ENGINEERING DOC. CONTROL-SRS
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# Calculation Cover Sheet

| | | |
|---|---|---|
| Project<br>F-Area Waste Storage Tanks 18 and 19 Closure | Calculation No.<br>K-CLC-F-00073 | Project No.<br>N/A |
| Title<br>Static Settlement of F-Area Waste Storage Tanks 18 and 19 | Functional Classification<br>SS | Sheet 1 of 17 |
| | Discipline<br>Geotechnical | |
| Calc Level<br>☒ Type 1 ☐ Type 2 | Type 1 Calc Status<br>☐ Preliminary ☒ Confirmed | |
| Computer Program No.<br>☒ N/A | Version/Release No.<br>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.

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NUCLEAR INFORMATION
ADC & Revisioning Official: Michael D. McHood
(Name and Title)
Date: 6-19-2006

**Revisions**

| Rev No. | Revision Description |
|---|---|
| 2 | Revised to add new cover sheet for Design Authority's re-approval |
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**Sign Off**

| Rev No. | Originator (Print) Sign/Date | Verification/ Checking Method | Verifier/Checker (Print) Sign/Date | Manager (Print) Sign//Date |
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| 2 | William T. Li 6/19/06 | Document review | Michael D. McHood 6/19/06 | M.R. Lewis 6/19/06 |
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| Design Authority — (Print)<br>JOHN J PHILLIPS | Signature<br>John J. Phillips | Date<br>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.

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# Calculation Cover Sheet

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|---|---|---|
| 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 16 |
| | Discipline: Geotechnical | |
| Calc Level: Type 1 Type 2 | Type 1 Calc Status: Preliminary Confirmed | |
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| 0 | Initial issue |
| 1 | Revised to incorporate settlement data through June 5, 2006. |
| | |

**Sign Off**

| Rev No. | Originator (Print) Sign/Date | Verification/ Checking Method | Verifier/Checker (Print) Sign/Date | Manager (Print) Sign/Date |
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| 0 | 5/18/06 William T. Li | Document review | 5/25/06 MICHAEL D. MCHOOD | M.R. Lewis 5/25/06 |
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TABLE OF CONTENTS

1. INTRODUCTION ..... 3
2. INPUT DATA ..... 3
3. COMPUTATIONS ..... 4
3.1 Settlement Data ..... 4
3.2 Settlement prior to Closure ..... 4
3.3 Immediate settlement after the Closure ..... 4
3.4 Long Term Settlement from creep and secondary compression ..... 5
4. RESULTS ..... 5
5. REFERENCES ..... 6

## 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 $2x10^{-4}$ 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 $\rho_I$ were computed using the time dependent settlement $\rho_c$ three or more years after the construction based on a method suggested by Burland and Burbidge (Ref. 10). 10). Settlement $\rho_t$ after time t at least 3 years following construction was estimated by:

$$\rho_t = f_t \, \rho_i$$

where $\rho_t$ is the settlement after time t

$\rho_i$ 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

$$\rho_i = \rho_t/f_t = \rho_c/1.397$$

Settlements at 3337 days ($\rho_c$) were calculated using the best fit logarithmic functions shown in Figure 7. Then the relationship above was used to back calculate immediate settlement ($\rho_i$). 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 ($\rho_i$) 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 ($\rho_i$) of the remaining three cases were computed proportional to the additional pressure. $\rho_i$ for case 2 is (0.6 inch x 6.64 ksf / 4.63 ksf) or 0.86 inch, $\rho_i$ for case 3 is (0.6 inch x 7.04 ksf / 4.63 ksf) or 0.91 inch and $\rho_i$ for case 4 is (0.6 inch x 8.66 ksf / 4.63 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 $\rho_t$ 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 $\rho_i$ 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 |

