Suggested Input Values for Oakland, CA Risk Assessments

Presented below are suggested input values for modeling risk from contamination at sites in Oakland. These values deviate from the default values employed in many risk models; however, they are appropriate for most sites in Oakland and there is significant precedence for their use.

AERIAL DISPERSION PARAMETERS

Table 1 presents suggested Oakland values for residential and commercial land use scenarios for three parameters relating to the aerial dispersion of contaminants.

Table 1. Suggested Oakland Values Relating to Aerial Dispersion

Input Parameter	Residential	Commercial
Building air volume/floor area (cm^3/cm^2)	229	305
Indoor air exchange rate (s^{-1})	5.6E-04	1.40E-03
Wind speed in outdoor air mixing zone (cm/s)	322	322

The following subsections discuss the justification for each of these values.

Building Air Volume/Floor Area

The building air volume divided by the floor area is the height of the ceiling. Larger rooms allow for a greater reduction in the concentration of a chemical in the air. Table 2 presents the suggested Oakland values for this parameter.

Table 2. Suggested Oakland Values for
Building Air Volume/Floor Area
(cm^3/cm^2)

Land Use Scenario	Suggested Oakland Value
Residential	229[a]
Commercial	305[b]

[a] California Building Code (1998)
[b] based on U.S. EPA (1997) delineation of "typical" ceiling heights

The value for the residential land use scenario is based on the minimum California Building Code (1998) requirement of seven feet, six inches for residential structures. The value for the commercial land use scenario assumes an average ceiling height of 10 feet. This value reflects the average of the values defined by U.S. EPA (1997) as "typical" for residential (eight feet) and commercial (12 feet), and accounts for commercial enterprises operating on the ground floor of older, mixed-use structures.

Indoor Air Exchange Rate

The indoor air exchange rate determines how much fresh air from outside is exchanged with indoor air in buildings. Table 3 presents the suggested Oakland values for this parameter.

Table 3. Suggested Oakland Values for Indoor Air Exchange Rate (s^{-1})

Land Use Scenario	Suggested Oakland Value
Residential	5.6E-04[a]
Commercial	1.4E-03[b]

[a] Sherman (1997); equals 2 air changes per hour
[b] Hydeman (1996); equals 5 air changes per hour

Oakland has an extremely temperate climate. For a residential land use scenario in California, a value of two air changes per hour (ACH) is considered reasonable (Sherman 1997). For a commercial land use scenario, a value of five ACH is employed because, when the outside temperature is between 60^{o} F and 70^{o} F, it is most efficient to use 100 percent fresh air for building ventilation (Hydeman 1996). Oakland temperatures are between 60^{o} F and 70^{o} F during the day for about six months of the year (National Climatic Data Center 1982).

Wind Speed in Outdoor Air Mixing Zone

Wind speed can affect the concentration of a chemical of concern in the outdoor air through dispersion.

Average annual wind speeds for different areas of Oakland were extrapolated from wind rose data provided by the Bay Area Air Quality Management District (BAAQMD, 1996).

Table 4. Location-specific Wind Speeds in Oakland (cm/s)

West Oakland (Sewage Treatment Plant)	East Oakland (Oakland International Airport)	Oakland-Berkeley Hills (Vollmer Peak)
322[a]	418[b]	640[c]

[a] measured from 4/1/92 through 3/31/93
[b] measured from 1/1/60 through 12/31/64
[c] measured from 1/1/90 through 12/4/90

SOIL PARAMETERS

There are three predominant soil types in Oakland: Merritt sands, sandy silts and clayey silts.

Merritt sands are mostly located in the flatlands area to the west of Lake Merritt. They are a fine-grained, silty sand with lenses of sandy clay and clay (Radbruch 1957). Merritt sands have a low moisture content and high permeability.

Sandy silts are found throughout Oakland. They are made up of unconsolidated, moderately-sorted sand, silt, and clay sediments, with both fine-grained and course-grained materials. Sandy silts have a medium moisture content and moderate permeability.

