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Fluvial geomorphology and restoration: low reach of the Guadiamar River, National Park of Doñana, Spain

Rafael Baena Escudero and Inmaculada Guerrero Amador
Department of Physical Geography, University of Seville, Spain

Abstract

We report on the results of our studies of the hydrogeomorphological dynamics in the environs of Entremuros (low reach of the River Guadiamar). Three basic morphohydrological units have been found in the this sector, which is affected by high tide and gulder as well as flood discharges, generating particular dynamics surrounded by man-made elements. A passive restoration has been taken on for the different morphological features like «lucios» (cuvette decantation), «vetas» (levee), cuvettes, lateral banks,... in the guadiamar floodplain located in the Entremuros area.

Keywords: fluvial geomorphology, passive restoration, Guadiamar River, National Park of Doñana

Introduction

The mining spill on to the River Guadiamar at Boliden-Apirsa was considered one of the largest natural disaster in Europe in the last years [1] due to its magnitude (over 5 millions m^3 of toxic residual deposits like mud and acid water) and size (4,000 ha). In 1999 the Consejeria de Medio Ambiente undertook the restoration of the damaged sector by founding a new protected area named «Corredor Verde» (the Green Corridor) [2]. The closed area of the National and Natural Park of Doñana was selected to implement the scheme. This is the Entremuros area, where the acid water was stored to stop it reaching the National Park of Doñana.

This scheme aims to restore the geohydrogeological function of the marsh of the River Guadiamar according to three basic principles: the ecological integrity of the fluvial system and its geomorphological formations [3]; the potentiation of the dynamic component of the fluvial process (hydrical flows and sediments) and finally, to improve understanding of a passive riparian system of the main morphohydrological elements [4]. Our task focuses on the last two terms, introducing our research procedure in order to identify and analyse the main morphohydrological units and their functions in discharge and sediment dynamics from the last reach of the Guadiamar for passive restoration.

Field of research and method

The catchment area of the River Guadiamar is located in western Andalusia and extends some 1,285 km² between the northern foothills of the Sierra Morena and the southern depression of the River Guadalquivir (Figure 1b). It lies 60 kilometers from the western side of Seville and the last important tributary of the Guadalquivir flows on its left side for 120 km. Its average roughness is 415 m. It is a Mediteranean-Continental climate river with an Atlantic influence, and that means: a warm temperature, 569 mm rainfall a year, 5.48 m³/s of average discharges and extreme torrents (500–700m³/s of Qmax) that promote periodical floods in the low reach of the marsh of the Guadalquivir. The studied area is located in this low premarsh environment (35 m.o.s.l.) of smooth hillocks of Plio- Quaternary sand which is found in the marsh of the Guadalquivir. This lies within the National Park of Doñana and it is named «Entremuros» due to its walling in the 1960s (Figure 1a).

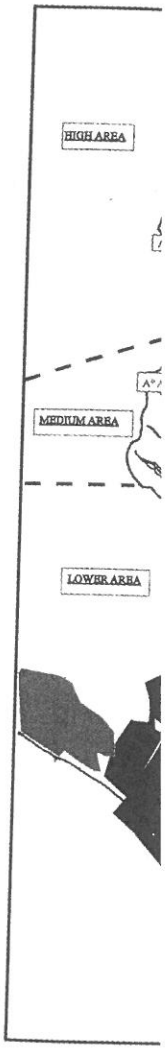
We started doing our research into the situation of the marsh in 1956, before the main man-made changes, like the building of two one-kilometer-wide walls of sand surrounding the flood-stage and a drainage channel within the River Guadiamar. Geomorphological cartography has been carried out at a scale of 1:30 000 by photointerpretation of the flight on 6 November 1956 and by later comparing it with the digital ortophoto of 1:8 000 scale of the flight on January 1999, as well as our fieldwork.

Analysis and results

The results of research into the situation of Entremuros in 1956 by identifying morphological elements on the map (Figure 2) highlights the mixed ecodynamic performance of the area, from a more continental stage to a more estuarine stage, depending on the discharge and the sedimentary charge from the Guadiamar, the Guadalquivir, and « Arroyo Majaberraque», as well as on the position held by the tidal obstruction inside the Brazo de la Torre. Three morphohydrologhical units can be found as follows:

A. La Tiesa–Vado de Don Simón Unit.

It is the most northern Unit and extends from the confluence of the River Guadiamar and the Stream Cigüeña and the Stream Cañada Honda to the confluence between the Madre Vieja del Guadiamar and the Stream Majaberraque. It is formed of a sequence of braided channels resulting from the considerable sedimentary accretion of small materials (sand and silt) from the Guadiamar. There is a sector of high group-sinuosity braided channels joined by sand-silt deposits (crevasse splay) obstructing and bypassing waterways. Another dynamic distortion element is the hydraulic drainage elements in agricultural activities to avoid inundation and instability in channels from the proximal floodplain. This unit is affected by ordinary increases in the main discharge. We understand that overflowing in stratum generates a crevasse splay in this near/proximal sector.



