M60050.001379

BECHTEL NATIONAL INC.

M60050.001379
MCAS EL TORO
SSIC # 5090.3

CLEAN II TRANSMITTAL/DELIVERABLE RECEIPT

Contract No. N-68711-92-D-4670 **Document Control No.:** CTO-0080/0084

File Code: ~~0217.3~~ .0227

TO: Commanding Officer
Naval Facilities Engineering Command
Southwest Division
Mr. Paul Kennedy, Code 0233.PK (1 copy)
Building 128
1220 Pacific Highway
San Diego, CA. 92132-5187

DATE: 10/09/95
CTO #: 0080
LOCATION: San Diego, CA

FROM: D. J. Tedaldi, CTO Leader

DESCRIPTION: Submittal of Review Comments on the Quick Reference Fact Sheet, the Draft Soil Screening Guidance: Issues Document and the Technical Background for Soil Screening Guidance, CLEAN II CTO-0080.

TYPE: ____ Contract Deliverable ____ CTO Deliverable X Change Notice/Project Note

VERSION: Final (e.g., draft, draft final, final) REVISION #: 0

ADMIN RECORD: (PM to Identify) Yes† ____ No ____ Category ____ Confidential ____

SCHEDULED DELIVERY DATE: None ACTUAL DELIVERY DATE: 10/09/95

NUMBER OF COPIES SUBMITTED: Five

COPIES TO (Include Name, Navy Mail Code, and No. of Copies):

SWDIV:	BECHTEL (Distributed by Bechtel):	OTHER (Distributed by Bechtel):
J. Rogers, Code 18C1 (1)	D. Cowser (1)	B. Arthur, US EPA (1)
J. Ashman, Code 1831.JA (1)	D. Tedaldi (1)	S. Beard, Cal EPA (1)
V. Garelick, Code 1853.VG (1)	T. Latas (1)	J. Jimenez, Cal EPA (1)
T. Broussard, Code 0233.DB (1)	C. Carlise (1)	J. Joyce, El Toro (1)
A. Piszkin, Code 1831.AP (1)	P. Brooks (1)	L. Vitale, CRWQCB (1)
	BNI Document Control (1)	

Date/Time Received

RECEIVED
COTR
10 OCT 95 10:30 AM

* Transmittal Only
† If "Yes" copy C. Potter

10/9/95, 1:29 PM, djact g:\cto80\transmit\transltr.doc

Bechtel

401 West A Street
Suite 1000
San Diego, CA 92101-7905

CLEAN II Program
Bechtel Job No. 22214
Contract N68711-92-D-4670
File Code: 0217.3

IN REPLY/REFERENCE: CTO-0080/0084

Thursday, October 05, 1995

Juan Jimenez, RPM Base Closure Branch
State of California Environmental Protection Agency
Department of Toxic Substances Control
245 West Broadway, Suite 350
Long Beach, CA 90802-4444

Subject: Submittal of Review Comments on the Quick Reference Fact Sheet, the Draft Soil Screening Guidance: Issues Document and the Technical Background for Soil Screening Guidance

Dear Mr. Jimenez:

I am providing this submittal of review comments on the above-referenced documents. I was selected by USEPA headquarters as part of nine peer reviewers nationwide and the attached comments should prove of interest to the MCAS El Toro BCT. I have provided comments on major issues, not a page-by-page critique of the documents. This submittal is mostly for information purposes only since the draft documents have not been finalized and issued by EPA yet.

In general, EPA's presentation was rigorous and well-documented. While I support EPA's attempts to address the interaction of soil systems and groundwater, I am not convinced that the generic Soil Screening Levels (SSLs) are defensible and believe that site-specific SSLs will inevitably be required for decision-making at CERCLA sites. To aid you in your study I have attached a copy of the Quick Reference Fact Sheet.

If I can be of any further assistance please call me in Bechtel's San Diego office at (619) 687-8780.

Sincerely,

Dante J. Tedaldi, Ph.D., P.E.
Technical Quality Assurance MCAS El Toro

Attachment: Review Comments on the Quick Reference Fact Sheet, the Draft Soil Screening Guidance: Issues Document and the Technical Background for Soil Screening Guidance

cc: Larry Vitale, Remedial Project Manager
Joseph Joyce, BRAC Environmental Coordinator
Bonnie Arthur, RPM

Bechtel

401 West A Street
Suite 1000
San Diego, CA 92101-7905

CLEAN II Program
Bechtel Job No. 22214
Contract N68711-92-D-4670
File Code: 0217.3
IN REPLY/REFERENCE: CTO-0080/0084

Thursday, October 05, 1995

Larry Vitale, Remedial Project Manager
California Regional Water Quality Control Board - Santa Ana Region
2010 Iowa Avenue, Suite 100
Riverside, CA 92507-2409

Subject: Submittal of Review Comments on the Quick Reference Fact Sheet, the Draft Soil Screening Guidance: Issues Document and the Technical Background for Soil Screening Guidance

Dear Mr. Vitale:

I am providing this submittal of review comments on the above-referenced documents. I was selected by USEPA headquarters as part of nine peer reviewers nationwide and the attached comments should prove of interest to the MCAS El Toro BCT. I have provided comments on major issues, not a page-by-page critique of the documents. This submittal is mostly for information purposes only since the draft documents have not been finalized and issued by EPA yet.

In general, EPA's presentation was rigorous and well-documented. While I support EPA's attempts to address the interaction of soil systems and groundwater, I am not convinced that the generic Soil Screening Levels (SSLs) are defensible and believe that site-specific SSLs will inevitably be required for decision-making at CERCLA sites. To aid you in your study I have attached a copy of the Quick Reference Fact Sheet.

If I can be of any further assistance please call me in Bechtel's San Diego office at (619) 687-8780.

Sincerely,

Dante J. Tedaldi, Ph.D., P.E.
Technical Quality Assurance MCAS El Toro

Attachment: Review Comments on the Quick Reference Fact Sheet, the Draft Soil Screening Guidance: Issues Document and the Technical Background for Soil Screening Guidance

cc: Juan Jimenez, RPM Base Closure Branch
Joseph Joyce, BRAC Environmental Coordinator
Bonnie Arthur, RPM

Bechtel

401 West A Street
Suite 1000
San Diego, CA 92101-7905

CLEAN II Program
Bechtel Job No. 22214
Contract N68711-92-D-4670
File Code: 0217.3

IN REPLY/REFERENCE: CTO-0080/0084

Thursday, October 05, 1995

Joseph Joyce BRAC Environmental Coordinator
Department of the Navy - Southwest Division
Naval Facilities Engineering Command
Environmental Division
1220 Pacific Highway, RM 18
San Diego, CA 92132-5181

Subject: Submittal of Review Comments on the Quick Reference Fact Sheet, the Draft Soil Screening Guidance: Issues Document and the Technical Background for Soil Screening Guidance

Dear Mr. Joyce:

I am providing this submittal of review comments on the above-referenced documents. I was selected by USEPA headquarters as part of nine peer reviewers nationwide and the attached comments should prove of interest to the MCAS El Toro BCT. I have provided comments on major issues, not a page-by-page critique of the documents. This submittal is mostly for information purposes only since the draft documents have not been finalized and issued by EPA yet.

In general, EPA's presentation was rigorous and well-documented. While I support EPA's attempts to address the interaction of soil systems and groundwater, I am not convinced that the generic Soil Screening Levels (SSLs) are defensible and believe that site-specific SSLs will inevitably be required for decision-making at CERCLA sites. To aid you in your study I have attached a copy of the Quick Reference Fact Sheet.

If I can be of any further assistance please call me in Bechtel's San Diego office at (619) 687-8780.

Sincerely,

Dante J. Tedaldi, Ph.D., P.E.
Technical Quality Assurance MCAS El Toro

Attachment: Review Comments on the Quick Reference Fact Sheet, the Draft Soil Screening Guidance: Issues Document and the Technical Background for Soil Screening Guidance

cc: Larry Vitale, Remedial Project Manager
Juan Jimenez, RPM Base Closure Branch
Bonnie Arthur, RPM

Bechtel

401 West A Street
Suite 1000
San Diego, CA 92101-7905

CLEAN II Program
Bechtel Job No. 22214
Contract N68711-92-D-4670
File Code: 0217.3

IN REPLY/REFERENCE: CTO-0080/0084

Thursday, October 05, 1995

Bonnie Arthur, RPM
U. S. Environmental Protection Agency Region IX
Hazardous Waste Management Division, H-9-2
75 Hawthorne Street
San Francisco, CA 94105-3901

Subject: Submittal of Review Comments on the Quick Reference Fact Sheet, the Draft Soil Screening Guidance: Issues Document and the Technical Background for Soil Screening Guidance

Dear Ms. Arthur:

I am providing this submittal of review comments on the above-referenced documents. I was selected by USEPA headquarters as part of nine peer reviewers nationwide and the attached comments should prove of interest to the MCAS El Toro BCT. I have provided comments on major issues, not a page-by-page critique of the documents. This submittal is mostly for information purposes only since the draft documents have not been finalized and issued by EPA yet.

In general, EPA's presentation was rigorous and well-documented. While I support EPA's attempts to address the interaction of soil systems and groundwater, I am not convinced that the generic Soil Screening Levels (SSLs) are defensible and believe that site-specific SSLs will inevitably be required for decision-making at CERCLA sites. To aid you in your study I have attached a copy of the Quick Reference Fact Sheet.

If I can be of any further assistance please call me in Bechtel's San Diego office at (619) 687-8780.

Sincerely,

Dante J. Tedaldi, Ph.D., P.E.
Technical Quality Assurance MCAS El Toro

Attachment: Review Comments on the Quick Reference Fact Sheet, the Draft Soil Screening Guidance: Issues Document and the Technical Background for Soil Screening Guidance

cc: Larry Vitale, Remedial Project Manager
Joseph Joyce, BRAC Environmental Coordinator
Juan Jimenez, RPM Base Closure Branch

Review Comments

I have reviewed the following documents: Draft Soil Screening Guidance Quick Reference Fact Sheet, Draft Soil Screening Guidance: Issues document, Technical Background Document for Soil Screening Guidance Review Draft, and the Chemical Properties for Soil Screening Levels document.

To tie in the potential impact of SSLs on MCAS El Toro I have included a summary and short discussion of the comparison of the SSLs and U.S. EPA Region IX PRGs 9 (Spring 1995 PRGs). Specific comments on the SSL methodology follow the PRG/SSL comparison.

Summary

There are some problems inherent in the SSL methodology as compared to the U.S. EPA Region IX PRGs:

- SSLs address soil contamination only and do not address all practical exposure routes (e.g., dermal exposure which could be significant for some organic chemicals).

- SSLs do not integrate results of the routes of exposure addressed, rather they use the most conservative SSL value for comparison of soil data results.

- SSLs for industrial use have not been developed and in many instances a residential scenario may be too conservative to use even for planning purposes.

- SSL applies only to individual chemicals. A few chemicals are addressed to provide a method for apportionment for chemicals which have similar target organ toxicity. This method is clearer in the PRG methodology.

- For carcinogens, the U.S. EPA "feels confident" that very few sites would pose cumulative risks outside the risk range and therefore do not address multi-chemical exposures. It is difficult to concur with this statement because the generic SSLs address evaluation of a soil matrix with only three routes of exposure anticipated; and other media such as surface waters, air sources, groundwater could add to the significance of an adverse health effect for some site conditions.

- The infinite source model represents an apparently necessary trade-off. However, the high degree of conservatism inherent in this approach detracts from the broad applicability of the SSL models.

- In general, the use of the PRGs for "direct contact" exposures with respect to health risk assessments appears sound; however, SSLs should be limited to screening sites with soil contamination only. The user of either approach should ensure that conditions used to develop the generic SSLs and site-specific SSLs are met.

Specific Comments

The following discussion focuses on the adequacy of the most critical assumptions and default values used to develop the generic SSLs as presented in U.S. EPA Technical Background Document for Soil Screening Guidance Review Draft (November 1994).

Soil Screening Framework

1. Default exposure factors

The critical parameters in the back-calculation for exposure to soil via soil ingestion are:

1) exposure frequency and duration

2) ingestion rate

These parameters have been assigned default values representative of a reasonable maximum exposure (RME) similar to PRGs, and as such, result in negligible (rounding errors) differences for both cancer and non-cancer calculation compared to the PRGs.

2. Use of a single exposure route: soil ingestion

The differences between the EPA Region IX PRG soil values and the generic SSL soil values can be significant. This is due to lack of exposure route integration. The EPA Region IX integrates these values to account for the potential for simultaneous exposure routes to exist (ingestion, inhalation, and dermal absorption). For a comparison, see Tables 1 and 2 (SSL ingestion and SSL inhalation, respectively). These tables highlight differences between the two EPA approaches and clearly identify (in bold) the more conservative value. Inspection of the tables indicates that the PRG approach consistently results in a lower value.

A significant concern is that SSLs will be universally applied without concern for the complexities of each site. Table 3 summarizes differences between the scenarios and exposure pathways addressed by the Region IX PRGs and those addressed by generic SSLs. The differences are presented in bold. The most significant differences between the SSLs and PRGs are lack of an industrial scenario for the SSLs, lack of a multimedia analysis for the SSLs, and lack of a groundwater migration pathway for the PRGs.

