To: Brad Bradley
USEPA, Region V
via Airmail

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137760

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

December 19, 1986 Our ref: 863-2041

Manville Service Corporation
12999 Deer Creek Canyon Road
Mail Stop 3-25
Littleton, Colorado 80127

ATTENTION: Mr. Marvin Clumpus, P.E., Senior Engineer

RE: UPDATED UPFREEZING COVER THICKNESS ANALYSIS -- USING McGAW (EPA) THERMAL (LAMBDA, N, K VALUES) -- ESTIMATES FOR THE WAUKEGAN, ILLINOIS PLANT WASTE DISPOSAL AREA

Dear Mr. Clumpus:

Attached for your review and consideration are updated UPFREEZ5 estimates for those areas of the site which have a potential for asbestos particle upfreezing through the proposed cover.

Calculations include values of strain (S) and heave fraction not recovered on thawing (F) ranging from S=10%, F=0.1, expected typical conditions, to S=30%, F=0.3, expected extreme conditions; also included are values for conditions beyond expected extremes, to S=50%, F=0.5. Cover thicknesses from 1.0 ft to 2.5 ft are analyzed.

Thermal input parameters have been updated to be consistent with values used by Mr. Richard McGaw in his letter report to Mr. Brad Bradley, dated December 5, 1986.

The focus of results are the R100 estimates. These are the estimated reliability (probability) that the cover upfreezing capacity is or exceeds 100 years.

Updated Thermal Input Parameters

Updated estimates use values for LAMBDA ($\lambda * n_s$) and N-FACTOR (n_t) identical to those used by EPA's upfreezing consultant, Mr. Richard McGaw, in his letter report to Mr. Brad Bradley, dated December 5, 1986. Mr McGaw used the following values in his calculations, resulting in a recommended 26 inches of required cover:

LAMBDA = 0.7 * n_s (= 0.85) = 0.60

N-FACTOR = n_t = 0.65

LAMBDA*SQR[N-FACTOR] = 0.60 * 0.81 = 0.48

Identical values (with a zero standard deviation (SD), the same as McGaw's calculations) are used in the attached UPFREEZ5 output. Note our original values for these parameters (UPFREEZ5 output transmitted to you October 27 and November 6, 1986) were about 46% more conservative (higher frost penetration) than McGaw's numbers.

Also, our original average thermal conductivity (Kf) parameters were about 15% to 40% more conservative (higher frost penetration) than Mr. McGaw's December 5, 1986 values (as he used in his modified Berggren equation calculations). Therefore, I have set the plus-one standard deviation error on K to zero. This will reduce some (but not all) of the relative conservatism in K values. To reduce Kf to Mr. McGaw's K values would give Kf too low a value to be consistent with Kersten's correlations, the candidate cover soil, and freezing conditions.

All other thermal and upfreezing input conditions and assumptions are identical to the UPFREEZ5 output transmitted to you on October 27 and November 6, 1986. However, R50 has been replaced by R100, as explained next.

R100 (100-Year Reliability) Estimates

Based on the discussion of "permanence" during the USEPA/IEPA/Manville meeting of December 16, 1986, I have modified UPFREEZ5 to calculate and display R100 instead of R50. This updated version of UPFREEZ5 is called UPFREEZ5Y. All other calculation procedures and assumptions are unchanged from UPFREEZ5X.

R100 is the estimated probability (reliability) that:

> Upfreezing of "critically sized" (i.e., $X - A \leq 0.3$ ft) asbestos particles initially at the worst-case location (top of waste pile or bottom of cover) will take 100 years or longer.

R100 is the complement of the estimated 100-year failure probability, F100, that is:

$$R100 = 100 - F100 \qquad \text{[with R100 and F100 in \%]}$$

F100 is the estimated probability that upfreezing of "critically sized" asbestos particles initially at the worst-case location will take less than 100 years.

We are more interested in obtaining success (reliability) than failure; therefore, R100 is a more appropriate parameter to display than F100. However, since (with certainty) F100 equals 100% minus R100, estimated failure probabilities are very easily and obviously obtained from R100.

All updated estimates make the assumptions shown on the program UPFREEZ5Y computer output. Variables, symbols and their relation to object upfreezing are defined, as before, using the upfreezing equation (Eq. 1) in Table 1.

Updated estimates shown on the attached UPFREEZ5Y output indicate the following for cover thicknesses up 2.2 ft (26 inches).

- o For what we expect to be typical site conditions, moderate-heaving, moderate-stability cover (S=10%, F=0.1) provides an R100 (100-year reliability) of 100% for all cover thicknesses exceeding 0.3 ft.

- o For extreme site conditions, representing the expected worst-case, resulting in high-heaving and poor-stability (S=30%, F=0.3) cover, R100 estimates are:

  - 98.9% for 1.5 ft of cover
  - 99.4% for 1.6 ft of cover
  - 99.8% for 1.7 ft of cover
  - 99.9% for 1.8 ft of cover
  - 99.96% for 1.9 ft of cover
  - 99.99% for 2.0 ft of cover
  - 99.995+% for 2.1 ft of cover
  - 99.995+% for 2.2 ft of cover

  The 2.0 ft cover gives an increase in R100 of 1.10% over the 1.5 ft cover, for this worst case situation.

- o R100 increases with very high-heaving soil, S > 30%. Worst-case or most-conservative S (strain) is about 20% to 30%. That is, for given F, beyond an S of about 30% upfreezing time increases; such very high strains are less conservative than S = 30%. Arguments that S should be higher than 30% are, therefore, irrelevant.

- o Sensitivity of R100 (100-year reliability) to S and F values beyond expected extremes (up to worst physically possible heave strain, S=100%) shows:

  - For a 1.5 ft cover R100 exceeds 96% for all S < 100% and F $\leq$ 0.5 and exceeds 98.8% for all F $\leq$ 0.3.

  - For a 1.7 ft cover R100 exceeds 98% for all S < 100% and F $\leq$ 0.5 and exceeds 99.7% for all F $\leq$ 0.3..

  - For a 1.8 ft cover R100 exceeds 99% for all S < 100% and F $\leq$ 0.5 and equals or exceeds 99.9% for all F $\leq$ 0.3.

Please call if you need any clarification, elaboration or further discussion.

Sincerely,

GOLDER ASSOCIATES

Charles L. Vita

Charles L. Vita, P.E.
Senior Project Manager

CLV/111/151

Attachment (UPFREEZ5Y output)

Table 1
Upfreezing Equation (Eq. 1) and UPFREEZ5 Output

$$U = (X - A - T) * S * F * C$$

U = Upfreezing distance of buried object. In program UPFREEZ5 U is the cover increment (0.1 ft) for DELTA and H1=TCT for UP.YRS for total cover thickness TCT.

X = Projected length of buried object.

Note all projected lengths are perpendicular to the freezing front--i.e., vertical for flat ground and for sloping ground inclined from vertical toward horizontal by the slope angle of the ground.

A = Projected length of buried object required for adfreeze to overcome anchorage before uplifting can occur.

T = Projected length of buried object below maximum depth of freezing front. T is a function of object depth below top of cover. T and C are functionally related.

Note (X - A - T) is the effective portion of the object over which frost heaving can cause upfreezing. (X - A) is called EPS.UF in program UPFEEZE5.

S = Average heave strain over the distance (X - A - T).

F = Heave fraction not recovered on thawing.

