K-ESR-K-00008
Rev. A
November 2011

K-Area PDC Sand Filter Soft Zone

Geotechnical Investigation Report

Prepared by
Savannah River Nuclear Solutions, LLC
Savannah River Site
Aiken, SC 29808

Prepared for the U.S. Department of Energy under Contract DE-AC09-08SR22470

K-ESR-K-00008, Rev. A
November 2011

PDC Sand Filter Soft Zone Geotechnical Investigation Report

Prepared By
Rucker J. Williams
Geotechnical Engineering

12-5-11
Date

Reviewer
D. Bruce Nothdurft
Geotechnical Engineering

12-13-11
Date

Approver
W. Nick Kennedy
Manager, C/S/A Engineering

12-13-11
Date

DISCLAIMER

TABLE OF CONTENTS

List of Tables

List of Figures

1. Introduction

The purpose of the field investigation was to delineate soft zones beneath the footprints of the proposed sand filter building and associated structures and to determine how well the subsurface stratigraphy compares to that recently discovered at Plant Vogtle, across the Savannah River from the Site. After the delineation of the soft zones, soft zone samples were taken to determine the compressibility parameters in order to estimate settlement resulting from the potential collapse of a soft zone.

Also, the information gained during this investigation could be used to correlate the local stratigraphy to that recently determined at Plant Vogtle. Plant Vogtle is located approximately seven miles southwest of K Area, see Figure 1. Similar soft zones and voids were found within the Utley Limestone member of the Clinchfield Formation at Plant Vogtle. In some cases, competent Utley material spanned over slurry filled voids or caves. Similar conditions could exist within the Utley formation at SRS, if the Utley is in fact present.

The Utley Limestone is located stratigraphically above the Santee member of the Lisbon formation, which is where soft zones have historically been thought to typically occur at SRS. In order to correlate the stratigraphy of K-Area to that of Plant Vogtle, it was necessary to determine if the Utley Limestone was present at K-Area.

1.1 Sand Filter Location

The proposed sand filter and ancillary structure locations are approximately 400 feet southeast of the 105-K reactor facility, see Figure 2. The sand filter was approximately 180 feet by 300 feet, with an assumed foundation elevation at 250 feet, msl or an embedment of 20 feet below surface. The footprint of the investigation was generally bound by the Savannah River Site coordinates below.

Southwest corner	N53100, E40800
Northeast corner	N53400, E41400

2. Subsurface Exploration

The subsurface exploration consisted of cone penetrometer soundings and soil borings to investigate the proposed Sand Filter site for the presence of soft zones and to determine soft zone properties. The sections below describe the field investigation.

A regular grid pattern of test locations could not be established for the investigation due to both surface and subsurface interferences. Figure 3 illustrates the location of the interferences at the project site. Interferences included cooling water lines and duct banks as well as the restriction that no work was allowed within 25 feet of the railroad tracks.

Locations of the investigation locations are summarized in Table 1.

2.1 Cone Penetration Tests (CPTs)

The CPT investigation was divided into two phases. The first phase consisted of 13 CPTs used to provide a broad coverage of the proposed area, followed by a second more concentrated phase, consisting of an additional 47 CPT soundings. See Figure 4.

The travel path of each CPT sounding was tracked using inclinometer data collected during the CPT investigation.

2.1.1 Phase 1

Thirteen (13) broadly-spaced CPT soundings were made as an initial attempt to determine the presence and location of soft zones at the proposed Sand Filter location. This phase consisted of 8 standard CPTs and 5 seismic CPTs (SCPTs).

Soft zones were found in 5 of the 13 CPTs, most notably in CPTs K-PDC-C01, K-PDC-C05, and K-PDC-C11.

2.1.2 Phase 2

The second phase of CPT soundings was performed to delineate soft zones identified in the first phase and to fill in data gaps within the structure footprint. Soft zones were observed in 29 of the 47 additional CPT soundings. The ratio of CPTs with soft zones to those without is much higher in Phase 2 than in Phase 1 primarily because Phase 2 focused on delineating soft zones and was concentrated around areas where soft zones were known to occur.

The Enhanced Access Penetration System (EAPS) was used to advance CPTs beyond where CPTs typically refused due to extremely high tip resistances. The EAPS system uses a rotary air or water drilling system to penetrate the hard layers. EAPS was performed on CPTs K-PDC-C59 and K-PDC-C60. While EAPS proved to be able to penetrate the hard layers, it was difficult to ascertain when we had drilled out of the hard layer and could begin pushing the CPT again.

During the push of K-PDC-C41, the sounding was stopped at 122 feet and CPT soil samples were taken between depths of 122 feet and 135 feet, Figure 5. Vugs were observed in the first two sample tubes between depths of 122 feet and 126 feet. Free water was present in these intervals. Moisture content analysis of these samples is summarized in Table 2.

2.2 Geotechnical Boreholes

Five (5) geotechnical boreholes were drilled at the project site. Borings K-PDC-B01, K-PDC-B02, and K-PDC-B05 were drilled in order to collect undisturbed fixed piston samples of soft zone material. Borings K-PDC-B03 and K-PDC-B04 were continuously drilled via continuous wireline coring for the purpose of further delineation of the local stratigraphy.

Undisturbed soil samples were taken in K-PDC-B01, K-PDC-B03, and K-PDC-B05 with 5-inch Shelby tubes and 5-inch fixed piston samplers in accordance with ASTM D 1587. The use of the 5-inch sampler, as opposed to the standard 3-inch sampler, was a decision based on results from the ongoing Soft Zone Research program. The use of the larger diameter tube sampler was to reduce sample disturbance and to evaluate different consolidation testing techniques. The different testing techniques will be discussed in a later section.

The use of the larger diameter sample reduces sample disturbance resulting from the sampling process by reducing the sidewall effects of the Shelby tube on the soil sample.

2.2.1 Boring K-PDC-B01

Boring K-PDC-B01 was located to the west of the railroad and north of the steam line, between CPTs K-PDC-C11 to the west and K-PDC-C43 to the east. CPTs K-PDC-C24 and K-PDC-C40 were located approximately 15 feet to the north. The target elevations for sampling were based on K-PDC-C11.

Three 5-inch Shelby tube samples were taken in K-PDC-B01 at depths of 122.70 (ST01), 124.74 (ST02), and 132.64 (ST03). The maximum pushing pressures were 900 psi for ST01, 2100 psi for ST02, and 2000 psi for ST03.

When over drilling after sample ST01, the borehole lost circulation at a depth of 123.92 feet. Upon losing circulation it was decided to trip back in the hole with another Shelby tube. The second Shelby tube was advanced 1.4 feet. Given that competent material was obtained at the bottom of the hole, it was reasoned that the loss of circulation occurred laterally.

2.2.2 Boring K-PDC-B02

Boring K-PDC-B02 was located adjacent to K-PDC-C05, with CPTs K-PDC-C19 and K-PDC-C34 were located approximately 15 feet to the north and east, respectively. This was the first boring performed at the project site. The target depths for sampling were based on the K-PDC-C05.

Three 5-inch fixed piston sample were taken at depths of 125.27 (FP01), 127.64 (FP02), and 140.52 (FP03). One 5-inch Shelby tube was taken at a depth of 143.05 (ST04). The maximum pushing pressure for all of the fixed piston samples ranged from 1900 to 2300 psi. For the Shelby tube sample, ST04, the maximum pushing pressure was 1500 psi. No soft zones were captured in this borehole. Shell fragments up to 1-inch in size were recovered in fixed piston samples FP01 and FP02. Sample FP03 had no recovery.

The drilling between samples FP01 (125.3 ft) and FP02 (127.6 ft) was described as “gravelly” by the driller. This is attributed to the presence of shelly material. Below sample FP02, from 128 feet to 135 feet, the drilling was again described as having alternating layers of chattering and smooth

drilling. From 135 feet to 140 feet the drilling was described as layers of hard and soft drilling.

Because we were unable to sample the intervals that were seen in the adjacent CPTs, there was some concern that the borehole was drifting from vertical due to the relatively large drill bit compared to the drill rods.

2.2.3 Boring K-PDC-B03

Boring K-PDC-B03 was a continuous wireline coring, located adjacent to CPTs K-PDC-C28 and K-PDC-C08. Total depth for the boring was 143.9 feet. The samples were taken in 5-foot runs. At a depth of 121 feet to 122 feet vuggy, sandy clay was observed; and at a depth of 130 feet to 132 feet "vuggy" clay was observed. Shell fragments were observed at a depth of 131 feet. Again the drilling from 137 feet to 138.5 feet was noted as soft followed by chattery drilling. At a depth of 142 feet 1-inch oyster shell fragments were observed in the core, see Figure 6.

Circulation was lost when coring the interval between 142 and 147 feet. The bottom of the borehole was tagged at 143.9 feet after the loss of circulation.

2.2.4 Boring K-PDC-B04

Boring K-PDC-B04 was a continuous wireline coring, located adjacent to CPT K-PDC-C37. Total depth for the boring was 147 feet. The samples were taken in 5-foot runs. The first appearance of shell fragments occurred at a depth of 124.6 feet. While cleaning out the borehole before drilling the 132- to 137-foot interval, circulation was lost at 127 feet. Core material was recovered in the 132- to 137-foot interval. The borehole was drilled out to a depth of 147 feet. From 140 feet to 147 feet, the drilling was denoted as 3 feet of hard drilling, 3 feet of soft drilling, and then 4 feet of hard drilling again.

2.2.5 Boring K-PDC-B05

Boring K-PDC-B05 was located adjacent to CPTs K-PDC-C49 and K-PDC-C52. This boring incorporated the use of a stabilizer rod, which was a larger diameter rod above the drill bit. The larger diameter stabilizer rod was intended to prevent the drill bit from walking or wobbling as it advanced, thus providing a more vertical drill hole. Three 5-inch fixed piston samples were taken at depths of 113.87 (FP01), 115.99 (FP02), and 117.78 (FP03). One Shelby tube sample was taken at a depth of 124.95 (ST04).

Sample FP01 had a maximum push-pressure of 1900 psi. Sample FP02 had a push-pressure of 450 psi to 500 psi, increasing to 800 psi for the final 7 inches. Sample FP03 was taken directly after FP02 and a push-pressure of 400 psi to 600 psi for the first 12 inches, increasing to a maximum of 1100 psi for the remainder of the push. Upon retrieval, the piston head was 0.72 inches from the bottom of the tube.

A Shelby tube was pushed from a depth of 124.95 feet to 126.97 feet. The push-pressure peaked at 800 psi, dropping to 650 psi. There was no recovery, except for some soft clay which was sticking inside the tube. This material was bagged for analysis.

2.3 Laboratory Tests

Laboratory tests were performed on the disturbed and undisturbed samples taken during this investigation. Lab tests included index tests, direct shear test of the matrix material (non-soft zone), and consolidation tests. The following samples were submitted for testing.

Boring ID	Sample	Depth (feet)	Testing Facility
K-PDC-B01	ST01*	122.70 to 124.68	MACTEC
K-PDC-B01	ST02	124.74 to 126.14	Georgia Tech
K-PDC-B05	FP01	113.87 to 115.79	MACTEC
K-PDC-B05	FP02	115.99 to 117.78	Georgia Tech
K-PDC-B05	ST01 (Bag)	124.95 to 126.97	MACTEC

* Sample ST01 incorrectly labeled as FP01 in the MACTEC report

Undisturbed samples for consolidation testing at MACTEC were trimmed to fit a 2.5 inch oedometer and also to fit a 4 inch oedometer. This was done as a comparison to the in-tube consolidation testing (no trimming) that Georgia Tech was performing. The results of the Georgia Tech work were not available at the writing of this report. The results of the MACTEC consolidation testing are summarized in Tables 3 and 4 (Ref. MACTEC)

Sample K-PDC-B01 ST01 showed signs of disturbance and was not included in this report. Four consolidation tests (two 2.5 inch, two 4-inch) were performed on the sample from K-PDC-B05 FP01. The sample showed some signs of disturbance, but not to the extent of the sample from K-PDC-B01. The preconsolidation pressure was determined by the Casagrande method. The minimum possible preconsolidation pressure was also determined from the intersection of the virgin compression curve with a horizontal line drawn from the initial void ration (e_0). Constructions are included Appendix A.

The results of the consolidation testing indicate that sample K-PDC-B05 FP01 has overconsolidation ratio (OCR) values ranging from 0.6 to 1.0 with an average of 0.8, based on the Casagrande method. The maximum push pressure during sampling was 1900 psi, this is too high for this sample to have been of soft zone material. The apparent degree of under-consolidation is likely due to sample disturbance. Based on the disturbance of the sample and its stratigraphic location, this sample should not be used in the determination of the K-Area soft zone strain.

The average OCR values and compression ratio (CR) values of the existing data from K Area are also summarized in Table 5. The average OCR is 0.32 and the average CR is 0.29.

3. Subsurface Conditions

3.1 Stratigraphy

The differentiation of the overlying shallow stratigraphic layers (generally less than 90 feet) was not taken into consideration at this time. The focus of this effort was on the soil layers at depth where soft zones occur. Historical stratigraphy picks for the Santee were part of "Layer 7" which included the Clinchfield formation and Tinker-Santee members of the Lisbon Formation. From the K-Area Complex (KAC) report, the average elevation of Layer 7 is approximately 150 feet, which corresponds to a depth of about 120 feet (Ref. K-ESR-K-00005). Stratigraphic picks for the new investigations are found in Table 1 (Ref. K-CLC-K-00026).

