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WATER-TABLE CORRECTION FACTORS APPLIED TO GASOLINE CONTAMINATION

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ABSTRACT: The application of correction factors to measured ground-water elevations is an important step in the process of characterizing sites contaminated by petroleum products such as gasoline. The water-table configuration exerts a significant control on the migration of free product (e.g., gasoline) and dissolved hydrocarbon constituents. An accurate representation of this configuration cannot be made on the basis of measurements obtained from monitoring wells containing free product, unless correction factors are applied. By applying correction factors, the effect of the overlying product on the apparent water-table configuration is removed, and the water table can be analyzed at its ambient (undisturbed) level. A case history is presented where corrected water-table elevations and elevations measured at wells unaffected by free product are combined as control points. The use of the combined data facilitates a more accurate assessment of the shape of the water table, which leads to better conclusions regarding the source(s) of contamination, the extent of free-product accumulation, and optimal areas for focusing remediation efforts.

INTRODUCTION

Fuels that leak from underground storage tanks are a major source of ground-water contamination. Many applications in the field of hydrogeology focus on the issue of remediating aquifers contaminated by gasoline and other petroleum products. Effective remediation is largely dependent on the quality of site characterization. Important issues in characterizing ground-water contaminated by underground-storage-tank leaks are contaminant-source identification, assessment of the spatial distribution of free product, and identification of potential migration pathways. A fundamental step in the characterization process is assessment of the slope of the water-table surface. Ideally, the water-table configuration is determined on the basis of measurements from monitoring wells unaffected by free product (e.g., gasoline) accumulated above and within the zone of saturation. However, in many cases, the number and locations of unaffected wells are inadequate to allow for an accurate assessment of the water table configuration. This condition is typical where: (1) Monitoring wells have been installed after significant product leakage has occurred; and (2) the zone of free-product accumulation is areally extensive. Where the number and/or locations of unaffected wells are inadequate, water-table elevations can be obtained from wells containing free product by applying water-table correction factors. The combined set of control points (unaffected and affected wells) can then be used to provide a more accurate representation of the water table.

BACKGROUND

The presence of free product in a monitoring well generally indicates an advanced stage of subsurface contamination. Laboratory studies by Abdul et al. (1989) indicate that product will flow into a well only after a significant amount of free product has accumulated in the adjacent porous medium. In practice, many site investigations do not begin until after ground-water contamination has occurred. In these situations, monitoring wells must serve the dual purposes of evaluating the extent of contamination and the configuration of the water table. Where free product has accumulated, wells screened across the water table (i.e., above and below the water-table surface) will likely be affected by an accumulation of product within the well casing. Free product depresses the water level within the well according to the relationship (e.g., Testa and Pacskowski 1989; "Guide" 1989):

$$CDTW = DTW - (PT \times G) \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (1)$$

where CDTW = corrected depth to water (L); DTW = measured depth to water (L); PT = product thickness (L); and G = specific gravity (of product). The depth to water equals the depth to the product-water interface minus the equivalent water height $(PT \times G)$ of the overlying product. The specific gravity (or relative density) of a substance is defined as (e.g., Freeze and Cherry 1979):

$$G = \frac{\rho}{\rho_w} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (2)$$

where ρ = density of substance (product) (M/L^3); and ρ_w = density of water (M/L^3). It follows from (1) that the corrected depth to water is less than the measured depth. The difference between corrected and measured depths reflects the rebound (rise in elevation) in the water level that would occur upon removal of the overlying free product. By subtracting the corrected depth to water from the reference measuring point (from which depth measurements are made), a corrected or undisturbed water-table elevation is obtained. Corrected water-table elevations and elevations obtained from wells unaffected by free product can then be used to construct an undisturbed water-table configuration. In studies that begin after extensive contamination has occurred, an estimate of the restored water-table configuration is instrumental in determining the locations of contaminant sources, assessing the extent of free-product contamination, and inferring the locations of optimal areas for future remediation.

Though not emphasized in this note, volume determination of free product is also an important issue at sites contaminated by hydrocarbon fuels. Analytical methods (e.g., Farr et al. 1989; Lenhard and Parker 1989) or field "bail-down" tests (e.g., Testa and Pacskowski 1989) can be employed for this purpose.

