Science Applications International Corporation
An Employee-Owned Company

October 13, 1998

Mr. Andrew Wittner
U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street S.W.
Washington, D.C. 20460

Reference: Revised Sensitivity Analysis Results
EPA Contract 68-W-98-025, WA 11
SAIC Project 06-5029-08-7436-200

Dear Andy:

Enclosed please find two copies of "Fossil Fuel Combustion Waste Risk Assessment: Revised Ground-water Analysis and Sensitivity Results." The report includes all of the materials that I provided to you on October 7 and 8, with FBC results included. In addition, we have pulled together the results of the individual experiments (e.g. impact of area on model results) for the your records. Note that I have also recompiled the summary results for all scenarios in the attached table. The results in this document supersede the previous deliverable results.

We have stopped work on the sensitivity analysis pending receipt of further technical direction and funding. However, I welcome your comments and questions on the enclosed.

Sincerely,
SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

Christopher Long
Environmental Scientist

Summary of Draft Risk Model Results for Ground-Water Pathway Scenarios (October 13, 1998)					
Scenario*	Constituent**	Deterministic Risk		Monte Carlo Risk	
		Central Tendency	High-End	Central Tendency	High-End***
CS	As	$3x10^{-6}$	$5x10^{-4}$	$1.1x10^{-6}$	$1.6x10^{-5}$
CL	As	$4x10^{-7}$	$3x10^{-4}$	$2.3x10^{-7}$	$4.3x10^{-5}$
	Cr	HQ<1	HQ=0.2	HQ=0.002	HQ=0.1
	Ni	HQ<1	HQ<0.1	HQ<<1	HQ=0.01
	Se	HQ<1	HQ=0.8	HQ=0.03	HQ=0.1
OS	As	$1x10^{-12}$	$7x10^{-5}$	$3x10^{-7}$	$2.6x10^{-5}$
	Ni	HQ<<1	HQ=28	HQ<<1	HQ=0.005
	V	HQ<<1	HQ=680	0.7	150
OM	As	$1x10^{-15}$	$2x10^{-5}$	$2x10^{-7}$	$3x10^{-5}$
	Ni	HQ<<1	HQ=1.8	HQ<<1	HQ=0.05
	V	HQ<<1	HQ=6.7	HQ=0.2	HQ=21
FL	Sb	HQ<<1	HQ=12	HQ<<1	HQ=0.007
	As	$1x10^{-8}$	$4.3x10^{-4}$	$5x10^{-20}$	$2x10^{-6}$
	Be	HQ<<1	1.4	HQ<<1	HQ<0.001
	Cr	HQ<<1	1.1	HQ<<1	HQ=0.002

CS = Comanaged Waste Impoundment; CL = Comanaged Waste Landfill; OS = Oil Ash Impoundment; OM = Oil Ash Landfill; and FL = FBC Waste Landfill.

* Scenarios are limited to comanaged waste, oil ash, and FBC waste landfills and comanaged waste and oil ash surface impoundments. Minefills and off-site landfills won't be modeled due to data and model limitations. Non-utility wastes are assumed to be bounded by other scenarios.
** Constituents are limited to those for which estimated risks exceeded target values in the April 1998 Draft Final Report.
*** *Numbers shown are 95th percentile Monte Carlo results.* Agency policy considers high-end to be 90th percentile or higher.

FOSSIL FUEL COMBUSTION WASTE RISK ASSESSMENT

Revised Groundwater Analysis and Sensitivity Results

October 9, 1998
01-0825-08-4736-200, Technical Directive No. 1

Submitted to:
U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street, S.W.
Washington, D.C. 20460

Prepared by:
Science Applications International Corporation
11251 Roger Bacon Drive
Reston, VA 20190

1.0 Introduction

In April 1998, SAIC prepared a report presenting results of risk analyses for fossil fuel combustion wastes ("Technical Background Document for the Supplemental Report to Congress on Remaining Fossil Fuel Combustion Wastes, Ground-water Pathway Human Health Risk Assessment"). In a further effort to properly characterize risk from fossil fuel waste disposal scenarios, SAIC conducted additional simulations using EPA's ground water transport model EPACMTP. These specific changes have included new sensitivity analyses on a limited number of variables, new statistical assumptions impacting input concentrations, and changes in their assumptions regarding leachate to waste ratios and other variables.

2.0 Revised Deterministic Results

Attachment 1 presents deterministic results for both central tendency and high end analyses.

3.0 Monte Carlo Results

Attachment 2 presents discussion and results of this analysis.

4.0 Comparison of Risk Using HBLs and MCLs as Benchmarks

Attachment 3 presents discussion and results of this analysis.

5.0 Comparison of Actual Groundwater Data at EPRI Sites to Model Results

Attachment 4 presents discussion and results of this analysis.

6.0 Comparison of FFC Waste Characteristics to Cement Kiln Dust and Background Data

Attachment 5 presents discussion and results of this analysis.

7.0 Sensitivity Runs

Attachment 6 presents discussion and results of this analysis.

Attachment 1
Deterministic Results

MEMORANDUM

An Employee-Owned Company

DATE: October 9, 1998

TO: Andrew Wittner

FROM: Chris Long and John Vierow

REFERENCE: Revised Summary of Deterministic Results and Uncertainties
EPA Contract 68-W-98-025
SAIC Project 06-5029-08-4736-100, WA 11

The April 1998 Report presented deterministic results for each of the four waste types (comanaged wastes, oil ash, FBC waste, and non-utility coal combustion wastes) for multiple scenarios (e.g., surface impoundment, onsite landfill). Following that report, sensitivity analyses were performed to determine the appropriateness of key model assumptions. Based on the findings of the sensitivity analyses, several modifications were made to the central tendency and high-end deterministic scenarios to allow for more appropriate analyses.

Adjustments to the high-end scenarios included the following:

(1) Adjusting the duration of leaching in a landfill scenario. The quantity of contaminant leaving the waste management unit was calculated using a mass balance. This was compared to the maximum quantity of contaminant that reasonably can be assumed to be present, as calculated from the waste's maximum contaminant concentration.

(2) Revising the concentration data for comanagement landfill scenarios. In the April report, the comanagement landfill leachate was assumed to be represented by pore water data collected from both impoundments and landfills. In this revised analysis, TCLP data are assumed to better reflect leachate from a comanagement landfill.

(3) Revising the concentration data for oil ash scenarios. In the April report, concentration data for individual wastes were facility averaged and a 95th percentile concentration calculated for each waste type, with the highest such concentration used in the analyses. In this revised analysis, all wastes were included in compiling a facility's average waste concentration; the 95th percentile concentration was then selected.

(4) Revising the concentration data for FBC wastes. In the April report, FBC waste concentration data reflected the 95th percentile concentrations of all samples

of wastes, irrespective of fuel type or facility of origin. To be consistent with other sectors, and to separate out the influence of Petroleum Coke as a fuel source, concentrations were recalculated based on the facility average concentrations of wastes from coal-fired FBC units only.

(5) A new RfD for chromium (VI) was published in IRIS in August. The RfD was lowered from 0.005 to 0.003 mg/kg/d, lowering the HBL from 0.26 to 0.15 mg/L (a factor of 0.6).

(6) Minefill scenarios were deleted from the analyses due to model limitations (EPACMTP can not model fractured flow conditions or placement of wastes below the water table) and data limitations (EPA does not have sufficient data to characterize background conditions in disturbed mining environments where ash may be placed).

(7) Off-site codisposal scenarios were deleted from the analyses due to model limitations discovered through sensitivity analyses.

Deterministic central tendency runs were conducted for all constituents and all scenarios showing a risk greater than 10^{-6} or HQ=1 in the revised deterministic high end analyses. The deterministic high end analyses consistently used central tendency values for all parameters except well location and initial concentration. Therefore, only these two parameters were changed for the central tendency analysis. The median initial concentration was calculated in the same manner as the high end concentration, for each scenario. The well location was fixed at a radial distance of 430 meters and an angle 45° from the centerline. The 430 m value corresponds to the 50th percentile used in the HWIR analysis, as presented in the EPACMTP Users Guide. It is virtually impossible to select a single well location angle for the central tendency value on statistical grounds. Instead, the following justification was used in selecting this value:

(1) A high end location would be located on the centerline because that is the maximum exposure; this reasoning was used in the April 1998 report for selecting well location. If a receptor was assumed to be anywhere downgradient of the unit, however, the receptor would have an equal chance of being on the centerline, perpendicular to the centerline, or any angle in between. In this case, the "central tendency" angle would correspond to 45°.

(2) Plume size, in turn affected by unit size and dispersion parameters, will affect the concentrations off centerline. A downgradient population would be less affected by a small source than a large one, due to differences in plume width. Therefore, selection of a 45° angle in all cases means that a smaller plume will result in a smaller receptor well concentration, which may appropriately result in a conclusion that, all things being equal, a smaller unit should show lower risk than a larger one.

Table 1, below, presents a summary of the revised deterministic model results for all pathways and constituents included in this analysis. Table 2 presents the specific changes made by scenario and constituent, comparing the April 1998 and revised result and comments regarding the uncertainty associated with the revised result. Table 3 presents the April 1998 and revised central tendency results for all pathways and constituents, and includes the specific changes made to each scenario.

Table 1: Summary of Draft Deterministic Model Results for Ground-Water Pathway Scenarios (October 10, 1998)

Scenario*	Constituent**	Deterministic Risk	
		Central Tendency	High-End
CS	As	$3x10^{-6}$	$5x10^{-4}$
CL	As	$4x10^{-7}$	$3x10^{-4}$
	Cr	HQ<1	HQ=0.2
	Ni	HQ<1	HQ<0.1
	Se	HQ<1	HQ=0.8
OS	As	$1x10^{-12}$	$7x10^{-5}$
	Ni	HQ<<1	HQ=28
	V	HQ<<1	HQ=680
OM	As	$1x10^{-15}$	$2x10^{-5}$
	Ni	HQ<<1	HQ=1.8
	V	HQ<<1	HQ=6.7
FL	Sb	HQ<<1	HQ=12
	As	$1x10^{-8}$	$4.3x10^{-4}$
	Be	HQ<<1	1.4
	Cr	HQ<<1	1.1

CS = Comanaged Waste Impoundment; CL = Comanaged Waste Landfill; OS = Oil Ash Impoundment; OM = Oil Ash Landfill; and FL = FBC Waste Landfill.

* Scenarios are limited to comanaged waste, oil ash, and FBC waste landfills and comanaged waste and oil ash surface impoundments. Minefills and off-site landfills won't be modeled due to data and model limitations. Non-utility wastes are assumed to be bounded by other scenarios.

** Constituents are limited to those for which estimated risks exceeded target values in the April 1998 Draft Final Report.

Table 2: Changes to High-End Deterministic Results:
All Constituents Exceeding HQ=1 or Risk=10^{-6} in April 1998 Report[1]
Comanaged coal combustion wastes, oil combustion wastes, and FBC wastes

Constituent	Old HQ or Risk	Change	New HQ or Risk	Range of Uncertainty
Comanaged Waste Impoundment				
Arsenic	Risk= $5.1x10^{-4}$	No change (represents all wastes including mill reject effects)	Risk= $5.1x10^{-4}$	Risks are likely overstated by the following amounts, due to the following cumulative effects: A. Risks range from values given to an order of magnitude or more in either direction. This is based on the sensitivity of waste hydraulic conductivity and waste management unit infiltration rate. The hydraulic conductivity of the waste, however, is not well characterized. B. Contaminant movement assumes 100 percent availability and retardation consistent with EPACMTP. Actual availability may be lower and retardation higher. Such effects are not quantified because of the lack of quantitative estimates.
	----	Initial leachate concentration changed from 9.64 mg/L to 5.37 mg/L to exclude mill rejects. Highest (95th percentile) concentration used.	Risk= $2.8x10^{-4}$	

Table 2: Changes to High-End Deterministic Results:
All Constituents Exceeding HQ=1 or Risk=10^{-6} in April 1998 Report [1]
Comanaged coal combustion wastes, oil combustion wastes, and FBC wastes

Constituent	Old HQ or Risk	Change	New HQ or Risk	Range of Uncertainty
Comanaged Waste Landfill				
Arsenic	Risk= $1.1x10^{-2}$	Initial leachate concentration changed from 9.64 mg/L to 0.24 mg/L based on use of TCLP data instead of pore water data.	Risk= $3.4x10^{-4}$	Risks are likely overstated by the following amounts, due to the following cumulative effects: A. Risks range from values given to twice those given. This is based on the difference between the use of environmental location parameters appropriate for FBC wastes versus those used for the comanagement scenario. Because it is difficult to suggest which is more appropriate, a range is presented. B. Risks range from values given to twice those given, or alternatively several orders of magnitude lower. This is based on the change of reduced infiltration rate. Small downward changes in infiltration rate create much lower risks; small increases of infiltration rate create only slightly higher risks. C. Contaminant movement assumes 100 percent availability and retardation consistent with EPACMTP. Actual availability may be lower and retardation higher. Such effects are not quantified because of the lack of quantitative estimates.
Chromium	1.6	Initial leachate concentration changed from 0.75 mg/L to 0.059 mg/L based on use of TCLP data instead of pore water data; RfD decreased by a factor of 0.6.	HQ=0.2	
Nickel	4.6	Initial leachate concentration changed from 8.3 mg/L to 0.05 mg/L based on use of TCLP data instead of pore water data.	HQ<0.1	
Selenium	1.8	Initial leachate concentration changed from 1.03 mg/L to 0.44 mg/L based on use of TCLP data instead of pore water data.	HQ=0.8	

Table 2: Changes to High-End Deterministic Results:
All Constituents Exceeding HQ=1 or Risk=10^{-6} in April 1998 Report [1]
Comanaged coal combustion wastes, oil combustion wastes, and FBC wastes

Constituent	Old HQ or Risk	Change	New HQ or Risk	Range of Uncertainty
Oil Waste Impoundment				
Arsenic	Risk= 2.6×10^{-4}	Initial concentration changed from 4.15 mg/L to 1.14 mg/L based on revised statistical approach.	Risk= 7.1×10^{-5}	Risks are likely overstated by the following amounts, due to the following cumulative effects: A. Risks range from values given to an order of magnitude or more in either direction. This is based on the sensitivity of waste hydraulic conductivity and waste management unit infiltration rate. The hydraulic conductivity of the waste, however, is not well characterized. B. Contaminant movement assumes 100 percent availability and retardation consistent with EPACMTP. Actual availability may be lower and retardation higher. Such effects are not quantified because of the lack of quantitative estimates.
Nickel	100	Initial concentration changed from 470 mg/L to 254 mg/L based on revised statistical approach.	28	
Vanadium	950	Initial concentration changed from 882 mg/L to 637 mg/L based on revised statistical approach.	680	