C = Effective number of complete freeze thaw cycles over the distance (X - A - T). C is modeled as a random variable to reflect the uncertainty in future yearly thermal loads (freeze indexes, FI) and thermal capacity of the waste pile and cover soil (to maintain frost out of the waste pile or maximize T). Thermal loads are modeled using a lognormal distribution based on a conservative interpretation of 1949-85 Waukegan FI estimates. Thermal capacity (TC) is modeled using the modified Berggren equation and thermal geotechnical assumptions, as stated on the program UPFREEZ5 output. In UPFREEZ5 C, is estimated as FP (probability of having frost to the depth H1 in any year) and FPY (return period for a frost table at H1). Results are displayed as averages (AVG) ± a coefficient of variation (CV%).

Program UPFREEZ5: 1. Searches for (X - A - T)*C which maximizes U for given S and F, subject to (X-A)<EPS.UF. Maximum (X-A) is displayed as H3M. 2. Calculates average years to upfreeze through an increment (set=0.1 ft) of cover, DELTA, estimated as [0.1/(X-A-T)*C*F*S]. 3. Calculates average years to upfreeze the object, UP.YRS, as the sum of DELTA for H1 from 0.1 to the total cover thickness, TCT. A minus one standard deviation estimate, LBOND, an absolute lower bound, ABD, and the estimated reliability (probability) that upfreezing through the cover will take 100 years or more, R100, are also calculated and displayed.

A more refined estimate for years of protection against upfreezing for a cover of thickness TCT is UP.YRS for H1=TCT using cover thermal properties plus the difference in DELTA for H1=TCT between UP.YRS for the cover thermal properties in H3 and UP.YRS for waste pile properties in H3.

All estimates are conditional on S and F, and EPS.UF.

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*****************************  PROGRAM UPFREEZ5Y  *****************************
SAVED UNDER FILE NAME: UPF1-5Y                          DATE: 12-18-1986
                                                         TIME: 15:55:50

                    PROBABILISTIC GEOTECHNICAL THERMAL ANALYSIS
                        1-LAYER FINE-GRAINED COVER SYSTEM

                    MODIFIED BERGGREN EQUATION WITH KERSTEN K'S

                              PROPERTIES OF COVER

COVER LAYER DRY DENSITY=100 PCF,  WATER CONTENT =20.3% (80% SAT)     100% S=25.4%
AVERAGE HEAVE STRAIN = 10% TO 50%
FRACTION OF HEAVE NOT RECOVERED ON THAWING (R) = 0.10 TO 0.50
LAMBDA*SQR[N-FACTOR]: AVG=0.48;  SD=0.00
(COVER AND WASTE PILE USE THE SAME VALUES)


                            PROPERTIES OF WASTE PILE

FINE-GRAINED SOIL
UNFROZEN DRY DENSITY = 100. [PCF], WATER CONTENT = 20% (80% SAT)     100% S=25.4%
AVERAGE HEAVE STRAIN = 10% TO 50%
FRACTION OF HEAVE NOT RECOVERED ON THAWING (R) = 0.10 TO 0.50

                            THERMAL LOAD INFORMATION

FREEZE INDEX (FI) FOR WAUKEKGAN ASSUMED LOGNORMAL WITH MEAN & STANDARD DEVIATION
FROM HISTORICAL DATA 1949-50 TO 1984-85 EXCEPT 1982-83 (TOTAL = 35 YEARS)
LOGNORMAL FREEZE INDEX (THERMAL LOAD): MEAN=848, MEDIAN=800, SD=320, CV=0.378,
          SD[LN FI]=0.365, SKEWNESS=1.277                              HOWEVER:
CONSERVATIVE LOGNORMAL ENVELOPE USED FOR FREEZE INDEX: MEDIAN = 875, MEAN = 935
                                                        SD[LN FI] =0.365
ALL YEARS HAVE HISTORICAL FI FREQUENCY <= FORCASTED (PREDICTED) PROBABILITIES
 (1983-84 [FI=1200] LIES ON THE ENVELOPE ALL OTHER YEARS ARE BELOW)


OBJECT UPFREEZING INFORMATION--EQUATION:   U = (X - A - T) * S * R * C

UPFREEZING ASSUMPTIONS:
EFFECTIVE PARTICLE SIZE (X - A) IS EPS.UF = 0.30 FT
AVERAGE HEAVE STRAIN (S) = 10 %  TO 50 %
FRACTION OF HEAVE NOT RECOVERED ON THAWING (R) = 0.10 TO 0.50
EFFECTIVE NUMBER OF COMPLETE FREEZE THAW CYCLES (C) = NUMBER OF FREEZE SEASONS
                                                      (YEARS) * P.H3
*NOTE:  BOTH C AND P.H3 ARE DEPTH DEPENDENT
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S=10% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF, WATER CONT.= 29.7% C/L=.0085 L=3658 KF=1.15
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF WATER CONT.= 29.7% C/L=.0085 L=3658 KF=1.15

BOT COVER AND WASTE PILE USE HEAVE STRAIN, S = 10%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE	
					--------- YEARS					PROB.%	YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DELTA
1.0	408	14	.976	1.9	1	350	0.2	349	333	100.00	47	.3	46
1.1	493	14	.931	4.9	1	403	0.6	400	367	100.00	59	.3	59
1.2	587	14	.851	9.9	1	472	1.7	464	400	100.00	81	.3	80
1.3	689	14	.737	16.7	1	572	3.8	550	433	100.00	119	.3	118
1.4	799	14	.601	24.6	2	721	7.5	668	467	100.00	179	.2	178
1.5	917	14	.463	32.9	2	952	12.8	830	500	100.00	282	.2	281
1.6	1044	14	.337	41.2	4	1330	20.0	1063	533	100.00	474	.2	472
1.7	1178	14	.233	49.0	6	1986	28.7	1417	567	100.00	839	.2	834
1.8	1321	14	.154	56.1	9	3183	38.0	1972	600	100.00	1554	.2	1545
1.9	1472	14	.097	62.3	17	5457	47.3	2877	633	100.00	2995	.2	2977
2.0	1630	14	.059	67.8	31	9936	55.7	4403	667	100.00	5964	.2	5927
2.1	1798	14	.035	72.4	60	18882	62.9	7009	700	100.00	11927	.1	11909
2.2	1973	14	.020	76.4	119	37055	68.9	11535	733	100.00	24420	.1	24380
2.3	2156	14	.011	79.8	244	74850	73.8	19592	767	100.00	51171	.1	51088
2.4	2348	14	.006	82.6	512	155099	77.9	34265	800	100.00	109325	.1	109145
2.5	2548	14	.003	85.0	1093	328434	81.3	61522	833	100.00	237345	.1	236955

S=10% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF, WATER CONT.= 29.7% C/L=.0085 L=3658 KF=1.15
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
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BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 10%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
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F	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WST'PILE
						YEARS				PROB.%	YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DEL
1.0	408	14	.976	1.9	1	175	0.2	175	167	100.00	23	.3	23
1.1	493	14	.931	4.9	1	201	0.6	200	183	100.00	29	.3	29
1.2	587	14	.851	9.9	1	236	1.7	232	200	100.00	40	.3	40
1.3	689	14	.737	16.7	1	286	3.8	275	217	100.00	60	.3	59
1.4	799	14	.601	24.6	2	361	7.5	334	233	100.00	89	.2	89
1.5	917	14	.463	32.9	2	476	12.8	415	250	100.00	141	.2	141
1.6	1044	14	.337	41.2	4	665	20.0	532	267	100.00	237	.2	236
1.7	1178	14	.233	49.0	6	993	28.7	708	283	100.00	419	.2	417
1.8	1321	14	.154	56.1	9	1591	38.0	986	300	100.00	777	.2	773
1.9	1472	14	.097	62.3	17	2729	47.3	1439	317	100.00	1497	.2	1488
2.0	1630	14	.059	67.8	31	4968	55.7	2202	333	100.00	2982	.2	2963
2.1	1798	14	.035	72.4	60	9441	62.9	3505	350	100.00	5964	.1	5954
2.2	1973	14	.020	76.4	119	18527	68.9	5768	367	100.00	12210	.1	12190
2.3	2156	14	.011	79.8	244	37425	73.8	9796	383	100.00	25586	.1	25544
2.4	2348	14	.006	82.6	512	77549	77.9	17132	400	100.00	54663	.1	54573
2.5	2548	14	.003	85.0	1093	164217	81.3	30761	417	100.00	118673	.1	118477