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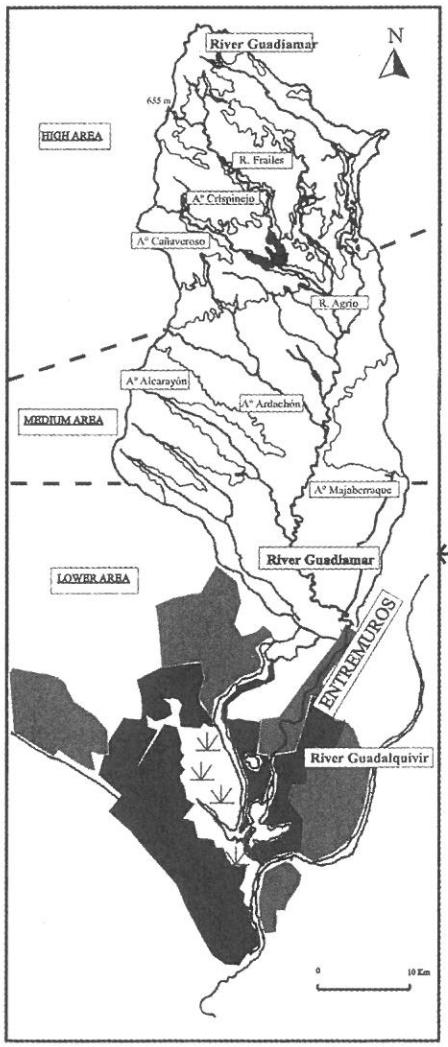


Figure 1a: Basin of the Guandimar River and situation of the Entremuros area

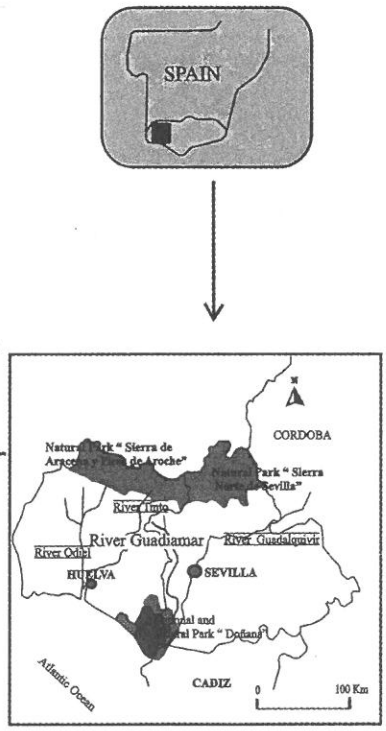


Figure 1b: River Guandimar in the western Andalucia

B. Brazo de la Torre–Norte de la Vuelta de la Arena Unit.

The calibrated bed of the Brazo de la Torre forms this unit, and it was the original location for the transition between the continental geomorphological domain of the River Guadiamar and

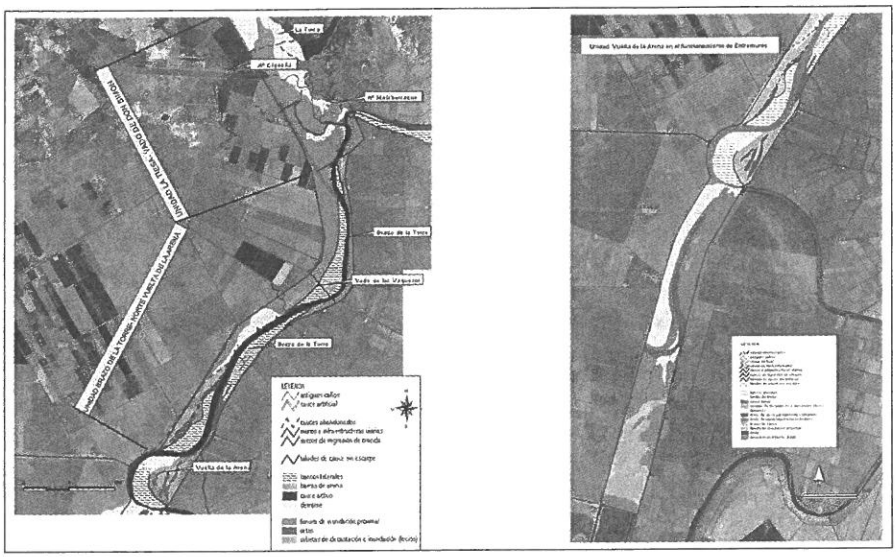
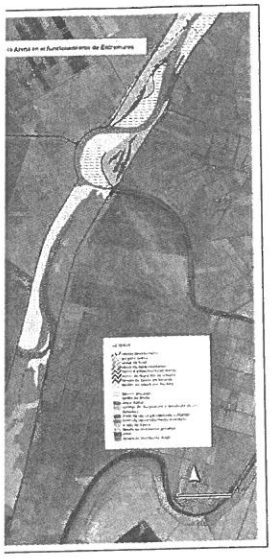


Figure 2: Morphohydrological units in Entremurous

the Brazo de la Torre estuary before man-made changes in the 1950s, reaching at nearest the tide impact the mouth of the new draining channel of the Guadiamar in Don Simon ford (Vado de Don Simón). It can be described as a calibrated and slightly winding bed and it is surrounded by many lagoon-shaped elements and fluvial-tidal lateral banks. These smooth morphological elements are below marsh level and their sediments come from a bank. The rapid action of overflowing in meanders generates a net longitudinal limit between these banks and the level ground.

