Managing groundwater in the Indus Basin Irrigation System of Pakistan

Sustainable conjunctive management of Pakistan's surface and groundwater resources is critical for national, provincial, and local economies. In the Indus basin irrigation system (IBIS), there is a strong linkage between the surface and groundwater resources where increases in groundwater use impact surface water losses. In areas of freshwater groundwater, levels continue to drop while in saline areas there are issues of waterlogging and expansion of saline areas. To help sustainably manage this resource, a new regional 5km-resolution groundwater model is being built for entire IBIS in Pakistan. When integrated with the Indus river system model it will quantify the total water resource and will help to support the national policy by providing an understanding of the impacts of different management and development options.

Background

In the Indus Basin Irrigation System (IBIS) in Pakistan, the area under irrigation has expanded greatly over the past five decades enhancing agricultural production to meet food and fibre demands. However, one of the key drivers for the expansion is a massive increase in groundwater use for irrigation. As a result, in areas of fresh groundwater quality, almost half of the irrigation supplies come from groundwater. There is a strong linkage between the surface and groundwater resources, hence due to the increasing demand from increased population and subsequent increases in irrigation areas the associated water demands have been met through increased groundwater usage, which in turn has impacted surface water losses. In areas of freshwater groundwater levels continue to drop while in saline areas there are issues of water logging and expansion of saline areas. There is a need to jointly sustainably manage surface and groundwater resources. To be able to do this effectively models need to be developed that consider the interaction between surface and groundwater systems. To date there is no regional scale groundwater model that covers the IBIS.

Purpose

A 5km-resolution regional MODFLOW groundwater model will provide a defensible understanding of the overall groundwater budgets on a regional and sub-regional scale and, in future, will provide a linkage to finer resolution child models in areas of interest (such as hotspots of salinity). Capacity builiding in groundwater modelling in Pakistan will ensure stakeholders in Pakistan (e.g. WAPDA, PID, SID), have a common modelling platform and skills to use it.

The model's primary objective is to better understand the interaction of shallow aquifers with surface water in irrigated areas. Of particular interest will be to visualise areas where groundwater usage could affect river streamflow. Another focus of surface-groundwater interaction could be the coupling of the Indus-basin wide SOURCE river system model to the groundwater model for a more defensible understanding of the total water resource. This linkage will help build a national integrated water resource plan for the IBIS.

Future child models coupled to this coarser resolution parent model can assess storage potentials of individual doabs or canal command areas, better represent the distribution of crop water use, and contain their own focused salinity analyses.

Extent

The groundwater model extends horizontally across the entire irrigated Indus basin of Pakistan and beyond encompassing the entire quaternary alluvial basin (Figure 1a) as well as surrounding areas that may influence boundary flows, such as metropolitan water users, the Indus delta, and mountain-front recharge from the Himalayas. It is limited vertically to the alluvial aquifer of the Indus basin as the primary focus is surface-groundwater interaction.

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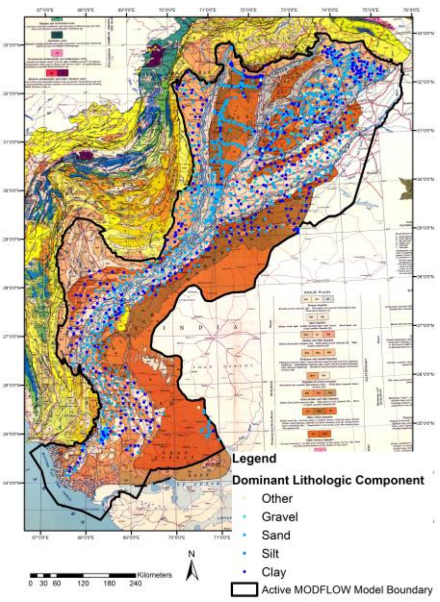

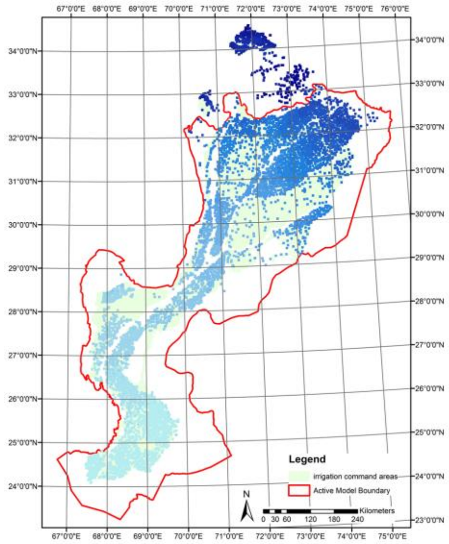

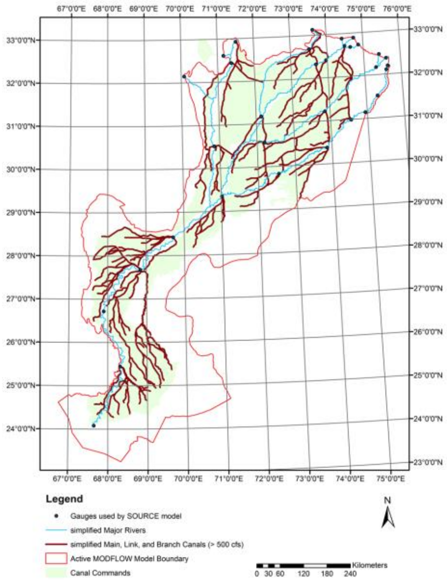

Figure 1: (a) Active MODFLOW model boundary of Quaternary Alluvial Aquifer and (b) Dominant lithology in borelogs

Figure 2: Waterlevels in the Indus Basin, KPK, and Peshawar

Figure 3: Simplified river and canal conveyance system

Data legacy

Data supplied by WAPDA, PID, and SID has resulted in a national compendium of hydrologic data:

(1) A geohydrologic framework was created based on digitized and georeferenced borelog lithology (Figure 1b). This framework allows for the delineation of the base of the alluvial aquifer and the association of major lithologic component with typical ranges of hyraulic parameters.

(2) A separate database was developed for observed hydraulic parameters.

(3) Water level data were organised in a common georeferenced database (Figure 2) and can now be used for water level trend analysis, contour maps, initial heads for the groundwater model, and the calibration of simulated heads.

Boundaries and boundary conditions

Previous doab-scale models assumed vertical-flux domination and no flows across no-flow boundaries formed by doab-bounding rivers. In contrast, a regional model can simulate horizontal groundwater flow across doab-bounding rivers induced by excessive groundwater extraction for irrigation and urban water in neighbouring doabs/areas. This transition from initial vertical-flux domination to ever increasing horizontal boundary flows is addressed by the regional model, or, in the case of potenial future doab-level child models, by dynamic parent-child boundary conditions.

By extending the external model boundaries to hard-rock formations (no-flow) and to the coast (general-head), river boundaries will be used no longer as external boundaries of doabs, but – along with the canal network – as internal sources or sinks of stream seepage into the aquifer or groundwater discharge into streams (Figure 3).

The calculated stream-aquifer interaction will also allow for a future linkage to the SOURCE river system model. This opens the door for future scenarios that help formulate constraints on streamflow, such as Global Climate Models and related changes in river streamflow.

Recharge into and evapotranspiration from groundwater, mountainfront recharge, and supplemental groundwater pumping and irrigation recharge are also considered in the IBIS groundwater model.

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FOR FURTHER INFORMATION

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