Clayey silts are primarily found along the Bay and estuary, and in land fills from those areas. They may contain organic materials, peaty layers and small lenses of sand. Clayey silts have a high moisture content and low permeability.

Table 5 presents the suggested Oakland values for parameters related to these soil types.

Table 5. Suggested Oakland Values for Soil Parameters

Input Parameter	Merritt Sands	Sandy Silts	Clayey Silts
Capillary fringe air content (cm^3/cm^3)	0.025	0.020	0.010
Capillary fringe water content (cm^3/cm^3)	0.330	0.380	0.490
Capillary fringe thickness (cm)	10	60	152
F_{oc} in soil (g/g)	0.010	0.015	0.020
Groundwater mixing zone thickness (cm)	305	762	1,524
Infiltration rate of water through the vadose zone (cm/yr)	9	6	3
Soil bulk density (g/cm^3)	1.72	1.59	1.33
Soil to skin adherence factor (mg/cm^2)	0.2	0.5	1.0
Total soil porosity (cm^3/cm^3)	0.35	0.40	0.50
Vadose zone air content (cm^3/cm^3)	0.20	0.15	0.10
Vadose zone water content (cm^3/cm^3)	0.15	0.25	0.40
Vadose zone thickness (cm)	290	240	148

The following subsections discuss the justification for each of these values.

Capillary Fringe Parameters: Air Content, Water Content and Thickness

The capillary fringe is the region above the water table that is completely saturated (Freeze and Cherry 1979; Knox et al. 1993). Table 6 presents the suggested Oakland values for *capillary fringe air content, capillary fringe water content* and *capillary fringe thickness*.

Table 6. Suggested Oakland Values for
Capillary Fringe Thickness, Water Content and Air Content

Input Parameter	Merritt Sands	Sandy Silts	Clayey Silts
Capillary fringe air content (cm^3/cm^3)	0.025[b]	0.020[b]	0.010[b]
Capillary fringe water content (cm^3/cm^3)	0.330[b]	0.380[b]	0.490[b]
Capillary fringe thickness (cm)	10[b]	60[b]	152[b]

[b] selected by Technical Advisory Committee (1996b)

These values represent an average of values recommended by environmental experts with Oakland field experience (Technical Advisory Committee 1996b). The finer the soil particles, the less air and more water is assumed to be present in the capillary fringe. The capillary fringe is also assumed to be thicker in finer-grained soils. These assumptions are supported by standard literature on the subject. Table 7 compares the capillary rise values reported by Guymon (1994) with the suggested Oakland values for *capillary fringe thickness*.

Table 7. Comparison of Standard Capillary Rise Values with Suggested Oakland Values for *Capillary Fringe Thickness*

Guymon (1994)			Suggested Oakland Value
Unconsolidated Material	Grain size (mm)	Capillary Rise* (cm)	Capillary Thickness (cm)
Medium sand	0.50 - 0.20	24.6	
Fine sand	0.20 - 0.10	42.8	10[a]
Silt (sample #1)	0.10 - 0.05	105.5	60[b]; 152[c]
Silt (sample #2)	0.05 - 0.02	200.0[d]	

*capillary rise measured after 72 days; all samples were approximately 41% porous
[a] input value for Merritt sands
[b] input value for sandy silts
[c] input value for clayey silts
[d] still rising after 72 days

The Oakland values are conservative because they assume that air is trapped in the capillary fringe, making it more permeable to chemicals volatilizing from the groundwater.

Fraction Organic Carbon in Soil

Fraction organic carbon in soil plays a major role in the ability of chemicals to sorb to soil. The suggested Oakland value for this parameter accounts for the fact that mineral surfaces, such as clay, and electromagnetic molecular forces also cause chemicals to sorb, even if no organic carbon is present (Lyman et al. 1992; Knox et al. 1993). Table 8 presents the suggested Oakland values for *fraction organic carbon in soil* with the ASTM (1995) default.