3.1.1 Griffins Landing and Utley Formations

Traditional stratigraphy in K Area did not include the delineation of the Griffins Landing Member of the Dry Branch Formation and Utley Limestone Member of the Clinchfield Formation. In light of the Vogtle excavation, where the problematic layer was the Utley, it became pertinent to try to better delineate the stratigraphy to determine if the Griffins Landing and Utley Members were present. The presence of both the Griffins Landing and Utley Members was preliminarily confirmed in the continuous wireline cores. The Griffins Landing Member was found at a depth of 132 feet in boring K-PDC-B04. The Utley Member was found in K-PDC-B03 at a depth of 142 feet.

Because it is difficult to distinguish among the Griffins Landing, Utley, and Santee layers based solely on the CPT signatures, stratigraphic picks were based on the traditional SRS criteria and nomenclature. However it is recognized that many of the higher elevation "top of Santee" picks are likely in the Griffins Landing or Utley Members. For example the Santee was picked at a depth of 129.2 feet in K-PDC-C37, while the adjacent boring K-PDC-B04 indicated the Griffins Landing at a depth of 132 feet.

Of the 60 CPTs pushed at the project site, 2 used the EAPS system to achieve depth and one was terminated at a shallow depth in order to obtain CPT soil samples. Of the 57 CPTs pushed to refusal, more than 75% refused before achieving a depth of 145 feet. Almost 50% of the CPTs (27) had refusal depths between 135 feet and 145 feet. The refusals in this 10-foot interval could be indicative of cemented facies within the Griffins Landing and Utley members. Of the 13 CPTs which made it passed 145 feet, 4 refused before 150 feet; the remaining 9 CPTs had refusal depths ranging from 162 feet to 184.5 feet.

3.2 Groundwater

The average groundwater elevation in the vicinity of the project site is estimated to be between 200 and 210 feet, MSL.

3.3 Soft Zones

Across the SRS, the soil from approximately 100 to 250 feet below the ground surface is a marine deposit laid down during the Middle-to-(early) Late Eocene epoch, roughly about 50 to 35 million years ago. Often found within these sediments are weak zones interspersed in stronger matrix

materials. These weak zones, which vary in thickness and lateral extent, have been termed "soft zones". These soft zones typically occur in the carbonate-bearing sediments of the Santee Limestone, the Utley Limestone, and the Griffins Landing Member of the lower Dry Branch Formation.

The prevailing assumption about the origin of soft zones involves dissolution of carbonate-rich, clastic sediments, resulting in vugular porosity (open pore space). When drilling into these zones, the drill rod meets little resistance and drops. Occasional rod drops have been described in numerous drilling reports for monitoring wells and geotechnical boreholes located in the central part of the SRS. Early subsurface investigations performed by the United States Army Corps of Engineers frequently described these zones as soft zones, or voids, and numerous subsequent subsurface investigations have described these same conditions at the SRS. However, much of the time, recovery of soil in the sampler precludes the zone from being characterized as a void.

For this project site, soft zones are indicated by CPT tip resistances (q_t) less than 15 tons per square foot (tsf) for soils within the Griffins Landing Member in the lower Dry Branch and lower stratigraphic layers. Also, the CPT q_t values were compared to both the total stress values due to soil overburden.

Figure 7 compares the location of soft zones within each CPT when using both the 15 tsf criteria and using total overburden stress as a criteria. A unit weight of 120 pcf was conservatively used for soil when determining the overburden stress. As seen in the figure, using overburden stress as a criteria results in fewer soft zones and thinner intervals. For the computation of soft zone settlement, the 15 tsf criteria will be used for conservatism.

In light of the Vogtle excavation, where slab span conditions and caves were found to exist, it is believed that the traditional tunneling approach to the settlement analysis is not the appropriate methodology for settlement analysis for soft zones. However, at this time, no new methodology is available. Since newer methods of soft zone analysis are not available, it is uncertain whether or not the current tunneling approach is conservative with respect to the magnitude of surface settlements resulting from the collapse of a soft zone.

3.3.1 Soft Zone Mapping

To create a map of soft zone thicknesses across the project site, the program Surfer® was used. For conservatism, the thickness of soft zone material within a CPT was assumed to be the summation of all soft zone thicknesses within the CPT.

A contour map of soft zone thicknesses was generated as described below. The contour map depicts the best judgment interpretation of soft zone thicknesses based on the available field data. The contour map will be utilized in the calculation of settlements due to the compression of soft zones.

> When generating the soft zone thickness contour map, all soft zones within a CPT profile are combined to provide the total thickness of soft zones within the CPT profile. All soft zones are taken to occur at the same elevation; here that elevation is 145 ft, msl. Based on Figure 8.

The soft zone input file contains CPT locations (CPT ID, SRS Northing, SRS Easting) and soft zone thickness, including zero thicknesses. The SRS Northing and Easting coordinates were based on inclination data. For CPTs with soft zones, the northing and easting are taken at the first occurrence of a soft zone. For CPTs without soft zones, the coordinates at depth are taken at elevation 145 ft., msl.

An initial grid (SZ Thickness – 15tsf.grd) was generated using the above input with the Kriging method on a 5 ft. x 5 ft. grid for the boundary given in Section 1.1. The intial grid contains negative thicknesses (as a result of the gridding process) which are neglected by showing only contours for thicknesses greater than 0 feet.

Using the contour map generated and engineering judgment, "edges" of the soft zone were generated. These edges define the lateral extent of the soft zones. The polygon used to define the edge of the soft zone is known as a zero-extent polygon since the edges are assumed to have zero thickness. Figure 8 contains the initial input contours and the zero-extent polygons. The boundaries of the zero-extent polygon are used to generate a breakline.

The final grid (SZ Thickness – 15 tsf with breakline.grd) is created using the original soft zone input file and the breakline created above using the same input parameters as in the first step. Again the new grid is zeroed to remove negative thicknesses generated during the gridding process (SZ Thickness – 15 tsf final.grd). See Figure 9 for the final contour map of interpreted soft zone thicknesses.

Soft zones are generally thought not to span a distance of more than 50 feet in width as it is unlikely that the arching effect of the stronger matrix soil could be supported over a greater distance. However for the determination of the zero-extent polygons, the 50 foot width limit was not strictly adhered to as a matter of conservatism, from the standpoint of settlement.

3.3.2 Soft Zone Settlement

Based on the excavation at plant Vogtle and the recent advances in the understanding of soft zones, it is currently believe that the existing method of soft zone settlement analysis is not wholly applicable. However, without a new model to analyze the settlement should a soft zone "collapse", the existing methodology will be utilized. The top elevation of the soft zones was taken as 145 feet msl, or 105 feet below the sand filter foundation.

Surface settlements at a point x were computed as (Ref. K-CLC-G-00087)

$$s_S = H\ \{C_c/(1 + e_o)\}\ \log\ \{(P_o + \Delta P)/P_o\} = H \times CR \times \log(1/OCR)$$

$$s(x) = R_{S/L}\ s_S\ W_{SZ}\ /W\ \mathrm{Exp}[-x^2/(2i^2)]$$

where $R_{S/L}$ is the ratio of the volume of the settlement to the volume lost at-depth

s_S is the compression of the soft zone at depth

W_{SZ} is the width of the soft zone

$i = W/(2\pi)^{1/2}$ is the distance from center of the probability curve to the point of inflection

W is the half width of the normal probability curve and estimated as

$W = z \tan \beta + W_{SZ}/2$

where z is the soft zone depth

β = based on soil type = 33°

The width of each soft zone was broken down into a series of 5-foot wide sub-intervals for analysis. Surface settlements for wide soft zones are calculated by superimposing settlement profiles for each of the sub-intervals to simulate the desired width. For the analysis of the project site, 4 cross-sections were taken as indicated in Figure 12. Surfer outputs the thicknesses where the cross-section crosses as a gridline. Since the cross-sections are not perpendicular to the grid pattern, the distance between output points can be more or less than 5 feet. The output points were interpolated to provide widths of 5 feet for the sub-intervals; see Figure 13.

Following the computations above, maximum settlements are calculated at approximately 8 inches for cross sections 1 and 4. Figure 14 illustrates the settlement profiles along cross sections 1 through 4. While cross section 2 shows a maximum settlement of less than 4 inches, the settlements from cross sections 1 and 3 would control for that area, as they are much larger; 8 and 7 inches respectively.

4. Summary and Conclusions

During the course of the investigation we were able to preliminarily confirm the presence of the Utley and Griffins Landing members at K Area. Recognizing the presence of the Utley and Griffins Landing members and their picked elevations, it is evident that many of the earlier stratigraphic picks based on the CPT in K Area may have incorrectly identified the cemented facies of the Griffins Landing and Utley as the top of the Santee. However due to the loss of circulation, we were unable to continue further and define a contact between the Utley and the Santee member of the Lisbon formations.

Slab span conditions could neither be confirmed nor refuted. The CPTs which refuse early are likely refusing in strongly cemented portions of the Griffins Landing or in strongly cemented Utley material.

As viable soft zone samples were unable to be obtained for testing, this investigation was ineffective in reducing the current strain value for K-Area soft zones. Thus the historical soft zone compressibility parameters were used which equate to a strain value of 14.3%.

When a new analytical model for the determination of surface settlements resulting from the collapse or compression of a soft zone becomes available, this report will be updated to include the new methodology.

5. References

1. K-CLC-G-00087, Rev. 1, Surface Settlement Due to the Compression of Soft Zone, April 2007.
2. K-CLC-K-00026 Rev. A, Subsurface Stratigraphy for the K-Area PDC Project Proposed Sand Filter, October 2011.
3. K-ESR-K-00005 Rev. 0, K-Area Complex Geotechnical Summary Report (U), August 2007.
4. MACTEC, SRNS Subcontract AC76229N, Final Report of Piezo Cone Penetration Tes (PCPT), AC76229N-001-C-LGE, September 2011.

Tables

Table 1: Summary of Investigation Locations and Stratigraphy

ID	Elevation (feet, MSL)	SRS Easting	SRS Northing	Depth (feet)	Elevation, feet MSL				
					TCCZ	bot TCCZ	Santee	Warley Hill	Congaree
K-PDC-B01	269.8	40,961.9	53,280.1	142	164.5				
K-PDC-B02									
K-PDC-B03	269.6	40,904.8	53,335.0	143.9	162.8				
K-PDC-B04									
K-PDC-B05	270.1	41,245.3	53,291.3	127	161.7				
K-PDC-C01	269.8	41,074.9	53,346.7	142	160.4	149.9	137.3		
K-PDC-C02	270.2	41,080.0	53,283.4	120	164.6	154.5			
K-PDC-C03	270.1	41,160.6	53,352.9	174.3	160	145	135.7	111.9	97.8
K-PDC-C04	270.3	41,130.3	53,292.2	136.7	161.2	152	147.4		
K-PDC-C05	270.3	41,266.2	53,277.7	130	159.8	150.3	141.2		
K-PDC-C06	269.6	41,266.1	53,180.0	129.3	161	150	140.9		
K-PDC-C07	269.6	40,867.1	53,209.0	115.2	168.9	158.8			
K-PDC-C08	269.8	40,917.3	53,336.5	140.8	160.5	151.8	133.6		
K-PDC-C09	269.8	40,870.5	53,286.1	144.6	161.1	153	140		
K-PDC-C10	270.1	40,869.3	53,366.5	162	158.5	149.6	135.6		
K-PDC-C11	269.8	40,958.3	53,278.6	139.9	163.4	155	133.8		
K-PDC-C12	269.8	41,084.6	53,327.1	137.2	157.6	146.4	134.5		
K-PDC-C13	269.8	41,229.7	53,345.3	133.2	159.8	150	139.2		
K-PDC-C14	269.3	41,330.0	53,189.1	137	154.7	145.6	133.4		
K-PDC-C15	269.6	41,059.1	53,346.1	140	157.6	145.7	134.8		
K-PDC-C16	269.7	41,074	53,357.1	129	161.3	150.6			
K-PDC-C17	270	41,074.1	53,331.1	141	156.7	145.4	133		
K-PDC-C18	270.2	41,249.9	53,277	142	156.8	144.9	135.5		
K-PDC-C19	270.1	41,264.9	53,292.1	135	158.5	148.9			
K-PDC-C20	269.7	40,946.1	53,279.0	131	161.1	151.8	140.4		
K-PDC-C21	269.3	41,073.9	53,371.0	138	156.1	145.4	136.2		
K-PDC-C22	270.2	41,264.8	53,254.0	143	155.6	145.6	132.5		
K-PDC-C23	269.8	40,957.1	53,253.9	127	166.5	151.1			
K-PDC-C24	269.6	40,956.9	53,291.0	144	160.4	150.6	128.7		
K-PDC-C25	269.6	41,027.9	53,204.0	169	156.4	142.4	131.2	105.1	
K-PDC-C26	269.5	40,926.1	53,209.1	144	158.8	151.2	132.5		
K-PDC-C27	268.6	41,200.2	53,178.0	131	161.1	150.9	139		
K-PDC-C28	269.8	40,908.0	53,329.8	180	157.7	148.3	136.6	105.3	90.7
K-PDC-C29	269.9	41,121.0	53,234.9	139	159.1	147.4	142.2		
K-PDC-C30	270	40,901.9	53,253.9	129	166.8	157.2			

