2D HD model comparison of Particle transport patterns in the río la Miel in Colombia

Using particle tracking and hydrodynamic simulations

Jordi Rafael Palacios Gonzalez
jordi.palacios@escuelaing.edu.co

Jorge Alberto Escobar Vargas
jorge-escobar@javeriana.edu.co

Germán Ricardo Santos Granado
german.santos@escuelaing.edu.co

Geraldo Augusto Corzo Pérez
g.corzo@un-ihe.org
Sustainable Hydropower and Multipurpose Storage to meet Water, Food, and Energy Development Goals: A Program for Collaborative Research and Innovation (S-MultiStor), project 106472
2017
Particle tracking is very important in for the appropriate management of water resources. Morphological heterogeneities of rivers make the prediction of the particle motions difficult due to the complex numerical and physical variations in the mathematical formulation. Data availability in recent years have allowed to extend dimensionality of the problem and even use coupled models for a better understanding of those patterns.
Motivation

The implementation of particle tracking in two-dimensional hydrodynamic models can improve the representation of the transport phenomena in high mountain rivers that present quite complex geometries. In this particular case of study, the flow characteristic present are even more complex due the construction of the Miel I hydroelectric.

Knowledge of particle transport phenomena in rivers needs to be developed as they can be implemented to describe the movement and behavior of small marine species, the travel trajectory of a pollutant and other local uses such as forensic investigation in rivers.
Methodology

Data Collection

- Satellite Images
- Hydrometeorological Information

Information Processing

- Topobathimetry
- Initial Conditions
- Boundary Conditions
- Physical and Numerical Parameters

- Analysis of Transport Patterns From Information Taken in Field

Hydrodynamic Model (2D)

- Particle Tracking

Hydroelectric Information

- Field Information

Particle Image Velocimetry
Data Collection
Hydrophysical recognition in “La Miel” river

Two campaigns

- 21 to 27 of July 2019
- 20 to 23 of February 2020
- Daily time in campaign: 10 hours
- Length of the river downstream of the hydroelectric: 9.8 Km
- Average width: 22 m
- Average Depth: 1.4 m
- Type of river bed: Rock
- The bathymetries were collected using a ECHOMA 54v
- Velocities of the river obtained with and ADCP River Ray, for a 10 km reach.
- The topography was obtained from images taken by phantom 4 drones and a Real Time Kinematic (RTK) equipment.
Particle Tracking
Dynamic Data

Helium balloons filled with water so that they could float.

A representative section was selected called "La moya de Jorge".

Hydraulic phenomena of rapids and sudden changes in geometry are presented.

Information Obtained:
- Balloons travel time in control volume defined by the area captured by the drone
- Displacement of the Balloons through the control volume
- Travel time of the balloons from the beginning to the end of the study section
- Balloons caught by “La Moya”
Information Processing
The images obtained from drones were used to generate the digital terrain image, which was processed using the Pix4D software.
An IDW interpolation Python code was made where the elevation the bathymetries values were obtained from the RTK. The values were then subtracted from the depth of the echo sounder and finally interpolated using the Kriging in ArcMap.
Finally, by using a topobathymetry smoothing technique, we obtained the DTM of the section to be studied (Moya de Jorge).
Hydrodynamic Model (2D)
Two meshes were
- non-structured (curvilinear)
- a structured mesh.

The best mesh was the structured one with a 90° orthogonality

The unstructured mesh generates convergence problems
The figures show the 3D and plant view of the XYZ format topobathymetry for the two-dimensional model of the "Moya de Jorge" section in the río La Miel downstream of the Amaní reservoir.
The figures show the plant view of the depth using a triangular interpolation of the topobatimetry of the "Moya de Jorge" section taking into account the mesh.
### Final Model

<table>
<thead>
<tr>
<th>Parameters</th>
<th>magnitude</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation start time</td>
<td>15-04-2020 00:00:00</td>
<td></td>
</tr>
<tr>
<td>Simulation stop time</td>
<td>15-04-2020 03:00:00</td>
<td></td>
</tr>
<tr>
<td>Time step</td>
<td>0.001</td>
<td>min</td>
</tr>
<tr>
<td>Initial conditions</td>
<td>195.4</td>
<td>m</td>
</tr>
<tr>
<td>Boundary upstream (Left)</td>
<td>14</td>
<td>m³/s</td>
</tr>
<tr>
<td>Boundary upstream (Right)</td>
<td>4</td>
<td>m³/s</td>
</tr>
<tr>
<td>Boundary Downstream</td>
<td>193.48</td>
<td>m</td>
</tr>
<tr>
<td>Manning</td>
<td>0.04</td>
<td></td>
</tr>
</tbody>
</table>
Results
Hydrodynamic Model (2D)
Depth averaged velocity

In the image you can see the results of the depth averaged velocity of the 2D hydrodynamic model. The maximum speeds are in the area of the rapid and at the right entrance before the change of geometry.

The minimum speeds are presented in the "moya de Jorge", as in the One-Dimensional model.

Regarding the trajectory of the particles, it is expected that the particles will be accelerated in the rapid and slowed down at the moya, where possibly a recirculation phenomena will be generated.
The magnitudes of velocities and the velocity vectors are shown in detail at the "moya de Jorge".

The influence of the confluence of the two arms of the river on the changes of velocity directions and patterns can be observed.

Low magnitudes are presented with an average of 0.2 m/s.
These figures show in detail the velocities magnitudes and the velocity vectors at the rapid. Due to the river bed geometry, the velocities are high, reaching 1.6 m/s, and in the "moya de Jorge" direction.
The shear stress in the rapid reach a magnitude of 60 N/m² and across the section with an average of 20 N/m². In the zone of the "Moya de Jorge" where due to the low speeds the forces tend to 0.
In the area of the rapids the water depth is 20 cm and in the area of the moya water depth depths are more than 3 m.

Inside the moya, there are two changes of geometry or what could be called two moyas, one that is on the left side of the rapid and another one much smaller on the right side.

The flow continues at an average depth of 1.3 m.
The graph shows the longitudinal profile from upstream to the downstream boundary, passing through the rapids. The riverbed is compared with the water level, where the influence of the complex geometry on the water depth can be observed.
Particle Image Velocimetry
The velocity vectors were obtained processing the drones videos with the River 2.4.3 and PIVlab 2.00 Software using the Particle Image Velocimetry (PIV) technique.

Upstream of this section, the water sheet has a considerable depth and the technique acceptably represents the velocity field. The directions in some places go against the mainstream flow.
The technique represents well the velocity field. In general, the vectors show a uniform direction except in a small zone that present a random behavior. Downstream of the section, the flow continues its normal direction.
CONCLUSIONS AND FUTURE WORK
Through the two fieldtrips and the information processing, it was possible to gather good quality topographic and bathymetric information to feed the hydrodynamic models.

The two-dimensional hydrodynamic model developed in Delft-3D was able to capture the hydraulic phenomena associated with the abrupt changes in geometry, water depths and complex velocity fields in the Moya. Velocities, from 0.1 m/s to 1.6 m/s and water depths from 20 cm to 3.5 m in were obtained in the modelling.

It was possible to observe the recirculation phenomena present in the moya from the Particle Image Velocimetry method, that has good precision to capture the direction of the velocity vectors.

We are currently implementing a two-dimensional particle tracking model using the Part module of the Delft 3D software.


• This research is partially supported by the Programmatic Cooperation between the Directorate-General for International Cooperation (DGIS) of the Dutch Ministry of Foreign Affairs, IHE Delft and Escuela Colombiana de Ingeniería, Bogota Colombia, in the period 2016 - 2020, also called DUPC2.
Gracias