INTEGRATION OF GIS AND HEC-RAS IN FLOODS MODELING OF THE OUERGHA RIVER, NORTHERN MOROCCO

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Abstract

In recent years, hydrological hazards continue to worsen due to climate changes affecting the whole world. In Morocco, after a long period of severe drought that has ravaged the country since the eighties, the last years were exceptionally rainy. Records have been exceeded in terms of rainfall and flooding that affected many parts of the country. The Ouergha River, contributing with 50% of total water yield of the Sebou basin which is one of the most important watersheds in Northern Morocco, broke all records in 2009/2010 providing an exceptional amount of water of 7,4 10^9 m^3. In this study, one-dimensional hydraulic modeling with HEC-RAS®, allowed to calculate the water flow profiles for some flood events that occurred downstream of Al Wahda dam. The exploitation of obtained results led to establish flood extension maps for each calculated profile, which made it possible to evaluate the management of the dam by the Sebou hydraulic Basin Agency. This type of results acquired from the hydraulic simulation and geographic information system, can significantly contribute in flood management interventions against overflows that persist despite the existence of a large dam (Al Wahda), because of extreme climatic and hydrologic events observed in recent years.

Keywords: Ouergha River, Modeling, Hec-Ras®, GIS

Introduction

After a long period of severe droughts that ravaged Morocco since the eighties, important values of rainfall and flow rates have been observed during the last past years. Many floods affected a large part of the country. The Ouergha River broke all records in 2009/2010 season, by providing exceptional amount of water: $7.4x10^9$ m^3, almost four times the annual average of this River (ABHS, 2006).

This study aims to understand the hydraulic behavior of the Ouergha River regarding the management of Al Wahda dam. The studied section is located downstream to the Ouergha watershed, from the dam towards the confluence with the Sebou River. The flow is mainly conditioned by the dam releases.

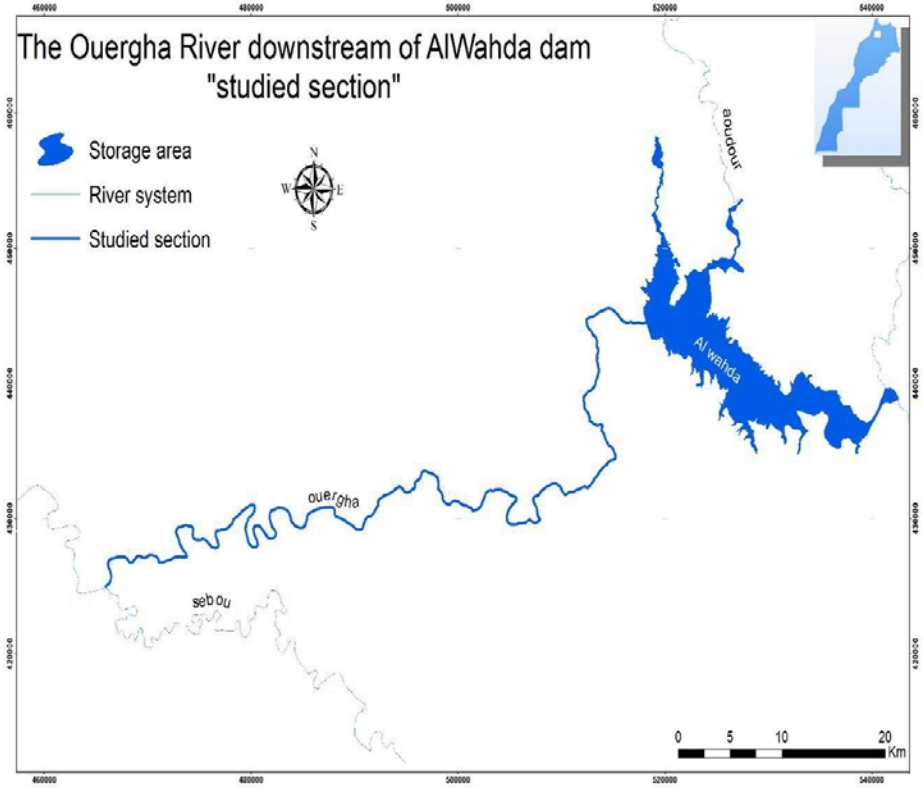

Figure 1: Geographical situation of Ouergha River

Problem and objectives

The Ouergha sub-catchment contributes by 50% to the total annual average intakes of Sebou basin. Figure (2) shows the importance of hydrological processes at the Ouergha and its tributaries.

