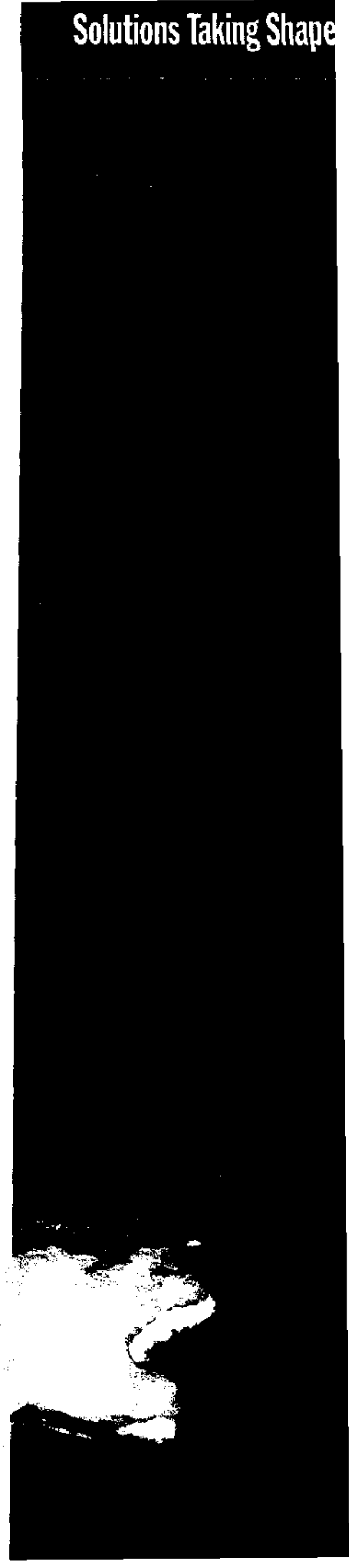

MODELING THE EFFECTS OF MONOLITH PERMEABILITY AND LEAD DIFFUSION COEFFICIENTS ON THE POTENTIAL LEAD CONCENTRATIONS AT THE KASSOUF-KIMMERLING SUPERFUND SITE IN TAMPA, FLORIDA

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Modeling the Effects of Monolith Permeability and Lead Diffusion Coefficients on the Potential Lead Concentrations at the Kassouf-Kimerling Superfund Site in Tampa, Florida

Background

Through contracts with Recycle Incorporated and OHM Remediation Services Corporation, I have been asked to evaluate the requirements for the monolith permeability and lead diffusion coefficients in the case of the proposed remedy at the Kassouf-Kimerling site. I am the principal scientist that developed a similar remedy at the Pepper's Steel and Alloys Site in Medley, Florida[1] in 1986 through 1988. Therefore, I will use the same reasoning that led to the choices of these parameters that led to that successful site closure[2]. After over four years of groundwater monitoring at the Medley site, the basis for the choices for the permeability and lead diffusion coefficients are validated by actual field data.

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[1] L. R. Dole, "In Situ Immobilization of PCBs at Pepper's Steel and Alloys Site: A Success Story," Proceedings of the PCB Forum, August 29-30, 1989, Houston, TX, PenWell Conferences, 3050 Post Oak Boulevard, Houston, TX 77056, August 1989.

[2] L. R. Dole, Section 2, "Report on Monolith Design and Performance, *Final Report on Remedial Action: Pepper's Steel and Alloys Superfund Site, Medley Florida*, Florida Power and Light Company, Juno Beach, FL 33408, June 1989.

Permeability

Permeability is the principal parameter for ensuring long-term durability. Any potentially disruptive scenario involves the permeation of the monolith fabric by some aggressive agent. Therefore, low permeability prevents the intrusion of water, chloride, sulfate, or oxygen. For example, ancient Chinese tombs constructed of impermeable soft clay have successfully resisted water and oxygen penetration for three thousand years. After three millennia, the garments are still pliable, and DNA scans can be performed on the human tissues. The 4" to 6" thickness of soft clay walls had less than 50 psi of unconfined compressive strength (UCS) and still provided complete isolation for millennia.

In an active hydraulic setting, the permeability of the monolith must be at least 100 times less than the surrounding soils. Then, a particle of water accelerated by a gradient will travel around the monolith as shown in Figure 1, instead of through it. Advection through the waste mass is prevented[3], and any potential releases of contaminants are controlled by diffusion. To reach the biosphere, a waste particle must diffuse through the fabric of the mass in order to reach the surface of the monolith. Given a geochemically stable monolith matrix and low diffusion coefficients, the monolith can sequester hazards for geological epochs.

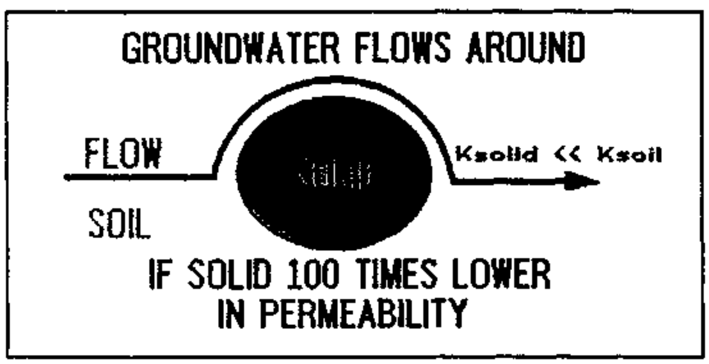

Figure 1 At the Kassouf-Kimerling site a monolith with a permeability of less than 5×10^{-6}cm/s will prevent advection.

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3 A. Atkinson, "The Influence of Waste form Permeability on the release of Radionuclides from a Repository", *Nuclear and Chemical Waste Management*, Vol. 5, pp. 203-214, 1985.

Appendix I shows the case at the Kassouf-Kimerling Superfund Site where the soils have permeabilities[4] ranging from $2.2x10^{-2}$ to $4.6x10^{-3}$ cm/s. These permeabilities control the rate at which groundwater moves across the site. The local groundwater gradient is 0.00005, and the site soils have a soil porosity of 30% by volume. These conservative gradient and porosity data are based on general regional conditions and represent 'worst-case' conditions.

Given these permeabilities, the range of movement of ground water in the soil from the gradient is between 3, 796 ft to 793 ft per millennium, when adjusted for the pore volume of the soil. If the monolith has a permeability of $5x10^{-6}$ cm/s and a porosity of 23% by volume, water could only travel a distance of 1.125 ft inside the monolith during the same time. Again, this monolith water-particle travel distance is adjusted for its pore volume.

The proposed Kassouf-Kimerling monolith will have the approximate dimensions of 700 ft long by 60 ft wide by 10.5 ft thick. Then, outside of the monolith, a groundwater particle travels 4.99 to 1.04 relative monolith half-perimeters (760 ft) in a millennium. This is compared to inside the monolith where the water particles can only travel 0.002 relative monolith lengths (700 ft) in the same period. Based on the site's soil permeability range, the ratios of outside-over-inside relative travel lengths are from 650 to 3,107 times. This ratio relates to a conservative leachate dilution factor that does not include any additional dilution by rainfall. Clearly, the advective contribution to the potential transport of contaminants from the interior of the monolith is negligible when its permeability is less than $5x10^{-6}$cm/s.

In Appendix I, the relative water particle travel model is applied to cases of theoretical monoliths with permeabilities between $5x10^{-8}$ to

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4 ***Final Remedial Investigation Report***, ERM Group South, pp. 119, June 13, 1988.

$5x10^{-5}$cm/s. The dilutions for both extremes in the site soil permeabilities are calculated. Figure 2 and Table I summarize the results of these calculations. This analysis conservatively assumed a TCLP leachate concentration for lead of 330 ppb, even though many TCLP results by OHM are less than 100 ppb for lead. Recent results from another site show lead below detection limits in laboratory expressed porewater[5]. Using ranges of these dilution factors and the conservative 330 ppb TCLP leachate case, the model in Appendix I calculates a potential lead concentrations at the down-gradient edge of the waste form.

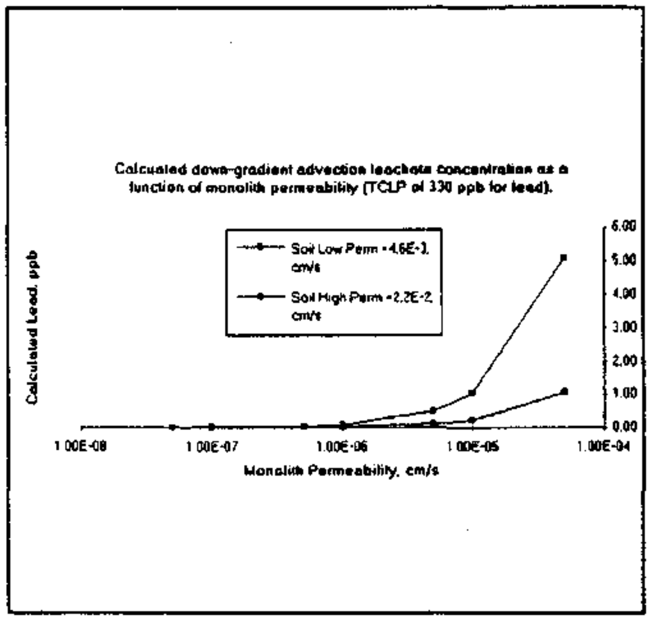

Figure 2 Below a permeability of $5x10^{-6}$cm/s the lead estimate falls to less than 1 ppb.

At the Kassouf-Kimerling Superfund Site, a permeability of $5x10^{-6}$ cm/s is adequate to protect the environment and human health. The dilution factors range from 650 to 3,107 times, resulting in concentrations of 0.5 to 0.1 ppb of lead. These estimates are very conservative. Normally, the TCLP lead concentrations are below 100 ppb for lead, and this analysis is based on 330 ppb. Even if the monolith's leachability were as high as 5 ppm, the TCLP limit for lead, the groundwater dilution would be to

[5] L. R. Dole, M.W. Grutzeck, and P.H. Licastro, ***Final Report: Performance Verification Study on the Solidification/Stabilization Waste Form for PCB-Contaminated Soils at the Rail Yard in Paoli, Pennsylvania***, Ogden Environmental and Energy Services, 1009 Commerce Park Drive, Oak Ridge, Tennessee 37830, January 28, 1993.

7.7 ppb to 1.6 ppb, which is still below the MCL for lead in the groundwater and is still protective of the environment and human health.

Also, this analysis does not consider additional dilution from the 60 inches of annual rainfall in this region. In the subsequent diffusion analysis in Appendix II, the rainfall on the monolith is over a hundred times greater than the groundwater flux. Consideration of the rainfall in this scenario would greatly reduce these calculated lead concentrations.

Table I Dilution effect of relative water transport through and around a monolith at the Kassouf-Kimerling Site (assuming a TCLP of 330 ppb).

	Low Permeability $4.6x10^{-3}$cm/s	High Permeability $2.2x10^{-2}$cm/s	Low Permeability $4.6x10^{-3}$cm/s	High Permeability $2.2x10^{-2}$cm/s
Monolith Permeability, cm/s	**Dilution Factor Ranges**		**Dilution Adjusted TCLP Concentration Ranges, ppb**	
$5x10^{-5}$	65 — 311		5 — 1	
$1x10^{-5}$	325 — 1,554		1.0 — 0.21	
$5x10^{-6}$	650 — 3,107		0.51 — 0.11	
$1x10^{-6}$	3,248 — 15,540		0.10 — 0.02	
$5x10^{-7}$	6,496 — 31,070		0.05 — 0.01	
$1x10^{-7}$	32,480 — 155,400		0.01 — 0.002	
$5x10^{-8}$	64,960 — 310,700		0.005 — 0.001	

In addition, the short-term value at 28 days for the permeability is higher than actually expected because the curing reactions are not complete. After 60 to 120 days, the initial permeability is expected to drop by a factor of 10 fold. Also, the high carbonate ground water at this site is expected to carbonize the surface of the monolith. The groundwater reaction is shown below.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

Limestone ($CaCO_3$,Calcite) accumulates in the surface pores of the monolith sealing its surface. This carbonization[6] further reduces the permeability of the monolith with time. This effect can also heal small cracks in the surface of the monolith. As a result, the in situ permeability of the monolith will be much lower than that measured in the laboratory after 28 days.

