



00831224

Calculation Cover Sheet

Project F-Area Waste Storage Tanks 18 and 19 Closure		Calculation No. K-CLC-F-00073	Project No. N/A	
Title Static Settlement of F-Area Waste Storage Tanks 18 and 19		Functional Classification SS	Sheet 1 of <u>17</u>	
		Discipline Geotechnical		
Calc Level <input checked="" type="checkbox"/> Type 1 <input type="checkbox"/> Type 2		Type 1 Calc Status <input type="checkbox"/> Preliminary <input checked="" type="checkbox"/> Confirmed		
Computer Program No. <input checked="" type="checkbox"/> N/A		Version/Release No. N/A		
Purpose and Objective This calculation estimates the static settlement of Tanks 18 and 19 during the closure phase.				
Summary of Conclusion see last section.				
<p>UNCLASSIFIED DOES NOT CONTAIN UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION</p> <p>ADC & Revising Official: <u>Michael D. McLeod</u> (Name and Title) Date: <u>6-19-2006</u></p>				
Revisions				
Rev No.	Revision Description			
2	Revised to add new cover sheet for Design Authority's re-approval			
Sign Off				
Rev No.	Originator (Print) Sign/Date	Verification/ Checking Method	Verifier/Checker (Print) Sign/Date	Manager (Print) Sign/Date
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Design Authority — (Print) JOHN J PHILLIPS		Signature <u>John J Phillips</u>		Date 06/20/06
Release to Outside Agency — (Print)		Signature		Date
Security Classification of the Calculation				

USQ - FTF - 2006 - 00234 Rev 1
Rev 2 of Calc has no change from Rev 1 of Calc.

ENGINEERING DOC. CONTROL - SRS



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Rev No.	Revision Description			
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1. INTRODUCTION

This calculation provides the static settlement for the F-Area Waste Storage Tanks 18 and 19 (Ref. 1) using the settlement data from November 16, 1991 through June 5, 2006.

2. INPUT DATA

(1) Facility configurations:

Existing ground elevation prior to the construction of the tanks was about 292 feet mean sea level (MSL) at the footprint of Tank 18, and about 290 feet MSL at the footprint of Tank 19 (Ref. 2).

Existing ground surface elevation around Tank 18 in the north is 269.5 feet MSL and around Tank 19 in the south is 268.5 feet MSL (Ref. 1).

Foundation elevation of Tank 18 in the north is 228.31 feet, MSL. Foundation elevation of Tank 19 in the south is 227.39 feet, MSL. Foundation diameter is 90' - 8-3/4" (Ref. 3).

Tanks were constructed in the late 1950's. Figure 1 shows the layout of the tanks (Ref. 4).

Tanks 17 and 20 were closed in 1997. Figures 2 and 3 show the schedules of the closure for Tank 17 and Tank 20, respectively.

(2) Settlement Data

Table 1 provides the settlement data for Tanks 17 through 20 since November 16, 1991 (Ref. 5 and 6).

(3) Elevation of the cap

The following four possible cases were considered for the top elevation of the cap (Ref. 7):

Case 1: No cap (soil surface at current state)

Case 2: 10 feet above the center riser. After the placement of 10-foot cap, the surface elevation will be 287.7 feet MSL at Tank 18 and 286.8 feet MSL at Tank 19.

Case 3: Up to the existing grade around the Tanks 17-20 pit. After the placement of the cap, the surface elevations will be approximately 288 feet MSL.

Case 4: 10 feet above top of Evaporator Building 242-F. After the placement of a cap 10 feet above 242-F, the surface elevation will be 304.5 feet MSL.

(4) Pressure due to tank foundation on soil (Ref. 8):

Total weight at the bottom of the foundation prior to the start of closure: 8,888.84 kips. Pressures after the closure for various cases are:

Case 1: 6.00 ksf.

Case 2: 8.01 ksf.

Case 3: 8.41 ksf.

Case 4: 10.09 ksf.

(5) Additional input by the Manager.

All four tanks were constructed in the late 1950's. However, we only have settlement data since November 16, 1997 (see Section 2 Item 2). Between November 16, 1991 and April 11, 1997 (before grouting), the settlement has remained essentially zero (see Section 3.2). The fluctuation shown in Figure 4 can be attributed to survey deviation and/or temperature fluctuation (see Section 3.2). Thus, we can assume that prior to filling tanks with grout in 1997, the tanks had settled very little and were in a stable condition (see Section 3.2).

3. COMPUTATIONS

3.1 Settlement Data

Table 2 shows the settlement of Tanks 17, 18, 19, and 20 since November 15, 1991 computed using the data from Table 1. Figure 4 shows the plot of the settlement. Settlement due to the closure of Tanks 17 and 20 can clearly be seen from the plot. The plot also indicates that based on the actual survey readings, differential settlement for any given tank is less than 0.1 inches. The resulting angular distortion for any given tank is less than 2×10^{-4} radians and is judged to be insignificant and therefore is not evaluated in this calculation. Following sections provide the evaluation of the settlement data and their relation with the loadings.

3.2 Settlement prior to Closure

Figure 5 shows the settlement of all the settlement points of the four tanks prior to the closure of Tanks 17 and 20. Also shown is the average settlement of these four tanks and a linear function best fit for the average settlement. The results indicate that during the period between 1991 and 1997, or approximately 40 years after the installation of the tanks, the elevation of the tank is very stable with the movement being attributed to survey error and/or temperature fluctuation. Settlement in the last six years prior to the starting of closure Tank 17 and 20 was near zero.

