# Optimal Groundwater Remediation*

Executive Summary
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*This work was done as part of the capstone chemical engineering class at the University of Oklahoma
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This report is an exercise in the use of computational fluid dynamics and mathematical modeling to analyze the remediation process of groundwater. The purpose of this model is to minimize contaminants in an aquifer while minimizing cost. The mathematical model involves differing well configurations, pumping rates, and the use of fluid flow characteristics to evaluate the concentration profiles in the aquifer. This model builds on previous two dimensional models by adding simulations in Fluent flow simulation software in order to create a three dimensional model, and by investigating dynamic optimization through changing well configuration with time.

The geometry of a 2000 $m^3$ aquifer was drawn into Gambit, Fluent's geometry software. This was imported into Fluent and boundary conditions were named for inlets and outlets of the aquifer. Fluid flow simulations were run. The velocities were analyzed at different points throughout the aquifer. Using the velocities in the contamination volume, a mathematical model was developed for the calculation of the contaminant concentration at points throughout the aquifer with time. The remediation time for each geometry and pumping rate was determined based on when the concentration of contamination within the aquifer dropped below the desired level.

Well configuration was found to have a very large effect on flow patterns within the contamination plume. Seven well configurations were used in the analysis of flow profiles. Seven flow rates were used in each of the well scenarios. Remediation time was seen to be highly dependent upon flow rate. In some portions of the plume where the velocity of the water was at a maximum, the concentration profile was seen to behave as a step function. Cost analysis was performed for each of the evaluated scenarios. The cost was based on fixed initial and continuous costs, and variable operating costs. The biggest factors affecting cost were then the number of wells and overall remediation time.

After this initial study was performed a refined fluid flow model was created. A more realistic geometry of an 8,000 $m^3$ aquifer was created in Gambit and, again, imported into Fluent where inlet and outlet boundary conditions were defined. Simulations were run and the velocity data was imported into excel for analysis. Three different initial contamination plumes were explored in this study. In order to more effectively clean the differing plumes, unique pumping schemes were designed and varied with time. The total flow rate into and out of the aquifer was held constant throughout the entire remediation process. Each simulation was examined individually and as part of the dynamic model. Then, final concentrations were compared to investigate the most efficient pumping scheme. It was found that pumping scheme optimization is highly dependent upon the initial contamination profile. It was also found that this method can effectively model a dynamic pumping optimization scheme and can produce concentrations lower than those achievable with constant pumping configuration.