ID	Elevation (feet, MSL)	SRS Easting	SRS Northing	Depth (feet)	Elevation, feet MSL				
					TCCZ	bot TCCZ	Santee	Warley Hill	Congaree
K-PDC-C31	269.8	40,920.9	53,279.0	185	161.3	151.6	136.3	105.8	89.8
K-PDC-C32	270	41,104.9	53,346.0	143	160.2	151.7	139.4		
K-PDC-C33	270.2	41,126.1	53,316.0	142	156.3	145.5	131.7		
K-PDC-C34	270.4	41,283.0	53,276.8	139	155.7	145.6	139.5		
K-PDC-C35	270.3	41,139.1	53,319.9	140	154.9	145	137.9		
K-PDC-C36	270.2	41,120.9	53,329.1	142	155.4	146.2	137.2		
K-PDC-C37	270.2	41,113.9	53,311.0	141	157.4	147.4	141		
K-PDC-C38	270.3	41,130.8	53,302.0	139	157.1	146.6	140.8		
K-PDC-C39	269.7	40,932.1	53,294.9	180	161.6	151.4	137.9	108.3	91.2
K-PDC-C40	268.9	40,957.1	53,294.1	142	160.3	149.7	133.7		
K-PDC-C41	270.1	41,265.0	53,302.2	122	156.4				
K-PDC-C42	269.4	40,865.1	53,204.0	106	167.2				
K-PDC-C43	269.8	40,965.2	53,280.1	128	161.5	152.6	147.6		
K-PDC-C44	269.7	40,953.0	53,247.2	172	161.5	143.1	126.8	109.4	
K-PDC-C45	269.8	40,891.9	53,277.0	169	159.8	150.6	134.4	108.6	
K-PDC-C46	270	40,888.9	53,254.0	148	160.6	150.2	134.3		
K-PDC-C47	269.7	40,914.1	53,303.1	142	159.2	149.9	133.5		
K-PDC-C48	269.9	40,930.0	53,317.1	171	158.2	148.9	132.4	108.4	
K-PDC-C49	270	41,249.1	53,297.1	131	158.3	149.1			
K-PDC-C50	270.2	41,232.0	53,277.0	132	154.3	144.2			
K-PDC-C51	269.7	40,901.0	53,241.1	146	161.9	152.4	129.6		
K-PDC-C52	270.1	41,248.9	53,289.1	135	157.8	147.1			
K-PDC-C53	269.2	41,058.1	53,357.0	130	157.9	148.5			
K-PDC-C54	269.3	41,042.9	53,353.0	135	159.3	149.4	136.5		
K-PDC-C55	269	41,039.8	53,337.0	136	158.3	148.4	134.1		
K-PDC-C56	269.7	41,027.9	53,190.1	146	156.4	142.7	129.2		
K-PDC-C57	269.5	41,008.0	53,200.2	141	157.4	143	133.9		
K-PDC-C58	269.7	41,086.1	53,345.9	136	159.9	150.3	138.2		
K-PDC-C59	269.5	41,327.1	53,177.8	161	159.2	148.5	135.8		
K-PDC-C60	270	41,074.1	53,331.1	163	151.1	141.6	136.6		

Table 2: Summary of Moisture Content from CPT Soil Samples from K-PDC-C41

	Depth	Location	MC (%)
K-PDC-C41	122-124		26.7
	124-126.5		24.5
	126.5-128.3		36.1
	128.3-130.8	Top 5 1/2 inches	46.9
	128.3-130.8	Bottom 5 1/2 inches	48.4
	130.8-132.8	Bottom 6 inches	79.1
	132.8-135	Top 6 inches	71.3

Table 3: Index Properties from Drilling Samples

Boring ID	Sample	Test	Fines Content (%)	Silt Content (%)	Clay Content (%)	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)	Specific Gravity	Moisture Content (%)
K-PDC-B01	ST01	Con	21.4	2.4	18.8	28	59	31	2.69	35.58
		Direct Shear	27.3	3.9	23.4	31	73	42	2.69	45.17
K-PDC-B05	FP01	Consol1 2.5	17.8	0.4	17.4	34	63	29	2.65	25.74
		Consol2 2.5	14.7	0.4	14.3	34	57	23	2.66	27.61
		Consol1 4	16.9	0.4	16.5	36	64	28	2.64	27.68
		Consol2 4	14.5	1.2	13.3	34	55	21	2.68	27.25
K-PDC-B05	ST01 (Bag)		27.1	3.1	24	37	88	51	2.71	69.3

Table 4: Consolidation Data from New PDC Samples

			Minimum					Casagrande				
	Sample	e_0	P_c (psf)	P_0 (psf)	OCR	C_c	CR	P_c (psf)	P_0 (psf)	OCR	C_c	CR
K-PDC-B05	FP01	0.86	4200	10500	0.40	0.25	0.134409	8000	10500	0.76	0.25	0.134409
K-PDC-B05	FP01	0.84	5500	10500	0.52	0.271	0.147283	11000	10500	1.05	0.271	0.147283
K-PDC-B05	FP01	0.89	3000	10500	0.29	0.258	0.136508	6700	10500	0.64	0.258	0.136508
K-PDC-B05	FP01	0.83	3400	10500	0.32	0.226	0.123497	7500	10500	0.71	0.226	0.123497
	Average	**0.855**	**4025**	**10500**	**0.38**	**0.25125**	**0.135445**	**8300**	**10500**	**0.79**	**0.25125**	**0.135445**

Table 5: Historical K-Area Soft Zone Consolidation Data

Boring	Sample	Depth	e_0	P_c (ksf)	P_0	OCR	C_c	CR	ε
K1005	FP4A	119.6	2.5600	2,900	11.2	0.26	1.420	0.399	23.3%
K1005	FP4D	120.5	1.8500	4,400	11.3	0.39	1.339	0.470	19.2%
K1005	FP7C	125.8	1.7200	4,700	11.6	0.40	0.680	0.250	9.9%
K1005	FP7D	126.4	1.2400	5,000	11.7	0.43	0.380	0.170	6.2%
K1006	FP8D	126.5	1.2600	1,400	11.7	0.12	0.360	0.159	14.7%
	Average		**1.7260**	**3.7**	**11.5**	**0.32**	**0.8358**	**0.29**	**14.3%**