3.3 Immediate settlement after the Closure

Figure 6 shows the average settlements of the tanks since the beginning of the closure of Tanks 17 and 20. Average settlements were also fitted to logarithmic functions and shown in Figure 7.

Immediate settlements ρ_i were computed using the time dependent settlement ρ_c three or more years after the construction based on a method suggested by Burland and Burbidge (Ref. 10). Settlement ρ_t after time t at least 3 years following construction was estimated by:

$$\rho_t = f_t \rho_i$$

where ρ_t is the settlement after time t

ρ_i is the immediate settlement

$$f_t = 1 + R_i + R_c \log (t/3)$$

where t is the time in years

R_i and R_c are the time-dependent settlement ratios.

Consider $R_i = 0.3$ and $R_c = 0.2$,

$$f_t = 1.3 + 0.2 \log (t/3)$$

Settlement at 3337 days after closure (i.e., grouting tanks), $t = 3337$ days, or 9.136 years is

$$f_t = 1.3 + 0.2 \log (9.136/3) = 1.397$$

Therefore

$$\rho_i = \rho_o / f_t = \rho_o / 1.397$$

Settlements at 3337 days (ρ_o) were calculated using the best fit logarithmic functions shown in Figure 7. Then the relationship above was used to back calculate immediate settlement (ρ_i). Back calculated immediate settlements after the closure were 0.40 and 0.47 inches for Tanks 20 and Tank 17, respectively, with an average immediate settlement of 0.43 inches. Back calculated immediate settlement of Tanks 18 and 19 due to the closure of Tank 17 and 20 was 0.12 inches.

Immediate settlements computed above are consistent with readings after the closure of tanks (see Figure 4). Immediate settlement shortly after the closure was not measured. However, readings that include immediate settlement were taken within several months after the closure.

It is conservatively estimated that the settlement after the closure (i.e., grouting of Tank 18 and 19) will be an additional 0.45 inches for Tanks 18 and 19, and an additional 0.15 inches for Tanks 17 and 20. Or a conservative total average settlement of 0.6 inch for each tank since the beginning of the closure of Tanks 17 and 20, April 16, 1997. A conservative estimate of the immediate settlement (ρ_i) for case 1 would be 0.6 inch.

Prior to the closure, the weight at the bottom of the tank is 8,888.84 kips for each tank, or a pressure of $8,888.84 / (\pi 45.36^2) = 1.37$ ksf. Elastic settlement immediately after the closure is due to the additional pressure of $(6.00 - 1.37 =) 4.63$ ksf. Immediate settlements (ρ_i) of the remaining three cases were computed proportional to the additional pressure. ρ_i for case 2 is $(0.6 \text{ inch} \times 6.64 \text{ ksf} / 4.63 \text{ ksf})$ or 0.86 inch, ρ_i for case 3 is $(0.6 \text{ inch} \times 7.04 \text{ ksf} / 4.63 \text{ ksf})$ or 0.91 inch and ρ_i for case 4 is $(0.6 \text{ inch} \times 8.66 \text{ ksf} / 4.63 \text{ ksf})$ or 1.12 inch. Immediate settlements for all cases are summarized in Table 3.

The amount of soil removed during the construction at the location of Tank 18 was 292 – 228.3 or 63.7 feet. Soil removed at the location of Tank 19 was 290 – 227.4 or 62.6 feet. Using the average weight of about 120 psf for the soils in F-Area (Ref. 9), the initial overburden pressure at the foundation was approximately 7.5 ksf. The worst case loading (Case 4 load of 10.09 ksf) only has a 2.6 ksf net load.

3.4 Long Term Settlement from creep and secondary compression

Settlement ρ_t from creep and secondary compression was computed using the relation

$$\rho_t = f_t \rho_i$$

$$f_t = 1.3 + 0.2 \log (t/3)$$

where t is the time in years and ρ_i is estimated as described in Section 3.3.

Table 4 provides the estimated settlement from creep and secondary compression effects at various times for the various cases.

4. RESULTS

The estimated settlements for various cases are summarized in Table 4. The final capping system should be designed to accommodate the settlements given in Table 4. This should be

possible, particularly if the final cap is not placed until after the first year when the majority of the settlement is expected to occur.

5. REFERENCES

- (1) W167477, Additional Waste Storage Tanks, Dome Plan and Details, Rev. 21.
- (2) SRS Map No. 3302 Sheets 0853 and 0854.
- (3) W167482, Additional Waste Storage Tanks, Bottom Slab Plan and Details, Rev. 22.
- (4) W167808, Additional Waste Storage Tanks, General Arrangement & Construction Details Concrete & Steel, Rev. 3.
- (5) K-ESR-00007, Settlement of F-Area Waste Storage Tanks and Structures, Rev. 0, September 1999.
- (6) K-ESR-F-00009, Settlement Summary for F-Area Tanks and Selected Structures, Rev. 1, November 2001.
- (7) K-CLC-F-00072, Bearing Capacity, Rev. 0.
- (8) T-CLC-F-00373, Tanks 18 and 19 Closure Structural Calculation, Rev. 0.
- (9) WSRC-TR-96-0069, F-Area Geotechnical Characterization Report, Rev. 0.
- (10) Burland and Burbidge, Settlement of Foundations on Sand and Gravel, *Proc. Instn. Civ. Engrs, Part I*, 1985, 78, Dec.

