Publications

TR-104 Vol. 1

Heat Transport in Groundwater Systems--Finite Element Model

E. K. Grubaugh, D. L. Reddell

- Full Text

Solar energy is a promising alternate energy source for space heating. A method of economic long term solar energy storage is needed. Researchers have proposed storing solar energy by injecting hot water heated using solar collectors into groundwater aquifers for long term energy storage. Analytical solutions are available that predict water temperatures as hot water is injected into a groundwater aquifer, but little field and laboratory data are available to verify these models. The objectives of this study were to construct a laboratory model to simulate hot water injection into a confined aquifer, to use data from the model to verify analytical solutions modeling this process, and to evaluate the effects of physical properties and design parameters on thermal recovery efficiency.

Initial studies of hot water injection into underground reservoirs were done by the petroleum industry while studying secondary and tertiary oil recovery methods. These studies involved small laboratory models. Advances in computer technology made it possible to model these systems numerically. Many assumptions must be made to predict temperature distributions and thermal efficiencies using analytical models which are not required in numerical solutions.

To simulate hot water injection into a confined aquifer, a laboratory model (a 1.8288 m deep, 0.2 radian sector tank, that was 7.01 m in the radial direction) was constructed. There were 39 temperature and 15 fluid pressure measuring locations through the model. Water was supplied to the model at a constant temperature and flow rate. The flow layer was composed of a fine grained Texblast blasting sand. Four runs were made. During the initial run, no heat transfer took place and the hydraulic conductivity was measured. Three runs were made where the heat transfer was monitored.

Water level data from the heat transfer runs showed that as the temperature of the aquifer increased, the hydraulic conductivity increased. Temperature data indicated that the three radii closest to the well bore reached thermal equilibrium. The equilibrium temperature decreased as radius increased. From Run 1 to Run 2, the equilibrium temperature increased at each radius because a larger flow rate was used. A vertical thermal gradient existed in the flow layer with the less dense warm water floating out over the cooler more dense water initially in the model. During the pumping cycle, the temperatures gradually decreased.

The temperature of the water as it was pumped out of the model was measured and the energy recovered was computed using the initial temperature as a reference. Various other temperatures were used as a base reference to calculate recovery efficiency.

There were heat losses out the sides of the model. The assumption of angular symmetry made in all analytical solutions was therefore not met. For this reason, the analytical solutions showed adequate, but not great, agreement with the experimental temperature distributions.

Using the analytical solutions, the effects of changing system design parameters were evaluated. Increasing thermal conductivity in the flow layer caused the temperature distribution to spread out but had no effect on thermal efficiency. Increasing the thermal conductivity in the confining layers caused the temperature profile to not move as far from the well, and decreased thermal efficiency. Injection rates are only indirectly related to thermal efficiency. The physical parameter having the greatest effect on thermal efficiency was the flow layer thickness. As thickness increased, thermal efficiency increased.

Texas Water Resources Institute

1500 Research Parkway A110
2260 TAMU
College Station, TX 77843-2260

Phone: 979.845.1851
Fax: 979.845.0662
Email: twri@tamu.edu