EVALUATION OF A BTEX PLUME IN FRACTURED CRYSTALLINE ROCK IN THE GEORGIA PIEDMONT

James B. Feild[1] and John F. Dowd[2]

AUTHORS: [1]Graduate Student, Department of Geology; [2]Assistant Professor, Department of Geology, 210 Field Street, University of Georgia, Athens, Georgia, 30602.

REFERENCE: Proceedings of the 1999 Georgia Water Resources Conference, held March 30-31, 1999, at the University of Georgia. Kathryn J. Hatcher, editor, Institute Ecology, The University of Georgia, Athens, Georgia.

Abstract. Water flow and chemical transport in fractured media has become a major concern in recent years. Traditionally, these problems have been viewed and modeled as flow through pipes. However, this approach is limited because it is very difficult to predict the orientation, size, and length of the fractures, hence the direction and velocity of the petroleum hydrocarbons.

Groundwater sampling of saprolite, residential, and bedrock wells at a site near Danielsville, Georgia has revealed the presence of petroleum constituents in the aquifer system beneath the site. The site has a documented history of spills over the past thirty years. Groundwater sampling of some of the residential and monitoring wells in the vicinity of the site has indicated benzene contamination ranging from non-detectable to approximately 2500 parts per billion. It has been established from groundwater samples collected from bedrock that contamination has migrated from the saprolite into the fractured bedrock aquifer. A suspected pathway of contaminant migration could possibly be an improperly cased bedrock well.

Physical and chemical conditions at the site have been modeled using a three dimensional visualization program. In this paper, we show how the use of this tool leads to understanding of the fracture flow system, and how this knowledge can be used to prepare a more comprehensive, physically based fracture flow model.

INTRODUCTION

In the Piedmont setting of North Georgia, the lithological units, consist of saprolite, partially weathered bedrock, and competent bedrock. Chemical spills that occur within the saprolite aquifer quite often will migrate into the bedrock aquifer below, sometimes through bedrock fractures that intersect with the bottom of saprolite aquifer, or through conduits such as monitoring wells or water supply wells. Thus the saprolite serves as the source of contamination for the fractured bedrock aquifer.

If the chemical constituents should migrate into the competent bedrock, then both the saprolite aquifer and the bedrock aquifer must be assessed, and if necessary remediated. Assessment and remediation of the bedrock aquifer can be time-consuming, difficult, and expensive, since the majority of competent bedrock in the Piedmont contains at least some fractures (Legrand, 1979). The size, orientation, and connectivity of these fractures is not always known, and cannot be determined easily.

If a remediation system is to be installed and used to mitigate the contaminants in the fractured bedrock and saprolite aquifers, then the remediation system must be capable of influencing both aquifers. Remediating only the saprolite aquifer will usually result in future contamination of the bedrock aquifer system..

The site presented in this study is located near Danielsville, Georgia where spills of non-aqueous phase liquids (NAPLs) have occurred at this site for the past thirty years. Assessment indicated that the saprolite and bedrock aquifers were both contaminated. A water supply well located within the site was suspected of being the main conduit for contaminant migration into the bedrock aquifer. This same well was later retrofitted as a recovery well for a remediation system, consisting of an air stripping tower and the recovery well mentioned above. The objectives of this study were to:

1) Determine how the petroleum hydrocarbons (benzene) at this site were migrating into the fractured bedrock aquifer.
2) Evaluate the current remediation system at the site and determine if the remediation system was influencing and treating both the saprolite and fractured bedrock aquifers.

METHODS

Figure 1 shows well locations at the site. Groundwater elevations and groundwater samples were collected from all applicable monitoring wells, both in the saprolite and the fractured bedrock. Samples were collected from the monitoring wells using micro-purge techniques. The groundwater samples were analyzed by EPA Method 8021B for benzene concentrations. Groundwater elevations were collected by gauging the level of the water column within each well using an electronic interface probe capable of detecting the interface between water and air to within a 0.01 of an inch.

The data collected from the chemical analysis and the gauging of the water level in the wells were input into the previously mentioned three dimensional visualization software used in this paper. The results of the three dimensional analysis were then transferred to Corel Draw® for printing.

