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# Flood modelling with the software Iber

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1. Introduction
2. General model capabilities
3. River inundation modelling
4. Pluvial flooding and urban drainage
5. Fully distributed hydrological modelling

# Flood modelling with the software Iber

## Introduction

**Turbillon**

GEAMA (UdC)

2010

**CARPA**

Flumen (UPC)

**GiD**

CIMNE

GOBIERNO DE ESPAÑA MINISTERIO DE FOMENTO MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

CEDEX CENTRO DE ESTUDIOS Y EXPERIMENTACIÓN DE OBRAS PÚBLICAS

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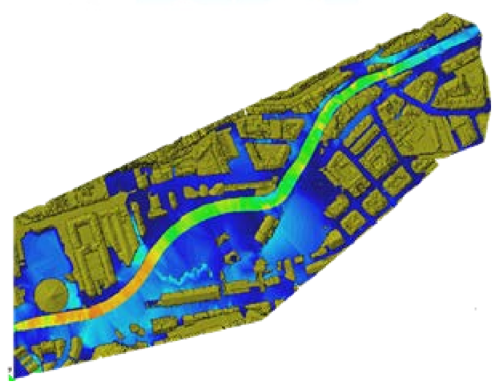

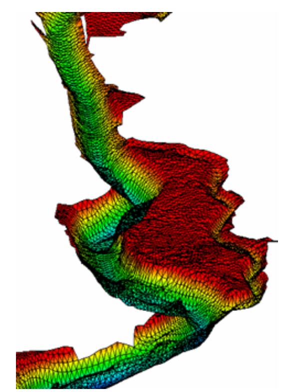

# Evolution

- River inundation
- Sediment transport
- Water quality
- Hydrological modelling
- River habitat simulation

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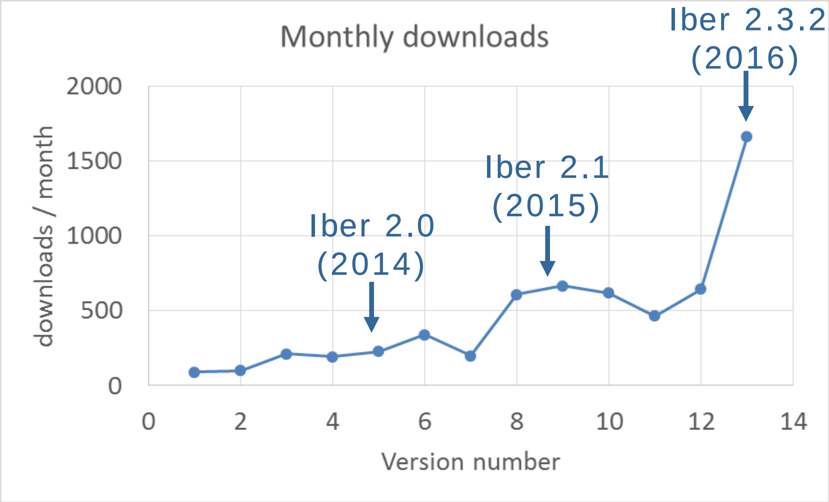
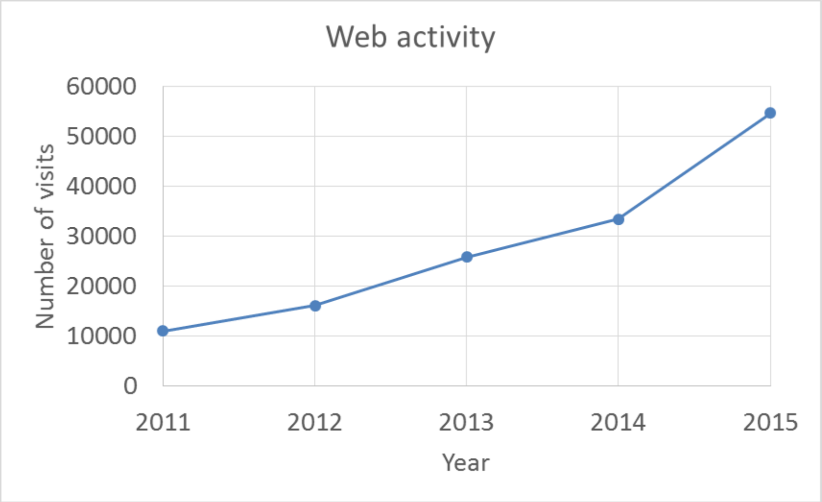


# Standard model capabilities

## Hydrodynamics

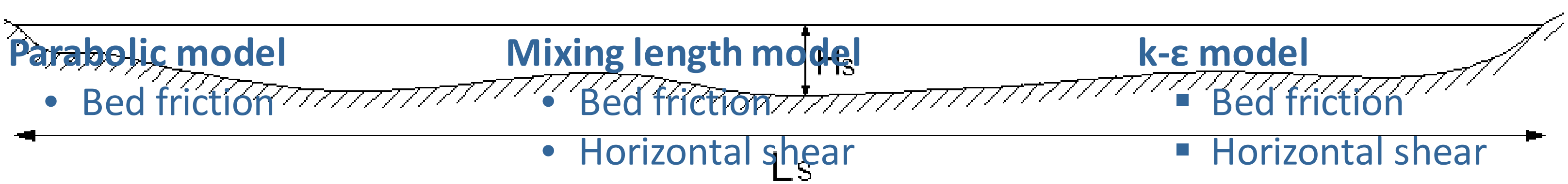
2D depth-averaged shallow water equations

$$\frac{\partial h}{\partial t}+\frac{\partial hU}{\partial x}+\frac{\partial hV}{\partial y}=0$$

$$\frac{\partial}{\partial t}(hU)+\frac{\partial}{\partial x}\left(hU^2+g\frac{h^2}{2}\right)+\frac{\partial}{\partial y}(hUV)=-gh\frac{\partial z_b}{\partial x}-\tau_{b,x}+\frac{\partial}{\partial x}\left(h\nu_e\frac{\partial U}{\partial x}\right)+\frac{\partial}{\partial y}\left(h\nu_e\frac{\partial U}{\partial y}\right)$$

$$\frac{\partial}{\partial t}(hV)+\frac{\partial}{\partial x}(hUV)+\frac{\partial}{\partial y}\left(hV^2+g\frac{h^2}{2}\right)=-gh\frac{\partial z_b}{\partial y}-\tau_{b,y}+\frac{\partial}{\partial x}\left(h\nu_e\frac{\partial V}{\partial x}\right)+\frac{\partial}{\partial y}\left(h\nu_e\frac{\partial V}{\partial y}\right)$$