TABLE 1
COMPARISON OF U.S. EPA PRGs and GENERIC SSLs
(soil Ingestion)

Chemical	PRG Values				Generic SSLs
	Cancer Risk soil-ingest (mg/kg)	Chronic HQ soil-ingest (mg/kg)	Integrated PRG (mg/kg)	Cancer/ Non-cancer Driver	Soil Ingestion (mg/kg)
Nickel and compounds	NA	1.6E+03	1.5E+03	*non-cancer*	1.6E+03
Nitrobenzene	NA	3.9E+01	**3.3E+01**	*non-cancer*	3.9E+01
N-Nitrosodiphenylamine	1.3E+02	NA	**9.1E+01**	cancer	1.3E+02
N-Nitroso di-n-propylamine	9.1E-02	NA	**6.3E-02**	cancer	9.0E-02
Pentachlorophenol	5.3E+00	2.3E+03	**2.5E+00**	cancer	3.0E+00
Phenol	NA	4.7E+04	**3.9E+04**	non-cancer	4.7E+04
Polychlorinated biphenyls (PCBs)	8.3E-02	NA	**6.6E-02**	cancer	1.0E+00
Polynuclear aromatic hydrocarbons					
Acenaphthene	NA	4.7E+03	**3.0E+03**	non-cancer	4.7E+03
Anthracene	NA	2.3E+04	**1.9E+04**	non-cancer	2.3E+04
Benz[a]anthracene	8.8E-01	NA	**6.1E-01**	cancer	9.0E-01
Benzo[b]fluoranthene	8.8E-01	NA	**6.1E-01**	cancer	9.0E-01
Benzo[k]fluoranthene	8.8E+00	NA	**6.1E+00**	cancer	9.0E+00
Benzo[a]pyrene	8.8E-02	NA	**6.1E-02**	cancer	9.0E-02
Chrysene	8.8E+01	NA	**6.1E+01**	cancer	8.8E+01
Dibenz[ah]anthracene	8.8E-02	NA	**6.1E-02**	cancer	9.0E-02
Fluoranthene	NA	3.1E+03	**2.6E+03**	non-cancer	3.1E+03
Fluorene	NA	3.1E+03	**2.5E+03**	non-cancer	3.1E+03
Indeno[1,2,3-cd]pyrene	8.8E-01	NA	**6.1E-01**	cancer	9.0E-01
Naphthalene	NA	3.1E+03	**1.6E+03**	non-cancer	3.1E+03
Pyrene	NA	2.3E+03	**2.0E+03**	non-cancer	2.3E+03
Selenium	NA	3.9E+02	**3.8E+02**	non-cancer	3.9E+02
Silver and compounds	NA	3.9E+02	**3.8E+02**	non-cancer	3.9E+02
Styrene	NA	1.6E+04	**6.4E+03**	non-cancer	1.6E+04
Tetrachloroethylene (PCE)	1.2E+01	7.8E+02	**7.0E+00**	cancer	1.2E+01
Toluene	NA	1.6E+04	**1.9E+03**	non-cancer	1.6E+04
Toxaphene	5.8E-01	NA	**4.0E-01**	cancer	6.0E-01
1,2,4-Trichlorobenzene	NA	7.8E+02	**6.2E+02**	cancer	7.8E+02
1,1,1-Trichloroethane	NA	7.0E+03	**3.2E+03**	non-cancer	NA
1,1,2-Trichloroethane	1.1E+01	3.1E+02	**1.4E+00**	cancer	1.1E+01
Trichloroethylene (TCE)	5.8E+01	4.7E+02	**7.1E+00**	cancer	5.8E+01
2,4,5-Trichlorophenol	NA	7.8E+03	**6.5E+03**	non-cancer	7.8E+03
2,4,6-Trichlorophenol	5.8E+01	NA	**4.0E+01**	cancer	5.8E+01
Vanadium	NA	5.5E+02	**5.4E+02**	non-cancer	5.5E+02
Vinyl acetate	NA	7.8E+04	**6.5E+04**	non-cancer	7.8E+04
Vinyl chloride	3.4E-01	NA	**5.2E-03**	cancer	3.0E-01
Xylene (mixed)	NA	1.6E+05	**1.3E+04**	non-cancer	1.6E+05
Zinc	NA	2.3E+04	**2.3E+04**	non-cancer	2.3E+04

NA - Not appicable or no data
Bold - Conservative value

TABLE 2
COMPARISON OF U.S. EPA PRGs AND GENERIC SSLs
(Inhalation)

Chemical	PRG Values				Generic SSLs
	Cancer Risk soil-inhale (mg/kg)	Chronic HQ soil-inhale (mg/kg)	Integrated PRG (mg/kg)	Cancer/ Non-cancer Driver	Soil Inhalation (mg/kg)
HCH (beta)	4.9E+03	NA	**2.5E-01**	cancer	1.6E+01
HCH (gamma) Lindane	6.8E+03	2.2E+06	**3.4E-01**	cancer	NA
Hexachlorocyclopentadiene	NA	1.4E+05	4.5E+02	non-cancer	**2.0E+00**
Hexachloroethane	6.3E+05	7.2E+06	**3.2E+01**	cancer	**4.9E+01**
Isophorone	9.3E+06	1.4E+09	**4.7E+02**	cancer	3.4E+03
Mercury (inorganic)	NA	6.2E+05	2.3E+01	non-cancer	**7.0E+00**
Methoxychlor	NA	3.6E+07	**3.3E+02**	non-cancer	NA
Methylene chloride	1.3E+01	4.4E+03	1.1E+01	cancer	**7.0E+00**
2-Methylphenol	NA	3.6E+08	**3.3E+03**	non-cancer	NA
Nickel and compounds	*NA*	*1.5E+03*	*1.5E+03*	*non-cancer*	*6.9E+03*
Nitrobenzene	NA	4.1E+06	**3.5E+01**	non-cancer	1.1E+02
N-Nitrosodiphenylamine	1.8E+06	NA	**9.1E+01**	cancer	NA
N-Nitroso di-n-propylamine	1.3E+03	NA	**6.3E-02**	cancer	NA
Pentachlorophenol	7.4E+04	2.2E+08	**2.5E+00**	cancer	NA
Phenol	NA	4.3E+09	**3.9E+04**	non-cancer	NA
Polychlorinated biphenyls (PCBs	1.1E+03	NA	**6.6E-02**	cancer	NA
Polynuclear aromatic hydrocarbons					
Acenaphthene	NA	1.3E+04	**3.0E+03**	non-cancer	NA
Anthracene	NA	7.0E+05	**1.9E+04**	non-cancer	NA
Benz[a]anthracene	1.2E+04	NA	**6.1E-01**	cancer	NA
Benzo[b]fluoranthene	1.2E+04	NA	**6.1E-01**	cancer	NA
Benzo[k]fluoranthene	1.2E+05	NA	**6.1E+00**	cancer	NA
Benzo[a]pyrene	1.2E+03	NA	**6.1E-02**	cancer	NA
Chrysene	1.2E+06	NA	**6.1E+01**	cancer	NA
Dibenz[ah]anthracene	1.2E+03	NA	**6.1E-02**	cancer	NA
Fluoranthene	NA	2.9E+08	**2.6E+03**	non-cancer	NA
Fluorene	NA	4.8E+04	**2.5E+03**	non-cancer	NA
Indeno[1,2,3-cd]pyrene	1.2E+04	NA	**6.1E-01**	cancer	NA
Naphthalene	NA	4.5E+03	**1.6E+03**	non-cancer	NA
Pyrene	NA	2.2E+08	**2.0E+03**	non-cancer	NA
Selenium	NA	NA	**3.8E+02**	non-cancer	NA
Silver and compounds	NA	NA	**3.8E+02**	non-cancer	NA
Styrene	NA	1.2E+04	6.4E+03	non-cancer	**1.4E+03**
Tetrachloroethylene (PCE)	3.9E+01	1.8E+02	**7.0E+00**	cancer	11
Toluene	NA	2.2E+03	1.9E+03	non-cancer	**5.2E+02**
Toxaphene	7.9E+03	NA	**4.0E-01**	cancer	5.0E+00
1,2,4-Trichlorobenzene	NA	1.3E+04	6.2E+02	non-cancer	**2.4E+02**
1,1,1-Trichloroethane	NA	6.9E+03	**3.2E+03**	non-cancer	9.8E+02
1,1,2-Trichloroethane	1.7E+00	9.0E+01	1.4E+00	cancer	**8.0E-01**
Trichloroethylene (TCE)	8.6E+00	7.2E+01	7.1E+00	cancer	**3.0E+00**
2,4,5-Trichlorophenol	NA	7.2E+08	**6.5E+03**	non-cancer	NA
2,4,6-Trichlorophenol	8.2E+05	NA	**4.0E+01**	cancer	2.1E+02
Vanadium	NA	NA	**5.4E+02**	non-cancer	NA
Vinyl acetate	NA	4.1E+08	6.5E+04	non-cancer	**370**
Vinyl chloride	5.3E-03	NA	5.2E-03	cancer	**2.0E-03**
Xylene (mixed)	NA	1.5E+04	1.3E+04	non-cancer	**3.2E+02**
Zinc	NA	NA	2.3E+04	non-cancer	NA

NA -Not applicable or no data
Bold - Conservative value

TABLE 2
COMPARISON OF U.S. EPA PRGs AND GENERIC SSLs
(Inhalation)

Chemical	PRG Values				Generic SSLs
	Cancer Risk soil-inhale (mg/kg)	Chronic HQ soil-inhale (mg/kg)	Integrated PRG (mg/kg)	Cancer/ Non-cancer Driver	Soil Inhalation (mg/kg)
Antimony and compounds	NA	NA	**3.1E+01**	non-cancer	NA
Acetone	NA	2.9E+03	**2.0E+03**	non-cancer	6.2E+04
Arsenic (cancer endpoint)	5.9E+02	NA	**3.2E-01**	cancer	3.8E+02
Barium and compounds	NA	1.0E+06	**5.3E+03**	non-cancer	3.5E+05
Beryllium and compounds	1.1E+03	NA	**1.4E-01**	cancer	690
Benzene	1.6E+00	NA	1.4E+00	cancer	**5.0E-01**
Bis(2-ethylhexyl)phthalate	6.3E+05	1.6E+08	**3.2E+01**	cancer	2.1E+02
Butyl benzyl phthalate	NA	1.4E+09	1.3E+04	non-cancer	**5.3E+02**
Cadmium and compounds	*1.4E+03*	*NA*	***3.8E+01***	*non-cancer*	*920*
Carbazole	4.4E+05	NA	**2.2E+01**	cancer	NA
Carbon disulfide	NA	1.6E+01	1.6E+01	non-cancer	1.1E+01
Carbon tetrachloride	5.5E-01	3.8E+00	4.7E-01	cancer	**2.0E-01**
Chlordane	6.8E+03	4.3E+05	**3.4E-01**	cancer	1.0E+01
Chlorobenzene	NA	1.8E+02	1.6E+02	non-cancer	**9.4E+01**
Chloroform	5.3E-01	1.0E+02	5.3E-01	cancer	**2.0E-01**
2-Chlorophenol	NA	3.6E+07	**3.3E+02**	non-cancer	53000
Chromium VI	3.0E+01	NA	**3.0E+01**	cancer	1.4E+02
Cyanides					NA
2,4-Dichlorophenol	NA	2.2E+07	**2.0E+02**	non-cancer	NA
2,4-Dimethylphenol	NA	1.4E+08	**1.3E+03**	non-cancer	NA
2,4-Dinitrophenol	NA	1.4E+07	**1.3E+02**	non-cancer	NA
DDD	3.7E+04	NA	**1.9E+00**	cancer	NA
DDE	2.6E+04	NA	**1.3E+00**	cancer	NA
DDT	2.6E+04	3.6E+06	**1.3E+00**	cancer	8.0E+01
1,2-Dichlorobenzene	NA	3.5E+03	2.2E+03	non-cancer	**3.0E+02**
1,4-Dichlorobenzene	1.2E+01	1.6E+04	**7.4E+00**	cancer	7.7E+03
1,1-Dichloroethane	NA	9.7E+02	**8.4E+02**	non-cancer	9.8E+02
1,2-Dichloroethane (EDC)	4.8E-01	NA	4.4E-01	cancer	**3.0E-01**
1,1-Dichloroethylene	4.0E-02	1.5E+01	**3.8E-02**	cancer	4.0E-02
1,2-Dichloroethylene (cis)	NA	6.5E+01	**5.9E+01**	non-cancer	1.5E+03
1,2-Dichloroethylene (trans)	NA	1.9E+02	**1.7E+02**	non-cancer	3.6E+03
1,2-Dichloropropane	7.6E-01	1.4E+01	**6.8E-01**	cancer	1.1E+01
1,3-Dichloropropene	6.4E-01	1.1E+02	5.1E-01	cancer	**1.0E-01**
Dieldrin	5.5E+02	3.6E+05	**2.8E-02**	cancer	2.0E+00
Diethyl phthalate	NA	5.8E+09	5.2E+04	non-cancer	**5.2E+02**
Dimethyl phthalate	NA	7.2E+10	6.5E+05	non-cancer	**1.6E+03**
2,4-Dinitrotoluene	NA	1.4E+07	**1.3E+02**	non-cancer	NA
2,6-Dinitrotoluene	NA	7.2E+06	**6.5E+01**	non-cancer	NA
di-n-Octyl phthalate	NA	1.4E+08	**1.3E+03**	non-cancer	NA
Endosulfan	NA	3.6E+05	**3.3E+00**	non-cancer	NA
Endrin	NA	2.2E+06	**2.0E+01**	non-cancer	NA
Ethylbenzene	NA	5.1E+03	2.9E+03	non-cancer	**2.6E+02**
Heptachlor	1.9E+03	3.6E+06	**9.9E-02**	cancer	3.0E-01
Heptachlor epoxide	9.7E+02	9.4E+04	**4.9E-02**	cancer	1.0E+00
Hexachlorobenzene	5.5E+03	5.8E+06	**2.8E-01**	cancer	1.0E+00
Hexachlorobutadiene	1.1E+05	1.4E+07	5.7E+00	cancer	**1.0E+00**
HCH (alpha)	1.4E+03	NA	**7.1E-02**	cancer	9.0E-01

NA -Not applicable or no data
Bold - Conservative value

Table 3

General Differences Between PRGs and SSLs

Parameter	Region IX PRGs	Generic SSL
residential scenario	yes	yes
industrial scenario	yes	**no**
adult receptor	yes	yes
child receptor	yes	yes
multi-media analysis		
soil	yes	yes
air	yes	**no**
water	yes	**no**
multi-pathway analysis		
soil ingestion	yes	yes
ground water ingestion	yes	**no**
surface water ingestion	yes	**no**
volatile inhalation	yes	yes
fugitive dust inhalation	yes	yes
produce consumption	no	no
livestock/fish consumption	no	no
groundwater migration	**no**	yes

3. Inadequate data on dermal absorption

According to the SSL methodology, dermal absorption is not evaluated (with the exception of pentachlorophenol) due to inadequate data on dermal absorption (Section 1.4.1, page 1-5). There is published (peer-reviewed) documentation on the dermal absorption of many chemicals and therefore EPA should consider inclusion of these data.

Inhalation Pathway

The critical parameters in the back-calculation for exposure to soil via inhalation and fugitive dust are the exposure frequency and duration, the dispersion term (Q/C), the volatilization factor (VF), the particulate emission factor (PEF), and the diffusivity coefficient. The exposure frequency and the exposure duration default values are comparable to the default values used in PRG calculations.

1. Exposure Interval (T) default value in derivation of VF

The exposure interval, T, used in the SSL methodology of 9.5×10^8 sec or 30 years is larger than the default value used by Region IV of 7.9×10^8 sec or 25 years. However, the increase is probably not significant.

2. Source size and the dispersion term (Q/C) in Derivation of VF/PEF

EPA Region IX uses the same approach for derivation of the Q/C term but uses a different contaminant source size assumption. The size of the source area used to calculate the SSL results in a significant reduction (typically by a factor of 5) in the SSL compared to the PRGs. Because of the significant difference we anticipate a conflict between EPA headquarters and Region IX over the use of SSLs.

Preliminary discussions with senior toxicologists have indicated a possible resistance to the acceptance of the SSL approach. While these types of resistance are to be anticipated until the approach is finalized, EPA should consider the inclusion of an additional default value for the Q/C term using a smaller source area.

3. SSL inhalation equation

The SSL equation combines both the VF and PEF values while the PRG equation addresses either one or the other. The PRG calculation uses the VF for chemicals with a Henry's Law constant (H) greater than 10^{-5} and a molecular weight less than 200 gram/mol. Those chemicals not meeting the above criteria are evaluated using the PEF.

Although the SSL inhalation equation combines the VF and PEF values, the combination is actually not critical for chemicals that are highly volatile or have a low volatility since the contribution from either the VF or the PEF will be negligible for those chemicals with physical-chemical properties that do not affect either the VF or the PEF value. This may not be the case for chemicals that fall in the 'middle" range of volatility. These chemicals may result in having a slightly more conservative acceptable soil value because both the VF and PEF contribute to the SSL inhalation equation.