Figures

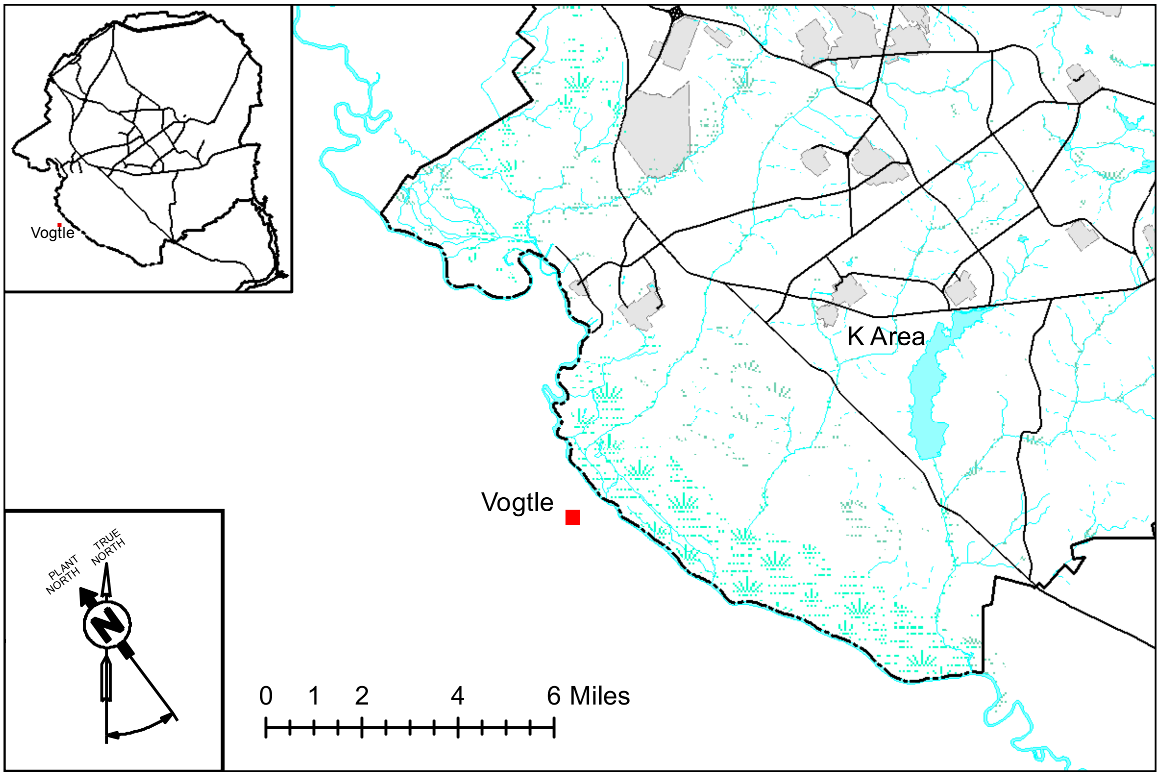


Figure 1: Location of Plant Vogtle and K Area

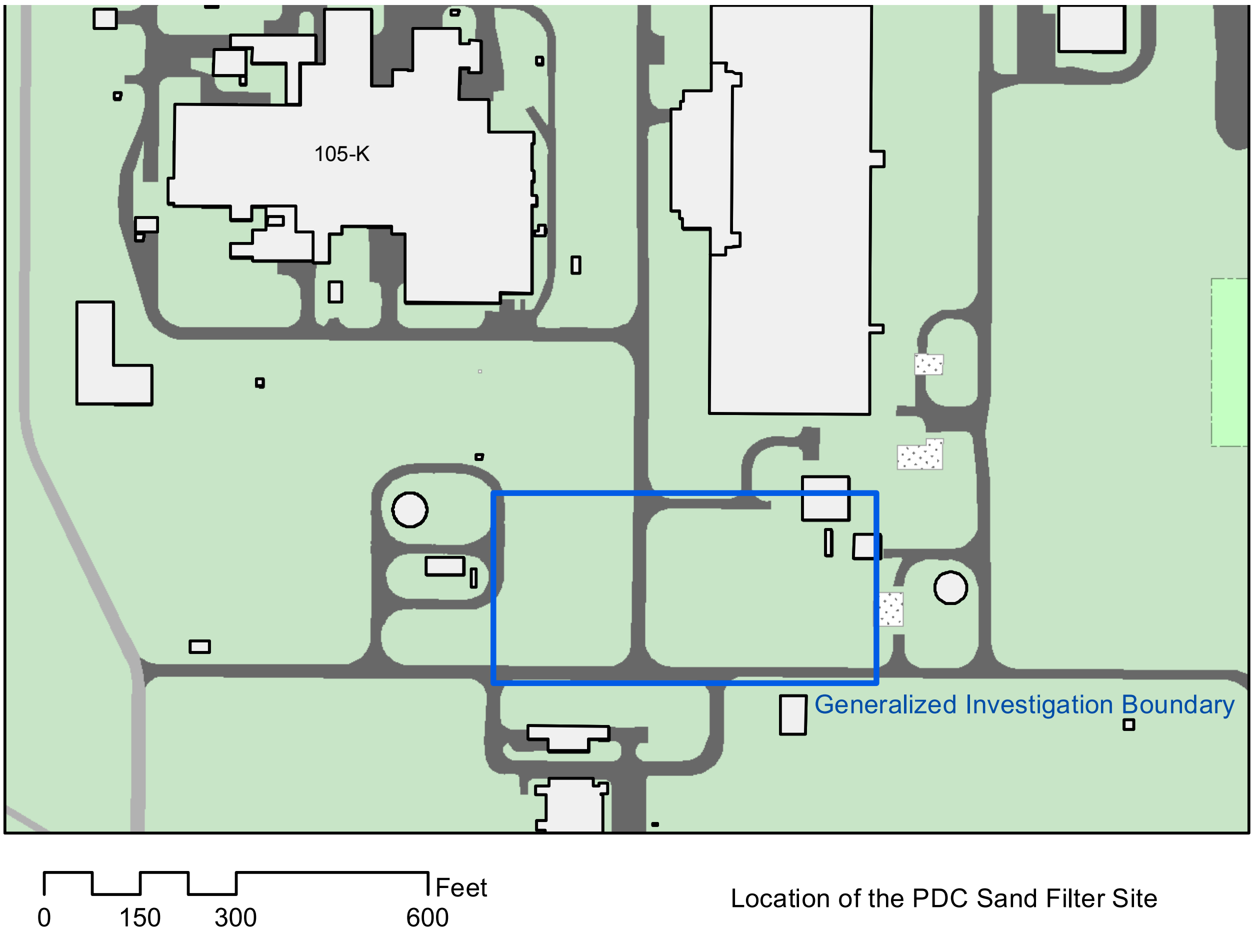


Figure 2: Location of the PDC Sand Filter Site

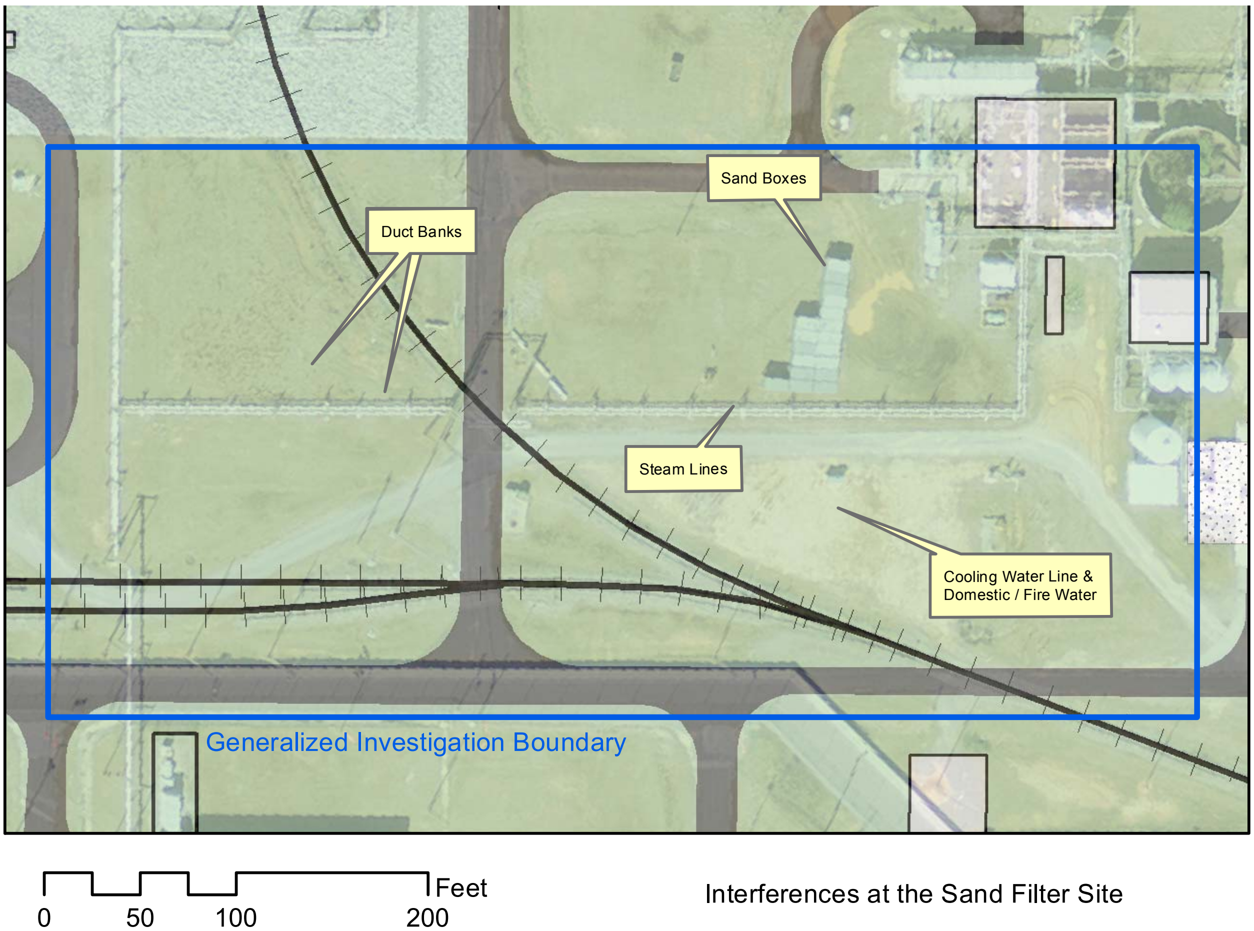


Figure 3: Interferences at the Sand Filter Site

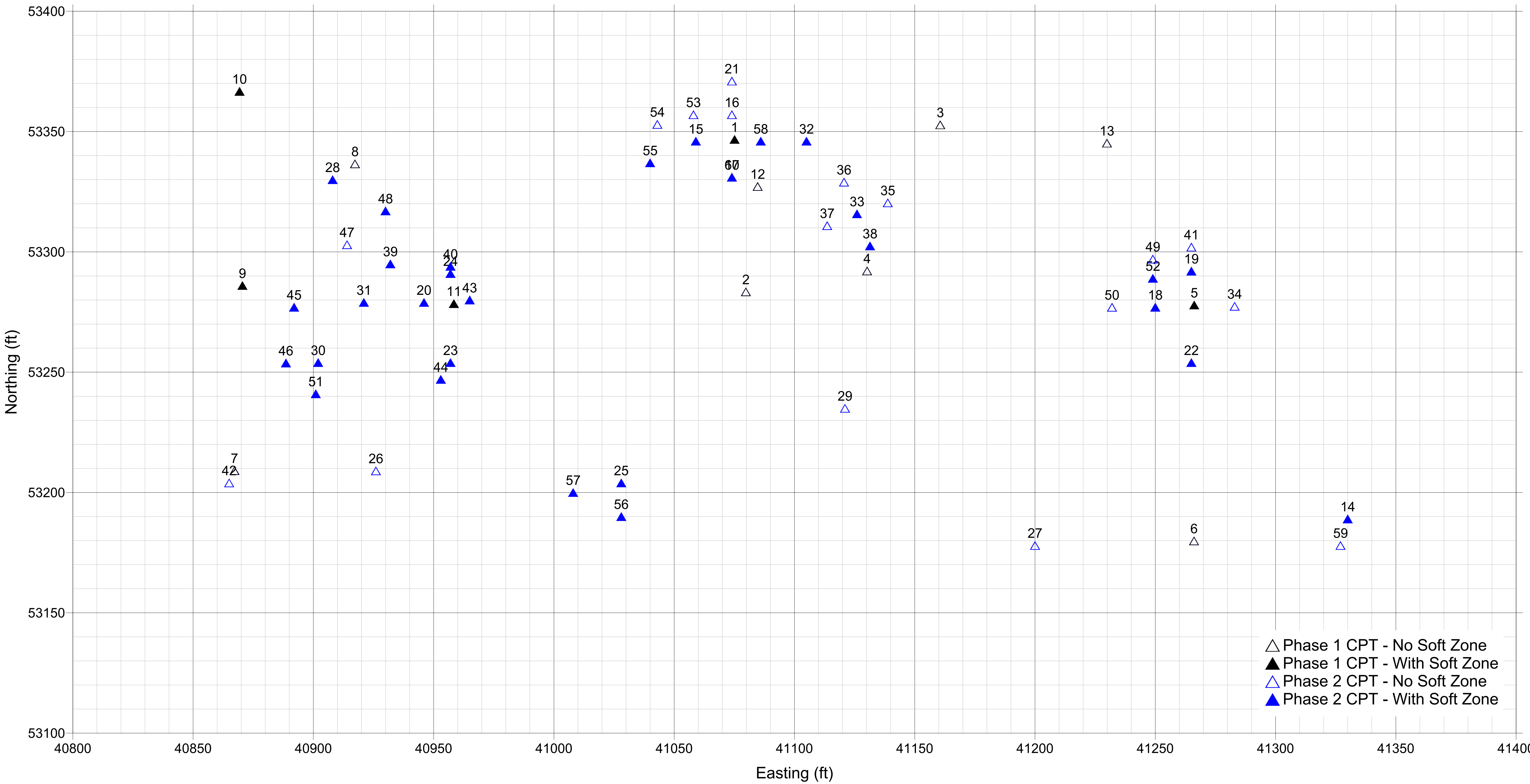


Figure 4: Location of CPTs at the PDC Sand Filter Site

Figure 5: CPT Soil Samples from K-PDC-C41, 122 feet to 135 feet

Figure 6: Oyster Shell Observed at Depth of 142 feet in K-PDC-B03

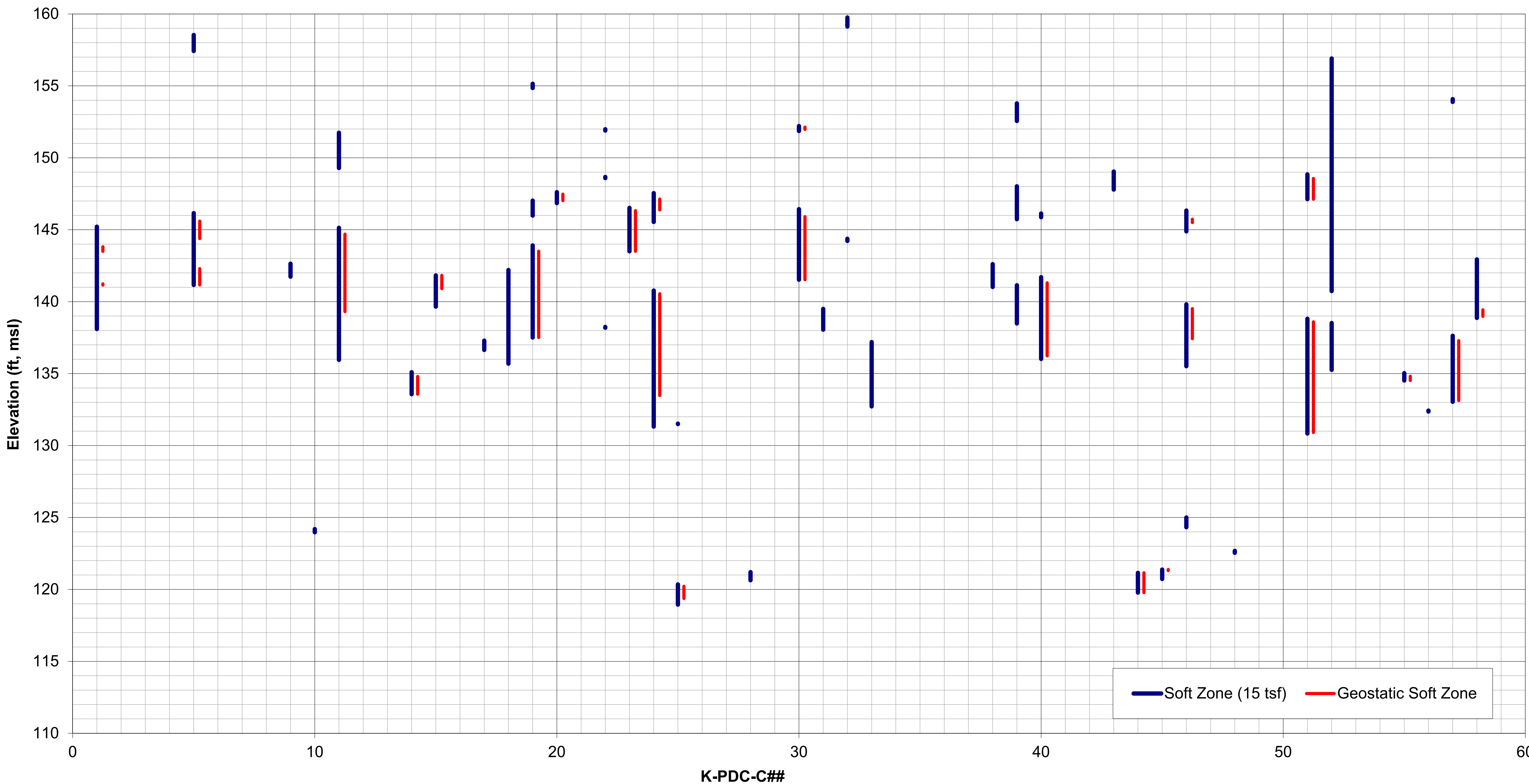


Figure 7: Comparison of Soft Zone Thickness when using both the 15 tsf criteria and total overburnden stress criteria

