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Workflow for Groundwater Flow from Saturated Zone to the Upper Vadose Zone to Explore River Flooding

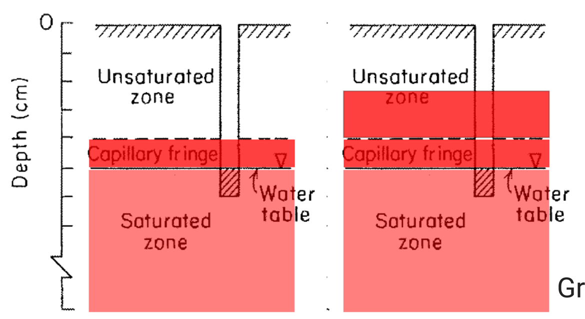
Rakiba Sultana[1], Raymond H Johnson[2], Charles J Paradis[1], Michael N Fienen[3] sultana.rakiba@gmail.com

[1]Department of Geosciences, University of Wisconsin-Milwaukee, [2]RSI EnTech, LLC, Contractor to the U.S. Department of Energy, [3]Upper Midwest Water Science Center U.S. Geological Survey

1 Introductory Statement

Contaminants can persist in the environment for extended periods, but to understand their transport, it is essential to first establish the groundwater flow dynamics within a hydrogeological system. The **objective** of this study is to develop a workflow to couple saturated zone and vadose zone flow to ultimately support contaminant transport and facilitate hypothesis testing. It is **hypothesized** that higher contaminant concentration in the vadose zone than groundwater can mobilize contaminants and increase groundwater contamination during recharge events, e.g., floods.

Hypothesis



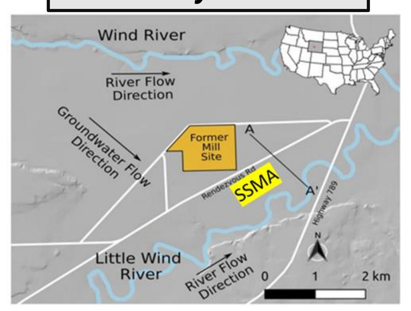
Higher contamination in capillary fringe layer only (left) and in both unsaturated and capillary fringe layer (right)

Figure Modified from: Freeze, R.A. and Cherry, J.A. (1979) Groundwater. Prentice-Hall Inc., Englewood Cliffs, Vol. 7632, 604.

2 Example Model Description

The *study area* is at a uranium-contaminated site in Riverton, WY. We utilized a regional steady-state (SS) flow model developed by the U.S. Department of Energy (*U.S. DoE, 2020, Numerical Groundwater Flow Model Update, Riverton, Wyoming Processing Site*), to construct local transient (Tr) flow and subsequently transport model at our experimental site. This study employs modeling software Groundwater Vistas 8 Pro for initial input file conversion followed by a repeatable workflow approach in python using groundwater model package, Flopy.