Table 1 Settlement Data

Survey Date	Settlement Point Elevations (feet, MSL)						
	Tank 17	Tank17	Tank 18	Tank 19	Tank 19	Tank 20	Tank 20
	Point 1	Point 2 (E)	Point 1	Point 1	Point 2 (SE)	Point 1	Point 2 (E)
11/16/1991	277.5705	270.9305	277.5640	276.5957	269.6558	276.7256	269.9076
3/1/1992	277.5683	270.9281	277.5614	276.5954	269.6551	276.7290	269.9098
6/1/1992	277.5708	270.9304	277.5686	276.5981	269.6577	276.7296	269.9114
9/1/1992	277.5670	270.9270	277.5635	276.5935	269.6529	276.7267	269.9080
2/1/1993	277.5692	270.9291	277.5603	276.5948	269.6541	276.7304	269.9114
10/1/1993	277.5698	270.9311	277.5631	276.5952		276.7318	269.9139
4/1/1994	277.5748	270.9331	277.5721	276.5984	269.6561	276.7332	269.9132
10/1/1994	277.5705	270.9323	277.5647	276.5962	269.6566	276.7329	269.9150
4/1/1995	277.5695	270.9271	277.5639	276.5953	269.6507	276.7312	269.9088
11/5/1995	277.5692	270.9293	277.5654	276.5956	269.6539	276.7327	269.9118
5/2/1996	277.5742	270.9317	277.5677	276.6005	269.6558	276.7365	269.9140
10/18/1996		270.9276		276.5940	269.6508		269.9113
4/11/1997				276.5978	269.6558		
10/1/1997			277.5556		269.6484	276.7060	269.8834
4/1/1998	277.5287	270.8858	277.5569	276.5921	269.6528	276.7065	269.8848
10/1/1998	277.5309	270.8912	277.5489	276.5856	269.6479	276.6967	269.8762
4/1/1999	277.5278	270.8819		276.5852	269.6434	276.6958	269.8718
10/15/1999	277.5245	270.8810	277.5519	276.5852	269.6465	276.6945	269.8742
10/6/2000	277.5273	270.8820	277.5516	276.5898	269.6495	276.6978	269.8757
4/26/2001	277.5187	270.8732	277.5444		269.6429	276.6888	269.8681
6/5/2006	277.5210	270.8741	277.5545	276.5880	269.6454	276.6916	269.8673

Table 2 Settlement since November 15, 1991

Survey Date	Days since 11/15/91	Settlement (inches)						
		Tank 17	Tank 17	Tank 18	Tank 19	Tank 19	Tank 20	Tank 20
		Point 1	Point 2 (E)	Point 1	Point 1	Point 2 (SE)	Point 1	Point 2 (E)
11/16/1991	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/1/1992	107	-0.026	-0.029	-0.031	-0.004	-0.008	0.041	0.026
6/1/1992	199	0.004	-0.001	0.055	0.029	0.023	0.048	0.046
9/1/1992	291	-0.042	-0.042	-0.006	-0.026	-0.035	0.013	0.005
2/1/1993	444	-0.016	-0.017	-0.044	-0.011	-0.020	0.058	0.046
10/1/1993	686	-0.008	0.007	-0.011	-0.006		0.074	0.076
4/1/1994	868	0.052	0.031	0.097	0.032	0.004	0.091	0.067
10/1/1994	1051	0.000	0.022	0.008	0.006	0.010	0.088	0.089
4/1/1995	1233	-0.012	-0.041	-0.001	-0.005	-0.061	0.067	0.014
11/5/1995	1451	-0.016	-0.014	0.017	-0.001	-0.023	0.085	0.050
5/2/1996	1630	0.044	0.014	0.044	0.058	0.000	0.131	0.077
10/18/1996	1799		-0.035		-0.020	-0.060		0.044
4/11/1997	1974				0.025	0.000		
10/1/1997	2147			-0.101		-0.089	-0.235	-0.290
4/1/1998	2329	-0.502	-0.536	-0.085	-0.043	-0.036	-0.229	-0.274
10/1/1998	2512	-0.475	-0.472	-0.181	-0.121	-0.095	-0.347	-0.377
4/1/1999	2694	-0.512	-0.583		-0.126	-0.149	-0.358	-0.430
10/15/1999	2891	-0.552	-0.594	-0.145	-0.126	-0.112	-0.373	-0.401
10/6/2000	3248	-0.518	-0.582	-0.149	-0.071	-0.076	-0.334	-0.383
4/26/2001	3450	-0.622	-0.688	-0.235		-0.155	-0.442	-0.474
6/5/2006	5316	-0.594	-0.677	-0.114	-0.092	-0.125	-0.408	-0.484

Placement of grout for Tank 17 occurred 9/22/97 through 12/18/97.

Placement of grout for Tank 20 occurred 4/17/97 through 7/30/97.

Table 3 Estimated Average Immediate Settlement

Case	Pressure at Foundation (ksf)	Additional Pressure at Foundation due to Closure (ksf)	Tanks 17 & 20 Immediate Settlement due to closure (inches)	Tanks 18 & 19 Immediate Settlement due to Closure (inches)
Prior to Closure	1.37	0.00	0.0	0.0
Closure of Tanks 17 & 20	6.00	4.63	0.45	0.15
Case 1	6.00	4.63	0.60	0.60
Case 2	8.01	6.64	0.86	0.86
Case 3	8.41	7.04	0.91	0.91
Case 4	10.09	8.72	1.12	1.12

Table 4 Estimated Average Total Settlement

Case	Immediate Settlement after installation of cap (inches)	Settlement 10 years after installation of cap (inches)	Settlement 100 years after installation of cap (inches)	Settlement 1,000 years after installation of cap (inches)	Settlement 10,000 years after installation of cap (inches)
Case 1	0.6	0.8	1.0	1.1	1.2
Case 2	0.9	1.2	1.4	1.6	1.7
Case 3	0.9	1.3	1.5	1.6	1.8
Case 4	1.1	1.6	1.8	2.0	2.2

