April 4, 1997

ENVIRONMENTAL
PROTECTION

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Chevron

Research and Technology

Ms. Juliet Shin
Alameda County Health Care Services
1131 Harbor Bay Parkway, Suite 250
Alameda, CA 94502-6577

**RE: Groundwater Evaluation**
*Chevron Station 9-0504*
15900 Hesperian Boulevard
San Lorenzo, California

Dear Ms. Shin:

In response to our telephone conversation of March 21, 1997, Chevron Research and Technology Company (CRTC) is providing additional information concerning the above referenced site. Recalling, further documentation was requested about the selection of the parameters used to evaluate vapor inhalation at the site. Specifically, Alameda County had concerns about the selection of the water and air content for the vadose zone, capillary fringe, and building foundation. To address these concerns, further justification on the selection of the parameters is provided. Additionally, where appropriate, some of the parameters were changed, as we discussed on the telephone, and the risk associated with vapor inhalation in indoor air by offsite residential receptors was recalculated with these new parameters.

**SUMMARY**

1) Total Porosity. A total porosity of 0.45 was selected to represent the clayey silt at the site.

2) Vadose Zone Parameters. The volumetric air content and volumetric water content of the vadose zone can be adequately approximated by specific yield and specific retention, respectively. Values of 0.07 for air content and 0.38 for water content were used for the clayey silt.

3) Capillary Fringe Parameters. The volumetric air content of the capillary fringe was estimated to be one-half of the specific yield of the vadose zone, which is 0.035. Likewise, the volumetric water content was estimated to be the specific retention of the vadose zone plus one-half of the specific yield, which is 0.415.

4) Building Foundation Parameters. The default parameters from ASTM E1739-95 were used for the air and water content of the foundation of the offsite residential building; the values being 0.26 and 0.12, respectively.

5) Potential Health Risk to Offsite Receptors. The potential health risk associated with the inhalation of benzene in indoor air by residential receptors due to volatilization from offsite groundwater is $1.8 \times 10^{-7}$.

## SELECTION OF PARAMETERS

Total Porosity. A total porosity value of 0.45 was selected to represent the clayey silt of the site. This value was taken from Everett et al. (1984; Table 3-1). The value represents the total porosity for a sandy clay, which CRTC believes adequately represents the conditions at the site.

Volumetric Air Content of the Vadose Zone. The volumetric air content of the vadose zone at the site was approximated by a specific yield value of 0.07 for a sandy clay (Everett et al., 1984). The specific yield value represents the portion of the porosity that is subject to gravity drainage. By using the specific yield value for the air content of the vadose zone, this assumes that the vadose zone at the site is fully gravity drained at all times and this void space is thus available as a pathway for vapor migration. Additionally, by making this assumption, any infiltrating water, whether rainfall or irrigation, would not occupy this void space, therefore inferring that the infiltrating water would percolate through other pore space within the vadose zone in order to recharge the aquifer.

Volumetric Water Content of the Vadose Zone. Specific retention was used to approximate the volumetric water content of the vadose zone. The specific retention, $S_r$, was determined from the following relationship (Fetter, 1993):

$$S_r = \theta_t - S_y$$

where:

| | | |
|---|---|---|
| $\theta_t$ | = | total porosity (0.45; Everett et al, 1984) |
| $S_y$ | = | specific yield (0.07; Everett et al, 1984) |

The specific retention, which is 0.38 in this case, is the water within a soil that is retained by capillary forces against gravity drainage. This value represents the water content that is relatively immobile; hence, if the soil is not subject to evapotranspiration, the specific retention will represent the minimum value for the volumetric water content.

Volumetric Air and Water Content of the Capillary Fringe. The volumetric air content and water content of the capillary fringe at the site was estimated. The volumetric air content was taken as one-half of the specific yield of the vadose zone, which is 0.035. Likewise, the volumetric water content was taken as the specific retention of the vadose zone plus one-half of the specific yield, which is 0.415. This approach for determining the volumetric water and air content assumes that half of the air space within the vadose zone becomes saturated with water in the capillary fringe area. The approach seems reasonable in that limited references are available for the selection of these parameters.

Volumetric Air and Water Content of the Building Foundation. Default values were used for the volumetric air and water content of the foundation of the residential building above the groundwater plume. The default parameters were taken from ATSM E1739-95. These values are 0.26 and 0.12, respectively.