Table 8. Suggested Oakland Values for *Fraction Organic Carbon in Soil* (g/g)

Merritt Sands	Sandy Silts	Clayey Silts
0.010[a]	0.015[a]	0.020[a]

[a] Spence and Gomez (1999)

(Spence and Gomez 1999). The soils characterization study was performed to more accurately predict sorption of organic chemicals to soil by taking into account factors other than organic carbon.

Although F_{oc} is known to be an important contributor to sorption, it is only a partial predictor of the total sorption that occurs. To address this shortcoming, the soils characterization study measured the partitioning (or sorption) of dissolved-phase benzene onto the three Oakland soil types. Once the actual partitioning was measured for benzene, an input value for the parameter F_{oc}* was calculated for each of the three soil types. The F_{oc}* value is used to predict the variability in the level of sorption, from one soil type to another, for all organic chemicals.

Groundwater Mixing Zone Thickness

The thickness of the mixing zone in groundwater is used to calculate the chemical concentration in groundwater at the down-gradient edge of the soil source. Table 9 presents the suggested Oakland values for *groundwater mixing zone thickness.*

Table 9. Suggested Oakland Values for *Groundwater Mixing Zone Thickness* (cm)

Merritt Sands	Sandy Silts	Clayey Silts
305[a]	762[a]	1,524[a]

[a] selected by Technical Advisory Committee (1998)

The input value for *groundwater mixing zone thickness* is used to estimate the concentration of a chemical in groundwater extracted from a well at the down-gradient edge of the soil source. Varying hydraulic conductivity in the three different soil types is assumed to influence the well screen length required to extract the same amount of groundwater. The lower the hydraulic conductivity is, the longer the well screen length that is required.

Infiltration Rate of Water through the Vadose Zone

The infiltration rate is the amount of water that travels through the vadose zone and reaches groundwater. Table 10 presents the suggested Oakland values for *infiltration rate of water through the vadose zone*.

Table 10. Suggested Oakland Values for *Infiltration Rate* (cm/yr)

Merritt Sands	Sandy Silts	Clayey Silts
9[b]	6[c]	3[a]

[a] Technical Advisory Committee (1998); equals 5 percent of average Oakland rainfall
[b] Technical Advisory Committee (1998); equals 15 percent of average Oakland rainfall
[c] Technical Advisory Committee (1998); equals 10 percent of average Oakland rainfall

The suggested Oakland values, which are calculated from the average Oakland rainfall of 24 inches per year (National Weather Service 1998), assume that infiltration rate is influenced by soil grain size and permeability. Standard literature indicates that these values are conservative. Table 11 compares the range of "recharge" rates reported by Walton (1988) for areas geologically similar to Oakland with the suggested Oakland rates.

Table 11. Comparison of Standard Recharge Rates with Suggested Oakland Values for *Infiltration Rate*
(in/yr)

Walton (1988) (Originally based on Heath 1982)		Suggested Oakland Values
Region	Recharge Rate	Infiltration Rate
Western Mountain Ranges	0.100 - 2	
Alluvial Basins	0.001 - 1	3.6[a]; 2.4[b]; 1.2[c]

[a] input value for Merritt sands (converted to inches per year)
[b] input value for sandy silts (converted to inches per year)
[c] input value for clayey silts (converted to inches per year)

Soil Bulk Density

The following equation is used to calculate soil bulk density:

Equation 1. Soil Bulk Density

$$\text{soil bulk density} = (1 - \text{total porosity})\,(2.65\ \text{g/cm}^3)$$

Table 12 presents the suggested Oakland values for *soil bulk density*.

Table 12. Suggested Oakland Values for
Soil Bulk Density Values
(g soil/cm^3 soil)

Merritt Sands	Sandy Silts	Clayey Silts
1.72[b]	1.59[b]	1.33[b]

[b] based on total soil porosity values selected by Technical Advisory Committee (1996b)

These values were calculated using the total soil porosity values selected by the Technical Advisory Committee (1996b).

