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Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

TRANSMITTAL LETTER

To Region V
U.S. Environmental Protection Agency
230 South Dearborn Street (5HE-12)
Chicago, Illinois 60604

ATTENTION: Brad W. Bradley

Date 11/7/86
Project No. 863-2041

RECEIVED
NOV 10 1986
U.S. EPA, REGION V
WASTE MANAGEMENT DIVISION
HAZARDOUS WASTE ENFORCEMENT BRANCH

Sent by

XX Mail
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☐ Under Separate Cover
XX Enclosed

Quantity	Item	Description
1	Letter Dated November 7, 1986	Upfreezing Cover Thickness Analysis -- To Three Feet -- Preliminary Estimates For the Waukegan, Illinois Plant Waste Disposal Area

Remarks

Per C.L. Vita CLV

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

November 6, 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: UPFREEZING COVER THICKNESS ANALYSIS -- TO THREE FEET -- PRELIMINARY ESTIMATES FOR THE WAUKEGAN, ILLINOIS PLANT WASTE DISPOSAL AREA

Dear Mr. Clumpus:

The attached UPFREEZ5 computer output extends the cover thicknesses (TCT) analyzed to 3.0 ft and also extends the extremes in F to 0.5 for S to 50%. These results can be used to examine the implications of cover in excess of 2.0 ft and also effects of extreme and very extreme values of F and S.

The conditions and assumptions are identical to the UPFREEZ5 output transmitted to you on October 27, 1986. You will note that extending TCT to 3.0 ft required modification to the output format of UPFREEZ5 because upfreeze estimates were too large to fit across the page. These output format modifications are contained in UPFREEZ5X. Calculation procedures and assumptions are all unchanged.

As in our October 27 transmittal, these preliminary estimates are for upfreezing of objects less than about four or five inches in size ($X - A \leq 0.3$ ft) initially located at the bottom of the H1=TCT-ft cover (i.e., at the top of the waste pile). We understand this size of object is considered the critical size for upfreezing by EPA's consultant Mr. Richard McGaw, P.E.

These preliminary estimates make the assumptions shown on the program UPFREEZE5X computer output. Variables, symbols and their relation to object upfreezing are defined using the upfreezing equation (Eq. 1) in Table 1.

Preliminary estimates shown on the attached UPFREEZ5X output indicate the following for cover thickness of 1.5 ft to 3.0 ft.

- A moderate-heaving, moderate-stability cover (S=10%, F=0.1) provides lower bound [i.e., LBOND or UP.YRS*(1 - CV)] upfreezing protection of:

  - 518 years for 1.5 ft of cover
  - 808 years for 2.0 ft of cover
  - 1,399 years for 2.5 ft of cover
  - 2,749 years for 3.0 ft of cover

  R50 (50-year reliability) is 100% in each case.

- For extreme conditions of high-heaving and poor-stability (S=30%, F=0.3) lower bound (LBOND) estimates are:

  - 71 years for 1.5 ft of cover
  - 154 years for 2.0 ft of cover
  - 427 years for 2.5 ft of cover
  - 1,881 years for 3.0 ft of cover

  R50 (50-year reliability) is 100% in each case.

- Sensitivity to values of S and F beyond expected extremes shows R50 (50-year reliability) estimates:

  - For a 1.5 ft cover R50 is or exceeds 90% for all $S \leq 50\%$ and $F \leq 0.3$ or for all $F \leq 0.4$ and $S \leq 30\%$.

  - For a 2.0 ft cover R50 is or exceeds 99% for all $S \leq 50\%$ and $F \leq 0.5$.

  - For a 2.5 ft cover the R50 is 100% for all $S \leq 50\%$ and $F \leq 0.5$.

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

DMCC/CLV/111

Attachment

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, ABOND, and the estimated reliability that upfreezing through the cover will take 50 years or more, R50, 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 UPFREEZ5X  *****************************
SAVED UNDER FILE NAME: UPF1-5X                          DATE: 10-31-1986
                                                         TIME: 17:04:13

                    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 0.30
LAMBDA*SQR[N-FACTOR]: AVG=0.70;  SD=0.10
(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 0.30
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 UPFREEZ5 -- 10-31-1986
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 = WASE 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 = 0.10,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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),
ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1) YEARS					%	YEARS	FT	WASTEPILE YEARS	FT
H1	TC(AVG&CV)		FP(AVG&CV)		FPY	UP.YRS	CV	LBOND	ABOND	R50	DELTA	H3M	DELTA	H
1.00	186	38%	.9998	0%	1	334	0%	334	333	100	34	0.3	34	0.3
1.10	225	38%	.9988	0%	1	368	0%	368	367	100	34	0.3	34	0.3
1.20	268	38%	.9953	0%	1	403	0%	403	400	100	36	0.3	35	0.3
1.30	315	38%	.9861	1%	1	439	0%	439	433	100	38	0.3	37	0.3
1.40	365	38%	.9670	3%	1	478	0%	477	467	100	41	0.3	41	0.3
1.50	419	38%	.9351	7%	1	522	1%	518	500	100	46	0.3	46	0.3
1.60	477	38%	.8898	12%	1	572	2%	563	533	100	54	0.3	53	0.3
1.70	539	38%	.8337	19%	1	631	3%	613	567	100	66	0.3	65	0.3
1.80	604	38%	.7711	28%	1	706	5%	669	600	100	84	0.3	83	0.3
1.90	673	38%	.7067	39%	2	804	9%	734	633	100	112	0.3	111	0.3
2.00	745	38%	.6440	49%	2	938	14%	808	667	100	157	0.3	155	0.3
2.10	822	38%	.5847	59%	3	1130	21%	894	700	100	228	0.3	225	0.3
2.20	902	38%	.5289	69%	4	1415	30%	994	733	100	343	0.3	339	0.3
2.30	986	38%	.4759	76%	5	1850	40%	1110	767	100	526	0.2	523	0.2
2.40	1073	38%	.4250	83%	7	2523	51%	1244	800	100	820	0.2	815	0.2
2.50	1165	38%	.3755	87%	11	3589	61%	1399	833	100	1312	0.2	1304	0.2
2.60	1260	38%	.3276	91%	18	5319	70%	1579	867	100	2148	0.2	2134	0.2
2.70	1358	38%	.2816	94%	28	8186	78%	1793	900	100	3585	0.2	3563	0.2
2.80	1461	38%	.2383	95%	47	13022	84%	2050	933	100	6086	0.2	6047	0.2
2.90	1567	38%	.1984	97%	78	21304	89%	2362	967	100	10479	0.2	10412	0.2
3.00	1677	38%	.1625	98%	133	35677	92%	2749	1000	100	18266	0.2	18151	0.2
3.10	1791	38%	.1310	98%	229	60901	95%	3233	1033	100	32182	0.2	31981	0.2