Table 2: Changes to High-End Deterministic Results:
All Constituents Exceeding HQ=1 or Risk=10^{-6} in April 1998 Report [1]
Comanaged coal combustion wastes, oil combustion wastes, and FBC wastes

Constituent	Old HQ or Risk	Change	New HQ or Risk	Range of Uncertainty
Oil Waste Monofill				
Arsenic	Risk= $9.1x10^{-5}$	Initial concentration changed from 4.15 mg/L to 1.14 mg/L based on revised statistical approach.	Risk= $2.5x10^{-5}$	Risks have uncertainty, due to the following cumulative effects. Insufficient information is available to determine if the net effect is an overestimation or an underestimation of risk. A. Risks range from values given to half of values given. This is based on the use of environmental location parameters consistent with comanagement scenarios. Because it is difficult to suggest which is more appropriate, a range is presented. B. Contaminant movement assumes 100 percent availability and retardation consistent with EPACMTP. Actual availability may be lower and retardation higher. Such effects are not quantified because of the lack of quantitative estimates. C. Risks may be understated by about 20 times. Units with larger areas have risks about 20 times that indicated here, due to the presence of an inflection point in model results at areas slightly larger than those modeled here.
Nickel	3.4	Initial concentration changed from 470 mg/L to 254 mg/L based on revised statistical approach.	1.8	
Vanadium	8.3	Initial concentration changed from 882 mg/L to 637 mg/L based on revised statistical approach. Additionally, the ratio C_W/C_L was changed from 230 to 109 to incorporate conservation of mass.	6.7	

Table 2: Changes to High-End Deterministic Results:
All Constituents Exceeding HQ=1 or Risk=10^{-6} in April 1998 Report [1]
Comanaged coal combustion wastes, oil combustion wastes, and FBC wastes

Constituent	Old HQ or Risk	Change	New HQ or Risk	Range of Uncertainty
Oil Waste Codisposal Landfill				
Arsenic	Risk= 2.4×10^{-3}	Results are expected to be equal to or less than those posed by the monofill scenario.	Risk= 2.5×10^{-5}	Risks cannot be quantified using EPACMTP because the model shows a dramatic inflection point in receptor well concentration, at an area of 26,000 square meters. Typical oil ash monofills are assumed to be smaller than this area; commercial offsite units larger. Adjusting other parameters such as waste fraction cannot overcome this limitation.
Barium	1.1		<1	
Cadmium	5.2		<1	
Chromium	2.5		<1	
Nickel	140		1.8	
Vanadium	360		6.7	

Table 2: Changes to High-End Deterministic Results:
All Constituents Exceeding HQ=1 or Risk=10^{-6} in April 1998 Report [1]
Comanaged coal combustion wastes, oil combustion wastes, and FBC wastes

Constituent	Old HQ or Risk	Change	New HQ or Risk	Range of Uncertainty
FBC Waste Landfill				
Antimony	20	The ratio C_W/C_L was changed from 1400 to 40 to incorporate conservation of mass.	12	Risks are likely overstated by the following amounts, due to the following cumulative effects: A. Risks range from values given to half of values given. This is based on the use of environmental location parameters consistent with comanagement scenarios. Because it is difficult to suggest which is more appropriate, a range is presented. B. Risks range from values given to an order of magnitude lower. This is based on the effect of reduced infiltration rate. The hydraulic conductivity of the waste as landfilled, however, is not well characterized. C. Contaminant movement assumes 100 percent availability and retardation consistent with EPACMTP. Actual availability may be lower and retardation higher. Such effects are not quantified because of the lack of quantitative estimates.
Arsenic	Risk= $5.6x10^{-4}$	Initial concentration was recalculated using facility averaging and excluding petroleum coke-fueled facilities. This lowered the initial concentration from 0.35 mg/L to 0.27 mg/L .	Risk= $4.3x10^{-4}$	
Beryllium	1.4	The ratio C_W/C_L was changed from 43 to 33 to incorporate conservation of mass.	1.4	
Chromium	0.66	The new RfD for chromium VI is used. This new RfD lowered the HBL from 0.26 to 0.15 mg/L.	1.1	

Table 3: Deterministic Results: All Constituents Exceeding HQ=1 or Risk=10^{-6} in April 1998 Report Comanaged coal combustion wastes, oil combustion wastes, and FBC wastes				
Constituent	New High End HQ or Risk	Central Tendency Values		Central Tendency HQ or Risk[1]
Comanaged Waste Impoundment				
Arsenic	Risk= 2.8×10^{-4}	C_0=0.13 mg/L; well distance is 430 m from unit and 45° from centerline		Risk=3×10^{-6}
Comanaged Waste Landfill				
Arsenic	Risk= 3.4×10^{-4}	C_0=0.0137 mg/L; well distance is 430 m from unit and 45° from centerline		Risk=4×10^{-7}
Chromium	HQ=0.2	Not determined. High end HQ is less than 1		HQ<1
Nickel	HQ<0.1			HQ<1
Selenium	HQ=0.8			HQ<1
Oil Waste Impoundment				
Arsenic	Risk= 7.1×10^{-5}	C_0=0.0808 mg/L	well distance is 430 m from unit and 45° from centerline	Risk=10^{-12}
Nickel	HQ=28	C_0=10.2 mg/L		HQ=10^{-8}
Vanadium	HQ=680	C_0=66.7 mg/L		HQ=10^{-7}
Oil Waste Monofill				
Arsenic	Risk= 2.5×10^{-5}	C_0=0.0808 mg/L	well distance is 430 m from unit and 45° from centerline	Risk=10^{-15}
Nickel	HQ=1.8	C_0=10.2 mg/L		HQ=10^{-11}
Vanadium	HQ=6.7	C_0=66.7 mg/L		HQ=10^{-10}
Oil Waste Codisposal Landfill: Not presented. Risks Comparable to or less than monofill				
FBC Waste Landfill				
Antimony	HQ=12	C_0=0.1 mg/L	well distance is 430 m from unit and 45° from centerline	HQ=0.0002
Arsenic	Risk= 4.3×10^{-4}	C_0=0.025 mg/L		Risk=1×10^{-8}
Beryllium	HQ=1.4	C_0=0.025 mg/L		HQ=0.00003
Chromium	HQ=1.1	C_0=0.028 mg/L		HQ=0.00007

1. All contaminants showing HQ less than 1 or risk less than 10^{-6} in the April report are expected to continue to show negligible risk, with the exception of chromium due to the recent change of its IRIS RfD. Scenarios where chromium had an HQ only slightly less than 1 in the April report are presented in this table.

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[1] Central tendency values for initial concentration and well location are used here. All other values (including exposure parameters) are unchanged from the high end scenario.

Attachment 2
Monte Carlo Results

MEMORANDUM

An Employee-Owned Company

DATE: October 10, 1998

TO: Andrew Wittner

FROM: Chris Long and John Vierow

REFERENCE: Revised Comparison of Draft High-end Deterministic and Monte Carlo Results for All Pathways and Constituents[1]
EPA Contract 68-W-98-025
SAIC Project 06-5029-08-4736-100, WA 11

The April draft final "Ground-water Pathway Human Health Risk Assessment" compared the deterministic high-end modeling results to their corresponding Monte Carlo analysis results to determine the relative conservatism of the high-end scenarios. The results generally demonstrated that the deterministic scenarios yielded a risk equal to or greater than that corresponding to the 90th percentile risk from the respective Monte Carlo analysis, with a few exceptions. As part of the sensitivity analysis of the risk assessment methodology and model, SAIC determined that the manner in which the distribution of starting concentrations is stated in EPACMTP can profoundly influence the resulting risk distribution. Further, sensitivity analyses have led to changes in concentration, unit area, contaminant availability, and/or other parameters in some of the deterministic high-end scenarios. Because these changes might affect the high-end and the Monte Carlo results of a given scenario unevenly, SAIC has re-compared the two sets of outputs.

Table 1, below, summarizes the deterministic and Monte Carlo results for each scenario, and lists the Monte Carlo percentile corresponding to each high-end result. The attached figures plot the distribution of Monte Carlo results (risk versus percentile) and show the revised high-end deterministic scenario result as a constant value.

Generally, the high-end risk exceeds the 95th percentile Monte Carlo risk in all waste management scenarios. The only exceptions to date are arsenic and vanadium in the oil ash monofill scenario, where the high-end results corresponds to the 93.5 and 85.9 percentiles, respectively, of the Monte Carlo distributions. In many instances, the high-end result exceeds the maximum (100th percentile) value observed in 2000 Monte Carlo iterations. Overall, the comparison supports the conclusion that the high-end scenarios yield exceedingly conservative results relative to the Monte Carlo analyses.

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[1] This memorandum replaces the October 7, 1998 memorandum of the same title. It reflects changes to the deterministic and Monte Carlo results for FBC wastes only. All other values are unchanged.

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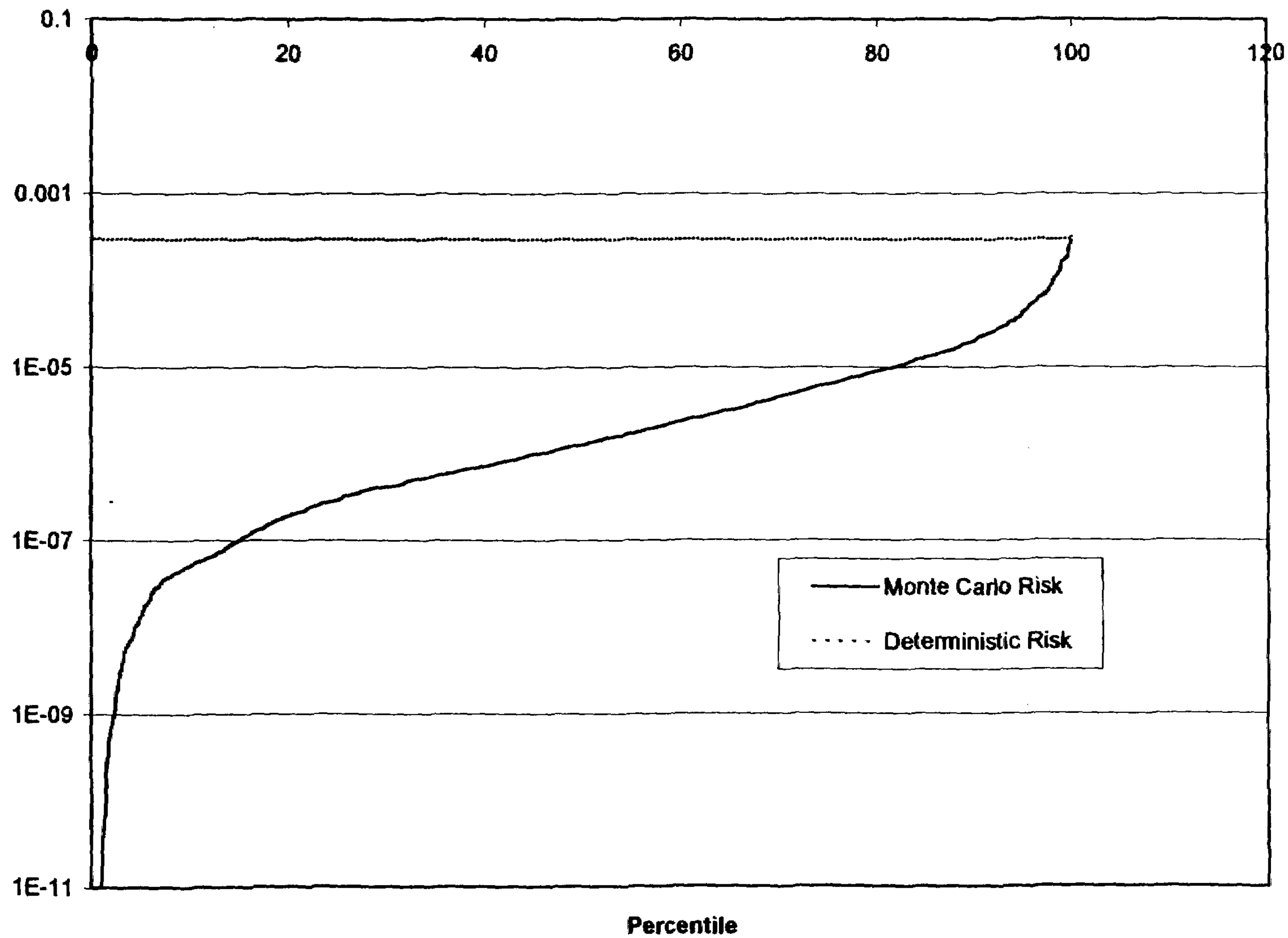
Table 1: Comparison of Draft Deterministic and Monte Carlo Risk Model Results for Ground-Water Pathway Scenarios (October 10, 1998)				
Scenario*	Constituent**	Deterministic Risk, High-End	Corresponding Monte Carlo Percentile	Monte Carlo 95th Percentile
CS	As	$5x10^{-4}$	>100	$1.6x10^{-5}$
CL	As	$3x10^{-4}$	>99.9	$4.3x10^{-5}$
	Cr	HQ=0.2	>99.4	HQ=0.1
	Ni	HQ<0.1	>100	HQ=0.01
	Se	HQ=0.8	>100	HQ=0.1
OS	As	$7x10^{-5}$	97.75	$2.6x10^{-5}$
	Ni	HQ=28	>100	HQ=0.005
	V	HQ=680	>99.9	150
OM	As	$2x10^{-5}$	93.45	$3x10^{-5}$
	Ni	HQ=1.8	>100	HQ=0.05
	V	HQ=6.7	85.9	HQ=21
FL	Sb	HQ=12	>100	HQ=0.007
	As	$4.3x10^{-4}$	>100	$2x10^{-6}$
	Be	1.4	>100	HQ<0.001
	Cr	1.1	>100	HQ=0.002

CS = Comanaged Waste Impoundment; CL = Comanaged Waste Landfill; OS = Oil Ash Impoundment; OM = Oil Ash Landfill; and FL = FBC Waste Landfill.