## RISK OF GROUNDWATER VAPOR INTRUSION

The predicted benzene concentration in groundwater for vapor intrusion into residential buildings is 11 parts per billion (see letter of March 11, 1997). The risk pursuant to this benzene concentration was re-calculated with the new parameters listed above. The potential risk for the inhalation of air in residential buildings is $1.8 \times 10^{-7}$. Hence, by better characterizing the above parameters, the risk for benzene inhalation has decreased as compared to our previous calculations. Recalling, the letter of March 11, 1997, stated that the potential risk was $2.9 \times 10^{-7}$. Additionally, this risk is significantly less than the acceptable risk range of $1 \times 10^{-4}$ and $1 \times 10^{-6}$ as established by the United States Environmental Protection

Agency. Hence, the potential risk associated with this pathway is deemed acceptable and no corrective action is warranted for this pathway.

Please note that except for the parameters mentioned above, all other parameters have remained unchanged from our letter of March 11, 1997 (Appendix 1).

If you have any questions, or require additional information, please contact me at (510) 242-1284.

Very truly yours,

Dan Gallagher

Dan Gallagher
Hydrogeologist

Attachments

cc: J. Randall, CPDS
P. Briggs, CPDS
J. Stambolis, CRTC
T. Buscheck, CRTC
R. Magaw, CRTC

# Fax Cover Sheet

| | | | |
|---|---|---|---|
| DATE: | March 21, 1997 | TIME: | 02:00 pm |
| TO: | Juliet Shin<br>Alameda County | PHONE:<br>FAX: | n/a<br>(510) 337-9335 |
| FROM: | Dan Gallagher<br>Chevron Research | PHONE:<br>FAX: | (510) 242-1282<br>(510) 242-1380 |
| RE: | Chevron Station 9-0504, San Lorenzo | | |

**Number of pages including cover sheet: 6**

## Message

To evaluate hydrocarbon transport at our site, I used a specific yield value to represent the effective porosity of the vadose zone and water table aquifer. The number was obtained from Everett et al. (1994). Attached are pages from the Everett book which contains the table I used. Additionally, there is some general information on specific yield and specific retention.

Please call me if you have additional questions.

# VADOSE ZONE MONITORING FOR HAZARDOUS WASTE SITES

by

**L.G. Everett**

**L.G. Wilson**

**E.W. Hoylman**

Kaman Tempo
Santa Barbara, California

NOYES DATA CORPORATION
Park Ridge, New Jersey, U.S.A.
1984

TABLE 3-3. RANGE OF POROSITY VALUES IN UNCONSOLIDATED DEPOSITS AND ROCKS (after Freeze and Cherry, 1979)

| | Porosity (percent) |
|---|---|
| Unconsolidated Deposits | |
| Gravel | 25 to 40 |
| Sand | 25 to 50 |
| Silt | 35 to 50 |
| Clay | 40 to 70 |
| Rocks | |
| Fractured basalt | 5 to 50 |
| Karst limestone | 5 to 50 |
| Sandstone | 5 to 30 |
| Limestone, dolomite | 0 to 20 |
| Shale | 0 to 10 |
| Fractured crystalline rock | 0 to 10 |
| Dense crystalline rock | 0 to 5 |

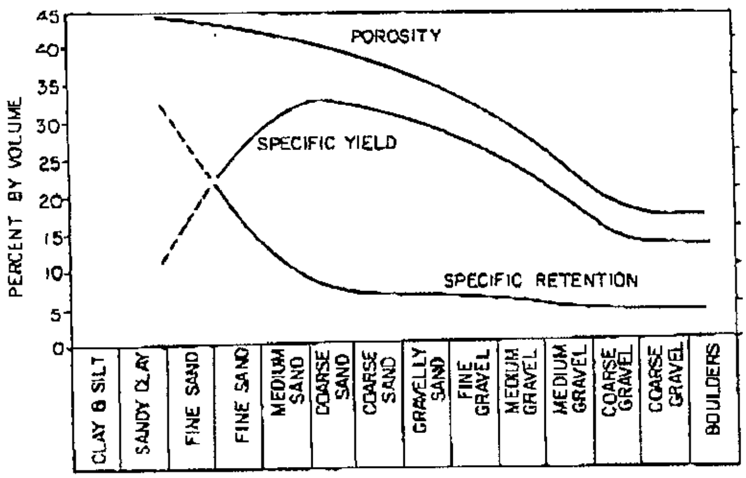


Figure 3-1. Variation of porosity, specific yield, and specific retention with grain size (after Scott and Scalmanini, 1978).