S=10% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5 -- 10-31-1986
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 = WASE 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
EAVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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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FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1) YEARS					%	YEARS FT		WASTEPILE YEARS FT	
H'	TC(AVG&CV)		FP(AVG&CV)		FPY	UP.YRS	CV	LBOND	ABOND	R50	DELTA	H3M	DELTA	H3M
1.00	186	38%	.9998	0%	1	167	0%	167	167	100	17	0.3	17	0.3
1.10	225	38%	.9988	0%	1	184	0%	184	183	100	17	0.3	17	0.3
1.20	268	38%	.9953	0%	1	201	0%	201	200	100	18	0.3	18	0.3
1.30	315	38%	.9861	1%	1	220	0%	219	217	100	19	0.3	19	0.3
1.40	365	38%	.9670	3%	1	239	0%	239	233	100	20	0.3	20	0.3
1.50	419	38%	.9351	7%	1	261	1%	259	250	100	23	0.3	23	0.3
1.60	477	38%	.8898	12%	1	286	2%	281	267	100	27	0.3	27	0.3
1.70	539	38%	.8337	19%	1	316	3%	306	283	100	33	0.3	32	0.3
1.80	604	38%	.7711	28%	1	353	5%	335	300	100	42	0.3	41	0.3
1.90	673	38%	.7067	39%	2	402	9%	367	317	100	56	0.3	55	0.3
2.00	745	38%	.6440	49%	2	469	14%	404	333	100	78	0.3	77	0.3
2.10	822	38%	.5847	59%	3	565	21%	447	350	100	114	0.3	112	0.3
2.20	902	38%	.5289	69%	4	708	30%	497	367	100	171	0.3	169	0.3
2.30	986	38%	.4759	76%	5	925	40%	555	383	100	263	0.2	262	0.2
2.40	1073	38%	.4250	83%	7	1262	51%	622	400	100	410	0.2	408	0.2
2.50	1165	38%	.3755	87%	11	1795	61%	699	417	100	656	0.2	652	0.2
2.60	1260	38%	.3276	91%	18	2660	70%	790	433	100	1074	0.2	1067	0.2
2.70	1358	38%	.2816	94%	28	4093	78%	897	450	100	1793	0.2	1781	0.2
2.80	1461	38%	.2383	95%	47	6511	84%	1025	467	100	3043	0.2	3023	0.2
2.90	1567	38%	.1984	97%	78	10652	89%	1181	483	100	5239	0.2	5206	0.2
3.00	1677	38%	.1625	98%	133	17838	92%	1374	500	100	9133	0.2	9076	0.2
3.10	1791	38%	.1310	98%	229	30450	95%	1617	517	100	16091	0.2	15991	0.2

S=10% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5 -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
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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 = WASE 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 = 10%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.30,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

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LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

F.	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WASTEPILE	
					---------- YEARS ----------				%	YEARS	FT	YEARS	FT
H1	TC(AVG&CV)		FP(AVG&CV)		FPY	UP.YRS	CV	LBOND	ABOND	R50	DELTA	H3M	DELTA	H
1.00	186	38%	.9998	0%	1	111	0%	111	111	100	11	0.3	11	0.3
1.10	225	38%	.9988	0%	1	123	0%	123	122	100	11	0.3	11	0.3
1.20	268	38%	.9953	0%	1	134	0%	134	133	100	12	0.3	12	0.3
1.30	315	38%	.9861	1%	1	146	0%	146	144	100	13	0.3	12	0.3
1.40	365	38%	.9670	3%	1	159	0%	159	156	100	14	0.3	14	0.3
1.50	419	38%	.9351	7%	1	174	1%	173	167	100	15	0.3	15	0.3
1.60	477	38%	.8898	12%	1	191	2%	188	178	100	18	0.3	18	0.3
1.70	539	38%	.8337	19%	1	210	3%	204	189	100	22	0.3	22	0.3
1.80	604	38%	.7711	28%	1	235	5%	223	200	100	28	0.3	28	0.3
1.90	673	38%	.7067	39%	2	268	9%	245	211	100	37	0.3	37	0.3
2.00	745	38%	.6440	49%	2	313	14%	269	222	100	52	0.3	52	0.3
2.10	822	38%	.5847	59%	3	377	21%	298	233	100	76	0.3	75	0.3
2.20	902	38%	.5289	69%	4	472	30%	331	244	100	114	0.3	113	0.3
2.30	986	38%	.4759	76%	5	617	40%	370	256	100	175	0.2	174	0.2
2.40	1073	38%	.4250	83%	7	841	51%	415	267	100	273	0.2	272	0.2
2.50	1165	38%	.3755	87%	11	1196	61%	466	278	100	437	0.2	435	0.2
2.60	1260	38%	.3276	91%	18	1773	70%	526	289	100	716	0.2	711	0.2
2.70	1358	38%	.2816	94%	28	2729	78%	598	300	100	1195	0.2	1188	0.2
2.80	1461	38%	.2383	95%	47	4341	84%	683	311	100	2029	0.2	2016	0.2
2.90	1567	38%	.1984	97%	78	7101	89%	787	322	100	3493	0.2	3471	0.2
3.00	1677	38%	.1625	98%	133	11892	92%	916	333	100	6089	0.2	6050	0.2
3.10	1791	38%	.1310	98%	229	20300	95%	1078	344	100	10727	0.2	10661	0.2

S=10% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5 -- 10-31-1986
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 = WASE 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
AVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
LAMBDA*SQRIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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),
ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1) YEARS					%	YEARS FT		WASTEPILE YEARS FT	
H1	TC(AVG&CV)		FP(AVG&CV)		FPY	UP.YRS	CV	LBOND	ABOND	R50	DELTA	H3M	DELTA	H3M
1.0	186	38%	.9998	0%	1	83	0%	83	83	100	8	0.3	8	0.3
1.10	225	38%	.9988	0%	1	92	0%	92	92	100	9	0.3	9	0.3
1.20	268	38%	.9953	0%	1	101	0%	101	100	100	9	0.3	9	0.3
1.30	315	38%	.9861	1%	1	110	0%	110	108	100	9	0.3	9	0.3
1.40	365	38%	.9670	3%	1	120	0%	119	117	100	10	0.3	10	0.3
1.50	419	38%	.9351	7%	1	130	1%	130	125	100	11	0.3	11	0.3
1.60	477	38%	.8898	12%	1	143	2%	141	133	100	13	0.3	13	0.3
1.70	539	38%	.8337	19%	1	158	3%	153	142	100	16	0.3	16	0.3
1.80	604	38%	.7711	28%	1	176	5%	167	150	100	21	0.3	21	0.3
1.90	673	38%	.7067	39%	2	201	9%	183	158	100	28	0.3	28	0.3
2.00	745	38%	.6440	49%	2	234	14%	202	167	100	39	0.3	39	0.3
2.10	822	38%	.5847	59%	3	282	21%	223	175	100	57	0.3	56	0.3
2.20	902	38%	.5289	69%	4	354	30%	249	183	100	86	0.3	85	0.3
2.30	986	38%	.4759	76%	5	462	40%	278	192	100	132	0.2	131	0.2
2.40	1073	38%	.4250	83%	7	631	51%	311	200	100	205	0.2	204	0.2
2.50	1165	38%	.3755	87%	11	897	61%	350	208	100	328	0.2	326	0.2
2.60	1260	38%	.3276	91%	18	1330	70%	395	217	100	537	0.2	534	0.2
2.70	1358	38%	.2816	94%	28	2047	78%	448	225	100	896	0.2	891	0.2
2.80	1461	38%	.2383	95%	47	3255	84%	512	233	100	1521	0.2	1512	0.2
2.90	1567	38%	.1984	97%	78	5326	89%	591	242	100	2620	0.2	2603	0.2
3.00	1677	38%	.1625	98%	133	8919	92%	687	250	100	4567	0.2	4538	0.2
3.10	1791	38%	.1310	98%	229	15225	95%	808	258	100	8046	0.2	7995	0.2

S=10% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5 -- 10-31-1986
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 = WASE 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 = 0.50,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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),
ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

				COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE	
F	F-DEG*DAYS	PROB.		YEARS					%	YEARS	FT	YEARS	FT
H1	TC(AVG&CV)	FP(AVG&CV)		FPY	UP.YRS	CV	LBOND	ABOND	R50	DELTA	H3M	DELTA	H3M
1.00	186 38%	.9998	0%	1	67	0%	67	67	100	7	0.3	7	[illegible]
1.10	225 38%	.9988	0%	1	74	0%	74	73	100	7	0.3	7	0.3
1.20	268 38%	.9953	0%	1	81	0%	81	80	100	7	0.3	7	0.3
1.30	315 38%	.9861	1%	1	88	0%	88	87	100	8	0.3	7	0.3
1.40	365 38%	.9670	3%	1	96	0%	95	93	100	8	0.3	8	0.3
1.50	419 38%	.9351	7%	1	104	1%	104	100	100	9	0.3	9	0.3
1.60	477 38%	.8898	12%	1	114	2%	113	107	100	11	0.3	11	0.3
1.70	539 38%	.8337	19%	1	126	3%	123	113	100	13	0.3	13	0.3
1.80	604 38%	.7711	28%	1	141	5%	134	120	100	17	0.3	17	0.3
1.90	673 38%	.7067	39%	2	161	9%	147	127	100	22	0.3	22	0.3
2.00	745 38%	.6440	49%	2	188	14%	162	133	100	31	0.3	31	0.3
2.10	822 38%	.5847	59%	3	226	21%	179	140	100	46	0.3	45	0.3
2.20	902 38%	.5289	69%	4	283	30%	199	147	100	69	0.3	68	0.3
2.30	986 38%	.4759	76%	5	370	40%	222	153	100	105	0.2	105	0.2
2.40	1073 38%	.4250	83%	7	505	51%	249	160	100	164	0.2	163	0.2
2.50	1165 38%	.3755	87%	11	718	61%	280	167	100	262	0.2	261	0.2
2.60	1260 38%	.3276	91%	18	1064	70%	316	173	100	430	0.2	427	0.2
2.70	1358 38%	.2816	94%	28	1637	78%	359	180	100	717	0.2	713	0.2
2.80	1461 38%	.2383	95%	47	2604	84%	410	187	100	1217	0.2	1209	0.2
2.90	1567 38%	.1984	97%	78	4261	89%	472	193	100	2096	0.2	2082	0.2
3.00	1677 38%	.1625	98%	133	7135	92%	550	200	100	3653	0.2	3630	0.2
3.10	1791 38%	.1310	98%	229	12180	95%	647	207	100	6436	0.2	6396	0.2

S=20% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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
EAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

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	% R50	YEARS FT DELTA	H3M	WASTEPILE YEARS DELTA
1.0	244	38	.998	0.22	1	168	0.02	168	167	100	18	.3	18
1.1	295	38	.991	0.91	1	186	0.07	186	183	100	19	.3	19
1.2	351	38	.974	2.71	1	206	0.25	205	200	100	21	.3	21
1.3	412	38	.940	6.31	1	228	0.67	226	217	100	24	.3	24
1.4	477	38	.890	12.25	1	254	1.60	250	233	100	29	.3	29
1.5	548	38	.825	20.70	1	288	3.38	278	250	100	37	.3	37
1.6	624	38	.752	31.29	1	332	6.51	310	267	100	51	.3	51
1.7	704	38	.679	43.16	2	395	11.56	349	283	100	74	.3	73
1.8	789	38	.609	55.15	2	488	19.02	395	300	100	113	.2	112
1.9	879	38	.544	66.14	3	632	28.73	450	317	100	174	.2	172
2.0	974	38	.483	75.37	5	858	40.10	514	333	100	279	.2	277
2.1	1074	38	.425	82.60	7	1231	52.14	589	350	100	466	.2	462
2.2	1179	38	.368	87.96	12	1866	63.67	678	367	100	805	.2	798
2.3	1288	38	.314	91.77	20	2984	73.68	785	383	100	1430	.2	1418
2.4	1403	38	.262	94.41	35	4999	81.66	917	400	100	2600	.2	2579
2.5	1522	38	.215	96.21	63	8710	87.59	1081	417	100	4822	.2	4782
2.6	1646	38	.172	97.43	115	15666	91.77	1289	433	100	9091	.2	9016
2.7	1776	38	.135	98.25	213	28901	94.61	1558	450	100	17379	.2	17238
2.8	1909	38	.104	98.80	403	54397	96.48	1913	467	100	33614	.2	33345
2.9	2048	38	.078	99.17	773	104035	97.70	2388	483	100	65661	.2	65145
3.0	2192	38	.058	99.42	1499	201527	98.49	3034	500	100	129323	.2	128327

S=20% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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 = 0.20,
LAMBDA*SQRIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT H1	F-DEG*DAYS TCAVG	&CV%	PROB. FPAVG	&CV%	COVER THERMAL PROPERTIES IN H3 (R1.3=1) YEARS FPY	UP.YRS	CV%	LBOND	ABD	% R50	YEARS FT DELTA	H3M	WASTEPILE YEARS DELT
1.0	244	38	.998	0.22	1	84	0.02	84	83	100	9	.3	9
1.1	295	38	.991	0.91	1	93	0.07	93	92	100	9	.3	9
1.2	351	38	.974	2.71	1	103	0.25	103	100	100	10	.3	10
1.3	412	38	.940	6.31	1	114	0.67	113	108	100	12	.3	12
1.4	477	38	.890	12.25	1	127	1.60	125	117	100	15	.3	14
1.5	548	38	.825	20.70	1	144	3.38	139	125	100	19	.3	18
1.6	624	38	.752	31.29	1	166	6.51	155	133	100	26	.3	25
1.7	704	38	.679	43.16	2	197	11.56	175	142	100	37	.3	37
1.8	789	38	.609	55.15	2	244	19.02	198	150	100	57	.2	56
1.9	879	38	.544	66.14	3	316	28.73	225	158	100	87	.2	86
2.0	974	38	.483	75.37	5	429	40.10	257	167	100	139	.2	138
2.1	1074	38	.425	82.60	7	615	52.14	294	175	100	233	.2	231
2.2	1179	38	.368	87.96	12	933	63.67	339	183	100	403	.2	399
2.3	1288	38	.314	91.77	20	1492	73.68	393	192	100	715	.2	709
2.4	1403	38	.262	94.41	35	2499	81.66	458	200	100	1300	.2	1289
2.5	1522	38	.215	96.21	63	4355	87.59	540	208	100	2411	.2	2391
2.6	1646	38	.172	97.43	115	7833	91.77	644	217	100	4545	.2	4508
2.7	1776	38	.135	98.25	213	14450	94.61	779	225	100	8689	.2	8619
2.8	1909	38	.104	98.80	403	27199	96.48	956	233	100	16807	.2	16673
2.9	2048	38	.078	99.17	773	52017	97.70	1194	242	100	32830	.2	32572
3.0	2192	38	.058	99.42	1499	100763	98.49	1517	250	100	64662	.2	64164