S=10% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZSY -- 12-18-1986
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					--------- YEARS					PROB.%	YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DELTA
1.0	408	14	.976	1.9	1	117	0.2	116	111	100.00	16	.3	15
1.1	493	14	.931	4.9	1	134	0.6	133	122	100.00	20	.3	20
1.2	587	14	.851	9.9	1	157	1.7	155	133	100.00	27	.3	27
1.3	689	14	.737	16.7	1	191	3.8	183	144	100.00	40	.3	39
1.4	799	14	.601	24.6	2	240	7.5	223	156	100.00	60	.2	59
1.5	917	14	.463	32.9	2	317	12.8	277	167	100.00	94	.2	94
1.6	1044	14	.337	41.2	4	443	20.0	354	178	100.00	158	.2	157
1.7	1178	14	.233	49.0	6	662	28.7	472	189	100.00	280	.2	278
1.8	1321	14	.154	56.1	9	1061	38.0	657	200	100.00	518	.2	515
1.9	1472	14	.097	62.3	17	1819	47.3	959	211	100.00	998	.2	992
2.0	1630	14	.059	67.8	31	3312	55.7	1468	222	100.00	1988	.2	1976
2.1	1798	14	.035	72.4	60	6294	62.9	2336	233	100.00	3976	.1	3970
2.2	1973	14	.020	76.4	119	12352	68.9	3845	244	100.00	8140	.1	8127
2.3	2156	14	.011	79.8	244	24950	73.8	6531	256	100.00	17057	.1	17029
2.4	2348	14	.006	82.6	512	51700	77.9	11422	267	100.00	36442	.1	36382
2.5	2548	14	.003	85.0	1093	109478	81.3	20507	278	100.00	79115	.1	78985

S=10% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
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OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF, WATER CONT.= 29.7% C/L=.0085 L=3658 KF=1.15
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF WATER CONT.= 29.7% C/L=.0085 L=3658 KF=1.15

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 10%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

FT H1	F-DEG*DAYS TCAVG	&CV%	PROB. FPAVG	&CV%	COVER THERMAL PROPERTIES IN H3 (R1.3=1) FPY	UP.YRS	CV%	LBOND	ABD	R100	WST'PILE YEARS DELTA	FT H3M	YEARS DE
					YEARS			YEARS		PROB.%			
1.0	408	14	.976	1.9	1	87	0.2	87	83	0.00	12	.3	12
1.1	493	14	.931	4.9	1	101	0.6	100	92	84.27	15	.3	15
1.2	587	14	.851	9.9	1	118	1.7	116	100	100.00	20	.3	20
1.3	689	14	.737	16.7	1	143	3.8	138	108	100.00	30	.3	30
1.4	799	14	.601	24.6	2	180	7.5	167	117	100.00	45	.2	45
1.5	917	14	.463	32.9	2	238	12.8	207	125	100.00	71	.2	70
1.6	1044	14	.337	41.2	4	332	20.0	266	133	100.00	118	.2	118
1.7	1178	14	.233	49.0	6	497	28.7	354	142	100.00	210	.2	209
1.8	1321	14	.154	56.1	9	796	38.0	493	150	100.00	389	.2	386
1.9	1472	14	.097	62.3	17	1364	47.3	719	158	100.00	749	.2	744
2.0	1630	14	.059	67.8	31	2484	55.7	1101	167	100.00	1491	.2	1482
2.1	1798	14	.035	72.4	60	4720	62.9	1752	175	100.00	2982	.1	2977
2.2	1973	14	.020	76.4	119	9264	68.9	2884	183	100.00	6105	.1	6095
2.3	2156	14	.011	79.8	244	18713	73.8	4898	192	100.00	12793	.1	12772
2.4	2348	14	.006	82.6	512	38775	77.9	8566	200	100.00	27331	.1	27286
2.5	2548	14	.003	85.0	1093	82108	81.3	15380	208	100.00	59336	.1	59239

S=10% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
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HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
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LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
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R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE	
					---------- YEARS ----------					PROB.%	YEARS FT		YEARS
H1	TCAVG	&CV%	FPAVG	&CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DELTA
1	408	14	.976	1.9	1	70	0.2	70	67	0.00	9	.3	9
1.1	493	14	.931	4.9	1	81	0.6	80	73	0.00	12	.3	12
1.2	587	14	.851	9.9	1	94	1.7	93	80	0.03	16	.3	16
1.3	689	14	.737	16.7	1	114	3.8	110	87	99.95	24	.3	24
1.4	799	14	.601	24.6	2	144	7.5	134	93	100.00	36	.2	36
1.5	917	14	.463	32.9	2	190	12.8	166	100	100.00	56	.2	56
1.6	1044	14	.337	41.2	4	266	20.0	213	107	100.00	95	.2	94
1.7	1178	14	.233	49.0	6	397	28.7	283	113	100.00	168	.2	167
1.8	1321	14	.154	56.1	9	637	38.0	394	120	100.00	311	.2	309
1.9	1472	14	.097	62.3	17	1091	47.3	575	127	100.00	599	.2	595
2.0	1630	14	.059	67.8	31	1987	55.7	881	133	100.00	1193	.2	1185
2.1	1798	14	.035	72.4	60	3776	62.9	1402	140	100.00	2385	.1	2382
2.2	1973	14	.020	76.4	119	7411	68.9	2307	147	100.00	4884	.1	4876
2.3	2156	14	.011	79.8	244	14970	73.8	3918	153	100.00	10234	.1	10218
2.4	2348	14	.006	82.6	512	31020	77.9	6853	160	100.00	21865	.1	21829
2.5	2548	14	.003	85.0	1093	65687	81.3	12304	167	100.00	47469	.1	47391

S=20% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

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FROZEN DRY DENS. = 80 PCF, WATER CONT.= 37.7% C/L=.0076 L=4124 KF=1.18
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HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
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FT H1	F-DEG*DAYS TCAVG	&CV%	PROB. FPAVG	&CV%	COVER THERMAL PROPERTIES IN H3 (R1.3=1) FPY	YEARS UP.YRS	CV%	LBOND	ABD	PROB.% R100	YEARS DELTA	FT H3M	WST'PILE YEARS DEL
1.0	533	14	.901	6.8	1	196	1.1	194	167	100.00	39	.3	38
1.1	645	14	.789	13.6	1	244	3.0	237	183	100.00	58	.2	58
1.2	767	14	.640	22.3	2	318	6.7	296	200	100.00	90	.2	89
1.3	900	14	.482	31.8	2	438	12.6	383	217	100.00	152	.2	151
1.4	1044	14	.336	41.3	4	653	21.0	516	233	100.00	278	.2	277
1.5	1199	14	.220	50.1	6	1066	31.1	734	250	100.00	546	.2	542
1.6	1364	14	.135	58.0	11	1884	41.6	1100	267	100.00	1091	.1	1090
1.7	1540	14	.079	64.8	22	3561	51.5	1727	283	100.00	2262	.1	2258
1.8	1726	14	.044	70.5	45	7146	60.1	2849	300	100.00	4909	.1	4899
1.9	1923	14	.024	75.4	98	15136	67.4	4936	317	100.00	11070	.1	11046
2.0	2131	14	.012	79.4	221	33545	73.3	8958	333	100.00	25749	.1	25694
2.1	2350	14	.006	82.6	515	77133	78.0	16946	350	100.00	61427	.1	61295
2.2	2579	14	.003	85.4	1229	182625	81.8	33218	367	100.00	149558	.1	149237
2.3	2818	14	.001	87.6	2991	442460	84.8	67086	383	100.00	370111	.1	369323
2.4	3069	14	.001	89.5	7402	1091392	87.3	%138865	400	100.00	927752	.1	92579
6													
2.5	3330	14	.000	91.0	18555	2729692	89.3	%293319	417	100.00	2348848	.1	234398
0													