Given these results, releases from the Kassouf-Kimerling monolith will be diffusion controlled under the expected monolith and site conditions. Then, Appendix II shows the calculation of the diffusion controlled releases from the proposed monolith at the Kassouf-Kimerling Superfund Site.

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[6] W. Czernin, *Cement Chemistry and Physics for Civil Engineers*, Chemical Publishing Company, New York, NY, pp. 72, 1962.

Diffusion Coefficient

As seen above, there is no significant release of lead by advection when the permeability of the monolith is below 5×10^{-6} cm/s. Therefore, diffusion from within the monolith mass to its surface is the most significant mechanism by which contaminants can escape the waste form. Appendix II models this case for the condition expected at the Kassouf-Kimerling Superfund Site. This analysis can be used to determine an adequate leach index or diffusion coefficient required to protect the environment and human health at this site.

The analysis in Appendix II uses the same model as the Pepper's Steel and Alloys site case[7]. The conservative source-term diffusion model predicts the highest theoretical release rates from the monolith[8]. However, the additives that control constituent movement within the monolith become stronger over time. Because particles must attempt to make their way to the surface of the monolith through increasing internal barriers, the potential rates of release must decrease with time.

As with permeability, aging of the monolith greatly reduces the "effective diffusion coefficients." Also, the sealing of the monolith surface pores though carbonization further reduces the diffusion coefficients. This

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[7] L. R. Dole, "In Situ Immobilization of PCBs at the Pepper's Steel and Alloys Site: A Success Story," QUALTEC, Inc./Ogden Environmental and Energy Services, Suite 100, 1009 Commerce Park drive, Oak Ridge, Tennessee, February 1991.

[8] American Nuclear Society, ANSI/ANS–16.1–1986, *Measurement of the Leachability of Solidified Low-Level Radioactive Wastes by a "Short-Term Leach Test Procedure,"* H.W. Godbee, ANS 16.1 Working Group Chairman, American Nuclear Society, LaGrange Park, Illinois 60535, 1986.

model is conservative because it overestimates the calculated releases by factors ranging from 20 to 125 times[9].

Based on the ANS 16.1 source-term model, this general equation describes the decrease in release-rate with time[10].

$$\frac{dF(t)}{dt} = \frac{S}{V}\sqrt{\frac{De}{\pi t}}$$

F(t)	=	***Fractional Release with time, t***
S	=	***Surface Area, cm^2***
V	=	***Volume, cm^3***
De	=	***Effective Diffusion Coefficient, cm^2s^{-1}***
π	=	***3.14159265...***

In Appendix II, this conservative model is applied to the proposed monolith and site conditions at the Kassouf-Kimerling Superfund Site. The estimated mass of lead-contaminated soils is 15,000 tons. With an average density of 88.9 pounds per cubic foot (1.2 tons per cubic yard), the estimated volume of contaminated soils is 13,000 cubic yards. With a 30% volume bulking during treatment, the final monolith will be approximately 16,260 cubic yards (density of 120 pounds per cubic foot). The binder addition is

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9 Ibid, Dole, *PSA Success Story*, Section 4.0, pp. 45–56.

10 L. R. Dole, Section 2, "Report on Monolith Design and Performance, *Final Report on Remedial Action: Pepper's Steel and Alloys Superfund Site, Medley Florida*, Florida Power and Light Company, Juno Beach, FL 33408, June 1989.

estimated to be 0.8 tons of admix to 1 ton of wet soil. Therefore, the mass dilution factor will be 1.8 times.

The clean-up at this site is to TCLP leaching level in the untreated soil of less than 5 ppm. Based on this and site data, the average total lead concentration in the untreated soil is conservatively estimated to be 2,500 ppm. While some total concentrations of lead at this site may exceed this level, most of the soil to be treated will be at a much lower level.

After admix mass dilution (factor 1.8) and a 30 volume percent increase, the monolith will average about 1,400 ppm of total lead. The length and width of the monolith is to be 700 ft and 60 ft, respectively. Therefore, the average thickness of the monolith will be approximately 10.5 ft. The permeability of the monolith will be less than $5x10^{-6}$ cm/s, and no significant advection can occur through the waste form.

The site soils are taken to have a 'worst-case' permeability of $4.6x10^{-3}$ cm/s, and there is only a 0.00005 groundwater gradient across the site. Taking the lowest site permeability and this very low gradient, the model calculates the lowest dilution by groundwater. Also, the 'worst-case' monolith is placed lengthwise with its smallest cross-section to the gradient, further minimizing groundwater dilution. The 60 inches of average annual rainfall is assumed to be continuous. In this model, the entire surface of the monolith is constantly awash in rain and/or groundwater.

In Appendix II, the average concentrations over the first millennia are calculated for a point within 5 feet of the monolith on its down gradient end. There is (1) no occlusion of the surface by contact with adjacent soil or rock, (2) no carbonization of the surface by CO_2 from the air or $CaHCO_3$ from the groundwater, and (3) no further densification of the matrix and reduction in the diffusion coefficient with age. This is a conservative model.

This model was applied to cases where the monolith's effective diffusion coefficients for lead were varied from $1x10^{-10}cm^2/s$ (LI=10) to $5x10^{-14}cm^2/s$ (LI=13.3). LI, the leach index, is defined by the ANS 16.1 short term leach procedure and is the negative Log_{10} of the effective diffusion coefficient[11].

In Appendix II, the fractional releases in pounds of lead were calculated for the first 1,000 years and divided by the sum of groundwater and rain that would have fallen on the monolith plus a five-foot zone-of-influence (or berm) around the monolith. Then, the monolith collects rain from over 49,700 square feet. In the first 1,000 years, $1.55x10^{10}$ pounds of precipitation washes over the monolith. The concentrations in Figure 3 and Table II are a result of the calculated fractional release of lead by diffusion divided by this mass of precipitation, which is over 100 times greater than the percolating groundwater mass.

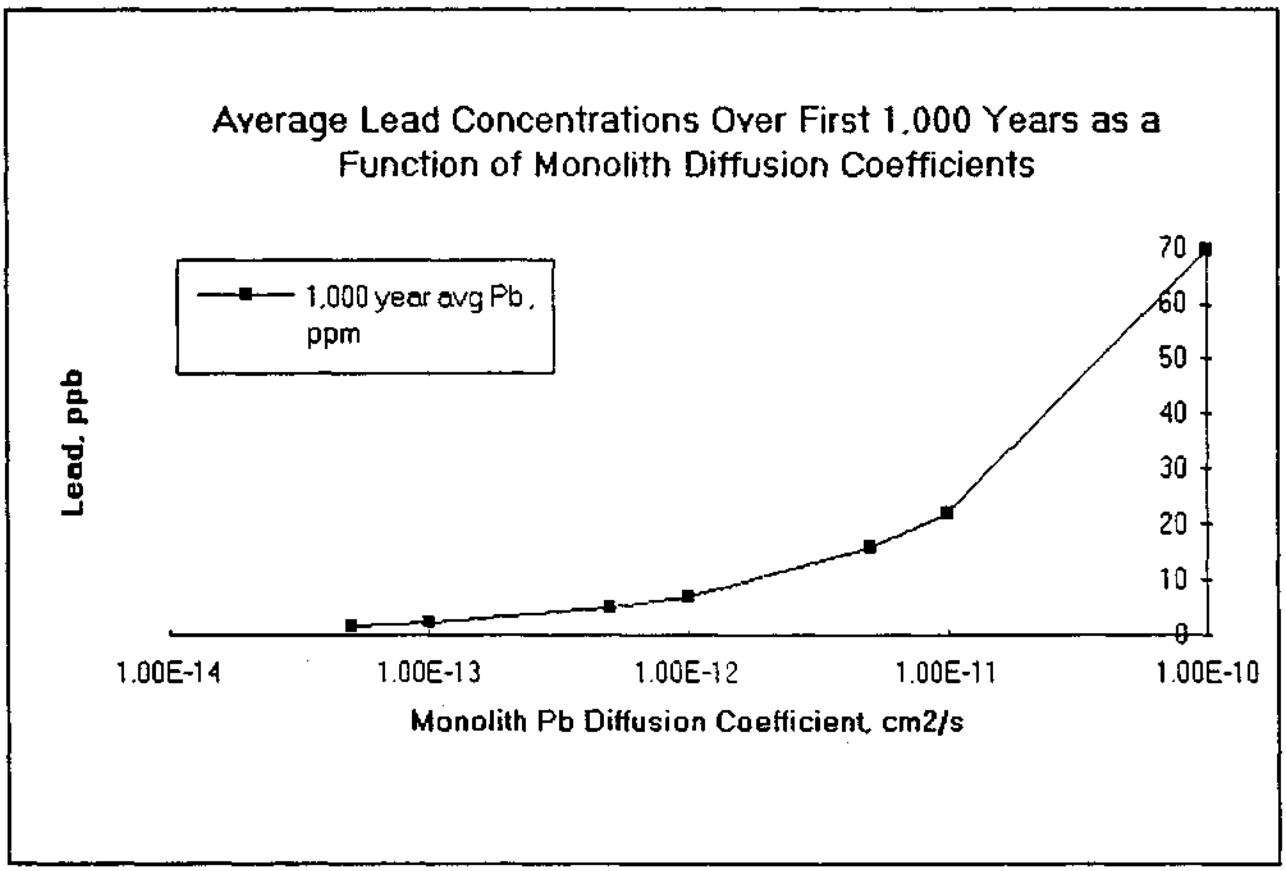


Figure 3 A lead diffusion coefficient of $1x10^{-12}cm^2/s$ (LI≥12) will protect the environment and human health at this site.

[11] Ibid, **ANSI/ANS-16.1-1986**, Section 3.3, 1986.

Table II	The calculated fraction lead releases and average concentrations over 1,000 years (assuming an average concentration of 2,500 ppm in the soil).	
Monolith diffusion coefficient, cm^2/s	**Fraction released after 1,000 years**	**Average concentration of lead, ppb**
$1x10^{-10}$	0.01499	70
$1x10^{-11}$	0.00474	22
$5x10^{-12}$	0.00335	16
$1x10^{-12}$	0.0015	7.0
$5x10^{-13}$	0.00106	5.0
$1x10^{-13}$	0.00047	2.2
$5x10^{-14}$	0.00034	1.6

These results show that the calculated lead concentration do not drop below current drinking water standards of 15 ppb for lead until the effective diffusion coefficient is less than $5x10^{-12}cm^2/s$ (LI≥11.3). With an effective diffusion coefficient of $1x10^{-12}cm^2/s$ (LI=12), the lead concentration drops to about 7 ppb, which is half the MCL for groundwater. Therefore, a LI of 12 or greater is sufficient to protect the environment and human health on this site.