4. Intrusion of Volatiles into Basements

EPA should consider retention of this pathway in the SSL framework for use under the site-specific assessments, with qualification of the variability that can exist. EPA has identified the limitations of the flux modeling. However, there is often a need to address this pathway in residential scenarios when contamination is left in-place below foundations. EPA must continue to evaluate approaches for the assessment of these situations.

Migration to groundwater pathway

1. General considerations

The numerous assumptions used to generate the generic soil values highlights the limitations to their usefulness as a "screening" tool if the majority of sites do not meet the criteria for use. There is some concern that the extreme conservatism of the assumptions reduces the applicability of generic SSLs to the point of exclusion. While I recognize the utility of generic SSLs, it is difficult to support the acceptance of values which have little or no connection to site conditions. The generic values do not seem to offer users a defensible position.

2. Module approach - Monte Carlo Simulations

The use of the Monte Carlo module for development of "default" values for the generic SSLs appears reasonable. However, it was noted that highly conservative scenarios were developed using upper-bound default values/parameters.

3. DAF for Generic SSLs

Information in the technical document shows that the source size is one of the most sensitive parameters used in the modeling effort. However, the 30-acre source area estimate is not useful for many hazardous waste sites. EPA's estimate was based on typical landfill sizes and is far larger than most CERCLA site source areas. Although CERCLA sites may be 30 acres or larger, there may be concern that the infinite source term covers 30 acres from ground surface to the water table and DAF values approach unity as the source size increases. The model results described in the Technical Background document show that variation of the DAF can be significant for smaller size source areas (i.e., less than 10 acres) compared to large source areas (i.e., 30 acres). In addition, the combined use of empirical and theoretical data used to develop the generic SSLs lend themselves to too much uncertainty to use the migration pathway SSLs.

That being the case, there is little point in using the default values and the user is forced to a site-specific evaluation.

United States Environmental Protection Agency

Office of Solid Waste and Emergency Response

9355.4-14FS
EPA/540/R-94/101
PB95-963529
December 1994

EPA

Soil Screening Guidance

Office of Emergency and Remedial Response
Hazardous Site Control Division

Quick Reference Fact Sheet

NOTICE: This document is draft for review only and should not be used until the guidance is finalized following public comment and peer review.

BACKGROUND

On June 19, 1991, the U.S. Environmental Protection Agency's (EPA's) Administrator charged the Office of Solid Waste and Emergency Response (OSWER) with conducting a 30-day study to outline options for accelerating the rate of cleanups at National Priorities List (NPL) sites. One of the specific proposals of the study was for OSWER to "examine the means to develop standards or guidelines for contaminated soils."

On June 23, 1993, EPA announced the development of "Soil Trigger Levels" as one of the Administrative Improvements to the Superfund program. On September 30, 1993, a draft fact sheet was released that presented generic Soil Screening Levels (SSLs) for 30 chemicals. The fact sheet presented standardized equations to model exposures to soil contaminants via ingestion, inhalation, and migration to ground water. The fact sheet provided generic defaults for each parameter in the equations and a sampling methodology to measure soil contaminant levels. The SSL initiative underwent widespread review both within and outside the Agency. Suggestions were made on how to improve the methodology and increase the usefulness of screening levels by finding simple ways to modify them using site-specific data.

Based on that review, EPA modified the SSLs into a **Soil Screening framework** that emphasizes the application of standardized equations for the site-specific evaluation of soil contaminants. This framework provides an overall approach for developing SSLs for specific contaminants and exposure pathways at a site under a residential land use scenario. Areas with soil contaminant concentrations below SSLs generally would not warrant further study or action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The Soil Screening framework's point of departure is a simple methodology for calculating site-specific SSLs using easily obtained site data with standardized equations. An option for conducting a more detailed site-specific analysis is also included in the framework. In addition, default parameters are used in the standardized equations to produce a table of generic Soil Screening Levels for 107 chemicals that update those presented in the September 30, 1993, draft SSL fact sheet. These generic SSLs are included in the framework as a default option for use when site-specific values are not available.

PURPOSE OF SOIL SCREENING FRAMEWORK

The Soil Screening framework represents the first of several tools EPA plans to develop to standardize the evaluation and cleanup of contaminated soils. SSLs streamline the remedial investigation/feasibility study (RI/FS) process by accelerating and increasing consistency in decisions concerning soil contamination. As a future companion to the Soil Screening framework, EPA also intends to develop a methodology to identify levels of contamination that clearly warrant a response action or, possibly, concentrations for which treatment would be required. The screening levels at the low end and the higher concentration values that warrant response can be used to identify the bounds of a risk management continuum (Figure 1). Generally, within this continuum lies a range of possible cleanup levels that will continue to be determined on a site-specific basis.

EPA anticipates the use of the Soil Screening framework as a tool to facilitate prompt identification of the contaminants and exposure areas of concern during both remedial actions and some removal actions under CERCLA. SSLs do **not** trigger

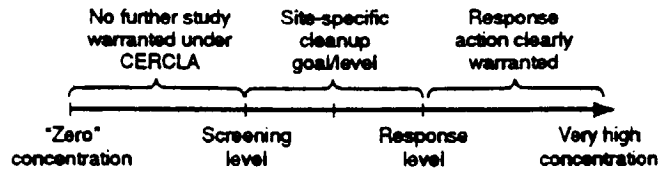


Figure 1. Risk management spectrum for contaminated soil.

the need for response actions or define "unacceptable" levels of contaminants in soil. SSLs may serve as Preliminary Remediation Goals (PRGs) under certain conditions (see ·ection on Use of SSLs as Preliminary Remediation ɔals/Cleanup Levels). In the future, EPA will consider expanding the guidance to address the Resource Conservation and Recovery Act (RCRA) Corrective Action program.

The SSLs are, as noted above, intended for use as a tool; their use is not mandatory at sites being addressed under CERCLA. The framework leaves a broad range of discretion to the site manager, both on whether the SSL approach is appropriate for a site and, if it is used, on the appropriate method. This guidance anticipates three optional approaches—simple site-specific, detailed site-specific, and generic. In the first two, some or all default values would be replaced as appropriate with site-specific data. Furthermore, the models themselves are not codified as rules and can be modified if appropriate, although some explanation should be provided if such modification is made.

SOIL SCREENING FRAMEWORK

A Soil Screening Level is a chemical concentration in soil that represents a level of contamination below which there is no concern under CERCLA, provided conditions associated with the SSLs are met. Generally, if contaminant concentrations in soil fall below the SSL, and there are no significant ecological receptors of concern, then no further study or action is ·rranted for residential use of that area. (Some States have ·eloped screening numbers that are more stringent than the generic SSLs presented in this fact sheet; therefore further study may be warranted under State programs.) Concentrations in soil above either the generic or site-specific screening level would not automatically designate a site as "dirty" or trigger a response action. However, exceeding a screening level suggests that a further evaluation of the potential risks that may be posed by site contaminants is appropriate to determine the need for a response action.

The Soil Screening framework presents three approaches for establishing screening levels. The option emphasized in this Fact Sheet is a simple method that incorporates readily obtainable, site-specific data into standardized equations to derive site-specific screening levels for selected contaminants. When questions still exist at a site regarding whether or not contaminant levels are of concern, as a second approach, more tailored screening levels can be derived for most contaminants by incorporating additional site data into more complex fate and transport models. The third approach is to apply the generic SSLs presented in Appendix A. Although the default parameters used to derive the generic SSLs are not necessarily "worst case," they are conservative.

The progression from generic to simple site-specific and ·ailed (full-scale) site-specific SSLs usually will involve an ·ease in investigation costs and a decrease in conservatism (Figure 2). Generally, the decision of which method to use

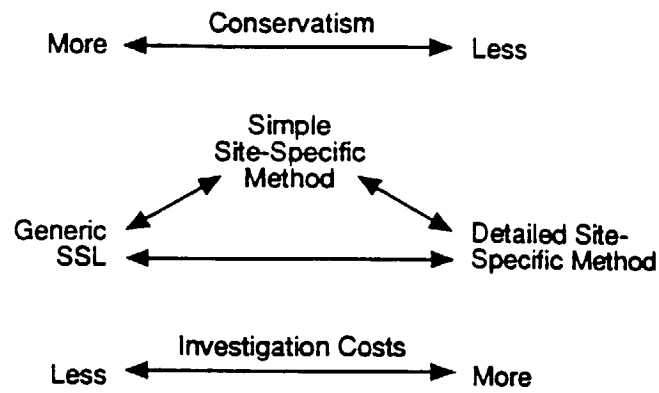


Figure 2. Components of the Soil Screening framework.

involves balancing the increased investigation costs with the potential savings associated with higher (but protective) SSLs. Therefore, the framework promotes the option of using site-specific data to derive screening levels. More guidance regarding which option to use is presented later in this fact sheet.

Site-Specific SSLs: Simple Method

The simple method for developing site-specific SSLs requires the collection of a small number of easily obtained site parameters (e.g., fraction organic carbon, percent soil moisture, and dry bulk density) for use in the standardized equations so that the calculated screening levels can be appropriately conservative for the site but not as conservative as the generic values. Once derived, the user then compares measured site or area contaminant concentrations to the site-specific screening levels. If concentrations do not exceed the SSLs for each pathway of concern, it would generally be appropriate to exclude the area from further investigation. If the levels are exceeded, the site manager may decide that a more comprehensive evaluation is needed to determine the risk posed via a particular exposure pathway (see Technical Background section).

Site-Specific SSLs: Detailed Approach

A more detailed method for developing site-specific SSLs is a full-scale model evaluation requiring the collection of additional site data. Full-scale modeling allows the application of complex transport and fate models and allows for consideration of a finite contaminant source. Applying these models will further define the risk associated with exposure via the inhalation or migration to ground water pathway. The model application may show that there is no concern over exposure from the pathway, thereby eliminating it from further concern. This potential outcome provides the incentive for incurring the cost and time to conduct a comprehensive site evaluation.

Generic SSLs

Generic SSLs can be used in place of site-specific screening levels. The decision to use generic SSLs will likely be driven by time and cost. The site manager must weigh the cost of conducting a more site-specific investigation with the potential for deriving a higher SSL that provides for an appropriate level of protection. The Technical Background section of this guidance presents a more detailed discussion of the level of effort required to conduct further study of site conditions and risks. Appendix A provides generic SSLs for 107 chemicals.

SCOPE OF SOIL SCREENING FRAMEWORK

The Soil Screening framework has been developed for 107 chemicals using assumptions for residential land use activities for three pathways of exposure (see Figure 3):

- Ingestion of soil
- Inhalation of volatiles and fugitive dusts
- Ingestion of contaminated ground water caused by migration of chemicals through soil to an underlying potable aquifer.

Reviews of risk assessments at hazardous waste sites indicate that these pathways are the most common routes of human exposure to contaminants in the residential setting. These are also the pathways for which generally accepted methods, models, and assumptions have been developed that lend themselves to a standardized approach. Data on dermal exposures have also been considered, and the generic SSL for pentachlorophenol has been modified accordingly. **The scope of the SSL framework is limited to human exposure via the pathways listed above; therefore, sites with other significant exposure pathways, nonresidential land uses, possible ecological concerns, or unusual site conditions should consider their associated risks on a site-specific basis apart from the SSL framework.** Key attributes of the Soil Screening framework are given in Highlight 1.

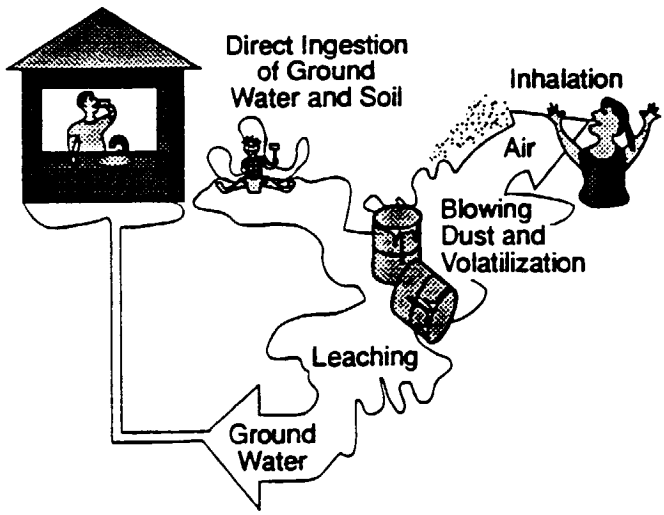


Figure 3. Exposure pathways addressed by the Soil Screening framework.

Highlight 1: Key Attributes of the SSL Framework

- Standardized equations are presented to address three individual human exposure pathways.
- Parameters are identified for which site-specific information is needed to develop site-specific SSLs.
- Default values are provided and used to calculate generic SSLs that are consistent with Superfund's concept of "Reasonable Maximum Exposure" (RME).
- SSLs are generally based on a 10^{-6} risk for carcinogens, or a hazard quotient of 1 for noncarcinogens. SSLs for migration to ground water are based on nonzero maximum contaminant level goals (MCLGs), or, when not available, maximum contaminant levels (MCLs). Where neither of these are available, the aforementioned risk-based targets are used.

Soil Ingestion Pathway

For the direct soil ingestion pathway, only generic SSLs were developed. Simple and full-scale site-specific methods were not developed because cost and complexity make developing site-specific data for this pathway, such as soil ingestion rates or chemical-specific bioavailability, generally impracticable. However, EPA is evaluating the data available to support adjustment of the exposure frequency term based on regional climatic conditions.

Inhalation Pathway

For **inhalation of volatiles and fugitive dust**, both generic values and a method for incorporating site-specific data into the standardized equations have been developed. To estimate the site-specific potential for volatilization of contaminants, soil conditions such as fraction organic carbon, soil moisture content, and dry bulk density must be evaluated. To estimate the site-specific potential for generation of fugitive dusts, other parameters must be evaluated, such as mean annual windspeed, threshold friction velocity, and the mode soil aggregate size to further tailor the SSLs to the site. For both the inhalation of volatiles and fugitive dust pathways, a site-specific determination of the area of contamination and meteor ic inputs can be incorporated into dispersion calculations.

Migration to Ground Water

The simple site-specific method for addressing potential ›ntaminant **migration to ground water** uses the same soil ;ameters required to address volatilization, along with easily obtainable hydrogeologic parameters. The simple site-specific method for this exposure pathway also requires a determination of the area of contamination.

Other Pathways

Additional exposure pathways to contaminants in soil—dermal absorption, plant uptake, and migration of volatiles into basements—may contribute significantly to the risk to human health in a residential setting. The Superfund program has evaluated the data and methods available to address these potential exposures and has incorporated as much information as possible into the SSL framework.