RESULTS

As can be seen from Figure 2, the groundwater elevations and contours of the fractured bedrock aquifer show that the local maximum or high point is located at well DW-4. Monitoring well DW-4 is located directly below the location of the known chemical spills. The streamlines (directional arrows) illustrate that the groundwater flow is divergent or flowing away from DW-4 in all directions. There exists in the area of DW-4 a groundwater remediation system which consists of a recovery well and an air stripping tower.

Figure 3 shows the benzene concentration of samples collected from the fractured bedrock wells. The figure shows two distinct areas of contaminated groundwater within the bedrock aquifer (DW-4 and DW-10). Samples from DW-4 and DW-10 were found to contain approximately 2500 and 800 ppb of benzene, respectively.

Figure 4 and 5 illustrate, for the purposes of comparison, a groundwater elevation and contour map, and a benzene concentration for the saprolite aquifer. The figures show the small cone of depression around the recovery well created by the remediation system. The cone of depression is characterized by steep gradients, but it does not completely capture the benzene plume in the saprolite aquifer.

CONCLUSIONS

From inspection of the groundwater elevations and contours (figure 2), it is clear that the remediation system has no effect upon the fractured bedrock aquifer. If the remediation system was affecting the bedrock aquifer, this would be apparent from the drawdown of the bedrock aquifer in the vicinity of the site (DW-4). A cone of depression in the surface of the groundwater would be evident surrounding the site. Since Figure 2 shows a groundwater elevation high or mound in the vicinity of the site (DW-4), it is assumed that the remediation system is not influencing the bedrock aquifer at all.

Since the area of known spills coincides with the highest groundwater concentration of benzene (DW-4), then the conduit responsible for the contamination of the fractured bedrock aquifer must also be in that same general area (Figures 1 and 2). A water supply well provided the site buildings with potable water which was drawn from both the saprolite and the bedrock aquifers. The design of the well suggests that the well is not cased properly through the saprolite to the bedrock. This allowed the transport of contaminants from the saprolite to the fractured bedrock beneath the casing. Soon after the initial assessment, this potable bedrock supply well was converted to the existing recovery well for the remediation system.

Because a groundwater high exists in the area of the site, any petroleum constituents that migrate from the saprolite aquifer into the fractured bedrock aquifer will have a tendency to be transported within the fractures away from the site, at a rate consistent with the gradient caused by the mounding of the fractured bedrock aquifer. The result of this migration can be seen in Figure 3. The two areas of contamination exist in monitoring wells DW-4 and DW-10. Inspection of Figure 1 shows that DW-4 is within the confines of the known spill areas. However, DW-10 is not in the vicinity of the known spill area. Monitoring well DW-10 is approximately 1000 feet to the northwest of DW-4. This leads to the conclusion that fractures were responsible for the migration of contaminants from the site to DW-10. This migration was enhanced by the gradient caused by the mounding of the groundwater surface in the fractured bedrock aquifer.

RECOMMENDATIONS

From simple review of the figures presented in this paper, it is obvious that a conduit exists in the vicinity of the site that is responsible for the transport of the petroleum hydrocarbons from the saprolite aquifer to the bedrock aquifer. This conduit which has been determined to be an improperly cased bedrock water supply well, and which currently operates as the remediation system recovery well, should be abandoned The remediation system is designed to recover and treat contaminated water from both the saprolite and bedrock aquifers. Unfortunately, it is recovering water only from the saprolite aquifer; and very little water is recovered and treated from the bedrock aquifer (see figures 2, 3, 4 and 5). This is because the recovery well is open to both the saprolite and the bedrock, and the recovery well is preferentially recovering water from the saprolite. The well should be abandoned and two separate wells should be used to treat the bedrock and the saprolite. This design will prevent further migration of contaminants from the saprolite aquifer to the bedrock aquifer, and will also increase the efficiency of the remediation system.

LITERATURE CITED

Legrand, H., 1979. Evaluation techniques of fractured-rock hydrology. Journal of Hydrology, 43:333-346.

