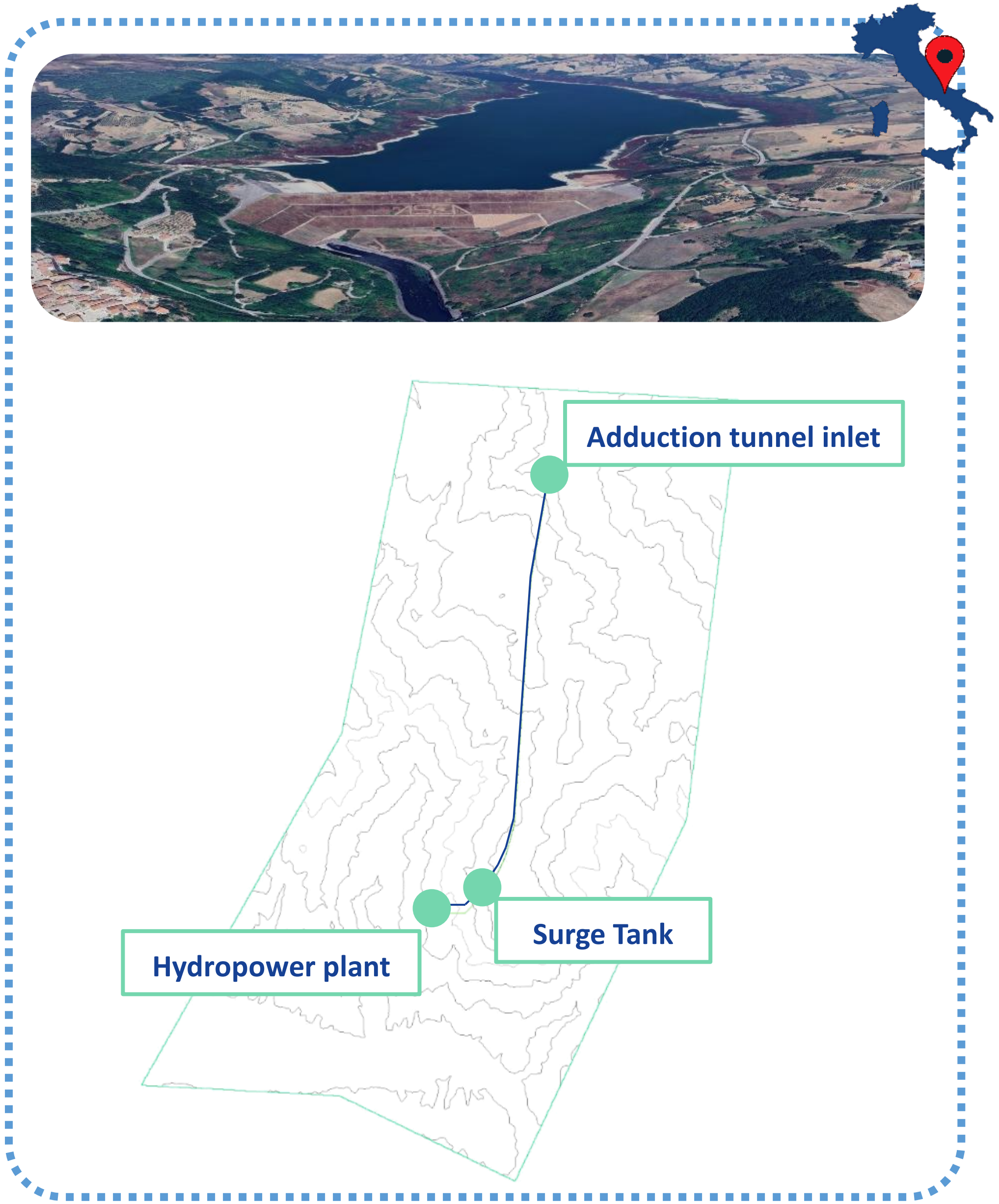
Dynamo

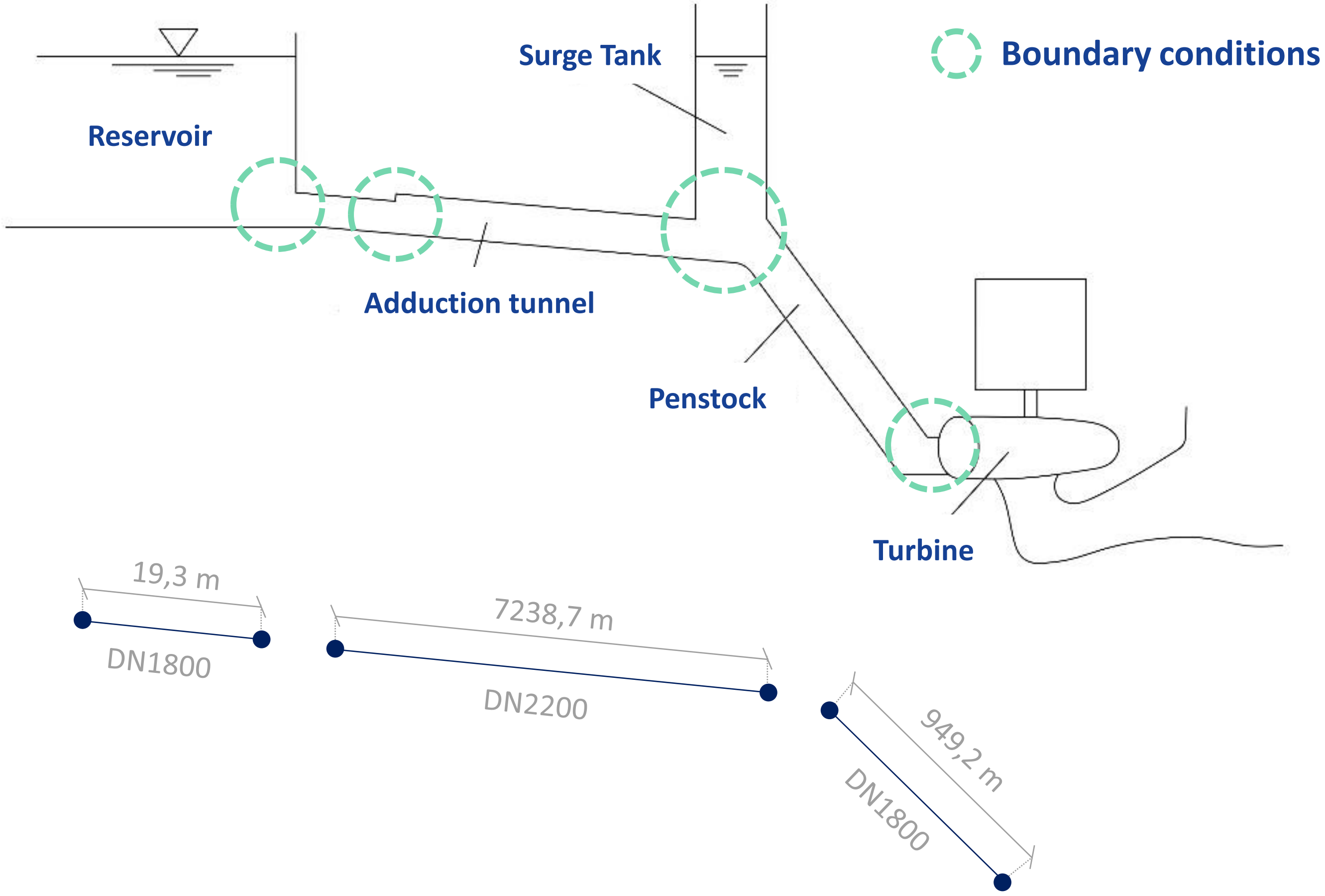
Dynamo:

Visual programming interface that allows customization of workflow related to building and infrastructure information through the use of **preset nodes** or **textual programming codes** written in Python.