Based on limited empirical data, the ingestion SSL for pentachlorophenol has been adjusted to account for potential dermal exposure. Additionally, empirical data indicate that plant uptake may be important for some chemicals (i.e., As, Cd, Hg, Ni, Se, Zn). The fact that these chemicals' potential for plant uptake and dermal absorption has been noted in Appendix A should not be misinterpreted to mean that other chemicals are not of potential concern for dermal exposure or plant uptake. As additional information becomes available, other chemicals may be addressed as well.

his time, Superfund does not believe that the potential for migration of contaminants into basements can be reasonably incorporated into the SSL framework. The parameters required for the models (e.g., the number and size of cracks in basement walls) do not lend themselves to standardization or to evaluation of potential future exposure, and the models have not been adequately validated. The Technical Background Document (U.S. EPA, 1994e) provides a detailed analysis of available modeling of this pathway.

Other Land Uses

Longer-term efforts will be required to develop standardized tools to address exposures relevant to other land uses such as industrial land use. The results of these efforts may be included in future revisions of this guidance.

Ecological Receptors

As part of the baseline risk assessment, an ecological assessment should be conducted at every Superfund site. The SSL framework does not attempt to define significant ecological receptors or quantify ecological risks. However, a comparable list of screening level benchmarks, called Ecotox Thresholds, is being developed by Office of Emergency and Remedial ›onse (OERR) for application during the ecological risk ;ssment addressed in OSWER Directive No. 9285.7-17 (U.S. EPA, 1994d). These values are defined as media-specific chemical concentrations above which there is sufficient concern regarding adverse effects to ecological receptors to warrant further site investigation. OERR is developing guidance on designing and conducting ecological risk assessments that will describe the use of such screening values in the Superfund Remedial Investigation process.

HOW TO USE THE SOIL SCREENING FRAMEWORK

The decision to use the Soil Screening framework at a site will be driven by the potential benefits of eliminating areas, exposure pathways, or contaminants from further investigation. By identifying areas where concentrations of contaminated soil are below levels of concern under CERCLA, the framework provides a means to focus resources on exposure areas, contaminants, and exposure pathways of concern.

Highlight 2 outlines the process of applying the Soil Screening framework at a site. To enable early comparison with site background concentrations and to provide information necessary for determining an adequate sample size, site-specific SSLs should be developed as early in the process as possible. They can be adjusted during the process to accommodate additional site information and the resulting changes to the conceptual site model.

Developing a Conceptual Site Model

The primary condition for use of SSLs is that exposure pathways of concern and conditions at the site match those taken into account by the Soil Screening framework. Thus, at all sites it will be necessary to develop a conceptual site model to identify likely contaminant source areas, exposure pathways, and potential receptors. This information can be used to

Highlight 2: Using the Soil Screening Framework

- Develop site conceptual model and compare with SSL conceptual model to determine applicability of framework.
- Determine if background contaminant concentrations are above generic SSLs.
- Select approach (simple or detailed site-specific, generic) and develop SSLs.
- Measure average soil contaminant concentrations in exposure areas (EAs) of concern.
- Compare average soil concentrations with SSLs and eliminate site or area of site where EA mean concentration is less than SSL.
- Consider further study or use of SSLs as PRGs for sites or site areas with contaminant concentrations greater than SSLs.

determine the applicability of the framework at the site and the need for additional information.

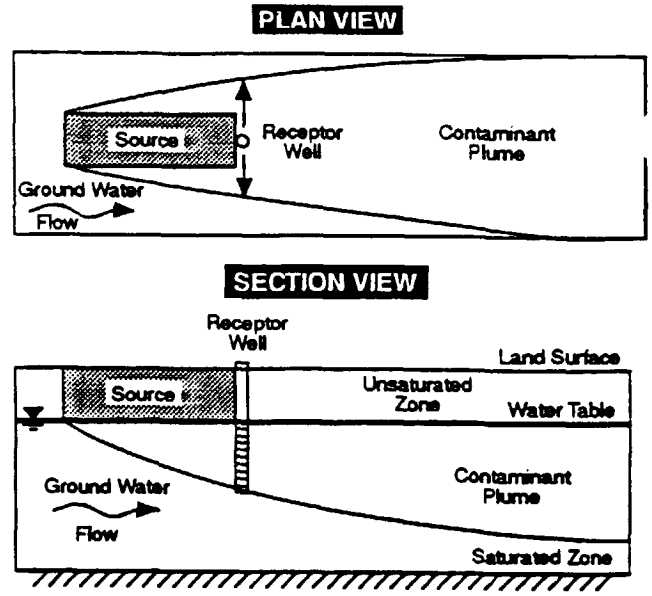
A conceptual site model is developed from available site sampling data, historical records, aerial photographs, and hydrogeologic information. The model establishes a hypothesis about possible contaminant sources, contaminant fate and transport, exposure pathways, and potential receptors. The DQO Guidance for Superfund (U.S. EPA, 1993a) provides an excellent discussion on the development of a conceptual site model. The rationale for including the contaminant migration to ground water exposure pathway should be consistent with EPA ground water policy (U.S. EPA, 1988, 1990b, 1992a, 1992b, 1993b).

The conceptual model upon which the generic SSLs are based is a 30-acre property that has been divided up for residential use. Thus, the generic SSLs have been developed to be protective for source areas up to 30 acres. The contamination is assumed to be evenly distributed across the area of concern and extends from the ground surface to the top of the aquifer. The soil type is assumed to be loam that has 50 percent vegetative cover. Loam is soil with approximately equal proportions of sand and silt. Exposure to contaminants can occur via ingestion of soils, inhalation of volatiles and fugitive dusts, or migration to ground water.

For the migration to ground water pathway, the point of compliance is assumed to be at the edge of the site, which is assumed to be homogeneously contaminated. No attenuation is considered in the unsaturated zone; however, dilution is assumed within the aquifer to the point of compliance. For the generic conceptual site model, the source is assumed to extend across the entire site. See Figures 3 and 4 for a graphic representation of aspects of the conceptual model applicable to the Soil Screening framework.

Partitioning of contaminant mass between media is not addressed in the SSL framework because the fate and transport models used to derive the generic SSLs are based on the assumption of an infinite source. Although the assumption is highly conservative, a finite source model cannot be applied unless there are accurate data regarding source size and volume. Obviously, in the case of the generic SSLs, such data are not available. It is also unlikely that such data will be available from the limited subsurface sampling that is done to apply the simple site-specific method. Thus, it is most likely that a finite source model would be applied as part of a detailed site-specific investigation. EPA will continue to seek consensus on the appropriate methods to incorporate contaminant partitioning and a finite source into the simple site-specific method. The results of these efforts may be included in future updates to this guidance.

The Technical Background Document (U.S. EPA, 1994e) presents information on equations and models that can accommodate finite sources and predict the subsequent impact on either ambient air or ground water. However, when using



Default assumptions:

- Infinite source
- Source extends to water table
- Well at downgradient edge of source
- 30-acre source size

Figure 4. Migration to ground water pathway—SSL conceptual model.

a finite source model, the site manager should recognize uncertainties inherent in site-specific estimates of subsurface contaminant distributions and use conservative estimates of source size and concentrations to allow for such uncertainties.

The following questions should always be considered in the development of the conceptual site model before applying the Soil Screening framework:

- Is the site **adjacent to surface waterbodies** where the potential for contamination of surface water by overland flow or release of contaminated ground water should be considered?
- Are there potential terrestrial or aquatic **ecological concerns**?
- Is there potential for **land use other than residential**?
- Are there **other likely human exposure pathways** that were not considered in development of the SSLs (e.g., local fish consumption; raising of beef, dairy, or other livestock)?
- Are there **unusual site conditions** (e.g., area of contamination greater than 30 acres, unusually high fugitive dust levels due to soil being tilled for agricultural use, or traffic on unpaved roads)?

If the conceptual site model indicates that residential assumptions are appropriate for your site and no pathways of concern other than those covered by the Soil Screening framework are present, then the framework may be applied directly to the site. If the conceptual site model indicates that the site is more complex than the scenario outlined in this guidance, the framework above will not be sufficient. Additional pathways, receptors, or chemicals must be evaluated on a site-specific basis.

Considering Background Contamination

A necessary step in determing the usefulness of the SSL framework is the consideration of background contaminant concentrations, since the framework will have little utility where background concentrations exceed the SSLs.

EPA may be concerned with two types of background at sites: naturally occurring and anthropogenic. Natural background is usually limited to metals whereas anthropogenic (i.e., human-made) background includes both organic and inorganic contaminants.

Generally, EPA does not clean up below natural background; however, where anthropogenic background levels exceed SSLs and EPA has determined that a response action is necessary and feasible, EPA's goal will be to develop a comprehensive response to the widespread contamination. This will often require coordination with different authorities that have jurisdiction over other sources of contamination in the area (such as a regional air board or RCRA program). This will avoid response actions that create "clean islands" amid widespread contamination. The background information and understanding of the site developed as part of the conceptual model can help determine background concentration.

When considering background, one should also consider the bioavailability and mobility of compounds. Some compounds may form complexes that are immobile and unlikely to cause significant risk. This situation is more likely to occur with naturally occurring compounds. Therefore, background concentrations of compounds exceeding the SSLs do not necessarily pose a threat. Alternately, activities at a site can adversely affect the natural soil geochemistry, resulting in the mobilization of compounds. Consequently, background contamination should be considered carefully. Regardless, where background concentrations are higher than the SSLs, the SSLs generally will not be the best tool for site decisionmaking.

Sampling Exposure Area

After the conceptual site model has been developed, and the applicability of the Soil Screening framework is determined, the next step is to collect a representative sample set for each exposure area. An exposure area is defined as that geographic area in which an individual may be exposed to contamination over time. Because SSLs are developed for a residential scenario, EPA assumes the exposure area is a 0.5-acre residential lot.

In those situations where little or no sampling has been done, it will be beneficial to collect the site data required for the simple site-specific methodology in tandem with the collection of samples to identify contaminant concentrations. The site manager should work to limit the total number of trips to the site by maximizing the usefulness of the samples collected. (See section on Measuring Contaminant Concentrations in Soil for additional guidance.)

Comparing Exposure Area Concentration to SSLs

The fourth step is to compare onsite soil contaminant concentrations with site-specific SSLs or the generic SSLs listed in Appendix A. At this point, it is reasonable to review the conceptual site model with the actual site data in hand to reconfirm the accuracy of the conceptual site model and the applicability of the Soil Screening framework. Once this is confirmed, site contaminant levels may be compared with the SSLs.

In Appendix A, the first column to the right of the chemical name presents levels based on direct ingestion of soil. The second column presents the levels based on inhalation of volatiles or soil particulates. The third column presents SSL values for the migration to ground water pathway multiplied by a dilution and attenuation factor (DAF) of 10 to account for natural processes that reduce contaminant concentrations in the subsurface. The fourth column contains the SSL multiplied by a DAF of 1, which may be appropriate to use in instances where there are high water tables, karst topography, fractured bedrock, or source size greater than 30 acres. The lowest SSL of the three pathways (ingestion, inhalation, and ground water with DAF of 10) is highlighted in bold for each contaminant.

Generally, the comparison of SSLs to site contaminant levels will result in one of three outcomes:

1. Site-measured values indicate that an area falls below all of the SSLs. Soils from these areas of the site generally can be eliminated from further evaluation under CERCLA.

2. Site-measured data indicate that one or more SSLs have clearly been exceeded. In this case, the SSLs have helped to identify site areas, contaminants, and exposure pathways of potential concern on which to focus further analysis or data-gathering efforts.

3. A site-measured value exceeds one pathway-specific value but not others. In this case, it is reasonable to focus additional site-specific data collection efforts only on data that will help determine whether there is truly a risk posed via that pathway or by a limited set of chemicals at the site. When an exceedance is marginally significant, a closer look at site-specific conditions and exposures may result in the area being eliminated from further study.

Use of SSLs as Preliminary Remediation Goals/Cleanup Levels

SSLs are **not nationwide cleanup levels or standards.** Where the basis for response action exists and all exposure pathways of concern are addressed by the SSLs, the SSLs may serve as PRGs as defined in HHEM, Part B (U.S. EPA, 1991d). A PRG is a strictly risk-based value that serves as the point of departure for the establishment of site-specific cleanup levels. **PRGs are modified to become final cleanup levels based on a consideration of the nine-criteria analysis** described in the National Contingency Plan (NCP; Section 300.430 (3)(2)(i)(A)), including cost, long-term effectiveness, and implementability. See *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (U.S. EPA, 1991e) for guidance on how to modify PRGs to generate cleanup levels.

The SSLs should only be used as site-specific cleanup levels when a nine-criteria evaluation using the SSLs as PRGs for soils indicates that a selected remedy achieving the SSLs is protective, ARAR-compliant, and appropriately balances the other criteria, including cost. An example is a small site or exposure area where the cost of additional study would exceed the cost of remediating to the generic SSLs.

Addressing Exposure to Multiple Chemicals

The SSLs generally correspond to a 10^{-6} risk level for carcinogens and a hazard quotient (HQ) of 1 for noncarcinogens. This "target" hazard quotient is used to calculate a soil concentration below which it is unlikely for even sensitive populations to experience adverse health effects. The potential for additive effects has not been "built in" to the SSLs through apportionment. For carcinogens, EPA believes that setting a 10^{-6} risk level for individual chemicals and pathways generally will lead to cumulative risks within the 10^{-4} to 10^{-6} risk range for the combinations of chemicals typically found at Superfund sites.

For noncarcinogens, there is no widely accepted risk range. Thus, for developing national screening levels, options are either (1) to set the risk level for individual contaminants at the RfD or RfC (i.e., a hazard quotient of 1), or (2) to set chemical-specific concentrations by apportioning risk based on some arbitrarily chosen fraction of the acceptable risk level (e.g., one-fifth or one-tenth the RfD or RfC). The Agency believes, and EPA's Science Advisory Board agrees (U.S. EPA, 1993d), that noncancer risks should be added only for those chemicals with the same toxic endpoint or mechanism of action.

Highlight 3 lists the chemicals from Appendix A that have SSLs based on noncarcinogenic toxicity and affect the same target organ. If more than one chemical detected at a site affects the same target organ (i.e., has the same critical effect as defined by the RfD methodology), site-specific SSLs for each chemical in the group should be divided by the number of chemicals present. The concentration of contaminants at the site should then be compared to the SSLs that have been modified to account for this potential additivity.

Highlight 3: SSL Chemicals with Noncarcinogenic Toxic Effects on Specific Target Organs

Kidney
- Acetone
- 1,1-Dichloroethane
- Dimethyl phthalate
- 2,6-Dinitrotoluene
- Di-*n*-octyl phthalate
- Nitrobenzene
- 2,4,5-Trichlorophenol
- Vinyl acetate

Liver
- Acetone
- Chlorobenzene
- Di-*n*-octyl phthalate
- Nitrobenzene
- 2,4,5-Trichlorophenol

Central Nervous System
- Butanol
- 2,4-Dichlorophenol
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- 2-Methylphenol

Circulatory System
- Antimony
- Barium
- *p*-Chloroaniline
- *cis*-1,2-Dichloroethylene
- Nitrobenzene
- Zinc

Reproductive System
- Carbon disulfide
- 2-Chlorophenol
- 1,2,4-Trichlorobenzene

Gross Pathology
- Diethyl phthalate
- 2-Methylphenol
- Naphthalene
- Nickel
- Vinyl acetate

Because the combination of contaminants will vary from site to site, apportioning risk to account for potential additive effects could not be considered in the development of generic SSLs. Furthermore, for certain noncarcinogenic organics (e.g., ethylbenzene, toluene), the generic SSLs are not based on toxicity but are determined instead by a "ceiling limit" concentration (C_{sat}) at which these chemicals may occur as nonaqueous phase liquids (NAPLs) in soil (see Technical Background section). For these reasons, the potential for additive effects and the need to apportion risk must be a site-specific determination.

