Reliability and Vulnerability Assessment using Global Sensitivity Analysis
Case Study of Saskatchewan River Basin

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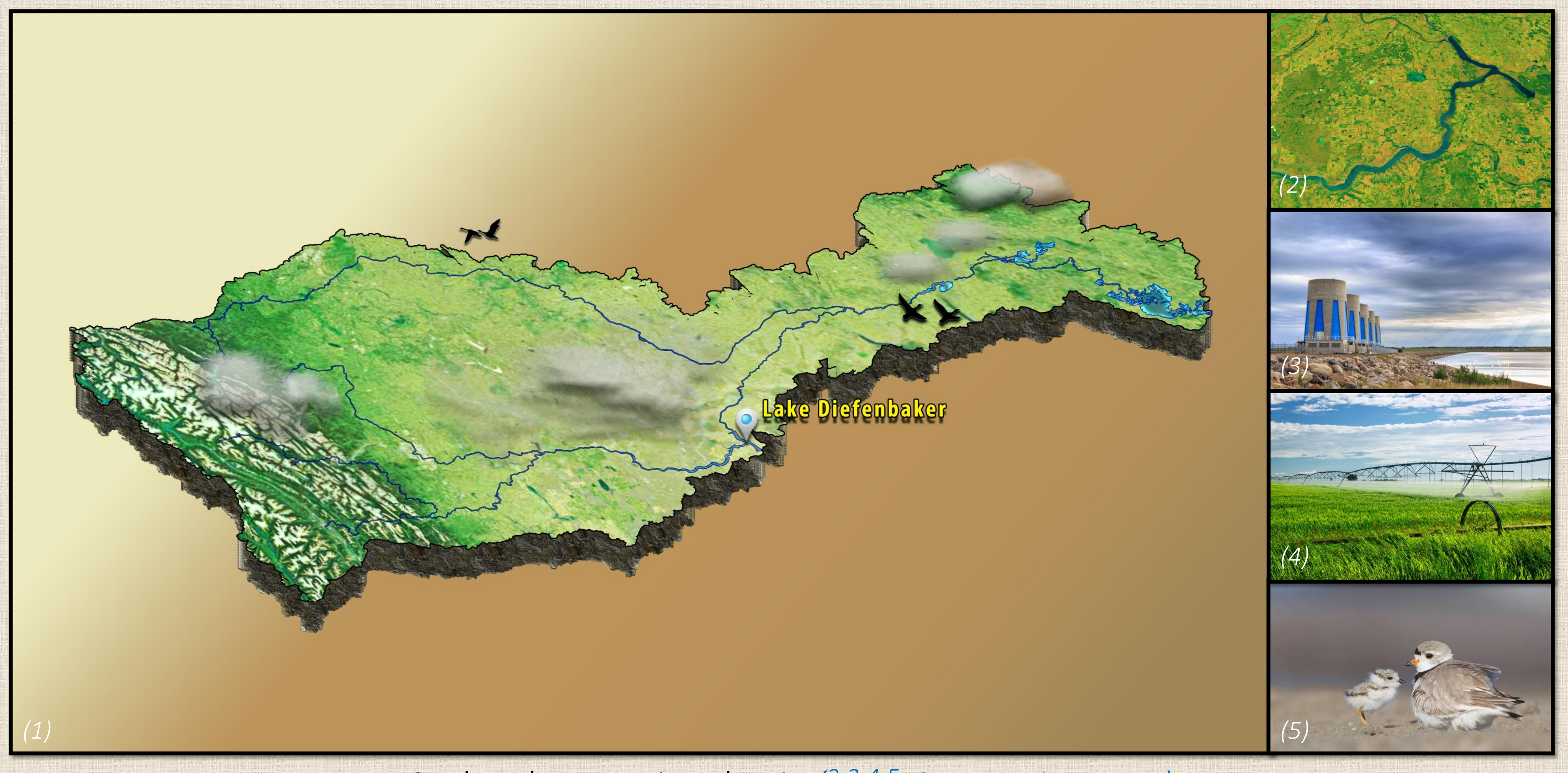
VISION