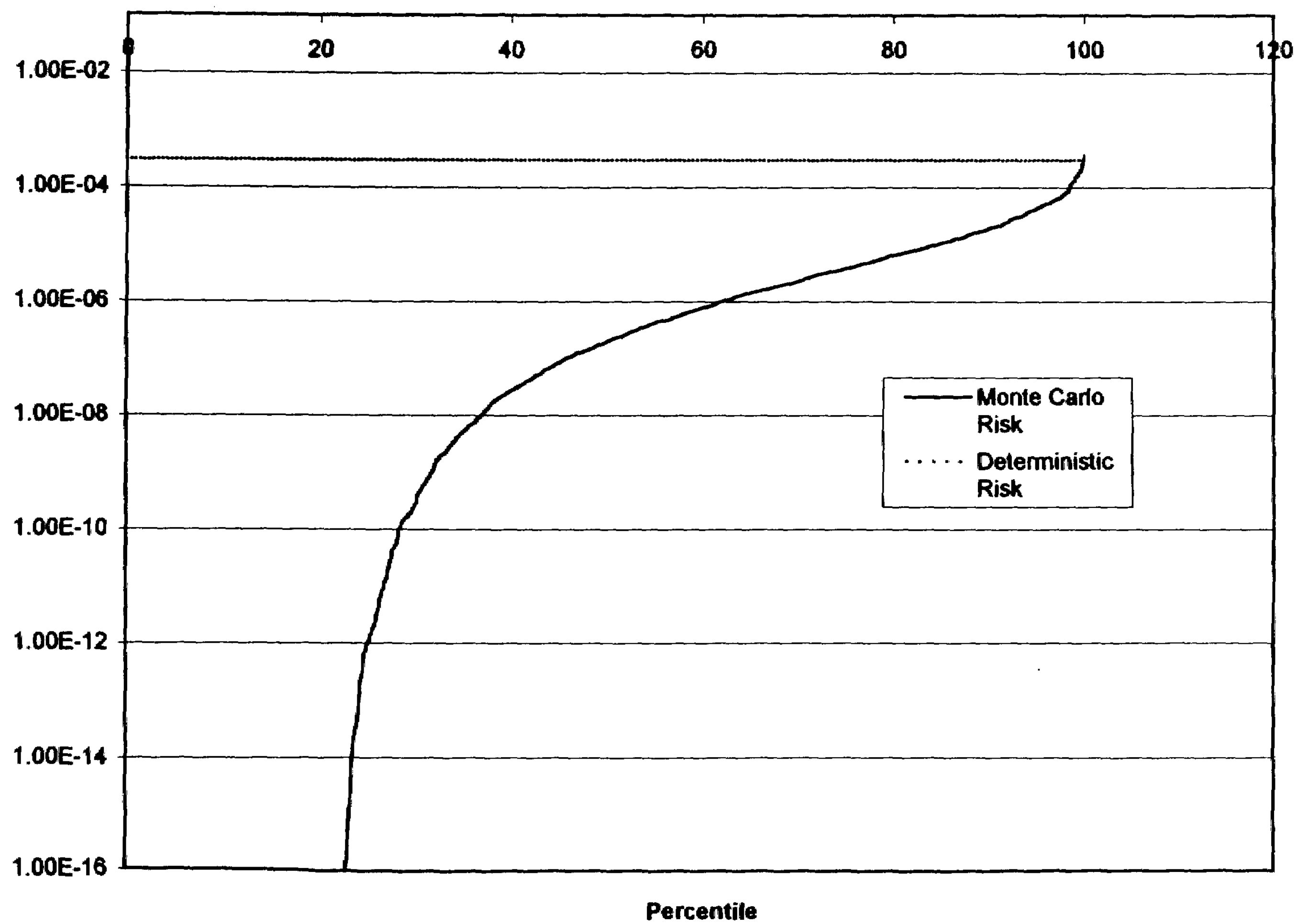
* Scenarios are limited to comanaged waste, oil ash, and FBC waste landfills and comanaged waste and oil ash surface impoundments. Minefills and off-site landfills won't be modeled due to data and model limitations. Non-utility wastes are assumed to be bounded by other scenarios.

** Constituents are limited to those for which estimated risks exceeded target values in the April 1998 Draft Final Report.

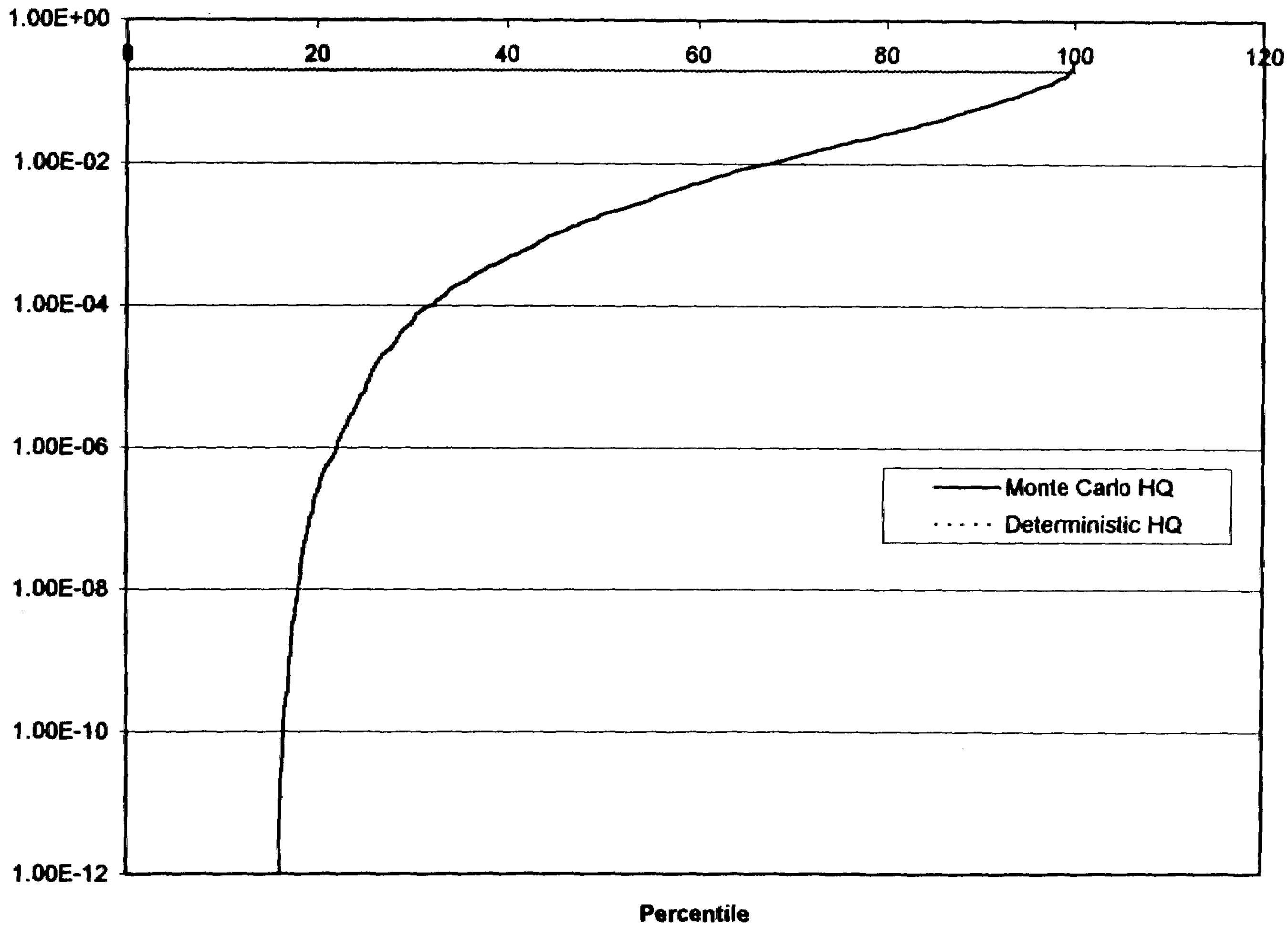
Comanaged Waste Impoundment: Arsenic Risk