S=20% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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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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 = WASE 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 = 0.30,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WASTEPILE	
					---------- YEARS ----------					%	YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1	244	38	.998	0.22	1	56	0.02	56	56	100	6	.3	6
1.1	295	38	.991	0.91	1	62	0.07	62	61	100	6	.3	6
1.2	351	38	.974	2.71	1	69	0.25	68	67	100	7	.3	7
1.3	412	38	.940	6.31	1	76	0.67	75	72	100	8	.3	8
1.4	477	38	.890	12.25	1	85	1.60	83	78	100	10	.3	10
1.5	548	38	.825	20.70	1	96	3.38	93	83	100	12	.3	12
1.6	624	38	.752	31.29	1	111	6.51	103	89	100	17	.3	17
1.7	704	38	.679	43.16	2	132	11.56	116	94	100	25	.3	24
1.8	789	38	.609	55.15	2	163	19.02	132	100	100	38	.2	37
1.9	879	38	.544	66.14	3	211	28.73	150	106	100	58	.2	57
2.0	974	38	.483	75.37	5	286	40.10	171	111	100	93	.2	92
2.1	1074	38	.425	82.60	7	410	52.14	196	117	100	155	.2	154
2.2	1179	38	.368	87.96	12	622	63.67	226	122	100	268	.2	266
2.3	1288	38	.314	91.77	20	995	73.68	262	128	100	477	.2	473
2.4	1403	38	.262	94.41	35	1666	81.66	306	133	100	867	.2	860
2.5	1522	38	.215	96.21	63	2903	87.59	360	139	100	1607	.2	1594
2.6	1646	38	.172	97.43	115	5222	91.77	430	144	100	3030	.2	3005
2.7	1776	38	.135	98.25	213	9634	94.61	519	150	100	5793	.2	5746
2.8	1909	38	.104	98.80	403	18132	96.48	638	156	100	11205	.2	11115
2.9	2048	38	.078	99.17	773	34678	97.70	796	161	100	21887	.2	21715
3.0	2192	38	.058	99.42	1499	67176	98.49	1011	167	100	43108	.2	42776

S=20% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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 = 0.40,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					YEARS					%	YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	244	38	.998	0.22	1	42	0.02	42	42	0	4	.3	
1.1	295	38	.991	0.91	1	46	0.07	46	46	0	5	.3	5
1.2	351	38	.974	2.71	1	51	0.25	51	50	100	5	.3	5
1.3	412	38	.940	6.31	1	57	0.67	57	54	100	6	.3	6
1.4	477	38	.890	12.25	1	64	1.60	63	58	100	7	.3	7
1.5	548	38	.825	20.70	1	72	3.38	69	63	100	9	.3	9
1.6	624	38	.752	31.29	1	83	6.51	78	67	100	13	.3	13
1.7	704	38	.679	43.16	2	99	11.56	87	71	100	19	.3	18
1.8	789	38	.609	55.15	2	122	19.02	99	75	100	28	.2	28
1.9	879	38	.544	66.14	3	158	28.73	113	79	100	43	.2	43
2.0	974	38	.483	75.37	5	215	40.10	129	83	100	70	.2	69
2.1	1074	38	.425	82.60	7	308	52.14	147	88	100	117	.2	116
2.2	1179	38	.368	87.96	12	467	63.67	169	92	100	201	.2	200
2.3	1288	38	.314	91.77	20	746	73.68	196	96	100	357	.2	355
2.4	1403	38	.262	94.41	35	1250	81.66	229	100	100	650	.2	645
2.5	1522	38	.215	96.21	63	2177	87.59	270	104	100	1205	.2	1195
2.6	1646	38	.172	97.43	115	3917	91.77	322	108	100	2273	.2	2254
2.7	1776	38	.135	98.25	213	7225	94.61	390	112	100	4345	.2	4309
2.8	1909	38	.104	98.80	403	13599	96.48	478	117	100	8404	.2	8336
2.9	2048	38	.078	99.17	773	26009	97.70	597	121	100	16415	.2	16286
3.0	2192	38	.058	99.42	1499	50382	98.49	759	125	100	32331	.2	32082

S=20% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE 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
EAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA*SQRIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS ----------				%	YEARS FT			YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	244	38	.998	0.22	1	34	0.02	34	33	0	4	.3	4
1.1	295	38	.991	0.91	1	37	0.07	37	37	0	4	.3	4
1.2	351	38	.974	2.71	1	41	0.25	41	40	0	4	.3	4
1.3	412	38	.940	6.31	1	46	0.67	45	43	0	5	.3	5
1.4	477	38	.890	12.25	1	51	1.60	50	47	86	6	.3	6
1.5	548	38	.825	20.70	1	58	3.38	56	50	100	7	.3	7
1.6	624	38	.752	31.29	1	66	6.51	62	53	100	10	.3	10
1.7	704	38	.679	43.16	2	79	11.56	70	57	100	15	.3	15
1.8	789	38	.609	55.15	2	98	19.02	79	60	100	23	.2	22
1.9	879	38	.544	66.14	3	126	28.73	90	63	100	35	.2	34
2.0	974	38	.483	75.37	5	172	40.10	103	67	100	56	.2	55
2.1	1074	38	.425	82.60	7	246	52.14	118	70	100	93	.2	92
2.2	1179	38	.368	87.96	12	373	63.67	136	73	100	161	.2	160
2.3	1288	38	.314	91.77	20	597	73.68	157	77	100	286	.2	284
2.4	1403	38	.262	94.41	35	1000	81.66	183	80	100	520	.2	516
2.5	1522	38	.215	96.21	63	1742	87.59	216	83	100	964	.2	956
2.6	1646	38	.172	97.43	115	3133	91.77	258	87	100	1818	.2	1803
2.7	1776	38	.135	98.25	213	5780	94.61	312	90	100	3476	.2	3448
2.8	1909	38	.104	98.80	403	10879	96.48	383	93	100	6723	.2	6669
2.9	2048	38	.078	99.17	773	20807	97.70	478	97	100	13132	.2	13029
3.0	2192	38	.058	99.42	1499	40305	98.49	607	100	100	25865	.2	25665

S=30% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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 = 0.10,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FI	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WASTEPILE		
					--------- YEARS ----------					%		YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M		DELTA
1.0	305	38	.989	1.15	1	114	0.10	113	111	100	13	.3		13
1.1	369	38	.965	3.60	1	128	0.36	127	122	100	15	.3		15
1.2	439	38	.921	8.55	1	144	1.05	143	133	100	18	.3		18
1.3	515	38	.855	16.58	1	166	2.60	161	144	100	24	.3		24
1.4	598	38	.777	27.56	1	195	5.66	184	156	100	34	.3		34
1.5	686	38	.695	40.57	2	238	11.06	212	167	100	52	.2		51
1.6	781	38	.616	54.04	2	304	19.22	246	178	100	80	.2		79
1.7	881	38	.543	66.38	3	409	30.09	286	189	100	130	.2		129
1.8	988	38	.474	76.53	5	585	42.98	334	200	100	224	.2		221
1.9	1101	38	.410	84.18	8	899	56.40	392	211	100	404	.2		400
2.0	1220	38	.347	89.57	15	1480	68.68	463	222	100	757	.2		749
2.1	1345	38	.288	93.22	27	2591	78.67	553	233	100	1466	.2		1451
2.2	1476	38	.232	95.61	50	4780	86.06	666	244	100	2912	.2		2882
2.3	1613	38	.183	97.15	98	9191	91.14	814	256	100	5909	.2		5848
2.4	1757	38	.140	98.15	195	18247	94.46	1011	267	100	12203	.2		12079
2.5	1906	38	.104	98.79	397	37133	96.55	1280	278	100	25568	.2		25314
2.6	2062	38	.076	99.20	823	76921	97.85	1652	289	100	54009	.1		53687
2.7	2223	38	.054	99.46	1730	161269	98.65	2175	300	100	114686	.1		114405
2.8	2391	38	.038	99.64	3678	341553	99.14	2925	311	100	245881	.1		245291
2.9	2565	38	.026	99.75	7894	730132	99.45	4019	322	100	531279	.1		530035
3.0	2745	38	.017	99.83	17070	1573341	99.64	5642	333	100	1155138	.1		1152502