TECHNICAL BACKGROUND

The models and assumptions supporting the Soil Screening framework were developed to be consistent with Superfund's concept of "reasonable maximum exposure" (RME) in the residential setting. The *Risk Assessment Guidance for Superfund, Volume 1* (U.S. EPA, 1989b) and the *Standard Default Exposure Factors* guidance (U.S. EPA, 1991b) outlined the Superfund program's approach to calculating an RME. Since that time, the Agency (U.S. EPA, 1991a) has coined a new term that the Superfund program believes corresponds to the definition of RME: "high-end individual exposure."

The Superfund program's method to estimate the RME for chronic exposures on a site-specific basis is to combine an average exposure point concentration with reasonably

conservative values for intake and duration in the exposure calculations. The default intake and duration assumptions are presented in the *Standard Default Exposure Factors* guidance (U.S. EPA, 1991b). The duration assumptions were chosen to represent individuals living in a small town or other nontransient community. (Exposure to members of a more transient community is assumed to be shorter and thus associated with lower risk.) Exposure point concentrations are either measured at the site (e.g., ground water concentrations at a receptor well) or estimated using exposure models with site-specific model inputs. An average concentration term is used in most assessments where the focus is on estimating long-term, chronic exposures. Where the potential for acute toxicity is of concern, exposure estimates based on maximum concentrations may be more appropriate.

The resulting site-specific estimate of RME is then compared with chemical-specific toxicity criteria such as RfDs or RfCs. EPA recommends using criteria from the Integrated Risk Information System (IRIS) (U.S. EPA, 1994c) and Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, 1993c), although values from other sources may be used in appropriate cases.

The Soil Screening framework differs from a site-specific estimate of risk in that the exposure equations and models are run in reverse to backcalculate to an "acceptable level" of contaminant in soil. Toxicity criteria are used to define the acceptable level: a level corresponding to a 10^{-6} risk for carcinogens and a hazard quotient of 1 for noncarcinogens. The concept of backcalculating to an acceptable level in soil was presented in RAGS Part B (U.S. EPA, 1991d), and the Soil Screening framework serves to update Part B for addressing residential soils. Site-specific SSLs are consistent with the Superfund approach to estimating RME on a site-specific basis. Standard default factors are used for the intake and duration assumptions, site-specific inputs are used in the exposure models, and chemical-specific concentrations averaged over the exposure area are used for comparison to the SSLs.

Consistent with the site-specific SSLs, the generic SSLs use the same intake and duration assumptions and are compared to area average concentrations. However, the generic SSLs are based on a hypothetical site model. In developing the parameters for the hypothetical site, the Superfund program considered the conservatism inherent in the exposure models (e.g., assumption of an infinite source) and then combined high-end and central tendency parameters for size, location, and soil characteristics. The resulting generic SSLs should be protective for most site conditions across the Nation.

OERR performed a sensitivity analysis to determine which parameters most influenced the output of the volatilization and fugitive dust models used to calculate SSLs for the inhalation pathway. For fugitive dusts, the particulate emission factor (PEF) was most sensitive to threshold friction velocity, which was set at a "high-end" value. For calculation of the volatilization factor (VF), soil moisture content was set at a conservative value because it drives the air-filled soil porosity that in turn provides the pathway for chemicals to volatilize from soils. Climatic conditions have a significant impact on dispersion of both volatile and particulate emissions and were set at high-end values to be protective for conditions at most sites. Different high-end meteorological data sets were selected to calculate 90th percentile dispersion coefficients for the VF and for the PEF.

For the migration of contaminants from soils to ground water, only average soil conditions are used to calculate generic SSLs because of the conservatism inherent in the partition equation. The generic DAF for this pathway was developed using a weight of evidence approach to be protective under most hydrogeologic conditions across the country as described in the following section on the migration to ground water.

Characteristics of the generic, hypothetical site used to develop generic SSLs were described previously in the section discussing the conceptual site model. The Technical Background Document (U.S. EPA, 1994e) accompanying this guidance describes the pathway-specific equations, assumptions, and methodology that form the basis for both the simple site-specific approach and the generic SSLs. The Technical Background Document also describes development of the specific default input values used to calculate generic SSLs for the inhalation and migration to ground water pathways.

The generic SSLs are based on default assumptions. EPA recognizes that site-specific conditions may differ significantly from these default assumptions. The Soil Screening framework emphasizes the substitution of some of the generic fate and transport assumptions with site-specific data to derive site-specific SSLs. However, one purpose of the SSLs is to define a level in soil below which no further study or action would be required. Therefore, alternative levels that are set using site-specific data should generally be calculated assuming the RME/"high-end" individual exposure.

The following sections present the standardized equations and default assumptions that form the basis for the simple site-specific methodology and the generic SSLs. The soil ingestion discussion is limited to default assumptions because only generic SSLs have been developed for this pathway.

Direct Ingestion

Agency toxicity criteria for noncarcinogens establish a level of daily exposure that is not expected to cause deleterious effects over a lifetime (i.e., 70 years). Depending on the contaminant, however, exceeding the RfD (i.e., the "acceptable" daily level) for a short period of time may be cause for concern. For example, if there is reason to believe that exposure to soil may be higher at a particular stage of an individual's lifetime, one would need to protect for that shorter period of high exposure. Because a number of studies have shown that inadvertent

ingestion of soil is common among children age 6 and younger (Calabrese et al., 1989; Davis et al., 1990; Van Wijnen et al., 1990), the SSLs in the default option are set at concentrations that are protective of this increased exposure during childhood by ensuring that the chronic reference dose (or RfD) is not exceeded during this shorter (6-year) time period (Equation 1). If there is reason to believe that exposures at a site may be significant over a short period of time (e.g., extensive soil excavation work in a dry region), depending on the contaminant, the site manager should consider the potential for acute health effects as well.

Equation 1: Screening Level Equation for Ingestion of Noncarcinogenic Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{THQ \times BW \times AT \times 365\ d/yr}{1/RfD_o \times 10^{-6}\ kg/mg \times EF \times ED \times IR}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
BW/body weight (kg)	15
AT/averaging time (yr)	6[a]
RfD_o /oral reference dose (mg/kg-d)	chemical-specific
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	6
IR/soil ingestion rate (mg/d)	200

[a] For noncarcinogens, averaging time is equal to exposure duration.

In some cases, children may ingest large amounts of soil (i.e., 3 to 5 grams) in a single event. This behavior, known as pica, may result in relatively high short-term exposures to contaminants in soils. Such exposures may be of concern for contaminants that primarily exhibit acute health effects. Review of clinical reports on contaminants addressed in this guidance suggests that acute effects of cyanide and phenol may be of concern in children exhibiting pica behavior. If soils containing cyanide and phenol are of concern and pica behavior is expected at a site, the protectiveness of the ingestion SSLs for these chemicals should be reconsidered.

For carcinogens, both the magnitude and duration of exposure are important. Duration is critical because the toxicity criteria are based on "lifetime average daily dose." Therefore, the total dose received, whether it be over 5 years or 50 years, is averaged over a lifetime of 70 years. To be protective of exposures to carcinogens in the residential setting, OERR focuses on exposures to individuals who may live in the same residence for a "high-end" period of time (i.e., 30 years). As mentioned previously, exposure to soil is higher during childhood and decreases with age. Thus, Equation 2 uses a time-weighted average soil ingestion rate for children and adults. The derivation of this time-weighted average is presented in U.S. EPA (1991d).

Equation 2: Screening Level Equation for Ingestion of Carcinogenic Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{TR \times AT \times 365\ d/yr}{SF_o \times 10^{-6}\ kg/mg \times EF \times IF_{soil/adj}}$$

Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10^{-6}
AT/averaging time (yr)	70
SF_o /oral slope factor $(mg/kg\text{-}d)^{-1}$	chemical-specific
EF/exposure frequency (d/yr)	350
$IF_{soil/adj}$ /age-adjusted soil ingestion factor (mg-yr/kg-d)	114

Inhalation of Volatiles and Fugitive Dusts

Agency toxicity data indicate that risks from exposure to some chemicals via inhalation far outweigh the risks via ingestion. **The models and assumptions used to calculate SSLs for inhalation of volatiles and fugitive dusts are updates of the equations presented in U.S. EPA's HHEM Part B guidance (U.S. EPA, 1991d). The volatilization factor (VF), soil saturation limit (C_{sat}), particulate emission factor (PEF), and dispersion model have all been revised.**

Another change from the Part B methodology is the sep[illegible] of the ingestion and inhalation pathways. Toxicity criteria for oral exposures are presented as administered doses in units of milligrams per kilograms per day (mg/kg-d); whereas, the inhalation criteria are presented as concentrations in air ($\mu g/m^3$ or mg/m^3) that require conversion to an estimate of internal dose to be comparable to the oral route. EPA's Office of Research and Development (ORD) now believes that the conversion from concentration in air to internal dose is not always appropriate and suggests evaluating these exposure routes separately.

As explained in HHEM Part B, the basic principle of the volatilization model is applicable only if the soil concentration is at or below soil saturation (C_{sat}). Above this level the model cannot predict an accurate VF. C_{sat} is the concentration at which soil air, pore water, and sorption sites are saturated and above which free-phase contaminants may be present. For compounds that are liquid at ambient soil temperatures, C_{sat} indicates a concentration above which NAPLs may be suspected in site soils and further investigation may be necessary. Thus, for liquid compounds for which the SSL exceeds C_{sat}, the SSL is set at C_{sat}. For compounds that are solid at soil temperatures for which the SSL exceeds C_{sat}, volatile emissions can be assumed to be of no concern and the SSL is calculated considering particulate emissions on[illegible] e., the 1/VF term in Equation 3 or 4 is set to zero).

Equation 3: Screening Level Equation for Inhalation of Carcinogenic Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{TR \times AT \times 365\ d/yr}{URF \times 1000\ \mu g/mg \times EF \times ED \times \left[\frac{1}{VF} + \frac{1}{PEF}\right]}$$

Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10^{-6}
AT/averaging time (yr)	70
URF/inhalation unit risk factor $(\mu g/m^3)^{-1}$	chemical-specific
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
VF/soil-to-air volatilization factor (m^3/kg)	chemical-specific
PEF/particulate emission factor (m^3/kg)	6.79×10^8

Equation 4: Screening Level Equation for Inhalation of Noncarcinogenic Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{THQ \times AT \times 365\ d/yr}{EF \times ED \times \left[\frac{1}{RfC} \times \left(\frac{1}{VF} + \frac{1}{PEF}\right)\right]}$$

meter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
AT/averaging time (yr)	30
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
RfC/inhalation reference concentration (mg/m^3)	chemical-specific
VF/soil-to-air volatilization factor (m^3/kg)	chemical-specific
PEF/particulate emission factor (m^3/kg)	6.79×10^8

Equations 3 through 7 form the basis for deriving both simple site-specific and generic SSLs for the inhalation pathway. The following parameters in the standardized equations can be replaced with specific site data to develop a more site-specific SSL:

- **VF and C_{sat}**
  - — Average soil moisture content
  - — Average fraction organic carbon content
  - — Dry soil bulk density

Equation 5: Derivation of the Volatilization Factor

$$VF\ (m^3/kg) = Q/C \times \frac{(3.14 \times \alpha \times T)^{1/2}}{(2 \times D_{ei} \times \theta_a \times K_{as})} \times 10^{-4}\ m^2/cm^2$$

where

$$\alpha = \frac{D_{ei} \times \theta_a}{\theta_a + (\rho_s)\ (1 - \theta_a)/K_{as}}$$

Parameter/Definition (units)	Default
VF/volatilization factor (m^3/kg)	--
Q/C/inverse of the mean conc. at the center of a 30-acre-square source $(g/m^2\text{-}s$ per $kg/m^3)$	35.10
T/exposure interval (s)	9.5×10^8 s
D_{ei} /effective diffusivity (cm^2/s)	$D_i(\theta_a^{3.33}/n^2)$
θ_a /air-filled soil porosity (L_{air}/L_{soil})	0.28 or n-wρ_b
D_i /diffusivity in air (cm^2/s)	chemical-specific
n/total soil porosity (L_{pore}/L_{soil})	0.43 (loam)
w/average soil moisture content $(g_{water}/g_{soil}$ or $cm^3_{water}/g_{soil})$	0.1 (10%)
ρ_b/dry soil bulk density (g/cm^3)	1.5 or (1 - n) ρ_s
ρ_s /soil particle density (g/cm^3)	2.65
K_{as} /soil-air partition coefficient (g-soil/cm^3-air)	$(H/K_d) \times 41$ (41 is a conversion factor)
H/Henry's law constant (atm-m^3/mol)	chemical-specific
K_d /soil-water partition coefficient (cm^3/g)	$K_{oc} \times f_{oc}$
K_{oc} /organic carbon partition coefficient (cm^3/g)	chemical-specific
f_{oc}/organic carbon content of soil (g/g)	0.006 (0.6%)

Equation 6: Derivation of the Soil Saturation Limit

$$C_{sat} = \frac{S}{\rho_b}\ (K_d\ \rho_b + \theta_w + H'\theta_a)$$

Parameter/Definition (units)	Default
C_{sat}/soil saturation concentration (mg/kg)	--
S/solubility in water (mg/L-water)	chemical-specific
ρ_b/dry soil bulk density (kg/L)	1.5 or (1 - n) ρ_s
n/total soil porosity (L_{pore}/L_{soil})	0.43 (loam)
ρ_s /soil particle density (kg/L)	2.65
K_d/soil-water partition coefficient (L/kg)	$K_{oc} \times f_{oc}$ (organics)
K_{oc} /soil organic carbon/water partition coefficient (L/kg)	chemical-specific
f_{oc}/fraction organic carbon of soil (g/g)	0.006 (0.6%)
θ_w/water-filled soil porosity (L_{water}/L_{soil})	wρ_b or 0.15
θ_a /air-filled soil porosity (L_{air}/L_{soil})	n - wρ_b or 0.28
w/average soil moisture content $(kg_{water}/kg_{soil}$ or $L_{water}/kg_{soil})$	0.1 (10%)
H'/Henry's law constant (unitless)	H x 41, where 41 is a conversion factor
H/Henry's law constant (atm-m^3/mol)	chemical-specific

Equation 7: Derivation of the Particulate Emission Factor

$$PEF(m^3/kg) = Q/C \times \frac{3600\,s/h}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}$$

Parameter/Definition (units)	Default
PEF/particulate emission factor (m^3/kg)	6.79×10^8
Q/C/inverse of the mean conc. at the center of a 30-acre-square source (g/m^2-s per kg/m^3)	46.84
V/fraction of vegetative cover (unitless)	0.5 (50%)
U_m /mean annual windspeed (m/s)	4.69
U_t /equivalent threshold value of wind-speed at 7 m (m/s)	11.32
F(x)/function dependent on U_m/U_t derived using Cowherd (1985) (unitless)	0.194

- **PEF**
  - — Mean annual windspeed
  - — Threshold friction velocity (as determined by):
    - – mode of the surface soil aggregate size
    - – roughness height
    - – correction for nonerodible particles
    - – f(x)
  - — Equivalent threshold windspeed at a 7-m anemometer height.