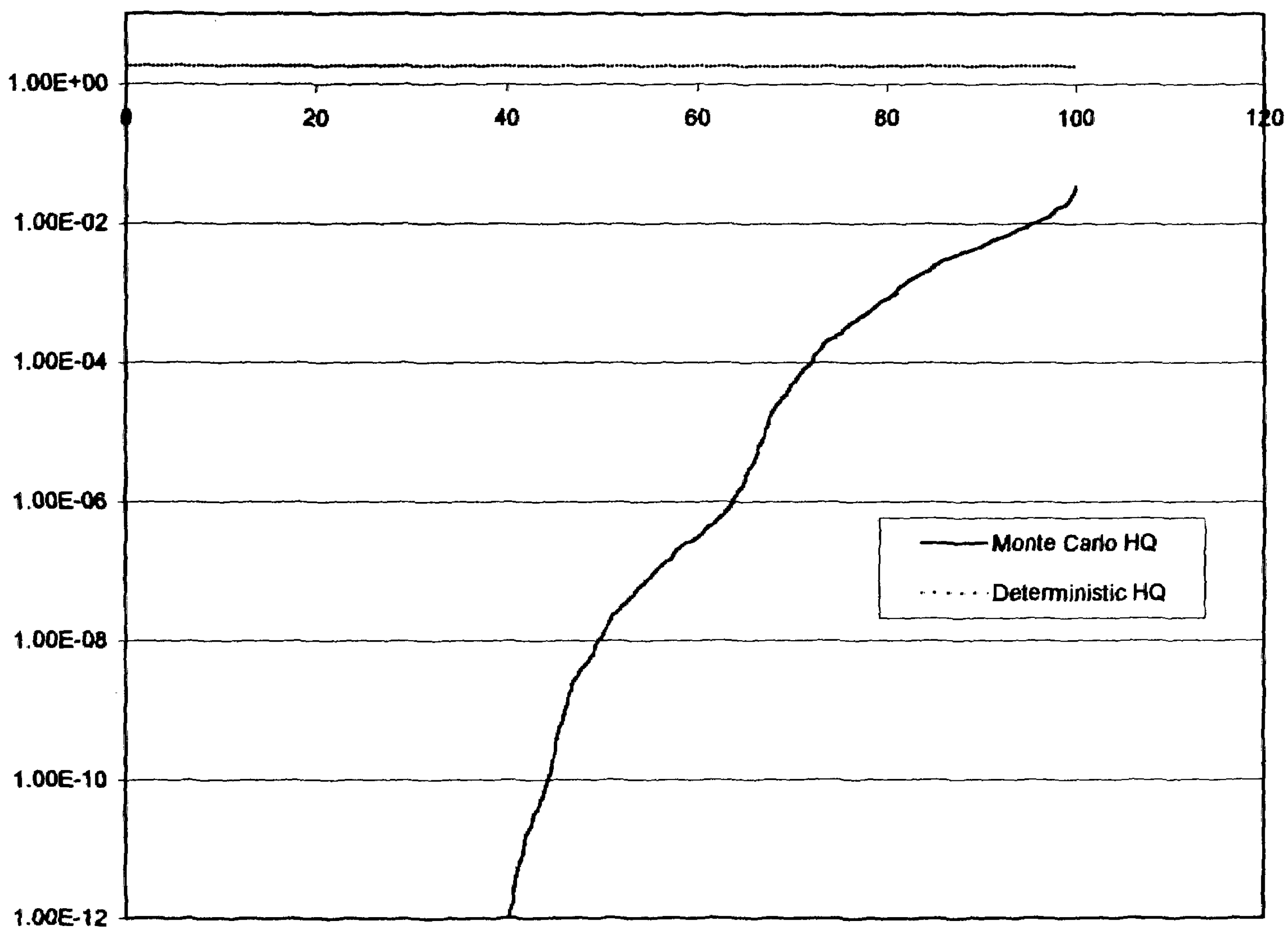
Comanaged Waste Landfill: Arsenic Risk

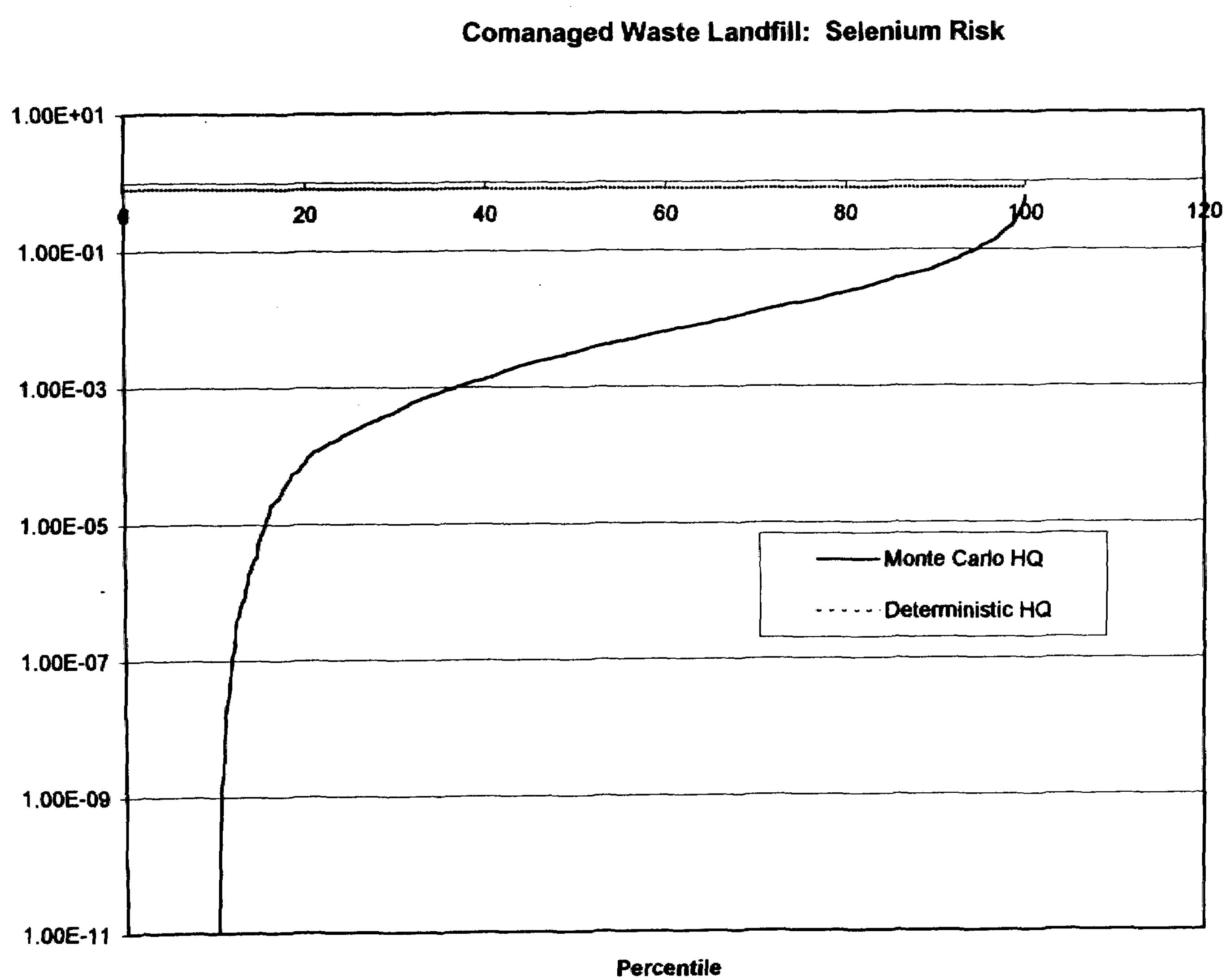


Comanaged Waste Landfill: Chromium Risk



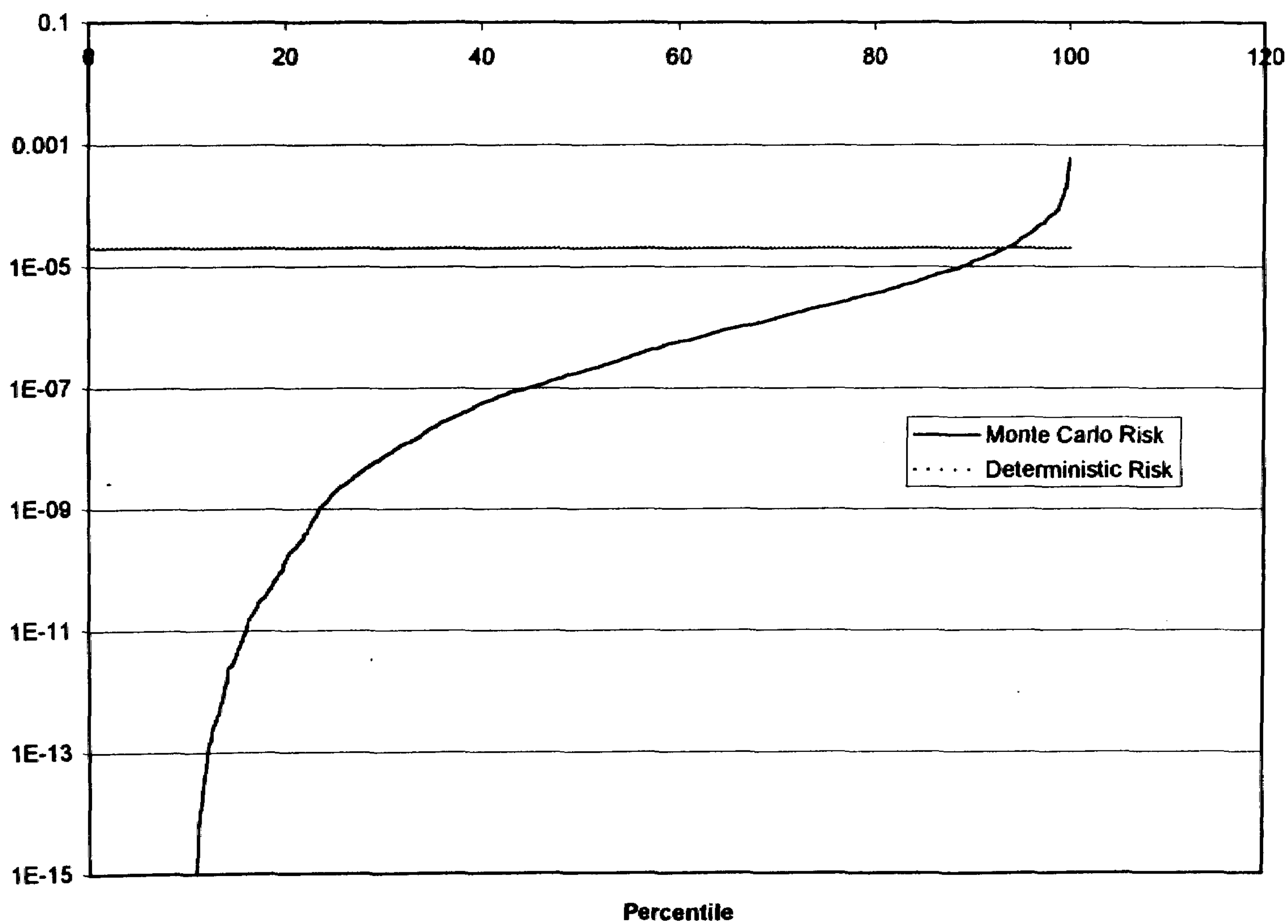
Comanaged Waste Landfill: Nickel Risk

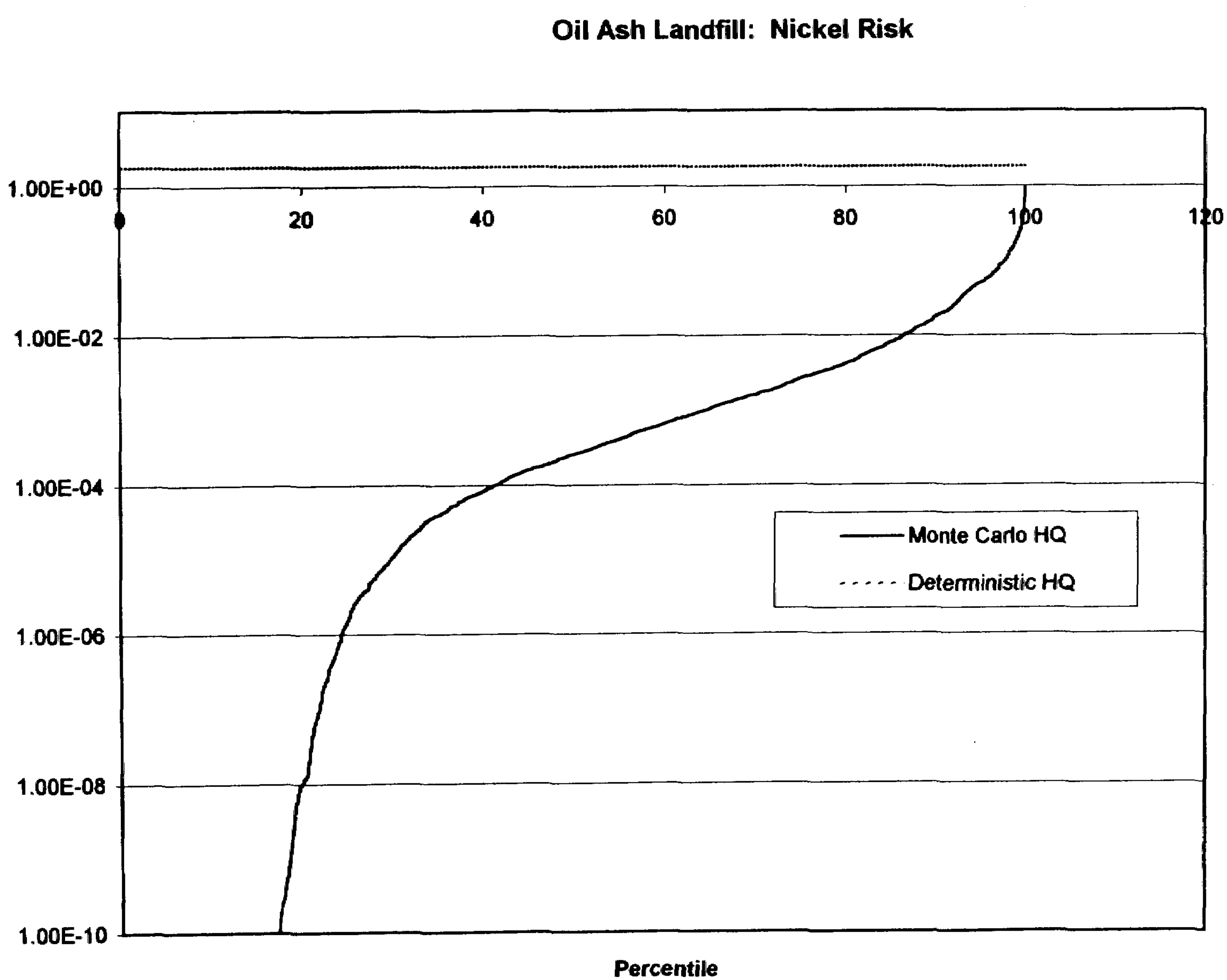




Comanaged Waste Landfill: Selenium Risk
1.00E+01
1.00E-01
1.00E-03
1.00E-05
1.00E-07
1.00E-09
1.00E-11
0
20
40
60
80
100
120
Monte Carlo HQ
Deterministic HQ
Percentile