S=20% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

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FT H1	F-DEG*DAYS TCAVG	&CV%	PROB. FPAVG	&CV%	COVER THERMAL PROPERTIES IN H3 (R1.3=1) FPY	UP.YRS	CV%	LBOND	ABD	PROB.% R100	WST'PILE YEARS DELTA	FT H3M	YEARS DELTA
1.0	533	14	.901	6.8	1	98	1.1	97	83	2.60	19	.3	19
1.1	645	14	.789	13.6	1	122	3.0	118	92	100.00	29	.2	29
1.2	767	14	.640	22.3	2	159	6.7	148	100	100.00	45	.2	45
1.3	900	14	.482	31.8	2	219	12.6	191	108	100.00	76	.2	76
1.4	1044	14	.336	41.3	4	327	21.0	258	117	100.00	139	.2	138
1.5	1199	14	.220	50.1	6	533	31.1	367	125	100.00	273	.2	271
1.6	1364	14	.135	58.0	11	942	41.6	550	133	100.00	546	.1	545
1.7	1540	14	.079	64.8	22	1780	51.5	864	142	100.00	1131	.1	1129
1.8	1726	14	.044	70.5	45	3573	60.1	1424	150	100.00	2455	.1	2450
1.9	1923	14	.024	75.4	98	7568	67.4	2468	158	100.00	5535	.1	5523
2.0	2131	14	.012	79.4	221	16773	73.3	4479	167	100.00	12874	.1	12847
2.1	2350	14	.006	82.6	515	38566	78.0	8473	175	100.00	30713	.1	30647
2.2	2579	14	.003	85.4	1229	91313	81.8	16609	183	100.00	74779	.1	74619
2.3	2818	14	.001	87.6	2991	221230	84.8	33543	192	100.00	185056	.1	184661
2.4	3069	14	.001	89.5	7402	545696	87.3	69433	200	100.00	463876	.1	462898
2.5	3330	14	.000	91.0	18555	1364846	89.3	%146659	208	100.00	1174424	.1	117199

0

S=20% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
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F	F-DEG*DAYS		PROB.			COVER THERMAL PROPERTIES IN H3 (R1.3=1)						WST'PILE	
						--------- YEARS		----------		PROB.%	YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DEL
1.0	533	14	.901	6.8	1	65	1.1	65	56	0.00	13	.3	13
1.1	645	14	.789	13.6	1	81	3.0	79	61	0.00	19	.2	19
1.2	767	14	.640	22.3	2	106	6.7	99	67	79.57	30	.2	30
1.3	900	14	.482	31.8	2	146	12.6	128	72	99.37	51	.2	50
1.4	1044	14	.336	41.3	4	218	21.0	172	78	99.61	93	.2	92
1.5	1199	14	.220	50.1	6	355	31.1	245	83	99.65	182	.2	181
1.6	1364	14	.135	58.0	11	628	41.6	367	89	99.78	364	.1	363
1.7	1540	14	.079	64.8	22	1187	51.5	576	94	99.92	754	.1	753
1.8	1726	14	.044	70.5	45	2382	60.1	950	100	100.00	1636	.1	1633
1.9	1923	14	.024	75.4	98	5045	67.4	1645	106	100.00	3690	.1	3682
2.0	2131	14	.012	79.4	221	11182	73.3	2986	111	100.00	8583	.1	8565
2.1	2350	14	.006	82.6	515	25711	78.0	5649	117	100.00	20476	.1	20432
2.2	2579	14	.003	85.4	1229	60875	81.8	11073	122	100.00	49853	.1	49746
2.3	2818	14	.001	87.6	2991	147487	84.8	22362	128	100.00	123370	.1	123108
2.4	3069	14	.001	89.5	7402	363797	87.3	46288	133	100.00	309251	.1	308599
2.5	3330	14	.000	91.0	18555	909897	89.3	97773	139	100.00	782949	.1	781327

S=20% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
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HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
LAMBDA*SQRIN-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

FT H1	F-DEG*DAYS TCAVG	&CV%	PROB. FPAVG	&CV%	FPY	COVER THERMAL PROPERTIES IN H3 (R1.3=1) YEARS UP.YRS	CV%	LBOND	ABD	PROB.% R100	YEARS DELTA	FT H3M	WST'PILE YEARS DELTA
1.0	533	14	.901	6.8	1	49	1.1	48	42	0.00	10	.3	10
1.1	645	14	.789	13.6	1	61	3.0	59	46	0.00	14	.2	14
1.2	767	14	.640	22.3	2	79	6.7	74	50	0.01	22	.2	22
1.3	900	14	.482	31.8	2	110	12.6	96	54	75.54	38	.2	38
1.4	1044	14	.336	41.3	4	163	21.0	129	58	96.89	70	.2	69
1.5	1199	14	.220	50.1	6	266	31.1	184	63	98.46	136	.2	135
1.6	1364	14	.135	58.0	11	471	41.6	275	67	99.02	273	.1	272
1.7	1540	14	.079	64.8	22	890	51.5	432	71	99.44	565	.1	564
1.8	1726	14	.044	70.5	45	1787	60.1	712	75	99.72	1227	.1	1225
1.9	1923	14	.024	75.4	98	3784	67.4	1234	79	99.88	2767	.1	2762
2.0	2131	14	.012	79.4	221	8386	73.3	2239	83	99.95	6437	.1	6423
2.1	2350	14	.006	82.6	515	19283	78.0	4237	88	99.98	15357	.1	15324
2.2	2579	14	.003	85.4	1229	45656	81.8	8305	92	100.00	37390	.1	37309
2.3	2818	14	.001	87.6	2991	110615	84.8	16772	96	100.00	92528	.1	92331
2.4	3069	14	.001	89.5	7402	272848	87.3	34716	100	100.00	231938	.1	231449
2.5	3330	14	.000	91.0	18555	682423	89.3	73330	104	100.00	587212	.1	585995

S=20% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 80 PCF, WATER CONT.= 37.7% C/L=.0076 L=4124 KF=1.18
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 80 PCF WATER CONT.= 37.7% C/L=.0076 L=4124 KF=1.18