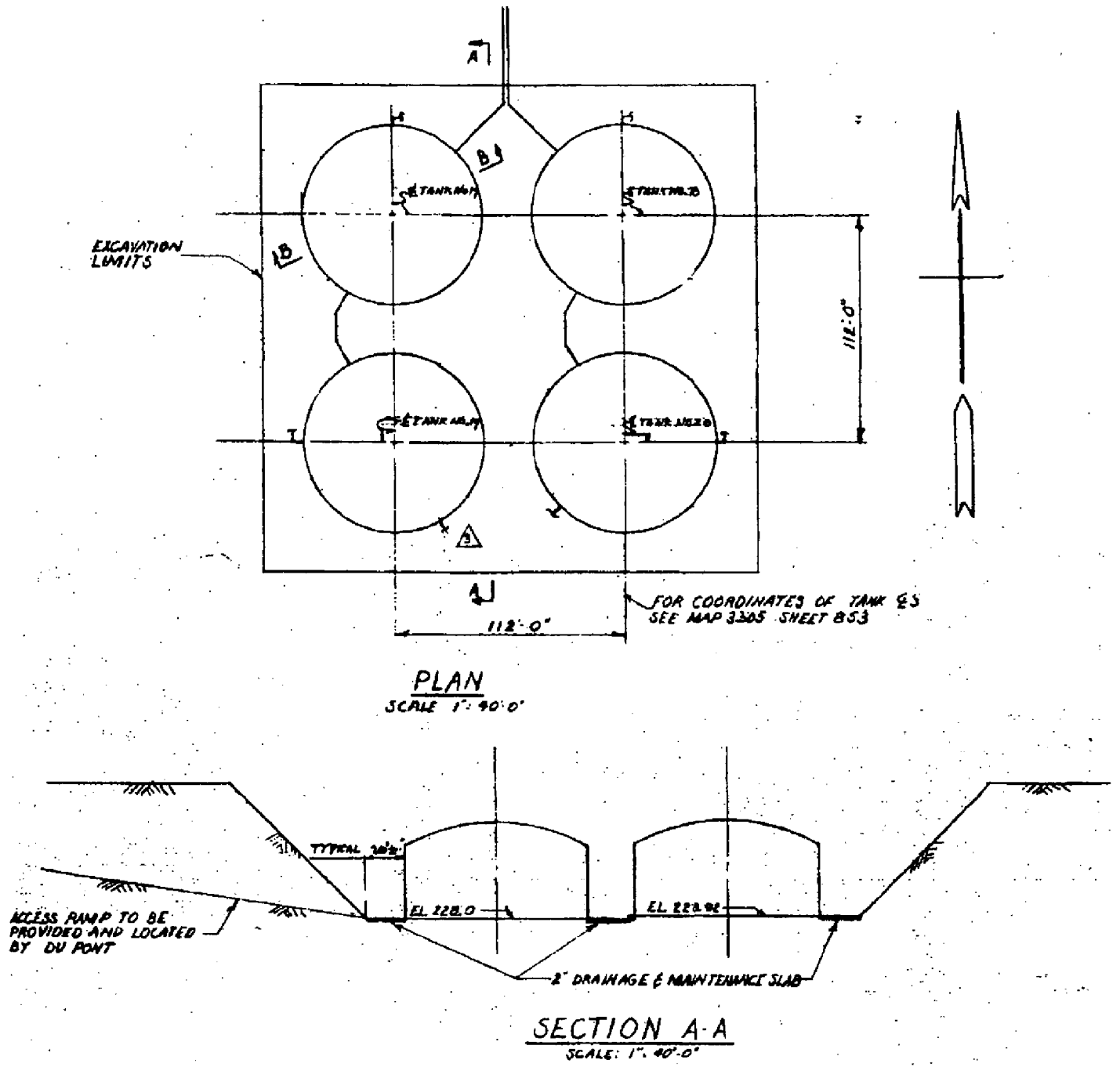


Figure 1 Tank layout

From Ref. 3

TANK 20 CLOSURE