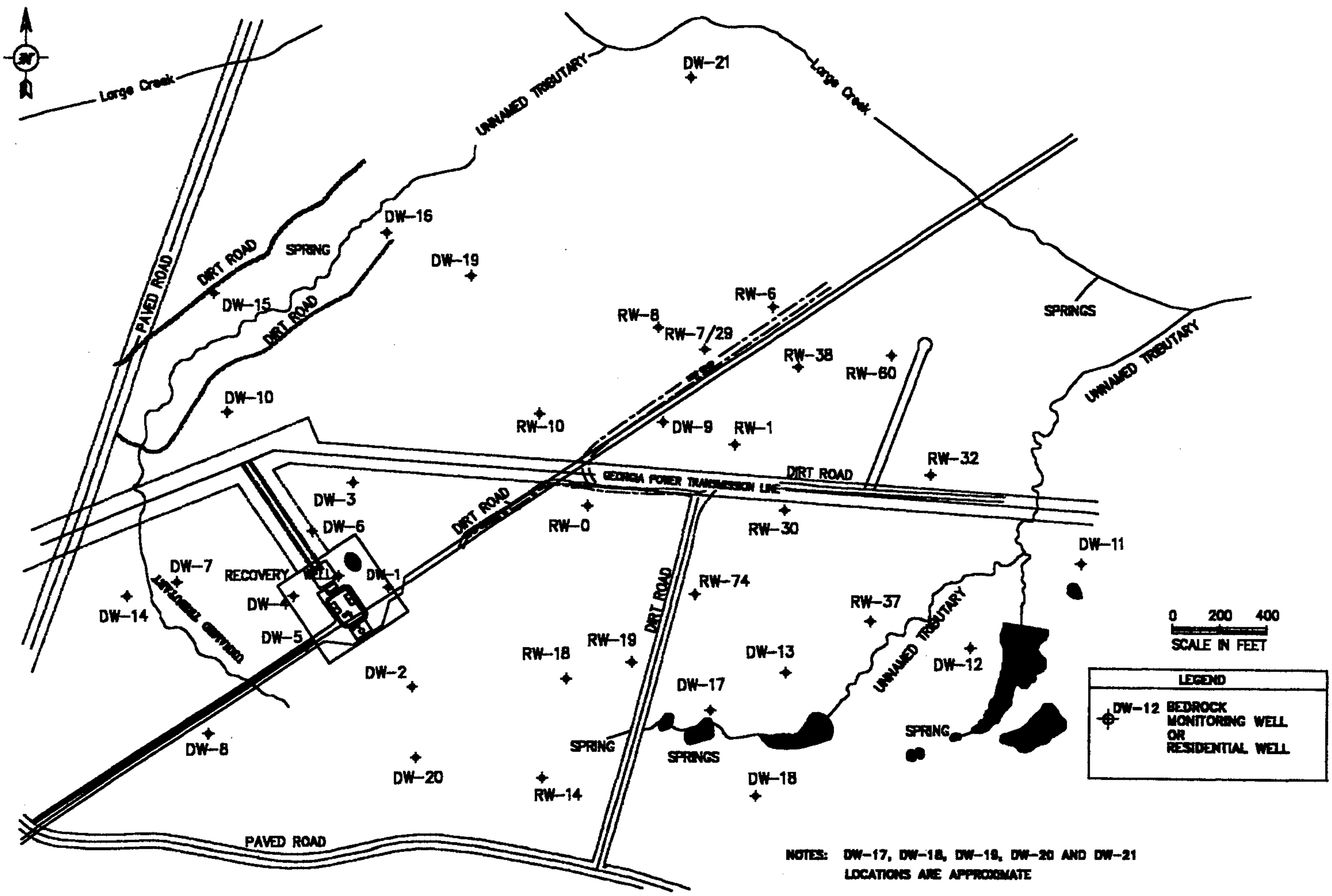

Figure 1. Site Map showing locations of deep bedrock wells, residential wells, streams, ponds, roads, and power lines.