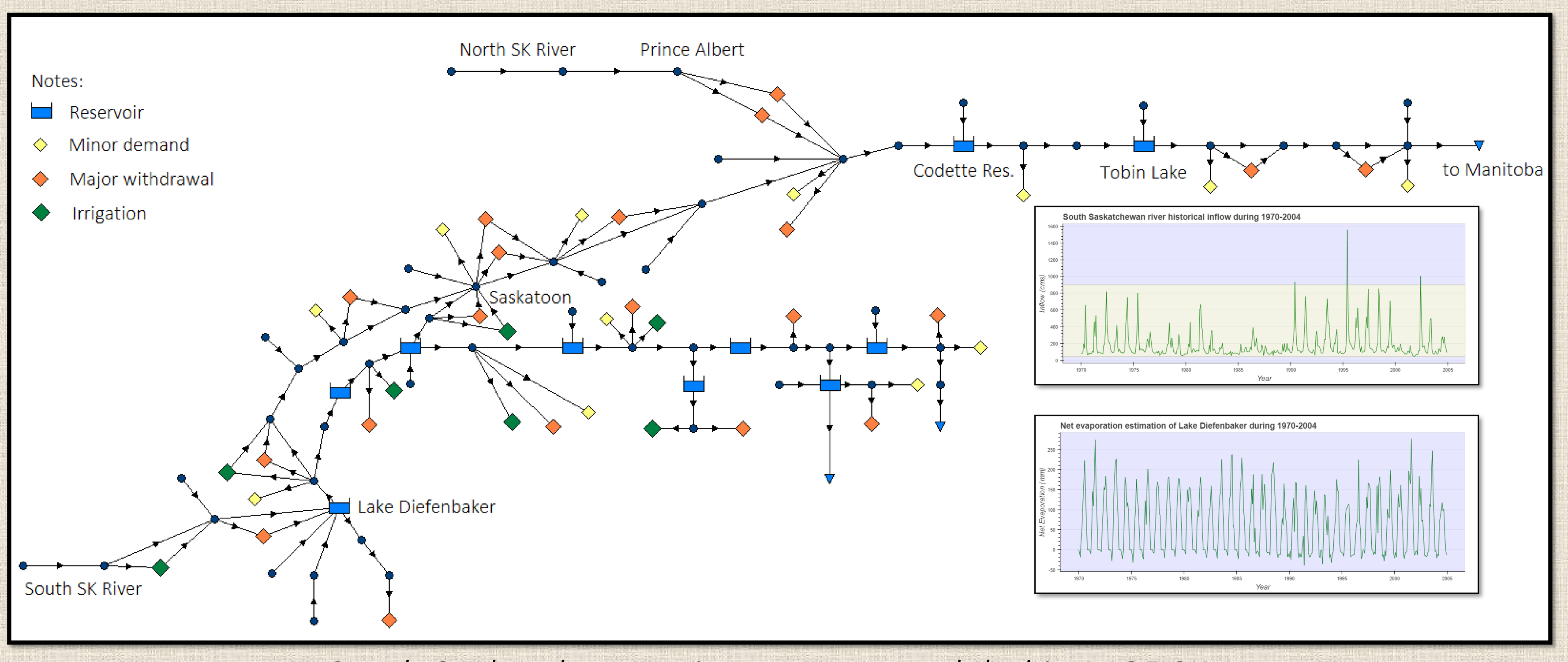
This research aims to develop a novel framework for identifying robust adaptation options and water resource vulnerability that account for deep uncertainty in future climate change and population growth impacts.

The case study is a water management model simulating the operation of Saskatchewan (SK) River system including the Lake Diefenbaker within the boarder of the province of Saskatchewan. The vulnerability, resilience and reliability of the water resources system are assessed by the use of a global sensitivity analysis tool, namely VARS *(Razavi and Gupta, 2016a)*.



Saskatchewan river basin ([2,3,4,5]-Source: internet)

TOOLS & METHODS



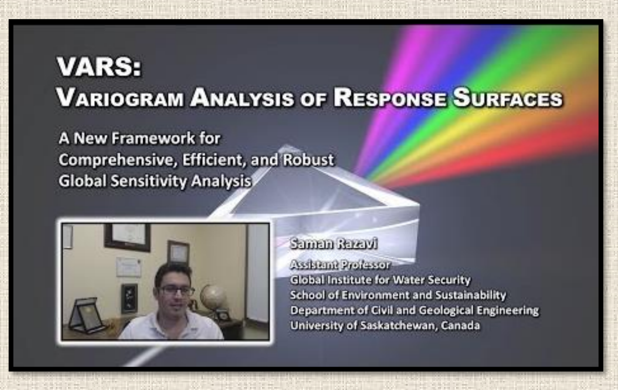
South Saskatchewan river system modeled in MODSIM

➢ MODSIM water management model

MODSIM-DSS software package is a generalized river basin Decision Support System and network flow model designed for basin-scale simulation of various components of water management.