S=30% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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
AVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
LAMBDA*SQRIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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),
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R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 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	% R50	WASTEPILE YEARS FT DELTA	H3M	YEARS DELTA
1.0	305	38	.989	1.15	1	57	0.10	57	56	100	7	.3	7
1.1	369	38	.965	3.60	1	64	0.36	64	61	100	8	.3	7
1.2	439	38	.921	8.55	1	72	1.05	71	67	100	9	.3	9
1.3	515	38	.855	16.58	1	83	2.60	81	72	100	12	.3	12
1.4	598	38	.777	27.56	1	97	5.66	92	78	100	17	.3	17
1.5	686	38	.695	40.57	2	119	11.06	106	83	100	26	.2	26
1.6	781	38	.616	54.04	2	152	19.22	123	89	100	40	.2	39
1.7	881	38	.543	66.38	3	204	30.09	143	94	100	65	.2	64
1.8	988	38	.474	76.53	5	293	42.98	167	100	100	112	.2	111
1.9	1101	38	.410	84.18	8	450	56.40	196	106	100	202	.2	200
2.0	1220	38	.347	89.57	15	740	68.68	232	111	100	379	.2	375
2.1	1345	38	.288	93.22	27	1296	78.67	276	117	100	733	.2	725
2.2	1476	38	.232	95.61	50	2390	86.06	333	122	100	1456	.2	1441
2.3	1613	38	.183	97.15	98	4595	91.14	407	128	100	2955	.2	2924
2.4	1757	38	.140	98.15	195	9123	94.46	506	133	100	6102	.2	6040
2.5	1906	38	.104	98.79	397	18566	96.55	640	139	100	12784	.2	12657
2.6	2062	38	.076	99.20	823	38461	97.85	826	144	100	27004	.1	26843
2.7	2223	38	.054	99.46	1730	80635	98.65	1088	150	100	57343	.1	57203
2.8	2391	38	.038	99.64	3678	170776	99.14	1463	156	100	122940	.1	122646
2.9	2565	38	.026	99.75	7894	365066	99.45	2010	161	100	265640	.1	265017
3.0	2745	38	.017	99.83	17070	786671	99.64	2821	167	100	577569	.1	576251

S=30% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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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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 = WASE 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 = 0.30,
LAMBDA*SQRIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WASTEPILE		
					YEARS					%		YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M		DELTA
1.0	305	38	.989	1.15	1	38	0.10	38	37	0	4	.3		4
1.1	369	38	.965	3.60	1	43	0.36	42	41	0	5	.3		5
1.2	439	38	.921	8.55	1	48	1.05	48	44	0	6	.3		6
1.3	515	38	.855	16.58	1	55	2.60	54	48	100	8	.3		8
1.4	598	38	.777	27.56	1	65	5.66	61	52	100	11	.3		11
1.5	686	38	.695	40.57	2	79	11.06	71	56	100	17	.2		17
1.6	781	38	.616	54.04	2	101	19.22	82	59	100	27	.2		26
1.7	881	38	.543	66.38	3	136	30.09	95	63	100	43	.2		43
1.8	988	38	.474	76.53	5	195	42.98	111	67	100	75	.2		74
1.9	1101	38	.410	84.18	8	300	56.40	131	70	100	135	.2		133
2.0	1220	38	.347	89.57	15	493	68.68	154	74	100	252	.2		250
2.1	1345	38	.288	93.22	27	864	78.67	184	78	100	489	.2		484
2.2	1476	38	.232	95.61	50	1593	86.06	222	81	100	971	.2		961
2.3	1613	38	.183	97.15	98	3064	91.14	271	85	100	1970	.2		1949
2.4	1757	38	.140	98.15	195	6082	94.46	337	89	100	4068	.2		4026
2.5	1906	38	.104	98.79	397	12378	96.55	427	93	100	8523	.2		8433
2.6	2062	38	.076	99.20	823	25640	97.85	551	96	100	18003	.1		17896
2.7	2223	38	.054	99.46	1730	53756	98.65	725	100	100	38229	.1		38135
2.8	2391	38	.038	99.64	3678	113851	99.14	975	104	100	81960	.1		81764
2.9	2565	38	.026	99.75	7894	243377	99.45	1340	107	100	177093	.1		176678
3.0	2745	38	.017	99.83	17070	524447	99.64	1881	111	100	385046	.1		384167

S=30% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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 = 0.40,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FI	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS ----------				%	YEARS FT			YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	305	38	.989	1.15	1	28	0.10	28	28	0	3	.3	3
1.1	369	38	.965	3.60	1	32	0.36	32	31	0	4	.3	4
1.2	439	38	.921	8.55	1	36	1.05	36	33	0	5	.3	5
1.3	515	38	.855	16.58	1	41	2.60	40	36	0	6	.3	6
1.4	598	38	.777	27.56	1	49	5.66	46	39	32	9	.3	8
1.5	686	38	.695	40.57	2	60	11.06	53	42	93	13	.2	13
1.6	781	38	.616	54.04	2	76	19.22	61	44	98	20	.2	20
1.7	881	38	.543	66.38	3	102	30.09	71	47	99	32	.2	32
1.8	988	38	.474	76.53	5	146	42.98	83	50	100	56	.2	55
1.9	1101	38	.410	84.18	8	225	56.40	98	53	100	101	.2	100
2.0	1220	38	.347	89.57	15	370	68.68	116	56	100	189	.2	187
2.1	1345	38	.288	93.22	27	648	78.67	138	58	100	366	.2	363
2.2	1476	38	.232	95.61	50	1195	86.06	167	61	100	728	.2	720
2.3	1613	38	.183	97.15	98	2298	91.14	204	64	100	1477	.2	1462
2.4	1757	38	.140	98.15	195	4562	94.46	253	67	100	3051	.2	3020
2.5	1906	38	.104	98.79	397	9283	96.55	320	69	100	6392	.2	6328
2.6	2062	38	.076	99.20	823	19230	97.85	413	72	100	13502	.1	13422
2.7	2223	38	.054	99.46	1730	40317	98.65	544	75	100	28672	.1	28601
2.8	2391	38	.038	99.64	3678	85388	99.14	731	78	100	61470	.1	61323
2.9	2565	38	.026	99.75	7894	182533	99.45	1005	81	100	132820	.1	132509
3.0	2745	38	.017	99.83	17070	393335	99.64	1411	83	100	288785	.1	288125

S=30% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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*SQRIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1) YEARS					%	WASTEPILE YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	305	38	.989	1.15	1	23	0.10	23	22	0	3	.3	3
1.1	369	38	.965	3.60	1	26	0.36	25	24	0	3	.3	3
1.2	439	38	.921	8.55	1	29	1.05	29	27	0	4	.3	4
1.3	515	38	.855	16.58	1	33	2.60	32	29	0	5	.3	5
1.4	598	38	.777	27.56	1	39	5.66	37	31	0	7	.3	7
1.5	686	38	.695	40.57	2	48	11.06	42	33	33	10	.2	10
1.6	781	38	.616	54.04	2	61	19.22	49	36	84	16	.2	16
1.7	881	38	.543	66.38	3	82	30.09	57	38	94	26	.2	26
1.8	988	38	.474	76.53	5	117	42.98	67	40	97	45	.2	44
1.9	1101	38	.410	84.18	8	180	56.40	78	42	99	81	.2	80
2.0	1220	38	.347	89.57	15	296	68.68	93	44	99	151	.2	150
2.1	1345	38	.288	93.22	27	518	78.67	111	47	100	293	.2	290
2.2	1476	38	.232	95.61	50	956	86.06	133	49	100	582	.2	576
2.3	1613	38	.183	97.15	98	1838	91.14	163	51	100	1182	.2	1170
2.4	1757	38	.140	98.15	195	3649	94.46	202	53	100	2441	.2	2416
2.5	1906	38	.104	98.79	397	7427	96.55	256	56	100	5114	.2	5063
2.6	2062	38	.076	99.20	823	15384	97.85	330	58	100	10802	.1	10737
2.7	2223	38	.054	99.46	1730	32254	98.65	435	60	100	22937	.1	22881
2.8	2391	38	.038	99.64	3678	68311	99.14	585	62	100	49176	.1	49058
2.9	2565	38	.026	99.75	7894	146027	99.45	804	64	100	106256	.1	106007
3.0	2745	38	.017	99.83	17070	314668	99.64	1128	67	100	231028	.1	230500