Depth-averaged RANS-type turbulence models




**Parabolic model**
- Bed friction

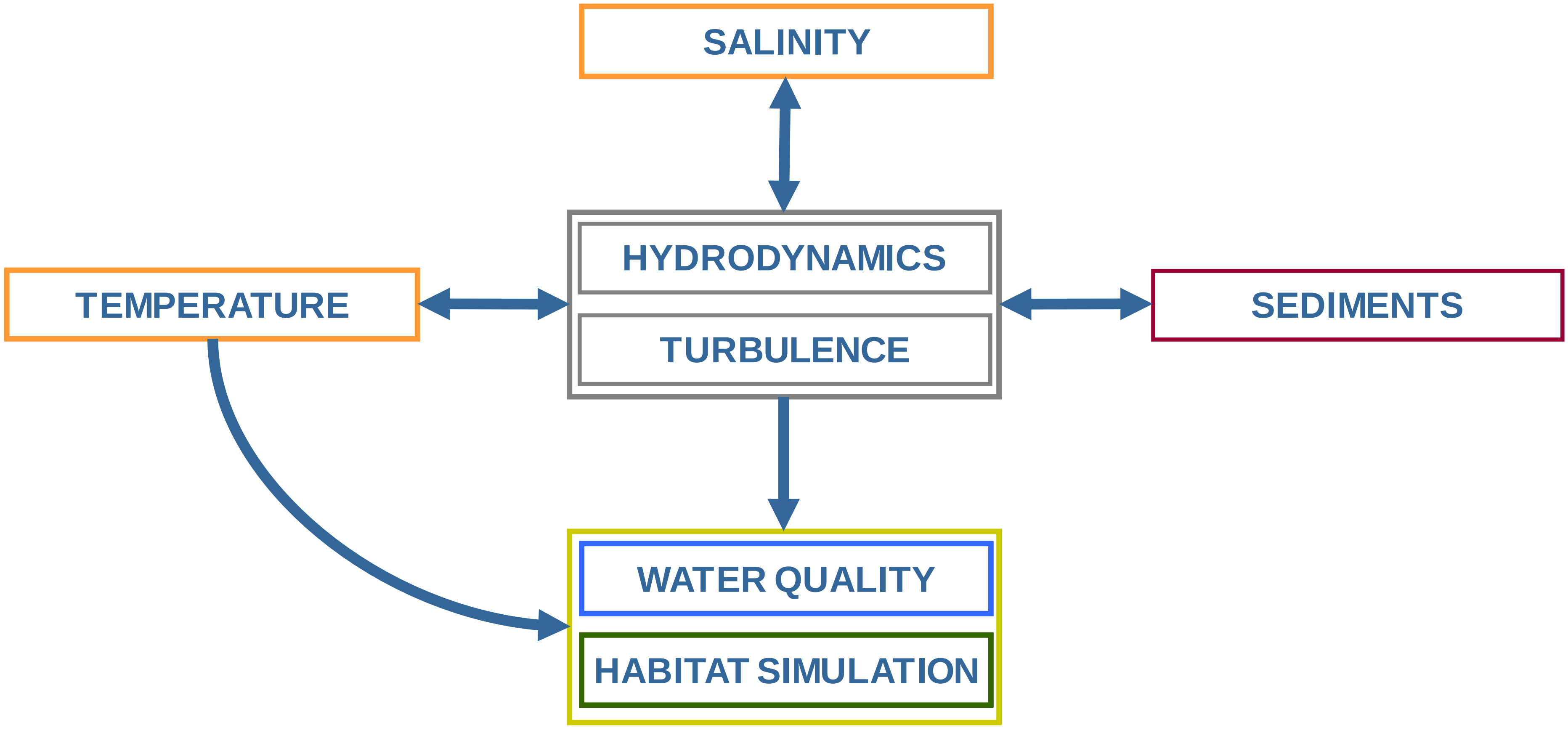
**Mixing length model**
- Bed friction
- Horizontal shear

**k-ε model**
- Bed friction
- Horizontal shear
- Diffusion
- Dissipation

- Hydrostatic pressure
- Uniform velocity profile over the water depth

# Standard model capabilities

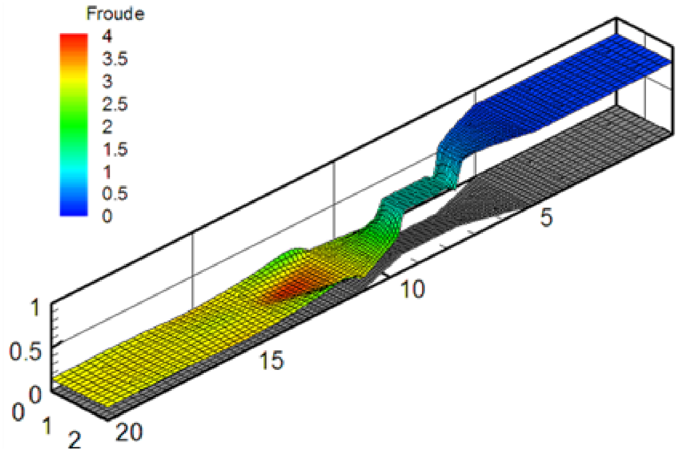
## Modules



# Flood modelling with the software Iber
## Standard model capabilities

### Numerical solver

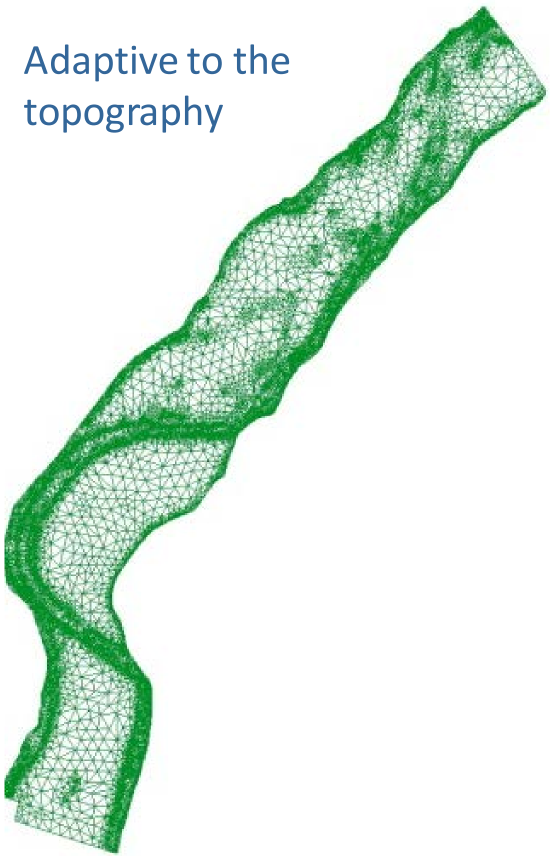
High resolution shock-capturing unstructured finite volume schemes




- Subcritical and supercritical flow
- Hydraulic jumps
- Inundation (wet-dry) fronts