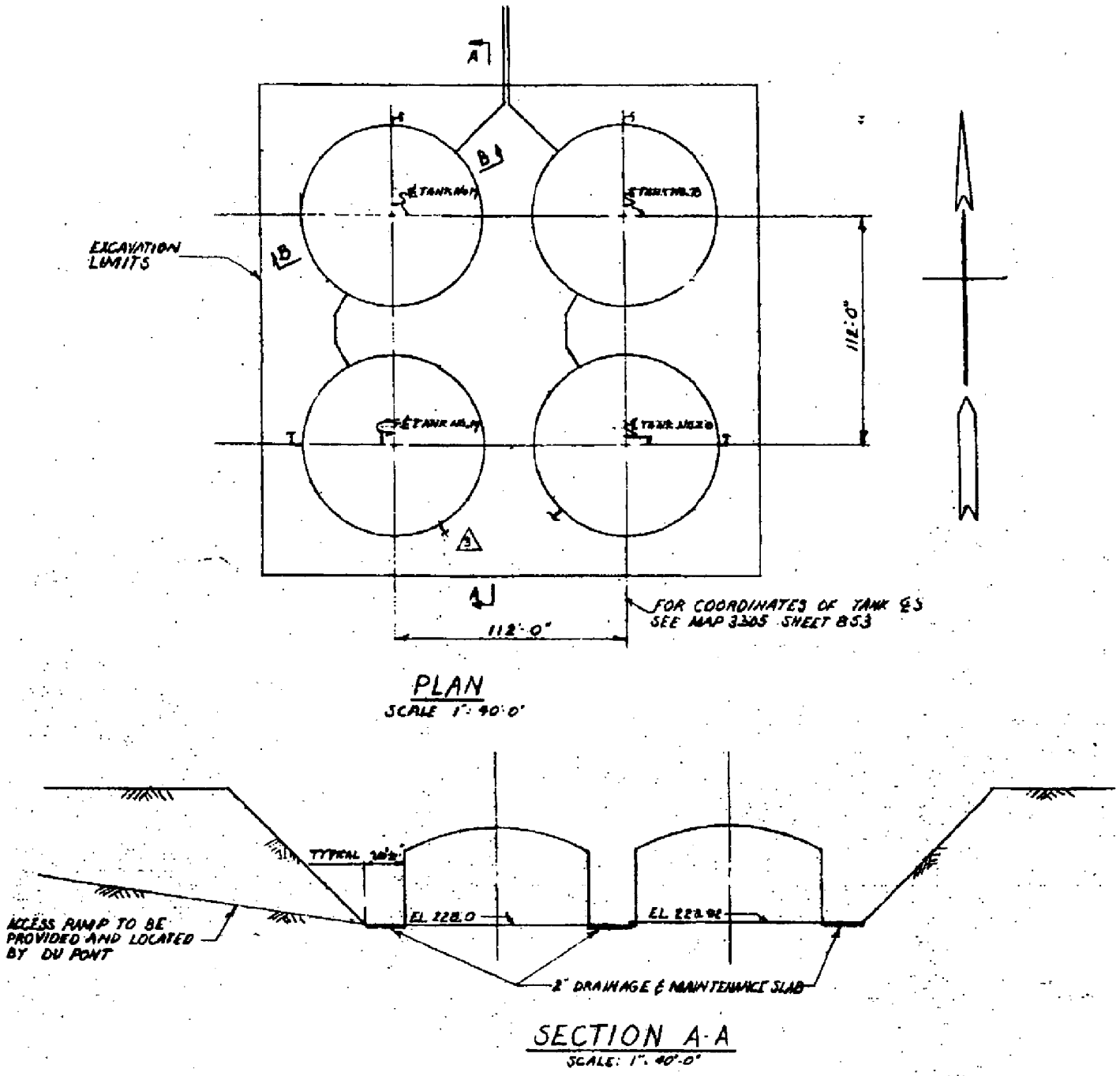


Figure 1 Tank layout

FROM REF. 3