For sandy soils, field capacity may be reached in a few hours. For soils finer than sandy soils (e.g., sandy loams), 2 or 3 days may be required to reach field capacity, and for medium- to fine-textured soils, a week may be required. For poorly structured clays, the time will be much greater (U.S. EPA et al., 1977). Approximate values of field capacity (on a mass basis) vary from 4 percent in sands to 45 percent in heavy clays and up to 100 percent or more in organic soils (Hillel, 1971). In terms of matric potentials, field capacity values for sands range from 0.1 to 0.15 bar (1 bar = 0.9869 atmosphere). For medium- to fine-textured soils, the corresponding range is 0.3 to 0.5 bar (U.S. EPA et al., 1977). The value of 0.3 bar is chosen as an average value.

Knowing the water content values of a given soil at field capacity and the observed water content value at a given time, the depth of water applied at the land surface to bring the soil to field capacity may be calculated from equation 3-1. For layered soil, it is necessary to account for the sum of the water contents of individual layers (see Brakensiek, Osborn, and Rawls, 1979).

Among the factors affecting the apparent field capacity are (Hillel, 1971): (1) soil texture, (2) type of clay (e.g., clays predominantly comprised of the montmorillonite type exhibit a higher water-holding capacity at field capacity), (3) organic matter content (the higher the organic matter level, the higher the field capacity), (4) antecedent water content, (5) presence of impeding layers, and (6) evapotranspiration. Soil structure is also an important factor in evaluating field capacity inasmuch as large interpedal cracks permit more rapid drainage than the micropores within the soil blocks.

The water content of a soil sample at 0.3 bar is obtained in the laboratory using the pressure membrane method discussed in Soil Water Characteristics, this section. An alternative method to estimate field capacity is to assume that field capacity equals one-half of the percentage of water content at saturation; that is, $F_c = SP/2$. Saturation percentage is measured in the laboratory by determining the number of grams of water to saturate 100 grams of air dry soil (U.S. EPA et al., 1977).

The above discussion relates to the concept of field capacity as employed by agriculturists. The parallel term used by geohydrologists is "specific retention," defined as the "quantity of water per unit total volume which will not drain under the influence of gravity" (Cooley, Harsh, and Lewis, 1972). Specific retention may be visualized as the water remaining in the dewatered region of the vadose zone after recession of the water table (Figure 3-1).

## Specific Yield

"Specific yield" is a term employed by geohydrologists to characterize storage in an unconfined aquifer. That is, specific yield is "... the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline in the water table" (Freeze and Cherry, 1979). Figure 3-1 shows the conceptual relationship between specific yield and specific retention. As shown in Figures 3-1 and 3-13, the specific yield for a medium equals the porosity value minus the value of specific retention.

where $T$ = surface tension of the liquid

$\alpha$ = contact angle

$\rho$ = density of liquid

$g$ = acceleration of gravity

$r$ = effective radius.

As discussed by Bouwer (1978), the negative pressure head in the vadose zone equals the vertical distance above a water table provided vertical flow is not occurring. Consequently, for uniform conditions, a plot of the change in volumetric water content with distance above a water table represents the water characteristic curve of the vadose zone material, again assuming no vertical flow. In practice, the volumetric water content could be determined using the neutron moisture logger.

Bouwer (1978) describes the nature of characteristic curves for layered conditions. The negative pressure head still equals the vertical distance above the water table. The water content-head relationship, however, depends on the soil at the measurement point. In other words, if an irregular water content distribution occurs above the water table, although head changes occur continuously with vertical distance, discontinuities may occur in water content distribution. Bouwer (1978) indicates that certain fine-textured soils may actually be saturated (e.g., contain perched groundwater lenses), whereas coarser-textured material above and below may be unsaturated.

## Field Capacity (Specific Retention)

Field capacity may be defined in a general sense as the volume of water that a unit volume of soil will retain against the force of gravity during drainage. The concept of field capacity was developed many years ago by agriculturists concerned with quantifying the amount of water to apply to irrigated fields. The original premise was that field capacity is a fixed value representing the amount of water stored in a soil a certain time after drainage has "essentially ceased." By the same token, it is usually assumed that during recharge (wetting), water movement will not occur until the medium has been wetted to field capacity. Although these concepts of field capacity are useful in an applied sense, they have certain technical limitations. Hillel (1971) discusses such limitations in detail. Briefly, one limitation is that the simplistic concept of field capacity fails to account for the dynamic nature of soil-water movement. In particular, drainage does not really cease at field capacity but may continue at a slower rate for a prolonged period of time. That is, "The redistribution process is in fact continuous and exhibits no abrupt 'breaks' or static levels. Although its rate decreases constantly, in the absence of a water table the process continues and equilibrium is approached, if at all, only after very long periods" (Hillel, 1971). The modern conception of field capacity is that it is not a unique soil property; instead, a range of values is possible.