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 20%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
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LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE	
FT	F-DEG*DAYS		PROB.		--------- YEARS ----------					PROB.%	YEARS	FT	YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DEL
1.0	533	14	.901	6.8	1	39	1.1	39	33	0.00	8	.3	8
1.1	645	14	.789	13.6	1	49	3.0	47	37	0.00	12	.2	12
1.2	767	14	.640	22.3	2	64	6.7	59	40	0.00	18	.2	18
1.3	900	14	.482	31.8	2	88	12.6	77	43	13.29	30	.2	30
1.4	1044	14	.336	41.3	4	131	21.0	103	47	86.96	56	.2	55
1.5	1199	14	.220	50.1	6	213	31.1	147	50	96.28	109	.2	108
1.6	1364	14	.135	58.0	11	377	41.6	220	53	98.04	218	.1	218
1.7	1540	14	.079	64.8	22	712	51.5	345	57	98.90	452	.1	452
1.8	1726	14	.044	70.5	45	1429	60.1	570	60	99.43	982	.1	980
1.9	1923	14	.024	75.4	98	3027	67.4	987	63	99.73	2214	.1	2209
2.0	2131	14	.012	79.4	221	6709	73.3	1792	67	99.88	5150	.1	5139
2.1	2350	14	.006	82.6	515	15427	78.0	3389	70	99.95	12285	.1	12259
2.2	2579	14	.003	85.4	1229	36525	81.8	6644	73	99.98	29912	.1	29847
2.3	2818	14	.001	87.6	2991	88492	84.8	13417	77	99.99	74022	.1	73865
2.4	3069	14	.001	89.5	7402	218278	87.3	27773	80	100.00	185550	.1	185159
2.5	3330	14	.000	91.0	18555	545938	89.3	58664	83	100.00	469770	.1	468796

S=30% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

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UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 70 PCF, WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
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BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 30%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

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R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

	F-DEG*DAYS		PROB.			COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE	
						--------- YEARS ----------				PROB.%	YEARS	FT	YEARS	
H1	TCAVG	&CV%	FPAVG	&CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DELTA	
1.0	667	14	.763	15.2	1	162	3.8	156	111	100.00	46	.2	46	
1.1	807	14	.591	25.2	2	225	8.7	205	122	100.00	79	.2	78	
1.2	961	14	.417	35.9	3	339	16.7	283	133	100.00	150	.2	149	
1.3	1128	14	.269	46.2	5	565	27.1	412	144	100.00	301	.1	300	
1.4	1308	14	.160	55.5	9	1029	38.5	632	156	100.00	627	.1	625	
1.5	1501	14	.089	63.4	19	2044	49.7	1029	167	100.00	1404	.1	1400	
1.6	1708	14	.047	70.0	42	4413	59.6	1785	178	100.00	3335	.1	3327	
1.7	1928	14	.023	75.5	100	10236	67.7	3304	189	100.00	8310	.1	8288	
1.8	2162	14	.011	79.9	249	25144	74.2	6489	200	100.00	21506	.1	21448	
1.9	2408	14	.005	83.4	645	64570	79.2	13412	211	100.00	57346	.1	57192	
2.0	2669	14	.002	86.3	1720	171518	83.1	28914	222	100.00	156550	.1	156130	
2.1	2942	14	.001	88.6	4696	467390	86.2	64501	233	100.00	435194	.1	434041	
2.2	3229	14	.000	90.5	13056	1298283	88.6	%147883	244	100.00	1226591	.1	122339	6
2.3	3529	14	.000	92.0	36798	3657845	90.5	%346534	256	100.00	3492534	.1	348365	1
2.4	3843	14	.000	93.2	104776	10412340	92.1	%826244	267	100.00	%10016460	.1	9991	550
2.5	4170	14	.000	94.2	300496	29852500	93.3	%1997194	278	100.00	%28863850	.1	%28	794100

S=30% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

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BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 30%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
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ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

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R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE	
F-	F-DEG*DAYS		PROB.		---------- YEARS ----------					PROB.%	YEARS	FT	YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DEL
1.0	667	14	.763	15.2	1	81	3.8	78	56	0.00	23	.2	23
1.1	807	14	.591	25.2	2	112	8.7	102	61	89.42	39	.2	39
1.2	961	14	.417	35.9	3	170	16.7	141	67	99.32	75	.2	75
1.3	1128	14	.269	46.2	5	282	27.1	206	72	99.44	150	.1	150
1.4	1308	14	.160	55.5	9	514	38.5	316	78	99.55	313	.1	313
1.5	1501	14	.089	63.4	19	1022	49.7	514	83	99.75	702	.1	700
1.6	1708	14	.047	70.0	42	2207	59.6	892	89	99.90	1668	.1	1663
1.7	1928	14	.023	75.5	100	5118	67.7	1652	94	99.98	4155	.1	4144
1.8	2162	14	.011	79.9	249	12572	74.2	3245	100	100.00	10753	.1	10724
1.9	2408	14	.005	83.4	645	32285	79.2	6706	106	100.00	28673	.1	28596
2.0	2669	14	.002	86.3	1720	85759	83.1	14457	111	100.00	78275	.1	78065
2.1	2942	14	.001	88.6	4696	233695	86.2	32250	117	100.00	217597	.1	217020
2.2	3229	14	.000	90.5	13056	649141	88.6	73941	122	100.00	613295	.1	611698
2.3	3529	14	.000	92.0	36798	1828922	90.5	%173267	128	100.00	1746267	.1	174182
5													
2.4	3843	14	.000	93.2	104776	5206170	92.1	%413122	133	100.00	5008229	.1	499577
5													
2.5	4170	14	.000	94.2	300496	14926250	93.3	%998597	139	100.00	%14431930	.1	%143
97050													

S=30% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

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FROZEN DRY DENS. = 70 PCF, WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
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BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 30%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.30,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
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					COVER THERMAL PROPERTIES IN H3 (R1.3=1)						WST'PILE	
F-	F-DEG*DAYS		PROB.		---------- YEARS ----------					PROB.%	YEARS FT	YEARS
H'	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA H3M	DELTA
1.[illegible]	667	14	.763	15.2	1	54	3.8	52	37	0.00	15 .2	15
1.1	807	14	.591	25.2	2	75	8.7	68	41	0.01	26 .2	26
1.2	961	14	.417	35.9	3	113	16.7	94	44	75.59	50 .2	50
1.3	1128	14	.269	46.2	5	188	27.1	137	48	96.11	100 .1	100
1.4	1308	14	.160	55.5	9	343	38.5	211	52	98.05	209 .1	208
1.5	1501	14	.089	63.4	19	681	49.7	343	56	98.89	468 .1	467
1.6	1708	14	.047	70.0	42	1471	59.6	595	59	99.44	1112 .1	1109
1.7	1928	14	.023	75.5	100	3412	67.7	1101	63	99.76	2770 .1	2763
1.8	2162	14	.011	79.9	249	8381	74.2	2163	67	99.90	7169 .1	7149
1.9	2408	14	.005	83.4	645	21523	79.2	4471	70	99.96	19115 .1	19064
2.0	2669	14	.002	86.3	1720	57173	83.1	9638	74	99.99	52183 .1	52043
2.1	2942	14	.001	88.6	4696	155797	86.2	21500	78	100.00	145065 .1	144680
2.2	3229	14	.000	90.5	13056	432761	88.6	49294	81	100.00	408864 .1	407799
2.3	3529	14	.000	92.0	36798	1219282	90.5	%115511	85	100.00	1164178 .1	116121
7												
2.4	3843	14	.000	93.2	104776	3470781	92.1	%275415	89	100.00	3338820 .1	333051
7												
2.5	4170	14	.000	94.2	300496	9950832	93.3	%665731	93	100.00	9621285 .1	959803
5												

S=30% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
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HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
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ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