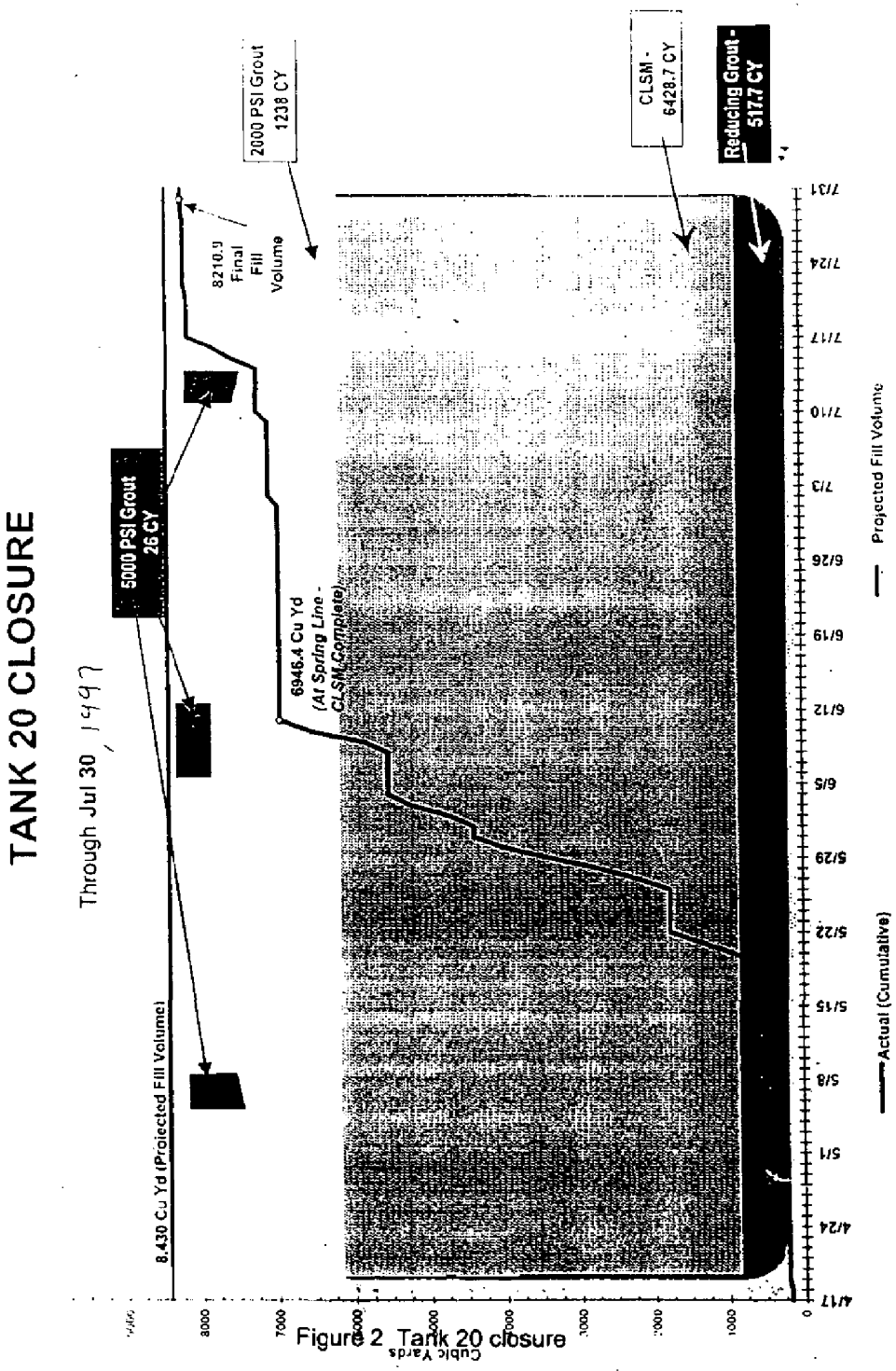


Figure 2 Tank 20 closure

