Geophysical and geochemical constraints on the regional hydrogeology of the Banff Hot Springs

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Summary

In Banff National Park, located within the Front Ranges of the Canadian Rockies, nine thermal springs occur along a 4 km interval of the Sulphur Mountain Thrust (SMT) fault [1]. In recent years the highest-elevation hot springs have experienced perennial flow stoppages over the late winter to spring months, threatening the critical habitats of an endangered snail species and causing operational interruption to a commercial spring-fed swimming pool [2]. We use geophysical and geochemical investigations to provide spatial and temporal constraints for regional scale hydrogeological models of the hot spring system. These models will be used to forecast future hot spring flow aiding in understanding the ecological and economic threats associated with flow stoppages. Reduced fresh water contributions are considered the main cause of spring flow stoppages. Previous studies show that spring flow is driven by precipitation infiltrating the flanks of Mount Rundle to the east, and Sulphur Mountain to the west of the SMT [1]. Water infiltrating the flanks of Mount Rundle flows down through a unit of carbonate rock and is heated by the Earth's natural geothermal gradient along its flow path. At a maximum depth of 3.2 km the groundwater intercepts the permeable SMT fault zone, is quickly returned to the surface, mixes with cold fresh water from Sulphur Mountain and discharges from the hot springs [1].

Method

We aim to use FEFLOW [3] to construct a two dimensional numerical model of coupled fluid and heat flow over the spatial domain of the conceptual model shown in Figure 1a. Forward/inverse modelling will be used to replicate the seasonal temperature and flow variation observed at Upper Hot Spring over the last three years (Figure 1b). The model calibration will be tested against previous years' monitoring data. Once adequately calibrated the model is used to forecast future flow and temperature behavior under various Weather Research and Forecasting Model (WRF) [4] pseudo-global warming scenarios, which are applied via changes in the upper boundary forcing conditions.

Eleven electrical resistivity profiles and seven seismic refraction profiles were collected perpendicular and across the SMT and provide constraints on the width and orientation of the SMT. Geochemical analysis of monthly water samples collected from each spring and apparent age dates from radio-carbon and tritium dating, provide constraints on seasonal behavior of changes the mixing ratio of shallow to deep thermal ground water.

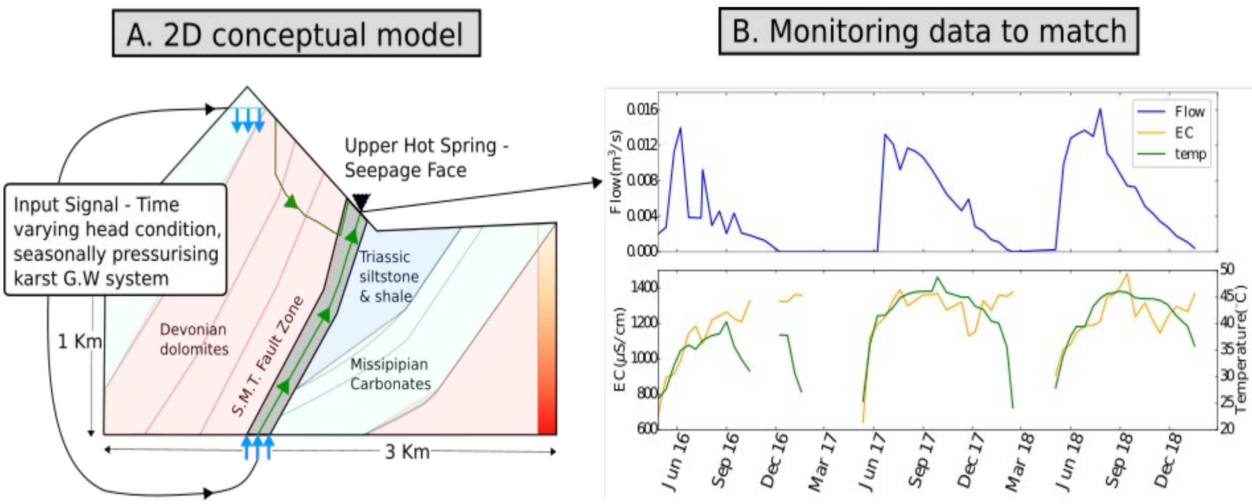

Figure 1: Approach for modeling the regional hydrogeology. (A): Two dimensional conceptual model; Right (b): Three years of monitoring data to calibrate the model against.

Results

Electrical resistivity and seismic refraction surveys show the springs are restricted to the lower elevation boundary of the 100 m wide SMT fault block, which is interpreted as a low resistivity zone (10 – 100's Ωm) associated with water bearing fractured rock (no data shown in this abstract). The fault zone strikes NNW-SSE and dips 60 degrees to the west, in agreement with regional structural geological maps. A positive correlation between spring water temperature, electrical conductivity and flow rate throughout an annual cycle suggests that snowmelt drives deep thermal water out from the reservoir connected to the springs, rather than seasonal melt water being routed into the springs (Figure 1b). Stable water isotope analysis of monthly water samples show that the water discharged from Upper Hot Spring is characteristic of snowmelt from a well-mixed reservoir.

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References

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