S=40% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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*SQRT[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

F.	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS ----------			%			YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1	367	38	.966	3.48	1	88	0.36	88	83	100	12	.3	12
1.1	444	38	.917	8.97	1	101	1.18	100	92	100	15	.3	15
1.2	528	38	.843	18.17	1	119	3.17	116	100	100	21	.3	21
1.3	620	38	.756	30.78	1	146	7.27	135	108	100	32	.2	31
1.4	719	38	.666	45.38	2	186	14.27	160	117	100	49	.2	48
1.5	825	38	.582	59.83	3	251	24.64	189	125	100	81	.2	80
1.6	939	38	.505	72.25	4	363	38.00	225	133	100	144	.2	143
1.7	1060	38	.432	81.74	7	572	52.75	270	142	100	273	.2	269
1.8	1189	38	.363	88.37	13	979	66.63	327	150	100	541	.2	534
1.9	1324	38	.297	92.73	24	1807	77.94	399	158	100	1115	.2	1101
2.0	1468	38	.236	95.48	48	3536	86.08	492	167	100	2342	.1	2335
2.1	1618	38	.181	97.19	100	7204	91.46	615	175	100	4995	.1	4980
2.2	1776	38	.135	98.25	213	15161	94.85	781	183	100	10918	.1	10884
2.3	1941	38	.097	98.90	468	32791	96.92	1011	192	100	24343	.1	24269
2.4	2113	38	.068	99.30	1045	72542	98.15	1340	200	100	55159	.1	54994
2.5	2293	38	.047	99.55	2371	163431	98.89	1820	208	100	126619	.1	126250
2.6	2480	38	.031	99.71	5450	373591	99.32	2540	217	100	293700	.1	292866
2.7	2675	38	.020	99.81	12655	863880	99.58	3641	225	100	686879	.1	684980
2.8	2876	38	.013	99.87	29623	2015668	99.73	5357	233	100	1616696	.1	1612355
2.9	3085	38	.008	99.91	69773	4735770	99.83	8078	242	100	3823509	.1	3813525
3.0	3302	38	.005	99.94	165107	11184500	99.89	12457	250	100	9073945	.1	9050954

S=40% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					YEARS					%	YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	367	38	.966	3.48	1	44	0.36	44	42	0	6	.3	[illegible]
1.1	444	38	.917	8.97	1	51	1.18	50	46	86	8	.3	7
1.2	528	38	.843	18.17	1	60	3.17	58	50	100	11	.3	10
1.3	620	38	.756	30.78	1	73	7.27	68	54	100	16	.2	16
1.4	719	38	.666	45.38	2	93	14.27	80	58	100	24	.2	24
1.5	825	38	.582	59.83	3	125	24.64	95	63	100	40	.2	40
1.6	939	38	.505	72.25	4	182	38.00	113	67	100	72	.2	71
1.7	1060	38	.432	81.74	7	286	52.75	135	71	100	136	.2	135
1.8	1189	38	.363	88.37	13	489	66.63	163	75	100	271	.2	267
1.9	1324	38	.297	92.73	24	903	77.94	199	79	100	558	.2	551
2.0	1468	38	.236	95.48	48	1768	86.08	246	83	100	1171	.1	1167
2.1	1618	38	.181	97.19	100	3602	91.46	308	88	100	2498	.1	2490
2.2	1776	38	.135	98.25	213	7580	94.85	390	92	100	5459	.1	5442
2.3	1941	38	.097	98.90	468	16396	96.92	506	96	100	12172	.1	12134
2.4	2113	38	.068	99.30	1045	36271	98.15	670	100	100	27579	.1	27497
2.5	2293	38	.047	99.55	2371	81716	98.89	910	104	100	63310	.1	63125
2.6	2480	38	.031	99.71	5450	186796	99.32	1270	108	100	146850	.1	146433
2.7	2675	38	.020	99.81	12655	431940	99.58	1821	112	100	343439	.1	342490
2.8	2876	38	.013	99.87	29623	1007834	99.73	2679	117	100	808348	.1	806178
2.9	3085	38	.008	99.91	69773	2367885	99.83	4039	121	100	1911754	.1	1906763
3.0	3302	38	.005	99.94	165107	5592249	99.89	6228	125	100	4536973	.1	4525477

S=40% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UFFREEZ5X -- 10-31-1986
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 = WASE 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] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE	
					YEARS					%	YEARS	FT	YEARS	
H1	TCAVG	&CV%	FPAVG	&CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA	
1.	367	38	.966	3.48	1	29	0.36	29	28	0	4	.3	4	
1.1	444	38	.917	8.97	1	34	1.18	33	31	0	5	.3	5	
1.2	528	38	.843	18.17	1	40	3.17	39	33	0	7	.3	7	
1.3	620	38	.756	30.78	1	49	7.27	45	36	35	11	.2	10	
1.4	719	38	.666	45.38	2	62	14.27	53	39	92	16	.2	16	
1.5	825	38	.582	59.83	3	84	24.64	63	42	97	27	.2	27	
1.6	939	38	.505	72.25	4	121	38.00	75	44	99	48	.2	48	
1.7	1060	38	.432	81.74	7	191	52.75	90	47	100	91	.2	90	
1.8	1189	38	.363	88.37	13	326	66.63	109	50	100	180	.2	178	
1.9	1324	38	.297	92.73	24	602	77.94	133	53	100	372	.2	367	
2.0	1468	38	.236	95.48	48	1179	86.08	164	56	100	781	.1	778	
2.1	1618	38	.181	97.19	100	2401	91.46	205	58	100	1665	.1	1660	
2.2	1776	38	.135	98.25	213	5054	94.85	260	61	100	3639	.1	3628	
2.3	1941	38	.097	98.90	468	10930	96.92	337	64	100	8114	.1	8090	
2.4	2113	38	.068	99.30	1045	24181	98.15	447	67	100	18386	.1	18331	
2.5	2293	38	.047	99.55	2371	54477	98.89	607	69	100	42206	.1	42083	
2.6	2480	38	.031	99.71	5450	124530	99.32	847	72	100	97900	.1	97622	
2.7	2675	38	.020	99.81	12655	287960	99.58	1214	75	100	228960	.1	228327	
2.8	2876	38	.013	99.87	29623	671889	99.73	1786	78	100	538899	.1	537452	
2.9	3085	38	.008	99.91	69773	1578590	99.83	2693	81	100	1274503	.1	1271175	
3.0	3302	38	.005	99.94	165107	3728166	99.89	4152	83	100	3024649	.1	3016985	

S=40% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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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] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

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ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