APPLICATION

The principle of water-table correction for the presence of free product was applied to a case study involving two potential contaminant sources (Fig. 1). The study area is situated on a coastal plain in Santa Barbara County, Calif. Deposits underlying the site consist of unconsolidated alluvial sand, silt, and clay. The study described in this note focused on property A (Fig. 1). Prior to this study, areas designated source A and source B were
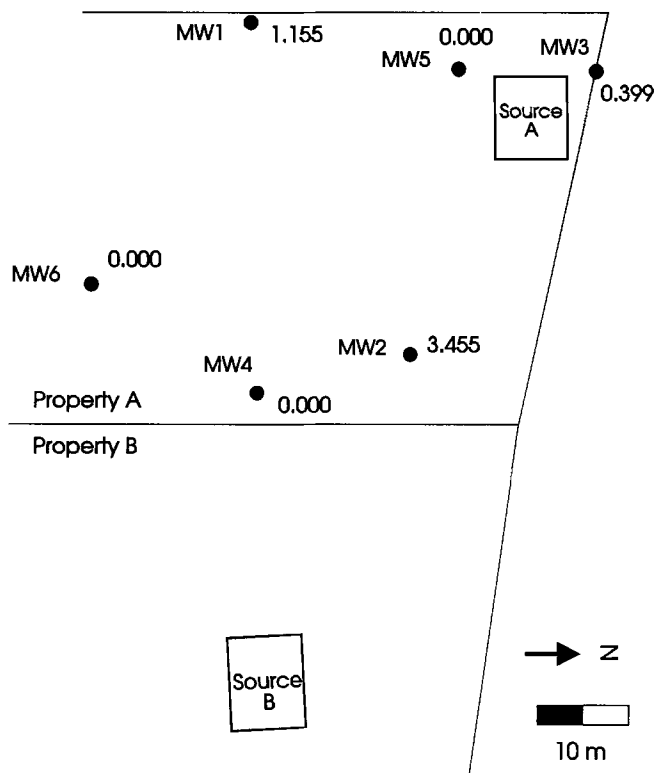
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FIG. 1. Map of Study Area of Illustrating Locations of Property Lines, Gasoline-Tank Storage Areas (Source A and Source B), Monitoring Wells (Dots), and Product Thickness Values (m) Measured in Wells (Numbers Next to Dots)

each occupied by three 37,900-L (10,000-gal.) underground gasoline storage tanks. Test results and observations made during tank removal indicated leaks in the fuel piping system at source A. During the course of this study, a gasoline contamination problem was known to exist at property B. Ground-water contamination and the presence of free product had been confirmed near source B, but the extent of contamination was unknown.

Six monitoring wells (MWs) were initially drilled on property A to establish the shape of the water table and the possible extent of free product (Fig. 1). Wells were screened over similar depth intervals, across the water-table surface. Free product was detected in three of the wells (MW 1, MW 2 and MW 3) in thicknesses ranging from approximately 0.4 to 3.5 m (1 to 12 ft) (Fig. 1). No product was encountered in the remaining wells. The free-phase plume defines a minimum extent of ground-water contamination (i.e., the dissolved plume extends further). Benzene concentrations of 0.5 parts per million (ppm) and 0.02 ppm were measured in samples from MW 4 and MW 5, respectively. The same constituent was not detected in a sample from MW 6 (detection limit of 0.0001 ppm).

An initial assessment of the shape of the water table was made on the basis of contemporaneous (i.e., same-day) measurements obtained only from the three wells that did not contain free product. The resulting con-
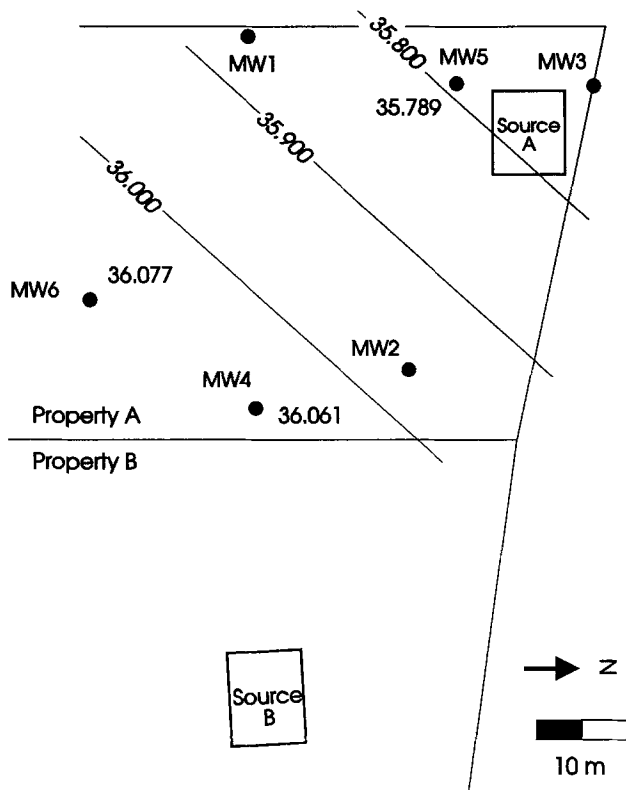
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FIG. 2. Water-Table Configuration Inferred from Measurements at Three Wells without Free Product; Elevations in Meters above Mean Sea Level