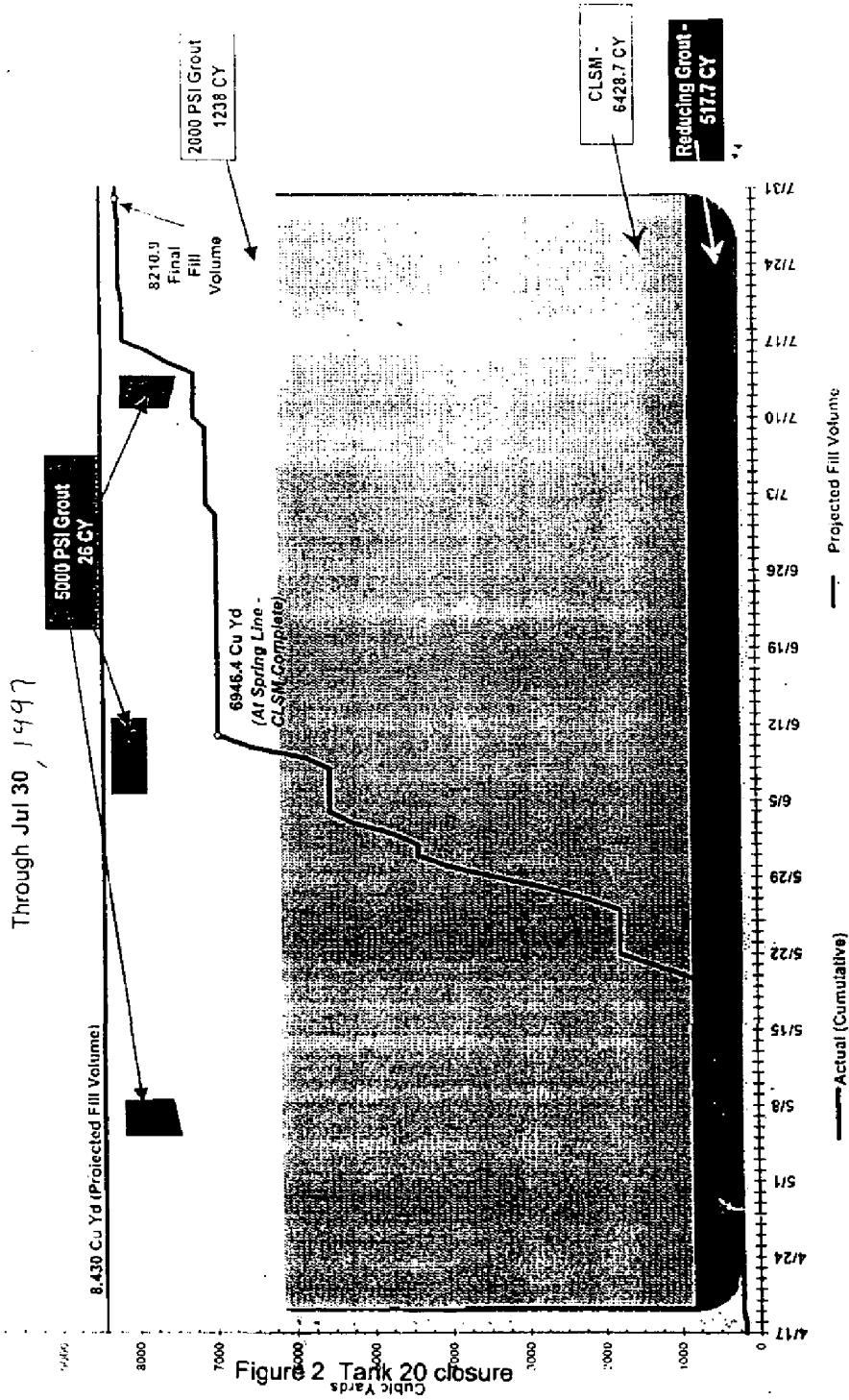
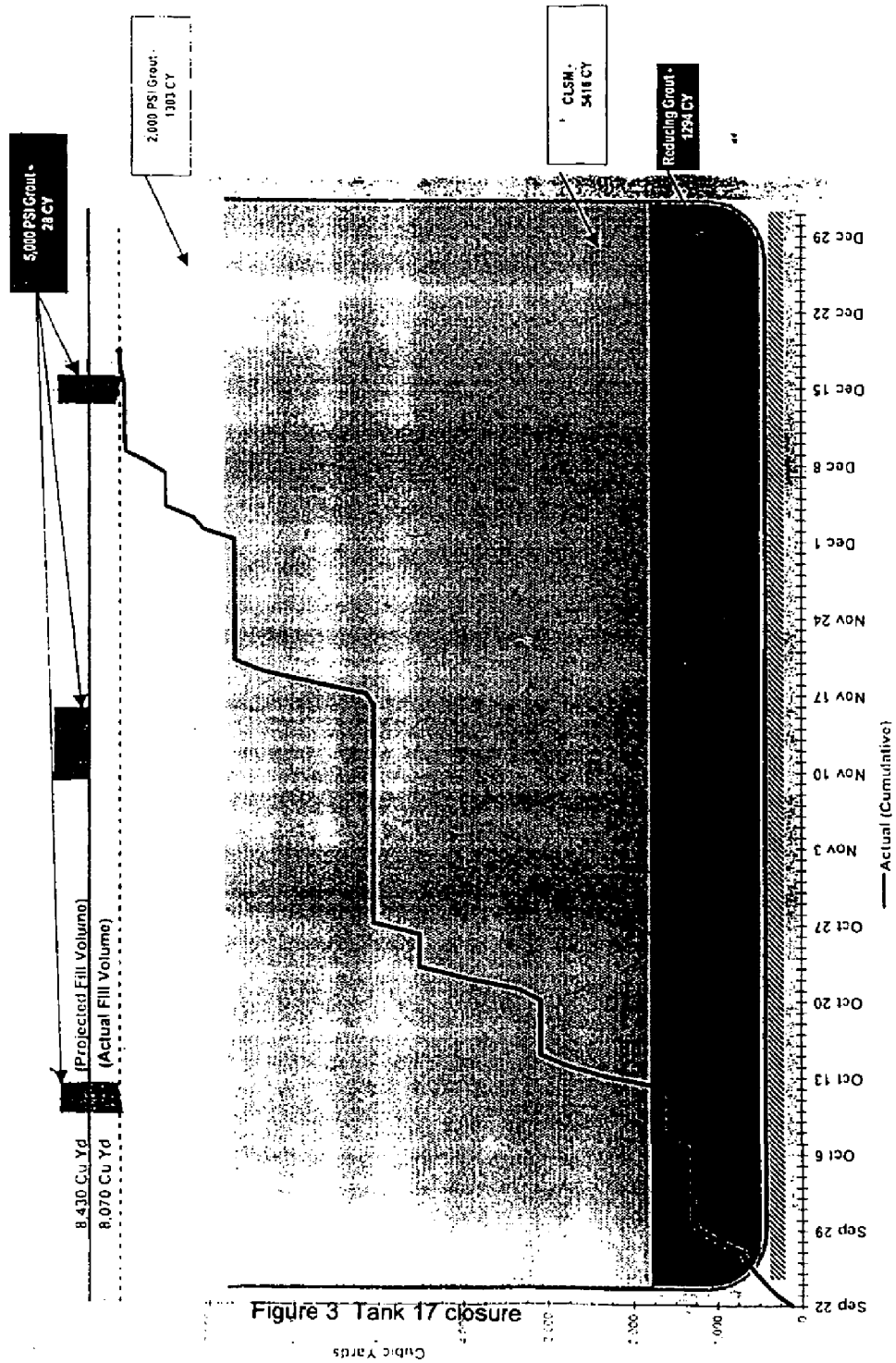