Soil Adherence Factor

The soil adherence factor determines the amount of soil that will stick to an individual's skin upon contact. Table 13 presents the suggested Oakland values for *soil to skin adherence factor*.

Table 13. Suggested Oakland Values for
Soil Adherence Factor
(mg soil/cm^2 soil)

Merritt Sands	Sandy Silts	Clayey Silts
0.2[b]	0.5[b]	1.0[b]

[a] ASTM (1995)
[b] U.S. EPA (1992)

These values are conservative and are based on studies reported by U.S. EPA (1992) that show soil adherence to skin to be a function of grain size. Based on these studies, U.S. EPA (1992) concluded that "0.2 [mg/cm^2] may be the best value to represent an average… and 1 [mg/cm^2] may be a reasonable upper value."

Total Soil Porosity, Vadose Zone Air Content and Vadose Zone Water Content

Total soil porosity, vadose zone air content and vadose zone water content are interrelated and are discussed here as a group. Total soil porosity is the sum of air content and water content. Table 14 presents the suggested Oakland values for *total soil porosity*, *vadose zone water content* and *vadose zone air content*.

Table 14. Suggested Oakland Values for
Total Soil Porosity, *Vadose Zone Water Content*, *Vadose Zone Air Content*
(cm^3/cm^3)

Input Parameter	Merritt Sands	Sandy Silts	Clayey Silts
Total soil porosity	0.35[a]	0.40[a]	0.50[a]
Vadose zone water content	0.15[a]	0.25[a]	0.40[a]
Vadose zone air content	0.20[a]	0.15[a]	0.10[a]

[a] selected by Technical Advisory Committee (1996b)
[b] ASTM (1995)

These values represent an average of values recommended by environmental experts with Oakland field experience (Technical Advisory Committee 1996b). The values selected for each soil type reflect the following considerations:

(1) The total soil porosity value ought to be reflective of the vadose zone in between the source and the building or the source and the ground surface. Low-permeability (i.e., higher-water-content) lenses will be the limiting layer for diffusion, and the air content and water content values should account for their presence.

(2) Total soil porosity in sand is diminished if the sand is "dirty" or not well-sorted because the larger pore spaces fill up with small particles.

(3) Total soil porosity in clays increases as the clay particle sizes decrease, resulting in a greater percent volumetric water content, and an absolute volumetric air content that is the same as or lower than that found in clays with larger particle sizes.

(4) Soils may be wetter in the winter and drier in the summer. The input values should reflect an annual average.

(5) *Total soil porosity* is not the critical parameter, per se; rather, the model is driven by the values selected for *vadose zone air content* and *vadose zone water content*.

The suggested Oakland values for *total soil porosity* are supported by standard groundwater and soils texts. Table 15 compares the ranges of total soil porosity values reported by Freeze and Cherry (1979) with the suggested Oakland values.

Table 15. Comparison of Standard Total Porosity Value Ranges for Various Soil Types with Suggested Oakland Values
(cm^3_{voids}/cm^3_{soil})

Freeze and Cherry (1979)		Suggested Oakland Values
Sand	0.25 - 0.50	0.35[a]
Silt	0.35 - 0.50	0.40[b]
Clay	0.40 - 0.70	0.50[c]

[a] input value for Merritt sands
[b] input value for sandy silts
[c] input value for clayey silts

Texts do not typically report standard values for air content and water content in the vadose zone. Heath (1989) defines specific yield as the amount of water in storage in the vadose zone that drains under the influence of gravity, and specific retention as the amount of water that is retained in the pore spaces under the influence of gravity. Specific yield may be considered a conservative air content value and specific retention a conservative water content value. Table 16 compares the Heath (1989) values for specific yield and retention with the suggested Oakland values for *vadose zone air content* and *vadose zone water content*, respectively.