Site location (to some extent) and site size (i.e., "area of contamination") can be factored into the simple site-specific methodology for the inhalation pathways. The dispersion factor (Q/C) for both volatiles and fugitive dusts was calculated using a 90th percentile meteorological data set selected from 29 data sets across the United States (see Technical Background Document [U.S. EPA, 1994e]). Los Angeles was selected as the 90th percentile data set for volatiles and Minneapolis was selected as the 90th percentile data set for fugitive dusts. Replacing the default city and site size of 30 acres will affect the Q/C values in both the VF and PEF equations (Equations 5 and 7). The Technical Background Document supporting this guidance (U.S. EPA, 1994e) provides a table of Q/C values for 29 cities across the country over a range of contaminant source areas for use in the simple site-specific method.

The particulate emission factor derived by using the default values in Equation 7 results in an ambient air concentration of approximately 1.5 µg/m^3. This represents an annual average emission rate that is based on wind erosion and is not appropriate for evaluating the potential for more acute exposures.

Migration to Ground Water

The methodology for addressing migration of contaminants from soil to ground water reflects the complex natur contaminant fate and transport in the subsurface. In methodology, a concentration in soil is backcalculated from ar acceptable ground water concentration. The generic SSLs presented in Appendix A for this pathway represent a conservative estimation of the concentration of a contaminant in soil that would not result in exceedances of the acceptable concentration of a contaminant in ground water. Flexibility tc consider site-specific conditions is addressed in the simple ano detailed site-specific methodologies.

The first step in applying the SSL framework is a comparison of the SSL conceptual model presented earlier in this document with the conceptual model developed for the site. This forms the basis for determining the appropriateness of conducting a more detailed investigation and the applicability of the SSL guidance for the migration to ground water pathway. Some of the assumptions used to develop the SSL conceptual model have implications for the ground water pathway. Highlight 4 lists assumptions implicit in the conceptual model that should be understood before applying the SSL ground water framework.

Both the simple site-specific and generic methods are based on the commonly used equilibrium soil/water partition equation (Equation 8) that describes the ability of contaminants to sorb

Equation 8: Soil Screening Level Partitioning Equation for Migration to Ground Water

$$\text{Screening Level in Soil (mg/kg)} = C_w\left[K_d + \frac{(\theta_w + \theta_a H')}{\rho_b}\right]$$

Parameter/Definition (units)	Default
C_w/target soil leachate concentration (mg/L)	nonzero MCLG, MCL, or HBL × 10 DAF
K_d/soil-water partition coefficient (L/kg)	chemical-specific, $K_{oc} \times f_{oc}$ (organics)
K_{oc}/soil organic carbon/water partition coefficient (L/kg)	chemical-specific
f_{oc} /fraction organic carbon in soil (g/g)	0.002 (0.2%)
θ_w/water-filled soil porosity (L_{water}/L_{soil})	0.3 or $w\rho_b$
w/average soil moisture content (kg_{water}/kg_{soil} or L_{water}/kg_{soil})	0.2 (20%)
ρ_b/dry soil bulk density (kg/L)	1.5 or (1 - n) ρ_s
n/soil porosity (L_{pore}/L_{soil})	0.43 (loam)
ρ_s/soil particle density (kg/L)	2.65
θ_a/air-filled soil porosity (L_{air}/L_{soil})	0.13 or (n - θ_w)
H'/Henry's law constant (unitless)	H × 41
H/Henry's law constant (atm-m^3/mol)	chemical-specific (assume to be zr for inorganic con taminants except mercury)

Highlight 4: Simplifying Assumptions of the Default Conceptual Model for Ground Water

1. The source of contamination is defined as an evenly contaminated 30-acre site. Source size has significant implications for the development of the dilution/attenuation factor. Large sources generally tend to result in low DAFs, while smaller sources generally justify higher DAFs. Where actual source size differs significantly from the default 30-acre assumption, the user should consider a site-specific evaluation to develop a more site-specific DAF.

2. The soil contamination extends from the surface to the top of the aquifer. This is a reasonable assumption for sites where the water table is fairly shallow (e.g., 5 to 10 feet below surface). However, in areas where the water table is very deep, this assumption may not be valid and should be considered in the decision to apply a detailed site-specific evaluation.

3. No attenuation is considered in the unsaturated zone. This assumption also has implications for the DAF. As discussed above, a detailed site-specific evaluation should be considered at sites that have a very thick uncontaminated unsaturated zone because a higher DAF may be justified.

4. The point of compliance is at the edge of the site, which is assumed to be uniformly contaminated. This conservative assumption also has implications for the calculation of the DAF. The user should consider whether this assumption is valid for the site in question and whether further evaluation would be appropriate.

5. The simple site-specific or generic DAF assumes that an unconfined, unconsolidated aquifer with homogeneous and isotropic hydrologic properties underlies the site. A DAF greater than 1 may not be appropriate for soils underlain by karst or fractured rock aquifers.

6. NAPLs are not present. If NAPLs are present in soils, the SSLs do not apply (i.e., further investigation is necessary).

to organic carbon in soil (Dragun, 1988). An adjustment to relate sorbed concentration in soil to the analytically measured total soil concentration has been added to the equation.

The partition equation contains parameters for chemical-specific (Henry's law constant; K_d or K_{oc}) and subsurface characteristic variables (dry bulk density, porosity, air-filled and water-filled pore space). In the default method, national default values for the parameters in the partition equation were used to calculate the generic SSLs in Appendix A. Nonzero ground water maximum contaminant level goals (MCLGs) re used as the acceptable ground water limits for each aminant in the partitioning equation. If nonzero MCLGs were not available, maximum contaminant levels (MCLs) were used. If MCLs were not available, concentrations associated with a target cancer risk of 10^{-6} and/or a noncancer HQ of 1 were derived using Agency toxicity criteria. The acceptable ground water limit is multiplied by the DAF of 10 to obtain a target soil leachate concentration for calculating generic SSLs.

In the simple site-specific method, site-measured data would replace the default values for the subsurface characteristic and soil variables (i.e., fraction organic carbon, dry bulk density, average soil moisture content). These variables would then be used to calculate a more site-specific screening value. Even this screening number is fairly conservative because of the underlying assumptions regarding the absence of attenuation and placement of the well adjacent to the source.

As described above, the C_{sat} ceiling limit defines (for organic chemicals that are liquid at soil temperatures) a concentration above which chemicals may occur as NAPLs in soil. For liquid chemicals present at concentrations greater than C_{sat}, NAPL presence may be suspected and the Soil Screening framework would not be applicable (i.e., further investigation is necessary). See U.S. EPA (1992b) for guidance on determining the likelihood of NAPL occurrence in the subsurface and on conducting the additional investigations necessary if NAPL occurrence is suspected at a site.

Partitioning of inorganic constituents in the subsurface is more complex than for organics. A variety of soil conditions affect the derivation of the partitioning coefficient for inorganics, while organic carbon is the parameter that most affects organic partitioning. For this reason, the EPA MINTEQ2 equilibrium geochemical speciation model was used to calculate K_d values for the metals, which were then used in Equation 8. K_d values for metals are most significantly affected by pH; therefore, metal K_d values were calculated over a range of subsurface pH conditions (4.9 to 8.0). K_d values corresponding to this pH range are presented in the revised Technical Background Document (U.S. EPA, 1994e) for use in the simple site-specific method. Based on the pH at the site, the appropriate K_d should be selected and used in the calculation. Also note that all metals except mercury are essentially nonvolatile and their Henry's law constant (H') in Equation 8 should be set at zero.

Generic SSLs for inorganics corresponding to a pH of 6.8 are presented in Appendix A for the default method. Table 1 lists inorganic SSLs corresponding to pH values of 4.9 and 8.0 and a DAF of 10. If pH conditions at a site are not known, the generic SSL corresponding to a pH of 6.8 should be used in the default method. Table 1 also includes SSLs for ionizing organics, whose partitioning behavior is also pH dependent. Readers are referred to the Technical Background Document (U.S. EPA, 1994e) for a more detailed discussion of the derivation of K_d values for inorganics and K_{oc} values for ionizing and nonionizing organics.

The framework also includes the option of using a leach test instead of the partitioning equation. In some instances a leach

Table 1. pH-Specific SSLs for Metals and Ionizing Organics (mg/kg) (DAF = 10)

Chemical	pH 4.9	pH 8
Arsenic	13	16
Barium	16	340
Beryllium	0.1	19,000
Cadmium	0.06	230
Chromium (+6)	31	14
Mercury	0.006	4
Nickel	1	140
Selenium	9	1
Thallium	0.2	0.5
Zinc	180	1.6E+6
Benzoic acid	300	280
2,4-Dichlorophenol	0.5	0.3
Pentachlorophenol	0.2	0.01
2,4,5-Trichlorophenol	200	26
2,4,6-Trichlorophenol	0.07	0.01

test may be more useful than the partitioning method, depending on the constituents of concern and the possible presence of RCRA wastes. This guidance suggests using the EPA Synthetic Precipitation Leaching Procedure (SPLP, EPA SW-846 Method 1312, see the Technical Background Dcoument [U.S. EPA, 1994e]). The SPLP was developed to model an acid rain leaching environment and is generally appropriate for a contaminated soil scenario. Like most leach tests, the SPLP may not be appropriate for all situations (e.g., soils contaminated with oily constituents may not yield suitable results). Therefore, discretion is advised when applying the SPLP.

The Agency is aware that there are many leach tests available for application at hazardous waste sites, some of which may be appropriate in specific situations (e.g., the Toxicity Characteristic Leaching Procedure, known as the TCLP, models leaching in a municipal landfill environment). It is beyond the scope of this document to discuss in detail other leaching procedures and the appropriateness of their use. *Stabilization/ Solidification of CERCLA and RCRA Wastes* (U.S. EPA, 1989c) and the SAB's review of leaching tests (U.S. EPA, 1991c) contain information on the application of various leach tests to various waste disposal scenarios. The user is encouraged to consult these doucments for further information.

DETERMINING THE DILUTION/ ATTENUATION FACTOR

As contaminants move through soil and ground water, they are subjected to a number of physical, chemical, and biological processes that generally reduce the eventual contaminant concentration level at receptor points. The reduction in concentration can be expressed succinctly by the DAF, defined as the ratio of the soil leachate concentration to the receptor point concentration. The lowest possible value of DAF is 1, corresponding to the situation where there is no dilution or attenuation of a contaminant; i.e., the concentration at th receptor point is the same as that in the soil leachate. High DAF values, on the other hand, correspond to a high degree of dilution and attenuation of the contaminant from the leachate to the receptor point.

The soil/water partition equation relates concentrations of contaminants adsorbed to soil organic carbon to soil leachate concentrations in the unsaturated zone. Contaminant migration through the unsaturated zone to the water table generally reduces the soil leachate concentration by attenuation processes such as adsorption and degradation. Ground water transport in the saturated zone further reduces concentrations through adsorption, degradation, and dilution. Generally, to account for this reduction in concentration, acceptable ground water limits are multiplied by a DAF to obtain a target soil leachate concentration for the partition equation.

A default DAF of 10 is applied to calculate the generic SSLs. A weight of evidence method was used to determine this default DAF. In the weight-of-evidence approach, OERR evaluated a number of methods for calculating DAFs. Included in this approach was an evaluation of DAFs calculated by the EPACMTP model, using a range of assumptions including those associated with the conceptual site model for the generic SSLs. The comparison also included DAFs calculated from a more simplified mixing-zone equation as well as acceptable DAFs used in existing State programs. The comparison indicated that, for the default scenario, a DAF of 10 is conservatively protective of the majority of site conditions, including the site scenario developed for the generic SSLs. The Technical Background Document (U.S. EPA, 1994e) supporting this guidance contains additional detail on the development of the generic DAF.

The simple site-specific method relies on a fairly simple mixing zone equation (Equation 9) to calculate a site-specific dilution factor to be used instead of the default DAF. In this method, site-measured values for hydraulic gradient, hydraulic

Equation 9: Derivation of Dilution Factor

$$\text{dilution factor} = 1 + \frac{Kid}{IL}$$

Parameter/Definition (units)

dilution factor (unitless)
K/aquifer hydraulic conductivity (m/yr)
i/hydraulic gradient (m/m)
d/mixing zone depth (m)
I/infiltration rate (m/yr)
L/source length parallel to ground water flow (m)

conductivity, and estimates of infiltration, contaminant source length, and mixing-zone depth are used to calculate the dilution factor. The mixing-zone depth is estimated from an equation relating it to aquifer thickness, infiltration rate, ground water velocity, and source length parallel to flow (Equation 10).

Equation 10: Estimation of Mixing Zone Depth

$$d = (0.0112\ L^2)^{0.5} + d_a\ \{1 - \exp[(-LI)/(Kid_a)]\}$$

Parameter/Definition (units)

d/mixing zone depth (m)
L/source length parallel to ground water flow (m)
I/infiltration rate (m/yr)
K/aquifer hydraulic conductivity (m/yr)
d_a/aquifer thickness (m)

Detailed Site-Specific Method

In this investigation, site-specific data are collected and used in a fate and transport model to determine whether a threat to ground water exists and, if so, to further determine site-specific cleanup goals as would typically be done for the remedial investigation/feasibility study (RI/FS). Consequently it represents the highest level of site-specificity in evaluating the migration to ground water pathway. A DAF is not used in this method because the model would account for fate and transport mechanisms in the subsurface. The advantage of this approach is that it accounts for site hydrogeologic, climatologic, and contaminant source characteristics and may result in fully protective but less stringent remediation goals. However, the additional cost of collecting the data required to apply the model should be factored into the decision to conduct a detailed site-specific investigation.

Choosing a model for site-specific application is integral to an accurate evaluation of potential concern. However, the data used in the application and interpretion of the results are equally important. In an effort to provide useful information for a model application, EPA's ORD Laboratories in Ada, Oklahoma, and Athens, Georgia, conducted an evaluation of nine unsaturated zone fate and transport models. The information in this report is summarized in the Technical Background Document (U.S. EPA, 1994e) supporting this guidance. These nine models are only a subset of the potentially appropriate models available to the public and are not meant to be construed as having received EPA approval. EPA also has developed guidance for the selection and application of ground water transport and fate models and for interpretation of model applications. The user is referred to *Ground Water Modeling Compendium* (U.S. EPA, 1994b) and *Framework for Assessing Ground Water Model Applications* (U.S. EPA, 1994a) for further information.

