Hydrogeological characteristics of a groundwater-dependent ecosystem (La Lantejuela, Spain)

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Abstract
By means of a simple water balance model, together with hydrogeochemical and morphological interpretation, the hydrogeological characteristics of a series of playa lakes forming an endorheic complex within the Guadalquivir river basin in Southern Spain (La Lantejuela) have been evaluated. The lakes are demonstrated to be groundwater-dependent ecosystems. The main source of groundwater input to the lakes is from an unconfined detritic aquifer, the playa lakes being the natural discharge points from the aquifer within the endorheic complex. High rates of evaporation from the lakes induce a centripetal groundwater flow pattern. This water body has been disturbed by a combination of extensive drainage works and intensive groundwater abstraction. There is a need for a sustainable water management strategy for the whole catchment area. It is hoped this will be an issue addressed within the Guadalquivir river basin management plan in accordance with the requirements of the European Water Framework Directive (WFD).

Introduction
Throughout southern Spain, there exist numerous closed basins hosting playa lakes, where small mountain ranges or hills separate semi-arid basins (García et al. 1997; Montes et al. 2004). Ephemeral playa lakes occur in arid to semi-arid environments whenever internally drained basins are formed by tectonic activity or dissolution processes, and the floor of such basins intersects the water table (Duffy & Al-Hassan 1988). Rainfall onto the related aquifers or the catchment area of the playas enters the groundwater through permeable materials overlying the impervious substratum. Normally, the substratum is related to the presence of Triassic sediments, which outcrop abundantly in the Betic Cordillera (Vera 2004) and present very low hydraulic conductivity. The groundwater returns to the surface in the form of springs, rivers or discharge to the playa lake system. However, a second type of circulation, which is unique to a closed basin, may also occur. Evaporation concentrates the playa lake water, which turns into a brine. This brine, which is much denser, may flow into the fresher groundwater. As long as brine is supplied, cellular flow circulation may take place below the playa lake bottom until it reaches the impermeable substratum. This scenario is known as ‘free convective flow’ (Fan et al. 1997).

The surface–groundwater relation between the playa lakes and the unconfined aquifers in the area is of evident interest in the correct management of such ecosystems, which are very sensitive to hydrological alterations such as groundwater pumping or surface drainage. The Water Framework Directive (WFD), which is applicable in all the member states, encourages the investigation of groundwater-dependent ecosystems (WFD-CISNo.2 2002, 2003). Finally, this type of methodology could help close the present gap that exists between water managers and researchers (Borowski & Hare 2007), thanks to its simplicity. The main objectives to be addressed in this work are (i) to describe the detritic aquifer Osuna-La Lantejuela (O-LL), about which only a few hydrogeological studies have previously been published; (ii) to investigate the hydrological relations between this aquifer and the playa lakes of La Lantejuela by means of a simple water budget and (iii) to carry out a preliminary hypothesis on the genesis of these systems.

Main exposition

Methods

Study site
The study zone is located near the town of Osuna in the southeast of the province of Seville (Andalusia, Spain) (Fig. 1).