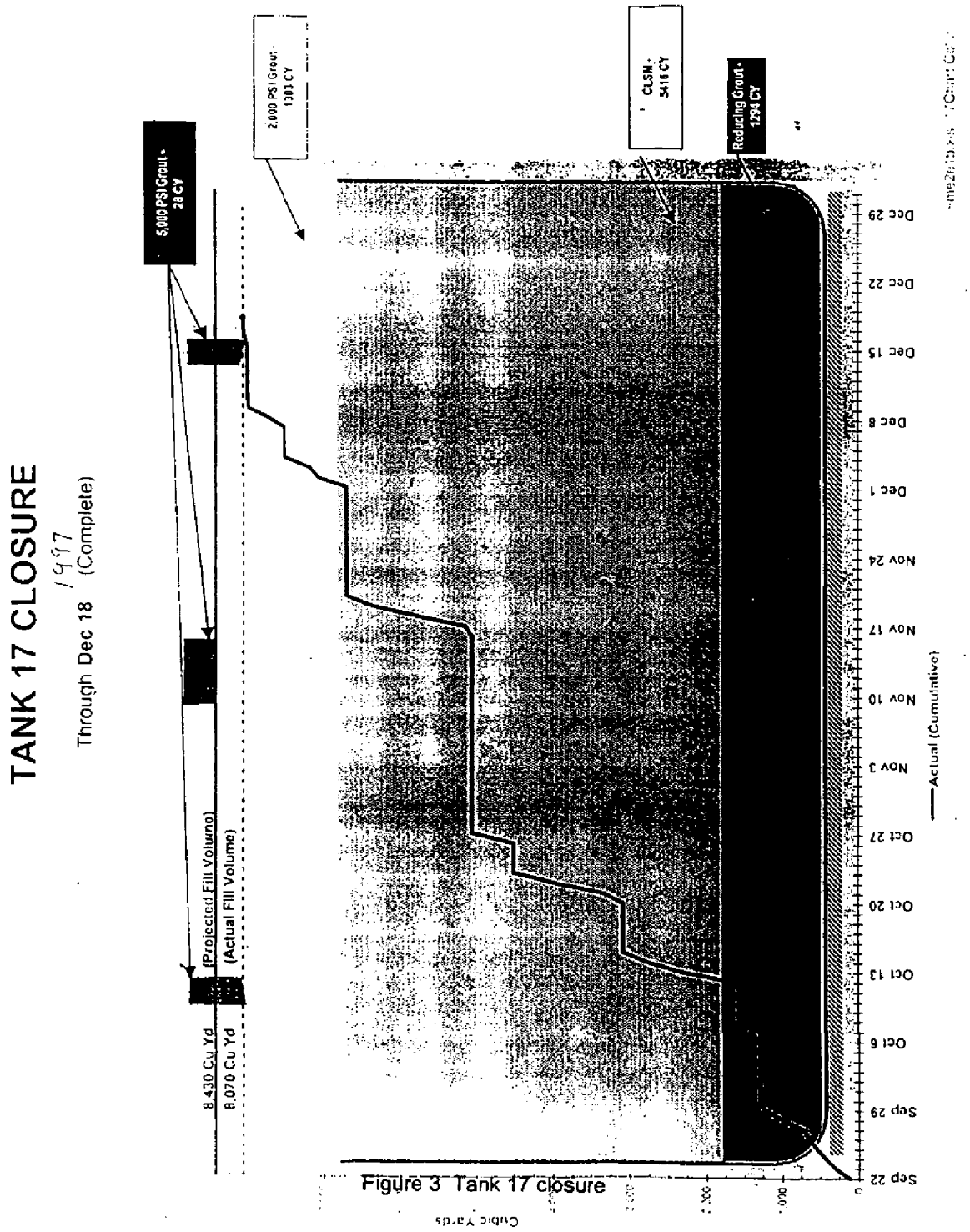


Figure 3 Tank 17 closure

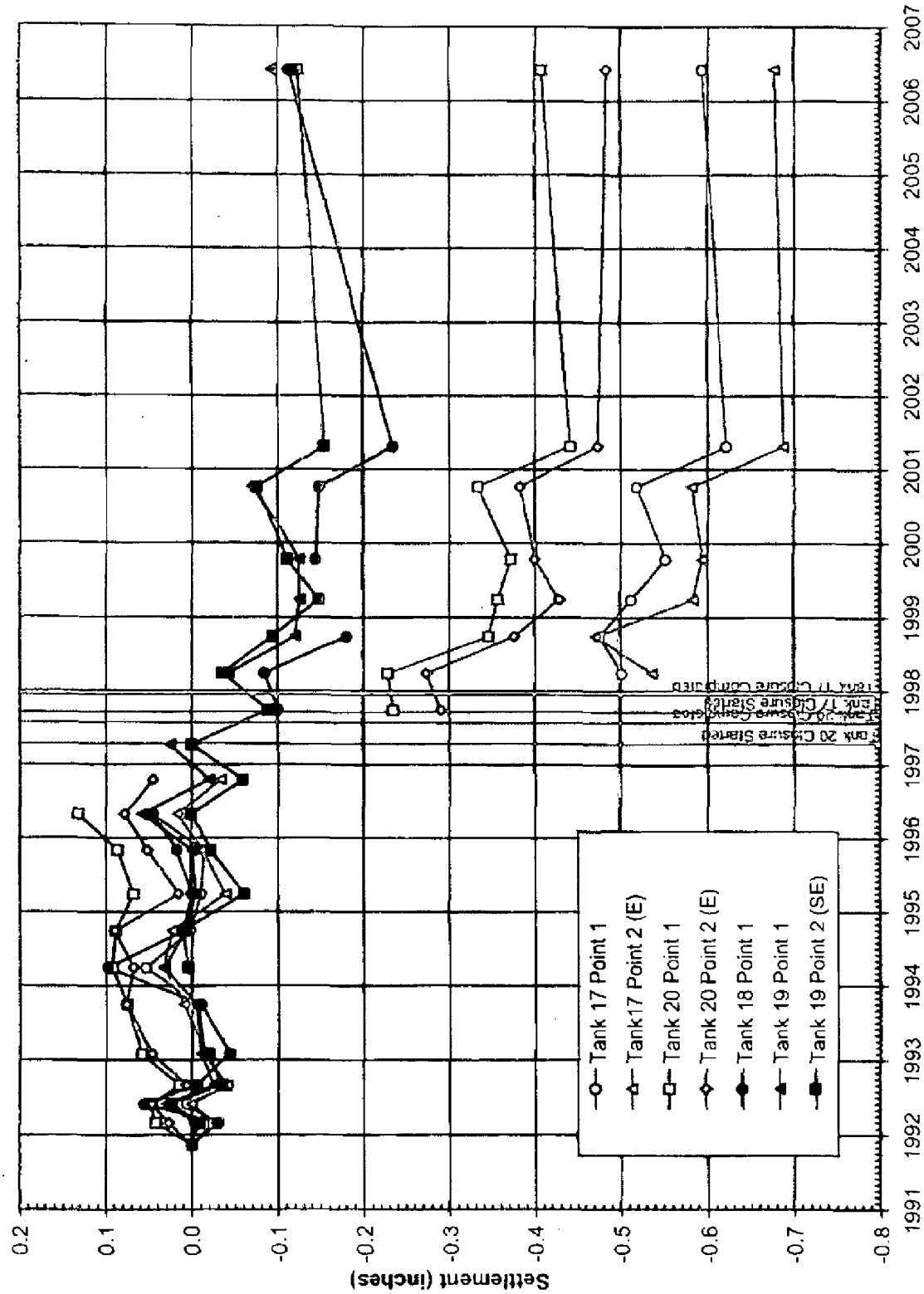