figuration is illustrated in Fig. 2. There is a significant degree of uncertainty in this configuration due to a lack of data. Three control points can only define a plane. The spatial relationships between the three points of observed free-product accumulation, the locations of possible contaminant sources, and directions of ground-water flow inferred from the water-table measurements do not lead to sound conclusions regarding the locations of actual contaminant sources. For example, assuming ground-water flow in a direction approximately perpendicular to the observed water-table contours, neither source A nor source B could logically account for the free product detected in MW 1.

An alternate water-table configuration was constructed on the basis of contemporaneous measurements taken from all six monitoring wells, applying correction factors to the wells containing free product. Product thickness and water-table elevation data are summarized in Table 1. A specific gravity value of 0.8 was obtained for the weathered gasoline on the basis of laboratory measurements. The water-table configuration inferred from the combined corrected and undisturbed data is illustrated in Fig. 3. The axis of the water-table trough coincides with an inferred subsurface fluvial sand deposit. Coarser sand and gravel sediments within the fluvial deposit effectively drain surrounding areas.

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TABLE 1. Product Thickness and Water-Table Elevation Summary

Measurement (1)	MW 1 (m) (2)	MW 2 (m) (3)	MW 3 (m) (4)	MW 4 (m) (5)	MW 5 (m) (6)	MW 6 (m) (7)
Measuring point elevation	44.046	51.390	51.122	43.970	48.204	42.723
Depth to product	8.171	14.890	15.040	—[b]	—[b]	—[b]
Depth to water	9.326	18.345	15.439	7.909	12.415	6.646
Product thickness	1.155	3.455	0.399	—[b]	—[b]	—[b]
Corrected depth to water[a]	8.402	15.581	15.120	—[b]	—[b]	—[b]
Corrected water-table elevation	35.644	35.809	36.002	36.061	35.789	36.077

[a]Product specific gravity = 0.8.
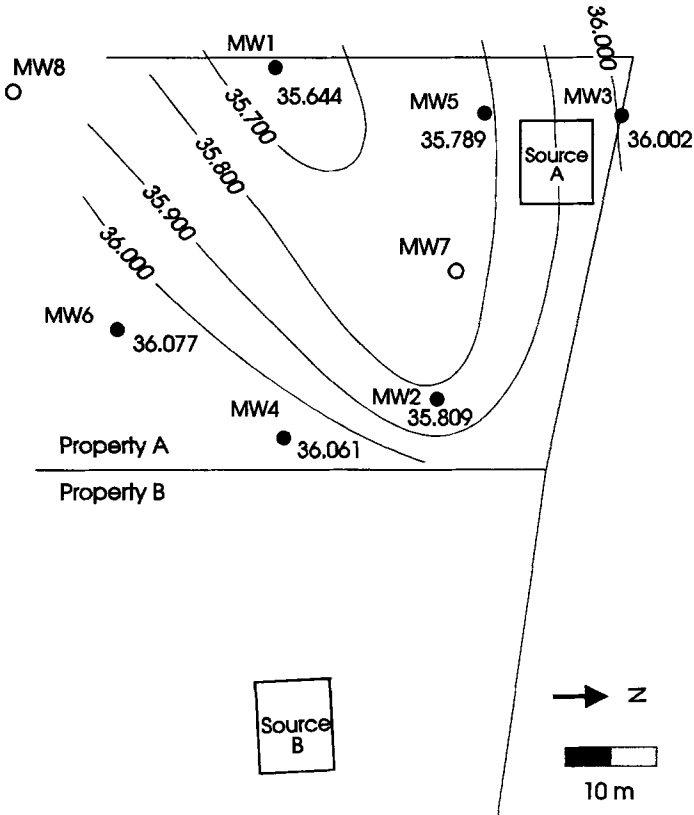[b]No product encountered.