Figure 2 Tank 20 closure

TANK 17 CLOSURE

1997
Through Dec 18 (Complete)



Time2000.xls Chart 001

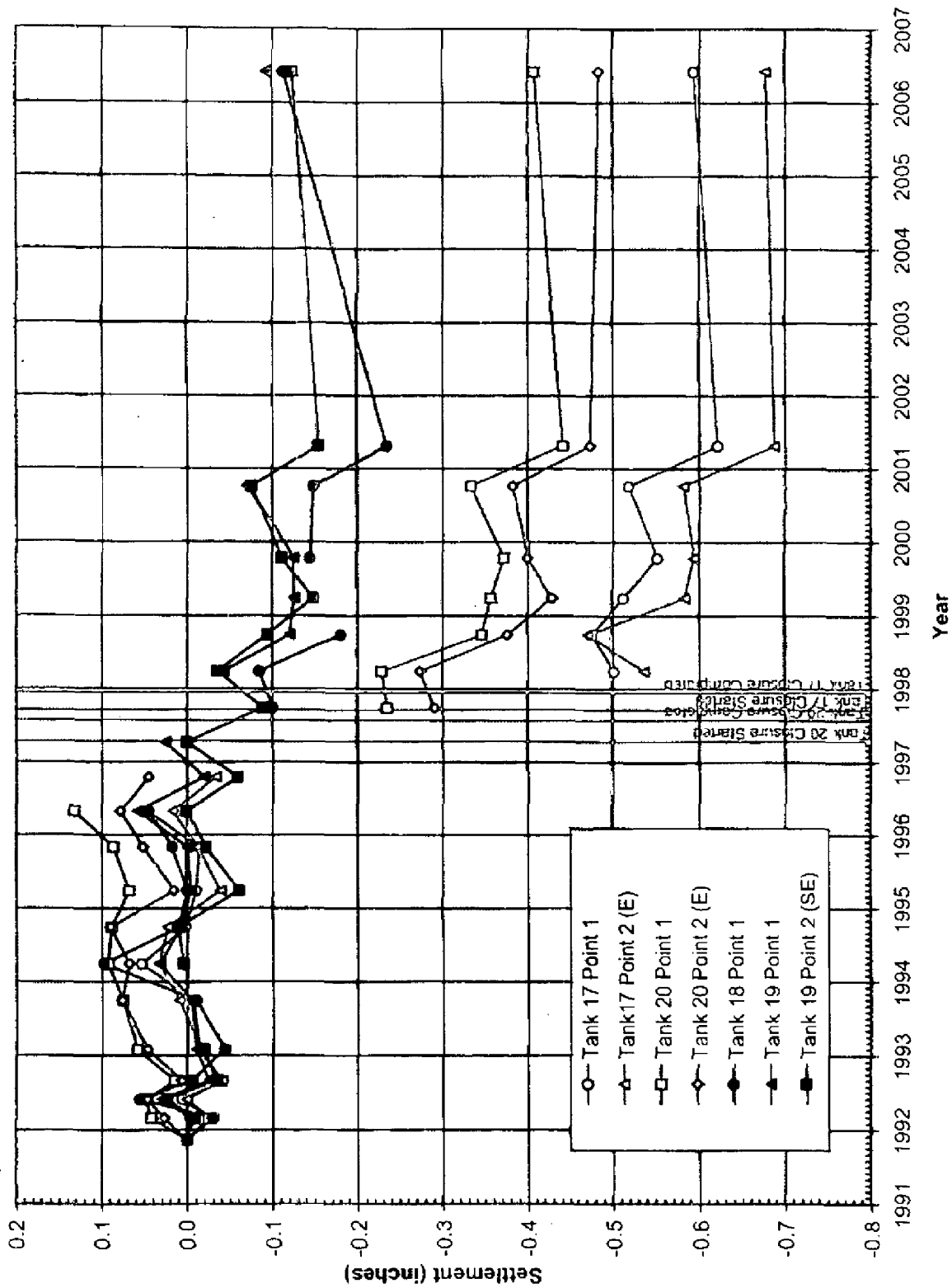


Figure 4 Tank Settlement