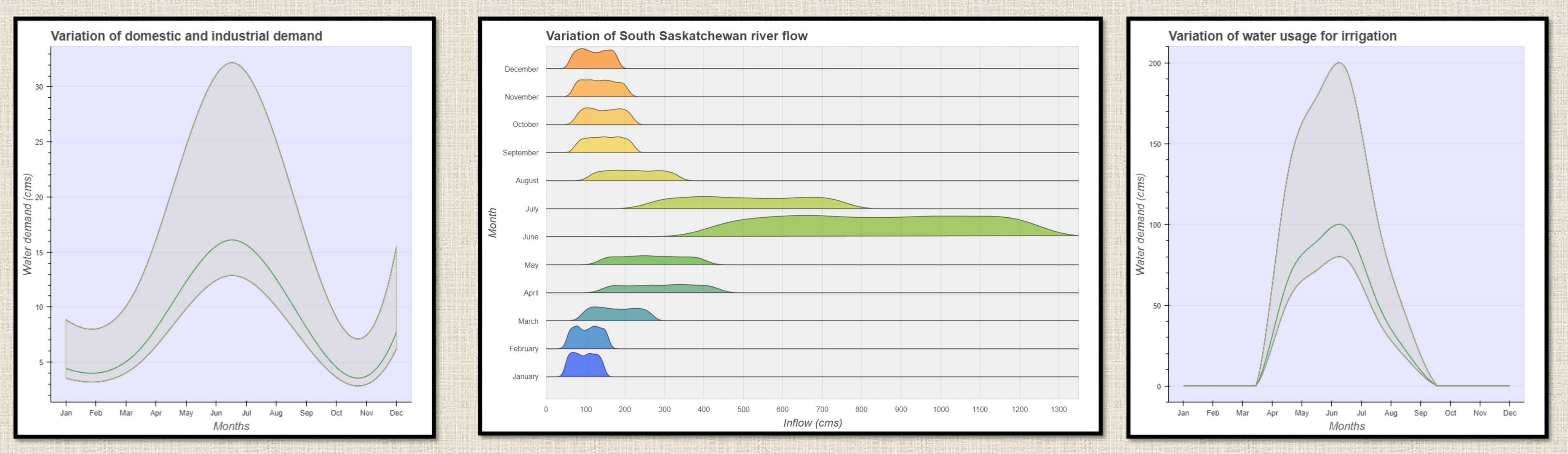
The Saskatchewan river system consists of the South SK river, North SK river, SK River, 10 reservoirs, and 38 water user categories. The system is integrated into MODSIM model and validated by comparing the model results with that of the Water Resources Management Model (WRMM), used by Saskatchewan Water Security Agency and Alberta Environment and Parks.

➢ VARS model



Based on an analogy to variogram analysis, VARS is designed to provide an intuitive and comprehensive characterization of sensitivity across the full spectrum of scales in the factor space *(Razavi and Gupta, 2016a, 2016b)*.

➢ Uncertainty



Example of uncertainty sources in South Saskatchewan river system

Uncertainty range of input parameters

#	Parameter multipliers	Range	#	Parameter multipliers	Range
1	Inflow of South SK river from May-Sep	0.5 ÷ 1.5	5	Irrigation	0.8 ÷ 2.0
2	Inflow of South SK river from Oct-Apr	0.5 ÷ 1.5	6	Inflow of North SK river from May-Sep	0.5 ÷ 1.5
3	Net evaporation of Lake Diefenbaker	0.5 ÷ 2.0	7	Inflow of North SK river fromOct-Apr	0.5 ÷ 1.5
4	Minor/Major Demand	0.8 ÷ 2.0			