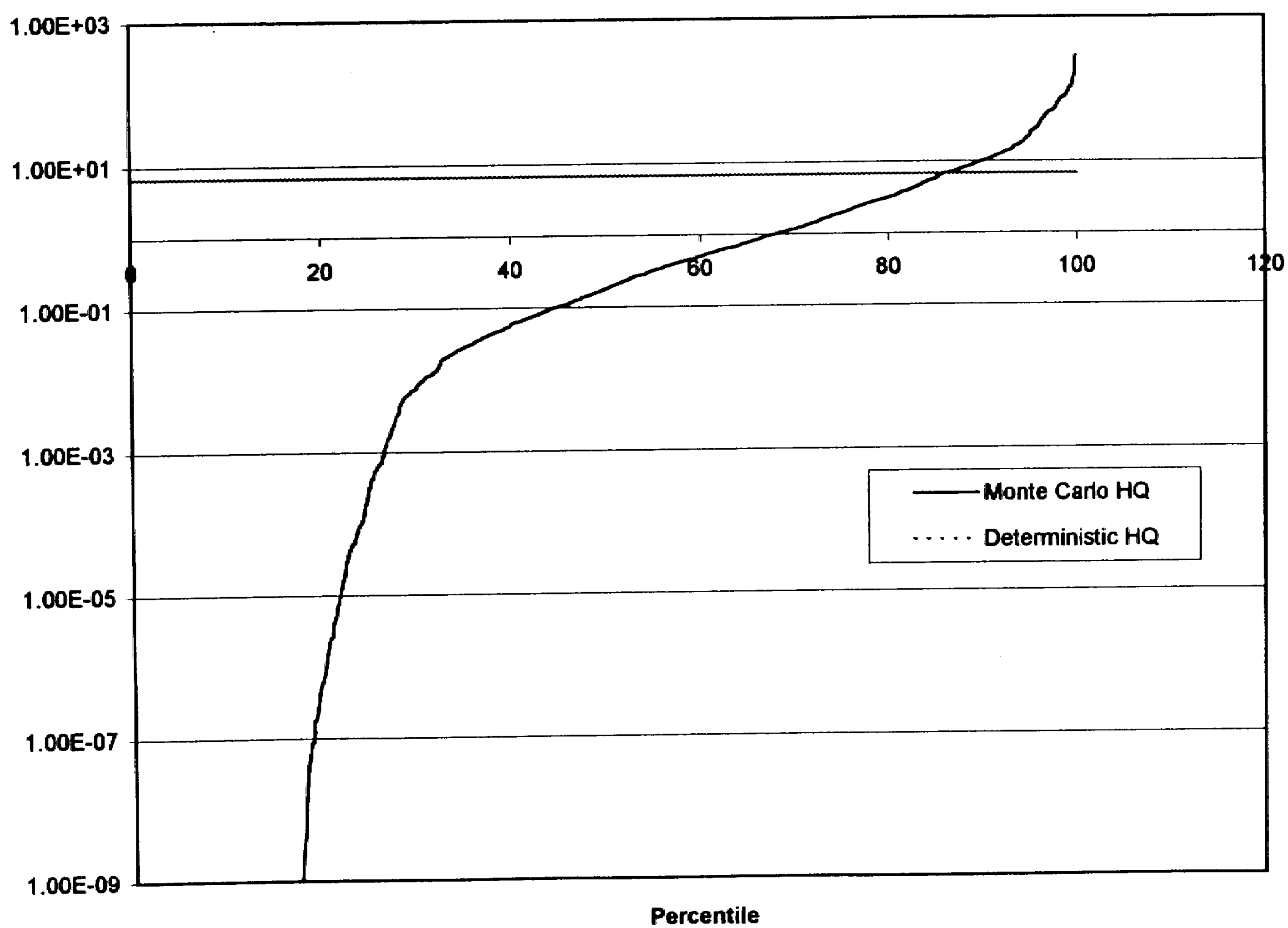
Oil Ash Landfill: Arsenic Risk



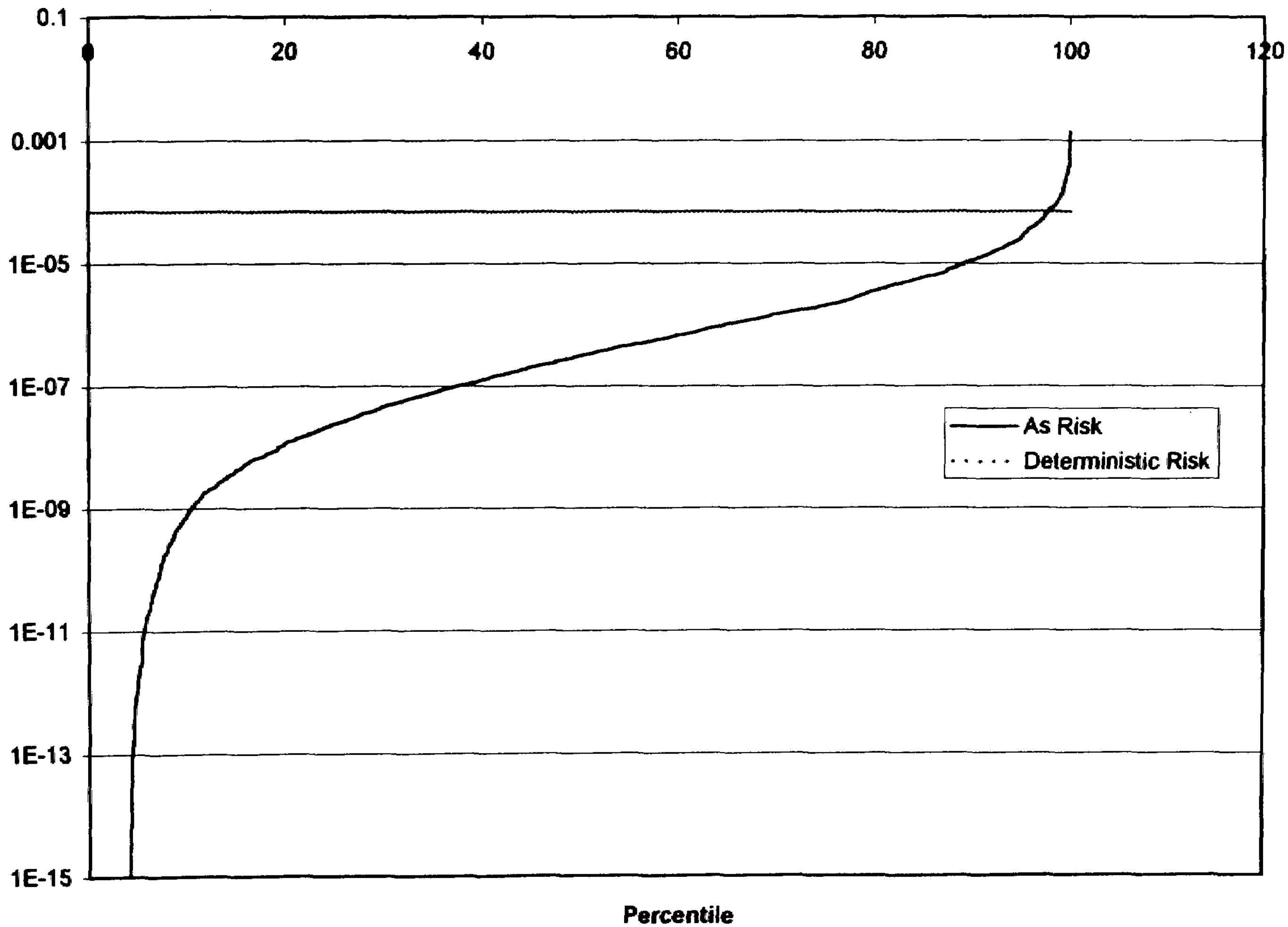


Oil Ash Landfill: Nickel Risk
1.00E+00
1.00E-02
1.00E-04
1.00E-06
1.00E-08
1.00E-10
0
20
40
60
80
100
120
Monte Carlo HQ
Deterministic HQ
Percentile

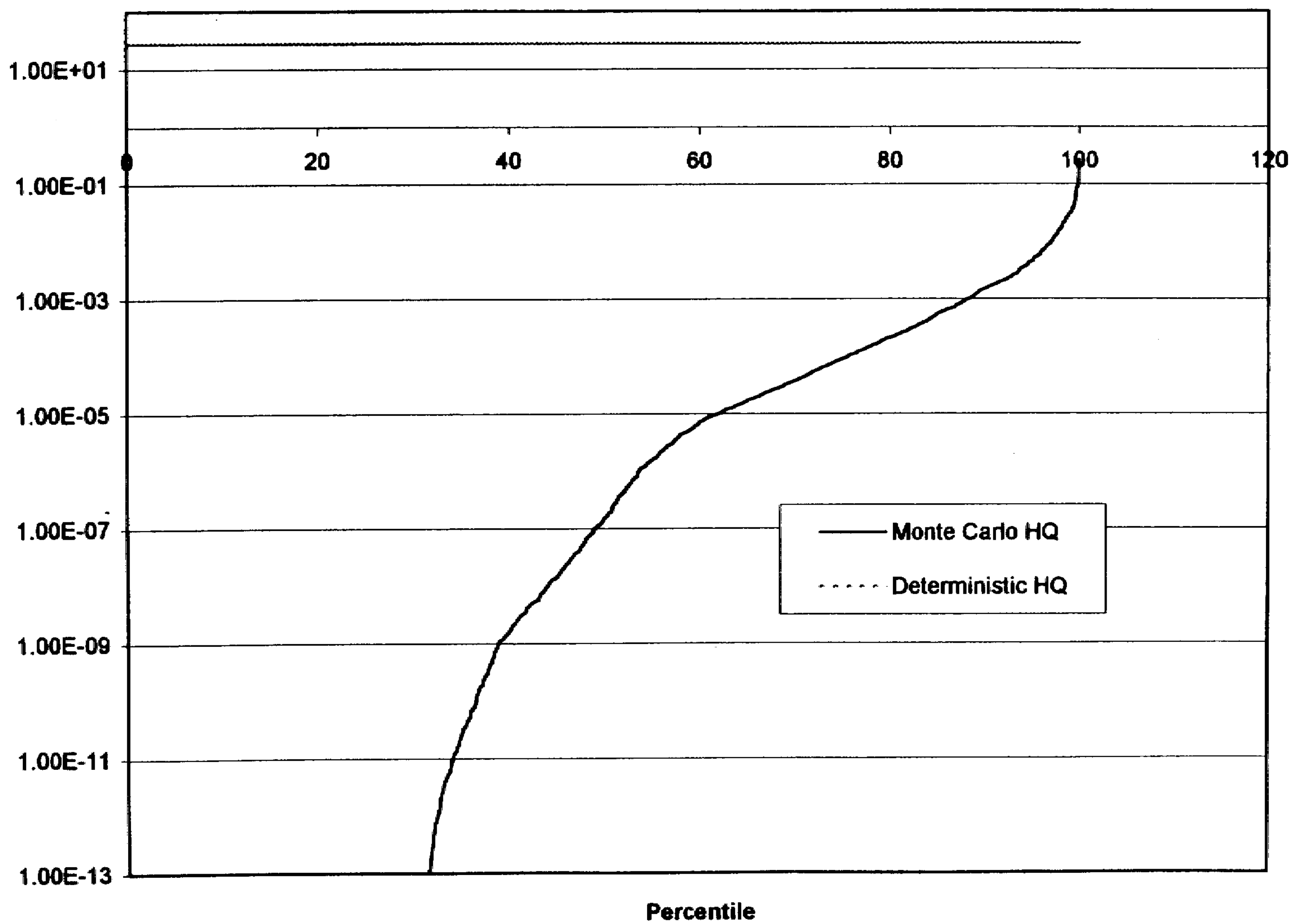
Oil Ash Landfill: Vanadium Risk



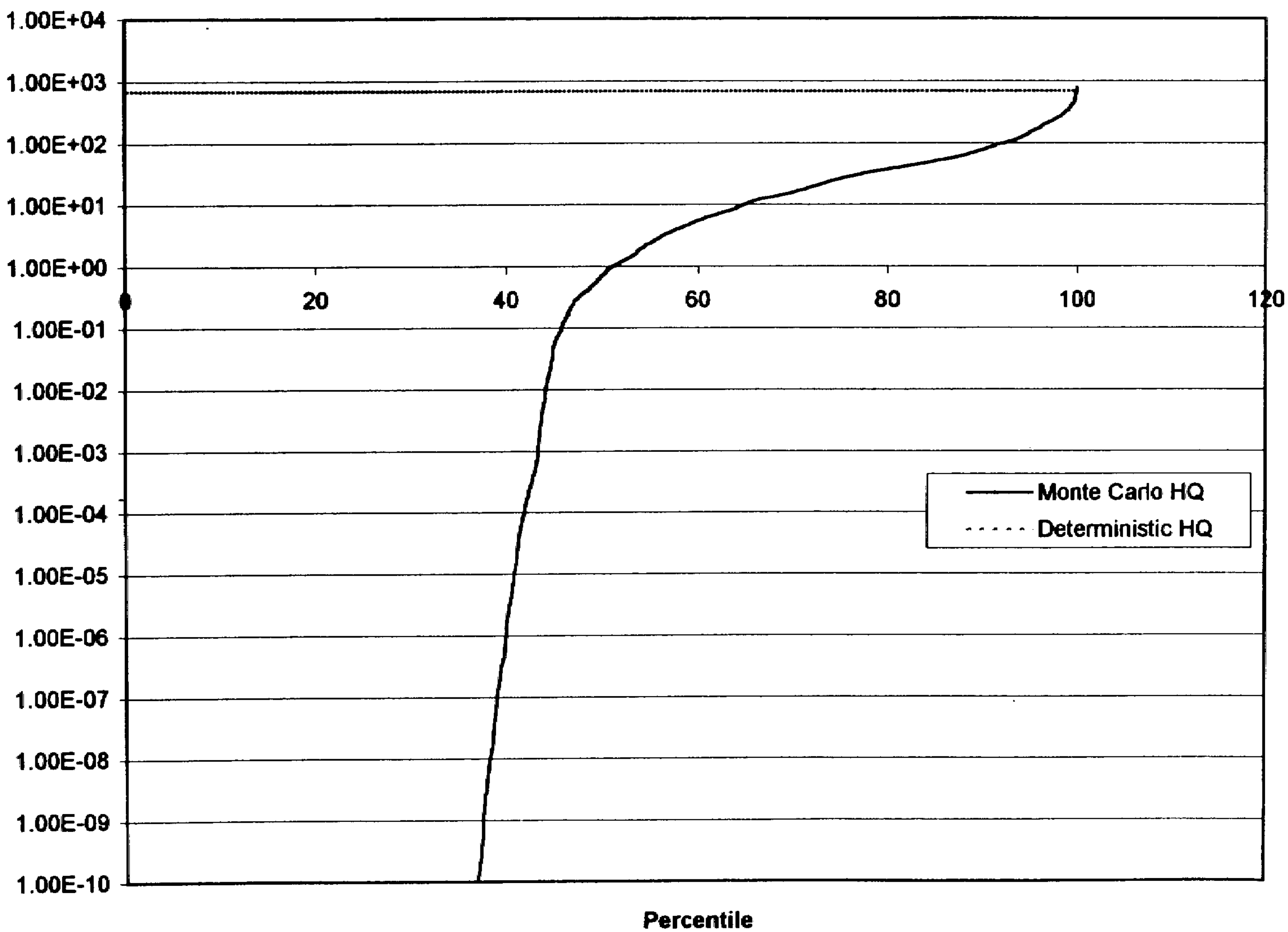
Oil Ash Surface Impoundment Scenario: Arsenic Risk

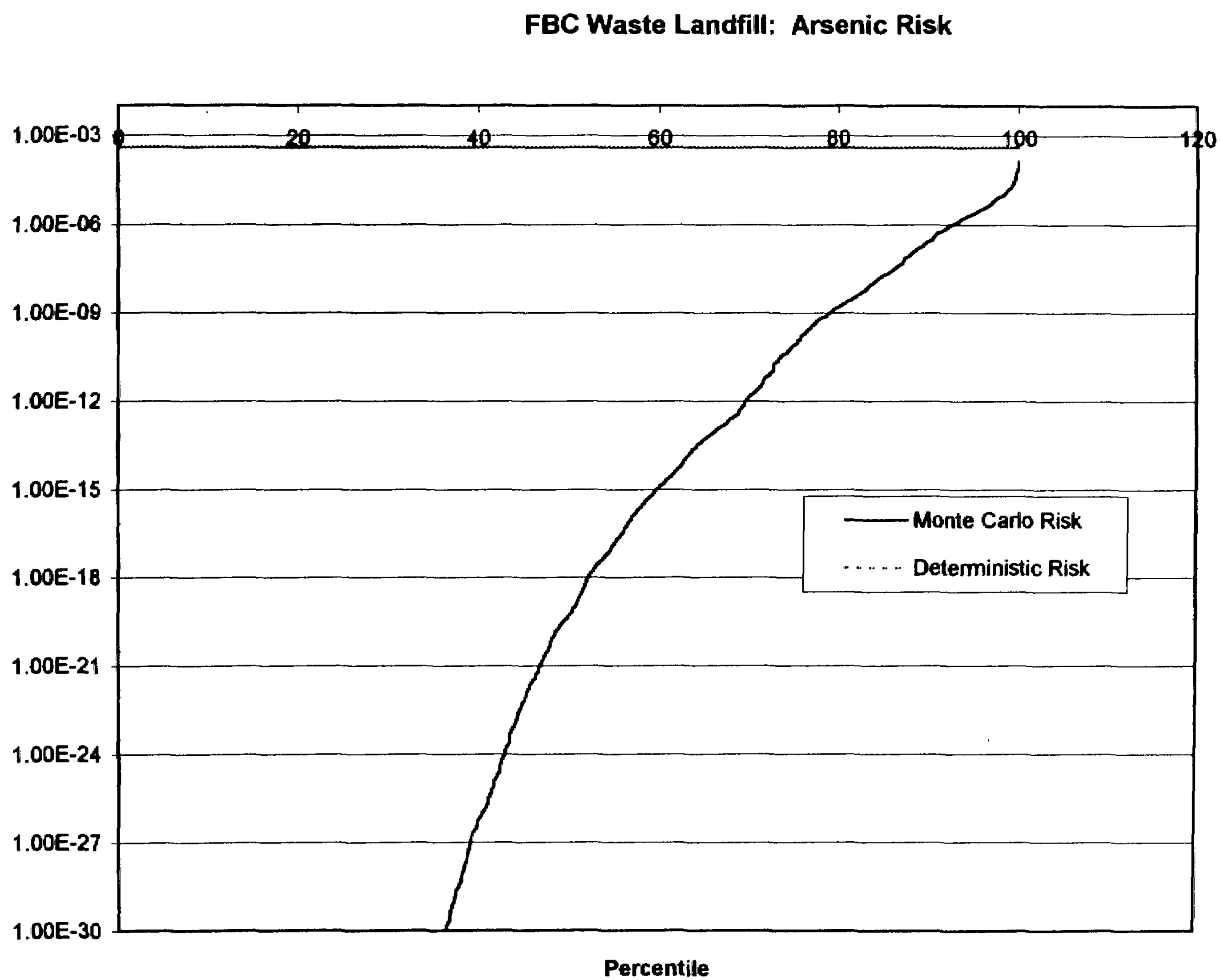


Oil Ash Surface Impoundment: Nickel Risk



Oil Ash Surface Impoundment: Vanadium Risk




FBC Waste Landfill: Arsenic Risk
1.00E-03
1.00E-06
1.00E-09
1.00E-12
1.00E-15
1.00E-18
1.00E-21
1.00E-24
1.00E-27
1.00E-30
0
20
40
60
80
100
120
Monte Carlo Risk
Deterministic Risk
Percentile

Attachment 3
Comparison of Risk Using HBLs and MCLs as Benchmarks

MEMORANDUM

An Employee-Owned Company

DATE:	October 10, 1998
TO:	Andrew Wittner
FROM:	Chris Long
REFERENCE:	Revised Comparison of Risks Using HBLs and MCLs as Benchmarks[1] EPA Contract 68-W-98-025 SAIC Project 06-5029-08-4736-100, WA 11

The April Draft Final Report "Ground-water Pathway Human Health Risk Assessment" provided estimates of risks to humans from exposure to ground water contaminated from releases of contaminants from fossil fuel combustion (FFC) waste management units. The risk estimates compared the predicted peak ground-water concentration (Cp) of each contaminant to a benchmark concentration below which human health risk would be negligible. The benchmarks, or Health-based Levels (HBLs), were derived using a variety of fixed exposure assumptions (e.g. daily water intake, mass of the exposed individual, the Reference Dose (RfD) or Cancer Slope Factor (CSF)). Specifically, the hazard quotient (HQ) for each contaminant for each management scenario was calculated using the following equation:

$$HQ = Cp/HBL.$$[2]

Peer review comments on the Draft Final Report included a suggestion that Maximum Contaminant Levels (MCLs) would also be an instructive basis for comparison with predicted ground-water concentrations. Accordingly, SAIC has prepared the attached table listing Cp/HBL and Cp/MCL for all pathways and constituents that showed a potential risk in the Draft Final Report. Note that the values shown in the table reflect the revised High-end and Monte Carlo simulation results reported to EPA on October 7, 1998.