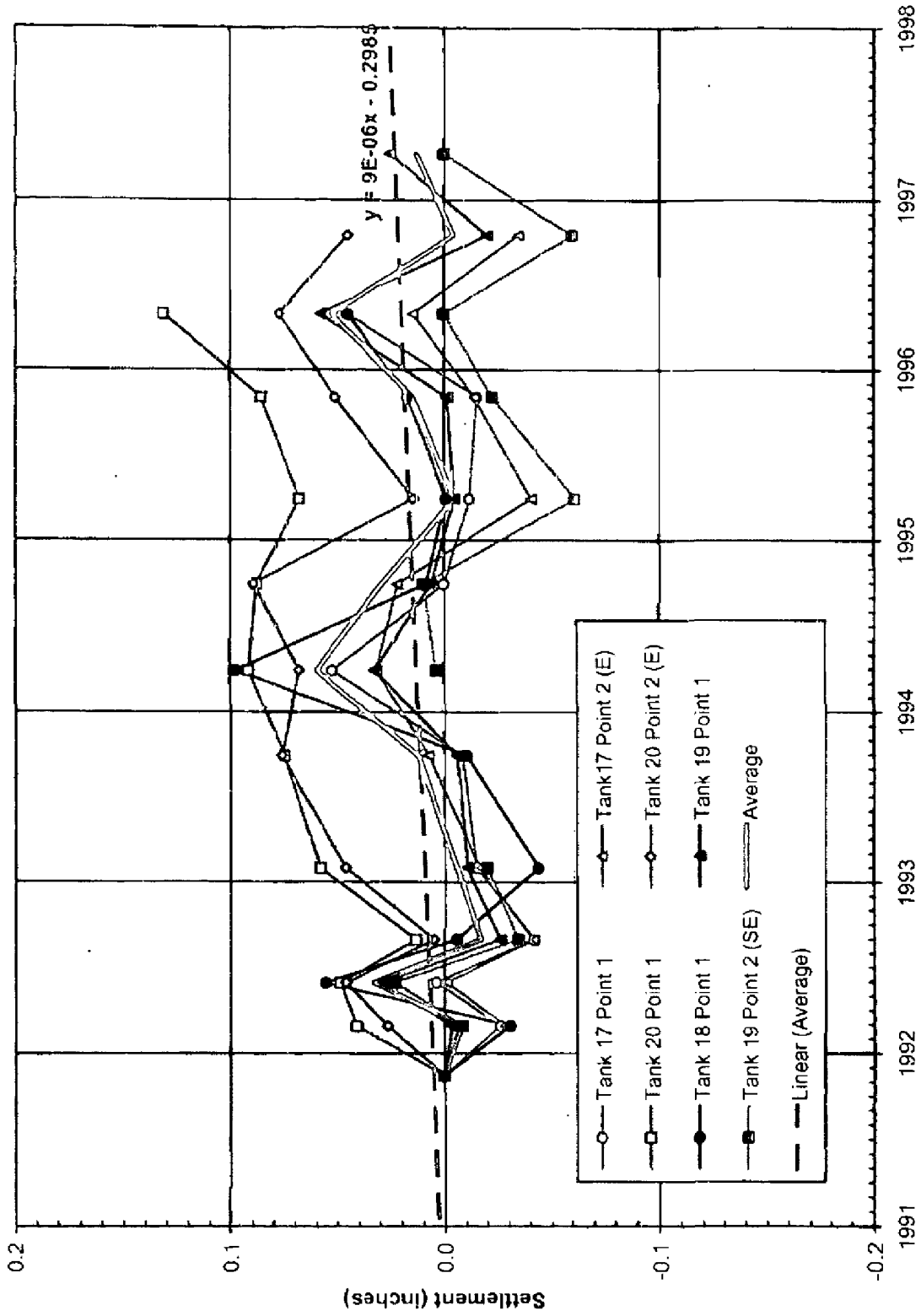


Figure 5 Settlement Prior to Closure

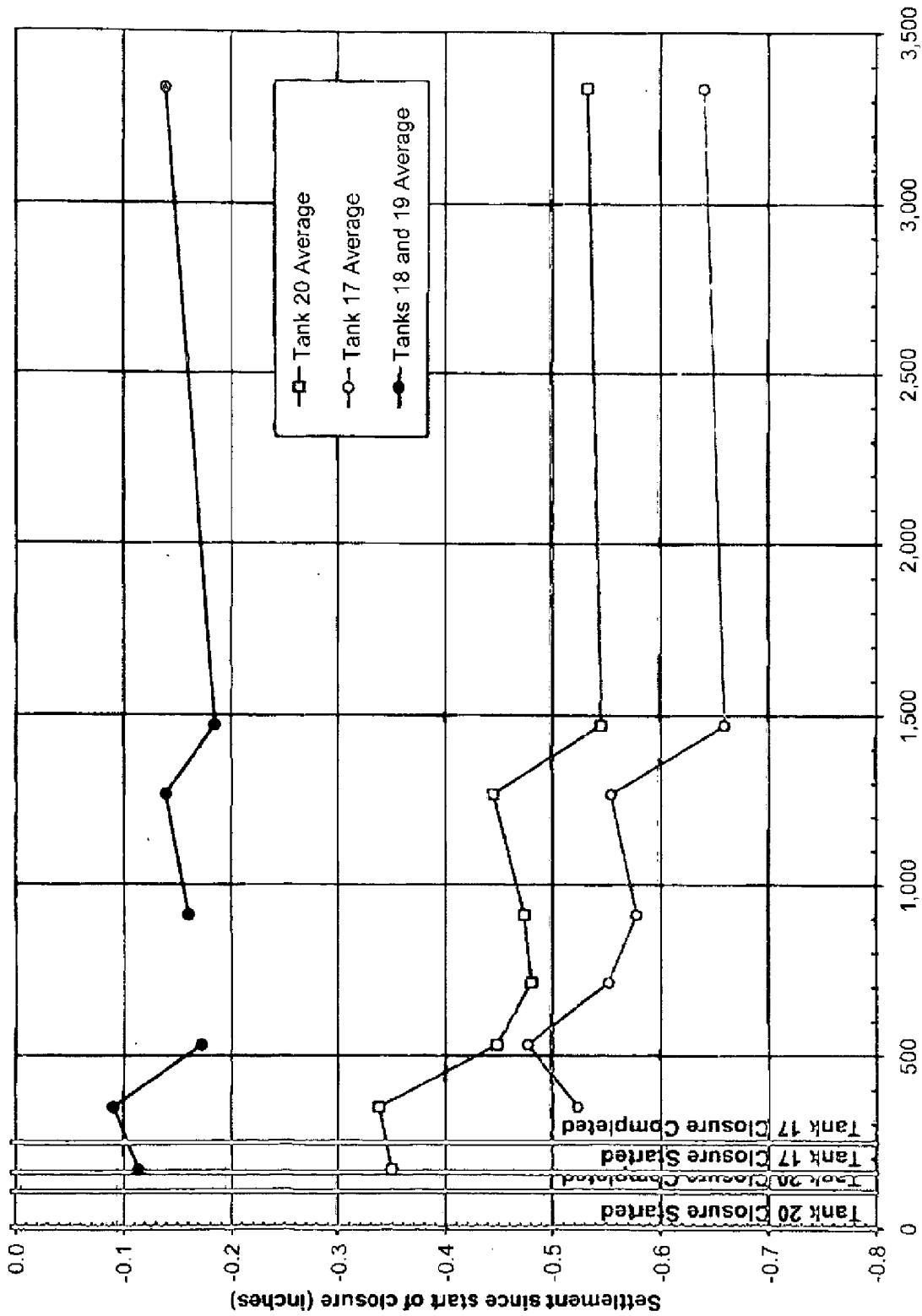
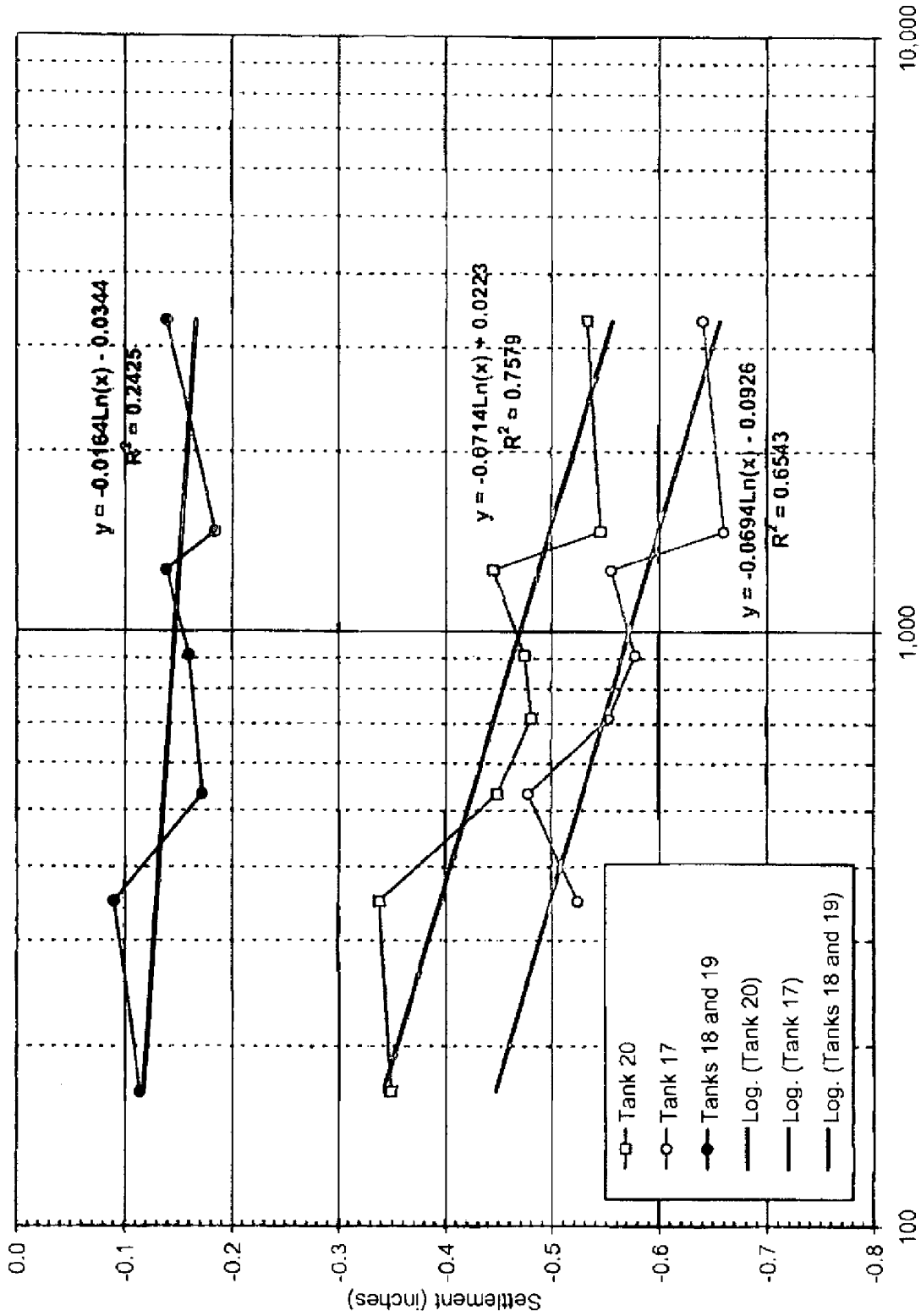


Figure 6 Average settlement after the closure of Tanks 20 and 17



Days since April 16, 1997
 Figure 7 Settlement after the closure of Tanks 20 and 17