Conclusions

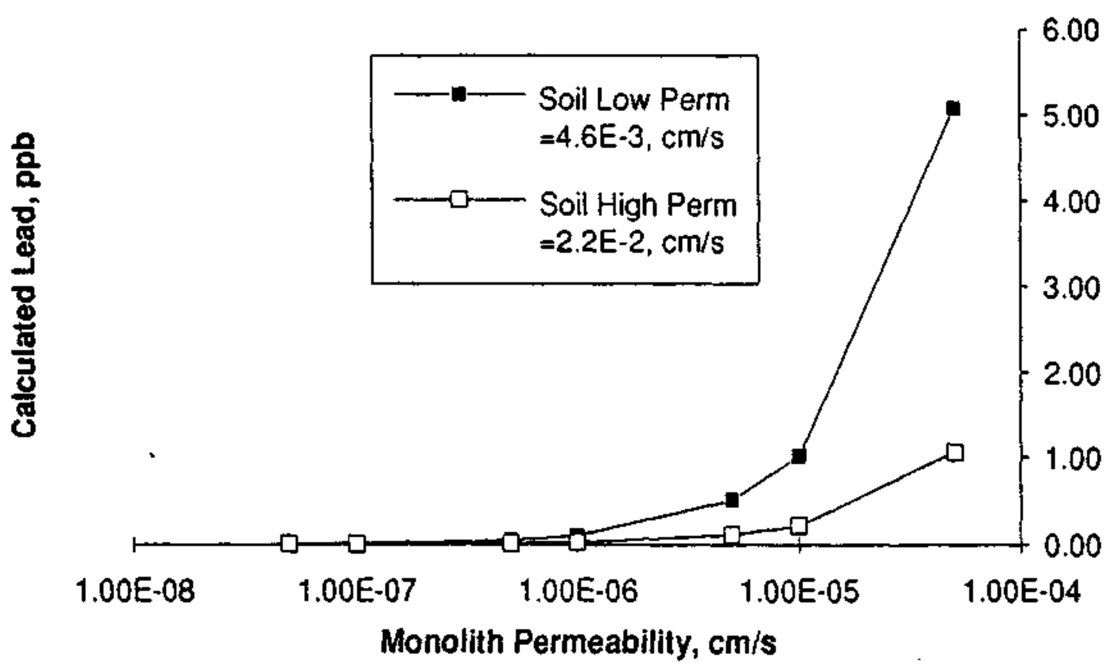
Given the Kassouf-Kimerling Superfund Site conditions, a solidification/stabilization remedy that results in a monolith with a permeability below $5x10^{-6}$ cm/s and a lead diffusion coefficient equal or below $1x10^{-12} cm^2/s$ (LI≥12) will protect the environment and human health in Tampa, Florida. These *in situ* performance criteria can be reached by current formulations.

Appendix I

Effect of Monolith Permeability on Water Advection at the Kassouf-Kimerling Superfund Site

Dilution effect of relative transport through and around an underground monolith in the water table at the 58th Street land fill (assuming a TCLP of 330 ppb).						
	Low Permeable Soil, 4.6E-3 cm/s		High Permeable Soil, 2.2E-2 cm/s	Low Permeable Soil, 4.6E-3 cm/s		High Permeable Soil, 2.2E-2 cm/s
Monolith Permeability, cm/s	Dilution Factor Ranges			Dilution Adjusted TCLP Concentration Ranges, ppb		
5.00E-05	65	-	311	5.08	-	1.061
1.00E-05	325	-	1,554	1.015	-	0.212
5.00E-06	650	-	3,107	0.508	-	0.106
1.00E-06	3,248	-	15,540	0.102	-	0.021
5.00E-07	6,496	-	31,070	0.051	-	0.011
1.00E-07	32,480	-	155,400	0.010	-	0.002
5.00E-08	64,960	-	310,700	0.0051	-	0.0011

Calcuated down-gradient advection leachate concentration as a function of monolith permeability (TCLP of 330 ppb for lead).



Site Soil Permeability = $2.2x10^{-2}$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$$Dmono := 5 \cdot 10^{-5} \cdot \frac{cm}{s}$$

$$Pore\_Mono := 0.23$$

$$L := 700 \cdot ft \qquad W := 60 \cdot ft$$

Darcy permeability of the site soil:

$$Dsoil := 2.2 \cdot 10^{-2} \cdot \frac{cm}{s}$$

$$Pore\_Soil := 0.3$$

$$Gradient := 0.00005$$

$$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760 \cdot ft$$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 11.254 \cdot ft$$

$$Dist\_Soil := \frac{Dsoil \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 3.796 \cdot 10^{3} \cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 0.003$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 0.016$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 4.995$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

Relative distance traved by a water particle around the monolith rather than through it.

$$Ratio\_External\_over\_Iternal\_Length = 310.702$$

Darcy permeability of Monolith:

$$Dmono := 1\cdot 10^{-5}\cdot\frac{cm}{s}$$

$$Pore\_Mono := 0.23$$

$$L := 700\cdot ft \qquad W := 60\cdot ft$$

Darcy permeability of the site soil:

$$Dsoil := 2.2\cdot 10^{-2}\cdot\frac{cm}{s}$$

$$Pore\_Soil := 0.3$$

$$Gradient := 0.00005$$

$$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760\cdot ft$$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono\cdot Gradient\cdot 1000\cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 2.251\cdot ft$$

$$Dist\_Soil := \frac{Dsoil\cdot Gradient\cdot 1000\cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 3.796\cdot 10^{3}\cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 5.929\cdot 10^{-4}$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 0.003$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 4.995$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

Relative distance traved by a water particle around the monolith rather than through it.

$$Ratio\_External\_over\_Iternal\_Length = 1.554\cdot 10^{3}$$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$Dmono := 5 \cdot 10^{-6} \cdot \frac{cm}{s}$

$Pore\_Mono := 0.23$

$L := 700 \cdot ft \qquad W := 60 \cdot ft$

Darcy permeability of the site soil:

$Dsoil := 2.2 \cdot 10^{-2} \cdot \frac{cm}{s}$

$Pore\_Soil := 0.3$

$Gradient := 0.00005$

$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760 \cdot ft$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 1.125 \cdot ft$$

$$Dist\_Soil := \frac{Dsoil \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 3.796 \cdot 10^{3} \cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 2.964 \cdot 10^{-4}$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 0.002$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 4.995$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

Relative distance traved by a water particle around the monolith rather than through it.

$Ratio\_External\_over\_Iternal\_Length = 3.107 \cdot 10^{3}$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$$Dmono := 1 \cdot 10^{-6} \cdot \frac{cm}{s}$$

$$Pore\_Mono := 0.23$$

$$L := 700 \cdot ft \qquad W := 60 \cdot ft$$

Darcy permeability of the site soil:

$$Dsoil := 2.2 \cdot 10^{-2} \cdot \frac{cm}{s}$$

$$Pore\_Soil := 0.3$$

$$Gradient := 0.00005$$

$$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760 \cdot ft$$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 0.225 \cdot ft$$

$$Dist\_Soil := \frac{Dsoil \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 3.796 \cdot 10^{3} \cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 5.929 \cdot 10^{-5}$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 3.215 \cdot 10^{-4}$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 4.995$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

Relative distance traved by a water particle around the monolith rather than through it.

$$Ratio\_External\_over\_Iternal\_Length = 1.554 \cdot 10^{4}$$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$$\mathrm{Dmono} := 5\cdot 10^{-7}\cdot\frac{\mathrm{cm}}{\mathrm{s}}$$

$$\mathrm{Pore\_Mono} := 0.23$$

$$L := 700\cdot\mathrm{ft} \qquad W := 60\cdot\mathrm{ft}$$

Darcy permeability of the site soil:

$$\mathrm{Dsoil} := 2.2\cdot 10^{-2}\cdot\frac{\mathrm{cm}}{\mathrm{s}}$$

$$\mathrm{Pore\_Soil} := 0.3$$

$$\mathrm{Gradient} := 0.00005$$

$$\mathrm{Half\_Mono\_Perimeter} := L + W \qquad \mathrm{Half\_Mono\_Perimeter} = 760\cdot\mathrm{ft}$$

Water particle travel in 1,000 years:

$$\mathrm{Dist\_Mono} := \frac{\mathrm{Dmono}\cdot\mathrm{Gradient}\cdot 1000\cdot\mathrm{yr}}{\mathrm{Pore\_Mono}} \qquad \mathrm{Dist\_Mono} = 0.113\cdot\mathrm{ft}$$

$$\mathrm{Dist\_Soil} := \frac{\mathrm{Dsoil}\cdot\mathrm{Gradient}\cdot 1000\cdot\mathrm{yr}}{\mathrm{Pore\_Soil}} \qquad \mathrm{Dist\_Soil} = 3.796\cdot 10^{3}\cdot\mathrm{ft}$$

$$\mathrm{Relative\_Distance} := \frac{\mathrm{Dist\_Mono}}{\mathrm{Dist\_Soil}} \qquad \mathrm{Relative\_Distance} = 2.964\cdot 10^{-5}$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$\mathrm{Monolith\_Lengths\_internal} := \frac{\mathrm{Dist\_Mono}}{L} \qquad \mathrm{Monolith\_Lengths\_internal} = 1.608\cdot 10^{-4}$$

Monolith lengths travel in 1,000 years for an external water particle:

$$\mathrm{Monolith\_Lengths\_external} := \frac{\mathrm{Dist\_Soil}}{\mathrm{Half\_Mono\_Perimeter}} \qquad \mathrm{Monolith\_Lengths\_external} = 4.995$$

$$\mathrm{Ratio\_External\_over\_Iternal\_Length} := \frac{\mathrm{Monolith\_Lengths\_external}}{\mathrm{Monolith\_Lengths\_internal}}$$

Relative distance traved by a water particle around the monolith rather than through it.

$$\mathrm{Ratio\_External\_over\_Iternal\_Length} = 3.107\cdot 10^{4}$$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$$Dmono := 1 \cdot 10^{-7} \cdot \frac{cm}{s}$$

$$Pore\_Mono := 0.23$$

$$L := 700 \cdot ft \qquad W := 60 \cdot ft$$

Darcy permeability of the site soil:

$$Dsoil := 2.2 \cdot 10^{-2} \cdot \frac{cm}{s}$$

$$Pore\_Soil := 0.3$$

$$Gradient := 0.00005$$

$$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760 \cdot ft$$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 0.023 \cdot ft$$

$$Dist\_Soil := \frac{Dsoil \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 3.796 \cdot 10^{3} \cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 5.929 \cdot 10^{-6}$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 3.215 \cdot 10^{-5}$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 4.995$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

Relative distance traved by a water particle around the monolith rather than through it.

$$Ratio\_External\_over\_Iternal\_Length = 1.554 \cdot 10^{5}$$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$$Dmono := 5 \cdot 10^{-8} \cdot \frac{cm}{s}$$

$$Pore\_Mono := 0.23$$

$$L := 700 \cdot ft \qquad W := 60 \cdot ft$$

Darcy permeability of the site soil:

$$Dsoil := 2.2 \cdot 10^{-2} \cdot \frac{cm}{s}$$

$$Pore\_Soil := 0.3$$

$$Gradient := 0.00005$$

$$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760 \cdot ft$$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 0.011 \cdot ft$$

$$Dist\_Soil := \frac{Dsoil \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 3.796 \cdot 10^{3} \cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 2.964 \cdot 10^{-6}$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 1.608 \cdot 10^{-5}$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 4.995$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

Relative distance traved by a water particle around the monolith rather than through it.

$$Ratio\_External\_over\_Iternal\_Length = 3.107 \cdot 10^{5}$$

Site Soil Permeability = $4.6x10^{-3}$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$$Dmono := 5 \cdot 10^{-5} \cdot \frac{cm}{s}$$

$$Pore\_Mono := 0.23$$

$$L := 700 \cdot ft \qquad W := 60 \cdot ft$$

Darcy permeability of the site soil:

$$Dsoil := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$$

$$Pore\_Soil := 0.3$$

$$Gradient := 0.00005$$

$$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760 \cdot ft$$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 11.254 \cdot ft$$

$$Dist\_Soil := \frac{Dsoil \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 793.772 \cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 0.014$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 0.016$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 1.044$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

Relative distance traved by a water particle around the monolith rather than through it.