➢ Assessment criteria

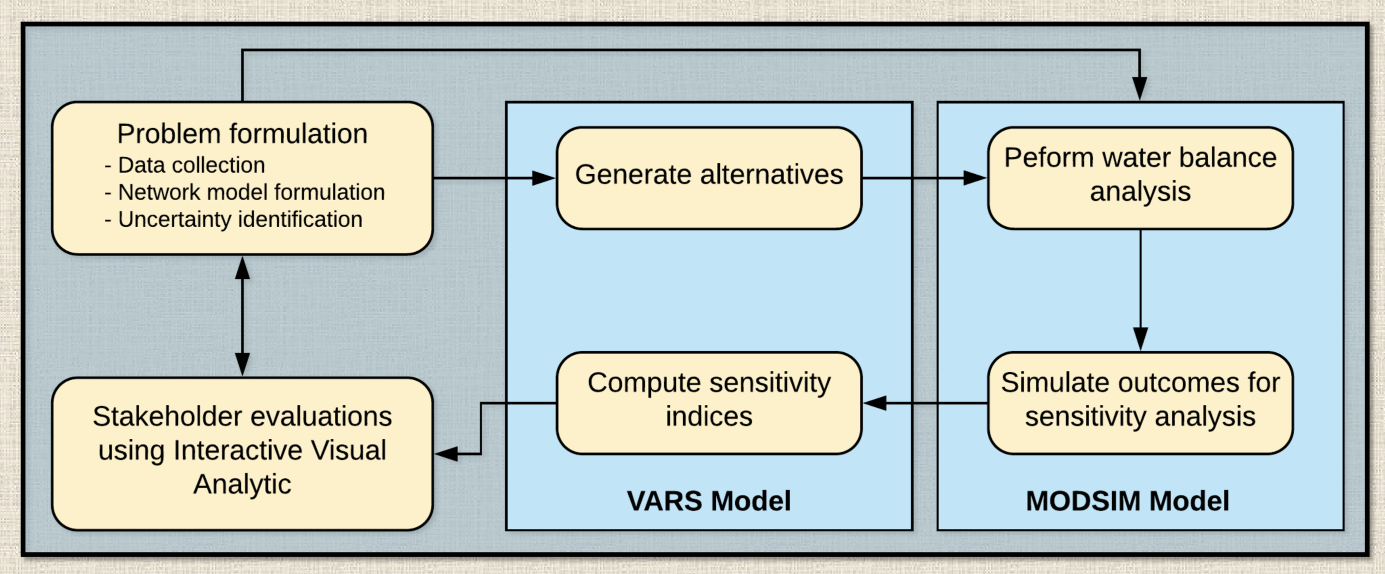
Reliability criteria: the probability that a system resides in a satisfactory state. Five reliability measures are assessed in this study, including: environmental flow, flood control, water supply, piping plover nesting habitat, and recreational activities .

Vulnerability criteria: the degree, to which a system is susceptible to, or unable to cope with, adverse effects of environmental change. Two vulnerability measures are considered: (1) the ability of the system to meet water demand in subsequent years and (2) the ability of the system to meet hydropower requirement.

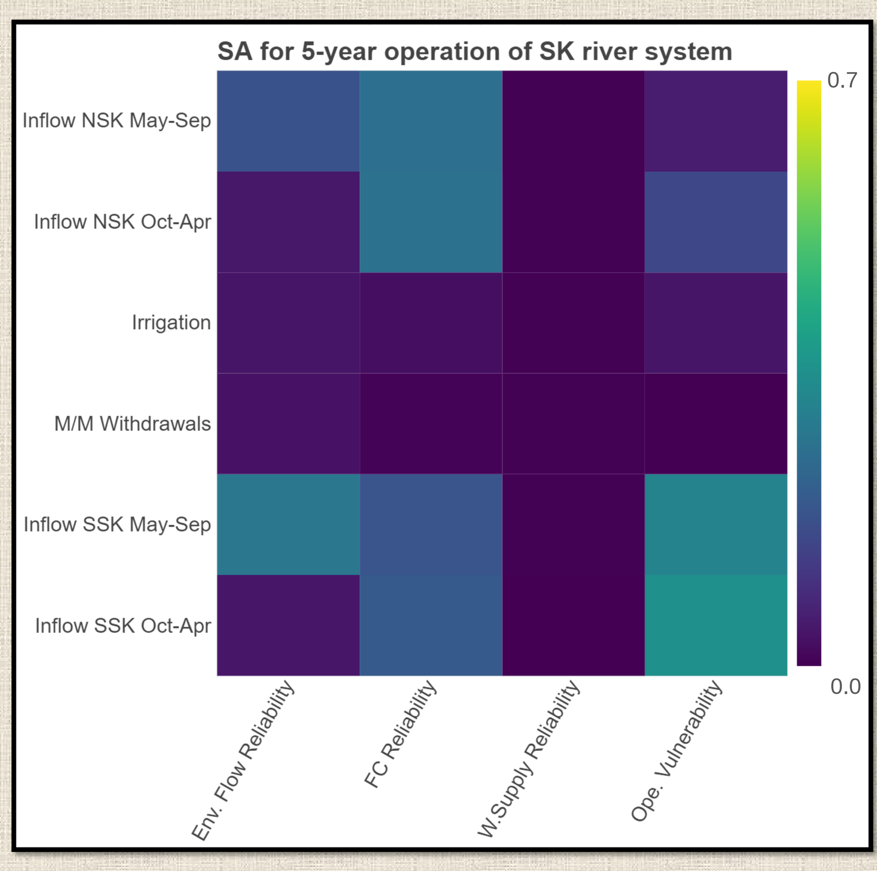
$$(1)\quad f_{reliability} = \frac{1}{N_T}\sum_{t=1}^{N_T} Z_t \qquad (2)\quad f_{vulnerability} = \frac{\sum_{R=1}^{N_R} V_{R,T}}{V_{targ}}$$