**Figure 4 Tank Settlement**

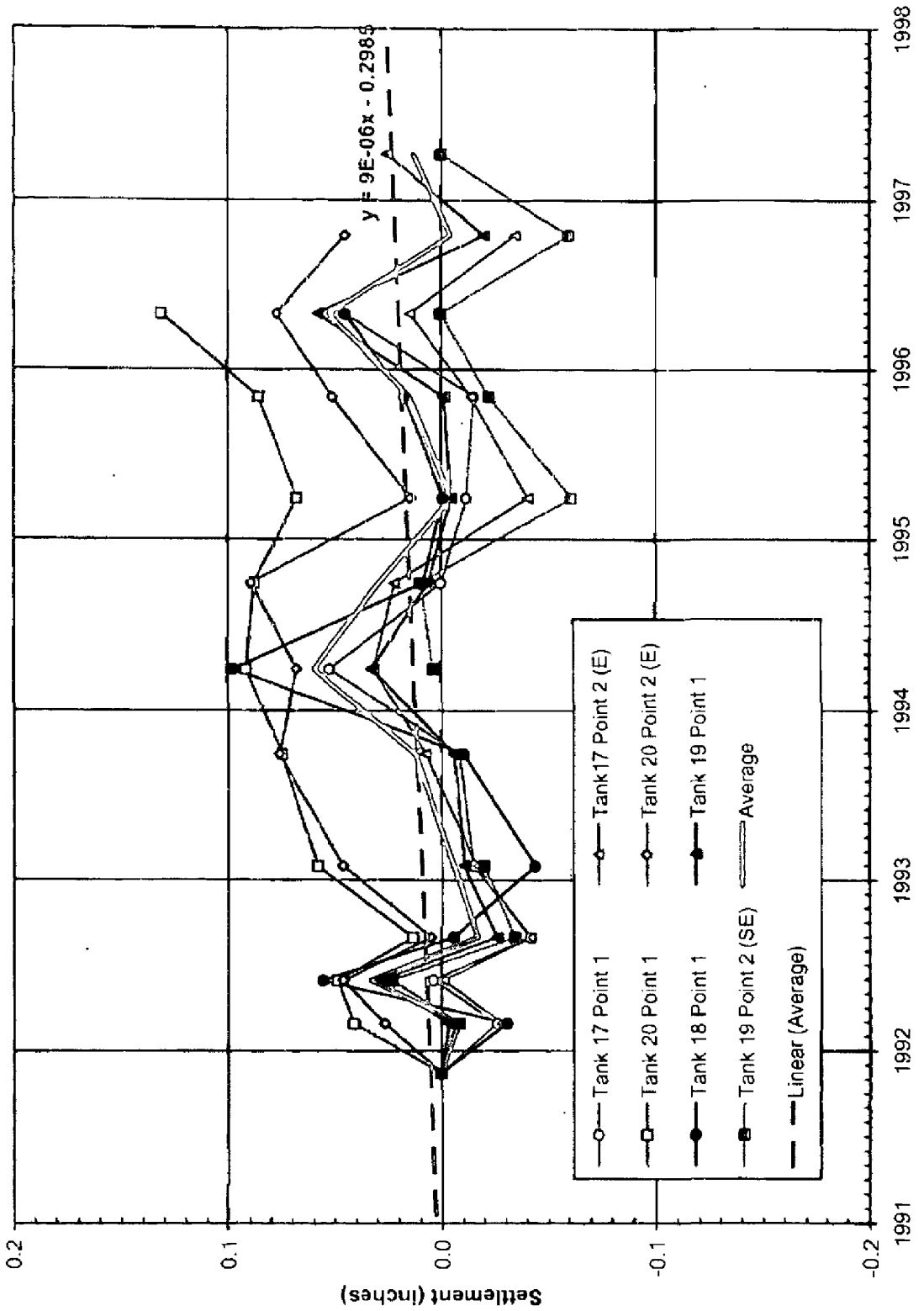