For all of the metals based on reference doses, the MCL is 20-80 percent of the HBL. As a result, the ratio of Cp/MCL exceeds the HQ for all metals except Arsenic by 25-500 percent. For Arsenic, the MCL is substantially greater than the HBL, but, accounting for the risk factor of 1×10^{-6}, the overall adjustment is an increase in the value shown by a factor of roughly 6000. Overall, the high-end deterministic model predicts that arsenic and selenium may exceed MCLs in

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[1] This memorandum replaces the October 8, 1998 memorandum of the same title. It reflects changes to the deterministic and Monte Carlo results for FBC wastes only. All other values are unchanged from the original.

[2] In the case of Arsenic, the HQ is replaced with an estimate of the individual lifetime cancer risk, calculated as Risk= 1e-6*Cp/HBL.

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ground water down-gradient of unlined coal comanaged waste units and that antimony, arsenic, beryllium, and chromium may exceed MCLs in ground water down-gradient of unlined FBC waste units. The predicted exceedences of MCLs are generally small (<3x) except for Antimony (42x) and Beryllium (91x). The high-end oil impoundment and landfill scenarios do not predict exceedences of MCLs for Arsenic in down-gradient ground water. There are no MCLs for comparison of results for Nickel or Vanadium.

The Monte Carlo simulation results predict that none of the examined parameters will exceed their respective MCLs in down-gradient ground water even at the 95th percentile risk level for any of the management scenarios. Thus, for example, any risk predicted for Arsenic in these scenarios results from contamination levels below the MCLs.

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Comparison of Risk Using HBLs and MCLs as Benchmarks (October 10, 1998)[1]					
Scenario*	Constituent**	Deterministic HE Scenario Result		95th Percentile Monte Carlo Result	
		Cp/HBL	Cp/MCL	Cp/HBL	Cp/MCL
CS	As	$5x10^{-4}$	2.9	$1.6x10^{-5}$	0.09
CL	As	$3x10^{-4}$	1.74	$4.3x10^{-5}$	0.25
	Cr	HQ=0.2	0.52	HQ=0.1	0.26
	Ni	HQ<0.1	--	HQ=0.01	--
	Se	HQ=0.8	4.11	HQ=0.1	0.51
OS	As	$7x10^{-5}$	0.41	$2.6x10^{-5}$	0.15
	Ni	HQ=28	--	HQ=0.005	--
	V	HQ=680	--	150	--
OM	As	$2x10^{-5}$	0.12	$3x10^{-5}$	0.17
	Ni	HQ=1.8	--	HQ=0.05	--
	V	HQ=6.7	--	HQ=21	--
FL	Sb	HQ=12	42	HQ=0.007	HQ=0.02
	As	$4.3x10^{-4}$	2.49	$2x10^{-6}$	0.01
	Be	1.4	91	HQ<0.001	HQ=0.04
	Cr	1.1	2.86	HQ=0.002	HQ=0.13

CS = Comanaged Waste Impoundment; CL = Comanaged Waste Landfill; OS = Oil Ash Impoundment; OM = Oil Ash Landfill; and FL = FBC Waste Landfill.

1. Hazard Quotient (HQ) equals the peak ground-water concentration (Cp) divided by the benchmark (either HBL or MCL). For Arsenic, the Risk equals Cp*1e-6/HBL.

* Scenarios are limited to comanaged waste, oil ash, and FBC waste landfills and comanaged waste and oil ash surface impoundments. Minefills and off-site landfills won't be modeled due to data and model limitations. Non-utility wastes are assumed to be bounded by other scenarios.

** Constituents are limited to those for which estimated risks exceeded target values in the April 1998 Draft Final Report.

Attachment 4
Comparison of Actual Groundwater Data at EPRI Sites to Model Results

MEMORANDUM

An Employee-Owned Company

DATE: October 7, 1998

TO: Andrew Wittner

FROM: Chris Long and John Vierow

REFERENCE: Comparison of Arsenic in Ground Water with CMTP, HBL, and MCL Concentrations
EPA Contract 68-W-98-025
SAIC Project 06-5029-08-4736-100, WA 11

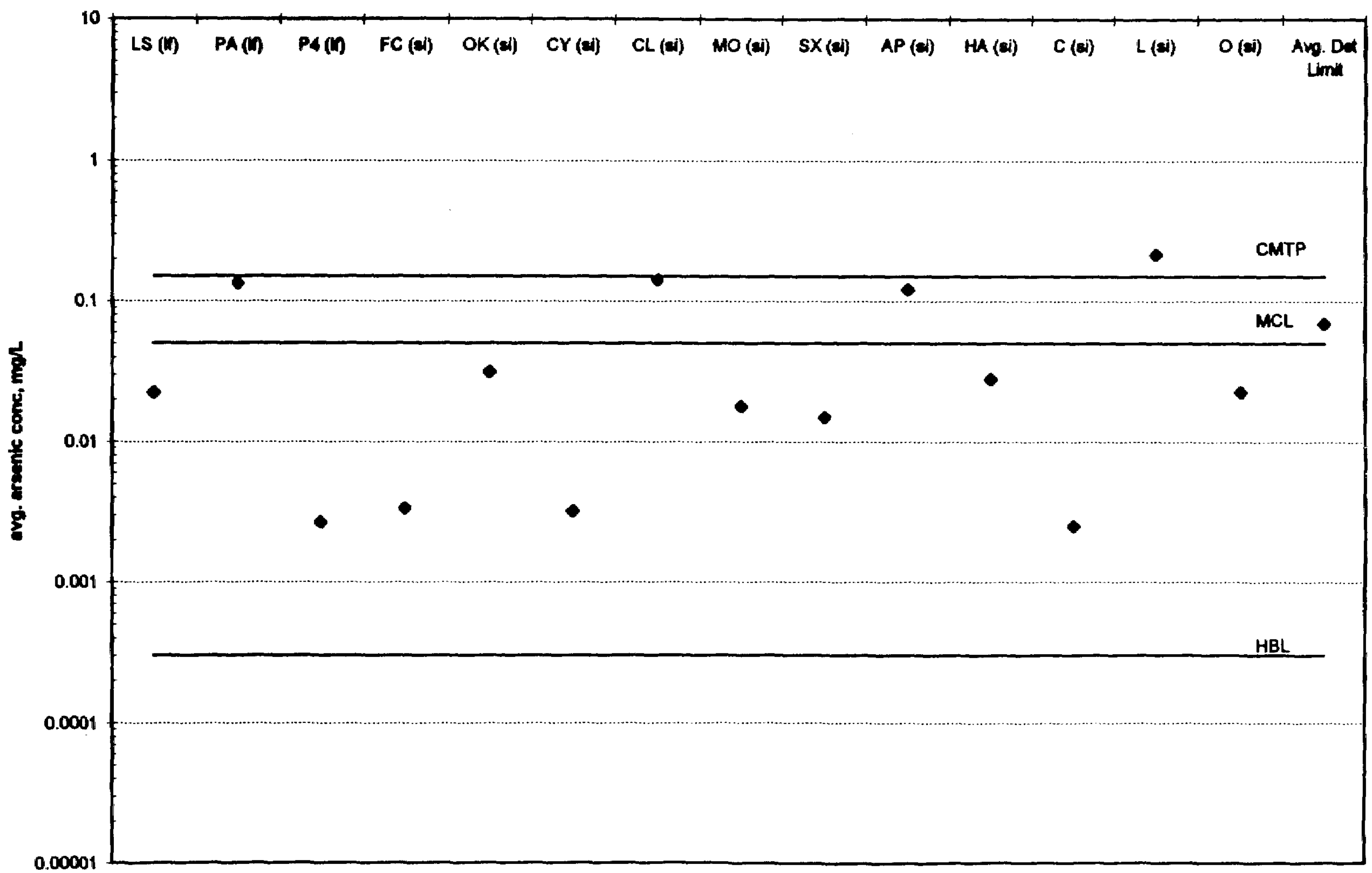
The attached figure shows the average concentration of arsenic observed in down-gradient ground water at each of the EPRI Comanagement Study sites. Each average was calculated using all down-gradient observations irrespective of distance from the waste management unit, and using a value equal to one-half the detection limit for all observations below detection. The plot also shows as a solid horizontal line the concentrations for the arsenic Health-based Level (HBL), the Maximum Contaminant Level (MCL), and the CMTP high-end surface impoundment scenario (April result).

- The plot shows that all sites exhibit an average down-gradient concentration well in excess of the HBL. Note that this is not a demonstration of impacts; the plot does not show the background concentrations for the same sites so the arsenic can not be attributed to the FFC waste management units. Also, the calculated average values shown reflect the detection limit only for many sites where arsenic was very close to or below detection limits in all samples.

- The plot shows that most sites exhibit an average down-gradient concentration below the arsenic MCL, irrespective of the influence of the site on ground-water conditions. Four sites showed a concentration greater than the MCL. Significantly, the average detection limit reported for all observations below detection at all sites is also above the MCL.

- The plot shows that As concentrations exceeded the CMTP high-end predicted concentration at only one site.

Arsenic in Ground Water at Comanaged Waste Sites



Attachment 5
Comparison of FFC Waste Characterization Data
to Cement Kiln Dust and Background Concentrations

Comparisons of Median and 95th Percentile Test Data for Various Fossil Fuel-Combustion Wastes, Cement Kiln Dust, and Background Values for Selected Constituents of Concern

Constituent and Material Type	Total Const. (ppm) Median	Total Const. (ppm) 95th %ile (a)	EP or TCLP (mg/L) Median	EP or TCLP (mg/L) 95th %ile (a)	Pore Water (mg/L) Median	Pore Water (mg/L) 95th %ile (a)
ARSENIC IN:						
1993 Wastes	18.0	204.5	EP - 0.012 TC - 0.005	0.409 0.825		
Comanaged Wastes (LF)	16.0	38.0	TC - 0.006	0.017	0.010	0.010
Comanaged Wastes (SI)	18.0	150.0	TC - 0.010	0.221	0.170	9.60
FBC Wastes (b)	23.2	77.2	TC - 0.047	0.700		
Oil Ash (c)	16.0	1650.0	0.154	4.15		
Cement Kiln Dust (OSW)	9.0	63.0	0.020	0.567		
Native Soil (USGS)	5.2	15.0				
Ground Water (USAF)					BDL	0.044
CHROMIUM IN:						
1993 Wastes	94.0	815.0	EP - 0.020 TC - 0.010	0.444 0.325		
Comanaged Wastes (LF)	38.0	78.0	TC - 0.012	0.067	0.007	0.270
Comanaged Wastes (SI)	86.0	290.0	TC - 0.0076	0.066	0.049	0.750
FBC Wastes (b)	36.2	181.0	TC - 0.045	0.250		
Oil Ash (c)	350.0	1250.0	0.300	3.44		
Cement Kiln Dust (OSW)	26.0	75.1	0.050	0.490		
Native Soil (USGS)	37.0	90.0				
Ground Water (USAF)					BDL	0.195
LEAD IN:						
1993 Wastes	32.0	327.0	EP - 0.005 TC - 0.006	0.381 0.580		
Comanaged Wastes (LF)	16.0	29.0	TC - 0.003	0.006		
Comanaged Wastes (SI)	24.0	150.0	TC - 0.003	0.010	0.014	0.470
FBC Wastes (b)	19.0	67.0	TC - 0.072	1.00		
Oil Ash (c)	320.0	1800.0	0.140	13.4		
Cement Kiln Dust (OSW)	113.0	1400.0	0.159	1.29		
Native Soil (USGS)	16.0	40.0				
Ground Water (USAF)					BDL	0.047

Comparisons of Median and 95th Percentile Test Data for Various Fossil Fuel-Combustion Wastes, Cement Kiln Dust, and Background Values for Selected Constituents of Concern

Constituent and Material Type	Total Const. (ppm) Median	Total Const. (ppm) 95th %ile (a)	EP or TCLP (mg/L) Median	EP or TCLP (mg/L) 95th %ile (a)	Pore Water (mg/L) Median	Pore Water (mg/L) 95th %ile (a)
ANTIMONY IN:						
1993 Wastes	4.4	33.5	EP - 0.030 TC - NA	0.560		
Comanaged Wastes (LF)	NA	NA	TC - 0.006	0.011		
Comanaged Wastes (SI)	6.1	47	TC - 0.002	0.012	0.043	0.075
FBC Wastes (b)	12.5	62	TC - 0.118	0.289		
Oil Ash (c)	66	66	NA	NA		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						
BARIUM IN:						
1993 Wastes	512	5426.1	EP - 0.250 TC - 0.300	5.00 1.76		
Comanaged Wastes (LF)	3200	3800	TC - 0.123	1.09		
Comanaged Wastes (SI)	510	8400	TC - 1.03	3.00	0.085	27.4
FBC Wastes (b)	184	690	TC - 0.391	10.5		
Oil Ash (c)	210	980	0.490	12.9		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						
BERYLLIUM IN:						
1993 Wastes	7.3	124	EP - 0.001 TC - NA	0.043		
Comanaged Wastes (LF)	NA	NA	TC - 0.000825	0.002		
Comanaged Wastes (SI)	BDL	16	TC - 0.001	0.007	0.004	0.006
FBC Wastes (b)	2.5	9.5	NA	NA		
Oil Ash (c)	NA	NA	NA	NA		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						