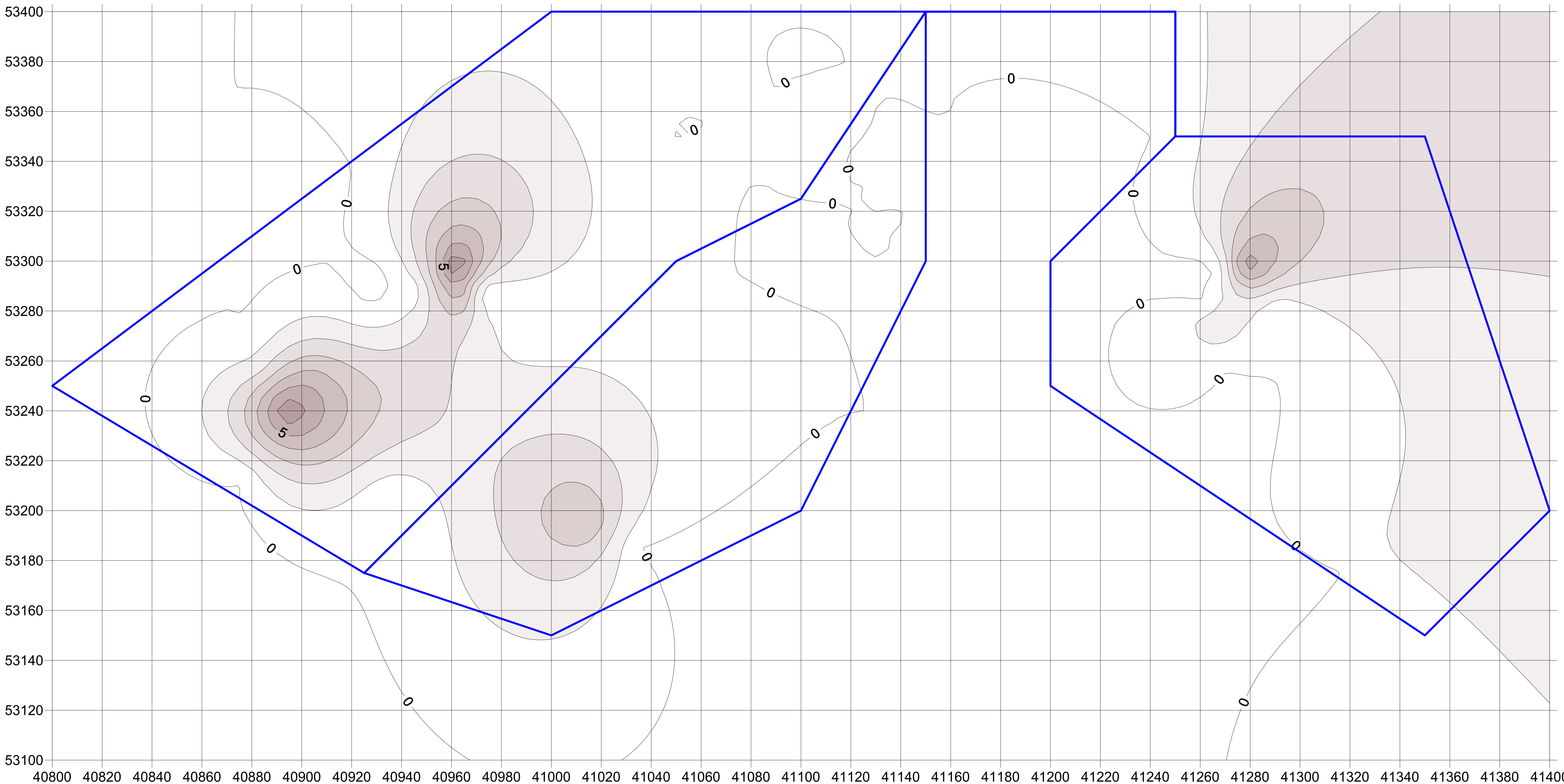


Figure 8: Initial Gridding Map of Soft Zone Thickness, 15 tsf Criteria

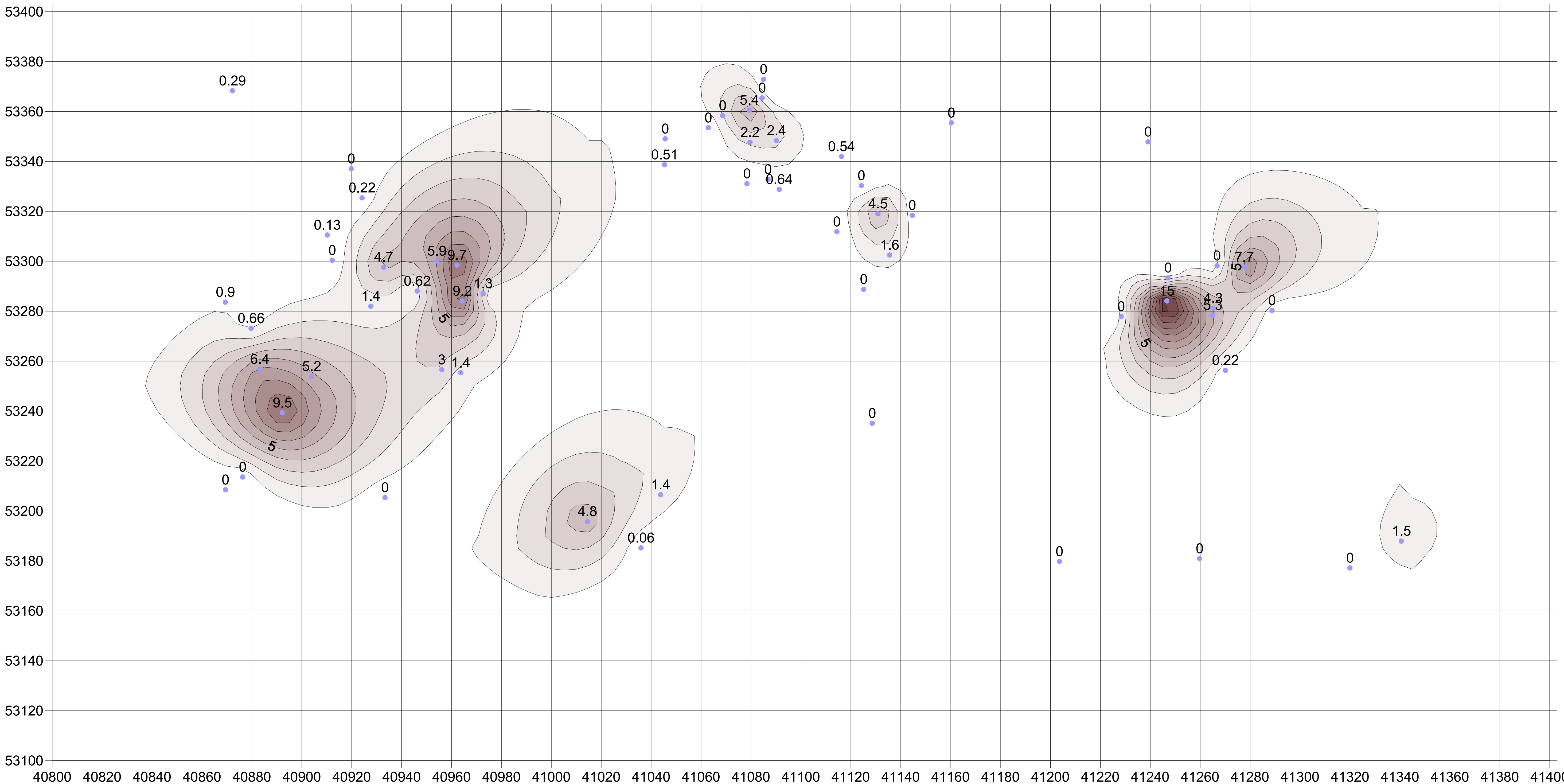


Figure 9: Contour Map of Soft Zone Thickness, 15 tsf criteria

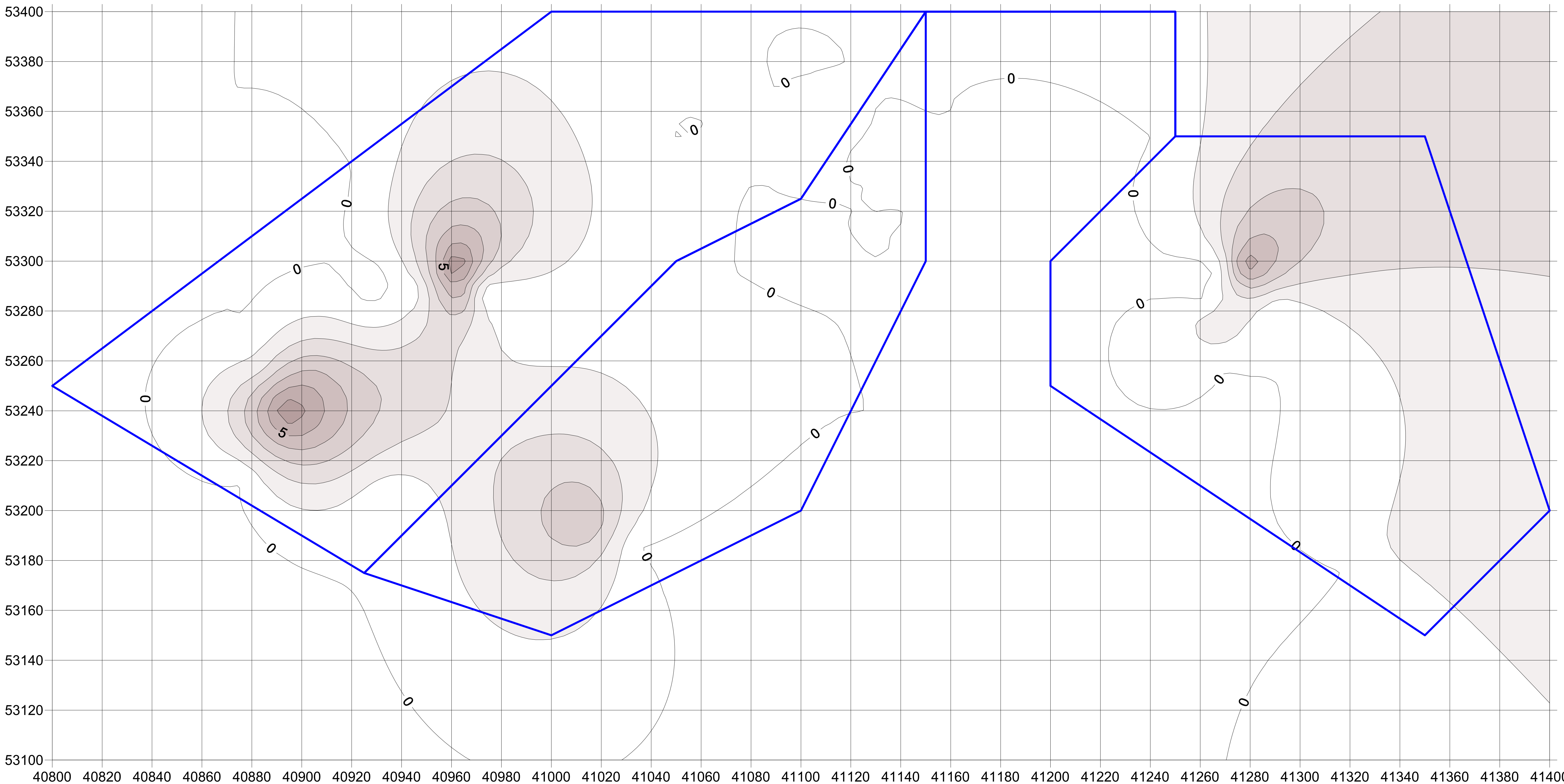


Figure 10: Initial Gridding Map of Soft Zone Thickness, Overburden Criteria

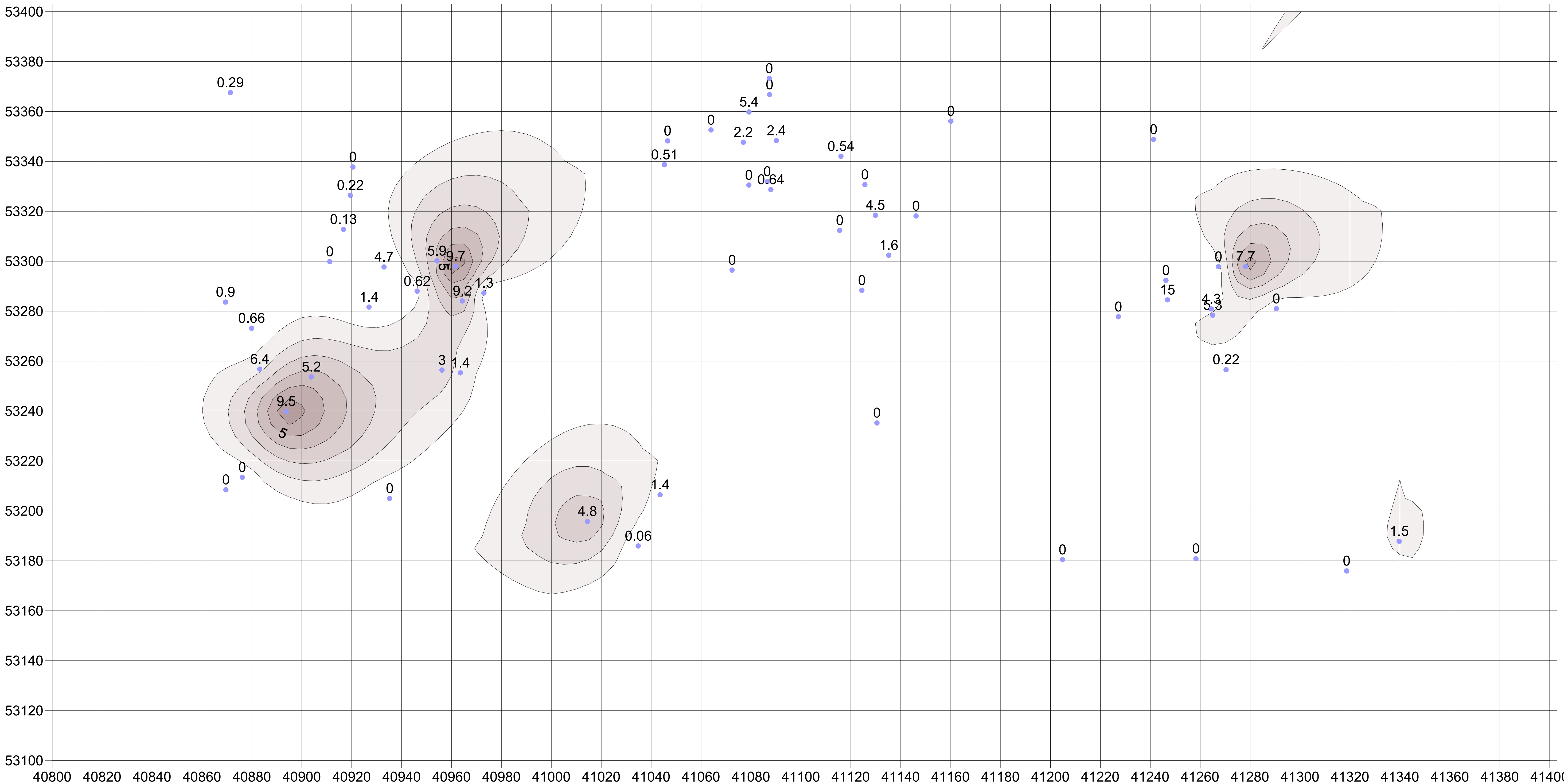


Figure 11: Contour Map of Soft Zone Thickness, Overburden Criteria

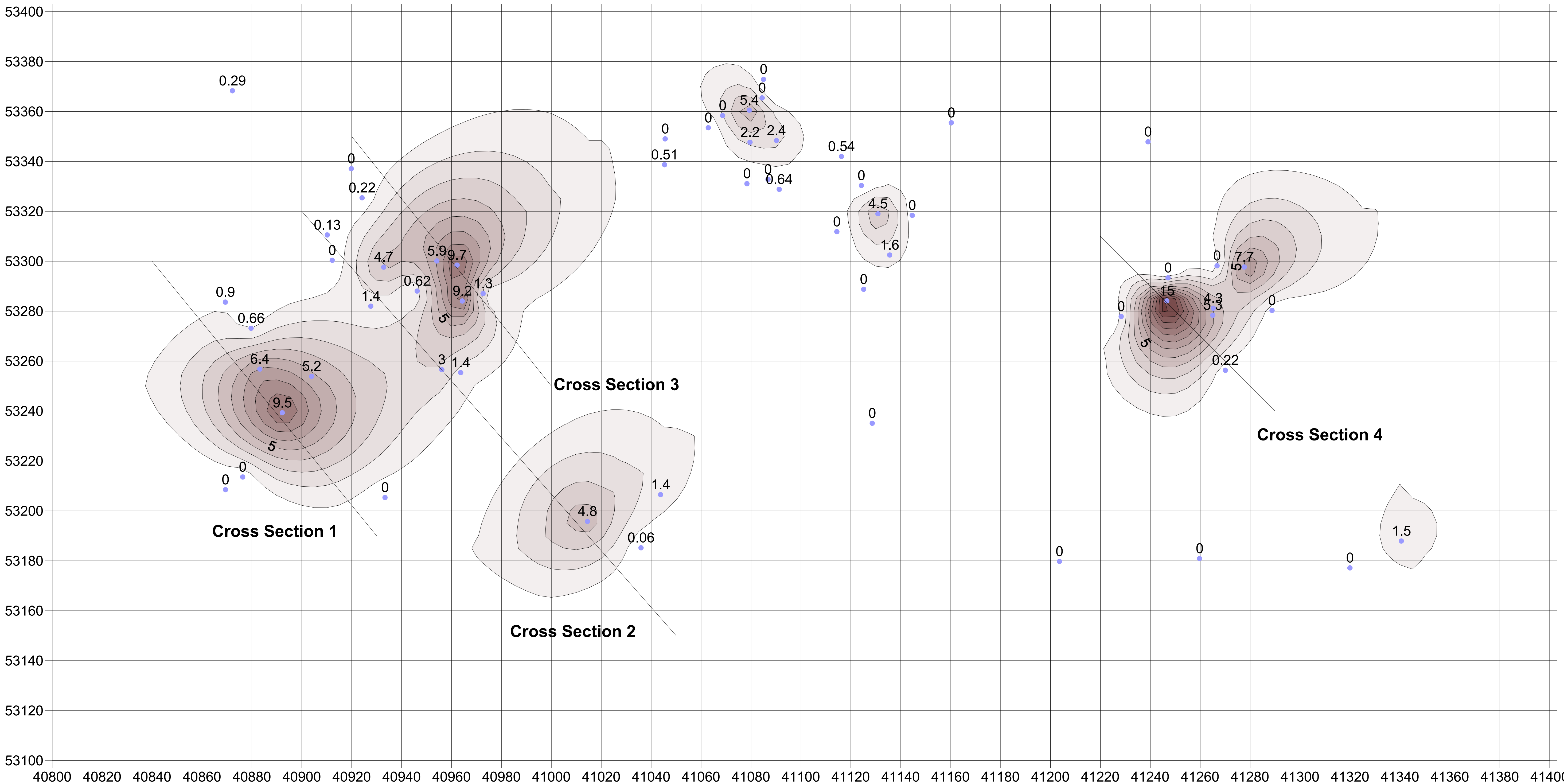


Figure 12: Cross Sections Used for Settlement Analysis, 15 tsf Criteria

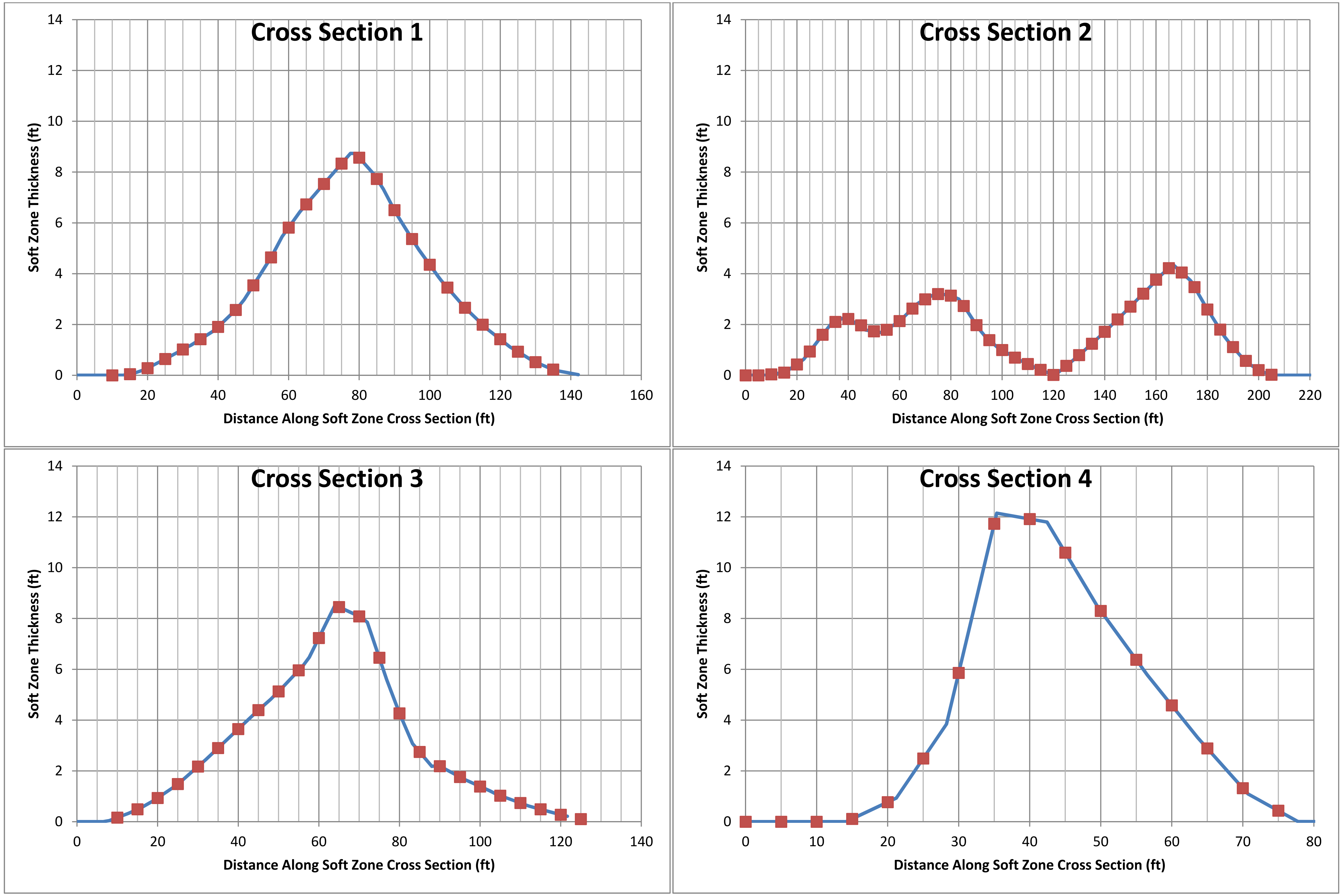


Figure 13: Soft Zone Thickness Across Cross Sections, 15 tsf Criteria

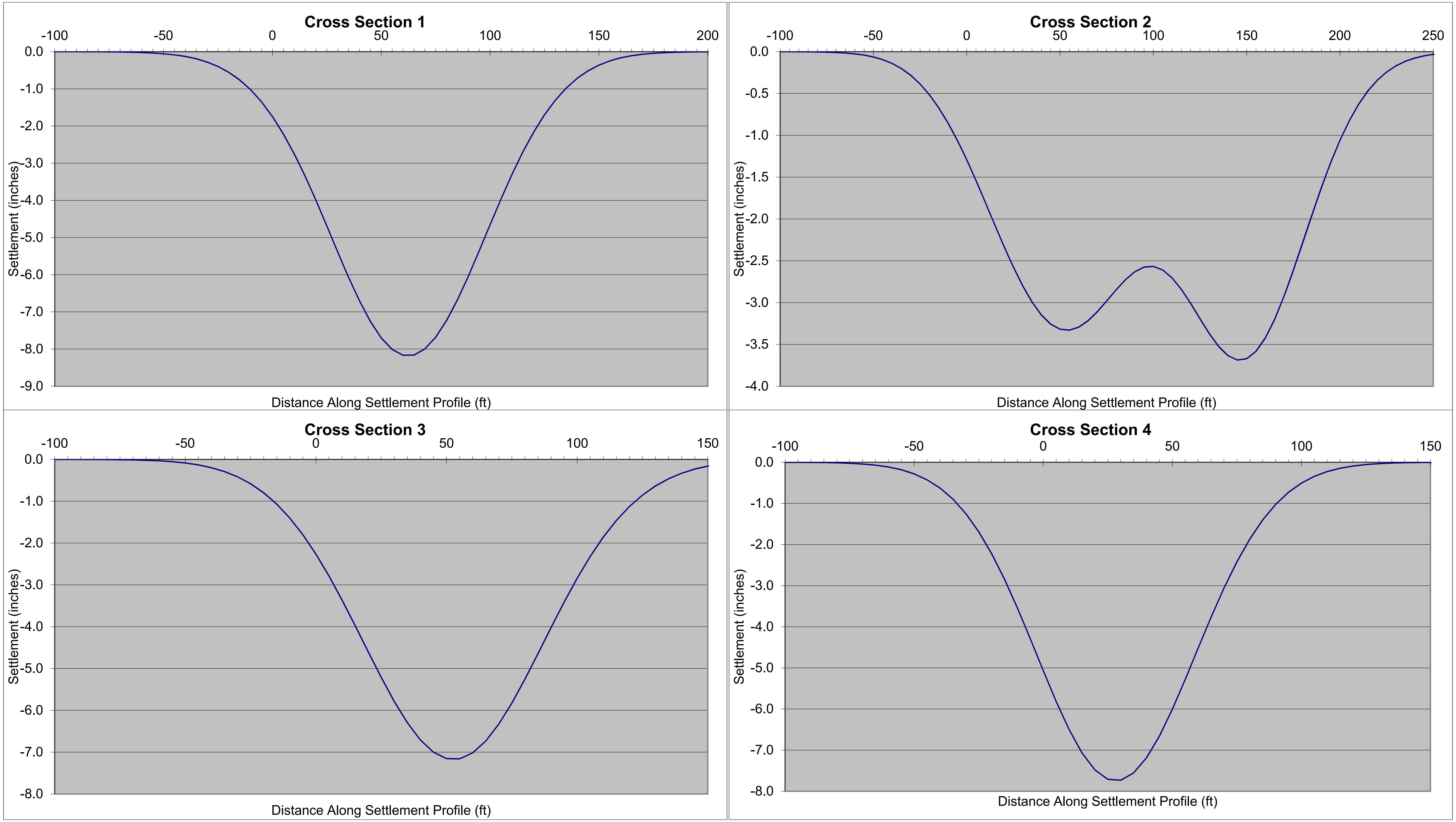


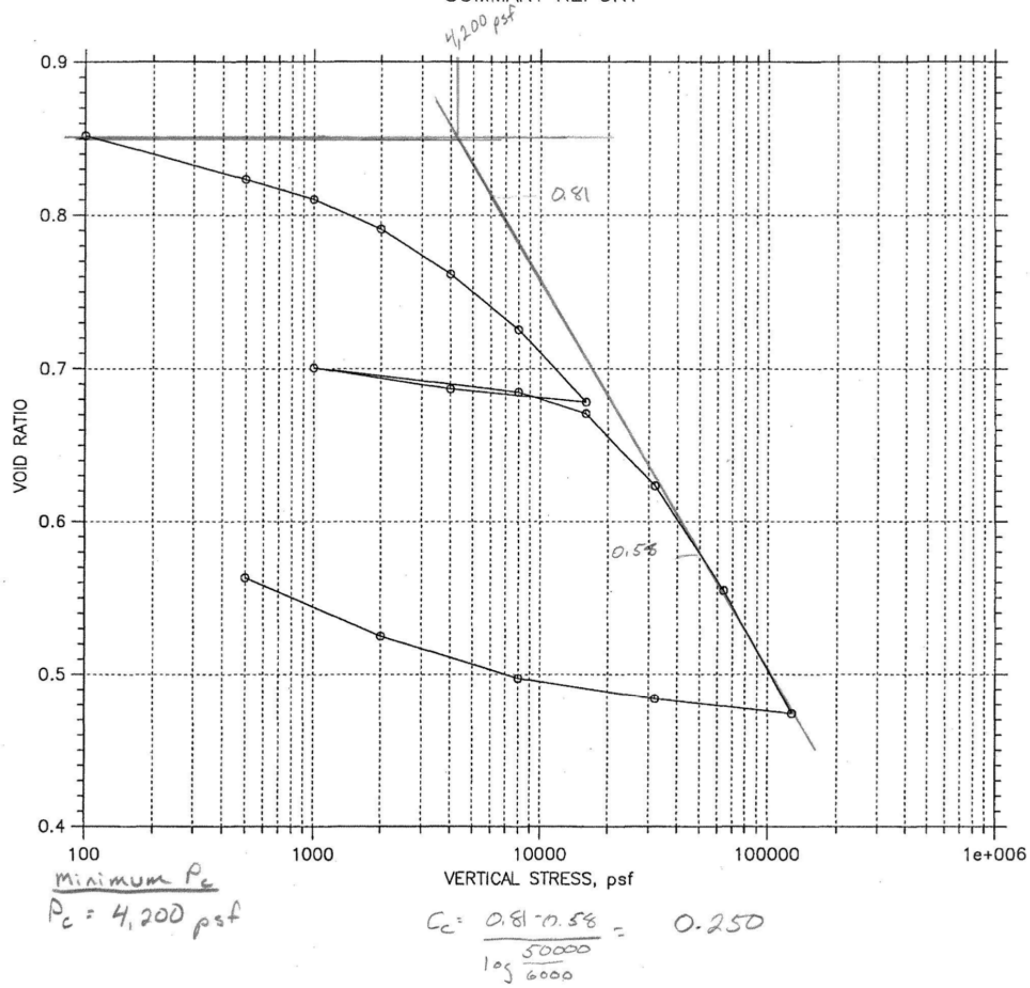
Figure 14: Settlement Profiles Along Cross Sections, 15 tsf Soft Zone Criteria

Appendix A – Consolidation Curve Constructions

(9 pages)

CONSOLIDATION TEST DATA

SUMMARY REPORT



					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	25.74	21.34
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	89.06	105.8