**Figure 5 Settlement Prior to Closure**

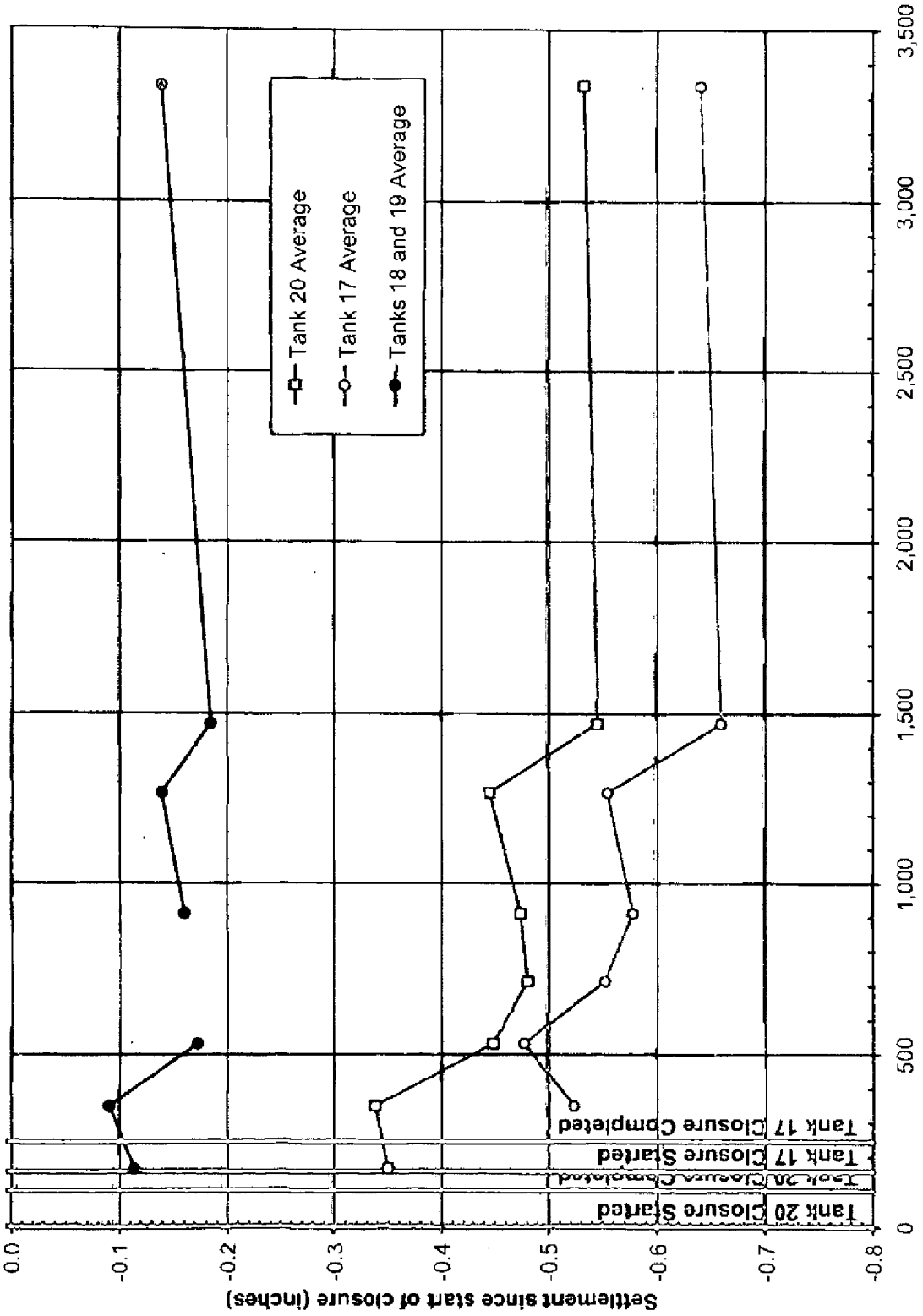