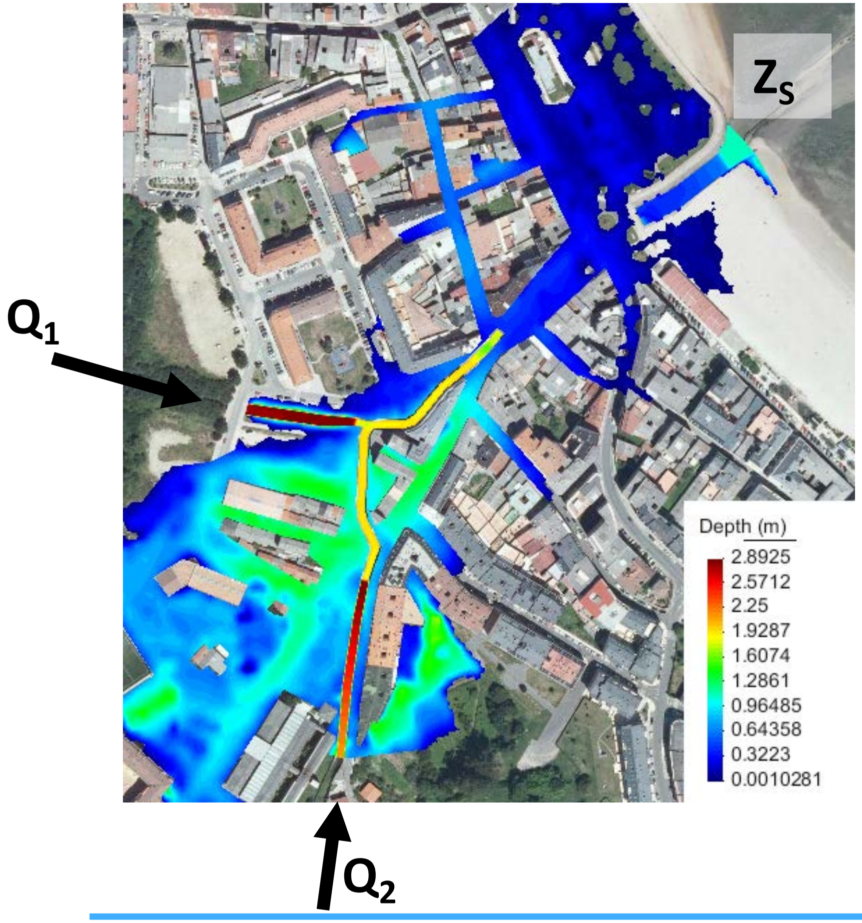
Meshing tools based on GiD

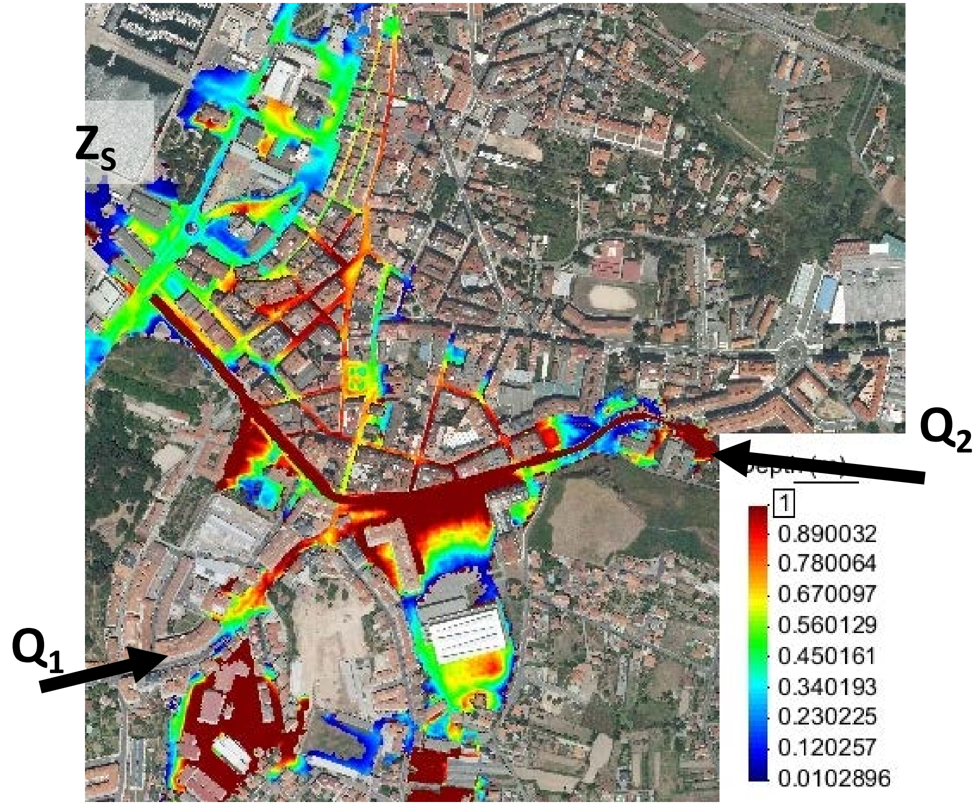
Adaptive to the topography



# River inundation modelling

## River inundation studies



# Flood modelling with the software Iber
# River inundation modelling

## Hydraulic structures

### Bridges

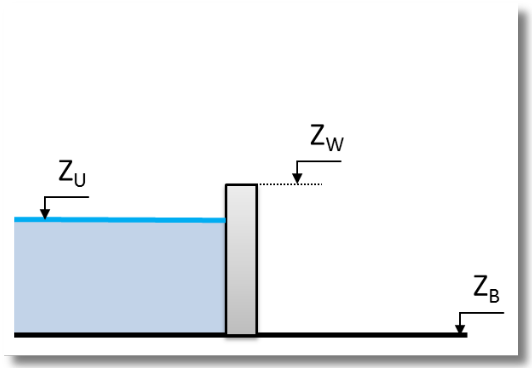
### Weirs

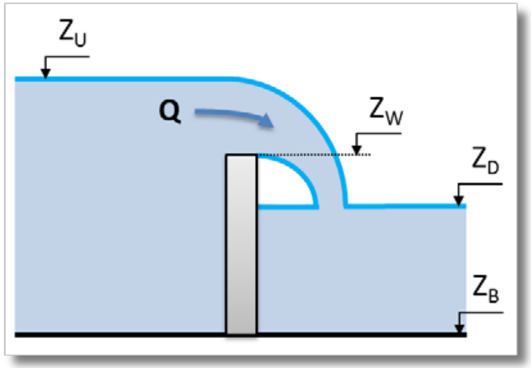
### Gates

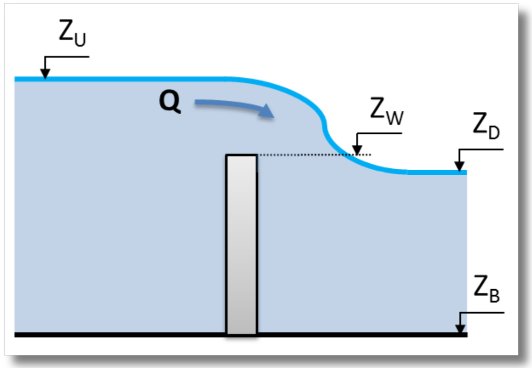
### Culverts

# River inundation modelling

## Modelling weirs

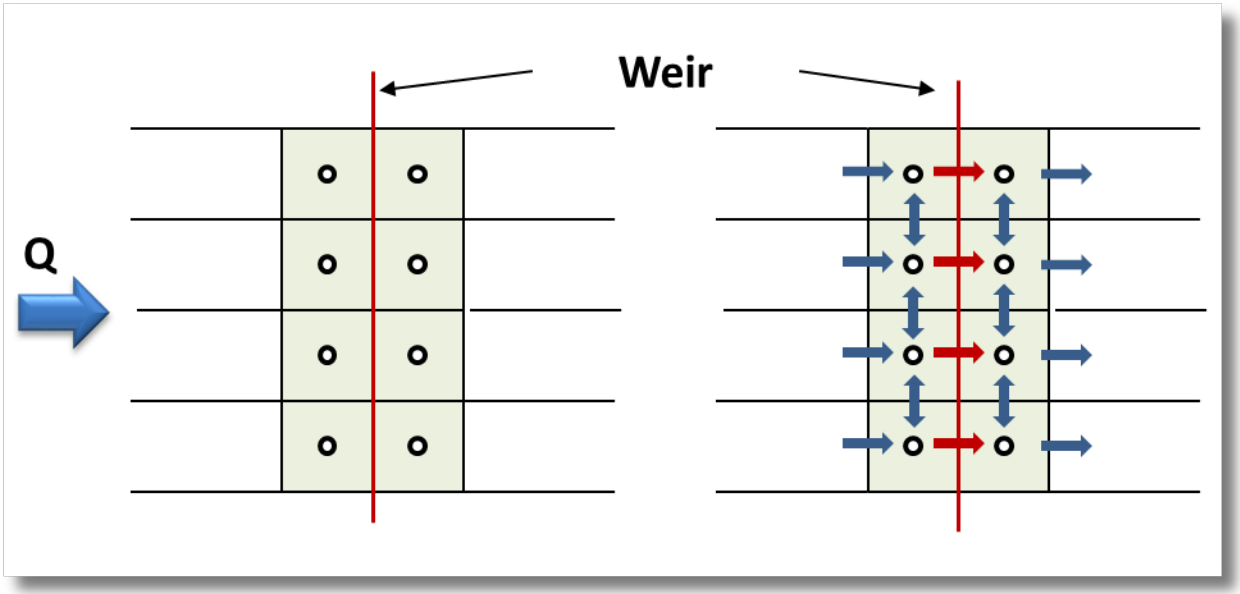



- Local flow is non hydrostatic and non-uniform over the water depth
- The most accurate solution would be to couple the 2D model with a 3D model → Future research line
- Present implementation → specific discharge equation with empirical discharge coefficients

## Modelling weirs

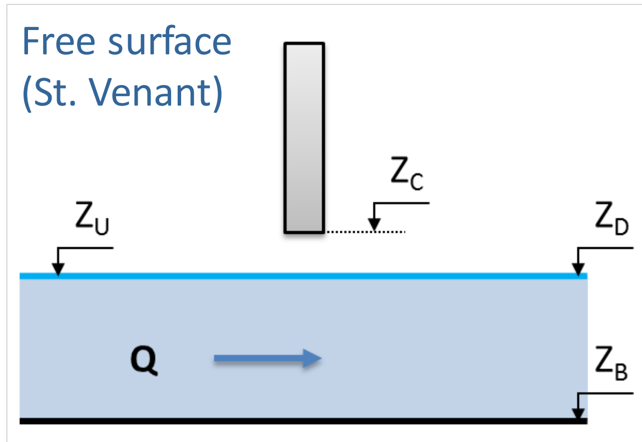



### Empirical weir discharge equation

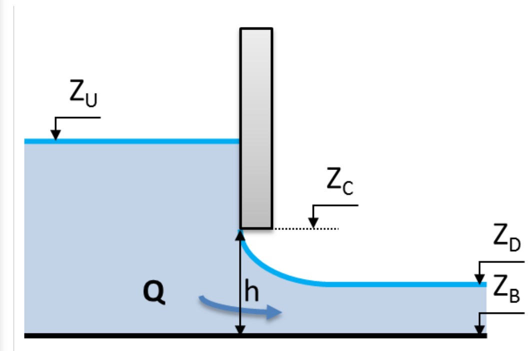
| Flow conditions | $Z_U$ / $Z_W$ | ($Z_D$-$Z_W$) / ($Z_U$-$Z_W$) | Discharge equation |
|---|---|---|---|
| Free weir | > 1 | < 0.67 | $Q = C_d B (Z_U - Z_W)^{1.5}$ |
| Submerged weir | > 1 | > 0.67 | $Q = 2.6 C_d B (Z_D - Z_W)\sqrt{(Z_U - Z_D)}$ |