Table 16. Comparison of Standard Specific Retention and Specific Yield Values with Suggested Oakland Values for *Vadose Zone Air Content* and *Vadose Zone Water Content*
(cm^3/cm^3)

Heath (1989)			Suggested Oakland Values	
Material	Specific Yield	Specific Retention	Air Content	Water Content
Sand	0.22	0.03	0.20[a]	0.15[a]
Soil	0.40	0.15	0.15[b]	0.25[b]
Clay	0.02	0.48	0.10[c]	0.40[c]

[a] input value for Merritt sands
[b] input value for sandy silts
[c] input value for clayey silts

The suggested Oakland values for *vadose zone air content* and *vadose zone water content* take into consideration that clays hold more water and sands less. The Oakland values are conservative because the vadose zone air content is assumed to be on the high end of potential values, which renders the vadose zone more permeable to chemicals volatilizing from the soil and groundwater.

Vadose Zone Thickness

The thickness of the vadose zone is determined by the thickness of the capillary fringe and the depth to groundwater. Table 17 presents the suggested Oakland values for *vadose zone thickness*.

Table 17. Suggested Oakland Values for *Vadose Zone Thickness* (cm)

Merritt Sands	Sandy Silts	Clayey Silts
290[b]	240[b]	148[b]

[b] calculated from values for *capillary fringe thickness* and *depth to groundwater* selected by Technical Advisory Committee (1996b)

TARGET RISK LEVELS

Table 18 presents the suggested Oakland value for Individual Excess Lifetime Cancer Risk.

Table 18. Suggested Oakland Target Risk Levels

Individual Excess Lifetime Cancer Risk (IELCR)	10^{-5}

The following subsections discuss in detail the selection of, and justification for, each of the target risk levels.

Individual Excess Lifetime Cancer Risk

The Oakland Tier 2 IELCR deviates from the ASTM (1995) default but falls within the range of target risks recommended by ASTM (1995). There is considerable and diverse support for the use of a 10^{-5} IELCR target level:

- Local representatives of the agencies charged with enforcing environmental regulations in Oakland agreed unanimously to 10^{-5} at a meeting of the ULR Program Technical Advisory Committee (1996a).
- The ULR Program Community Review Panel approved 10^{-5} by consensus. The Panel consisted of Oakland residents representing a cross-section of the Oakland community. The Panel included individuals from: African American Development Association, GEI Consultants, People United for a Better Oakland, Northern California Minority Business Opportunity Committee, Sierra Club, Urban Habitat and Uribe & Associates Environmental Consulting Services. Their additional experience included participation with: Alameda Naval Air Station Restoration Advisory Board, Chevron USA Refinery Community Advisory Panel, City of Oakland Planning Commission, Community Assistance Panel for Verdese Carter Park, Regional Brownfields Working Group, Oakland Army Base Restoration Advisory Board, Oakland Sharing the Vision, Oakland General Plan Congress and United Parents Against Lead. The Panel met twelve times between September 1996 and August 1997 to review the ULR Program (now known as the "RNUL Program"). In its report, *Consensus Recommendations for Implementing the Oakland Urban Land Redevelopment Program (1997)*, the Panel recommended that:

  [a] cancer risk level not to exceed 10^{-5} should be employed to calculate cleanup levels, provided that the following conditions are met: (1) the chemicals of concern at the site in question are well-known and well-characterized; (2) the conservatism of the assumptions that are proposed for use in the ULR cleanup

calculations (such as those for exposure duration, soil ingestion and drinking water consumption) are maintained, thereby effectively reducing the risk further; (3) whenever possible, engineering controls (such as vapor barriers or asphalt caps) are considered to eliminate exposure through certain pathways; and (4) a comprehensive and effective plan for protecting the public from any remaining concentrations of contaminants is prepared, implemented and enforced.

- State Proposition 65 enforcement is based on 10^{-5}. The Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65) requires the Governor of California to publish annually a list of chemicals known to the State to cause cancer or reproductive toxicity. All persons who operate a business that might expose individuals to a listed chemical must give a clear and reasonable warning to such individuals, unless there is “no significant risk” posed by the carcinogen(s) in question. The State has defined “no significant risk” as less than one excess case of cancer per 100,000 individuals.

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