**Figure 6 Average settlement after the closure of Tanks 20 and 17**

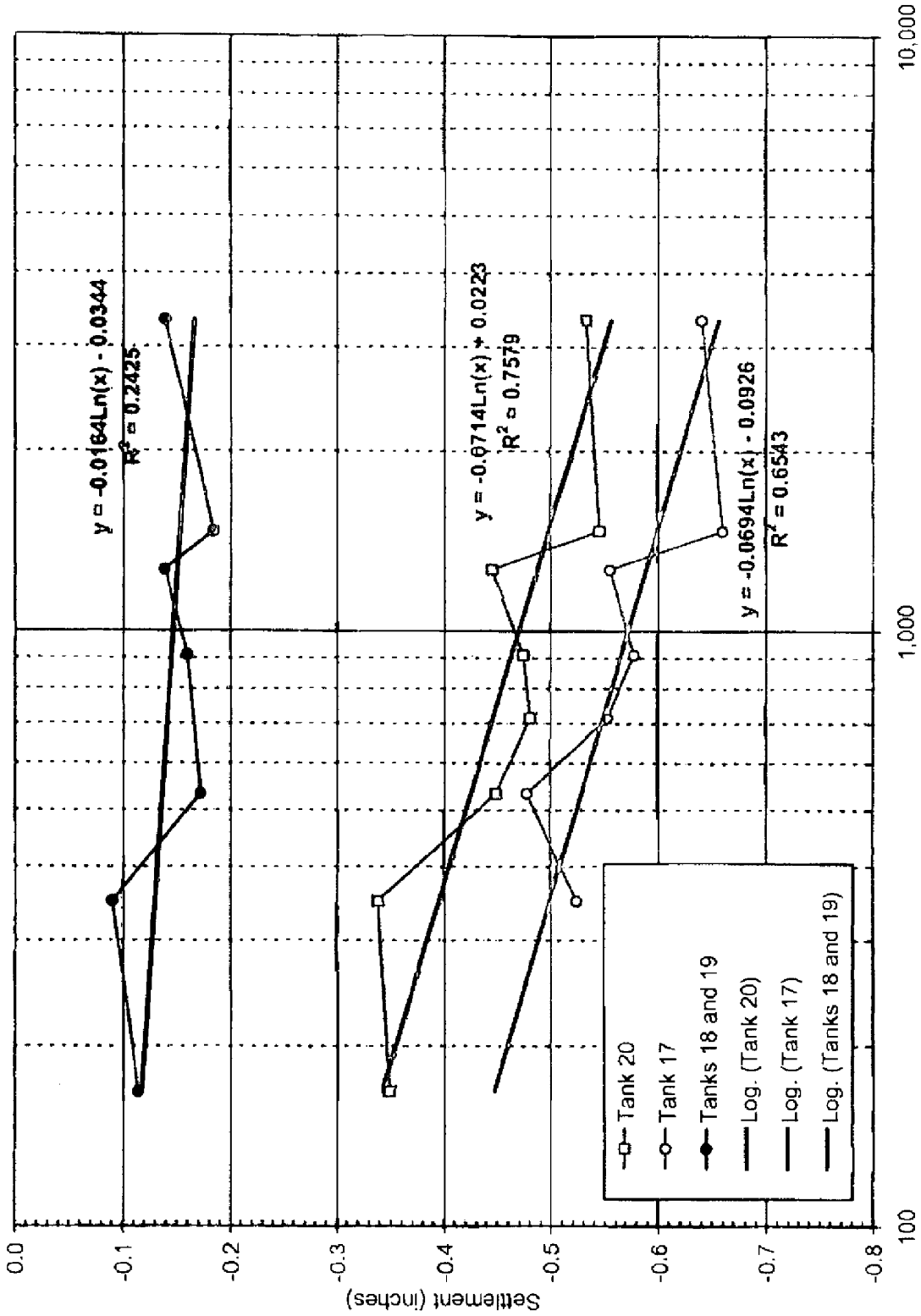


Figure 7 Settlement after the closure of Tanks 20 and 17