## Modelling gates

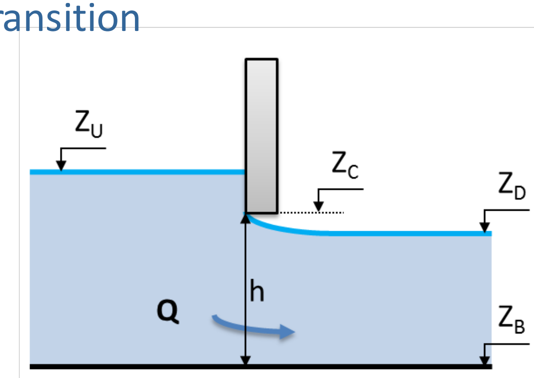
Free surface (St. Venant)



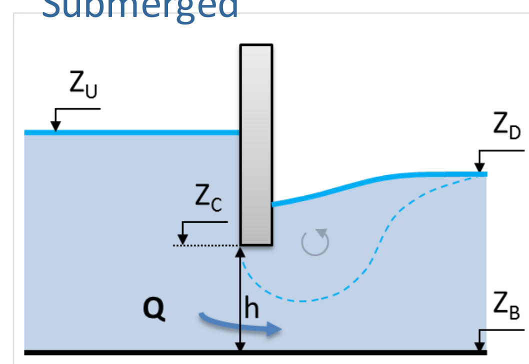

Free discharge



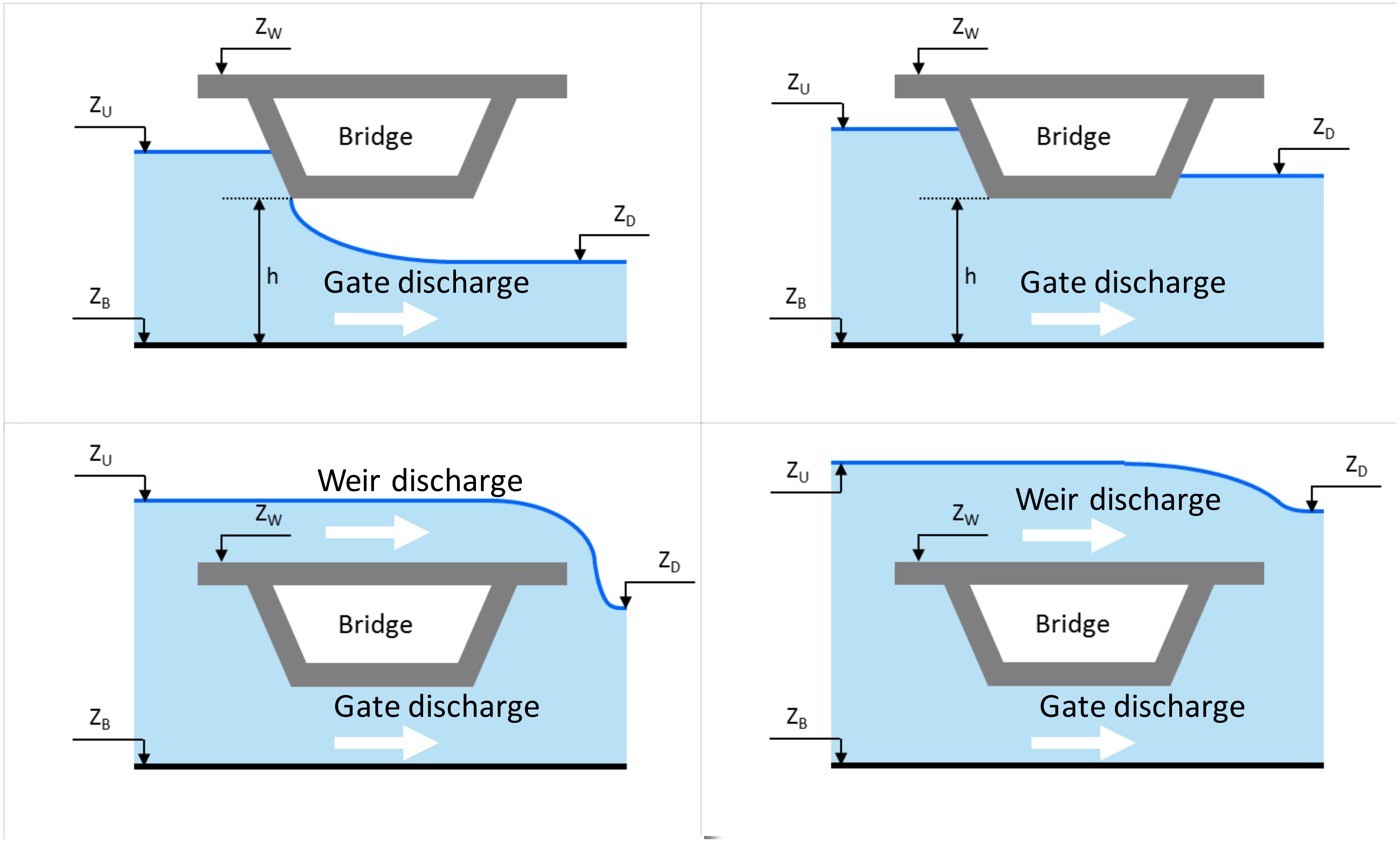

Transition



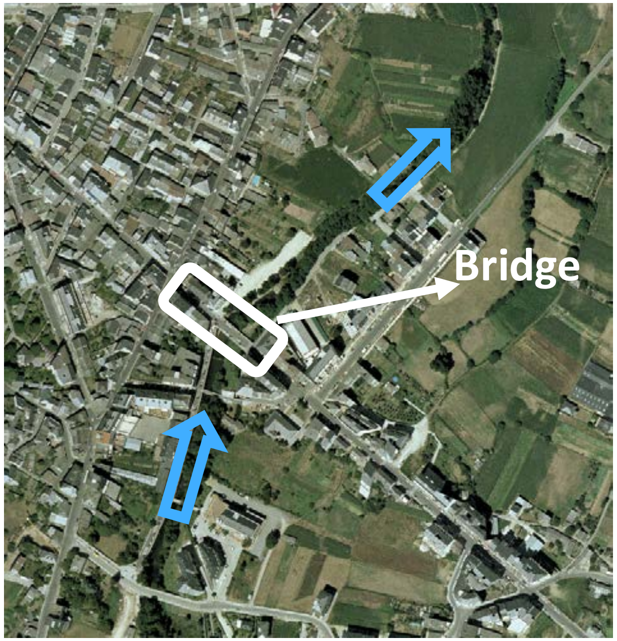

Submerged

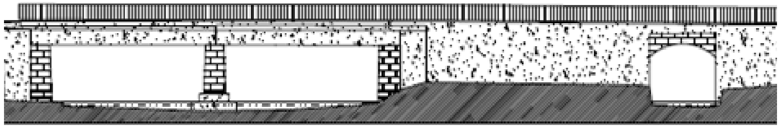


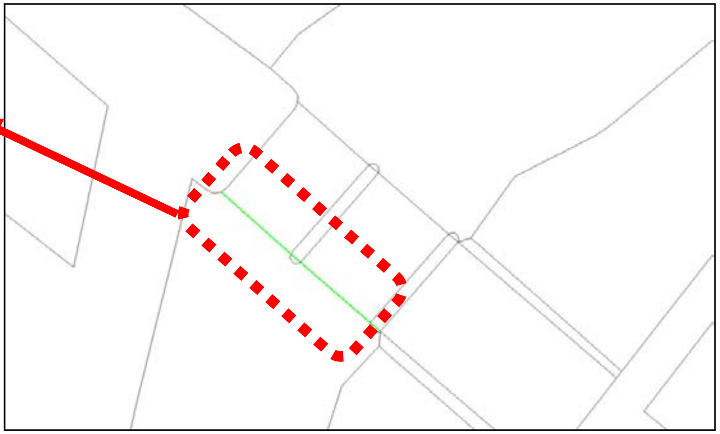
## Modelling bridges

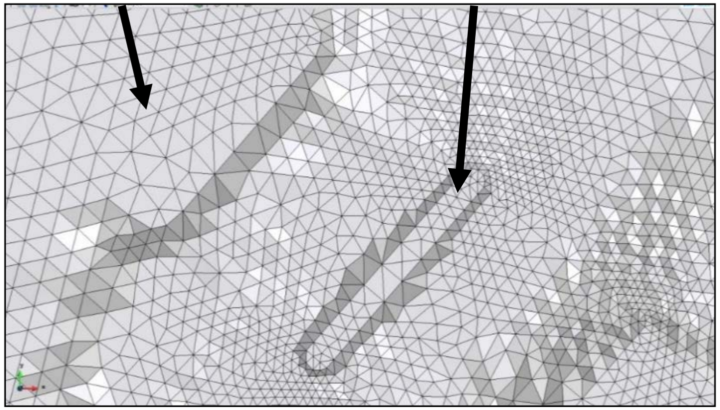


## Modelling bridges

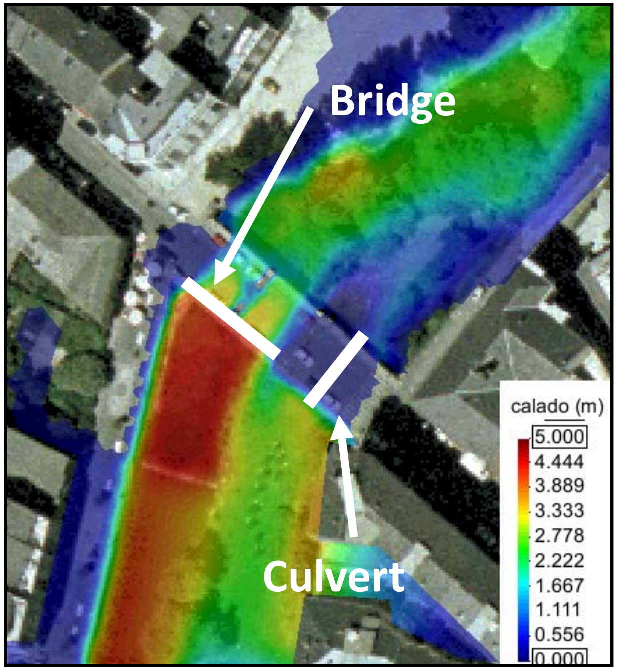


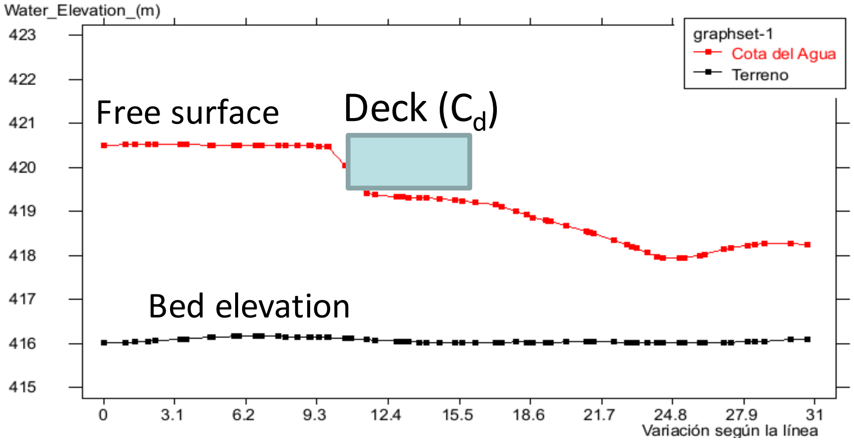