Study Area



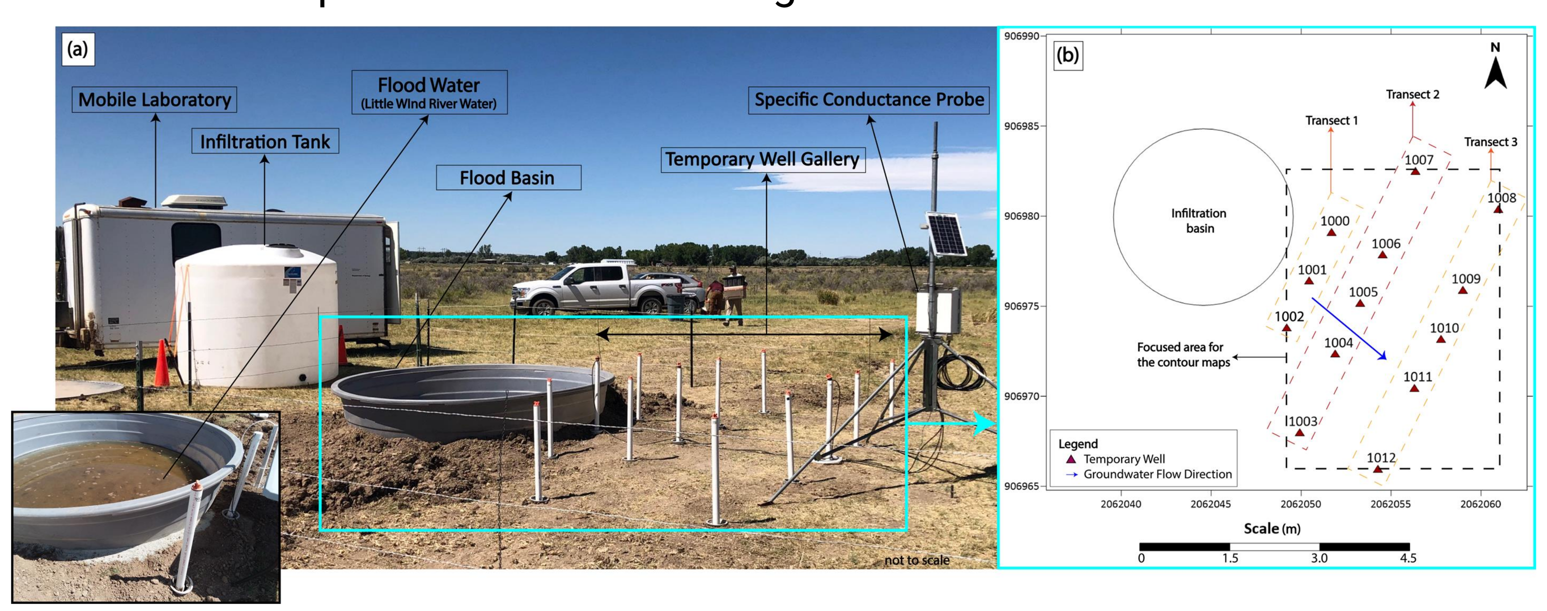
Model Summary

- MF USG regional model-unstructured (U.S. DoE)
- MF 6 regional model-unstructured
- MF 6 local model-structured