Compression Index: 0				Saturation, %	79.55	100.44
Diameter: 2.5 in		Height: 1.002 in		Void Ratio	0.86	0.56
LL: 63	PL: 34	PI: 29	GS: 2.65			

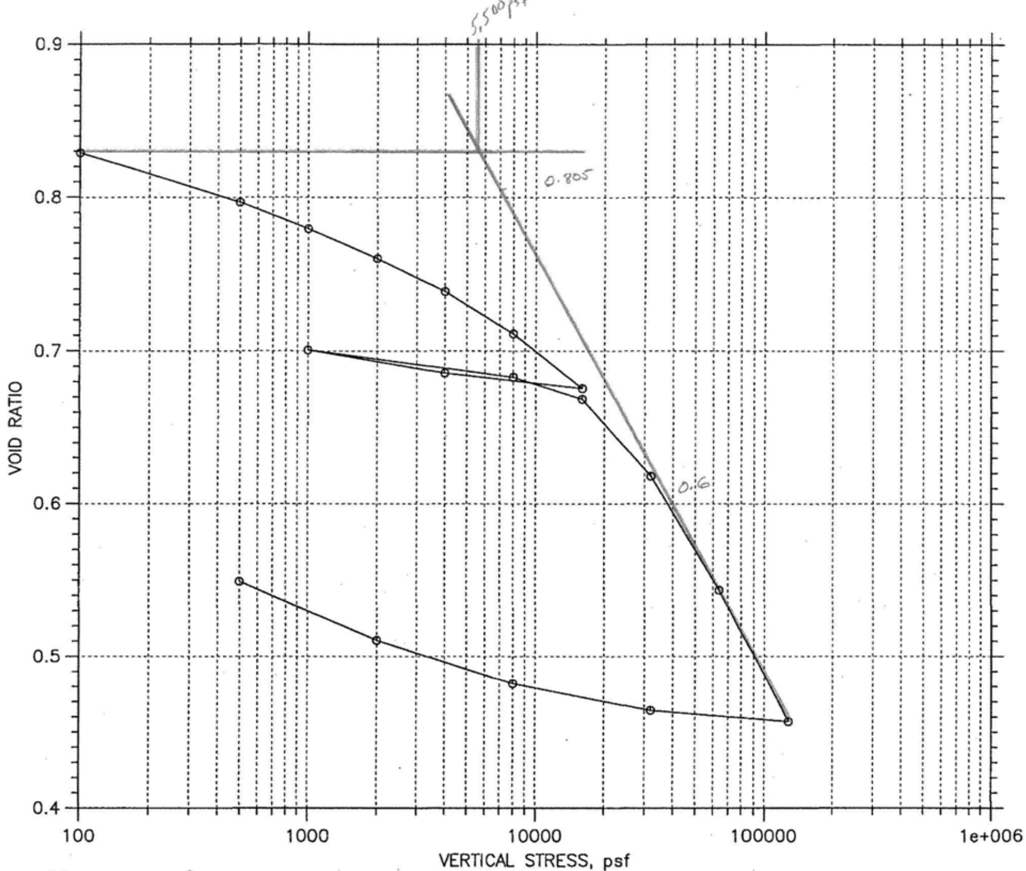
MACTEC	Project: PDC Soft Zone Samples	Location: K-PDC-B05	Project No.: 6152080031
	Boring No.: K-PDC-B05	Tested By: JW	Checked By: JGJ
	Sample No.: FP01	Test Date: 5/3/11	Depth: 113.9-115.8
	Test No.: 10855C1-2.5	Sample Type: UD	Elevation: N/A
	Description: Pale Yellow Silty Sand (SM)		
	Remarks: ASTM D2435-04		

Fri, 27-MAY-2011 09:31:03

SRS147 Page 26 of 55

CONSOLIDATION TEST DATA

SUMMARY REPORT



Minimum P_c

P_c = 5,500 psf

$C_c = \frac{0.805 - 0.6}{\log \frac{40,000}{7,000}} = 0.271$

					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	27.61	20.59
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	90.41	107.2
Compression Index: 0				Saturation, %	87.79	99.77
Diameter: 2.5 in		Height: 1.005 in		Void Ratio	0.84	0.55
LL: 57	PL: 34	PI: 23	GS: 2.66			

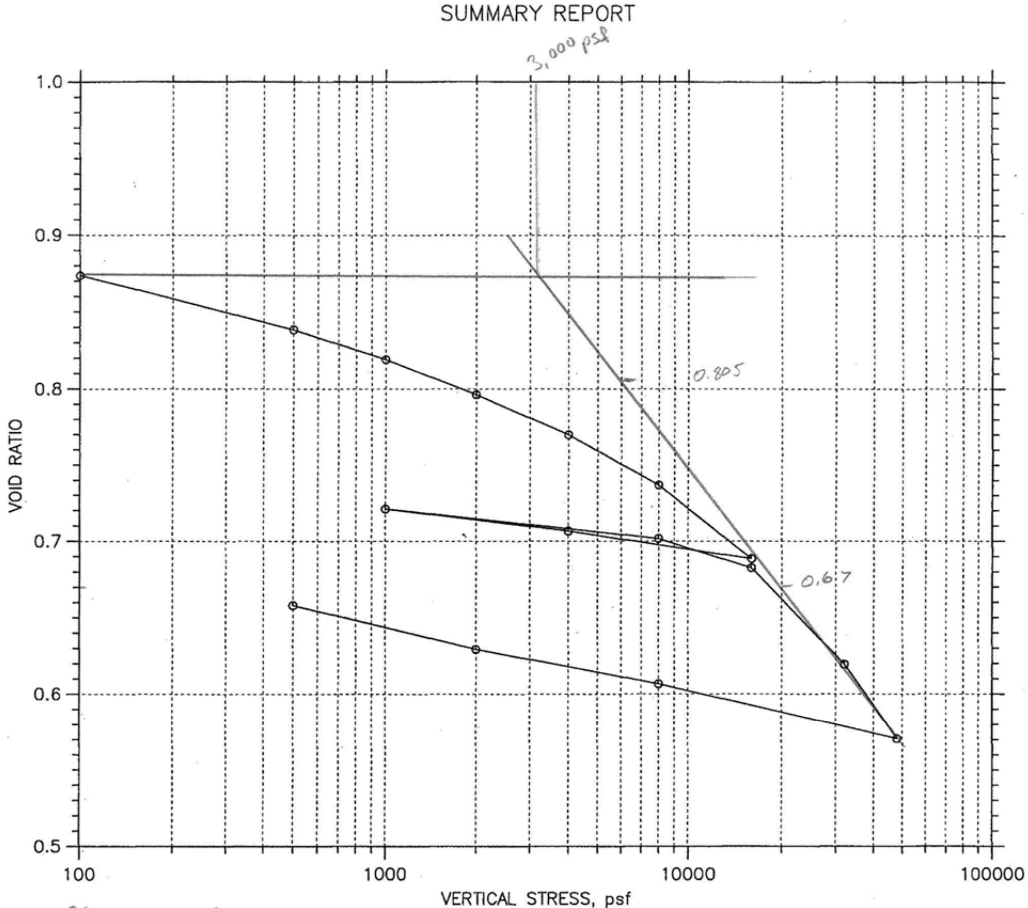
MACTEC	Project: PDC Soft Zone Samples	Location: K-PDC-B05	Project No.: 6155080031