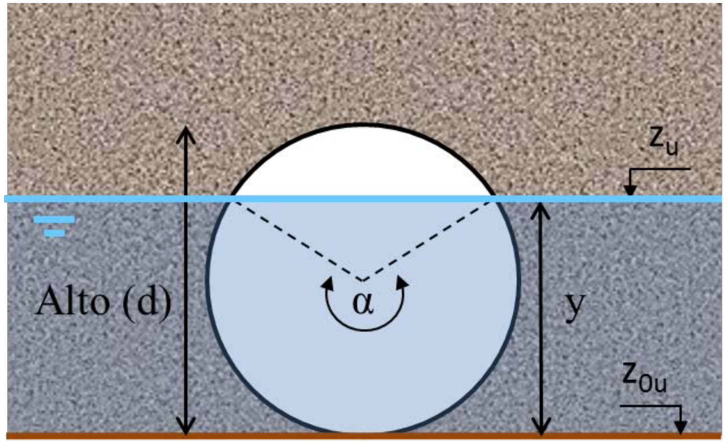



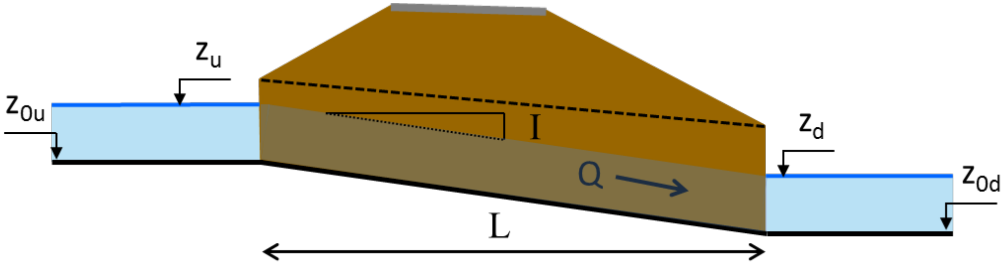
## Modelling bridges



## Modelling culverts



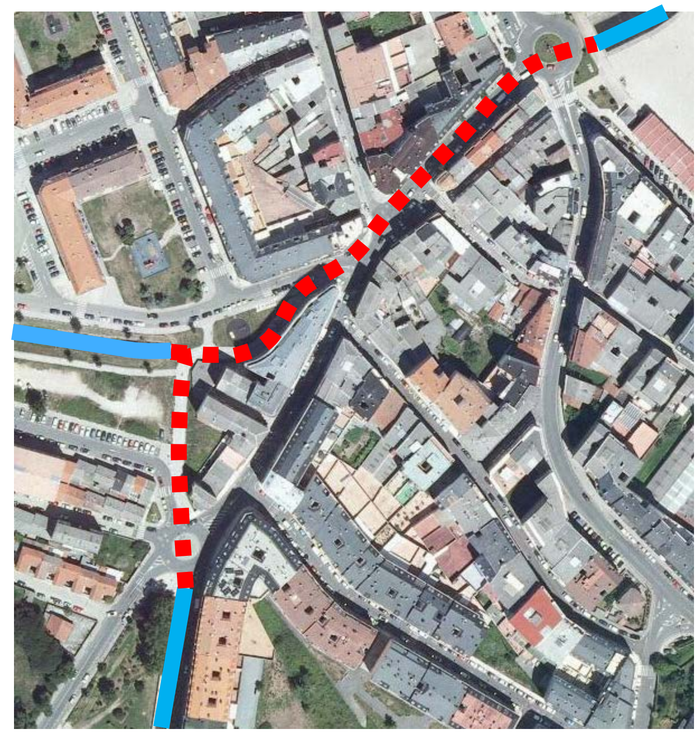




Different approaches

- Manning equation (Inlet/Outlet Control)
- 1D diffusive wave equation
- 1D Saint Venant equations

# River inundation modelling

## Underground river reaches



Very limited hydraulic capacity

Underground reach

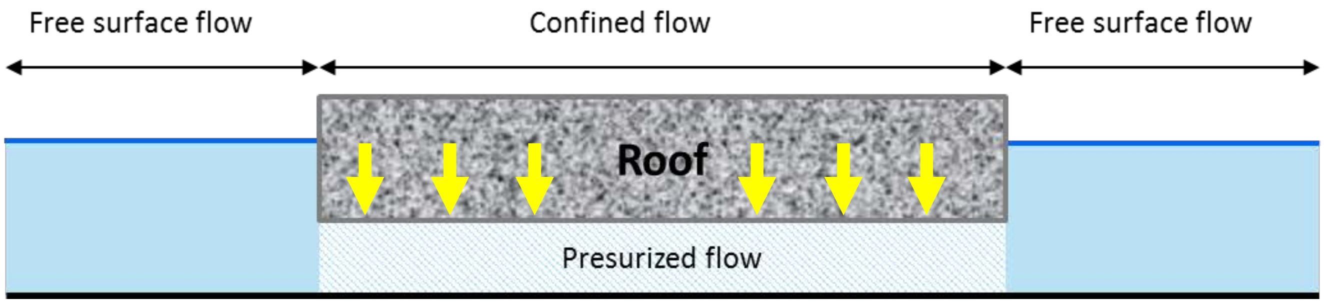
Free surface flow

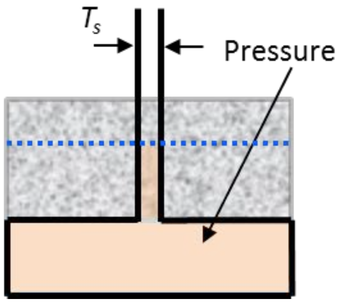
## Modelling pressurized (confined) flow

