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Optimization of Geothermal Well Placement under Geological Uncertainty

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Well placement optimization is critical to commercial success of geothermal projects. However, uncertainties of geological parameters prohibit optimization based on a single scenario of the subsurface, particularly when few expensive wells are to be drilled. The optimization of borehole locations is usually based on numerical reservoir models to predict reservoir performance and entails the choice of objectives to optimize (total enthalpy, minimum enthalpy rate, production temperature) and the development options to adjust (well location, pump rate, difference in production and injection temperature). Optimization traditionally requires trying different development options on a single geological realization yet there are many possible different interpretations possible. Therefore, we aim to optimize across a range of representative geological models to account for geological uncertainty in geothermal optimization.

We present an approach that uses a response surface methodology based on a large number of geological realizations selected by experimental design to optimize the placement of geothermal wells in a realistic field example. A large number of geological scenarios and design options were simulated and the response surfaces were constructed using polynomial proxy models, which consider both geological uncertainties and design parameters. The polynomial proxies were validated against additional simulation runs and shown to provide an adequate representation of the model response for the cases tested. The resulting proxy models allow for the identification of the optimal borehole locations given the mean response of the geological scenarios from the proxy (i.e. maximizing or minimizing the mean response).

The approach is demonstrated on the realistic Watt field example by optimizing the borehole locations to maximize the mean heat extraction from the reservoir under geological uncertainty. The training simulations are based on a comprehensive semi-synthetic data set of a hierarchical benchmark case study for a hydrocarbon reservoir, which specifically considers the interpretational uncertainty in the modeling work flow. The optimal choice of boreholes prolongs the time to cold water breakthrough and allows for higher pump rates and increased water production temperatures.