MEASURING CONTAMINANT CONCENTRATIONS IN SOIL

In order to compare site soil concentrations with the SSLs, it is important to develop a sampling strategy that will result in an accurate representation of site contamination. This Soil Screening Guidance recommends that site managers use the Data Quality Objectives (DQO) process (Figure 5) to develop a sampling strategy that will satisfy Superfund program objectives. The site manager can use the DQO process to conveniently organize and document many site-specific features and assumptions underlying the sampling plan. In the last step of the DQO process, "Optimize the Design for Obtaining Data," the site manager can choose between two alternative approaches to measuring surface soil contaminant concentrations. The first is a site-specific strategy that uses site-specific estimates of contaminant variability to determine how many samples are needed to support the screening decision. The second is a fairly prescriptive approach that can be used in lieu of the site-specific strategy. Recommendations for subsurface sampling that can be modified to accommodate site-specific conditions are also included in the guidance.

Exposure to site contaminants over a long (chronic) period of time is best represented by an arithmetic average concentration for an exposure area (U.S. EPA, 1992d). Therefore, measurement of site concentrations for comparison to the SSLs should

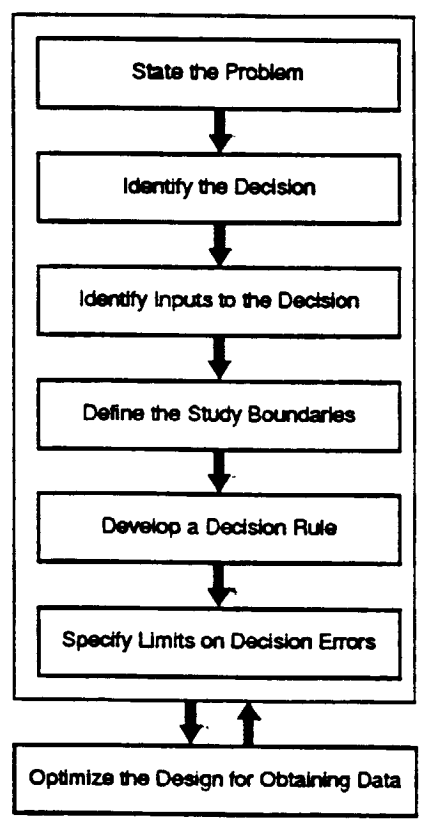


Figure 5. The Data Quality Objectives process.

be based on the arithmetic mean concentration as well. For the purposes of this guidance, the Agency has assumed that the size of a typical residential lot (0.5 acre) is an appropriate averaging area for residential land use. For large sites that could be divided into multiple residential lots, the site should be sectioned into appropriate 0.5-acre parcels.

For measurement of surface soil samples for the inhalation and ingestion pathways, samples should be collected over a depth of 6 inches because it is the top 6 inches of soil that is most likely to be ingested or inhaled as fugitive dusts. Additional sampling beyond 6 inches may be appropriate, depending on the contaminant's mobility. If soils at the site are of concern for the migration to ground water pathway as well as the ingestion and/or inhalation pathways, then surface soils should be sampled first since the results of the composite samples may indicate source areas to target for subsurface sampling.

As discussed previously, the initial steps for implementing the Soil Screening framework are to (1) develop the conceptual site model and determine the applicability of the framework; (2) determine if background concentrations exceed the (generic) SSLs; and (3) select the method (simple site-specific, detailed site-specific, or generic) to determine the SSLs. Once these steps have been completed, it will then be necessary to choose either a site-specific or a generic, prescriptive sampling strategy for surface soils.

Surface Soils—Site-Specific Strategy

The site-specific sampling strategy utilizes a sampling design approach that allows statistically valid conclusions to be drawn about contaminant concentrations at a site based on relatively limited sampling. EPA recommends that site managers use this strategy to determine the number of samples needed to compare average contaminant concentrations within each exposure area against the SSLs. The site-specific strategy provides procedures for ensuring that screening decisions can be made with acceptable levels of confidence despite variability in soil contaminant concentrations that can sometimes mask true conditions at the site. This approach provides flexibility to incorporate site-specific information about likely contamination patterns so that sampling can be concentrated in areas where uncertainty about the risk posed by soil contaminants is greatest.

The sampling design developed for the site should be based on the conceptual site model and should reflect conditions at the site. It is flexible in that the information used to develop the conceptual site model (historical records, aerial photographs, existing sampling data, etc.) can also be used to develop an appropriate sampling strategy. Such a strategy may include stratification of the site, if appropriate, into areas where soil contaminant concentrations are expected to clearly exceed the SSLs, areas where soil contaminant concentrations are expected to fall well below the SSLs, and areas of the site where there is greater uncertainty as to whether soil contaminant concentrations exceed the SSLs.

This classification of areas of the site can help in designing an efficient sampling plan, since the number of samples required to support good decision making depends on the contaminant variability likely to be encountered and how greatly contaminant concentrations differ from the SSLs. By grouping similar areas together, each area can be sampled in accordance with the level of uncertainty or variability associated with that area. For example, EPA expects that a relatively small number of samples will be needed to make the screening decision where average contaminant concentrations clearly exceed or are well below the SSLs. More intensive sampling is expected for those areas where relatively high contaminant variability or concentrations close to the SSLs make it more difficult to determine with confidence whether the average contaminant concentration exceeds the screening level.

Inherent in the statistically based site-specific sampling strategy is the specification of limits on decision errors, which is performed in the sixth step of the DQO process. Limits on decision errors are quantitative performance requirements for the quality and quantity of data that will support the screening decision. These performance requirements are specified in terms of the probability of making a decision error, which can occur in two ways:

- Type I: The data mislead the site manager into deciding that the exposure area concentration is below the SSLs when the true average contaminant concentration exceeds the screening level; or

- Type II: The data mislead the site manager into deciding that the exposure area concentration is above the SSL and further investigation is required when in fact the true average contaminant concentration is less than the SSL.

To ensure consistency in applying the framework, EPA has specified tolerable limits on decision errors at the program level. The Technical Background Document (U.S. EPA, 1994e) provides a full discussion of the Soil Screening framework's limits on decision errors and of the site-specific strategy in general. EPA encourages the project manager to seek the assistance of a statistician or the Regional quality assurance staff for the development of the sampling strategy. For more detailed guidance on the DQO process the user should refer to the Technical Background Document and *Data Quality Objectives for Superfund (Interim Final)* (U.S. EPA, 1993a).

Surface Soils—Prescriptive Approach

The guidance provides a second sampling methodology—a "prescriptive approach"—that can be used as an alternative to the site-specific approach. A sampling design effort is required for the site-specific strategy, whereas the prescriptive approach provides a simple, standard sampling approach that will be most useful for small sites that do not warrant extensive design effort. It emphasizes composite sampling for

nonvolatile contaminants and specifies the number of samples to be collected for analysis of volatile contaminants. It differs from the site-specific approach in that the same sampling strategy must be applied to each 0.5-acre exposure area. Although it does not explicitly control decision errors, preliminary simulations suggest that it does not underestimate mean concentrations for commonly occurring patterns of soil contamination. Additional simulations comparing the performance of the prescriptive approach to the site-specific strategy will be a subject of peer review.

Studies by ORD indicate that at least 20 samples per exposure area are needed to closely estimate the true mean. To balance the need for statistical confidence in determining a meaningful arithmetic mean contaminant concentration with the costs of analyzing multiple samples for each exposure area, EPA recognizes the benefits of composite samples and advocates compositing, where appropriate. Compositing may mask contaminant levels that are slightly higher than the SSL, but areas of high contamination will still be detected. Compositing is a reasonable approach and an efficient use of resources since the Superfund program is interested in the average exposure over time. (See the Technical Background Document [U.S. EPA, 1994e] for a more detailed discussion of compositing and its limitations.)

Using the prescriptive approach, 20 discrete samples can be reduced to four composite samples. (The exposure area can be divided into quadrants and five random samples can be collected and composited within each quadrant.) The contaminant concentrations from the four composite samples should be compared directly with their respective SSLs. If any one of the composites equals or exceeds the SSL, then that portion of the exposure area should be studied further.

Compositing is not appropriate for volatile organic compounds (VOCs) since much of the contaminant will be lost during homogenization of the soil (U.S. EPA, 1989a, 1992c). For VOCs, 10 discrete samples can be taken per exposure area and any sample above the SSL would trigger the need for additional study in that exposure area. Additionally, it is not appropriate to average the contaminant levels in each exposure area and evaluate the mean concentration against the SSLs because 10 discrete samples may underestimate the true mean.

Subsurface Sampling

For the migration to ground water pathway, subsurface soils that have constituents that might contribute to ground water contamination are of primary concern. Therefore, it is the **source areas** that are of interest and not necessarily a 0.5-acre exposure area as specified for the ingestion and inhalation pathways. To determine whether contaminants in the subsurface soils (defined as below 6 inches for the purposes of implementing SSLs) potentially pose a risk to ground water, the guidance suggests sampling at least two boreholes using split spoon or Shelby tube samples in each source area. Samples should begin at 6 inches below ground surface and continue at 2-foot intervals until no contamination is encountered. If the average concentration in any borehole exceeds the SSL, then further site-specific study is warranted.

Subsurface sampling depths and intervals can be adjusted at a site to accommodate site-specific information on subsurface contaminant distributions and geological conditions. In addition, soil investigation for the migration to ground water pathway should not be conducted independent of ground water investigation. Ground water should be sampled to determine whether there is concern for existing ground water contamination, and the results should be considered in the holistic application of the Soil Screening framework.

Geostatistics

If the SSLs are to be compared with the data resulting from the initial sample collection efforts of the remedial investigation, the site manager may want to consider using geostatistics to estimate contaminant concentrations across the site. Geostatistics is probably most appropriate to use in the detailed site-specific approach. Geostatistics is a field of study in which statistical analyses of geologic or environmental data are conducted. It differs from single-sample classical statistics in that it assumes that variability and independence between samples is not random, but that there is some spatial continuity between samples. Geostatistics can be used to estimate contaminant concentrations at unsampled points and estimate average contaminant concentrations across the site.

Software packages have been developed to facilitate geostatistical analyses. One package is GEO-EAS, developed by EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada. Assistance and consultation with skilled geostatisticians is recommended prior to initiating any sampling plan to ensure that the sampling strategy will capture the critical data necessary for the geostatistical analyses.

WHERE TO GO FOR FURTHER INFORMATION

More detailed discussions of the technical background and assumptions supporting the development of the Soil Screening framework are presented in the *Technical Background Document for Soil Screening Guidance* (U.S. EPA, 1994e). For additional copies of this Fact Sheet and/or the Technical Background Document, call the National Technical Information Service (NTIS) at (703) 487-4650.

NOTICE: This guidance is based on policies in the Final Rule of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which was published on March 8, 1990 (55 *Federal Register* 8666). The NCP should be considered the authoritative source.

The policies set out in this document are intended solely as guidance to the U.S. Environmental Protection Agency (EPA) personnel; they are not final EPA actions and do not constitute rulemaking. These policies are not intended, nor can they be relied upon, to create any rights enforceable by any party in litigation with the United States. EPA officials may decide to follow the guidance provided in this document, or to act at variance with the guidance, based on an analysis of specific site circumstances. EPA also reserves the right to change the guidance at any time without public notice.

REFERENCES

Calabrese, E.J., H. Pastides, R. Barnes, et al. 1989. How Much Soil Do Young Children Ingest: An Epidemiologic Study. In: *Petroleum Contaminated Soils*, Vol. 2. E.J. Calabrese and P.T. Kostecki, eds. pp. 363-417. Chelsea, MI, Lewis Publishers.

Cowherd, C., G. Muleski, P. Engelhart, and D. Gillette. 1985. *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination*. EPA/600/8-85/002. Prepared for Office of Health and Environmental Assessment, U.S. Environmental Protection Agency, Washington, DC. NTIS PB85-192219 7AS.

Davis, S., P. Waller, R. Buschom, J. Ballou, and P. White. 1990. Quantitative estimates of soil ingestion in normal children between the ages of 2 and 7 years: population-based estimates using Al, Si, and Ti as soil tracer elements. *Archives of Environmental Health*, 45:112-122.

Dragun, J. 1988. *The Soil Chemistry of Hazardous Materials*. Hazardous Materials Control Research Institute, Silver Spring, MD.

U.S. EPA. 1988. *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*. Directive 9283.1-2. EPA/540/G-88/003. Office of Emergency and Remedial Response, Washington, DC. NTIS PB89-184618/CCE.

U.S. EPA. 1989a. *Methods for Evaluating the Attainment of Soil Cleanup Standards. Volume 1: Soils and Solid Media*. EPA 230/02-89-042. Statistical Policy Branch, Office of Policy, Planning, and Evaluation, Washington, DC.

U.S. EPA. 1989b. *Risk Assessment Guidance for Superfund: Volume 1: Human Health Evaluation Manual, Part A, Interim Final*. EPA/540/1-89/002. Office of Emergency and Remedial Response, Washington, DC. NTIS PB90-155581/CCE.

U.S. EPA. 1989c. *Stabilization/Solidification of CERCLA and RCRA Wastes*. EPA/625/6-89/022.

U.S. EPA. 1990a. *Guidance on Remedial Actions for Superfund Sites with PCB Contamination*. EPA 540G-90/007. Office of Emergency and Remedial Response, Washington, DC. NTIS PB91-921206/CCE.

U.S. EPA. 1990b. *Suggested ROD Language for Various Ground Water Remediation Options*. Directive 9283.1-03. Office of Emergency and Remedial Response, Washington, DC. NTIS PB91-921325/CCE.

U.S. EPA. 1991a. *Guidance for Risk Assessment*. Risk Assessment Council, Office of the Administrator, Washington, DC.

U.S. EPA. 1991b. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors*. Publication 9285.6-03. Office of Emergency and Remedial Response, Washington, DC. NTIS PB91-92131

U.S. EPA. 1991c. *Leachability Phenomena. Recommendations and Rationale for Analysis of Contaminant Release by the Environmental Engineering Committee*. EPA-SAB-EEC-92-003. Science Advisory Board, Washington, DC.

U.S. EPA. 1991d. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals)*. Publication 9285.7-01B. Office of Emergency and Remedial Response, Washington, DC. NTIS PB92-963333.

U.S. EPA. 1991e. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*. Publication 9355.0-30. Office of Emergency and Remedial Response, Washington, DC. NTIS PB91-921359/CCE.

U.S. EPA. 1992a. *Considerations in Ground-Water Remediation at Superfund Sites and RCRA Facilities—Update*. Directive 9283.1-06. Office of Emergency and Remedial Response, Washington, DC. NTIS PB91-238584/CCE.

U.S. EPA. 1992b. *Estimating Potential for Occurrence of DNAPL at Superfund Sites*. Publication 9355.4-07FS. Office of Emergency and Remedial Response, Washingt DC. NTIS PB92-963338.

U.S. EPA. 1992c. *Guidance for Data Usability in Risk Assessment (Part A).* Office of Emergency and Remedial Response, Washington, DC. NTIS PB92-963356.

U.S. EPA. 1992d. *Supplemental Guidance to RAGS: Calculating the Concentration Term,* Volume 1, Number 1. Publication 9285.7-01I. Office of Emergency and Remedial Response, Washington, DC. NTIS PB92-963373.

U.S. EPA. 1993a. *Data Quality Objectives for Superfund: Interim Final Guidance.* EPA 540-R-93-071. Publication 9255.9-01. Office of Emergency and Remedial Response, Washington, DC. NTIS PB94-963203.