Furthermore, recent years have recorded unusual hydrological phenomena, following the exceptional meteorological disturbances. The season 2009/2010 was one the important records over 72 years (1939 - 2010)

regarding the intake and flow of the Ouergha River, which was the main cause of floods, occurred downstream in the Gharb Plain.

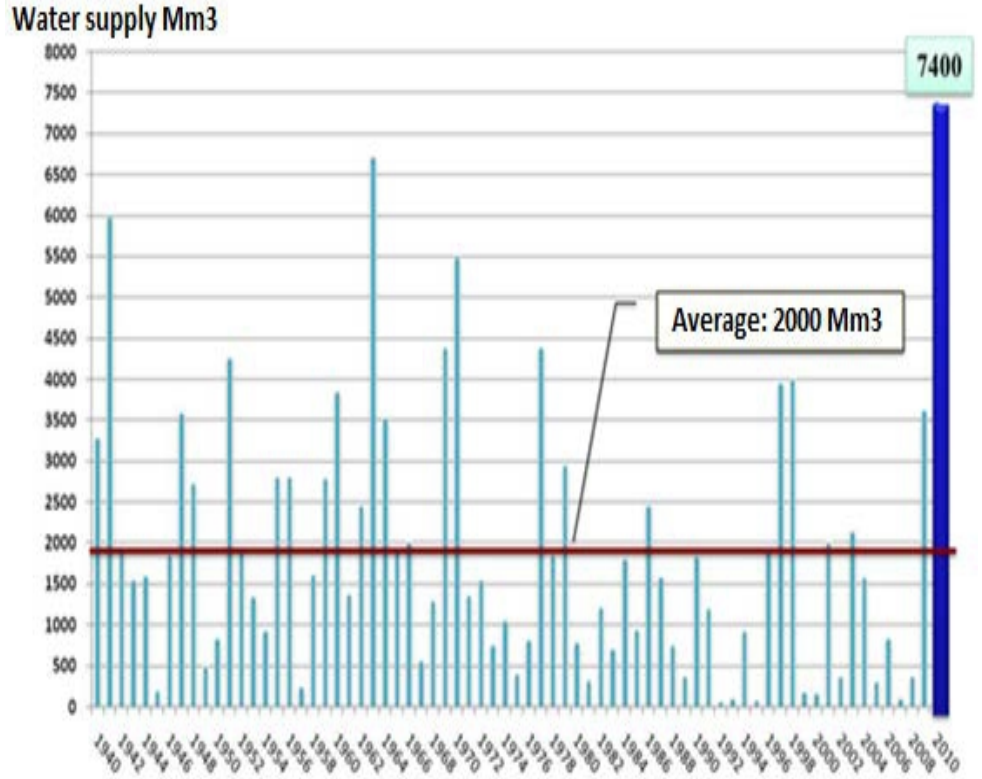

Figure 2: Ouergha river basin annual water supply on 1939-2010 (ABHS, 2006)

From December 19, 2009 to January15, 2010, the Ouergha basin upstream to Al Wahda dam experienced three major floods with hourly peaks ranging from 4000 m^3/s to 6030 m^3/s, which can be considered as a complex flood with a total volume of $3x10^9m^3$. The maximum outflow of the dam has reached 2000 m^3/s, with 67% as peak-flow reduction rate, while restraint exceeded the normal rating to 104% fill.

To better understand the sequence of events that occurred during the flood of September 2009 to January 2010, in the studied area, a hydraulic model was built with the aim of simulating the flow. Then, results were used in mapping flooded areas, which also allowed assessing the role of Al Wahda dam in the peak-flow reduction.

Building the hydraulic model

Device and tools used

Beavers (1994) performed some of the first work connecting the hydraulic modeling and GIS. This work was based on the same approach using HecRas (Hydrologic Engineering Center River Analysis System®)

which gives good predictions results as well as two-dimensional models (Horritt *and Bates*, 2002) and the ArcGis®. The Connection between the two programs is provided by the HEC-GEORAS extension dedicated to run on ArcGis (Cameron, 2011).

The whole (Figure 3) constitutes therefore a coherent computing tool that allows primarily to prepare the geometric data (preprocessing) then, to make the necessary calculations (simulation) and finally, to exploit the results (post-processing).