The morphometric characteristics of this unit are similar to higher discharges than the Guadiamar, revealing an ancient origin as an estuarine branch of the Guadalquivir. This is the reason why the later filling by the Guadiamar (less than 5.48 m^3/s of discharge) contains a new smaller (width and depth) channel. Its ancient channel plays an important role. Most of it has disappeared due to agriculture activities, except the main segment, which is almost filled up. Furthermore, the channel from Brazo de la Torre generates a system of superficial depressions or «Lucios» (cuvettes decantation). They are located both in the proximal floodplain and in lateral banks retaining rain and floodwater from freshets. Therefore we are dealing with geohydroecological valuable seasonal lagoons, which control hydrical and sedimentary excess from alluvial systems.

The overflowing discharges settle suspended silt loads near the active channel, between lateral deposits and «lucios» (cuvette decantation), creating levees that are less than 50-cm-long extensions with smooth lateral slopes. They play a double role as sediment controllers and provider elements with hydrical flows in the floodplain. In this way, levees are essential morphological elements for retaining the morphological continuum of the river, as well as its spatial dynamics.



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C. Vuelta de la Arena–Southern Sector.

It lies in an area full of meanders in the eastern marsh of the Guadalquivir, from the Meander Vuelta de la Arena to the Meander Matochar near the mouth of the Guadalquivir. Its dynamics changed in the 1950s when its natural outlet through the Brazo de la Torre to the Guadalquivir was closed with a part of the Levant wall and an artificial channel (low discharge) was built in order to drain the active channel of the Guadiamar. This channel flows close to the Levant walls by the Meander Vuelta de la Arena and meets its mouth in the Brazo de la Torre in the low reach of the Matochar. As a result, the Caño Travieso area and the ancient marsh surrounded by the walls have turned into a cuvette decantation for freshet, giving the floodwater a double function: first, overflow lamination and sediments storage and decantion; afterwards, discharging water to the north and the east once the level decreases in the active channel from the Brazo de la Torre in the Vuelta de la Torre and in a man-made channel. Two morphohydrological sectors can be found before the ordinary movement of hydraulical flows in the Brazo de la Torre has been altered by the Levante wall. We deal with:

The Brazo de la Torre area lies from the Vuelta de la Arena to the Matochal. It is hydrologically a functional area of both ordinary fluvial discharge regime and tidal dynamics. There is an abundance of lateral banks, original morphological elements from this fluvial-estuarine system, as well as «lucios» (cuvette decantation) and «vetas» (levee) due to ancient channel fills or sedimentary dynamics in high-sinuosity meander areas like Vuelta de la Arena.

Discussion and conclusions

The longitudinal and transverse performance of Entremuros shapes smooth morphological profiles, where roughness can vary from a few centimetres to some meters. The main energy in the fluvial system originates from the flow inertia instead of the topographic gradient. The following two situations can be defined in the Entremuros area:

A. Low discharge dynamics and processes.

Concerning the ordinary discharges of the Guadiamar and its tributaries, the hydrical dynamics comprise only of the active channels. Nowadays they are formed by the man-made channel and its surface height depends on the rising tide storing fine sediments on it by sliding and flocculation. Draining discharges, obstruction process and rotary sliding in the left bank of the channel are otherwise found when there is a low water level or ebb tide. These dynamics took place throughout the channel of the Brazo de la Torre before 1956, as its lenght and width most likely promote the interaction of the continental and tidal flows. Thus, we guess that the fluvial riparian system must lead to a recovery of the original situation, before the area was enclosed by the Levant wall.

B. High-medium discharge dynamics and process.

On one hand, the effects of low flood flows depend on tidal level, causing overflowing through and over the lateral banks of meanders. These banks function as a «flood channel» and generate the minimum space for «fluvial freedom». On the other hand «mantle» flood dynamics appear

from the north to the south on the proximal plain when there are higher than 500 m^3/s flood discharges. These dynamics appear once the active channels and lateral banks are filled up. Both flows and sedimentary discharges are controlled by «vetas» (levees), whose position is in turn controlled by ground geometry and roughness.

But today the longitudinal profile has been changed by transverse buildings that accumulate a vast amount of sediments on channel and lateral banks. Its amount is gradually increasing by the approaching Vuelta de la Arena. The longitudinal profile has changed from Vado de los Vaqueros, promoting a flow removement to the headwater once the rising wave inertia is over. Re-establishing the main original components implies that the transversal channel profiles recover a low discharge and the hydromorphological process is activated

From all the above, we maintain that the recovery of the original dynamics must be aimed at the passive riparian system of the centimetre morphologies in the lateral banks and floodplains («lucios», cuvettes, «vetas» and lateral bank scarps) and in the channel, obtaining the optimal section of its hydraulic radius (perimeter, width and depth).

Acknowledgements

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