F	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS ----------				%	YEARS	FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELT
1.0	367	38	.966	3.48	1	22	0.36	22	21	0	3	.3	3
1.1	444	38	.917	8.97	1	25	1.18	25	23	0	4	.3	4
1.2	528	38	.843	18.17	1	30	3.17	29	25	0	5	.3	5
1.3	620	38	.756	30.78	1	36	7.27	34	27	0	8	.2	8
1.4	719	38	.666	45.38	2	47	14.27	40	29	30	12	.2	12
1.5	825	38	.582	59.83	3	63	24.64	47	31	81	20	.2	20
1.6	939	38	.505	72.25	4	91	38.00	56	33	93	36	.2	36
1.7	1060	38	.432	81.74	7	143	52.75	68	35	97	68	.2	67
1.8	1189	38	.363	88.37	13	245	66.63	82	38	98	135	.2	134
1.9	1324	38	.297	92.73	24	452	77.94	100	40	99	279	.2	275
2.0	1468	38	.236	95.48	48	884	86.08	123	42	100	586	.1	584
2.1	1618	38	.181	97.19	100	1801	91.46	154	44	100	1249	.1	1245
2.2	1776	38	.135	98.25	213	3790	94.85	195	46	100	2729	.1	2721
2.3	1941	38	.097	98.90	468	8198	96.92	253	48	100	6086	.1	6067
2.4	2113	38	.068	99.30	1045	18136	98.15	335	50	100	13790	.1	13748
2.5	2293	38	.047	99.55	2371	40858	98.89	455	52	100	31655	.1	31563
2.6	2480	38	.031	99.71	5450	93398	99.32	635	54	100	73425	.1	73216
2.7	2675	38	.020	99.81	12655	215970	99.58	910	56	100	171720	.1	171245
2.8	2876	38	.013	99.87	29623	503917	99.73	1339	58	100	404174	.1	403089
2.9	3085	38	.008	99.91	69773	1183943	99.83	2019	60	100	955877	.1	953381
3.0	3302	38	.005	99.94	165107	2796124	99.89	3114	62	100	2268486	.1	2262739

S=40% F=0.50

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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 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.91
FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BL 1 COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
AMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

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R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					YEARS					%	YEARS FT		YEARS
H1	TCAVG	&CV%	FPAVG	&CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.1	367	38	.966	3.48	1	18	0.36	18	17	0	2	.3	2
1.1	444	38	.917	8.97	1	20	1.18	20	18	0	3	.3	3
1.2	528	38	.843	18.17	1	24	3.17	23	20	0	4	.3	4
1.3	620	38	.756	30.78	1	29	7.27	27	22	0	6	.2	6
1.4	719	38	.666	45.38	2	37	14.27	32	23	1	10	.2	10
1.5	825	38	.582	59.83	3	50	24.64	38	25	52	16	.2	16
1.6	939	38	.505	72.25	4	73	38.00	45	27	83	29	.2	29
1.7	1060	38	.432	81.74	7	114	52.75	54	28	93	55	.2	54
1.8	1189	38	.363	88.37	13	196	66.63	65	30	97	108	.2	107
1.9	1324	38	.297	92.73	24	361	77.94	80	32	98	223	.2	220
2.0	1468	38	.236	95.48	48	707	86.08	98	33	99	468	.1	467
2.1	1618	38	.181	97.19	100	1441	91.46	123	35	100	999	.1	996
2.2	1776	38	.135	98.25	213	3032	94.85	156	37	100	2184	.1	2177
2.3	1941	38	.097	98.90	468	6558	96.92	202	38	100	4869	.1	4854
2.4	2113	38	.068	99.30	1045	14508	98.15	268	40	100	11032	.1	10999
2.5	2293	38	.047	99.55	2371	32686	98.89	364	42	100	25324	.1	25250
2.6	2480	38	.031	99.71	5450	74718	99.32	508	43	100	58740	.1	58573
2.7	2675	38	.020	99.81	12655	172776	99.58	728	45	100	137376	.1	136996
2.8	2876	38	.013	99.87	29623	403134	99.73	1071	47	100	323339	.1	322471
2.9	3085	38	.008	99.91	69773	947154	99.83	1616	48	100	764702	.1	762705
3.0	3302	38	.005	99.94	165107	2236900	99.89	2491	50	100	1814789	.1	1810191

S=50% F=0.10

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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

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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 = WASE 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] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
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LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE	
					YEARS					%	YEARS	FT	YEARS	
H1	TCAVG	&CV%	FPAVG	&CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELT	
1.0	423	38	.933	7.17	1	74	0.93	73	67	100	12	.3	12	
1.1	512	38	.859	16.11	1	88	2.82	86	73	100	17	.3	17	
1.2	609	38	.766	29.15	1	109	6.94	102	80	100	26	.2	25	
1.3	715	38	.670	44.72	2	143	14.34	122	87	100	41	.2	40	
1.4	829	38	.580	60.23	3	199	25.67	148	93	100	71	.2	70	
1.5	951	38	.497	73.37	4	301	40.36	180	100	100	134	.2	132	
1.6	1082	38	.420	83.10	8	503	56.21	220	107	100	270	.2	266	
1.7	1222	38	.346	89.64	15	919	70.40	272	113	100	563	.1	561	
1.8	1370	38	.277	93.76	30	1801	81.19	339	120	100	1199	.1	1194	
1.9	1526	38	.213	96.26	64	3727	88.58	426	127	100	2655	.1	2645	
2.0	1691	38	.158	97.75	142	8089	93.28	544	133	100	6069	.1	6047	
2.1	1865	38	.113	98.64	326	18238	96.11	709	140	100	14229	.1	14178	
2.2	2046	38	.078	99.16	766	42373	97.76	948	147	100	34042	.1	33924	
2.3	2237	38	.053	99.48	1837	100776	98.71	1304	153	100	82763	.1	82484	
2.4	2435	38	.034	99.67	4473	244049	99.24	1851	160	100	203783	.1	203113	
2.5	2642	38	.022	99.79	11029	599310	99.55	2710	167	100	506741	.1	505125	
2.6	2858	38	.014	99.87	27454	1487504	99.73	4090	173	100	1269646	.1	1265715	
2.7	3082	38	.008	99.91	68844	3721789	99.83	6351	180	100	3198924	.1	3189307	
2.8	3315	38	.005	99.94	173571	9366943	99.89	10119	187	100	8091385	.1	8067859	
2.9	3556	38	.003	99.96	439261	23671590	99.93	16502	193	100	%20517900	.1	%20460030	
3.0	3805	38	.002	99.97	%1114284	50600850	99.95	24961	200	100	%33340640	.3	%33340870	

S=50% F=0.20

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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 = WASE 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] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

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R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FI	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WASTEPILE	
					---------- YEARS ----------					%	YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	423	38	.933	7.17	1	37	0.93	36	33	0	6	.3	6
1.1	512	38	.859	16.11	1	44	2.82	43	37	0	8	.3	8
1.2	609	38	.766	29.15	1	55	6.94	51	40	89	13	.2	13
1.3	715	38	.670	44.72	2	71	14.34	61	43	98	20	.2	20
1.4	829	38	.580	60.23	3	99	25.67	74	47	99	36	.2	35
1.5	951	38	.497	73.37	4	151	40.36	90	50	100	67	.2	66
1.6	1082	38	.420	83.10	8	251	56.21	110	53	100	135	.2	133
1.7	1222	38	.346	89.64	15	460	70.40	136	57	100	282	.1	281
1.8	1370	38	.277	93.76	30	900	81.19	169	60	100	599	.1	597
1.9	1526	38	.213	96.26	64	1864	88.58	213	63	100	1327	.1	1323
2.0	1691	38	.158	97.75	142	4044	93.28	272	67	100	3034	.1	3023
2.1	1865	38	.113	98.64	326	9119	96.11	354	70	100	7114	.1	7089
2.2	2046	38	.078	99.16	766	21186	97.76	474	73	100	17021	.1	16962
2.3	2237	38	.053	99.48	1837	50388	98.71	652	77	100	41382	.1	41242
2.4	2435	38	.034	99.67	4473	122024	99.24	926	80	100	101891	.1	101556
2.5	2642	38	.022	99.79	11029	299655	99.55	1355	83	100	253370	.1	252563
2.6	2858	38	.014	99.87	27454	743752	99.73	2045	87	100	634823	.1	632857
2.7	3082	38	.008	99.91	68844	1860894	99.83	3175	90	100	1599462	.1	1594653
2.8	3315	38	.005	99.94	173571	4683472	99.89	5060	93	100	4045693	.1	4033929
2.9	3556	38	.003	99.96	439261	11835790	99.93	8251	97	100	%10258950	.1	%10230
010													
3.0	3805	38	.002	99.97	%1114284	25300430	99.95	12480	100	100	%16670320	.3	%166
70440													