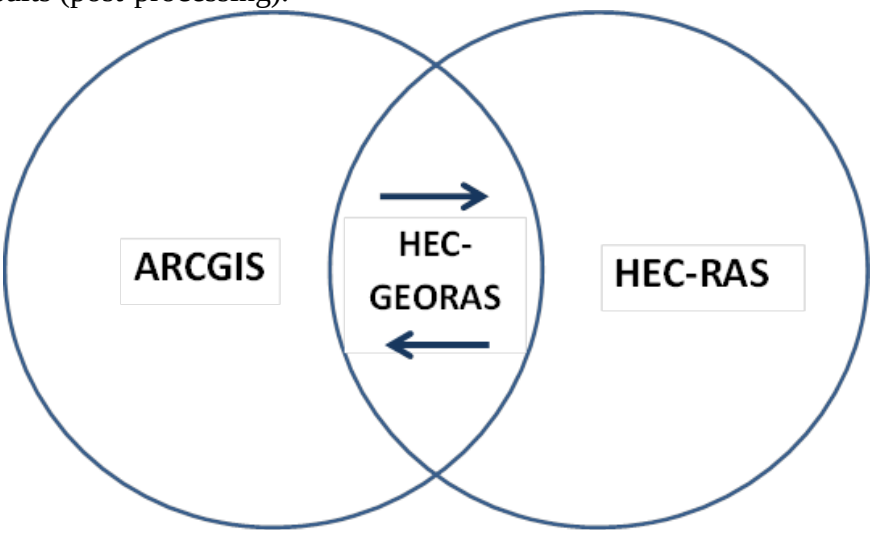

Figure 3: Schematic representation of the used computer device

The following products were used, as background to extract the elevation data and to digitize geometric entities:

* GDEM ASTER (ASTER: Advanced Space borne Thermal Emission and Reflection Radiometer, GDEM: Global Digital Elevation Model), developed jointly by the Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA). This is a high resolution Digital Elevation Model (30 meters) geo-referenced in WGS84 coordinates system, published in 1°x1° tiles, in GeoTIFF format with a margin of error equal to 12.6 m.

* Topographic maps at 1/50 000 scale, used to scan and verify some entities: stream lines, banks...

* The Google Earth® satellite images with much more information and details.

Stages of model development

At first, the geometry file was developed under ArcMap® using the Hec-GeoRas extension; the result is then exported and completed under HecRas®. Then, the flow file describing the initial conditions of the

boundary conditions was developed. The model was finally tested in order to correct any malfunctioning. Figure 4 presents the followed methodology.

Simulated events and selected parameters

The objective is to study the complex flood of December 19, 2009 to January 15, 2010. Both inflow and outflow peaks of Al Wahda dam storage have been considered in order to simulate the hydraulic behavior in downstream part of the Ouergha River. We chose the flow peaks that provide the following table (Table 1).

Tab. 1: The flow rates of simulated events

Date		**Inflow(m^3/s)**	**Outflow(m^3/s)**
21/12/09		3979	450
07/01/10		4704	600
14/01/10	6030	2000	

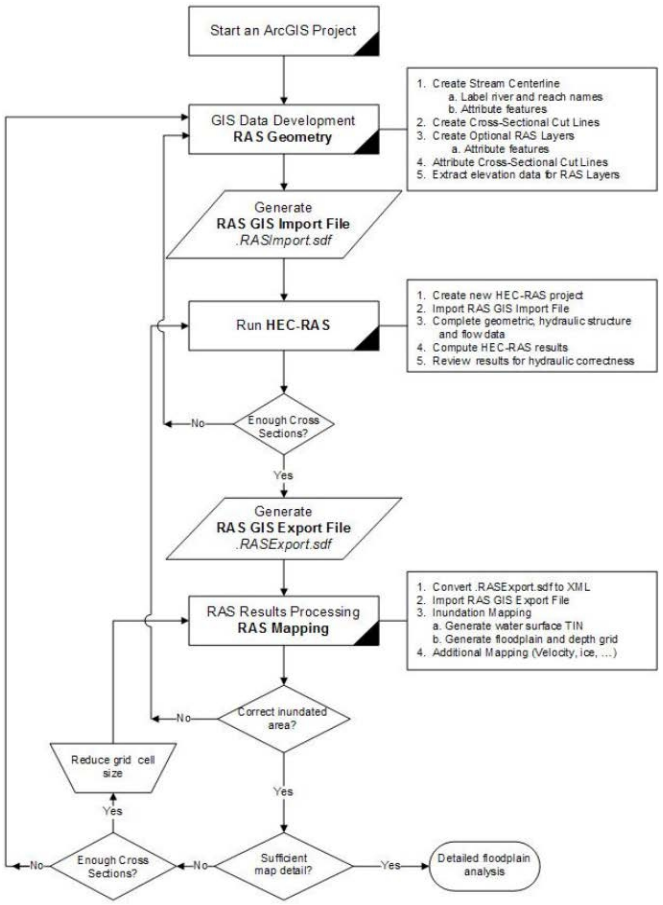

Figure 4: Diagram showing the methodology used in the modeling (Gary, 2010)

Boundary Conditions

In the case of steady flow with subcritical regime, only downstream conditions are required. We chose the condition: normal Depth that is about 4.10^{-4}.