Comparisons of Median and 95th Percentile Test Data for Various Fossil Fuel-Combustion Wastes, Cement Kiln Dust, and Background Values for Selected Constituents of Concern

Constituent and Material Type	Total Const. (ppm) Median	Total Const. (ppm) 95th %ile (a)	EP or TCLP (mg/L) Median	EP or TCLP (mg/L) 95th %ile (a)	Pore Water (mg/L) Median	Pore Water (mg/L) 95th %ile (a)
CADMIUM IN:						
1993 Wastes	3.3	53.9	EP - 0.005 TC - 0.005	0.096 0.050		
Comanaged Wastes (LF)	7.3	7.3	TC - 0.000425	0.001		
Comanaged Wastes (SI)	5.4	24	TC - 0.001	0.017	0.005	0.25
FBC Wastes (b)	1.06	5.9	TC - 0.008	0.096		
Oil Ash (c)	3.6	21.7	0.085	0.620		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						
COPPER IN:						
1993 Wastes	73.3	211.6	EP - 0.050 TC - 0.050	0.190 0.260		
Comanaged Wastes (LF)	99	120	TC - 0.002	0.052		
Comanaged Wastes (SI)	86	150	TC - 0.011	0.114	0.048	0.67
FBC Wastes (b)	29	192	TC - 0.048	0.208		
Oil Ash (c)	529	16,460	0.430	3.42		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						
MERCURY IN:						
1993 Wastes	0.1	10.3	EP - 0.001 TC - 0.0001	0.010 0.003		
Comanaged Wastes (LF)	NA	NA	ND	ND		
Comanaged Wastes (SI)	NA	NA	TC - 0.00005	0.000095	0.001	0.001
FBC Wastes (b)	0.3	1.68	TC - 0.00024	0.0337		
Oil Ash (c)	0.2	0.38	0.001	0.500		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						

FAS, 8/12/98

Comparisons of Median and 95th Percentile Test Data for Various Fossil Fuel-Combustion Wastes, Cement Kiln Dust, and Background Values for Selected Constituents of Concern

Constituent and Material Type	Total Const. (ppm) Median	Total Const. (ppm) 95th %ile (a)	EP or TCLP (mg/L) Median	EP or TCLP (mg/L) 95th %ile (a)	Pore Water (mg/L) Median	Pore Water (mg/L) 95th %ile (a)
NICKEL IN:						
1993 Wastes	75.3	325	EP - 0.548 TC - NA	5.08		
Comanaged Wastes (LF)	54	65	TC - 0.028	0.040		
Comanaged Wastes (SI)	71	160	TC - 0.025	0.079	0.1	8.33
FBC Wastes (b)	18.6	985	TC - 0.072	0.46		
Oil Ash (c)	7,150	32,350	30.7	470		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						
SELENIUM IN:						
1993 Wastes	3.8	18.5	EP - 0.015 TC - 0.004	0.248 0.32		
Comanaged Wastes (LF)	9.1	32	TC - 0.187	0.556		
Comanaged Wastes (SI)	6.6	320	TC - 0.023	0.094	0.125	1.03
FBC Wastes (b)	6.15	18	TC - 0.060	0.350		
Oil Ash (c)	9.9	35	0.077	0.370		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						
SILVER IN:						
1993 Wastes	3.2	37	EP - 0.005 TC - 0.005	0.062 0.084		
Comanaged Wastes (LF)	6.8	8	ND	ND		
Comanaged Wastes (SI)	4.6	14	TC - 0.001	0.002	0.003	0.005
FBC Wastes (b)	2.45	39,000	TC - 0.017	1.91		
Oil Ash (c)	2.7	9.7	0.032	0.180		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						

Comparisons of Median and 95th Percentile Test Data for Various Fossil Fuel-Combustion Wastes, Cement Kiln Dust, and Background Values for Selected Constituents of Concern

Constituent and Material Type	Total Const. (ppm) Median	Total Const. (ppm) 95th %ile (a)	EP or TCLP (mg/L) Median	EP or TCLP (mg/L) 95th %ile (a)	Pore Water (mg/L) Median	Pore Water (mg/L) 95th %ile (a)
VANADIUM IN:						
1993 Wastes	151.5	456.6	EP - 0.050	10.4		
			TC - 0.010	0.317		
Comanaged Wastes (LF)	77	160	TC - 0.044	0.070		
Comanaged Wastes (SI)	60	350	TC - 0.020	0.108	0.1303	0.800
FBC Wastes (b)	440	5,000	NA	NA		
Oil Ash (c)	27,000	69,670	273	882		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						
ZINC IN:						
1993 Wastes	91	1,132.9	EP - 0.053	10.5		
			TC - 0.077	36.7		
Comanaged Wastes (LF)	53	160	TC - 0.087	0.192		
Comanaged Wastes (SI)	79	860	TC - 0.068	0.676	0.096	2.31
FBC Wastes (b)	26	45,321	0.075	0.38		
Oil Ash (c)	437	4,010	2.35	13.9		
Cement Kiln Dust (OSW)						
Native Soil (USGS)						
Ground Water (USAF)						

Notes:

a) In most cases, the 95th percentile equals the maximum observed concentration, since generally less than 20 samples were available for each constituent for each waste.

b) Concentrations are facility-averaged, i.e. multiple measurements from a single site were averaged and the median and 95th percentile values of the resulting population of site averages were calculated. Only concentrations from FBC combined ash samples are presented here.

c) Concentrations are facility-averaged, i.e. multiple measurements from a single site were averaged and the median and 95th percentile values of the resulting population of site averages were calculated. The median value presented here is the highest median value of the separate values calculated for settling basin solids, fly ash, and bottom ash by TCLP or EP.

ND = Data for this constituent showed less than 3 samples above detection limit.
NA = Data not available

Comparisons of Median and 95th Percentile Test Data for Various Fossil Fuel-Combustion Wastes, Cement Kiln Dust, and Background Values for Selected Constituents of Concern

Constituent and	Total Const. (ppm)		EP or TCLP (mg/L)		Pore Water (mg/L)	
Material Type	Median	95th %ile (a)	Median	95th %ile (a)	Median	95th %ile (a)

BDL = Below detection limit

Attachment 6
Sensitivity Analyses

Landfill infiltration rate

SAIC investigated the effect of two input parameters, infiltration and recharge rates, on the potential risk to a receptor. A single constituent and scenario was selected, arsenic in a comanaged landfill. Infiltration and recharge rates are specific to a geographical area. In the analyses conducted for the April report, HELP-model derived infiltration and recharge rates were assigned to each of the waste management unit locations, and median values of these two parameters were selected for the entire distribution. Identifying the sensitivity of infiltration rate is important for two reasons: (1) the actual distribution of waste management unit locations may be different, now or in the future, from those for which data were available; (2) the assumptions for soil and landfill properties used in HELP may not correspond to those seen in practice.

At this time, SAIC is not assuming that these two assumptions are true or false, but is investigating a "what if" case, to estimate the effect of potential errors on the results. The following investigative modeling was performed to assess both of the effects enumerated above:

- The infiltration rate was varied from its central tendency value of 0.0894 m/y over a range of 33 percent to 200 percent of this value. In all cases the recharge rate was set equal to the infiltration rate. The results of these runs are presented in Figure 1a.

- The infiltration rate was varied from its central tendency value of 0.0894 m/y over a range of 33 percent to 200 percent of this value. The recharge rate was left unchanged from its value used in the April report. The results of these runs are presented in Figure 1b.

Figure 1a shows that the peak receptor well concentration decreases with decreasing infiltration rate, which is expected because there is less contaminant leaving the unit. Figure 1a also shows that the steady state concentration decreases with decreasing infiltration. Steady state behavior was investigated because the peak concentration was 10,000 years in all cases (the study period), implying that receptor well concentration was still increasing after this time.

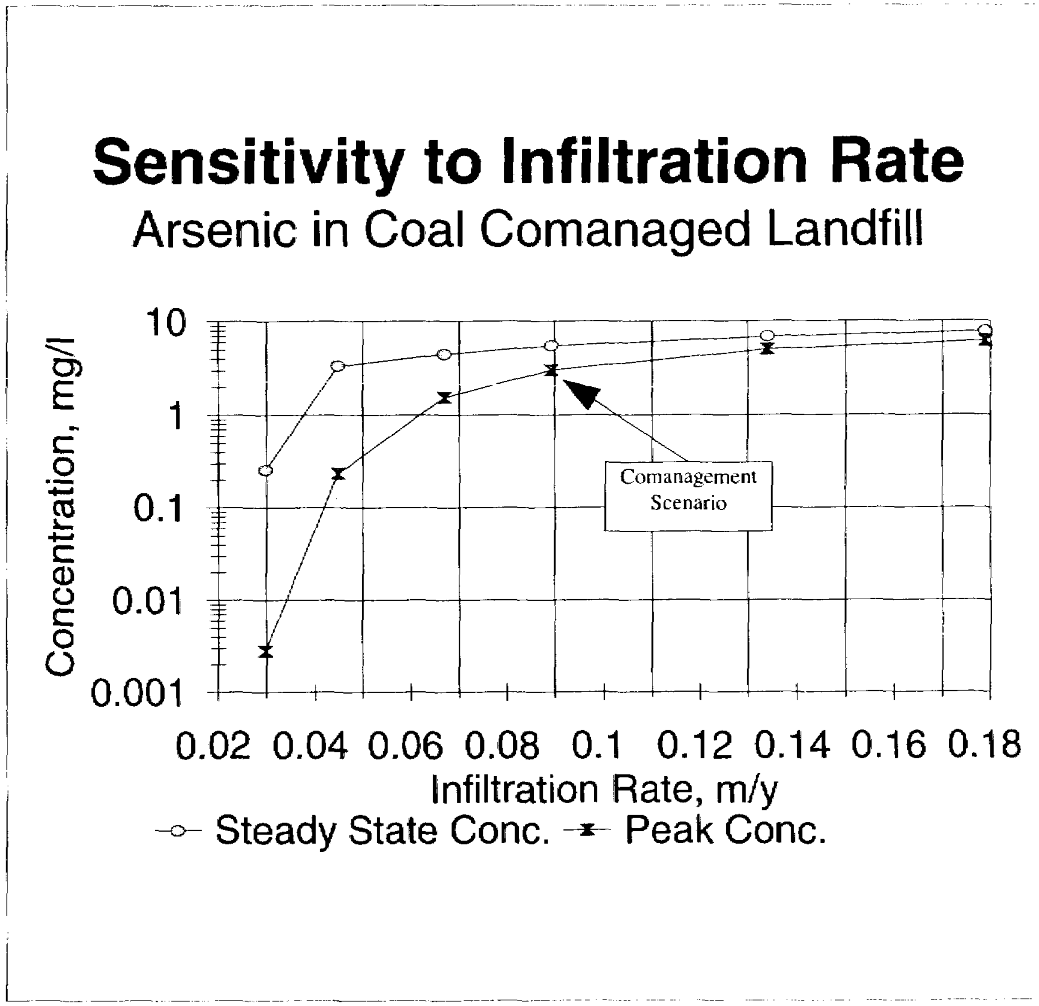
Figure 1b again shows peak receptor well concentration for varying infiltration rate; one of the lines corresponds to the data used in Figure 1a (where infiltration and recharge rate were set equal) while the other line corresponds to a case where recharge rate is held constant. The fact that the two lines are virtually on top of one another indicates that recharge rate has very little effect on receptor well concentration for this large unit.

The infiltration rate of 0.0894 m/y was used as the central tendency value in analyses prepared for the April 1998 report. Figures 1a and 1b show that increasing this value by 50 percent increases the receptor well concentration by 67 percent. Decreasing the infiltration rate to 50 percent of this value, however, decreases the receptor well concentration to only 8 percent of its original value.

In conclusion, this analysis has shown that if the infiltration rate of the unit was actually lower than that used in the analysis, the risks would also be lower, with results more sensitive for lower values of infiltration rate than higher values of infiltration rate. Additional analysis would be useful in obtaining field data on leachate generation rates (e.g., from leachate collection systems) to assess the reasonableness of the selected infiltration rate.

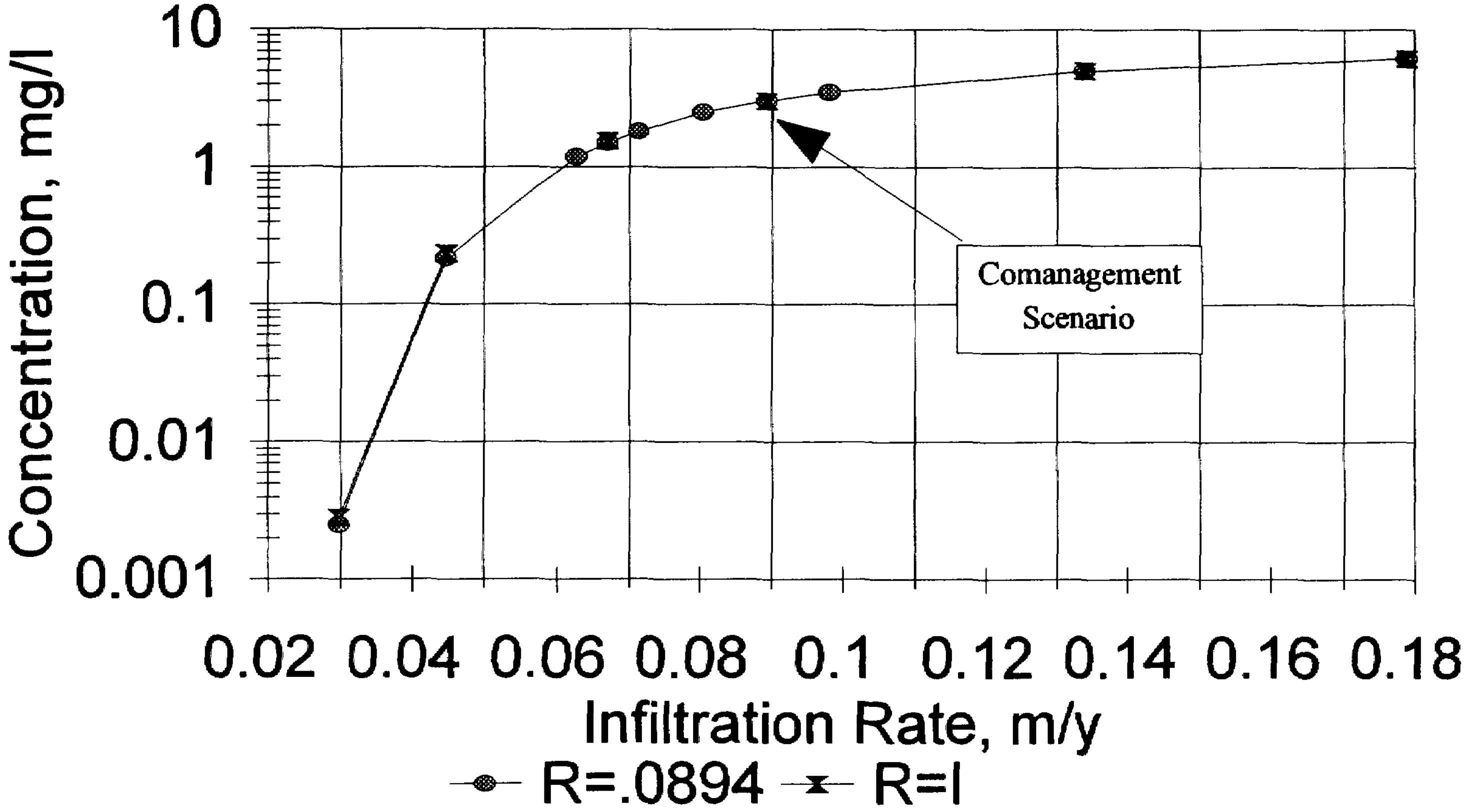
Infilitration Rate Sensitivity in Coal Comanaged Landfills

