CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS FOR FURTHUR STUDY

5.1 Summery

In this work, an attempt is made to enhance the capabilities of the U_DYSAC2 finite element computer code. The main focus is to modify U_DYSAC2 computer code for applications in environmental problems by replacing the air phase with a NAPL phase and analyze NAPL transport patterns in the subsurface. In Chapter 2, the review of relevant works on NAPL modeling and experiment on DNAPL transport is presented. The constitutive equations between NAPL and water are also discussed in this chapter. The modifications of U_DYSAC2 and the validation procedure are given in Chapter 3. In Chapter 4, validation results are discussed. The validation is divided into 2 sections, a parametric study and comparisons with experimental results.

5.2 Conclusions

The following conclusions can be made based on the validation results presented:

1. The modified U_DYSAC2 computer code can simulate DNAPL movement in saturated porous media. The saturation contours show that the DNAPL penetrates the saturated porous media from the source and then accumulates at the bottom of the deposit.

2. The simulation results show that the front velocity of a DNAPL plume is proportional to the density of the DNAPL and inversely proportional to the DNAPL viscosity. The predicted results qualitatively agree with expected patterns of DNAPL migration.

3. When there is groundwater flow, the DNAPL not only moves downward, but also moves in the direction of the groundwater flow.

4. The modified U_DYSAC2 can also be used to simulate LNAPL transport in saturated confine aquifers. The simulations show that the LNAPL will accumulate on top of the confined aquifer.

5. The modified U_DYSAC2 reasonably predicts experimentally observed low density, high viscosity DNAPL transport patterns. The simulation results also show that for this case the capillary pressure-water saturation curve has very little influence on the predicted DNAPL patterns.

6. For DNAPL transport through heterogeneous soil structure, the results show that the modified U_DYSAC2 can simulate the observed DNAPL plume reasonably well. The predicted DNAPL patterns for this case are sensitive to the constitutive parameters used for capillary pressure-water saturation curves. Some of the discrepancies between the observed and predicted plume patterns are likely due to the assumed constitutive model parameters.

5.3 Recommendations for further study

1. The rapid change of water saturation for a small change of capillary pressure for certain types of soils, such as sands, causes numerical problems in the modified U_DYSAC2. Better numerical integration algorithms should be investigated to solve this problem.

2. There is a lack of experimental data to define the capillary pressure-saturation curves for NAPL-water systems in various soils. Experiments should be performed to create these curves so simulations can be carried out for various contamination situations.

3. The soil deformation is important for many engineering problems such as subsidence caused by groundwater pumping. The modified U_DYSAC2 has the

capability to predict soil deformations coupled with DNAPL transport. These predictions still have to be validated.

4. The U_DYSAC2 should be further modified to include the air phase. This will allow a user to simulate a four-phase system consisting of soil, water, air, and NAPL.