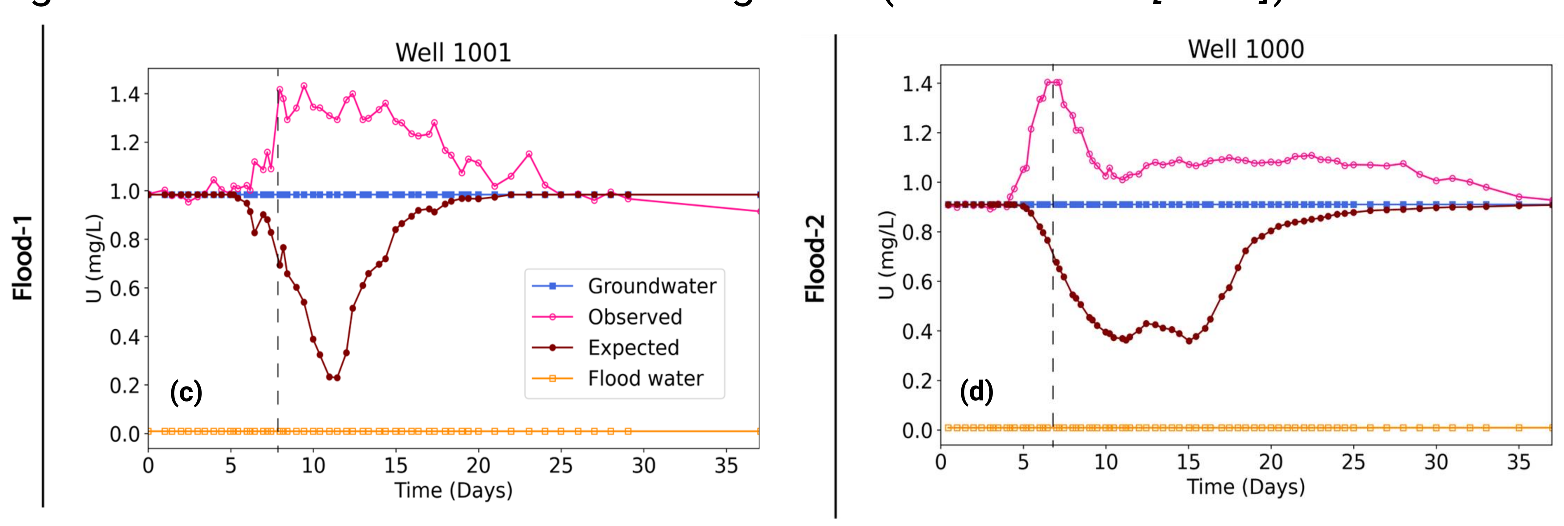
This Study

3 Experimental Design and Observations

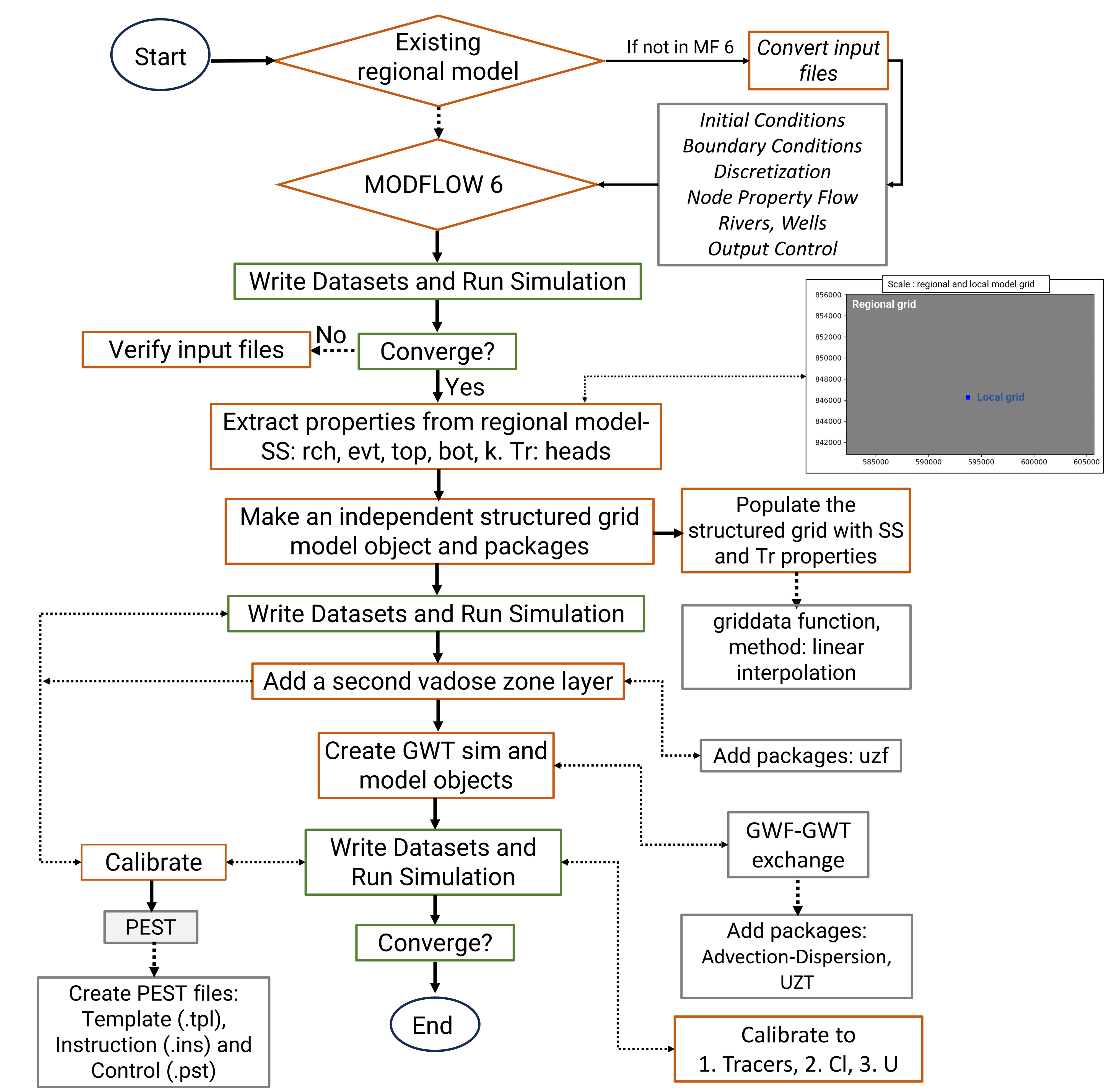
Two tracer field experiments (Flood-1 and Flood-2), each simulating a flooding event, were conducted, fig. (a) and (b), with an interval of one year, near the banks of Little Wind River, Riverton, WY. The goal of the experiments was to elucidate contaminant transport mechanisms during flood.



Earlier arrival of contaminant than expected with an extended breakthrough curve during experimental floods, Flood-1 and Flood-2 (fig. c and d) show contaminant-rich evaporite dissolution and pore-water release from the vadose zone are significant release mechanisms during flood (*Sultana et al. [2024]*).