U.S. EPA. 1993b. *Guidance for Evaluating Technical Impracticability of Ground-Water Restoration.* Directive 9234.2-25. EPA/540-R-93-080. Office of Emergency and Remedial Response, Washington, DC.

U.S. EPA. 1993c. Health Effects Assessment Summary Tables (HEAST): Annual Update, FY1993. Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Office of Research and Development, Cincinnati, OH.

U.S. EPA. 1993d. Science Advisory Board Review of the Office of Solid Waste and Emergency Response draft *Risk Assessment Guidance for Superfund (RAGS), Human Health Evaluation Manual (HHEM).* EPA-SAB-EHC-93-007. Science Advisory Board, Washington, DC.

U.S. EPA. 1994a. *Framework for Assessing Ground Water Modeling Applications.* EPA-500-B-94-004. Resource Management and Information Staff. Office of Solid Waste and Emergency Response, Washington, DC.

U.S. EPA. 1994b. *Ground Water Modeling Compendium, Second Edition.* EPA-500-B-94-003. Resource Management and Information Staff. Office of Solid Waste and Emergency Response, Washington, DC.

U.S. EPA. 1994c. Integrated Risk Information System (IRIS). Duluth, MN.

U.S. EPA. 1994d. *Role of the Ecological Risk Assessment in the Baseline Risk Assessment.* OSWER Directive No. 9285.7-17. Office of Solid Waste and Emergency Response, Washington, DC. August 12.

U.S. EPA. 1994e. *Technical Background Document for Soil Screening Guidance.* EPA/540/R-94/102. Office of Emergency and Remedial Response, Washington, DC. PB95-963530.

Van Wijnen, J.H., P. Clausing, and B. Brunekreef. 1990. Estimated Soil Ingestion by Children. *Environmental Research,* 51:147-162.

Appendix A. Generic Soil Screening Levels for Superfund[a]

NOTICE: These values were developed for use in application of the Soil Screening Guidance only. They were developed for specific exposure pathways constituting a residential scenario and should only be used in that context.

CAS No.	Chemical	Pathway-specific values for surface soils (mg/kg)		Migration to ground water pathway levels (mg/kg)	
		Ingestion	Inhalation	With 10 DAF	With 1 DAF
83-32-9	Acenaphthene	4,700 [b]	— [c]	200 [b]	20 [b]
67-64-1	Acetone	7,800 [b]	62,000 [d]	8 [b]	0.8 [b]
309-00-2	Aldrin	0.04 [e]	0.5 [e]	0.005 [e]	5E-4 [e,f]
120-12-7	Anthracene	23,000 [b]	— [c]	4,300 [b]	430 [b]
71-43-2	Benzene	22 [e]	0.5 [e]	0.02	0.002 [f]
56-55-3	Benzo(*a*)anthracene	0.9 [e]	— [c]	0.7	0.07 [f]
205-99-2	Benzo(*b*)fluoranthene	0.9 [e]	— [c]	4	0.4
207-08-9	Benzo(*k*)fluoranthene	9 [e]	— [c]	4	0.4
50-32-8	Benzo(*a*)pyrene	0.09 [e,f]	— [c]	4	0.4
111-44-4	Bis(2-chlorethyl)ether	0.6 [e]	0.3 [e,f]	3E-4 [e,f]	3E-5 [e,f]
117-81-7	Bis(2-ethylhexyl)phthalate	46 [e]	210 [d]	11	1
75-27-4	Bromodichloromethane	5 [e]	1,800 [d]	0.3	0.03
75-25-2	Bromoform	81 [e]	46 [e]	0.5	0.05
71-36-3	Butanol	7,800 [b]	9,700 [d]	8 [b]	0.8 [b]
85-68-7	Butyl benzyl phthalate	16,000 [b]	530 [d]	68	7
86-74-8	Carbazole	32 [e]	— [c]	0.2 [e,f]	0.02 [e,f]
75-15-0	Carbon disulfide	7,800 [b]	11 [b]	14 [b]	1 [b]
56-23-5	Carbon tetrachloride	5 [e]	0.2 [e]	0.03	0.003 [f]
57-74-9	Chlordane	0.5 [e]	10 [e]	2	0
108-90-7	Chlorobenzene	1,600 [b]	94 [b]	0.6	0.0[illegible]
124-48-1	Chlorodibromomethane	8 [e]	1,900 [d]	0.2	0.02
67-66-3	Chloroform	110 [e]	0.2 [e]	0.3	0.03
218-01-9	Chrysene	88 [e]	— [c]	1	0.1 [f]
72-54-8	DDD	3 [e]	— [c]	0.7 [e]	0.07 [e]
72-55-9	DDE	2 [e]	— [c]	0.5 [e]	0.05 [e]
50-29-3	DDT	2 [e]	80 [e]	1 [e]	0.1 [e]
53-70-3	Dibenzo(*a,h*)anthracene	0.09 [e,f]	— [c]	11	1
84-74-2	Di-*n*-butyl phthalate	7,800 [b]	100 [d]	120 [b]	12 [b]
95-50-1	1,2-Dichlorobenzene (*o*)	7,000 [b]	300 [d]	6	0.6
106-46-7	1,4-Dichlorobenzene (*p*)	27 [e]	7,700 [b]	1	0.1 [f]
91-94-1	3,3-Dichlorobenzidine	1 [e]	— [c]	0.01 [e,f]	0.001 [e,f]
75-34-3	1,1-Dichloroethane	7,800 [b]	980 [b]	11 [b]	1 [b]
107-06-2	1,2-Dichloroethane	7 [e]	0.3 [e]	0.01 [f]	0.001 [f]
75-35-4	1,1-Dichloroethylene	1 [e]	0.04 [e]	0.03	0.003 [f]
156-59-2	*cis*-1,2-Dichloroethylene	780 [b]	1,500 [d]	0.2	0.02
156-60-5	*trans*-1,2-Dichloroethylene	1,600 [b]	3,600 [d]	0.3	0.03
78-87-5	1,2-Dichloropropane	9 [e]	11 [b]	0.02	0.002 [f]
542-75-6	1,3-Dichloropropene	4 [e]	0.1 [e]	0.001 [e,f]	1E-4 [e,f]
60-57-1	Dieldrin	0.04 [e]	2 [e]	0.001 [e,f]	1E-4 [e,f]
84-66-2	Diethyl phthalate	63,000 [b]	520 [d]	110 [b]	11 [b]
131-11-3	Dimethyl phthalate	7.8E+5 [b]	1,600 [d]	1,200 [b]	120 [b]
121-14-2	2,4-Dinitrotoluene	160 [b]	— [c]	0.2 [b,f]	0.02
606-20-2	2,6-Dinitrotoluene	78 [b]	— [c]	0.1 [b,f]	0.01

(continued)

Appendix A (continued)

CAS No.	Chemical	Pathway-specific values for surface soils (mg/kg)		Migration to ground water pathway levels (mg/kg)	
		Ingestion	Inhalation	With 10 DAF	With 1 DAF
117-84-0	Di-*n*-octyl phthalate	1,600 [b]	— [c]	— [g]	— [g]
115-29-7	Endosulfan	470 [b]	— [c]	4 [b]	0.4 [b]
72-20-8	Endrin	23 [b]	— [c]	0.4	0.04
100-41-4	Ethylbenzene	7,800 [b]	260 [d]	5	0.5
206-44-0	Fluoranthene	3,100 [b]	— [c]	980 [b]	98 [b]
86-73-7	Fluorene	3,100 [b]	— [c]	160 [b]	16 [b]
76-44-8	Heptachlor	0.1 [e]	0.3 [e]	0.06	0.006
1024-57-3	Heptachlor epoxide	0.07 [e]	1 [e]	0.03	0.003
118-74-1	Hexachlorobenzene	0.4 [e]	1 [e]	0.8	0.08 [f]
87-68-3	Hexachloro-1,3-butadiene	8 [e]	1 [e]	0.1 [f]	0.01 [f]
319-84-6	α-HCH (α-BHC)	0.1 [e]	0.9 [e]	4E-4 [e,f]	4E-5 [e,f]
319-85-7	β-HCH (β-BHC)	0.4 [e]	16 [e]	0.002 [e]	2E-4 [e,f]
58-89-9	γ-HCH (Lindane)	0.5 [e]	— [c]	0.006	6E-4 [f]
77-47-4	Hexachlorocyclopentadiene	550 [b]	2 [b]	10	1
67-72-1	Hexachloroethane	46 [e]	49 [e]	0.2 [e,f]	0.02 [e,f]
193-39-5	Indeno(1,2,3-*c,d*)pyrene	0.9 [e]	— [c]	35	3
78-59-1	Isophorone	670 [e]	3,400 [d]	0.2 [e,f]	0.02 [e,f]
72-43-5	Methoxychlor	390 [b]	— [c]	62	6
74-83-9	Methyl bromide	110 [b]	2 [b]	0.1 [b]	0.01 [b,f]
75-09-2	Methylene chloride	85 [e]	7 [e]	0.01 [f]	0.001 [f]
91-20-3	Naphthalene	3,100 [b]	— [c]	30 [b]	3 [b]
98-95-3	Nitrobenzene	39 [b]	110 [b]	0.09 [b,f]	0.009 [b,f]
1336-36-3	Polychlorinated biphenyls (PCBs)	1 [h]	— [c,h]	— [h]	— [h]
129-00-0	Pyrene	2,300 [b]	— [c]	1,400 [b]	140 [b]
100-42-5	Stryene	16,000 [b]	1,400 [d]	2	0.2
79-34-5	1,1,2,2-Tetrachloroethane	3 [e]	0.4 [e]	0.001 [e,f]	1E-4 [e,f]
127-18-4	Tetrachloroethylene	12 [e]	11 [e]	0.04	0.004 [f]
108-88-3	Toluene	16,000 [b]	520 [d]	5	0.5
8001-35-2	Toxaphene	0.6 [e]	5 [d]	0.04 [f]	0.004 [f]
120-82-1	1,2,4-Trichlorobenzene	780 [b]	240 [b]	2	0.2 [f]
71-55-6	1,1,1-Trichloroethane	— [c]	980 [d]	0.9	0.09
79-00-5	1,1,2-Trichloroethane	11 [e]	0.8 [e]	0.01 [f]	0.001 [f]
79-01-6	Trichloroethylene	58 [e]	3 [e]	0.02	0.002 [f]
108-05-4	Vinyl acetate	78,000 [b]	370 [b]	84 [b]	8 [b]
75-01-4	Vinyl chloride	0.3 [e]	0.002 [e,f]	0.01 [f]	0.001 [f]
1330-20-7	Xylenes (total)	1.6E+5 [b]	320 [d]	74	7
	Ionizable Organics				
65-85-0	Benzoic acid	3.1E+5 [b]	— [c]	280 [b,i]	28 [b,i]
106-47-8	*p*-Chloroaniline	310 [b]	— [c]	0.3 [b,f,i]	0.03 [b,f,i]
95-57-8	2-Chlorophenol	390 [b]	53,000 [d]	2 [b,i]	0.2 [b,f,i]
120-83-2	2,4-Dichlorophenol	240 [b]	— [c]	0.5 [b,i]	0.05 [b,f,i]
105-67-9	2,4-Dimethylphenol	1,600 [b]	— [c]	3 [b,i]	0.3 [b,f,i]
51-28-5	2,4-Dinitrophenol	160 [b]	— [c]	0.1 [b,f,i]	0.01 [b,f,i]
95-48-7	2-Methylphenol	3,900 [b]	— [c]	6 [b,i]	0.6 [b,i]

(continued)

Appendix A (continued)

CAS No.	Chemical	Pathway-specific values for surface soils (mg/kg) Ingestion	Inhalation	Migration to ground water pathway levels (mg/kg) With 10 DAF	With 1 DAF
86-30-6	*N*-Nitrosodiphenylamine	130 [e]	— [c]	0.2 [e,f,i]	0.02 [e,f,i]
621-64-7	*N*-Nitrosodi-*n*-propylamine	0.09 [e,f]	— [c]	2E-5 [e,f,i]	2E-6 [e,f,i]
87-86-5	Pentachlorophenol	3 [e,j]	— [c]	0.01 [f,i]	0.001 [f,i]
108-95-2	Phenol	47,000 [b]	— [c]	49 [b,i]	5 [b,i]
95-95-4	2,4,5-Trichlorophenol	7,800 [b]	— [c]	120 [b,i]	12 [b,i]
88-06-2	2,4,6-Trichlorophenol	58 [e]	210 [e]	0.06 [e,f,i]	0.006 [e,f,i]
	Inorganics				
7440-36-0	Antimony	31 [b]	— [c]	— [k]	— [k]
7440-38-2	Arsenic ⚘	0.4 [e]	380 [e]	15 [i]	1 [i]
7440-39-3	Barium	5,500 [b]	3.5E+5 [b]	32 [i]	3 [i]
7440-41-7	Beryllium	0.1 [e]	690 [e]	180 [i]	18 [i]
7440-43-9	Cadmium ⚘	39 [b]	920 [e]	6 [i]	0.6 [i]
7440-47-3	Chromium (6+)	390 [b]	140 [e]	19 [i]	2 [i]
7439-92-1	Lead	400 [l]	—	—	—
7439-97-6	Mercury ⚘	23 [b]	7 [b,i]	3 [i]	0.3 [i]
7440-02-0	Nickel ⚘	1,600 [b]	6,900 [e]	21 [i]	2 [i]
7782-49-2	Selenium ⚘	390 [b]	— [c]	3 [i]	0.3 [i]
7440-22-4	Silver	390 [b]	— [c]	— [k]	— [k]
7440-28-0	Thallium	— [c]	— [c]	0.4 [i]	0.04
7440-62-2	Vanadium	550 [b]	— [c]	— [k]	— [k]
7440-66-6	Zinc ⚘	23,000 [b]	— [c]	42,000 b,i	4,200 b,i
57-12-5	Cyanide	1,600 [b]	— [c]	— [k]	— [k]

DAF = Dilution and attenuation factor.

[a] Screening levels based on human health criteria only.

[b] Calculated values correspond to a noncancer hazard quotient of 1.

[c] No toxicity criteria available for that route of exposure.

[d] Soil saturation concentration (C_{sat}).

[e] Calculated values correspond to a cancer risk level of 1 in 1,000,000.

[f] Level is at or below Contract Laboratory Program required quantitation limit for Regular Analytical Services (RAS).

[g] Chemical-specific properties are such that this pathway is not of concern at any soil contaminant concentration.

[h] A preliminary remediation goal of 1 ppm has been set for PCBs based on *Guidance on Remedial Actions for Superfund Sites with PCB Contamination*, EPA/540G-90/007, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC, 1990, and on Agency-wide efforts to manage PCB contamination.

[i] SSL for pH of 6.8.

[j] Ingestion SSL adjusted by a factor of 0.5 to account for dermal exposure.

[k] Soil/water partition coefficients not available at this time.

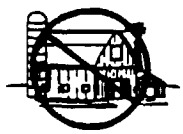
[l] A preliminary remediation goal of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities*, OSWER Directive #9355.4-12, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, DC, July 14, 1994.

⚘ Indicates potential for soil-plant-human exposure.

Levels developed for residential use only:

Residential

Industrial



Agricultural