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CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)						WST'PILE		
					--------- YEARS ----------					PROB.%	YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DEL
1.0	667	14	.763	15.2	1	41	3.8	39	28	0.00	11	.2	11
1.1	807	14	.591	25.2	2	56	8.7	51	31	0.00	20	.2	20
1.2	961	14	.417	35.9	3	85	16.7	71	33	14.12	38	.2	37
1.3	1128	14	.269	46.2	5	141	27.1	103	36	86.19	75	.1	75
1.4	1308	14	.160	55.5	9	257	38.5	158	39	95.68	157	.1	156
1.5	1501	14	.089	63.4	19	511	49.7	257	42	97.88	351	.1	350
1.6	1708	14	.047	70.0	42	1103	59.6	446	44	98.96	834	.1	832
1.7	1928	14	.023	75.5	100	2559	67.7	826	47	99.53	2078	.1	2072
1.8	2162	14	.011	79.9	249	6286	74.2	1622	50	99.81	5376	.1	5362
1.9	2408	14	.005	83.4	645	16143	79.2	3353	53	99.93	14337	.1	14298
2.0	2669	14	.002	86.3	1720	42880	83.1	7228	56	99.97	39138	.1	39033
2.1	2942	14	.001	88.6	4696	116848	86.2	16125	58	99.99	108798	.1	108510
2.2	3229	14	.000	90.5	13056	324571	88.6	36971	61	100.00	306648	.1	305849
2.3	3529	14	.000	92.0	36798	914461	90.5	86634	64	100.00	873133	.1	870913
2.4	3843	14	.000	93.2	104776	2603086	92.1	%206561	67	100.00	2504115	.1	249788
8													
2.5	4170	14	.000	94.2	300496	7463125	93.3	%499298	69	100.00	7215964	.1	719852
6													

S=30% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 70 PCF, WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 70 PCF WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 30%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE		
					---------- YEARS ----------					PROB.%	YEARS	FT	YEARS
H	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DELTA
1.0	667	14	.763	15.2	1	32	3.8	31	22	0.00	9	.2	9
1.1	807	14	.591	25.2	2	45	8.7	41	24	0.00	16	.2	16
1.2	961	14	.417	35.9	3	68	16.7	57	27	0.22	30	.2	30
1.3	1128	14	.269	46.2	5	113	27.1	82	29	66.62	60	.1	60
1.4	1308	14	.160	55.5	9	206	38.5	126	31	92.16	125	.1	125
1.5	1501	14	.089	63.4	19	409	49.7	206	33	96.70	281	.1	280
1.6	1708	14	.047	70.0	42	883	59.6	357	36	98.44	667	.1	665
1.7	1928	14	.023	75.5	100	2047	67.7	661	38	99.30	1662	.1	1658
1.8	2162	14	.011	79.9	249	5029	74.2	1298	40	99.71	4301	.1	4290
1.9	2408	14	.005	83.4	645	12914	79.2	2682	42	99.89	11469	.1	11438
2.0	2669	14	.002	86.3	1720	34304	83.1	5783	44	99.96	31310	.1	31226
2.1	2942	14	.001	88.6	4696	93478	86.2	12900	47	99.98	87039	.1	86808
2.2	3229	14	.000	90.5	13056	259657	88.6	29577	49	99.99	245318	.1	244679
2.3	3529	14	.000	92.0	36798	731569	90.5	69307	51	100.00	698507	.1	696730
2.4	3843	14	.000	93.2	104776	2082468	92.1	%165249	53	100.00	2003292	.1	199831
0													
2.5	4170	14	.000	94.2	300496	5970500	93.3	%399439	56	100.00	5772771	.1	575882
1													

S=40% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF, WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
LAMBDA*SQRIN-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

	F-DEG*DAYS		PROB.			COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE	
						--------- YEARS					PROB.%	YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M		DEL
1.0	803	14	.597	24.8	2	163	9.0	148	83	100.00	65	.2		85
1.1	971	14	.406	36.6	3	261	17.9	214	92	99.99	130	.1		130
1.2	1156	14	.248	47.8	5	461	29.3	326	100	100.00	271	.1		270
1.3	1356	14	.138	57.7	11	907	41.8	528	108	100.00	621	.1		619
1.4	1573	14	.071	65.9	25	1991	53.6	924	117	100.00	1546	.1		1542
1.5	1806	14	.034	72.6	62	4817	63.7	1749	125	100.00	4106	.1		4093
1.6	2055	14	.016	78.0	164	12603	71.7	3573	133	100.00	11467	.1		11430
1.7	2319	14	.007	82.2	459	34992	77.7	7793	142	100.00	33311	.1		33203
1.8	2600	14	.003	85.6	1332	101511	82.3	17936	150	100.00	99725	.1		99404
1.9	2897	14	.001	88.2	3989	304094	85.8	43075	158	100.00	305441	.1		304468
2.0	3210	14	.000	90.3	12218	932545	88.5	%106958	167	100.00	951462	.1		94848
4														
2.1	3539	14	.000	92.0	38059	2908290	90.6	%272578	175	100.00	3000029	.1		299087
4														
2.2	3884	14	.000	93.4	120001	9177257	92.3	%708815	183	100.00	9537904	.1		950960
7														
2.3	4246	14	.000	94.4	381516	29186100	93.6	%1872131	192	100.00	%30479780	.1		%30
391900														
2.4	4623	14	.000	95.3	%1219190	67673400	94.4	%3806713	200	100.00	%46494790	.3		%
46631210														
2.5	5016	14	.000	96.0	%3906034	%118387000	94.9	%5983238	208	100.00	%54932500	.3		
%55294600														

S=40% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT
TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF, WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

F	F-DEG*DAYS		PROB.			COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE		
						YEARS					PROB.%		YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100		DELTA	H3M		DELTA
1.0	803	14	.597	24.8	2	82	9.0	74	42	0.57		33	.2		32
1.1	971	14	.406	36.6	3	130	17.9	107	46	90.46		65	.1		65
1.2	1156	14	.248	47.8	5	231	29.3	163	50	97.72		135	.1		135
1.3	1356	14	.138	57.7	11	454	41.8	264	54	98.63		311	.1		310
1.4	1573	14	.071	65.9	25	995	53.6	462	58	99.26		773	.1		771
1.5	1806	14	.034	72.6	62	2408	63.7	874	63	99.67		2053	.1		2046
1.6	2055	14	.016	78.0	164	6302	71.7	1786	67	99.88		5734	.1		5715
1.7	2319	14	.007	82.2	459	17496	77.7	3897	71	99.96		16656	.1		16602
1.8	2600	14	.003	85.6	1332	50755	82.3	8968	75	99.99		49863	.1		49702
1.9	2897	14	.001	88.2	3989	152047	85.8	21537	79	100.00		152721	.1		152234
2.0	3210	14	.000	90.3	12218	466273	88.5	53479	83	100.00		475731	.1		474242
2.1	3539	14	.000	92.0	38059	1454145	90.6	%136289	88	100.00		1500014	.1		1495437
2.2	3884	14	.000	93.4	120001	4588629	92.3	%354407	92	100.00		4768952	.1		4754804
2.3	4246	14	.000	94.4	381516	14593050	93.6	%936065	96	100.00		%15239890	.1		%15195950
2.4	4623	14	.000	95.3	%1219190	33836690	94.4	%1903356	100	100.00		%23247400	.3		%23315610
2.5	5016	14	.000	96.0	%3906034	59193510	94.9	%2991619	104	100.00		%27466250	.3		%27647300