Application in a real case study



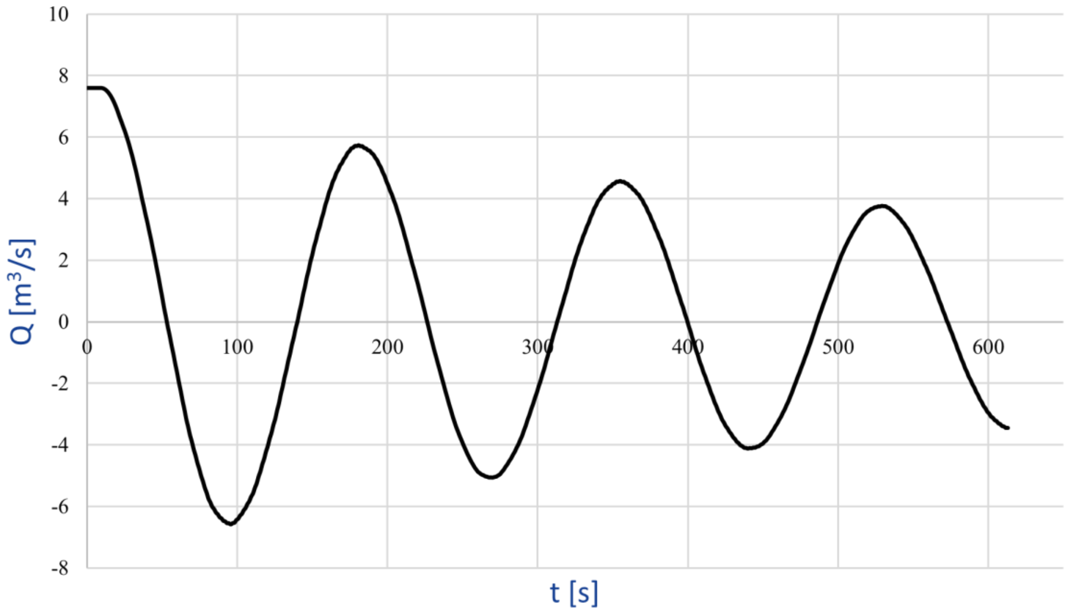


Results

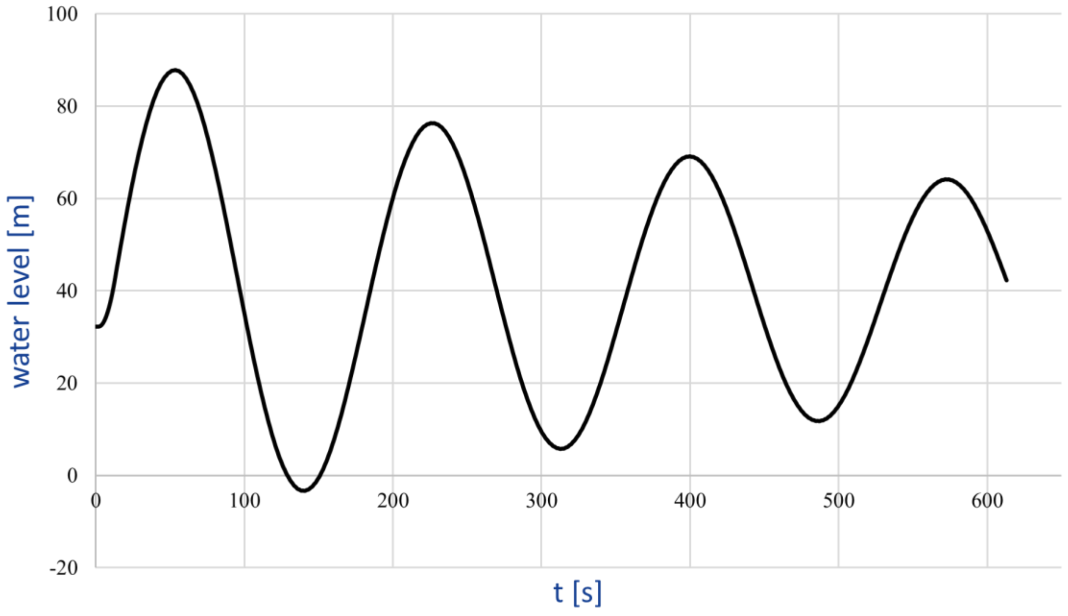
Simulated manoeuvre: total downstream valve closure in 12 s with an initial flow of 7,6 m^3/s

VPL tool used to store **results in matrices**. The **rows** of these matrices correspond to a **specific simulated time instant**, while the columns refer to the **spatial nodes** of the system. This format allows to plot flow and head values at specific points of the calculation mesh or flow and head values along the system at a specific time instant.

Flow rate at the entry of the adduction tunnel



Water level evolution in the surge tank



Conclusions

Unique platform in which data are taken directly from a BIM model and used as input for hydraulic simulations

Any changes in the model geometry are automatically reflected in the inputs of the programming code used for hydraulic simulations