Representative specific yield values for valley sediments in California are listed in Table 3-4.

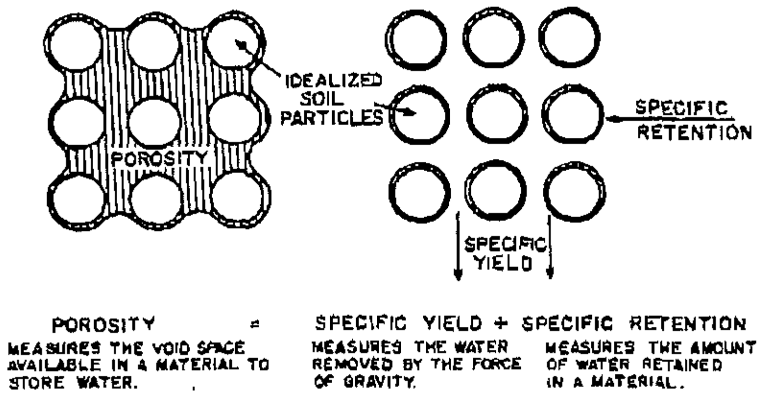


*Figure 3-13.* *Schematic representation of porosity, specific yield, and specific retention (after Scott and Scalmanini, 1978).*

TABLE 3-4. COMPILATION OF SPECIFIC YIELD VALUES FOR VARIOUS MATERIALS IN CALIFORNIA VALLEYS (after Cooley, Harsh, and Lewis, 1972)

| Material | Average Specific Yield (percent) |
|---|---|
| Clay | 2 |
| Silt | 8 |
| Sandy clay | 7 |
| Fine sand | 21 |
| Medium sand | 26 |
| Coarse sand | 27 |
| Gravelly sand | 25 |
| Fine gravel | 25 |
| Medium gravel | 23 |
| Coarse gravel | 22 |

## APPENDIX 1

**SUMMARY OF CHEMICAL AND PHYSICAL PROPERTIES**
**Chevron Station 9-0504**
**San Lorenzo**

Table of parameters used to determine the volatilization factor $VF_{wesp}$.

| PARAMETER | VALUE | REFERENCE |
|---|---|---|
| H: henry's law constant for benzene (unitless) | 0.22 | ASTM, 1995 |
| $h_v$: *thickness vadose zone (cm)* | 185 | estimate |
| $h_{cap}$: thickness capillary zone (cm) | 30 | estimate |
| ER: enclosed air exchange rate (L/s) | 0.00014 | ASTM, 1995 (residential) |
| $L_b$: enclosed space volume/infiltration area ratio (cm) | 200 | ASTM, 1995 (residential) |
| $L_{crack}$: foundation or wall thickness (cm) | 15 | ASTM, 1995 |
| n: areal fraction of cracks in wall/foundation (unitless) | 0.01 | ASTM, 1995 |
| $D_{air}$: *air diffusion coefficient for benzene* ($cm^2/s$) | 0.093 | ASTM, 1995 |
| $D_{water}$: water diffusion coefficient for benzene ($cm^2/s$) | 0.000011 | ASTM, 1995 |
| $\theta_t$: soil porosity (unitless) | 0.45 | Everett et al., 1984 |
| $\theta_{as}$: air content in vadose zone soils (unitless) | 0.07 | Everett et al., 1984 |
| $\theta_{ws}$: water content in vadose zone soils (unitless) | 0.38 | Everett et al., 1984 |
| $\theta_{acrack}$: air content in foundation/wall cracks (unitless) | 0.26 | ASTM, 1995 |
| $\theta_{wcrack}$: *water content in foundation/wall cracks (unitless)* | 0.12 | ASTM, 1995 |
| $\theta_{acap}$: air content in capillary fringe (unitless) | 0.035 | estimate |
| $\theta_{wcap}$: water content in capillary fringe (unitless) | 0.415 | estimate |

Note:

1) Sum of $\theta_{as}$ and $\theta_{ws}$ must equal total soil porosity ($\theta_t$).
2) Sum of $\theta_{acap}$ and $\theta_{wcap}$ must equal total soil porosity ($\theta_t$).
3) Residential parameters were used for ER and $L_b$.