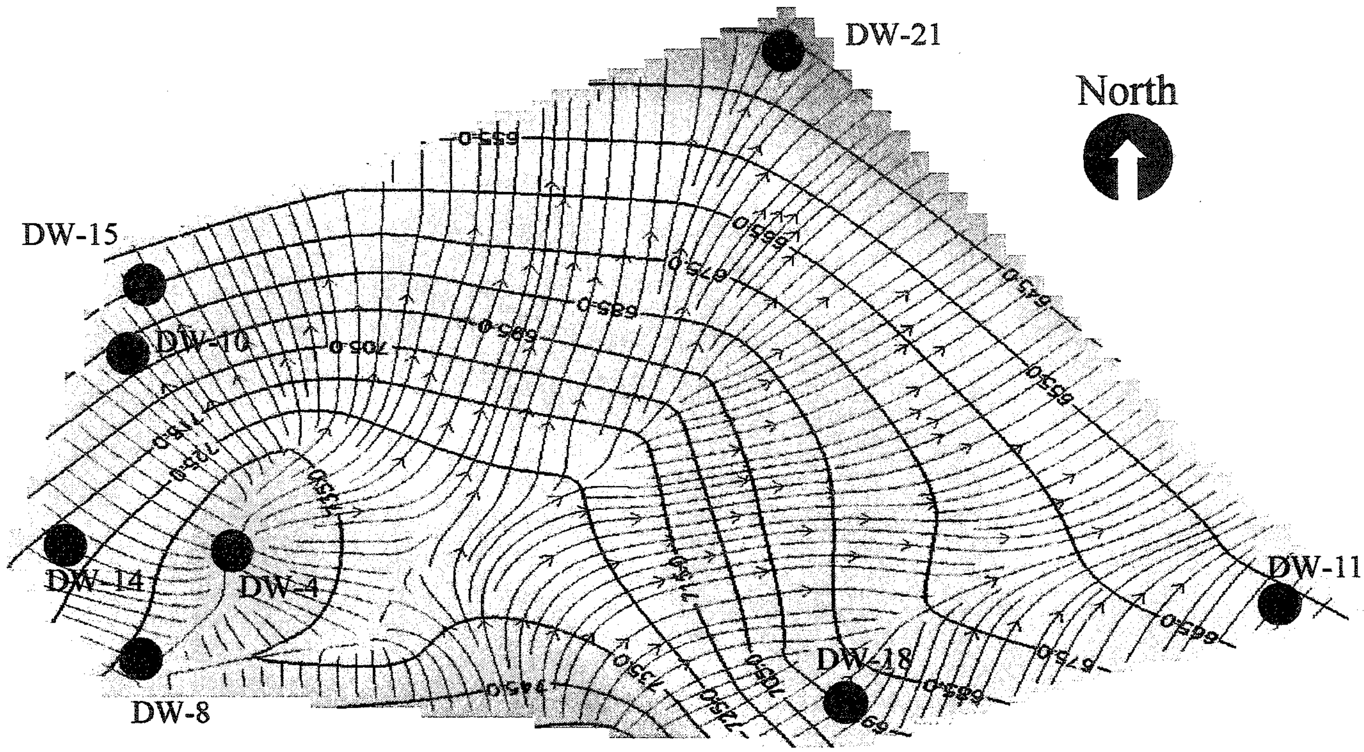

Figure 2. Bedrock groundwater elevations and groundwater contours on May 25, 1998.