Model Test and calibrating

After developing both geometry and flow files, several tests were conducted to assess the stability of the model.

While the model run correctly, the calibration is required. This was made possible by the existence of a dam upstream of the studied area. The releases rates are known and the corresponding downstream water surface levels are gauged. The final value chosen for the Manning coefficient after calibration is n=0.035.

Results and Discussions

Results of hydraulic modeling

The analysis of obtained graphs for rates relative to the three flood peaks mentioned above (that of 14/01/2010 in the Figure 5), showed that the water level corresponding to the inflow is significantly higher compared to the rates of releases. This explains the role of the dam in reducing peak flows and therefore, moderating the extent of downstream hydrological phenomena.

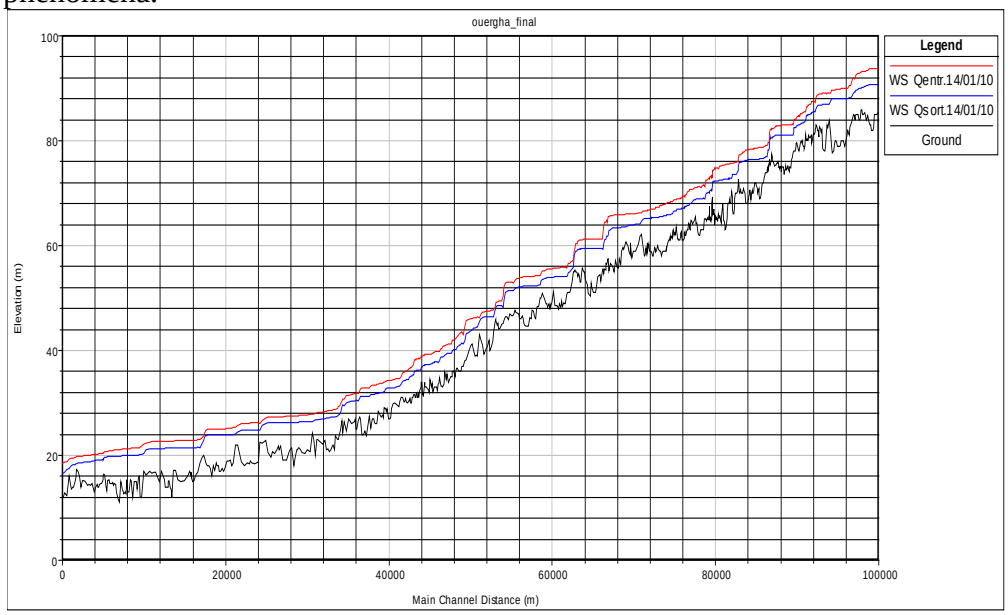

Figure 5: Resulting water profiles of the two inflow (WSQent) and outflow (WSQsort) of 14/01/2010.

The cross section shown in Figure 6 provides a comparison at this point, the heights of the resulting water flowing out *vs* the incoming flows.