4 Workflow

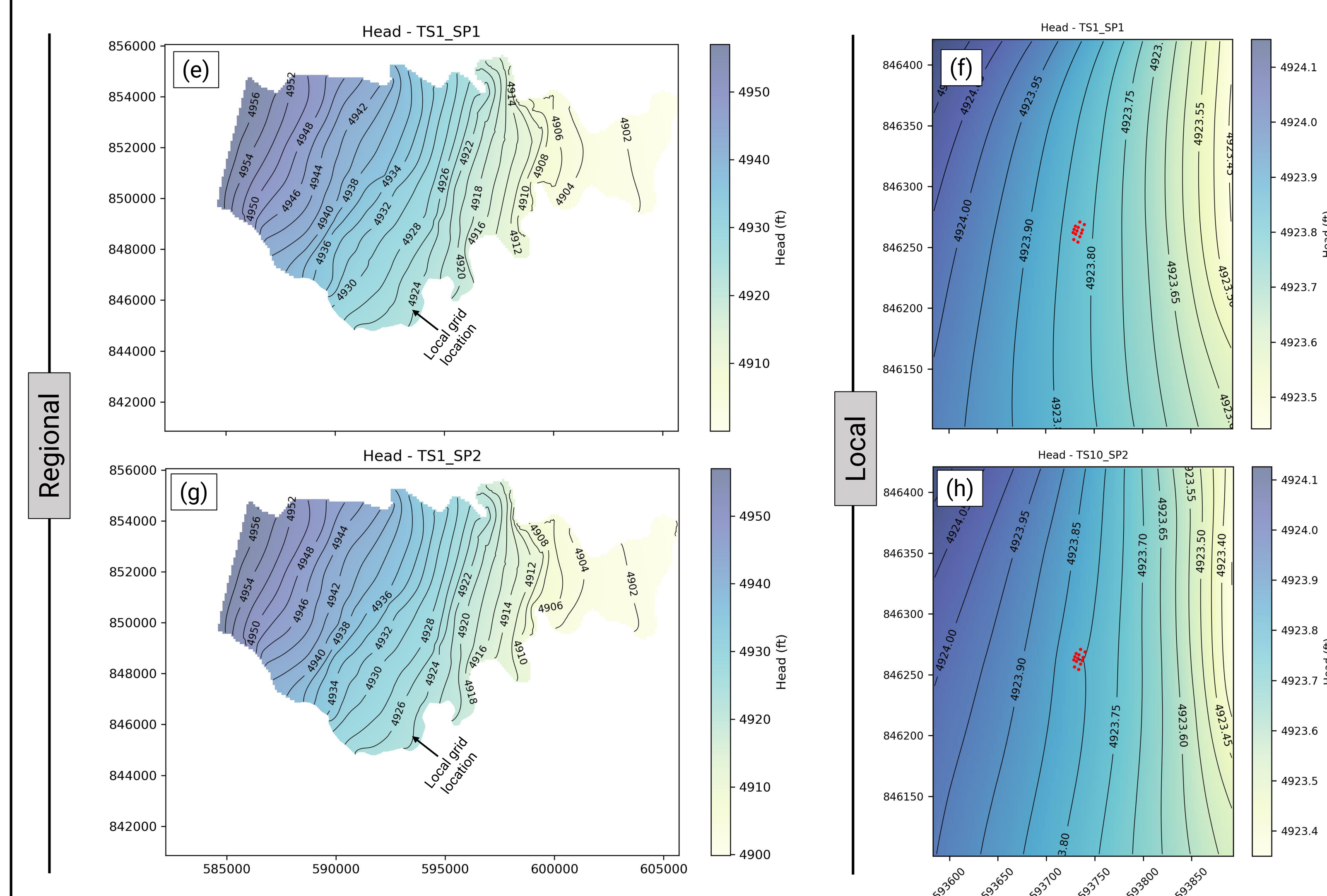


Key Take Aways

Integrating in-situ controlled experiments with repeatable flow and transport modeling workflow, provides an efficient way to study complex subsurface processes across multi-hydrogeological systems, especially during unpredictable events such as, floods.

5 Model Pre- and Post-Processing Results

Regional head regime at time step-01 (TS) of stress period-01 (SP) steady state (fig. e) and stress period-02 transient (fig. g), respectively in MODFLOW 6 unstructured grid. Local head regime at time step-01 of stress period-01 steady state (fig. f) and stress period-02 transient (fig. h), respectively in MODFLOW 6 structured grid. The red dots in (fig. f) and (fig. h) indicate the monitoring wells.



The local structured grid, which is buffered around the experimental site, is populated with interpolated values from the regional MF 6 transient model : top (fig. i) and bottom (fig. j) elevations, evapotranspiration (fig. k), hydraulic conductivity (fig. l), hydraulic heads at TS-01 of SP-01 (Fig. m) and SP-02 (fig. n); to be applied as input parameters for the local model.