	Boring No.: K-PDC-B05	Tested By: JW	Checked By: JGB
	Sample No.: FP01	Test Date: 5/3/11	Depth: 113.9-115.8
	Test No.: 10855C2-2.5	Sample Type: UD	Elevation: N/A
	Description: Pale Yellow Silty Sand (SM)		
	Remarks: ASTM D2435-04		

Tue, 17-MAY-2011 15:22:21

SRS147 Page 33 of 55

CONSOLIDATION TEST DATA

SUMMARY REPORT



Minimum P_c

$P_c = 3,000 psf$

$C_c = \frac{0.805 - 0.67}{\log \frac{20,000}{6000}} = 0.258$

					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	27.68	24.89
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	87.42	99.41
Compression Index: 0				Saturation, %	82.56	99.89
Diameter: 4 in		Height: 1.012 in		Void Ratio	0.89	0.66
LL: 64	PL: 36	PI: 28	GS: 2.64			

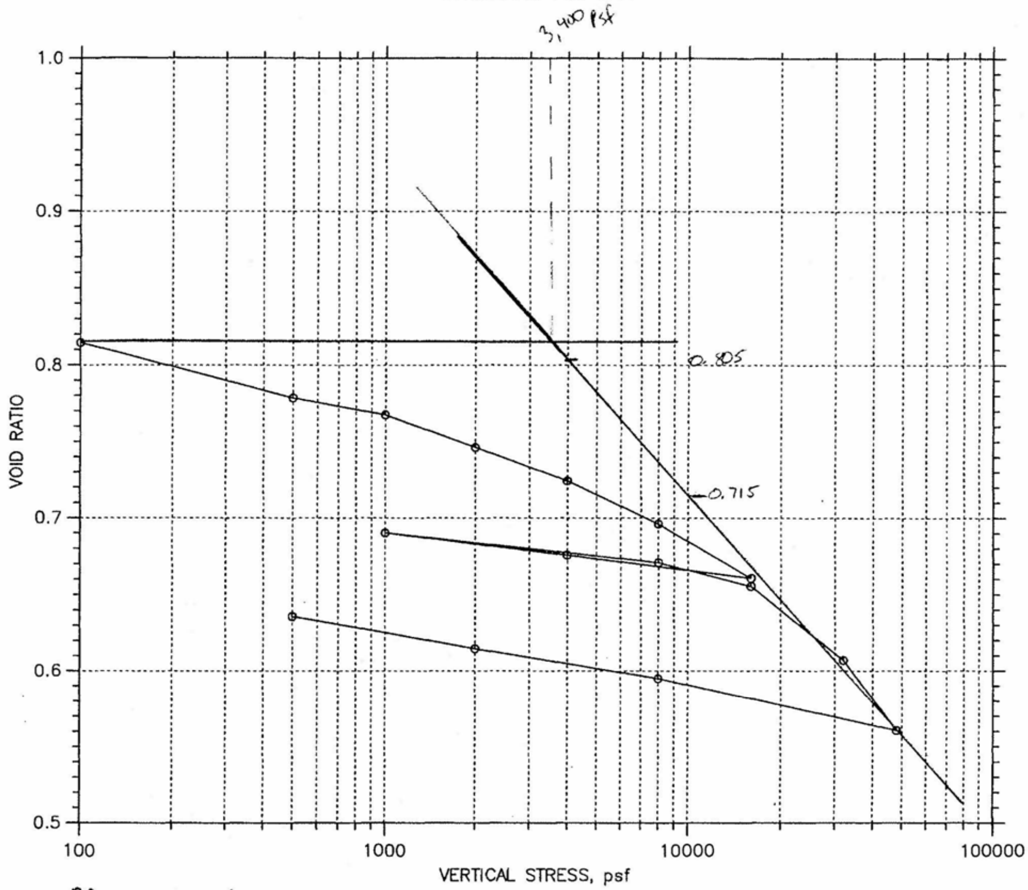
MACTEC			
	Project: PDC Soft Zone Samples	Location: K-PDC-B05	Project No.: 6155080031
	Boring No.: K-PDC-B05	Tested By: JW	Checked By: JEJ
	Sample No.: FP01	Test Date: 5/3/11	Depth: 113.9-115.8
	Test No.: 10855C1-4.0	Sample Type: UD	Elevation: N/A
	Description: Pale Yellow Silty Sand (SM)		
	Remarks: ASTM D2435-04		

