Supplementary Materials

The SWAT Calibration and Uncertainty Procedures (SWAT-CUP) developed by Abbaspour et al. [1] were used for parameter sensitivity analysis and model calibration of the KRB SWAT model. In this study, the sequential uncertainty fitting (SUFI2) algorithm was used. With global sensitivity analyses of 100 SWAT-CUP runs considering the Nash-Sutcliffe Efficiency (NSE) [2] as the objective function. Twenty-nine major runoff and flow parameters were selected in the KRB SWAT model sensitivity analyses. Parameter values after SWAT-CUP model calibration are listed in Table S1.

Table S1. Major runoff and flow parameters in the KRB SWAT modelling

No	Parameter	Description	Best value
1	SFTMP	Snowfall temperature (°C)	-1.85
2	SMTMP	Snow melt base temperature (°C)	2.75
3	SMFMX	Maximum melt rate for snow during year (mm/°C/day)	5.70
4	SMFMN	Minimum melt rate for snow during the year (mm/°C/day)	2.75
5	TIMP	Snowpack temperature lag factor	0.05
6	PLAPS	Precipitation lapse rate (mm/km)	7.10
7	TLAPS	Temperature lapse rate (°C/km)	6.25
8	SNO_SUB	Initial snow water content (mm)	20.0
9	ALPHA_BF	Baseflow alpha-factor (days)	0.35
10	GW_DELAY	Groundwater delay (days)	265
11	GWQMN	Threshold depth of water required for return flow to occur (mm)	3050
12	REVAPMN	Threshold depth of water for "revap" to occur (mm)	450
13	GW_REVAP	Groundwater "revap" coefficient	0.10
14	RCHRG_DP	Deep aquifer percolation fraction	0.05
15	SOL_Z	Depth from soil surface to bottom of layer (mm)	-0.05*
16	SOL_BD	Moist bulk density (m^3/m^3)	0.10*
17	SOL_AWC	Available water capacity of the soil layer (mm)	0.03*
18	SOL_K	Saturated hydraulic conductivity (mm/hr)	0.06*
19	SOL_ALB	Moist soil albedo	0.15*
20	SOL_CRK	Crack volume potential of soil	0.05
21	CANMX	Maximum canopy storage (mm)	9.65*
22	ESCO	Soil evaporation compensation factor	0.75
23	EPCO	Plant uptake compensation factor	0.65
24	SURLAG	Surface runoff lag time (days)	2.50
25	OV_N	Manning's "n" value for overland flow	-0.10*
26	SLSUBBSN	Average slope length (m)	-0.05*
27	CN2	SCS runoff curve number	-0.11*
28	CH_N2	Manning's "n" value for the main channel	0.055
29	CH_K2	Effective hydraulic conductivity in the main channel (mm/hr)	15.5

Figure S1 shows a good match between the observed and simulated daily Kabul River flows at the Nowshera station "near Motorway-1 Bridge" from 2008 to 2014 over the calibration period with bias of 3.4%, NSE of 0.74, and R^2 of 0.80.

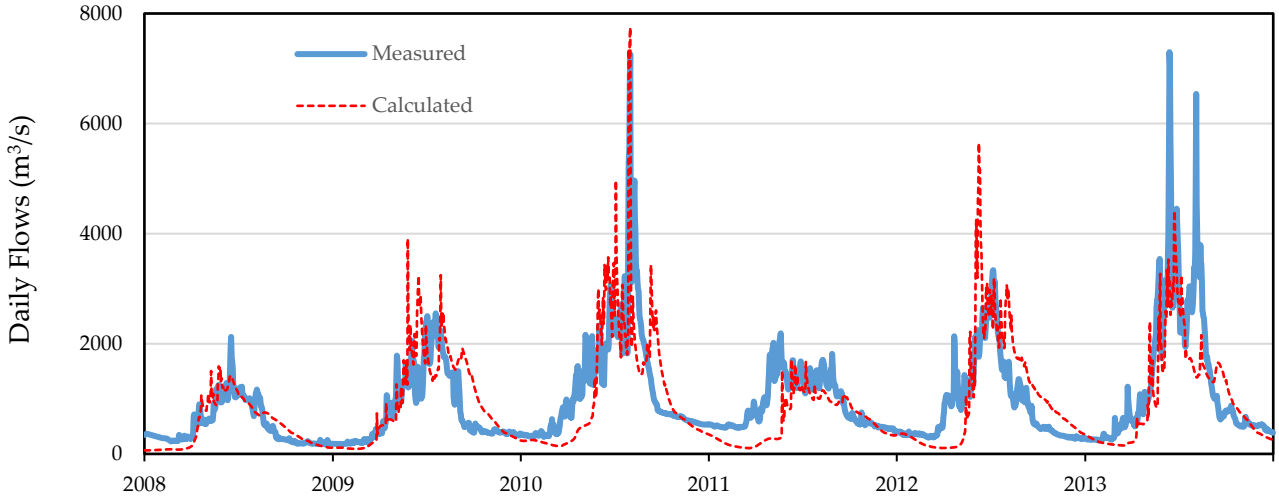

Figure S1. *Measured and SWAT model calculated daily Kabul River flows at the Nowshera station*

HEC-RAS Model for Flood Innundation Mapping

In this study, Hydrologic Engineering Center (HEC) River Analysis System (RAS) was used to develop the flood innundation maps under different historic and future climate scenarios with and without the proposed dams. HEC-RAS was developed by the United States Army Corps of Engineers [3]. The urban area of Nowshera was chosen as case study to determine the flood flow impacts. The HEC-RAS model was calibrated using the 2010 flood event in Nowshera based on the observed water level and satellite-based flood inundation imagery. The main calibration parameters in the HEC-RAS model, include the Manning's Roughness Coefficient and the river channel geometry and slope (obtained from the Digital levelation Maps). Manning's Roughness Coefficient values used in this research for different Kabul River zones were 0.04 and 0.15 for the main channel and the flood plains [4].

References

1. Abbaspour, K.C., Johnson, C.A. and Van Genuchten, M.T., 2004. Estimating uncertain flow and transport prameters using a sequential uncertainty fitting procedure. *Vadose Zone Journal*, *3*(4), pp.1340-1352.

2. Nash, J. E., & Sutcliffe, J. V. (1970). River flow forecasting through conceptual models part I—A discussion of principles. *Journal of hydrology*, *10*(3), 282-290.

3. Yuan, Y., & Qaiser, K. (2011). *Floodplain modeling in the Kansas river basin using hydrologic engineering center (HEC) models: impacts of urbanization and wetlands for mitigation*. US Environmental Protection Agency, Office of Research and Development.

4. Khattak, M. S., Anwar, F., Saeed, T. U., Sharif, M., Sheraz, K., & Ahmed, A. (2016). Floodplain mapping using HEC-RAS and ArcGIS: A case study of Kabul River. *Arabian Journal for Science and Engineering*, *41*(4), 1375-1390.