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Recognizing spatial heterogeneity in aquifer distributions and characterizing groundwater dynamics in NW India

Sinha, RAJIV[1], Densmore, ALEXANDER [2], Gupta, SANJEEV[3], Joshi, SUNEEL[1], Nayak, NIBEDITA[1], Rai, S.P.[4], Shekhar, SHASHANK[5], Van Dijk, WOUT[2], Singh, AJIT[1,3]

[1]Department of Earth Sciences, Indian Institute of Technology Kanpur, India (rsinha@iitk.ac.in)
[2]Department of Geography, University of Durham, UK
[3]Department of Earth Sciences and Engineering, Imperial College London, UK
[4]National Institute of Hydrology, Roorkee, India
[5]Department of Geology, University of Delhi, Delhi, India

The northwestern state of Indian such as Punjab, Haryana and Rajasthan have seen an unprecedented groundwater decline during the last 4-5 decades primarily due to large scale groundwater abstraction for agricultural production. A mean rate of groundwater decline of ~4 cm/yr and regional depletion rates of ~20 Gt/yr have been suggested from 10 years of GRACE measurements by earlier workers and this has made this region as one of the largest hotspots of groundwater depletion in the world. Increasing demands from a burgeoning population and industrialization has made the situation worse and the potential impacts of climate-driven changes on groundwater systems are largely unknown. Aquifer systems in northwestern India are thought to be largely hosted within narrow, buried sand bodies which represent former river channels, which extend from the Himalayas toward the southwest and are separated by fine-grained muds. The alluvial surface of this region is generally devoid of any major river channels at present and the existence of such buried channels has to be based on interpretation of sub-surface data or geophysical surveys. Asustainable groundwater management strategy needs several questions to be answered: (a) What is the spatial distribution of groundwater depletion? (b) How are aquifer bodies distributed in the sub-surface, and what controls this distribution? (c) What are the sources and residence times of the groundwater in different parts of the system? (d) How connected are the aquifers, and how has connectivity changed in recent geological time?

Our recent research based on the historial groundwater level data suggest that the greatest decline in groundwater levels during the last four decades has occurred within the Ghaggar River basin along the Punjab-Haryana border, with broader areas of loss across central Punjab and Haryana. Estimates of rainfall, abstraction, and tubewell densities for 10x10 km grids, and their changes over the time period, do not match these patterns and so cannot, by themselves, explain the observed decline. It is therefore important to understand the geology and geometry of the aquifer system defined by the buried channels before we can hope to estimate the way it will respond to a complex set of present and future stresses. An efficient way to do this is to combine stratigraphic investigations aimed at documenting how aquifer-body geometry and properties vary across the region, with geomorphic investigations of the river systems that have deposited those aquifer bodies. This powerful combination of surface and sub-surface data gives us a conceptual or predictive model for aquifer body dimensions and how they vary across the region. We find that the aquifer system in NW India consists of large sedimentary fans deposited by the Sutlej and Yamuna rivers that sets the thickness, stacking pattern, and connectivity of individual aquifer bodies. These individual bodies are limited in both thickness and width, and not laterally extensive. The number, dimensions, and connectivity of the aquifer bodies in turn help to determine the magnitude of groundwater decline. Further, isotopic signatures of groundwater samples from this region show that the groundwater above 60m bgl is recharged by direct infiltration of precipitation through canal or river. However, groundwater below 60m bgl is older possibly recharged under different hydro-meteorological conditions. We note a remarkable longitudinal disconnectivity in groundwater structure as reflected from electrical conductivity & isotopic variability in upstream and downstream reaches of the Ghaggar basin. The rapid drawdown of the NW Indian aquifer system indicates that management of alluvial aquifers in India now needs a serious rethink. The combination of geomorphic and stratigraphic mapping, made possible by the wealth of data held by CGWB and state groundwater boards as well as the advent of new technologies of terrain mapping, is a promising but unexplored approach.