Infilration Rate	Steady State Conc.	Peak Conc.
0.179	7.76	6.17
0.134	6.87	5.03
0.0894	5.46	3.02
0.0671	4.46	1.54
0.0447	3.32	0.233
0.0298	0.255	0.0028



Sensitivity to Infiltration Rate

Arsenic in Coal Comanaged Landfill



Areas for Offsite and Onsite Units

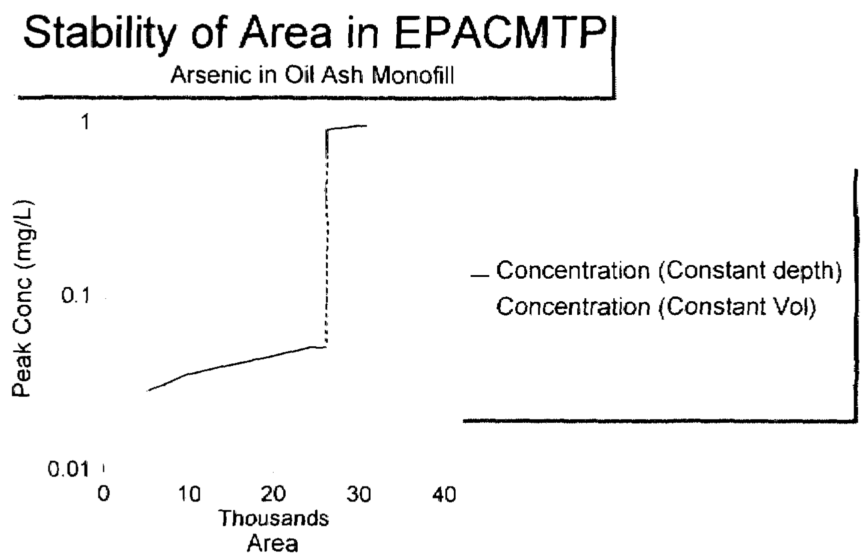
The April 1998 report presented results for oil ash managed in an onsite monofill and an offsite codisposal landfill. In each unit, the same quantity of waste was disposed in similar environments (i.e., critical parameters such as infiltration rate and aquifer thickness were unchanged). However, the results showed much higher risks from the offsite disposal than from onsite disposal, even though the total quantity of waste represented by the two scenarios was unchanged. The principal differences between the two scenarios are unit area, unit depth, and waste fraction.

The effect of one parameter, unit area, was isolated. Starting with a scenario representing the oil ash monofill used in the April 1998 report, a series of runs were conducted by increasing the area but keeping the depth and waste fraction constant. Another series of runs where the depth decreased as area increased, to simulate a constant waste quantity, was also conducted.

The results, shown in the following figure, showed that small increases in area resulted in small increased in receptor well concentration. For example, increasing the area by five times (from 4,860 m^2 to 24300 m^2) resulted in an increase of the receptor well concentration by about two times (from 0.0291 mg/L to 0.0529 mg/L). However, a further small increase in area revealed a sudden jump in the receptor well concentration from 0.0529 to 0.942, an increase of 18 times. Following this jump, the effect of increasing area again resulted in only slight increases in receptor well concentration. The results are similar for the case where depth is held constant and when volume is held constant.

From these results, it is impossible to determine if risks from oil ash disposal are better represented by the April 1998 onsite results or the offsite results.

A, m2	----- Constant depth ---- Cp	Tp	--- Constant volume ---- Cp	Tp
4860	0.0291	6930	0.0291	6930
9720	0.0368	6990	0.0348	6630
14580	0.0417	6940	0.0376	6410
19440	0.0465	6910	0.04	6278
24300	0.0529	7024	0.0435	6230
25300	0.0523	7030	0.0426	6200
26100	0.0529	7030	0.0428	6160
26200	0.942	10000	0.679	9190
26300	0.943	10000	0.68	9200
27300	0.963	10000	0.688	9190
28300	0.967	10000	0.678	9180
29160	0.98	10000	0.68	9210
34400	1.04	10000	0.679	9110



Inflection point is A=26,200 m2.
A= 5,000 m2 corresponds to an onsite landfill
A=34,000 m2 corresponds to an offsite codisposal landfill
Waste fraction = 1 in all cases. C0=4.15 mg/L

Fig 2

Uncertainty in Environmental Parameters for Comanaged and FBC Waste Disposal

In the April 1998 report, many different parameters are used to represent the comanagement and the FBC scenarios. These parameters include landfill depth and area, infiltration rate, groundwater pH, etc. These values were incorporated to allow for likely differences in these parameters, however, additional rums are presented here to acknowledge the uncertainty in all the data. Specifically, these runs show the effect of isolating differences in waste volume and characteristics, and assuming (for the moment) that environmental differences are unchanged.

To conduct these runs, three scenarios were constructed for FBC wastes, all assuming a monofill, with the same quantity of waste. In each scenario the waste characteristics (i.e., initial leachate concentration and C_W/C_L) are the same.

Scenario 1 (FCN) uses data presented in the April 1998 report. Scenario 2 (FCL) has two principal differences. First, the shape of the landfill is different (larger but shallower than the landfill represented by the April report) to simulate a shape similar to that used for comanaged wastes. Secondly, many of the environmental parameters are different; these include infiltration and recharge rate (decreased), aquifer thickness (increased), conductivity (decreased), gradient (increased), and aquifer temperature (decreased). Scenario 3 uses the 'old' landfill dimensions from the April report but the 'new' environmental parameters used in Scenario 2 to better isolate model drivers.

The results show that the risks in Scenario 2 create an overall decrease in the receptor well concentration, based on the cumulative effects of these parameters. Scenario 3 better isolates the reason for this difference. Scenario 3 produces very similar results to Scenario 2, which uses the same environmental parameters but a different sized landfill. Therefore, landfill dimensions appear to be a relatively insensitive input parameter, compared to the other values.

In conclusion, the FBC scenarios may pose less risk than presented in the April report by a factor of 2, if the environmental parameters associated with comanagement were more appropriate. Conversely, the risks from comanagement would probably increase by the same amount, if the FBC environmental parameters were a better reflection. This result is expressed as uncertainty because it is impossible to "know" which data sets are more appropriate.

Results for Three Onsite Landfill Scenarios FBC Waste Disposal				
Constituent	Onsite Scenario	Initial concentration, mg/L	Peak Concentration, mg/L	Steady State Concentration, mg/L
Antimony	1	1.29	0.328	0.802
	2	1.29	0.164	0.724
	3	1.29	0.174	0.598
Arsenic	1	0.35	0.161	0.218
	2	0.35	0.104	0.196
	3	0.35	0.101	0.162
Beryllium	1	0.28	0.136	0.174
	2	0.28	0.0869	0.157
	3	0.28	0.0828	0.130

Time to reach peak concentration is 10,000 years in all cases.

Study Period

Table 5-23 of the April 1998 report presented the time for a particular constituent to reach levels of concern at a receptor well; Table 5-22 presented the maximum risk anticipated in a study period of 10,000 years. An analysis was conducted to better demonstrate the effect of a study period shorter than 10,000 years for comanaged and oil combustion wastes.

Model results provide the maximum well concentration within a present study period, and the time at which the maximum receptor well concentration occurs. For the evaluation of arsenic in a comanaged waste landfill and a comanaged waste impoundment, the study period was changed to show the well concentrations at intervals of time much shorter than the 10,000 year period. The same exercise was conducted for oil combustion wastes.

Results are shown in the following table. The results show that the peak well concentration in an impoundment occurs in about 1500 years, while in a landfill the well concentration is still rising after 10,000 years. If a study period of 1,000 years is assumed, the receptor well concentration for an impoundment after 1,000 years would be about one third of its value after 1500 years. However, the receptor well concentration for a landfill after 1,000 years would be negligible, and certainly below its health based level. Both waste types provide this similar conclusion, although differ somewhat in the speed at which the contaminant reached the well in, say, 5,000 years.

Time Profile for Arsenic
HBL=0.00029 mg/L

Time (years)	Oil Ash Scenario, Initial Concentration 1.14 mg/L		Comanagement Scenario, Initial Concentration 9.64 mg/L	
	Well Concentration, Impoundment (mg/L)	Well Concentration, Monofill (mg/L)	Well Concentration, Impoundment (mg/L)	Well Concentration, Monofill (mg/L)
500	0.0008	negligible	0.00003	negligible
1,000	0.0120	negligible	0.054	negligible
1,200	0.0169	negligible	0.107	negligible
1,500	0.0203	negligible	0.146	negligible
1,560	0.0204 (peak)	negligible	0.147 (peak)	negligible
2,000		$2x10^{-7}$		negligible
3,000		0.00012		0.00007
4,000		0.0020		
5,000		0.0058		0.103
10,000		0.0080		3.04

Mass Balance Check

For all constituents showing a risk greater than 10^{-6} or HQ=1 in the April 1998 report for any scenario, a mass balance was conducted to determine if the total quantity of contaminant that leaches out was less than the maximum quantity that reasonably be placed in the unit. Up to now, the initial leachate concentration and the leaching duration have been determined independently. Although EPACMTP maintains a mass balance, the combination of these independently derived values could imply a solid phase concentration that is many times that observed.

For the landfill scenarios, the maximum total quantity of contaminant present was determined using the unit dimensions and the 95th percentile total constituent concentrations used in RTI's risk assessment. The total quantity of contaminant leaching out of the unit over the 10,000 year study period was calculated using equations provided in the EPACMTP User's Guide; the total quantity leaching is a function of initial leachate concentration, infiltration rate, C_W/C_L, and other parameters. If the total quantity of contaminant leaching out was found to be greater than the total quantity likely to be available, the ratio C_W/C_L was lowered until the balance was met.

For the impoundment scenarios, a similar approach was conducted. The total quantity of contaminant entering the impoundment over 40 years (calculated using unit dimensions and 95th percentile total constituent concentrations) was compared to the quantity leaching out over 40 years, determined from infiltration rate, initial concentration, and unit area.

Results of this analysis are presented on the following table. A mass balance was maintained for the impoundment scenarios. For two constituents in the landfill scenarios, a greater quantity of contaminant was found to be leaving the unit than was likely to be entering. The C_W/C_L ratio was lowered until the balance was maintained, for the high end analysis. For the central tendency analysis, below, no change was necessary because the mass balance would be plausibly maintained at the lower initial concentration.

Mass Balance Check All Constituents Exceeding HQ=1 or Risk=10^{-6} in April 1998 Report Comanaged coal combustion wastes, oil combustion wastes, and FBC wastes		
Constituent	Total Quantity Leached over Lifetime[1] as a Percentage of Maximum Total Quantity Available	Actions to Maintain Mass Balance
Comanaged Waste Impoundment		
Arsenic	33%	No change
Comanaged Waste Landfill		
Arsenic	13%	No change
Chromium	2%	No change
Nickel	3%	No change
Selenium	11%	No change
Oil Waste Impoundment		
Arsenic	0.7%	No change
Nickel	8%	No change
Vanadium	9%	No change
Oil Waste Monofill		
Arsenic	15%	No change
Nickel	70%	No change
Vanadium	200%	C_W/C_L ratio decreased from 230 to 109, to ensure no more than 100 percent of contaminant leaves unit.
FBC Waste Landfill		
Antimony	73%	No change
Arsenic	16%	No change
Beryllium	127%	C_W/C_L ratio decreased from 43 to 33, to ensure no more than 100 percent of contaminant leaves unit.
Chromium	25%	No change

1. Maximum leaching duration for landfills is the 10,000 year study period, although the combination of specific parameters may result in a leaching duration less than 10,000 years. Leaching duration for impoundments is 40 years.

Hydraulic Conductivity: Surface Impoundment Liners

With the goal of determining the relative effect of liner hydraulic conductivity on both the peak concentration and the time to reach peak, a sensitivity analysis was performed varying only hydraulic conductivity in the high-end coal comanaged waste surface impoundment, for arsenic. It was thought from previous analysis that the impact of changing hydraulic conductivity was dramatic. To test its influence, liner hydraulic conductivity was changed over a range that included the high-end value. The data from those deterministic runs was then plotted as can be seen in the following graph. The graph shows the time-to-peak in years on the top and the peak concentration in mg/L on the bottom section of the graph. While the liner hydraulic conductivity is increased over three orders of magnitude, the time to peak drops by three orders of magnitude and the peak concentration increases by three orders of magnitude. As mentioned above, this was the trend that was expected because increasing liner conductivity effectively increases infiltration rate, thus reducing peak times and increasing peak concentrations.

Liner Sensitivity Data

Liner Conductivity (m/yr)	Peak Concentration (mg/l)	Time to Peak (yr)	Infiltration Rate (m/yr)
3.16	1.19	286.2	4.98
1.58	0.641	481.9	2.55
0.316	0.148	1560	0.546
0.158	0.0795	2549	0.284
0.0316	0.016	8630	0.0635
0.0158	0.00807	15080	0.0337
0.00316	0.000921	46900	0.00787