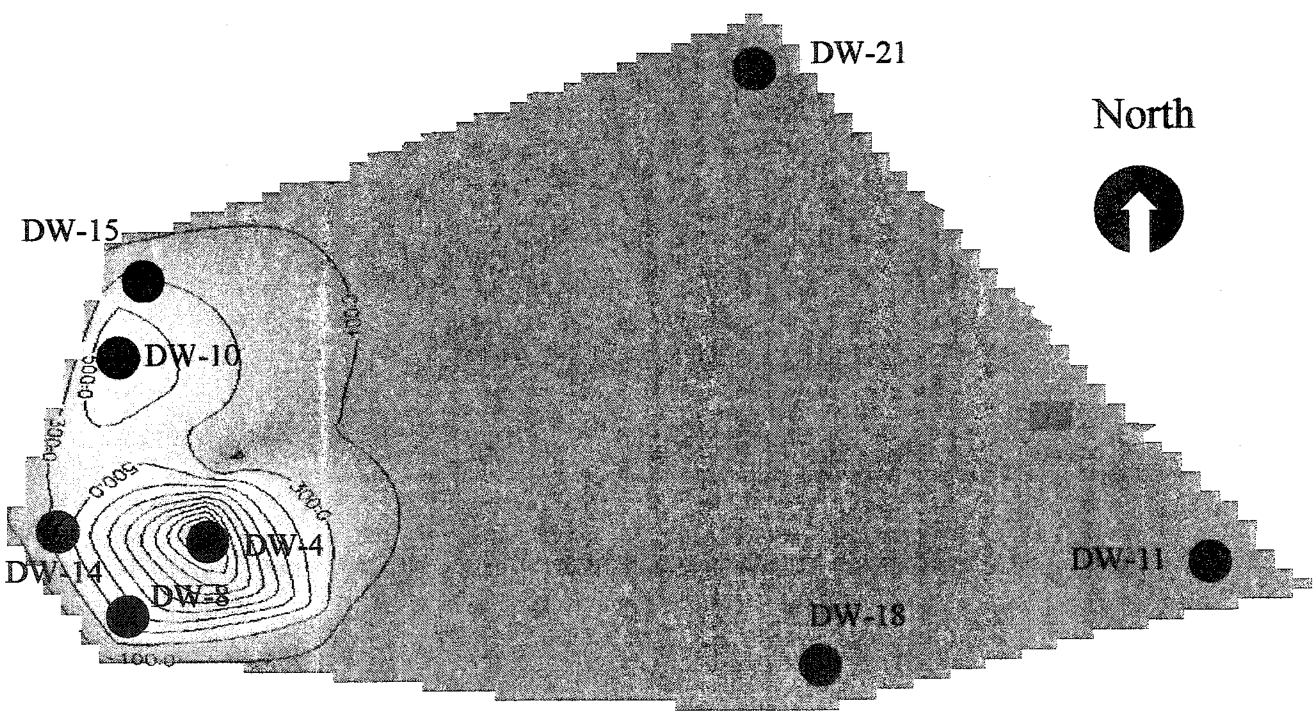

Figure 3. Bedrock benzene concentrations and benzene contours on May 27, 1998.