Free surface elevation < Roof elevation ⇒ Standard 2D-SWE

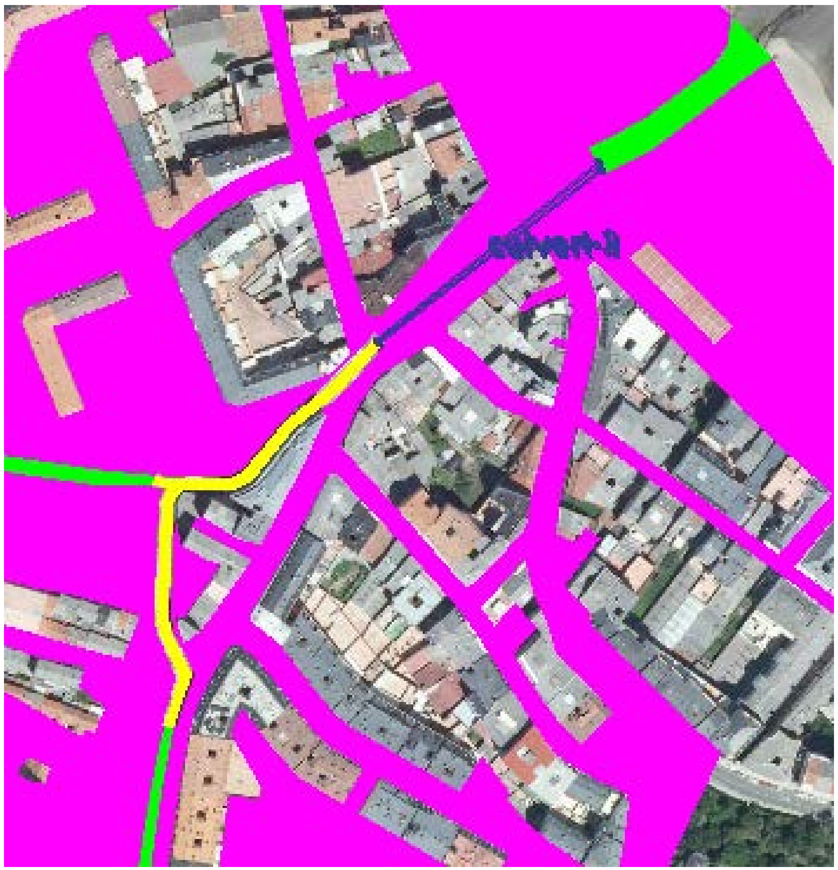
Free surface elevation = Roof elevation ⇒ + Pressure head

additional pressure head



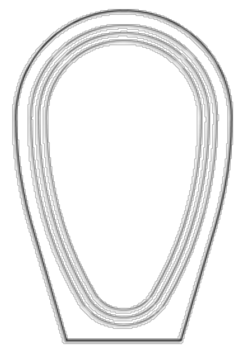
## Modelling pressurized (confined) flow



Free surface flow

Confined flow

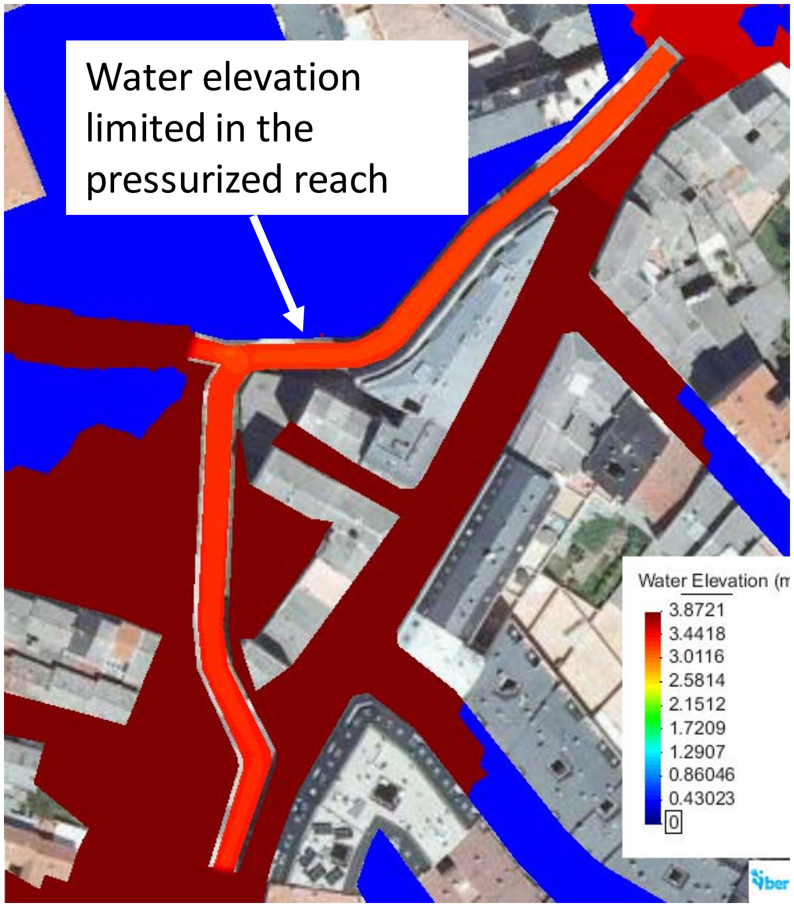
Culverts

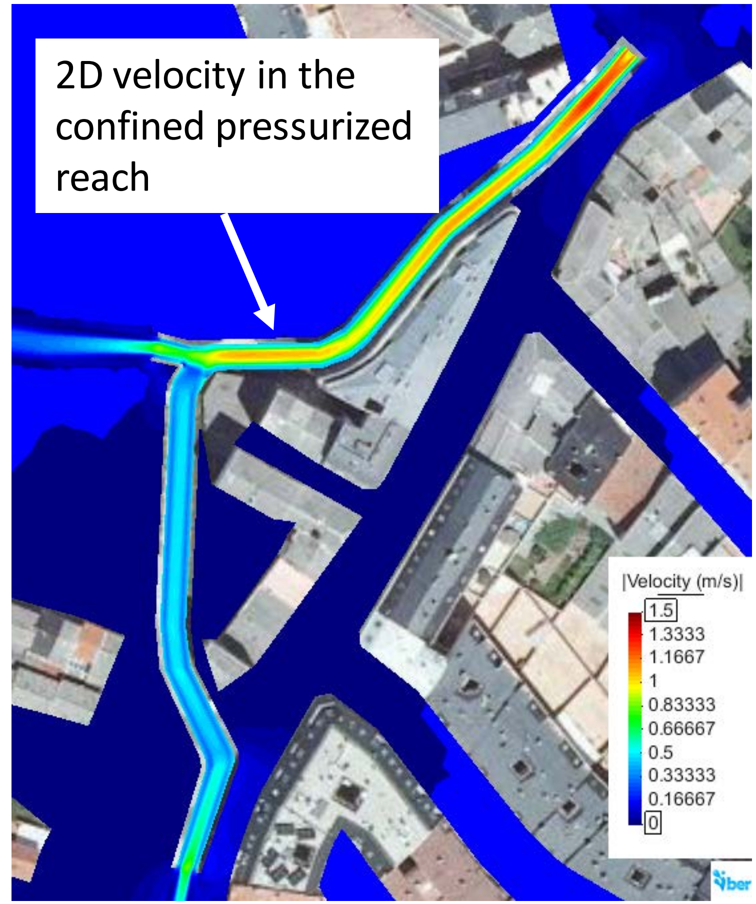


Culverts
(1D)