$$Ratio\_External\_over\_Iternal\_Length = 64.965$$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$$Dmono := 1 \cdot 10^{-5} \cdot \frac{cm}{s}$$

$$Pore\_Mono := 0.23$$

$$L := 700 \cdot ft \qquad W := 60 \cdot ft$$

Darcy permeability of the site soil:

$$Dsoil := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$$

$$Pore\_Soil := 0.3$$

$$Gradient := 0.00005$$

$$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760 \cdot ft$$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 2.251 \cdot ft$$

$$Dist\_Soil := \frac{Dsoil \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 793.772 \cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 0.003$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 0.003$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 1.044$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

Relative distance traved by a water particle around the monolith rather than through it.

$$Ratio\_External\_over\_Iternal\_Length = 324.825$$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$$\mathrm{Dmono} := 5\cdot 10^{-6}\cdot\frac{\mathrm{cm}}{\mathrm{s}}$$

$$\mathrm{Pore\_Mono} := 0.23$$

$$\mathrm{L} := 700\cdot\mathrm{ft} \qquad \mathrm{W} := 60\cdot\mathrm{ft}$$

Darcy permeability of the site soil:

$$\mathrm{Dsoil} := 4.6\cdot 10^{-3}\cdot\frac{\mathrm{cm}}{\mathrm{s}}$$

$$\mathrm{Pore\_Soil} := 0.3$$

$$\mathrm{Gradient} := 0.00005$$

$$\mathrm{Half\_Mono\_Perimeter} := \mathrm{L} + \mathrm{W} \qquad \mathrm{Half\_Mono\_Perimeter} = 760\cdot\mathrm{ft}$$

Water particle travel in 1,000 years:

$$\mathrm{Dist\_Mono} := \frac{\mathrm{Dmono}\cdot\mathrm{Gradient}\cdot 1000\cdot\mathrm{yr}}{\mathrm{Pore\_Mono}} \qquad \mathrm{Dist\_Mono} = 1.125\cdot\mathrm{ft}$$

$$\mathrm{Dist\_Soil} := \frac{\mathrm{Dsoil}\cdot\mathrm{Gradient}\cdot 1000\cdot\mathrm{yr}}{\mathrm{Pore\_Soil}} \qquad \mathrm{Dist\_Soil} = 793.772\cdot\mathrm{ft}$$

$$\mathrm{Relative\_Distance} := \frac{\mathrm{Dist\_Mono}}{\mathrm{Dist\_Soil}} \qquad \mathrm{Relative\_Distance} = 0.001$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$\mathrm{Monolith\_Lengths\_internal} := \frac{\mathrm{Dist\_Mono}}{\mathrm{L}} \qquad \mathrm{Monolith\_Lengths\_internal} = 0.002$$

Monolith lengths travel in 1,000 years for an external water particle:

$$\mathrm{Monolith\_Lengths\_external} := \frac{\mathrm{Dist\_Soil}}{\mathrm{Half\_Mono\_Perimeter}} \qquad \mathrm{Monolith\_Lengths\_external} = 1.044$$

$$\mathrm{Ratio\_External\_over\_Iternal\_Length} := \frac{\mathrm{Monolith\_Lengths\_external}}{\mathrm{Monolith\_Lengths\_internal}}$$

Relative distance traved by a water particle around the monolith rather than through it.

$$\mathrm{Ratio\_External\_over\_Iternal\_Length} = 649.649$$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$Dmono := 1 \cdot 10^{-6} \cdot \frac{cm}{s}$

$Pore\_Mono := 0.23$

$L := 700 \cdot ft \qquad W := 60 \cdot ft$

Darcy permeability of the site soil:

$Dsoil := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$

$Pore\_Soil := 0.3$

$Gradient := 0.00005$

$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760 \cdot ft$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 0.225 \cdot ft$$

$$Dist\_Soil := \frac{Dsoil \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 793.772 \cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 2.836 \cdot 10^{-4}$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 3.215 \cdot 10^{-4}$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 1.044$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

Relative distance traved by a water particle around the monolith rather than through it.

$Ratio\_External\_over\_Iternal\_Length = 3.248 \cdot 10^{3}$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$Dmono := 5 \cdot 10^{-7} \cdot \frac{cm}{s}$

$Pore\_Mono := 0.23$

$L := 700 \cdot ft \qquad W := 60 \cdot ft$

Darcy permeability of the site soil:

$Dsoil := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$

$Pore\_Soil := 0.3$

$Gradient := 0.00005$

$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760 \cdot ft$

Water particle travel in 1,000 years:

$Dist\_Mono := \frac{Dmono \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 0.113 \cdot ft$

$Dist\_Soil := \frac{Dsoil \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 793.772 \cdot ft$

$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 1.418 \cdot 10^{-4}$

Monolith lengths travel in 1,000 years for an internal water particle:

$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 1.608 \cdot 10^{-4}$

Monolith lengths travel in 1,000 years for an external water particle:

$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 1.044$

$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$

Relative distance traved by a water particle around the monolith rather than through it.

$Ratio\_External\_over\_Iternal\_Length = 6.496 \cdot 10^{3}$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$$Dmono := 1 \cdot 10^{-7} \cdot \frac{cm}{s}$$

$$Pore\_Mono := 0.23$$

$$L := 700 \cdot ft \qquad W := 60 \cdot ft$$

Darcy permeability of the site soil:

$$Dsoil := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$$

$$Pore\_Soil := 0.3$$

$$Gradient := 0.00005$$

$$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760 \cdot ft$$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 0.023 \cdot ft$$

$$Dist\_Soil := \frac{Dsoil \cdot Gradient \cdot 1000 \cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 793.772 \cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 2.836 \cdot 10^{-5}$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 3.215 \cdot 10^{-5}$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 1.044$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

Relative distance traved by a water particle around the monolith rather than through it.

$$Ratio\_External\_over\_Iternal\_Length = 3.248 \cdot 10^{4}$$

Comparason of Groundwater Transport through and around a Monolith at the Kassouf-Kimerling Site

Darcy permeability of Monolith:

$$Dmono := 5\cdot 10^{-8}\cdot \frac{cm}{s}$$

$$Pore\_Mono := 0.23$$

$$L := 700\cdot ft \qquad W := 60\cdot ft$$

Darcy permeability of the site soil:

$$Dsoil := 4.6\cdot 10^{-3}\cdot \frac{cm}{s}$$

$$Pore\_Soil := 0.3$$

$$Gradient := 0.00005$$

$$Half\_Mono\_Perimeter := L + W \qquad Half\_Mono\_Perimeter = 760\cdot ft$$

Water particle travel in 1,000 years:

$$Dist\_Mono := \frac{Dmono\cdot Gradient\cdot 1000\cdot yr}{Pore\_Mono} \qquad Dist\_Mono = 0.011\cdot ft$$

$$Dist\_Soil := \frac{Dsoil\cdot Gradient\cdot 1000\cdot yr}{Pore\_Soil} \qquad Dist\_Soil = 793.772\cdot ft$$

$$Relative\_Distance := \frac{Dist\_Mono}{Dist\_Soil} \qquad Relative\_Distance = 1.418\cdot 10^{-5}$$

Monolith lengths travel in 1,000 years for an internal water particle:

$$Monolith\_Lengths\_internal := \frac{Dist\_Mono}{L} \qquad Monolith\_Lengths\_internal = 1.608\cdot 10^{-5}$$

Monolith lengths travel in 1,000 years for an external water particle:

$$Monolith\_Lengths\_external := \frac{Dist\_Soil}{Half\_Mono\_Perimeter} \qquad Monolith\_Lengths\_external = 1.044$$

$$Ratio\_External\_over\_Iternal\_Length := \frac{Monolith\_Lengths\_external}{Monolith\_Lengths\_internal}$$

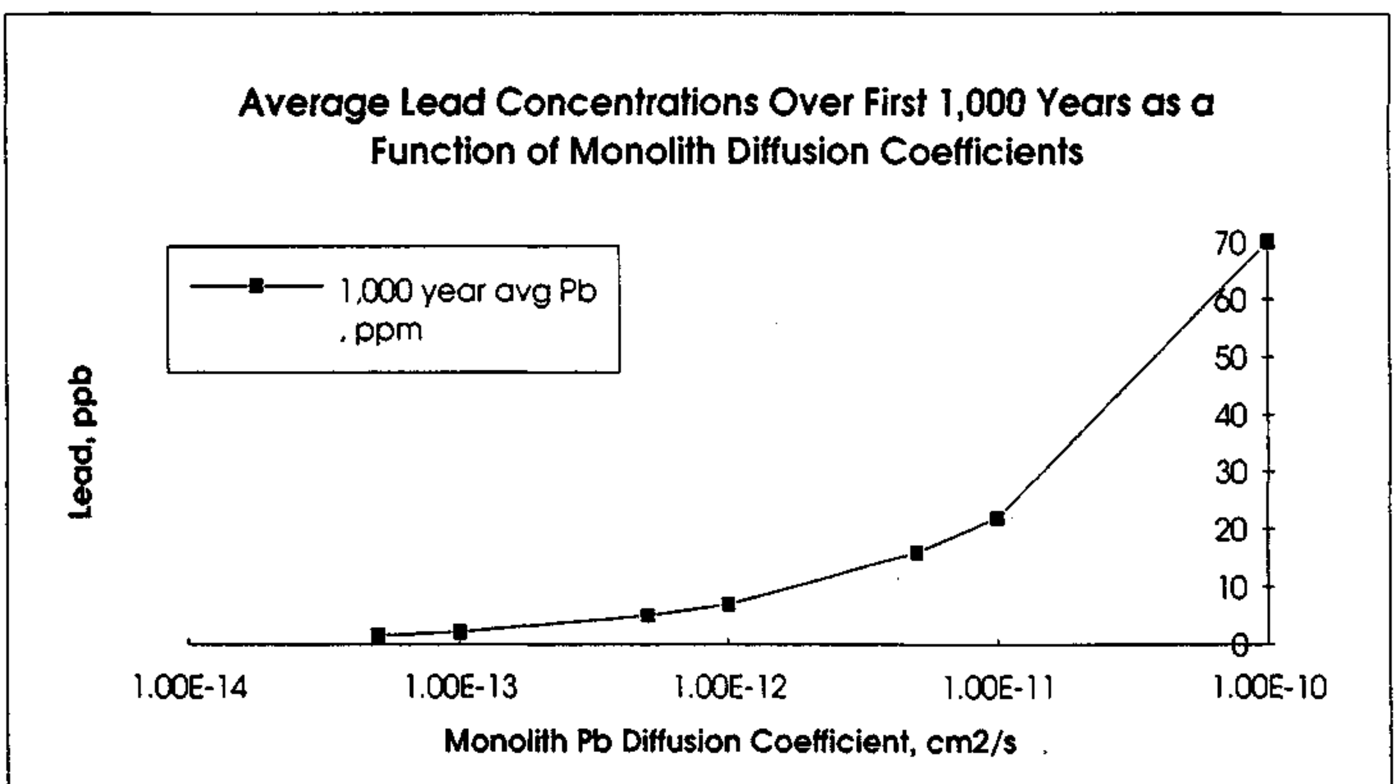
Relative distance traved by a water particle around the monolith rather than through it.

$$Ratio\_External\_over\_Iternal\_Length = 6.496\cdot 10^{4}$$

Appendix II

Effect of Monolith Diffusion Coefficients on Potential Groundwater Lead Concentrations at the Kassouf-Kimerling Superfund Site

The fractional releases over 1,000 years of leaching and the calcluated average concentrations of lead near the monolith surface (assuming a average lead concentration of 2,500 ppm in the soil).		
Monolith diffusion coefficient, cm2/s	**Fraction released after 1,000 years**	**Average concentration of lead, ppb**
1.00E-10	0.01499	70
1.00E-11	0.00474	22
5.00E-12	0.00335	16
1.00E-12	0.0015	7
5.00E-13	0.00106	5
1.00E-13	0.00047	2.2
5.00E-14	0.00034	1.6