FIG. 3. Water-Table Configuration Inferred from Measurements at Six Monitoring Wells and Locations of Confirmation Wells (Circles); Elevations in Meters above Mean Sea Level

Inferences regarding the location of contaminant sources and the extent of free product made on the basis of the configuration obtained from all six wells significantly differ from those based on the three-well configuration (Fig. 2). The combined data presented in Fig. 3 suggest that:

1. Free-product accumulation in the area of MW 2 most likely originated from source B.

2. Product at MW 1 could have originated from either source A or B, or from a combination of both sources. The absence of free product at MW 5 (Fig. 1) suggests that a plume originating at source A and moving to the south, toward MW 1, would probably be relatively narrow in a lateral (east-west) direction.

3. Source B probably did not contaminate the area around MW 3. The proximity of this well to source A suggests that source A is the more likely origin for the observed free product. One possible explanation for product at MW 3 is mounding of free phase on the capillary fringe causing free-phase migration in the apparent upgradient direction. However, this explanation is inconsistent with the absence of product at MW 5. Alternatively, the free-phase accumulation at MW 3 may have been caused by a local leak in the overlying tank piping.

4. Assuming that the free product in MW 2 originated from source B, and given the large amount of product encountered in this well (more than 3.4 m [11 ft]), it is likely that a plume originating from source B extends further west, along the axis of the water-table trough. Furthermore, the axis of the trough represents a low in the water table and would constitute a probable area of relatively thick free-product accumulation. In this regard, it would be a good area to focus remedial efforts.

The outlined inferences are based on the assumption that the ground-water system is in an approximate steady-state condition (i.e., the local ground-water flow direction is similar over time). In some multiple-potential source studies, inferences regarding an actual source of contamination can be facilitated by a fuel fingerprint analysis, in which the chemistry of the source is compared with contaminated samples. This procedure was not conducted here because the study was initiated after source removal. The procedure is generally ineffective where hydrocarbons are highly weathered, as in this study.

The six-well water-table configuration was considered in locating two additional (confirmation) wells, installed for the purpose of providing more detail on the spatial distribution of free product accumulation. The locations of these wells are illustrated in Fig. 3. MW 7 was drilled in the central area of the trough to provide data that might verify this area as a zone of free product accumulation. The second well, MW 8, was drilled near the southwest end of property A to provide information regarding the lateral extent of contamination. As expected, a relatively thick accumulation of free product 2.168 m (7.11 ft), was detected in MW 7. No product was observed in MW 8. These wells were not used to constrain the water table configuration because site access opportunity ended before the well heads could be surveyed. Based on these findings, the areas along the axis of the water-table trough and the northwestern side of property A were recommended for focusing remedial action.

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CONCLUSIONS

Water-table correction factors are important for assessing the shape of the undisturbed water table at gasoline contamination sites that contain free-phase product. The application of water-table correction factors constitutes one component of a comprehensive site characterization process. In studies that begin after a layer of free product has accumulated, the water-table configuration is an important issue in determining the likely source(s) of contamination, the extent of free-product accumulation, possible pathways of free product and dissolved constituent migration, and areas that may be effective for focusing remediation efforts. The use of correction factors is particularly warranted in situations where an inadequate number of unaffected wells are available as control points. An inadequate number of control points can lead to a highly inaccurate representation of the undisturbed water-table configuration.

APPENDIX I. REFERENCES

Abdul, A. S., Kia, S. F., and Gibson, T. L. (1989). "Limitations of monitoring wells for the detection and quantification of petroleum products in soils and aquifers." *Ground Water Monitoring Rev.*, 9(2), 90–99.

"A guide to the assessment and remediation of underground petroleum releases." (1989). *API Publication 1628*, Am. Petroleum Inst. (API), Washington, D.C.

Farr, A. M., Houghtalen, R. J., and McWhorter, D. B. (1989). "Volume estimation of light nonaqueous phase liquids in porous media." *Ground Water*, 28(1), 48–56.

Freeze, R. A., and Cherry, J. A. (1979). *Groundwater*. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Lenhard, R. J., and Parker, J. C. (1989). "Estimation of free hydrocarbon volume from fluid levels in monitoring wells." *Ground Water*, 28(1), 57–67.

Testa, S., and Pacskowski, M. (1989). "Volume determination and recoverability of free hydrocarbon." *Ground Water Monitoring Rev.*, 9(1), 120–128.

APPENDIX II. NOTATION

The following symbols are used in this paper:

$CDTW$ = corrected depth to water (L);
DTW = measured depth to water (L);
G = specific gravity of product;
PT = product thickness (L);
ρ = density of product (M/L^3); and
ρ_w = density of water (M/L^3).

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