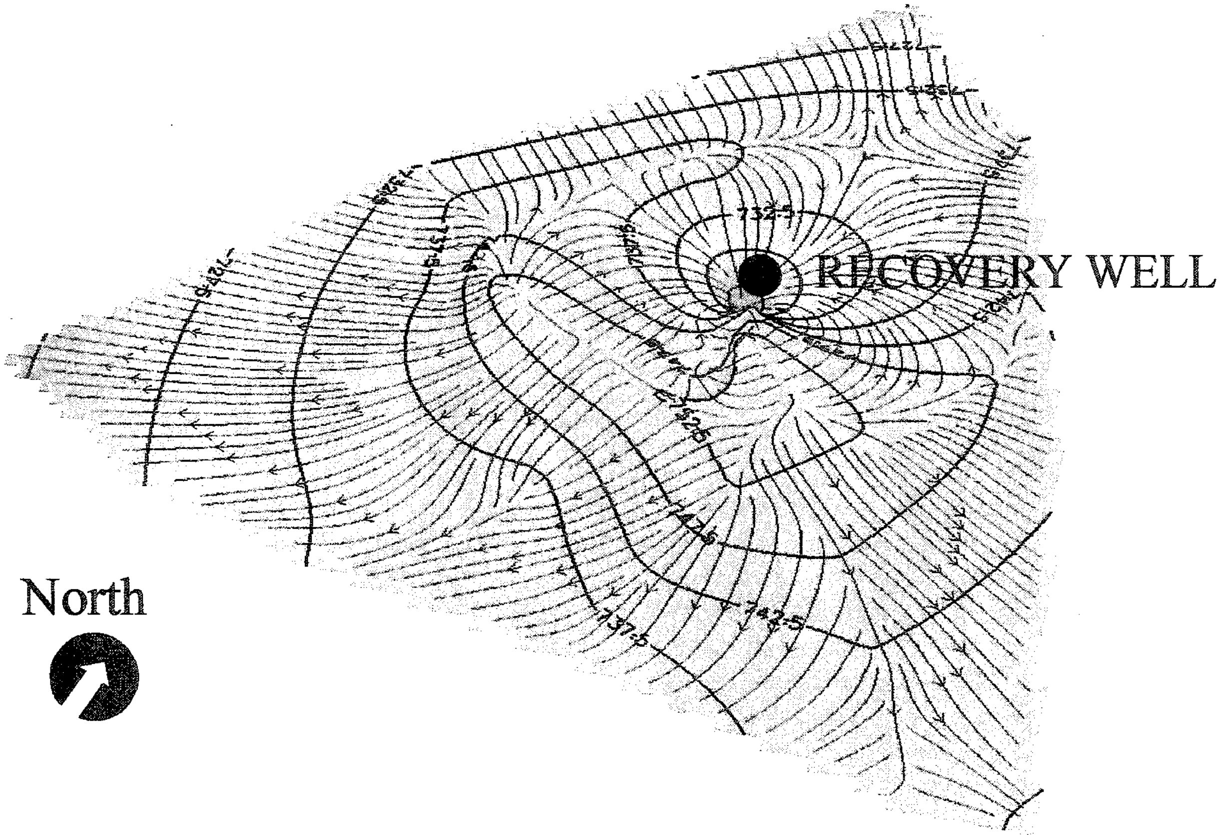

Figure 4. Groundwater Elevations Contours and Flowlines for Saprolite Aquifer. November 28, 1997

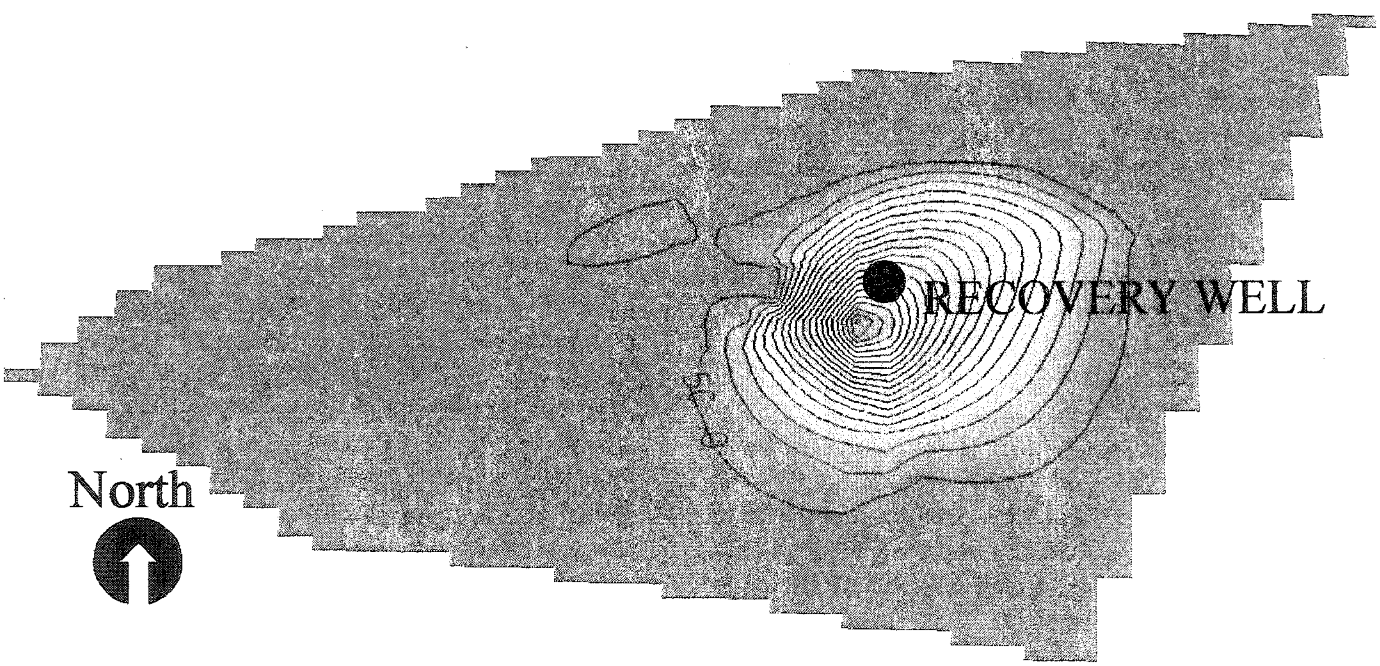

Figure 5. Benzene Contours for Saprolite Aquifer February 11, 1997