S=50% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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,
LAMEDA*SQRIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS ----------					%	YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA H3M		DELTA
1.0	423	38	.933	7.17	1	25	0.93	24	22	0	4	.3	4
1.1	512	38	.859	16.11	1	29	2.82	29	24	0	6	.3	6
1.2	609	38	.766	29.15	1	36	6.94	34	27	0	9	.2	8
1.3	715	38	.670	44.72	2	48	14.34	41	29	36	14	.2	13
1.4	829	38	.580	60.23	3	66	25.67	49	31	85	24	.2	23
1.5	951	38	.497	73.37	4	100	40.36	60	33	94	45	.2	44
1.6	1082	38	.420	83.10	8	168	56.21	73	36	97	90	.2	89
1.7	1222	38	.346	89.64	15	306	70.40	91	38	99	188	.1	187
1.8	1370	38	.277	93.76	30	600	81.19	113	40	100	400	.1	398
1.9	1526	38	.213	96.26	64	1242	88.58	142	42	100	885	.1	882
2.0	1691	38	.158	97.75	142	2696	93.28	181	44	100	2023	.1	2016
2.1	1865	38	.113	98.64	326	6079	96.11	236	47	100	4743	.1	4726
2.2	2046	38	.078	99.16	766	14124	97.76	316	49	100	11347	.1	11308
2.3	2237	38	.053	99.48	1837	33592	98.71	435	51	100	27588	.1	27495
2.4	2435	38	.034	99.67	4473	81350	99.24	617	53	100	67928	.1	67704
2.5	2642	38	.022	99.79	11029	199770	99.55	903	56	100	168914	.1	168375
2.6	2858	38	.014	99.87	27454	495835	99.73	1363	58	100	423215	.1	421905
2.7	3082	38	.008	99.91	68844	1240596	99.83	2117	60	100	1066308	.1	1063102
2.8	3315	38	.005	99.94	173571	3122315	99.89	3373	62	100	2697129	.1	2689286
2.9	3556	38	.003	99.96	439261	7890529	99.93	5501	64	100	6839300	.1	6820009
3.0	3805	38	.002	99.97	%1114284	16866950	99.95	8320	67	100	%11113550	.3	%111

13620

S=50% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FI	F-DEG*DAYS TCAVG	&CV%	PROB. FPAVG	&CV%	COVER THERMAL PROPERTIES IN H3 (R1.3=1) FPY	UP.YRS	CV%	LBOND	ABD	% R50	WASTEPILE YEARS FT DELTA	H3M	YEARS DELTA
H'													
1	423	38	.933	7.17	1	18	0.93	18	17	0	3	.3	3
1.1	512	38	.859	16.11	1	22	2.82	21	18	0	4	.3	4
1.2	609	38	.766	29.15	1	27	6.94	25	20	0	6	.2	6
1.3	715	38	.670	44.72	2	36	14.34	31	22	0	10	.2	10
1.4	829	38	.580	60.23	3	50	25.67	37	23	50	18	.2	18
1.5	951	38	.497	73.37	4	75	40.36	45	25	84	33	.2	33
1.6	1082	38	.420	83.10	8	126	56.21	55	27	93	67	.2	66
1.7	1222	38	.346	89.64	15	230	70.40	68	28	97	141	.1	140
1.8	1370	38	.277	93.76	30	450	81.19	85	30	99	300	.1	299
1.9	1526	38	.213	96.26	64	932	88.58	106	32	99	664	.1	661
2.0	1691	38	.158	97.75	142	2022	93.28	136	33	100	1517	.1	1512
2.1	1865	38	.113	98.64	326	4559	96.11	177	35	100	3557	.1	3545
2.2	2046	38	.078	99.16	766	10593	97.76	237	37	100	8510	.1	8481
2.3	2237	38	.053	99.48	1837	25194	98.71	326	38	100	20691	.1	20621
2.4	2435	38	.034	99.67	4473	61012	99.24	463	40	100	50946	.1	50778
2.5	2642	38	.022	99.79	11029	149828	99.55	678	42	100	126685	.1	126281
2.6	2858	38	.014	99.87	27454	371876	99.73	1023	43	100	317411	.1	316429
2.7	3082	38	.008	99.91	68844	930447	99.83	1588	45	100	799731	.1	797327
2.8	3315	38	.005	99.94	173571	2341736	99.89	2530	47	100	2022846	.1	2016965
2.9	3556	38	.003	99.96	439261	5917897	99.93	4126	48	100	5129475	.1	5115007
3.0	3805	38	.002	99.97	%1114284	12650210	99.95	6240	50	100	8335160	.3	833521
8													

S=50% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
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 = WASE 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 = 0.50,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 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
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)						WASTEPILE		
					YEARS					%	YEARS FT		YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	423	38	.933	7.17	1	15	0.93	15	13	0	2	.3	2
1.1	512	38	.859	16.11	1	18	2.82	17	15	0	3	.3	3
1.2	609	38	.766	29.15	1	22	6.94	20	16	0	5	.2	5
1.3	715	38	.670	44.72	2	29	14.34	24	17	0	8	.2	8
1.4	829	38	.580	60.23	3	40	25.67	30	19	16	14	.2	14
1.5	951	38	.497	73.37	4	60	40.36	36	20	70	27	.2	26
1.6	1082	38	.420	83.10	8	101	56.21	44	21	89	54	.2	53
1.7	1222	38	.346	89.64	15	184	70.40	54	23	95	113	.1	112
1.8	1370	38	.277	93.76	30	360	81.19	68	24	98	240	.1	239
1.9	1526	38	.213	96.26	64	745	88.58	85	25	99	531	.1	529
2.0	1691	38	.158	97.75	142	1618	93.28	109	27	100	1214	.1	1209
2.1	1865	38	.113	98.64	326	3648	96.11	142	28	100	2846	.1	2836
2.2	2046	38	.078	99.16	766	8475	97.76	190	29	100	6808	.1	6785
2.3	2237	38	.053	99.48	1837	20155	98.71	261	31	100	16553	.1	16497
2.4	2435	38	.034	99.67	4473	48810	99.24	370	32	100	40757	.1	40623
2.5	2642	38	.022	99.79	11029	119862	99.55	542	33	100	101348	.1	101025
2.6	2858	38	.014	99.87	27454	297501	99.73	818	35	100	253929	.1	253143
2.7	3082	38	.008	99.91	68844	744358	99.83	1270	36	100	639785	.1	637861
2.8	3315	38	.005	99.94	173571	1873389	99.89	2024	37	100	1618277	.1	1613572
2.9	3556	38	.003	99.96	439261	4734317	99.93	3300	39	100	4103580	.1	4092006
3.0	3805	38	.002	99.97	%1114284	10120170	99.95	4992	40	100	6668128	.3	666817
5													

UPFREEZ3 RUN COMPLETE