2D Pressurized flow

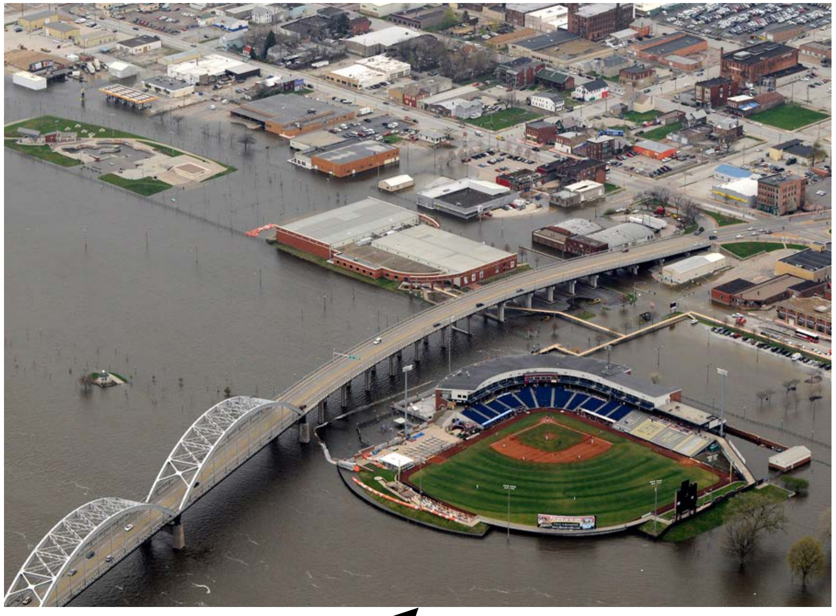
## Modelling pressurized (confined) flow



# Pluvial flooding

## River flooding vs. Pluvial flooding



- river discharge
- capacity of the main channel

- local rainfall
- capacity of the sewer network

# Flood modelling with the software Iber

## Pluvial flooding

### River flooding vs. Pluvial flooding

**River flooding**

**Rainfall**

HYDROLOGICAL MODELLING

Aggregated (basin scale) or distributed → **Discharge**

HYDRAULIC MODELLING

Open Channel Flow Eqs

1D or 2D, River + Flood Plain → **Depths** **Velocities**

HAZARD AND RISK ASSESSMENT

**Pluvial flooding**

**Rainfall** — **Discharge**

INTEGRATED HYDROLOGICAL AND HYDRAULIC MODELLING

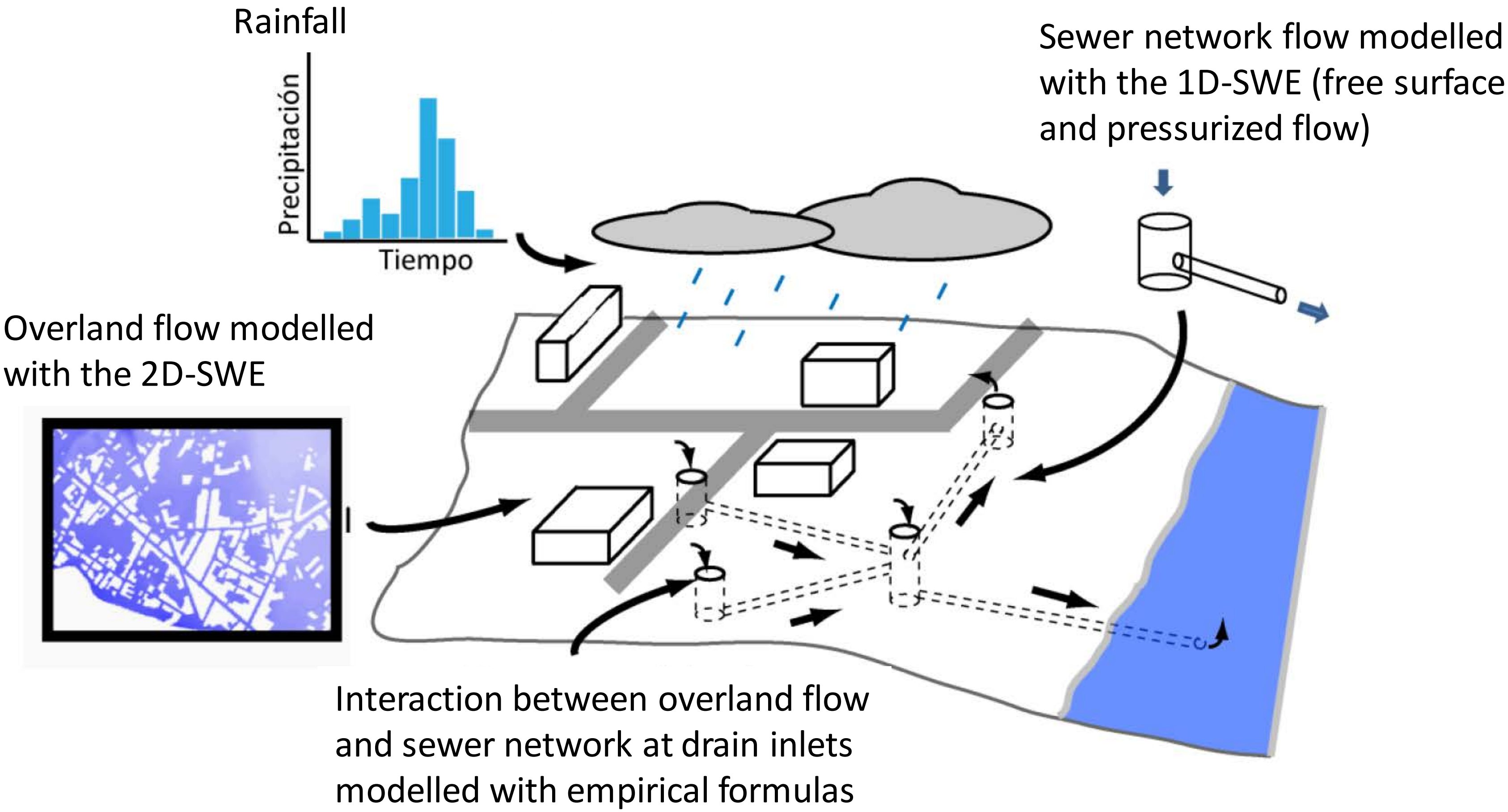
**Rainfall-runoff transformation**

**Urban environments (Surface + Sewer System)** → **Discharge** **Depths** **Velocities**

HAZARD AND RISK ASSESSMENT

# Pluvial flooding

## Dual urban drainage model



# Flood modelling with the software Iber

## Pluvial flooding

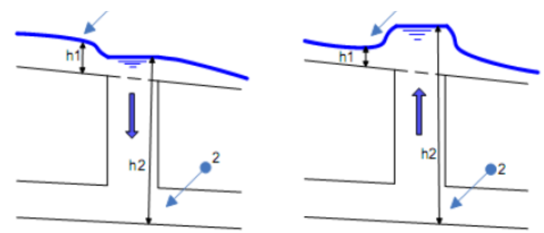
### 2D-1D Dual urban drainage model

- I. Fraga (2015)
- J.L. Aragón (2014)

$$\frac{\partial h}{\partial t} + \frac{\partial hU}{\partial x} + \frac{\partial hV}{\partial y} = R - I + Q_{2D-1D}$$

$$\frac{\partial}{\partial t}(hU) + \frac{\partial}{\partial x}\left(hU^2 + g\frac{h^2}{2}\right) + \frac{\partial}{\partial y}(hUV) = -gh\frac{\partial z_b}{\partial x} - \tau_{b,x}$$

$$\frac{\partial}{\partial t}(hV) + \frac{\partial}{\partial x}(hUV) + \frac{\partial}{\partial y}\left(hV^2 + g\frac{h^2}{2}\right) = -gh\frac{\partial z_b}{\partial y} - \tau_{b,y}$$

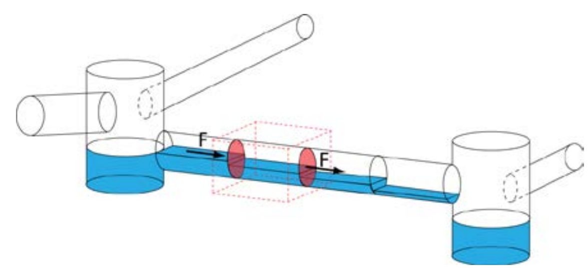




+

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = Q_{1D-2D}$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q^2}{A} + gI\right) = gA(S_0 - S_f)$$