Table of parameters used to characterize the cancer risk.

| PARAMETER | VALUE | REFERENCE |
|---|---|---|
| CR: contact rate ($m^3$/day) | 15 | ASTM, 1995 (residential) |
| EF: exposure frequency (days/year) | 350 | ASTM, 1995 (residential) |
| ED: exposure duration (years) | 30 | ASTM, 1995 (residential) |
| BW: body weight (kg) | 70 | ASTM, 1995 (residential) |
| AT: averaging time (days) | 25550 | ASTM, 1995 (residential) |
| CSF: cancer slope factor for benzene (kg-d/mg) | 0.1 | CAL-EPA, 1994 |

# Fax Cover Sheet

| | | | |
|---|---|---|---|
| DATE: | March 21, 1997 | TIME: | 02:00 pm |
| TO: | Juliet Shin<br>Alameda County | PHONE:<br>FAX: | n/a<br>(510) 337-9335 |
| FROM: | Dan Gallagher<br>Chevron Research | PHONE:<br>FAX: | (510) 242-1282<br>(510) 242-1380 |
| RE: | Chevron Station 9-0504, San Lorenzo | | |

**Number of pages including cover sheet: 6**

## Message

To evaluate hydrocarbon transport at our site, I used a specific yield value to represent the effective porosity of the vadose zone and water table aquifer. The number was obtained from Everett et al. (1994). Attached are pages from the Everett book which contains the table I used. Additionally, there is some general information on specific yield and specific retention.

Please call me if you have additional questions.

ENVIRONMENTAL PROTECTION

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Chevron

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**Marketing – Sales West**
Phone 510 842-9500

March 14, 1997

Ms. Juliet Shin
Alameda County Health Care Services
Department of Environmental Health
1131 Harbor Bay Parkway, Suite 250
Alameda, CA 94502-6577

Re: **Chevron Service Station #9-0504**
**15900 Hesperian Blvd., San Lorenzo, California**

Dear Ms. Shin:

Enclosed is a copy of the re-evaluated Groundwater Transport Evaluation Report, that was prepared by our Chevron Research and Technology Company (CRTC), for the above noted site. This re-evaluation was conducted at your request to determine the maximum concentration of benzene within well C-10 if benzene breakthrough occurs, and to quantify the potential health risk of benzene inhalation for offsite residential receptors.

To evaluate the potential for benzene occurring in monitoring well C-10 from the upgradient source area near well C-8, CRTC used the "PRINCE" software program to predict the transport of the benzene constituent. This software program was used in the original Evaluation Report, however two of the input parameters were changed as requested. This was that the ninety-five percent upper confidence level ( 95UCL). be used in place of the arithmetic mean of the historical benzene concentrations observed in monitoring well C-8; and that the porosity of the site be more effectively characterized. The 95UCL calculation produced a value of 100 ppb for the value of the benzene observed in well C-8, while the arithmetic mean produced a value of 81 ppb. The effective porosity selected was 0.07, which was to characterize the clayey silt of the site and CRTC believes adequately represents the conditions at the site. CRTC originally used a porosity of 0.15 for the groundwater modeling.

The results of the latest modeling using the "PRINCE" program and with the changes to the two parameters noted above, indicate that the maximum benzene concentration in well C-10 should be about 11 ppb. This predicted concentration of benzene in well C-10 exceeded the Tier 1 Risk-Based Screening Levels for benzene, and for groundwater vapor intrusion into residential buildings. Therefore, to address this concern, CRTC evaluated this exposure pathway with site-specific data to quantify the potential health risk. CRTC technically performed a Tier 2 evaluation for this pathway and determined that the health risk for offsite receptors due to vapor intrusion from groundwater into residential buildings is 2.9 x 10-7. This risk is less that the acceptable risk range of 1 x 10-4 and 1 x 10-6 and therefore, the risk associated with this pathway is accetable and no corrective action is needed.

If you have any questions or comments to this evaluation, contact Dan Gallagher with CRTC at (510) 242-1284, or call me at (510) 842-9136.

Sincerely,
CHEVRON PRODUCTS COMPANY

Philip R. Briggs
Site Assessment and Remediation Project Manger

Enclosure

cc. Mr. Bill Scudder, Chevron

Mr. Ron Sykora
David E. Bohannon Organization
60 Hillsdale Mall
San Mateo, CA 94403