1,000 Year Release Model for the Kassouf-Kimberling Site

Monolith Dimensions:

Length	Width	Depth	Volume	Surface
$L := 700 \cdot ft$	$W := 60 \cdot ft$	$D := 10.43 \cdot ft$	$V := L \cdot W \cdot D$	$S := 2 \cdot (W \cdot D + L \cdot W + L \cdot D)$
			$V = 4.3806 \cdot 10^5 \cdot ft^3$	$S = 99853.6 \cdot ft^2$
			$V = 16224 \cdot yd^3$	$S = 11095 \cdot yd^2$

Effective diffusion Coefficient:

$$De := 1 \cdot 10^{-10} \cdot \frac{cm^2}{s}$$

Surface to Volume:

$$\frac{S}{V} = 0.00748 \cdot cm^{-1}$$

Time iteration

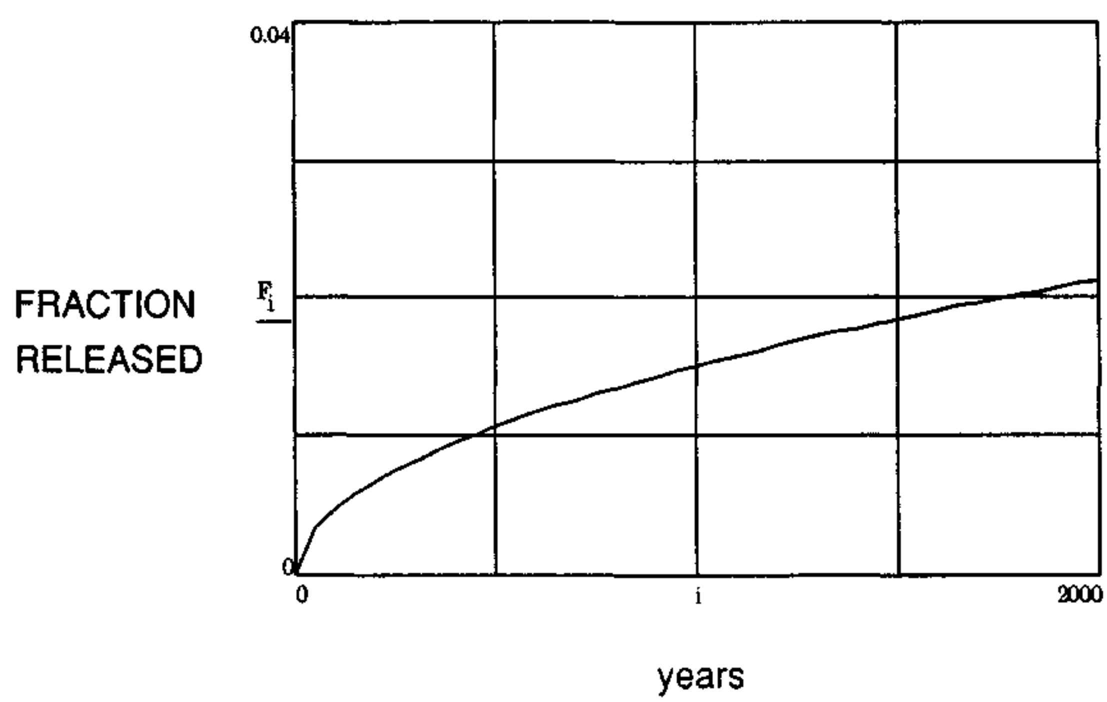
$$i := 0, 50 .. 2000$$

$$t_i := i \cdot yr$$

Infinite slab diffusion model:

$$F_i := 2 \cdot \frac{S}{V} \cdot \sqrt{De \cdot \frac{t_i}{\pi}}$$

RELEASE FROM 700x60x10.5 ft MONOLITH



$F_{50} = 0.00335$ $F_{150} = 0.00581$

Calculate Monolith Lead Content

Monolith Weight:

$density := 120 \cdot \frac{lbs}{ft^3}$ $V = 4.3806 \cdot 10^5 \cdot ft^3$

$Mono\_wgt := density \cdot V$ $Mono\_wgt = 5.25672 \cdot 10^7 \cdot lbs$

$Mass\_Dilution := 1.8$

Average Soil Concnetration:

$Pb\_Soil := 2500 \cdot ppm$

Concnetration in Monolith

$Pb\_Mono := \frac{Pb\_Soil}{1.8}$

Weight of Lead in Monolith:

$Pb\_Mass := Mono\_wgt \cdot Pb\_Mono$

$Pb\_Mass = 73010 \cdot lbs$

Lead Released Over 1,000 years

$F_{1000} = 0.01499$

$Pb\_Loss := Pb\_Mass \cdot F_{1000}$

$Pb\_Loss = 1094.47 \cdot lbs$

Dilution by Groundwater and Rain over a 1,000 Years

Site Darcy permeability:

$Permeability := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$

Site hydraulic gradient

$Gradient := 0.00005$

Cross Section of Monolith End:

$Cross\_area := D \cdot (W + 10 \cdot ft)$ $Cross\_area = 730.1 \cdot ft^2$

Groundwater Flowing over Monolith:

$Horz\_Flux := Permeability \cdot Gradient \cdot Cross\_area$ $Horz\_Flux = 173.86 \cdot \frac{ft^3}{yr}$

Horazontal Weight in 1,000 years

$Horz\_Mass := 1000 \cdot Y \cdot Horz\_Flux \cdot 62 \cdot \frac{lbs}{ft^3}$ $Horz\_Mass = 1.07793 \cdot 10^7 \cdot lbs$

Rain falling on the Monolith over 1,000 YEARS

Annual Rainfall:

$Rain := 60 \cdot \frac{in}{Y}$

Area of Monolith and Berms:

$Top\_Area := (W + 10 \cdot ft) \cdot (L + 10 \cdot ft)$

Annual Volume of Rain on Monolith:

$Rain\_Year := Rain \cdot Top\_Area$ $Rain\_Year = 2.485 \cdot 10^5 \cdot \frac{ft^3}{Y}$

Total Pounds of Water over and around the Monolith in 1,000 Years

$Horz\_Mass = 1.07793 \cdot 10^{7} \cdot lbs$

$Vert\_Mass = 1.55064 \cdot 10^{10} \cdot lbs$

$Horz\_Mass + Vert\_Mass = 1.55172 \cdot 10^{10} \cdot lbs$

Average Maximum Lead Concnetration over the First 1,000 Years

$$Ave\_Conc := \frac{Pb\_Loss}{Horz\_Mass + Vert\_Mass}$$

$Ave\_Conc = 0.07053 \cdot ppm$

National Drinking Water Standards = 0.015 ppm

Tennessee Water Qualtity Standards = 0.05 ppm

Detection Limits Ion Coupled Plasma Method = 0.2 ppm

Detection Limits Graphite Furnace Atomic Adsorption = 0.004 ppm

1,000 Year Release Model for the Kassouf-Kimberling Site

Monolith Dimensions:

Length	Width	Depth	Volume	Surface
$L := 700 \cdot ft$	$W := 60 \cdot ft$	$D := 10.43 \cdot ft$	$V := L \cdot W \cdot D$	$S := 2 \cdot (W \cdot D + L \cdot W + L \cdot D)$
			$V = 4.3806 \cdot 10^{5} \cdot ft^{3}$	$S = 99853.6 \cdot ft^{2}$
			$V = 16224 \cdot yd^{3}$	$S = 11095 \cdot yd^{2}$

Effective diffusion Coefficient:

$$De := 1 \cdot 10^{-11} \cdot \frac{cm^{2}}{s}$$

Surface to Volume:

$$\frac{S}{V} = 0.00748 \cdot cm^{-1}$$

Time iteration

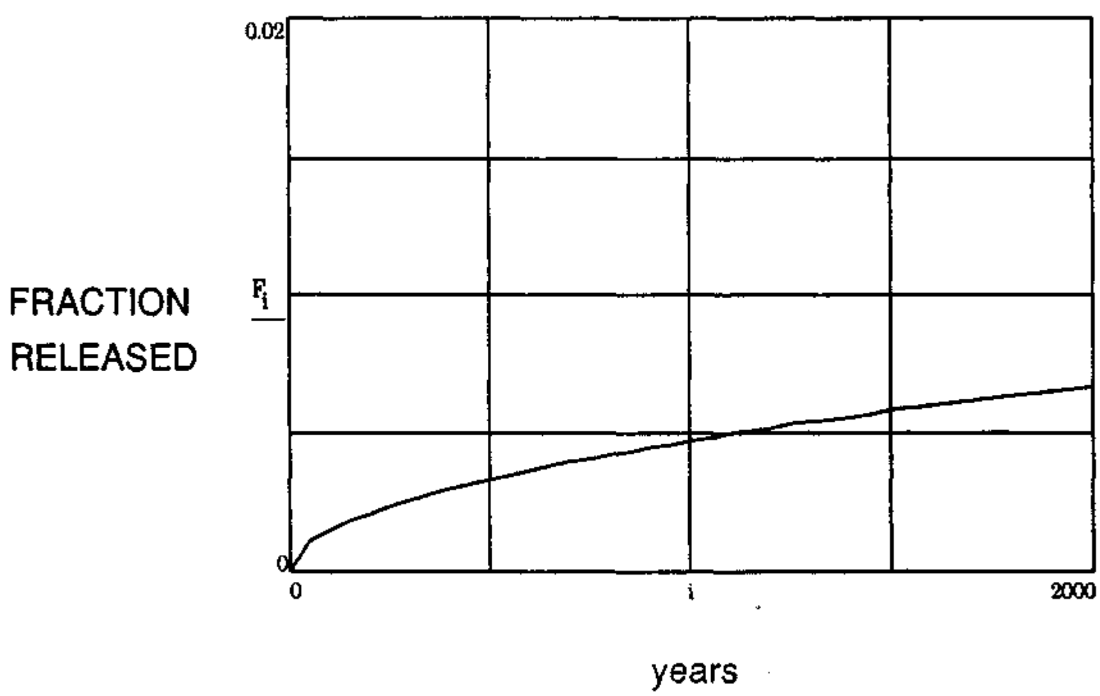
$$i := 0, 50 .. 2000$$

$$t_{i} := i \cdot yr$$

Infinite slab diffusion model:

$$F_{i} := 2 \cdot \frac{S}{V} \cdot \sqrt{De \cdot \frac{t_{i}}{\pi}}$$

RELEASE FROM 700x60x10.5 ft MONOLITH



$F_{50} = 0.00106$ $F_{150} = 0.00184$

Calculate Monolith Lead Content

Monolith Weight:

$density := 120 \cdot \frac{lbs}{ft^3}$ $V = 4.3806 \cdot 10^5 \cdot ft^3$

$Mono\_wgt := density \cdot V$ $Mono\_wgt = 5.25672 \cdot 10^7 \cdot lbs$

$Mass\_Dilution := 1.8$

Average Soil Concnetration:

$Pb\_Soil := 2500 \cdot ppm$

Concnetration in Monolith

$Pb\_Mono := \frac{Pb\_Soil}{1.8}$

Weight of Lead in Monolith:

$Pb\_Mass := Mono\_wgt \cdot Pb\_Mono$

$Pb\_Mass = 73010 \cdot lbs$

Lead Released Over 1,000 years

$F_{1000} = 0.00474$

$Pb\_Loss := Pb\_Mass \cdot F_{1000}$

$Pb\_Loss = 346.1 \cdot lbs$

Dilution by Groundwater and Rain over a 1,000 Years

Site Darcy permeability:

$Permeability := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$

Site hydraulic gradient

$Gradient := 0.00005$

Cross Section of Monolith End:

$Cross\_area := D \cdot (W + 10 \cdot ft)$ $Cross\_area = 730.1 \cdot ft^2$

Groundwater Flowing over Monolith:

$Horz\_Flux := Permeability \cdot Gradient \cdot Cross\_area$ $Horz\_Flux = 173.86 \cdot \frac{ft^3}{yr}$

Horazontal Weight in 1,000 years

$Horz\_Mass := 1000 \cdot Y \cdot Horz\_Flux \cdot 62 \cdot \frac{lbs}{ft^3}$ $Horz\_Mass = 1.07793 \cdot 10^7 \cdot lbs$

Rain falling on the Monolith over 1,000 YEARS

Annual Rainfall:

$Rain := 60 \cdot \frac{in}{Y}$

Area of Monolith and Berms:

$Top\_Area := (W + 10 \cdot ft) \cdot (L + 10 \cdot ft)$

Annual Volume of Rain on Monolith:

$Rain\_Year := Rain \cdot Top\_Area$ $Rain\_Year = 2.485 \cdot 10^5 \cdot \frac{ft^3}{Y}$

Total Pounds of Water over and around the Monolith in 1,000 Years

$\text{Horz\_Mass} = 1.07793 \cdot 10^{7} \cdot \text{lbs}$

$\text{Vert\_Mass} = 1.55064 \cdot 10^{10} \cdot \text{lbs}$

$\text{Horz\_Mass} + \text{Vert\_Mass} = 1.55172 \cdot 10^{10} \cdot \text{lbs}$

Average Maximum Lead Concnetration over the First 1,000 Years

$$\text{Ave\_Conc} := \frac{\text{Pb\_Loss}}{\text{Horz\_Mass} + \text{Vert\_Mass}}$$

$\text{Ave\_Conc} = 0.0223 \cdot \text{ppm}$

National Drinking Water Standards = 0.015 ppm

Tennessee Water Qualtity Standards = 0.05 ppm

Detection Limits Ion Coupled Plasma Method = 0.2 ppm

Detection Limits Graphite Furnace Atomic Adsorption = 0.004 ppm

1,000 Year Release Model for the Kassouf-Kimberling Site

Monolith Dimensions:

Length	Width	Depth	Volume	Surface
$L := 700 \cdot ft$	$W := 60 \cdot ft$	$D := 10.43 \cdot ft$	$V := L \cdot W \cdot D$	$S := 2 \cdot (W \cdot D + L \cdot W + L \cdot D)$
			$V = 4.3806 \cdot 10^{5} \cdot ft^{3}$	$S = 99853.6 \cdot ft^{2}$
			$V = 16224 \cdot yd^{3}$	$S = 11095 \cdot yd^{2}$

Effective diffusion Coefficient:

$$De := 5 \cdot 10^{-12} \cdot \frac{cm^{2}}{s}$$

Surface to Volume:

$$\frac{S}{V} = 0.00748 \cdot cm^{-1}$$

Time iteration

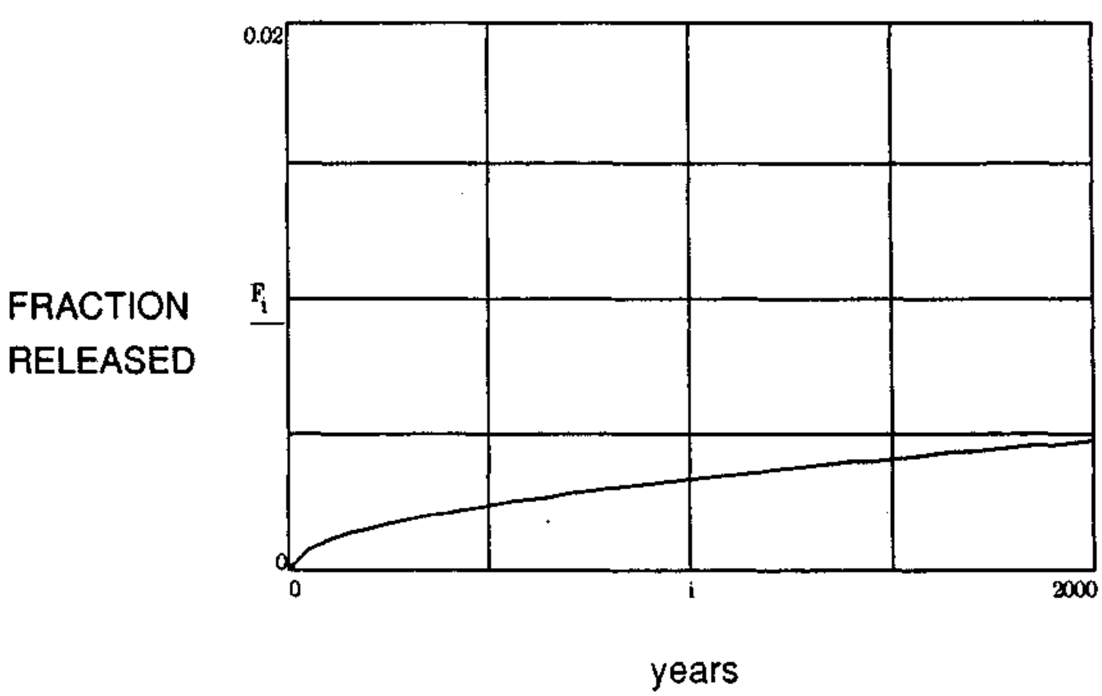
$i := 0, 50 .. 2000$

$t_{i} := i \cdot yr$

Infinite slab diffusion model:

$$F_{i} := 2 \cdot \frac{S}{V} \cdot \sqrt{De \cdot \frac{t_{i}}{\pi}}$$

RELEASE FROM 700x60x10.5 ft MONOLITH



$F_{50} = 0.00075$ $F_{150} = 0.0013$

Calculate Monolith Lead Content

Monolith Weight:

$density := 120 \cdot \frac{lbs}{ft^3}$ $V = 4.3806 \cdot 10^5 \cdot ft^3$

$Mono\_wgt := density \cdot V$ $Mono\_wgt = 5.25672 \cdot 10^7 \cdot lbs$

$Mass\_Dilution := 1.8$

Average Soil Concnetration:

$Pb\_Soil := 2500 \cdot ppm$

Concnetration in Monolith

$Pb\_Mono := \frac{Pb\_Soil}{1.8}$

Weight of Lead in Monolith:

$Pb\_Mass := Mono\_wgt \cdot Pb\_Mono$

$Pb\_Mass = 73010 \cdot lbs$

Lead Released Over 1,000 years

$F_{1000} = 0.00335$

$Pb\_Loss := Pb\_Mass \cdot F_{1000}$

$Pb\_Loss = 244.73 \cdot lbs$

Dilution by Groundwater and Rain over a 1,000 Years

Site Darcy permeability:

$Permeability := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$

Site hydraulic gradient

$Gradient := 0.00005$

Cross Section of Monolith End:

$Cross\_area := D \cdot (W + 10 \cdot ft)$ $Cross\_area = 730.1 \cdot ft^2$

Groundwater Flowing over Monolith:

$Horz\_Flux := Permeability \cdot Gradient \cdot Cross\_area$ $Horz\_Flux = 173.86 \cdot \frac{ft^3}{yr}$

Horazontal Weight in 1,000 years

$Horz\_Mass := 1000 \cdot Y \cdot Horz\_Flux \cdot 62 \cdot \frac{lbs}{ft^3}$ $Horz\_Mass = 1.07793 \cdot 10^7 \cdot lbs$

Rain falling on the Monolith over 1,000 YEARS

Annual Rainfall:

$Rain := 60 \cdot \frac{in}{Y}$

Area of Monolith and Berms:

$Top\_Area := (W + 10 \cdot ft) \cdot (L + 10 \cdot ft)$

Annual Volume of Rain on Monolith:

$Rain\_Year := Rain \cdot Top\_Area$ $Rain\_Year = 2.485 \cdot 10^5 \cdot \frac{ft^3}{Y}$

1,000 Year Weight of Rain

Total Pounds of Water over and around the Monolith in 1,000 Years

$Horz\_Mass = 1.07793 \cdot 10^{7} \cdot lbs$

$Vert\_Mass = 1.55064 \cdot 10^{10} \cdot lbs$

$Horz\_Mass + Vert\_Mass = 1.55172 \cdot 10^{10} \cdot lbs$

Average Maximum Lead Concnetration over the First 1,000 Years

$$Ave\_Conc := \frac{Pb\_Loss}{Horz\_Mass + Vert\_Mass}$$

$Ave\_Conc = 0.01577 \cdot ppm$

National Drinking Water Standards = 0.015 ppm

Tennessee Water Qualtity Standards = 0.05 ppm

Detection Limits Ion Coupled Plasma Method = 0.2 ppm

Detection Limits Graphite Furnace Atomic Adsorption = 0.004 ppm

1,000 Year Release Model for the Kassouf-Kimberling Site

Monolith Dimensions:

Length	Width	Depth	Volume	Surface
$L := 700 \cdot ft$	$W := 60 \cdot ft$	$D := 10.43 \cdot ft$	$V := L W \cdot D$	$S := 2 \cdot (W \cdot D + L W + L D)$
			$V = 4.3806 \cdot 10^5 \cdot ft^3$	$S = 99853.6 \cdot ft^2$
			$V = 16224 \cdot yd^3$	$S = 11095 \cdot yd^2$

Effective diffusion Coefficient:

$$De := 1 \cdot 10^{-12} \cdot \frac{cm^2}{s}$$

Surface to Volume:

$$\frac{S}{V} = 0.00748 \cdot cm^{-1}$$

Time iteration

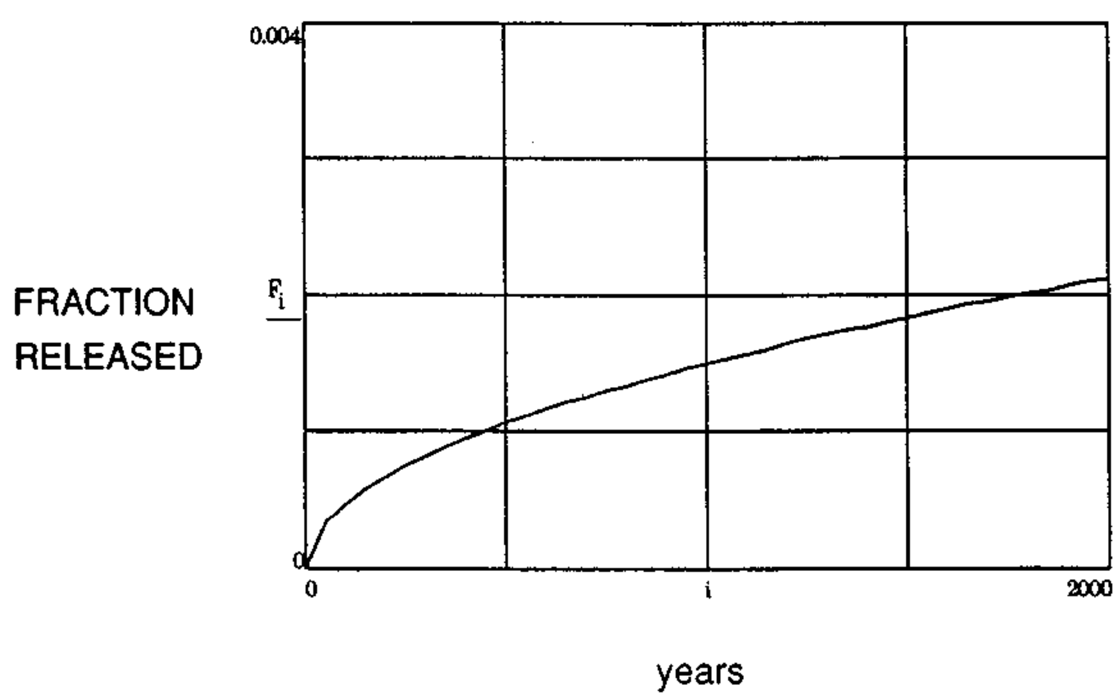
$i := 0, 50 .. 2000$

$t_i := i \cdot yr$

Infinite slab diffusion model:

$$F_i := 2 \cdot \frac{S}{V} \cdot \sqrt{De \cdot \frac{t_i}{\pi}}$$

RELEASE FROM 700x60x10.5 ft MONOLITH



$F_{50} = 0.00034$ $F_{150} = 0.00058$

Calculate Monolith Lead Content

Monolith Weight:

$density := 120 \cdot \frac{lbs}{ft^3}$ $V = 4.3806 \cdot 10^5 \cdot ft^3$

$Mono\_wgt := density \cdot V$ $Mono\_wgt = 5.25672 \cdot 10^7 \cdot lbs$

$Mass\_Dilution := 1.8$

Average Soil Concnetration:

$Pb\_Soil := 2500 \cdot ppm$

Concnetration in Monolith

$Pb\_Mono := \frac{Pb\_Soil}{1.8}$

Weight of Lead in Monolith:

$Pb\_Mass := Mono\_wgt \cdot Pb\_Mono$

$Pb\_Mass = 73010 \cdot lbs$

Lead Released Over 1,000 years

$F_{1000} = 0.0015$

$Pb\_Loss := Pb\_Mass \cdot F_{1000}$

$Pb\_Loss = 109.45 \cdot lbs$

Dilution by Groundwater and Rain over a 1,000 Years

Site Darcy permeability:

$Permeability := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$

Site hydraulic gradient

$Gradient := 0.00005$

Cross Section of Monolith End:

$Cross\_area := D \cdot (W + 10 \cdot ft)$ $Cross\_area = 730.1 \cdot ft^2$

Groundwater Flowing over Monolith:

$Horz\_Flux := Permeability \cdot Gradient \cdot Cross\_area$ $Horz\_Flux = 173.86 \cdot \frac{ft^3}{yr}$

Horazontal Weight in 1,000 years

$Horz\_Mass := 1000 \cdot Y \cdot Horz\_Flux \cdot 62 \cdot \frac{lbs}{ft^3}$ $Horz\_Mass = 1.07793 \cdot 10^7 \cdot lbs$

Rain falling on the Monolith over 1,000 YEARS

Annual Rainfall:

$Rain := 60 \cdot \frac{in}{Y}$

Area of Monolith and Berms:

$Top\_Area := (W + 10 \cdot ft) \cdot (L + 10 \cdot ft)$

Annual Volume of Rain on Monolith:

$Rain\_Year := Rain \cdot Top\_Area$ $Rain\_Year = 2.485 \cdot 10^5 \cdot \frac{ft^3}{Y}$

Total Pounds of Water over and around the Monolith in 1,000 Years

$Horz\_Mass = 1.07793 \cdot 10^{7} \cdot lbs$

$Vert\_Mass = 1.55064 \cdot 10^{10} \cdot lbs$

$Horz\_Mass + Vert\_Mass = 1.55172 \cdot 10^{10} \cdot lbs$

Average Maximum Lead Concnetration over the First 1,000 Years

$$Ave\_Conc := \frac{Pb\_Loss}{Horz\_Mass + Vert\_Mass}$$

$Ave\_Conc = 0.00705 \cdot ppm$

National Drinking Water Standards = 0.015 ppm

Tennessee Water Qualtity Standards = 0.05 ppm

Detection Limits Ion Coupled Plasma Method = 0.2 ppm

Detection Limits Graphite Furnace Atomic Adsorption = 0.004 ppm

1,000 Year Release Model for the Kassouf-Kimberling Site

Monolith Dimensions:

Length	Width	Depth	Volume	Surface
$L := 700 \cdot ft$	$W := 60 \cdot ft$	$D := 10.43 \cdot ft$	$V := L \cdot W \cdot D$	$S := 2 \cdot (W \cdot D + L \cdot W + L \cdot D)$
			$V = 4.3806 \cdot 10^{5} \cdot ft^{3}$	$S = 99853.6 \cdot ft^{2}$
			$V = 16224 \cdot yd^{3}$	$S = 11095 \cdot yd^{2}$

Effective diffusion Coefficient:

$$De := 5 \cdot 10^{-13} \cdot \frac{cm^{2}}{s}$$

Surface to Volume:

$$\frac{S}{V} = 0.00748 \cdot cm^{-1}$$

Time iteration

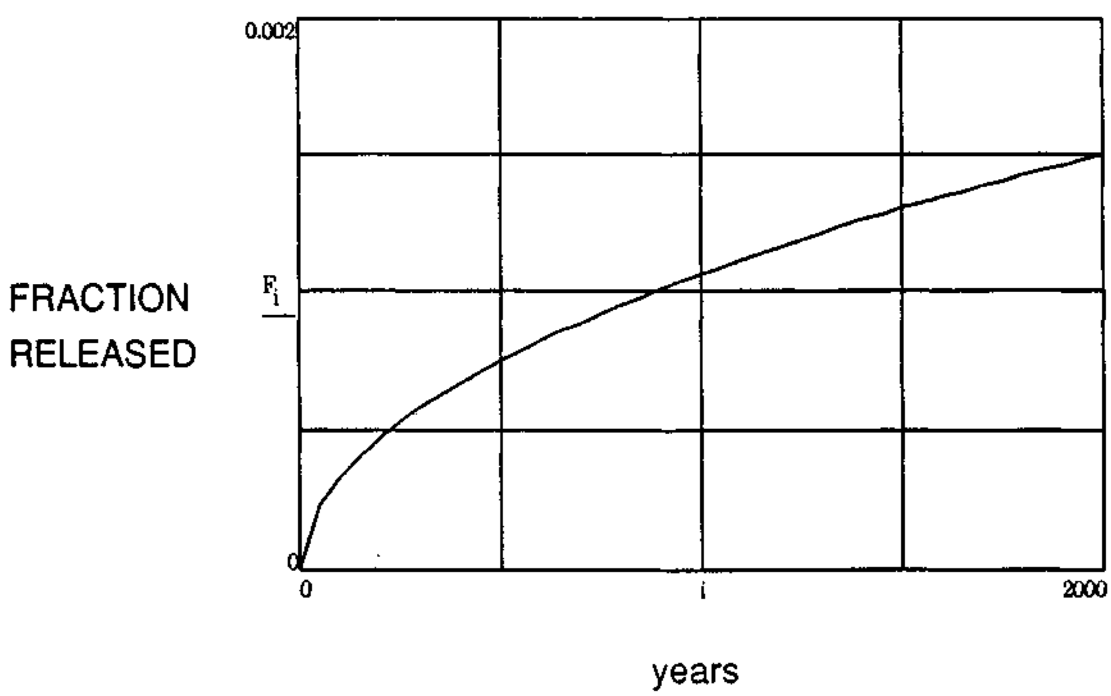
$i := 0, 50 .. 2000$

$t_i := i \cdot yr$

Infinite slab diffusion model:

$$F_i := 2 \cdot \frac{S}{V} \cdot \sqrt{De \cdot \frac{t_i}{\pi}}$$

RELEASE FROM 700x60x10.5 ft MONOLITH



$F_{50} = 0.00024$ $F_{150} = 0.00041$

Calculate Monolith Lead Content

Monolith Weight:

$density := 120 \cdot \frac{lbs}{ft^3}$ $V = 4.3806 \cdot 10^5 \cdot ft^3$

$Mono\_wgt := density \cdot V$ $Mono\_wgt = 5.25672 \cdot 10^7 \cdot lbs$

$Mass\_Dilution := 1.8$

Average Soil Concnetration:

$Pb\_Soil := 2500 \cdot ppm$

Concnetration in Monolith

$Pb\_Mono := \frac{Pb\_Soil}{1.8}$

Weight of Lead in Monolith:

$Pb\_Mass := Mono\_wgt \cdot Pb\_Mono$

$Pb\_Mass = 73010 \cdot lbs$

Lead Released Over 1,000 years

$F_{1000} = 0.00106$

$Pb\_Loss := Pb\_Mass \cdot F_{1000}$

$Pb\_Loss = 77.39 \cdot lbs$

Dilution by Groundwater and Rain over a 1,000 Years

Site Darcy permeability:

$Permeability := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$

Site hydraulic gradient

$Gradient := 0.00005$

Cross Section of Monolith End:

$Cross\_area := D \cdot (W + 10 \cdot ft)$ $Cross\_area = 730.1 \cdot ft^2$

Groundwater Flowing over Monolith:

$Horz\_Flux := Permeability \cdot Gradient \cdot Cross\_area$ $Horz\_Flux = 173.86 \cdot \frac{ft^3}{yr}$

Horazontal Weight in 1,000 years

$Horz\_Mass := 1000 \cdot Y \cdot Horz\_Flux \cdot 62 \cdot \frac{lbs}{ft^3}$ $Horz\_Mass = 1.07793 \cdot 10^7 \cdot lbs$

Rain falling on the Monolith over 1,000 YEARS

Annual Rainfall:

$Rain := 60 \cdot \frac{in}{Y}$

Area of Monolith and Berms:

$Top\_Area := (W + 10 \cdot ft) \cdot (L + 10 \cdot ft)$

Annual Volume of Rain on Monolith:

$Rain\_Year := Rain \cdot Top\_Area$ $Rain\_Year = 2.485 \cdot 10^5 \cdot \frac{ft^3}{Y}$

Total Pounds of Water over and around the Monolith in 1,000 Years

$Horz\_Mass = 1.07793 \cdot 10^{7} \cdot lbs$

$Vert\_Mass = 1.55064 \cdot 10^{10} \cdot lbs$

$Horz\_Mass + Vert\_Mass = 1.55172 \cdot 10^{10} \cdot lbs$

Average Maximum Lead Concnetration over the First 1,000 Years

$$Ave\_Conc := \frac{Pb\_Loss}{Horz\_Mass + Vert\_Mass}$$

$Ave\_Conc = 0.00499 \cdot ppm$

National Drinking Water Standards = 0.015 ppm

Tennessee Water Qualtity Standards = 0.05 ppm

Detection Limits Ion Coupled Plasma Method = 0.2 ppm

Detection Limits Graphite Furnace Atomic Adsorption = 0.004 ppm

1,000 Year Release Model for the Kassouf-Kimberling Site

Monolith Dimensions:

Length	Width	Depth	Volume	Surface
$L := 700 \cdot ft$	$W := 60 \cdot ft$	$D := 10.43 \cdot ft$	$V := L \cdot W \cdot D$	$S := 2 \cdot (W \cdot D + L \cdot W + L \cdot D)$
			$V = 4.3806 \cdot 10^5 \cdot ft^3$	$S = 99853.6 \cdot ft^2$
			$V = 16224 \cdot yd^3$	$S = 11095 \cdot yd^2$