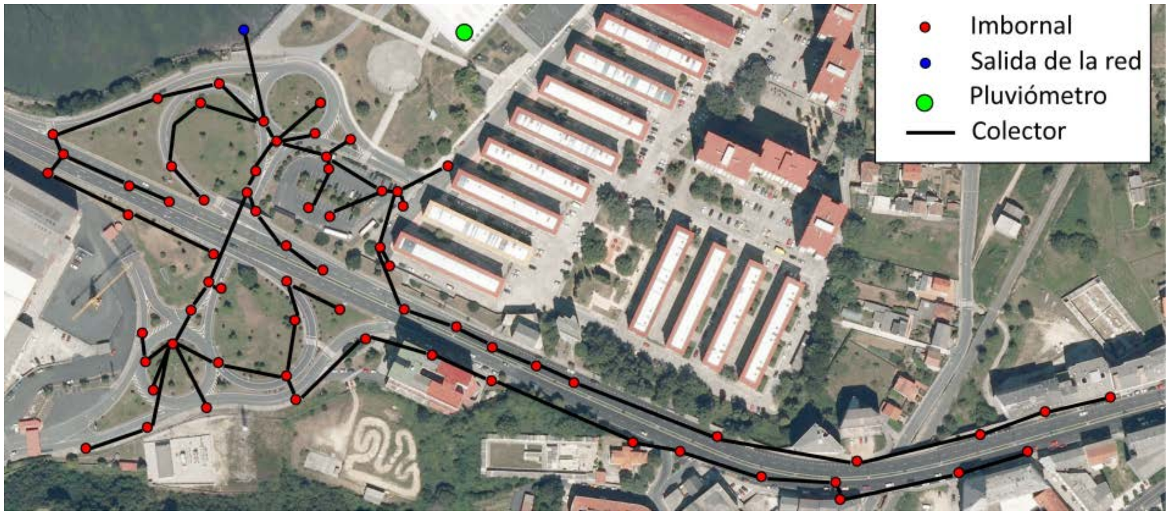
1D-SWE +
Preissmann slot or
Two Pressure
Approach (TPA)



# Flood modelling with the software Iber
# Pluvial flooding

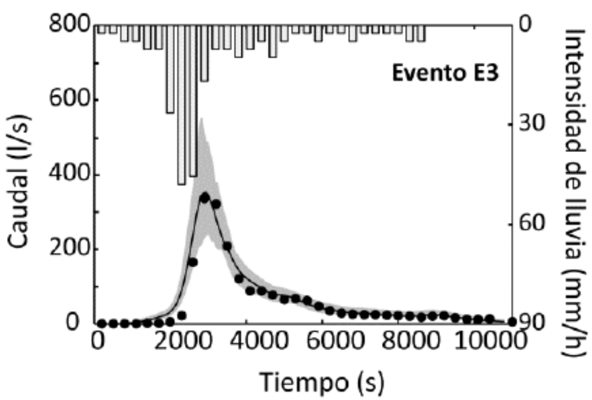
## 2D-1D Dual urban drainage model

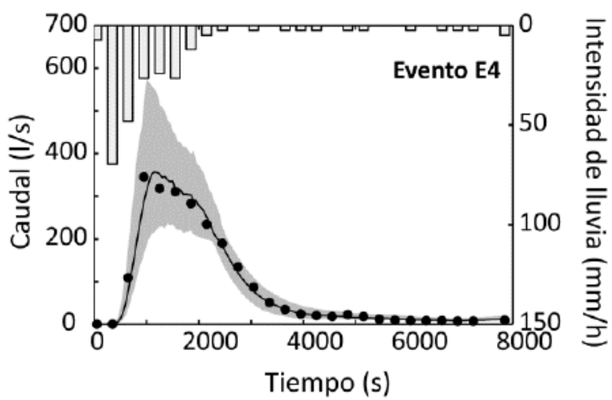
Fraga (2015)




Input data:

- DTM and land uses
- Rainfall intensity
- Sewers characteristics
- Drain inlets discharge coefficients
- Infiltration parameters



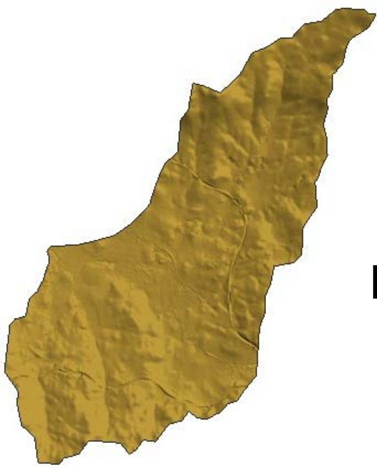




- Good model performance at basin outlet, but…
- Important need for calibration, specially of infiltration parameters

# Flood modelling with the software Iber

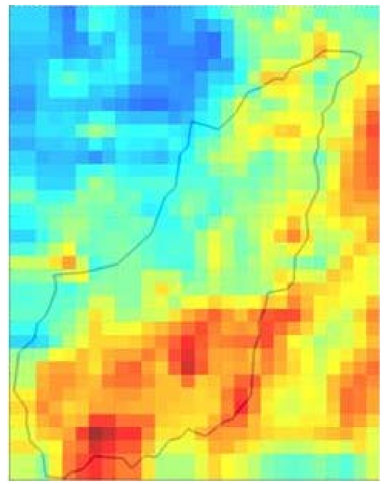
## Distributed hydrological modelling

DTM



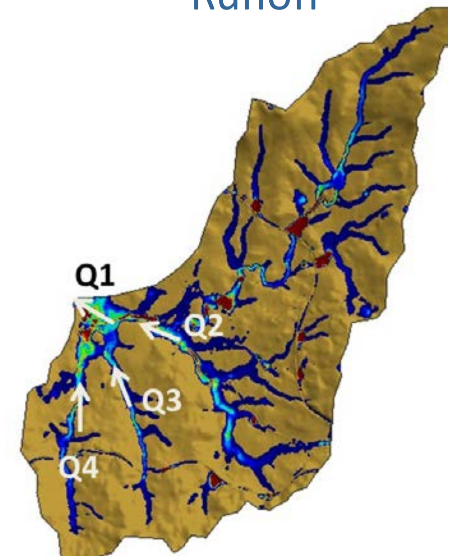
Small basins

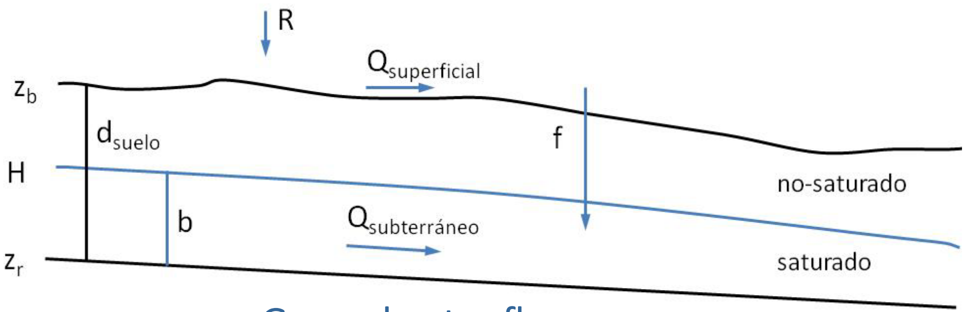
Distributed Rainfall



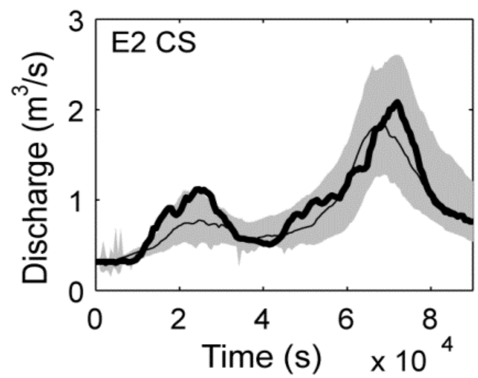
Event scale

Runoff




Groundwater flow




Uncertainty in predictions

# Distributed hydrological modelling

# Conclusions and research lines

- Iber is a well established tool for 2D river inundation modelling.
- Near-future developments and implementations in the public version are focused on pluvial flooding and urban drainage applications.
- Hydrological flood modelling in small catchments at the event scale is one of the present research lines.
- Coupling Iber with 3D models for local phenomena (near field in dam-break problems, bridges, weirs, gates or other urban features) is also a present research line.