S=40% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF, WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.30,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE	
F-	F-DEG*DAYS		PROB.		---------- YEARS			----------		PROB.%	YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DEL
1.0	803	14	.597	24.8	2	54	9.0	49	28	0.00	22	.2	22
1.1	971	14	.406	36.6	3	87	17.9	71	31	20.07	43	.1	43
1.2	1156	14	.248	47.8	5	154	29.3	109	33	88.73	90	.1	90
1.3	1356	14	.138	57.7	11	302	41.8	176	36	96.24	207	.1	206
1.4	1573	14	.071	65.9	25	664	53.6	308	39	98.23	515	.1	514
1.5	1806	14	.034	72.6	62	1606	63.7	583	42	99.21	1369	.1	1364
1.6	2055	14	.016	78.0	164	4201	71.7	1191	44	99.69	3822	.1	3810
1.7	2319	14	.007	82.2	459	11664	77.7	2598	47	99.89	11104	.1	11068
1.8	2600	14	.003	85.6	1332	33837	82.3	5979	50	99.96	33242	.1	33135
1.9	2897	14	.001	88.2	3989	101365	85.8	14358	53	99.99	101814	.1	101489
2.0	3210	14	.000	90.3	12218	310848	88.5	35653	56	100.00	317154	.1	316161
2.1	3539	14	.000	92.0	38059	969430	90.6	90859	58	100.00	1000010	.1	996958
2.2	3884	14	.000	93.4	120001	3059086	92.3	%236272	61	100.00	3179302	.1	316986
9													
2.3	4246	14	.000	94.4	381516	9728700	93.6	%624044	64	100.00	%10159930	.1	%101
30630													
2.4	4623	14	.000	95.3	%1219190	22557800	94.4	%1268904	67	100.00	%15498260	.3	%
15543740													
2.5	5016	14	.000	96.0	%3906034	39462350	94.9	%1994413	69	100.00	%18310830	.3	%
18431530													

S=40% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZSY -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF, WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

						COVER THERMAL PROPERTIES IN H3 (R1.3=1)									WST'PILE		
FT	F-DEG*DAYS		PROB.			--------- YEARS ----------					PROB.%		YEARS	FT	YEARS		
H1	TCAVG	&CV%	FPAVG	&CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DELTA				
1.0	803	14	.597	24.8	2	41	9.0	37	21	0.00	16	.2	16				
1.1	971	14	.406	36.6	3	65	17.9	54	23	0.14	33	.1	33				
1.2	1156	14	.248	47.8	5	115	29.3	82	25	67.79	68	.1	67				
1.3	1356	14	.138	57.7	11	227	41.8	132	27	92.59	155	.1	155				
1.4	1573	14	.071	65.9	25	498	53.6	231	29	97.03	387	.1	385				
1.5	1806	14	.034	72.6	62	1204	63.7	437	31	98.73	1026	.1	1023				
1.6	2055	14	.016	78.0	164	3151	71.7	893	33	99.49	2867	.1	2858				
1.7	2319	14	.007	82.2	459	8748	77.7	1948	35	99.81	8328	.1	8301				
1.8	2600	14	.003	85.6	1332	25378	82.3	4484	38	99.94	24931	.1	24851				
1.9	2897	14	.001	88.2	3989	76023	85.8	10769	40	99.98	76360	.1	76117				
2.0	3210	14	.000	90.3	12218	233136	88.5	26740	42	99.99	237865	.1	237121				
2.1	3539	14	.000	92.0	38059	727073	90.6	68145	44	100.00	750007	.1	747719				
2.2	3884	14	.000	93.4	120001	2294315	92.3	%177204	46	100.00	2384476	.1	237740				
2																	
2.3	4246	14	.000	94.4	381516	7296526	93.6	%468033	48	100.00	7619946	.1	759797				
5																	
2.4	4623	14	.000	95.3	%1219190	16918350	94.4	%951678	50	100.00	%11623700	.3	%1				
1657800																	
2.5	5016	14	.000	96.0	%3906034	29596760	94.9	%1495810	52	100.00	%13733130	.3	%				
13823650																	

S=40% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT
TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF, WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE	
F	F-DEG*DAYS		PROB.		---------- YEARS ----------					PROB.%	YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DEL
1.0	803	14	.597	24.8	2	33	9.0	30	17	0.00	13	.2	
1.1	971	14	.406	36.6	3	52	17.9	43	18	0.00	26	.1	26
1.2	1156	14	.248	47.8	5	92	29.3	65	20	38.92	54	.1	54
1.3	1356	14	.138	57.7	11	181	41.8	106	22	87.41	124	.1	124
1.4	1573	14	.071	65.9	25	398	53.6	185	23	95.66	309	.1	308
1.5	1806	14	.034	72.6	62	963	63.7	350	25	98.23	821	.1	819
1.6	2055	14	.016	78.0	164	2521	71.7	715	27	99.30	2293	.1	2286
1.7	2319	14	.007	82.2	459	6998	77.7	1559	28	99.74	6662	.1	6641
1.8	2600	14	.003	85.6	1332	20302	82.3	3587	30	99.91	19945	.1	19881
1.9	2897	14	.001	88.2	3989	60819	85.8	8615	32	99.97	61088	.1	60894
2.0	3210	14	.000	90.3	12218	186509	88.5	21392	33	99.99	190292	.1	189697
2.1	3539	14	.000	92.0	38059	581658	90.6	54516	35	100.00	600006	.1	598175
2.2	3884	14	.000	93.4	120001	1835452	92.3	%141763	37	100.00	1907581	.1	190192
1													
2.3	4246	14	.000	94.4	381516	5837220	93.6	%374426	38	100.00	6095957	.1	607838
0													
2.4	4623	14	.000	95.3	%1219190	13534680	94.4	%761343	40	100.00	9298958	.3	9326
242													
2.5	5016	14	.000	96.0	%3906034	23677410	94.9	%1196648	42	100.00	%10986500	.3	%
11058920													

S=50% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT
TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF, WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 50%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE		
						YEARS				PROB.%	YEARS	FT		YEARS
H'	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M		DELTA
1.0	925	14	.454	33.5	2	181	15.5	153	67	99.81	92	.1		92
1.1	1119	14	.275	45.7	5	326	27.2	237	73	99.68	198	.1		197
1.2	1332	14	.149	56.6	10	664	40.5	395	80	99.69	478	.1		476
1.3	1563	14	.073	65.6	24	1538	53.4	717	87	99.86	1271	.1		1267
1.4	1813	14	.033	72.8	64	3995	64.2	1431	93	99.97	3641	.1		3628
1.5	2081	14	.014	78.5	182	11335	72.5	3115	100	100.00	11039	.1		10998
1.6	2368	14	.006	82.9	552	34327	78.8	7293	107	100.00	34945	.1		34814
1.7	2673	14	.002	86.3	1747	108934	83.4	18104	113	100.00	114271	.1		113847
1.8	2997	14	.001	89.0	5714	357434	86.8	47021	120	100.00	382729	.1		381333
1.9	3339	14	.000	91.1	19136	1200842	89.5	%126443	127	100.00	1304086	.1		1299440
2.0	3699	14	.000	92.7	65205	4100974	91.5	%349153	133	100.00	4496179	.1		4480601
2.1	4079	14	.000	94.0	224809	14158140	93.1	%983768	140	100.00	%15618150	.1		%15565750
2.2	4476	14	.000	95.0	780906	40272800	94.1	%2368210	147	100.00	%36611180	.3		%36718620
2.3	4893	14	.000	95.8	%2723563	80094170	94.8	%4179668	153	100.00	%43031560	.3		%43337810
2.4	5327	14	.000	93.5	%5166669	%132641100	94.7	%7078955	160	100.00	%62062240	.3		%62936120
2.5	5780	14	.000	82.1	%5491672	%197005500	92.4	%15049690	167	100.00	%66666670	.3		%66666670