Effective diffusion Coefficient:

$$De := 1 \cdot 10^{-13} \cdot \frac{cm^2}{s}$$

Surface to Volume:

$$\frac{S}{V} = 0.00748 \cdot cm^{-1}$$

Time iteration

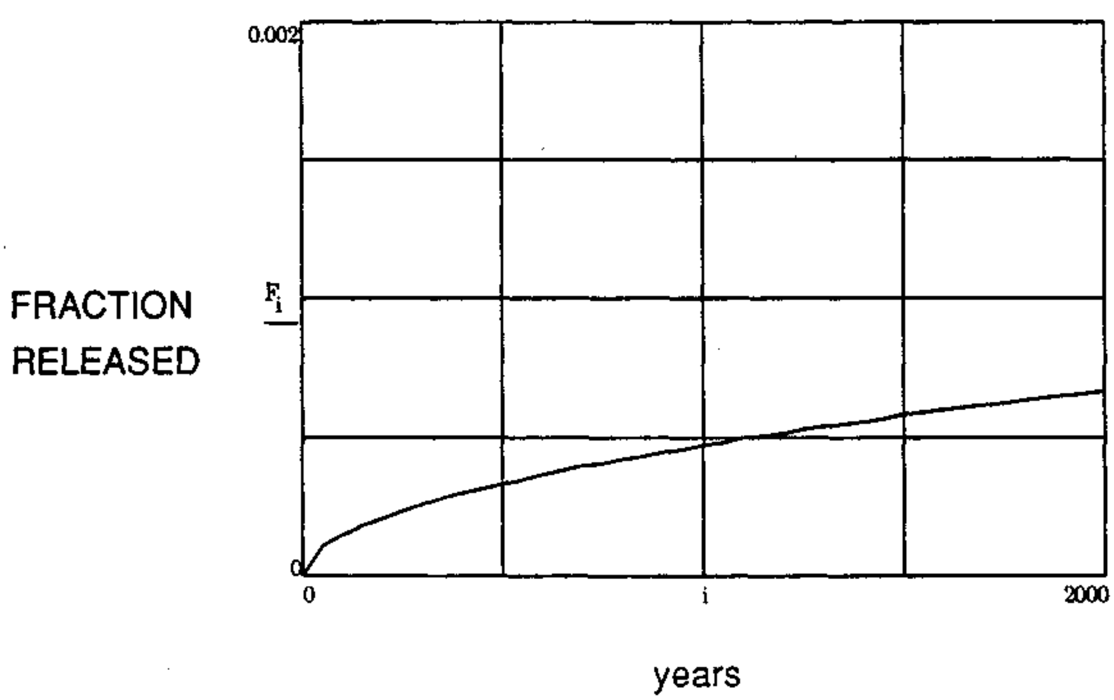
$$i := 0, 50 .. 2000$$

$$t_i := i \cdot yr$$

Infinite slab diffusion model:

$$F_i := 2 \cdot \frac{S}{V} \cdot \sqrt{De \cdot \frac{t_i}{\pi}}$$

RELEASE FROM 700x60x10.5 ft MONOLITH



$F_{50} = 0.00011$ $\quad$ $F_{150} = 0.00018$

Calculate Monolith Lead Content

Monolith Weight:

$density := 120 \cdot \frac{lbs}{ft^3}$ $V = 4.3806 \cdot 10^5 \cdot ft^3$

$Mono\_wgt := density \cdot V$ $Mono\_wgt = 5.25672 \cdot 10^7 \cdot lbs$

$Mass\_Dilution := 1.8$

Average Soil Concnetration:

$Pb\_Soil := 2500 \cdot ppm$

Concnetration in Monolith

$Pb\_Mono := \frac{Pb\_Soil}{1.8}$

Weight of Lead in Monolith:

$Pb\_Mass := Mono\_wgt \cdot Pb\_Mono$

$Pb\_Mass = 73010 \cdot lbs$

Lead Released Over 1,000 years

$F_{1000} = 0.00047$

$Pb\_Loss := Pb\_Mass \cdot F_{1000}$

$Pb\_Loss = 34.61 \cdot lbs$

Dilution by Groundwater and Rain over a 1,000 Years

Site Darcy permeability:

$Permeability := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$

Site hydraulic gradient

$Gradient := 0.00005$

Cross Section of Monolith End:

$Cross\_area := D \cdot (W + 10 \cdot ft)$ $Cross\_area = 730.1 \cdot ft^2$

Groundwater Flowing over Monolith:

$Horz\_Flux := Permeability \cdot Gradient \cdot Cross\_area$ $Horz\_Flux = 173.86 \cdot \frac{ft^3}{yr}$

Horazontal Weight in 1,000 years

$Horz\_Mass := 1000 \cdot Y \cdot Horz\_Flux \cdot 62 \cdot \frac{lbs}{ft^3}$ $Horz\_Mass = 1.07793 \cdot 10^7 \cdot lbs$

Rain falling on the Monolith over 1,000 YEARS

Annual Rainfall:

$Rain := 60 \cdot \frac{in}{Y}$

Area of Monolith and Berms:

$Top\_Area := (W + 10 \cdot ft) \cdot (L + 10 \cdot ft)$

Annual Volume of Rain on Monolith:

$Rain\_Year := Rain \cdot Top\_Area$ $Rain\_Year = 2.485 \cdot 10^5 \cdot \frac{ft^3}{Y}$

Total Pounds of Water over and around the Monolith in 1,000 Years

$\text{Horz\_Mass} = 1.07793 \cdot 10^{7} \cdot \text{lbs}$ $\text{Vert\_Mass} = 1.55064 \cdot 10^{10} \cdot \text{lbs}$

$$\text{Horz\_Mass} + \text{Vert\_Mass} = 1.55172 \cdot 10^{10} \cdot \text{lbs}$$

Average Maximum Lead Concnetration over the First 1,000 Years

$$\text{Ave\_Conc} := \frac{\text{Pb\_Loss}}{\text{Horz\_Mass} + \text{Vert\_Mass}}$$ $$\text{Ave\_Conc} = 0.00223 \cdot \text{ppm}$$

National Drinking Water Standards = 0.015 ppm

Tennessee Water Qualtity Standards = 0.05 ppm

Detection Limits Ion Coupled Plasma Method = 0.2 ppm

Detection Limits Graphite Furnace Atomic Adsorption = 0.004 ppm

1,000 Year Release Model for the Kassouf-Kimberling Site

Monolith Dimensions:

Length	Width	Depth	Volume	Surface
$L := 700 \cdot ft$	$W := 60 \cdot ft$	$D := 10.43 \cdot ft$	$V := L \cdot W \cdot D$	$S := 2 \cdot (W \cdot D + L \cdot W + L \cdot D)$
			$V = 4.3806 \cdot 10^{5} \cdot ft^{3}$	$S = 99853.6 \cdot ft^{2}$
			$V = 16224 \cdot yd^{3}$	$S = 11095 \cdot yd^{2}$

Effective diffusion Coefficient:

$$De := 5 \cdot 10^{-14} \cdot \frac{cm^{2}}{s}$$

Surface to Volume:

$$\frac{S}{V} = 0.00748 \cdot cm^{-1}$$

Time iteration

$i := 0, 50 .. 2000$

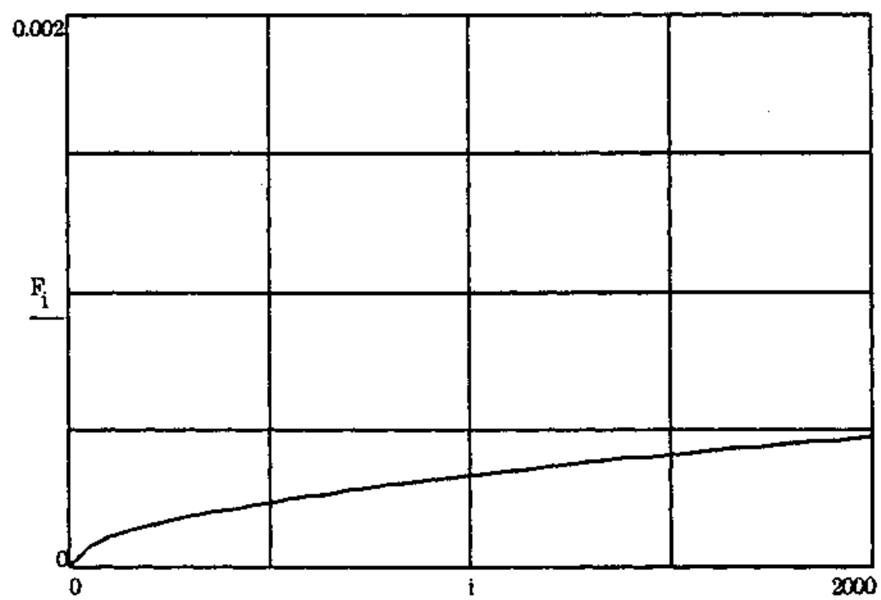
$t_i := i \cdot yr$

Infinite slab diffusion model:

$$F_i := 2 \cdot \frac{S}{V} \cdot \sqrt{De \cdot \frac{t_i}{\pi}}$$

RELEASE FROM 700x60x10.5 ft MONOLITH

FRACTION RELEASED



years

$F_{50} = 0.00007$ $F_{150} = 0.00013$

Calculate Monolith Lead Content

Monolith Weight:

$density := 120 \cdot \frac{lbs}{ft^3}$ $V = 4.3806 \cdot 10^5 \cdot ft^3$

$Mono\_wgt := density \cdot V$ $Mono\_wgt = 5.25672 \cdot 10^7 \cdot lbs$

$Mass\_Dilution := 1.8$

Average Soil Concnetration:

$Pb\_Soil := 2500 \cdot ppm$

Concnetration in Monolith

$Pb\_Mono := \frac{Pb\_Soil}{1.8}$

Weight of Lead in Monolith:

$Pb\_Mass := Mono\_wgt \cdot Pb\_Mono$

$Pb\_Mass = 73010 \cdot lbs$

Lead Released Over 1,000 years

$F_{1000} = 0.00034$

$Pb\_Loss := Pb\_Mass \cdot F_{1000}$

$Pb\_Loss = 24.47 \cdot lbs$

Dilution by Groundwater and Rain over a 1,000 Years

Site Darcy permeability:

$Permeability := 4.6 \cdot 10^{-3} \cdot \frac{cm}{s}$

Site hydraulic gradient

$Gradient := 0.00005$

Cross Section of Monolith End:

$Cross\_area := D \cdot (W + 10 \cdot ft)$ $Cross\_area = 730.1 \cdot ft^2$

Groundwater Flowing over Monolith:

$Horz\_Flux := Permeability \cdot Gradient \cdot Cross\_area$ $Horz\_Flux = 173.86 \cdot \frac{ft^3}{yr}$

Horazontal Weight in 1,000 years

$Horz\_Mass := 1000 \cdot Y \cdot Horz\_Flux \cdot 62 \cdot \frac{lbs}{ft^3}$ $Horz\_Mass = 1.07793 \cdot 10^7 \cdot lbs$

Rain falling on the Monolith over 1,000 YEARS

Annual Rainfall:

$Rain := 60 \cdot \frac{in}{Y}$

Area of Monolith and Berms:

$Top\_Area := (W + 10 \cdot ft) \cdot (L + 10 \cdot ft)$

Annual Volume of Rain on Monolith:

$Rain\_Year := Rain \cdot Top\_Area$ $Rain\_Year = 2.485 \cdot 10^5 \cdot \frac{ft^3}{Y}$

1,000 Year Weight of Rain:

Total Pounds of Water over and around the Monolith in 1,000 Years

$\text{Horz\_Mass} = 1.07793 \cdot 10^{7} \cdot \text{lbs}$ $\text{Vert\_Mass} = 1.55064 \cdot 10^{10} \cdot \text{lbs}$

$$\text{Horz\_Mass} + \text{Vert\_Mass} = 1.55172 \cdot 10^{10} \cdot \text{lbs}$$

Average Maximum Lead Concnetration over the First 1,000 Years

$\text{Ave\_Conc} := \frac{\text{Pb\_Loss}}{\text{Horz\_Mass} + \text{Vert\_Mass}}$ $\text{Ave\_Conc} = 0.00158 \cdot \text{ppm}$

National Drinking Water Standards = 0.015 ppm

Tennessee Water Qualtity Standards = 0.05 ppm

Detection Limits Ion Coupled Plasma Method = 0.2 ppm

Detection Limits Graphite Furnace Atomic Adsorption = 0.004 ppm