where: N_T - no. of time steps within the operating period, Z_t - indicator function, V_T, V_{targ} - actual & target values of storage/energy of reservoir R.

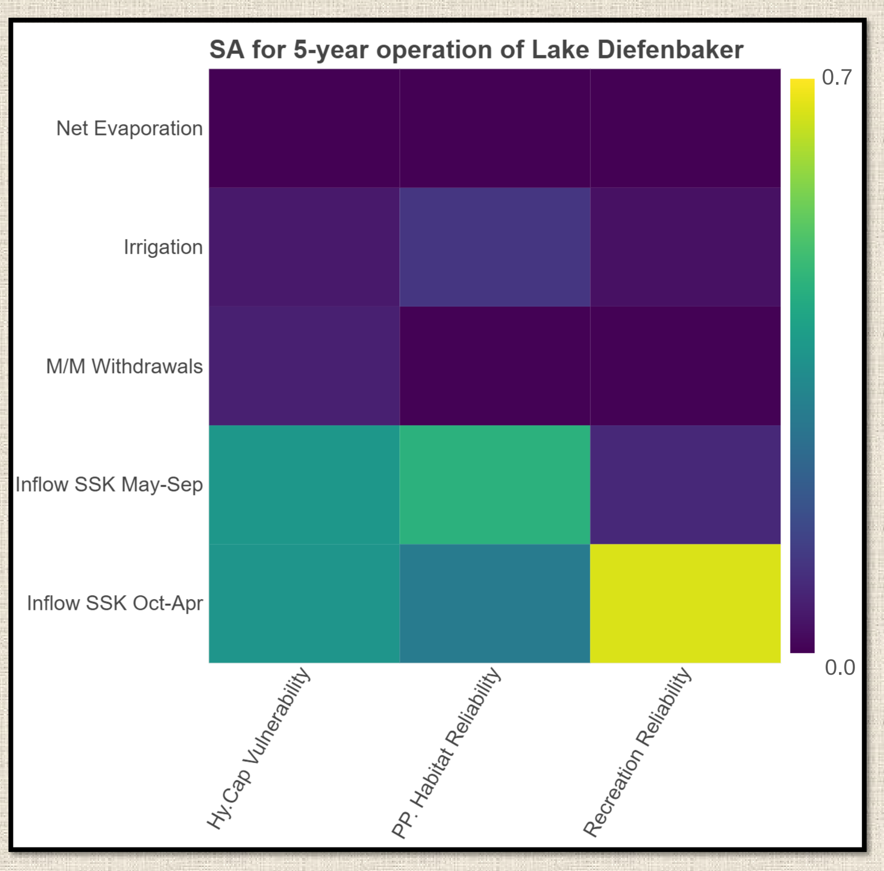
➢ Sensitivity analysis framework for MODSIM model



RESULTS & CONCLUSIONS



Sensitivity analysis for the reliability and vulnerability of SK water resource system



Sensitivity analysis for the reliability and vulnerability of Lake Diefenbaker operation

- This study examines and classifies the dominant controls of the vulnerability and reliability of the SK river basin. Results show that the flow of the South SK river from Oct-Apr is the most influential factor. Other factors include the flow of South SK river from May-Sept and the flows of North SK river.

- Uncertainties of the river flows are considerably sensitive to the vulnerability of the reservoir operations. This highlights the necessity for a flexible modeling framework for the management of the SK water resource system under deep uncertainties of climate change.

References:

Razavi, S. and Gupta, H. V. 2016a 'A new framework for comprehensive, robust, and efficient global sensitivity analysis: 1. Theory', *Water Resources Research*, 52(1), pp. 423–439. doi: 10.1002/2015WR017558.

Razavi, S. and Gupta, H. V. 2016b 'A new framework for comprehensive, robust, and efficient global sensitivity analysis: 2. Application', *Water Resources Research*, 52(1), pp. 440–455. doi: 10.1002/2015WR017559.

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