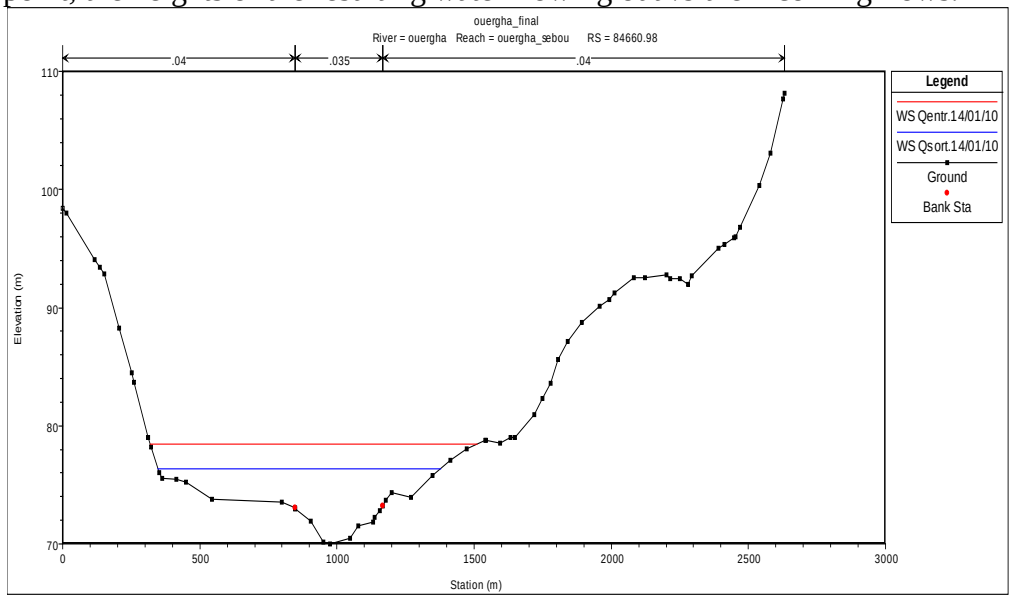

Figure 6: Resulting water levels of inflow and outflow of 14/01/2010 at the cross section 84660.98

Results of mapping

Based on the modeling results obtained by HEC-RAS and exported to ArcGIS, cartographic documents related to the extension of flooded areas for each calculated water profile were developed.

The overlay of both flooded areas corresponding to inflow and outflow peaks of the three major studied events (Figure 7), helped to visualize the role of the appropriate management of Al Wahda dam storage in the extenuation of hydrological extremes and therefore the protection against flooding downstream.

In fact, simulation results corresponding to the incoming flow at the dam can be considered as real flooding that would have happened in the absence of the dam, or in the case of bed management preparatory to the rainy season.

The analysis of these results reveals that the management of the dam helped to avoid a flood on December 21, 2009 and another one on January 07, 2010, when it failed to stop flooding on January 14, 2010. The dam storage has already reached an occupancy rate of 104%, but the flood amplitude was significantly attenuated.

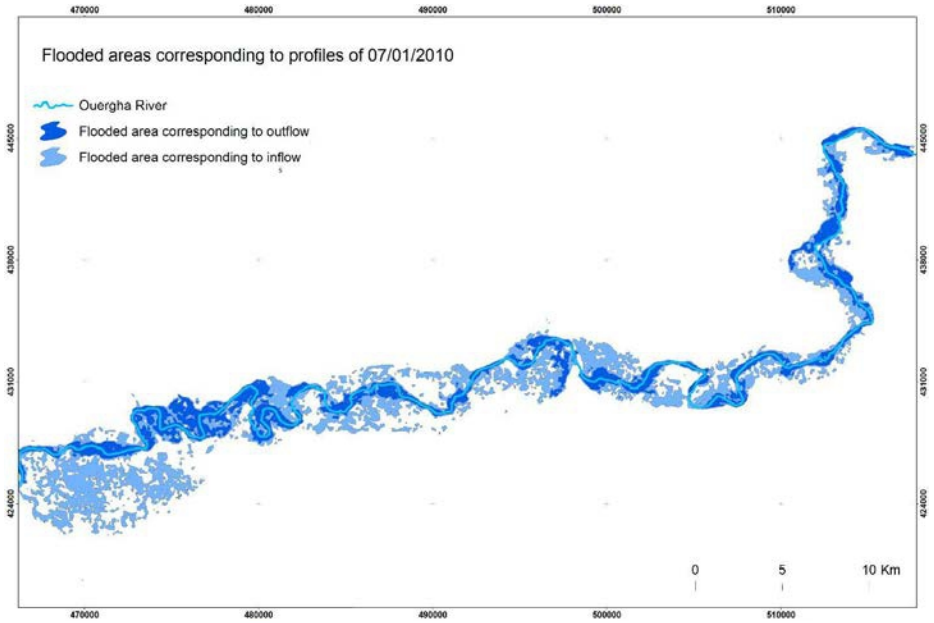

Figure 7: Flooded areas corresponding to profiles of 07/01/2010

Conclusion

The one-dimensional hydraulic model permitted to simulate the flow events that occurred at the Ouergha River downstream of Al Wahda dam.

The model was used to calculate the respective water profiles for three peak flows recorded during the floods having occurred between December 19, 2009 and January 18, 2010. The diagnostic of obtained results by ArcGis® permitted establishing the extension flood maps simulated for each calculated water profile. The analysis of the results showed that the preparatory management for rainy seasons has significantly attenuated the extent of flooding during this period.

The use of this kind of results based on hydraulic simulation and geographic information system can contribute meaningfully to develop strategies to fight against flood hazards that persist despite the existence of a large dam, because of the meteorological and hydrological extreme phenomena.

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