S=50% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZSY -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF, WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 50%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)						WST'PILE	
FI	F-DEG*DAYS		PROB.		---------- YEARS ----------					PROB.%	YEARS FT	YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA H3M	DEL
1.0	925	14	.454	33.5	2	91	15.5	77	33	25.43	46 .1	46
1.1	1119	14	.275	45.7	5	163	27.2	119	37	92.45	99 .1	98
1.2	1332	14	.149	56.6	10	332	40.5	197	40	97.22	239 .1	238
1.3	1563	14	.073	65.6	24	769	53.4	359	43	98.65	636 .1	633
1.4	1813	14	.033	72.8	64	1997	64.2	716	47	99.43	1821 .1	1814
1.5	2081	14	.014	78.5	182	5667	72.5	1557	50	99.79	5519 .1	5499
1.6	2368	14	.006	82.9	552	17163	78.8	3647	53	99.93	17472 .1	17407
1.7	2673	14	.002	86.3	1747	54467	83.4	9052	57	99.98	57135 .1	56924
1.8	2997	14	.001	89.0	5714	178717	86.8	23510	60	99.99	191365 .1	190666
1.9	3339	14	.000	91.1	19136	600421	89.5	63221	63	100.00	652043 .1	649720
2.0	3699	14	.000	92.7	65205	2050487	91.5	%174577	67	100.00	2248089 .1	224030
1												
2.1	4079	14	.000	94.0	224809	7079069	93.1	%491884	70	100.00	7809076 .1	778287
4												
2.2	4476	14	.000	95.0	780906	20136400	94.1	%1184105	73	100.00	%18305590 .3	%18
359310												
2.3	4893	14	.000	95.8	%2723563	40047090	94.8	%2089834	77	100.00	%21515780 .3	%
21668900												
2.4	5327	14	.000	93.5	%5166669	66320530	94.7	%3539478	80	100.00	%31031120 .3	%
31468060												
2.5	5780	14	.000	82.1	%5491672	98502750	92.4	%7524843	83	100.00	%33333330 .3	%
33333330												

S=50% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF, WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 50%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.30,
LAMBDA*SQRIN-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

	F-DEG*DAYS		PROB.			COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE		
						---------- YEARS ----------					PROB.%		YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100	DELTA	H3M	DELTA
1.0	925	14	.454	33.5	2	60	15.5	51	22	0.00	31	.1	31
1.1	1119	14	.275	45.7	5	109	27.2	79	24	61.73	66	.1	66
1.2	1332	14	.149	56.6	10	221	40.5	132	27	92.58	159	.1	159
1.3	1563	14	.073	65.6	24	513	53.4	239	29	97.17	424	.1	422
1.4	1813	14	.033	72.8	64	1332	64.2	477	31	98.85	1214	.1	1209
1.5	2081	14	.014	78.5	182	3778	72.5	1038	33	99.58	3680	.1	3666
1.6	2368	14	.006	82.9	552	11442	78.8	2431	36	99.86	11648	.1	11605
1.7	2673	14	.002	86.3	1747	36311	83.4	6035	38	99.95	38090	.1	37949
1.8	2997	14	.001	89.0	5714	119145	86.8	15674	40	99.99	127576	.1	127111
1.9	3339	14	.000	91.1	19136	400281	89.5	42148	42	100.00	434695	.1	433147
2.0	3699	14	.000	92.7	65205	1366991	91.5	%116384	44	100.00	1498726	.1	1493534
2.1	4079	14	.000	94.0	224809	4719380	93.1	%327923	47	100.00	5206051	.1	5188583
2.2	4476	14	.000	95.0	780906	13424270	94.1	%789403	49	100.00	%12203730	.3	%12239540
2.3	4893	14	.000	95.8	%2723563	26698060	94.8	%1393223	51	100.00	%14343850	.3	%14445940
2.4	5327	14	.000	93.5	%5166669	44213690	94.7	%2359652	53	100.00	%20687410	.3	%20978710
2.5	5780	14	.000	82.1	%5491672	65668510	92.4	%5016563	56	100.00	%22222220	.3	%22222220

S=50% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF, WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 50%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

F	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE		
					--- YEARS ---					PROB.%		YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100		DELTA	H3M	DEL
1.0	925	14	.454	33.5	2	45	15.5	38	17	0.00		23	.1	23
1.1	1119	14	.275	45.7	5	82	27.2	59	18	20.30		49	.1	49
1.2	1332	14	.149	56.6	10	166	40.5	99	20	84.94		119	.1	119
1.3	1563	14	.073	65.6	24	385	53.4	179	22	95.40		318	.1	317
1.4	1813	14	.033	72.8	64	999	64.2	358	23	98.25		910	.1	907
1.5	2081	14	.014	78.5	182	2834	72.5	779	25	99.36		2760	.1	2750
1.6	2368	14	.006	82.9	552	8582	78.8	1823	27	99.78		8736	.1	8704
1.7	2673	14	.002	86.3	1747	27234	83.4	4526	28	99.93		28568	.1	28462
1.8	2997	14	.001	89.0	5714	89359	86.8	11755	30	99.98		95682	.1	95333
1.9	3339	14	.000	91.1	19136	300210	89.5	31611	32	99.99		326021	.1	324860
2.0	3699	14	.000	92.7	65205	1025244	91.5	87288	33	100.00		1124045	.1	1120150
2.1	4079	14	.000	94.0	224809	3539535	93.1	%245942	35	100.00		3904538	.1	3891437
2.2	4476	14	.000	95.0	780906	10068200	94.1	%592052	37	100.00		9152795	.3	9179655
2.3	4893	14	.000	95.8	%2723563	20023540	94.8	%1044917	38	100.00		%10757890	.3	%10834450
2.4	5327	14	.000	93.5	%5166669	33160270	94.7	%1769739	40	100.00		%15515560	.3	%15734030
2.5	5780	14	.000	82.1	%5491672	49251390	92.4	%3762422	42	100.00		%16666670	.3	%16666670

S=50% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5Y -- 12-18-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF, WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 50%, 95% OF MAX L
LEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA*SQR[N-FACTOR] = .48 (AVG) .00 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 0% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
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CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R100 = EST'ED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 100 YEARS

FT	F-DEG*DAYS		PROB.			COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WST'PILE		
						YEARS					PROB.%		YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R100			DELTA	H3M	DELTA
1.0	925	14	.454	33.5	2	36	15.5	31	13	0.00			18	.1	18
1.1	1119	14	.275	45.7	5	65	27.2	47	15	2.51			40	.1	39
1.2	1332	14	.149	56.6	10	133	40.5	79	16	73.99			96	.1	95
1.3	1563	14	.073	65.6	24	308	53.4	143	17	93.30			254	.1	253
1.4	1813	14	.033	72.8	64	799	64.2	286	19	97.61			728	.1	726
1.5	2081	14	.014	78.5	182	2267	72.5	623	20	99.14			2208	.1	2200
1.6	2368	14	.006	82.9	552	6865	78.8	1459	21	99.71			6989	.1	6963
1.7	2673	14	.002	86.3	1747	21787	83.4	3621	23	99.91			22854	.1	22769
1.8	2997	14	.001	89.0	5714	71487	86.8	9404	24	99.97			76546	.1	76267
1.9	3339	14	.000	91.1	19136	240168	89.5	25289	25	99.99			260817	.1	259888
2.0	3699	14	.000	92.7	65205	820195	91.5	69831	27	100.00			899236	.1	896120
2.1	4079	14	.000	94.0	224809	2831628	93.1	%196754	28	100.00			3123631	.1	311315
0															
2.2	4476	14	.000	95.0	780906	8054561	94.1	%473642	29	100.00			7322236	.3	734372
4															
2.3	4893	14	.000	95.8	%2723563	16018840	94.8	%835934	31	100.00			8606312	.3	8667
562															
2.4	5327	14	.000	93.5	%5166669	26528220	94.7	%1415791	32	100.00			%12412450	.3	%
12587220															
2.5	5780	14	.000	82.1	%5491672	39401110	92.4	%3009938	33	100.00			%13333330	.3	%
13333330															

UPFREEZ5 RUN COMPLETE