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Hydrological response to an environmental flood: Pulse flow 2014 on the Colorado River Delta

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ABSTRACT

Increasing pressure on water availability in the Colorado River Basin due to a long and severe drought, water over-allocation, increasing water demands, and a warming climate point toward the need to optimize use of water to meet all goals, including environmental restoration. In this paper, we analyze the hydrologic response of the Colorado River Delta to the 2014 pulse flow. In so doing, we identify hydrological criteria for optimizing the use of water for riparian restoration. We analyzed continuous hydrographs obtained from discharge measurement sites along the river channel, quantified areas inundated by water, and interpreted groundwater dynamics and their implications for riparian vegetation. Our most important finding is that 91.4% of the delivered water infiltrated into the first 61.2 km of the riverbed (between Morelos Dam and Pescaderos), recharging the underlying aquifer. This large volume of infiltration occurred mainly because several obstructions along the main channel impeded downstream surface flow, abandoned river meanders acted as infiltration basins, sandy riverbed and terrace sediments allowed for rapid infiltration, and a depressed groundwater table created a large unsaturated zone to fill. Most of the water was delivered at Morelos Dam. However, smaller water deliveries via Mexicali Valley's irrigation canal system bypassed the reaches of maximum infiltration, enabling the achievement of longitudinal river connectivity from Morelos Dam to the Gulf of California, and inundating important flood-dependent restoration sites. To optimize future environmental water deliveries, we encourage the use of irrigation infrastructure to deliver water directly to specific restoration sites to the extent possible, thereby avoiding reaches with high infiltration capacity and low riparian restoration potential. To improve river channel functionality in high-infiltration reaches, we recommend strategies to flood only the main channel and avoid off-channel depressions. By considering hydrological responses to environmental flow deliveries, riparian restoration goals can be achieved efficiently, even in highly controlled rivers with limited water availability.

1. Introduction

Hydrological and ecological responses of regulated rivers to environmental flows have been studied for several years (Merritt and Poff, 2010; Stanford et al., 1996; Tockner et al., 2000). The Colorado River (CR) is one of the most regulated rivers in the world; as a result, its delta in particular is completely transformed (Glenn et al., 2013; Schmidt, 2007). There, riparian habitat is severely degraded due to a nearly complete lack of streamflow.

Since 2003, water use in the CR has exceeded supply (Bureau of Reclamation 2015) due to an annual over-allocation of more than 3700 million cubic meters (hm^3) (Getches, 2003), continually increasing demands, and prolonged drought (Ellis et al., 2010). The expectation of water availability in the near future is not encouraging (Cayan et al., 2010). Global climate models predict that human-induced climate change will reduce runoff in the CR basin by 10–30% (Barnett et al., 2009). Therefore, water use for environmental purposes must be highly efficient in order to restore degraded riparian habitat using far less water than flowed under natural conditions. Understanding hydrological responses to environmental water deliveries is key to achieving this goal.

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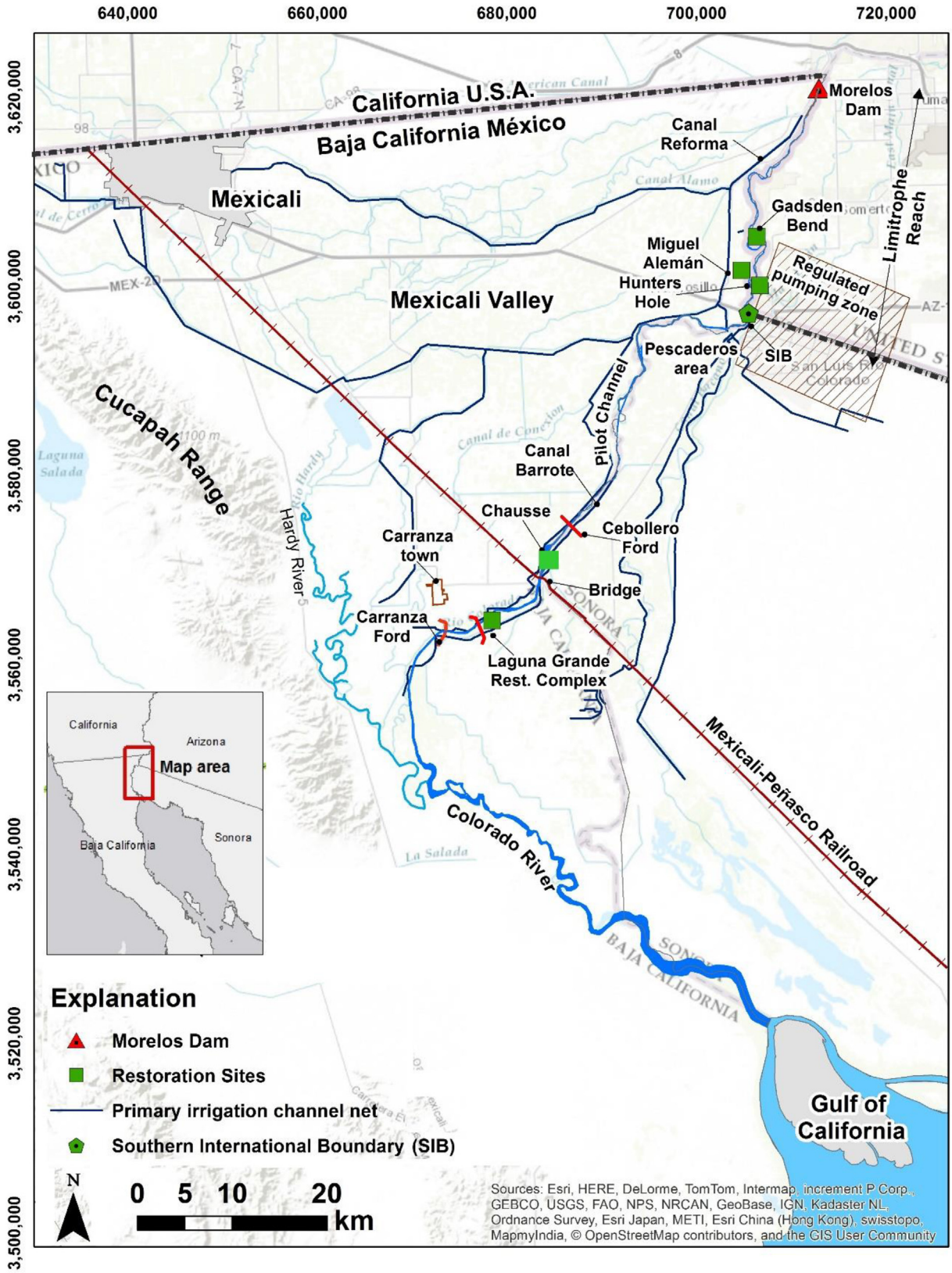

Fig. 1. Map of the Colorado River delta region showing the restoration sites along the riparian corridor.

Currently, only 1850 hm^3 of water discharges to the CR delta from the United States of America (USA) annually, according to the binational Water Treaty signed in 1944 by USA and México (CILA, 1944). All of the water allocated to México is diverted at José María Morelos Diversion Dam (Morelos Dam) into the irrigation canal system for consumptive uses (Fig. 1). Nevertheless, during exceptionally wet years in the 1980s and 1990s, when users did not request surplus water, extreme high-flow events allowed water