Design

- Geometry optimization
- Sizing components

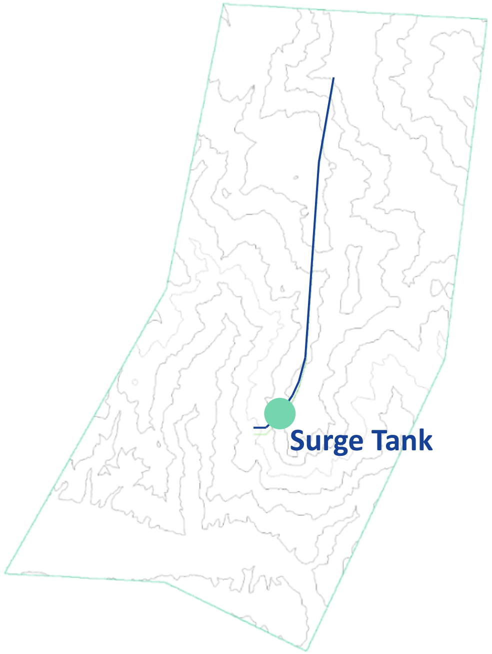
Facility Management

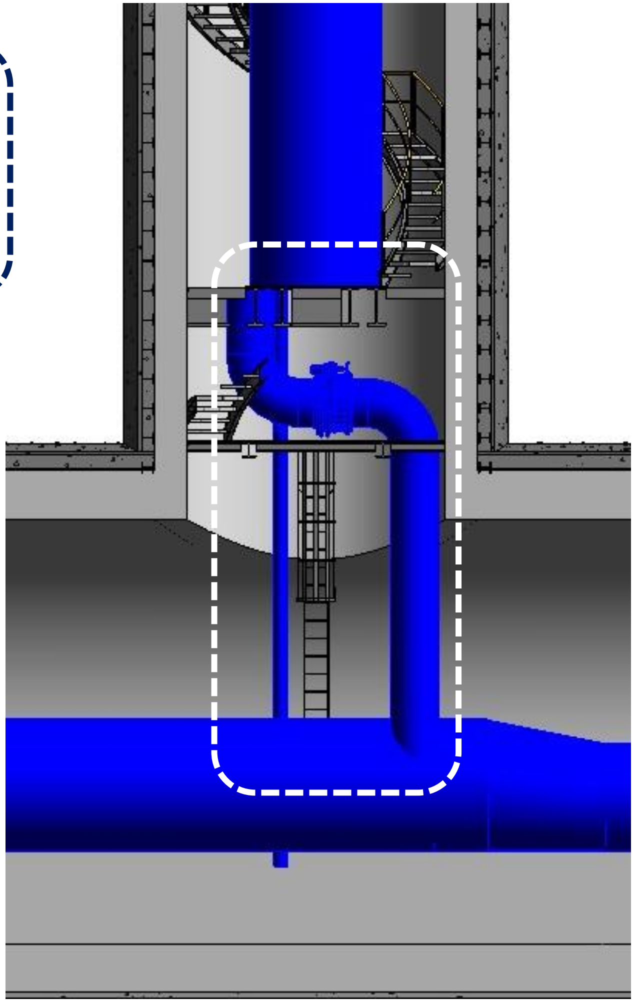
- Evaluate valve maneuvers to ensure correct flow rates are distributed to utilities
- Simulate effectively manage extraordinary situations

Future steps

Programming code improvement

More accurate **head losses** estimations at **discontinuity points**, such as the Surge Tank inlet

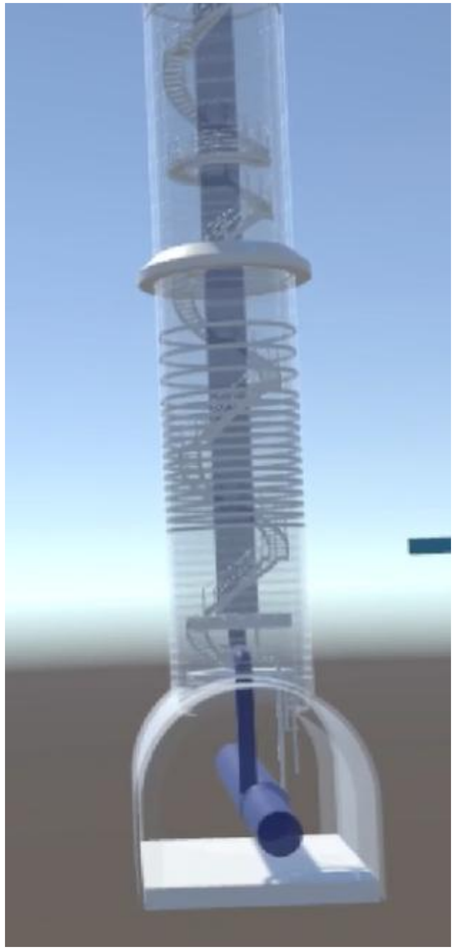




Virtual Reality (VR) visualization

VR's goals:

- **Design support**
- **Formation** of the maintenance workforce
- raising **awareness** of the role of hydropower



Thanks for your attention

Prof. Anna Osello
Politecnico di Torino
anna.osello@polito.it

Dr. Francesco Loddo
Politecnico di Torino
francesco.loddo@polito.it