Tue, 17-MAY-2011 15:26:17

SRS147 Page 38 of 55

CONSOLIDATION TEST DATA

SUMMARY REPORT



Minimum P_c

P_c = 3,400 psf

$C_c = \frac{0.805 - 0.715}{\log \frac{10,000}{4,000}} = 0.226$

					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	27.25	23.78
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	91.47	102.3
Compression Index: 0				Saturation, %	88.09	100.24
Diameter: 4 in		Height: 1.005 in		Void Ratio	0.83	0.64
LL: 55	PL: 34	PI: 21	GS: 2.68			

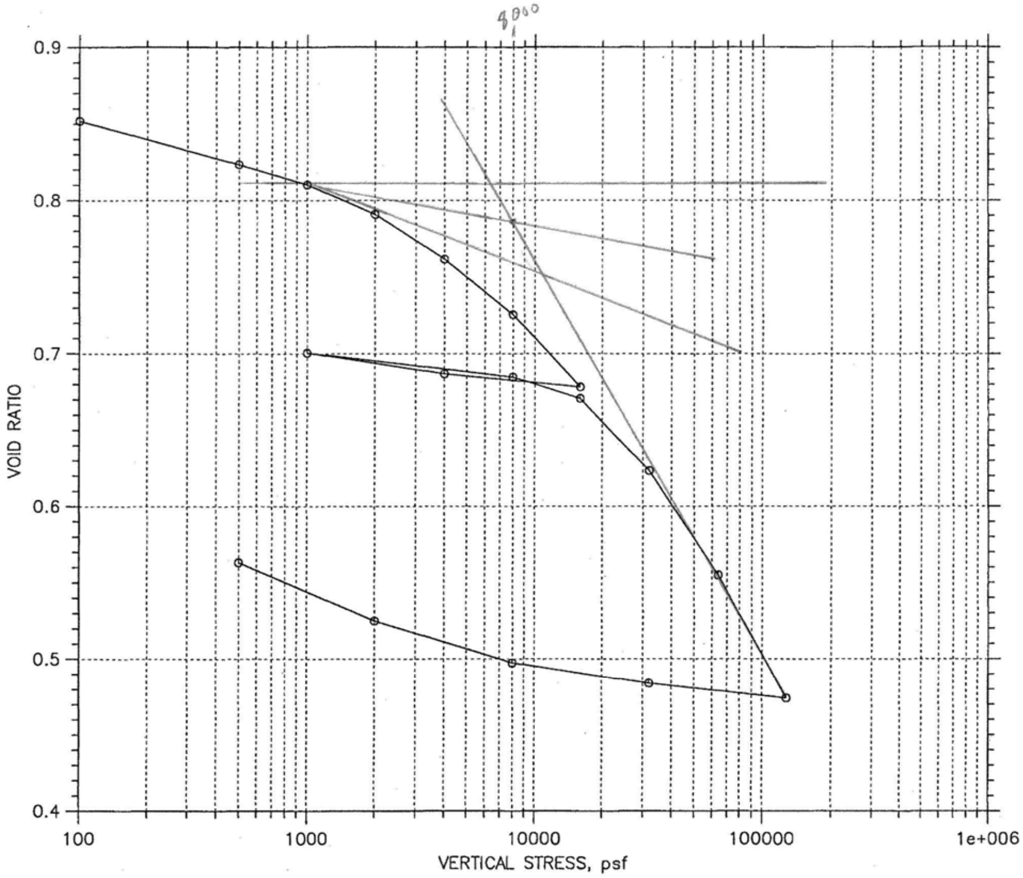
MACTEC			
	Project: PDC Soft Zone Samples	Location: K-PDC-B05	Project No.: 6155080031
	Boring No.: K-PDC-B-05	Tested By: JW	Checked By: JEJ
	Sample No.: FP01	Test Date: 5/3/11	Depth: 113.9-115.8
	Test No.: 10855C2-4.0	Sample Type: UD	Elevation: N/A
	Description: Pale Yerllow Silty Sand (SM)		
	Remarks: ASTM D-2435-04		

Tue, 17-MAY-2011 15:32:36

SRS147 Page 43 of 55

CONSOLIDATION TEST DATA

SUMMARY REPORT



C_c = 0.250
P_c = 8,000 psf

					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	25.74	21.34
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	89.06	105.8
Compression Index: 0				Saturation, %	79.55	100.44
Diameter: 2.5 in		Height: 1.002 in		Void Ratio	0.86	0.56
LL: 63	PL: 34	PI: 29	GS: 2.65			

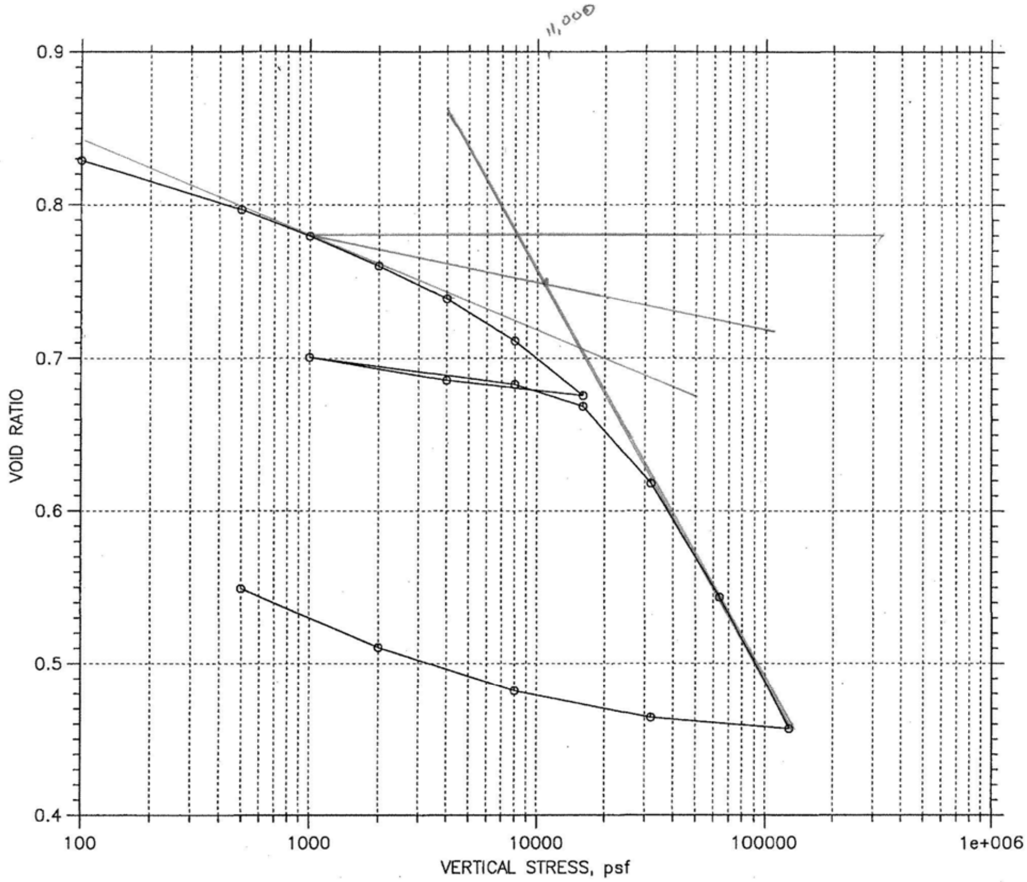
MACTEC			
	Project: PDC Soft Zone Samples	Location: K-PDC-B05	Project No.: 6152080031
	Boring No.: K-PDC-B05	Tested By: JW	Checked By: JGJ
	Sample No.: FP01	Test Date: 5/3/11	Depth: 113.9-115.8
	Test No.: 10855C1-2.5	Sample Type: UD	Elevation: N/A
	Description: Pale Yellow Silty Sand (SM)		
	Remarks: ASTM D2435-04		

Fri, 27-MAY-2011 09:31:03

SRS147 Page 26 of 55

CONSOLIDATION TEST DATA

SUMMARY REPORT



C_c = 0.271
P_c = 11,000 psf

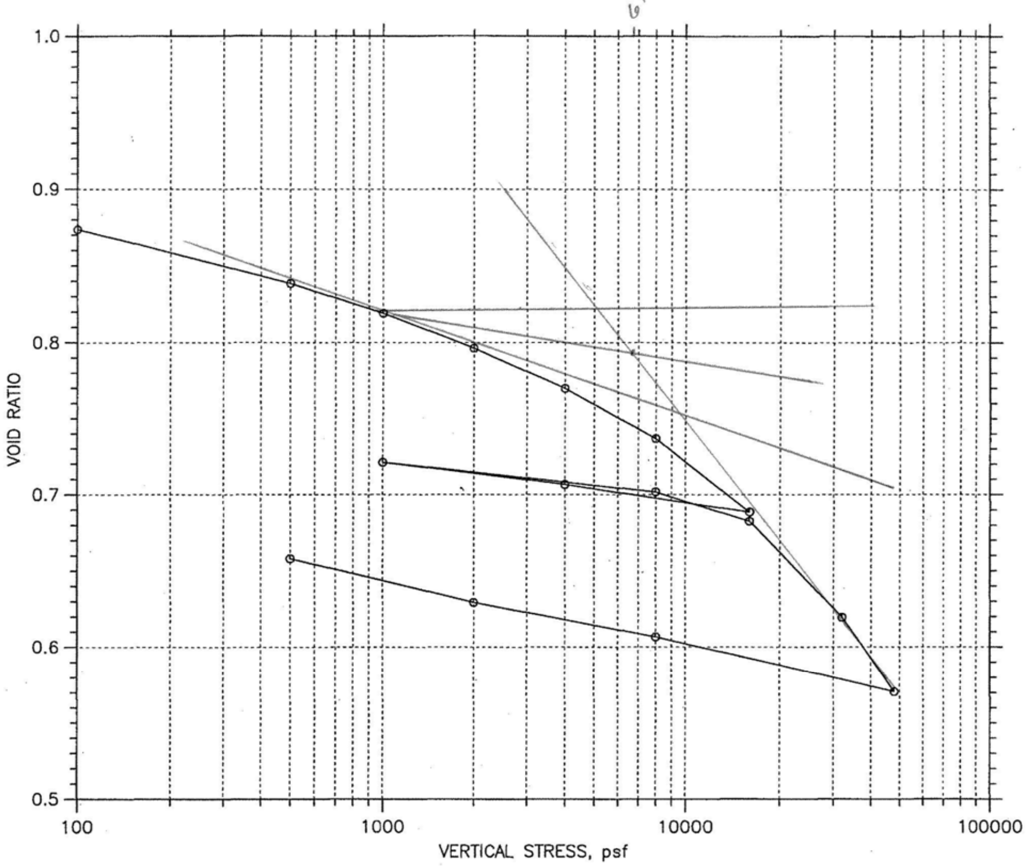
					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	27.61	20.59
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	90.41	107.2
Compression Index: 0				Saturation, %	87.79	99.77
Diameter: 2.5 in		Height: 1.005 in		Void Ratio	0.84	0.55
LL: 57	PL: 34	PI: 23	GS: 2.66			

MACTEC	Project: PDC Soft Zone Samples	Location: K-PDC-B05	Project No.: 6155080031
	Boring No.: K-PDC-B05	Tested By: JW	Checked By: JGR
	Sample No.: FP01	Test Date: 5/3/11	Depth: 113.9-115.8
	Test No.: 10855C2-2.5	Sample Type: UD	Elevation: N/A
	Description: Pale Yellow Silty Sand (SM)		
	Remarks: ASTM D2435-04		

Tue, 17-MAY-2011 15:22:21

CONSOLIDATION TEST DATA

SUMMARY REPORT



C_c = 0.258
P_c = 6,700 psf

					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	27.68	24.89
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	87.42	99.41
Compression Index: 0				Saturation, %	82.56	99.89
Diameter: 4 in		Height: 1.012 in		Void Ratio	0.89	0.66
LL: 64	PL: 36	PI: 28	GS: 2.64			

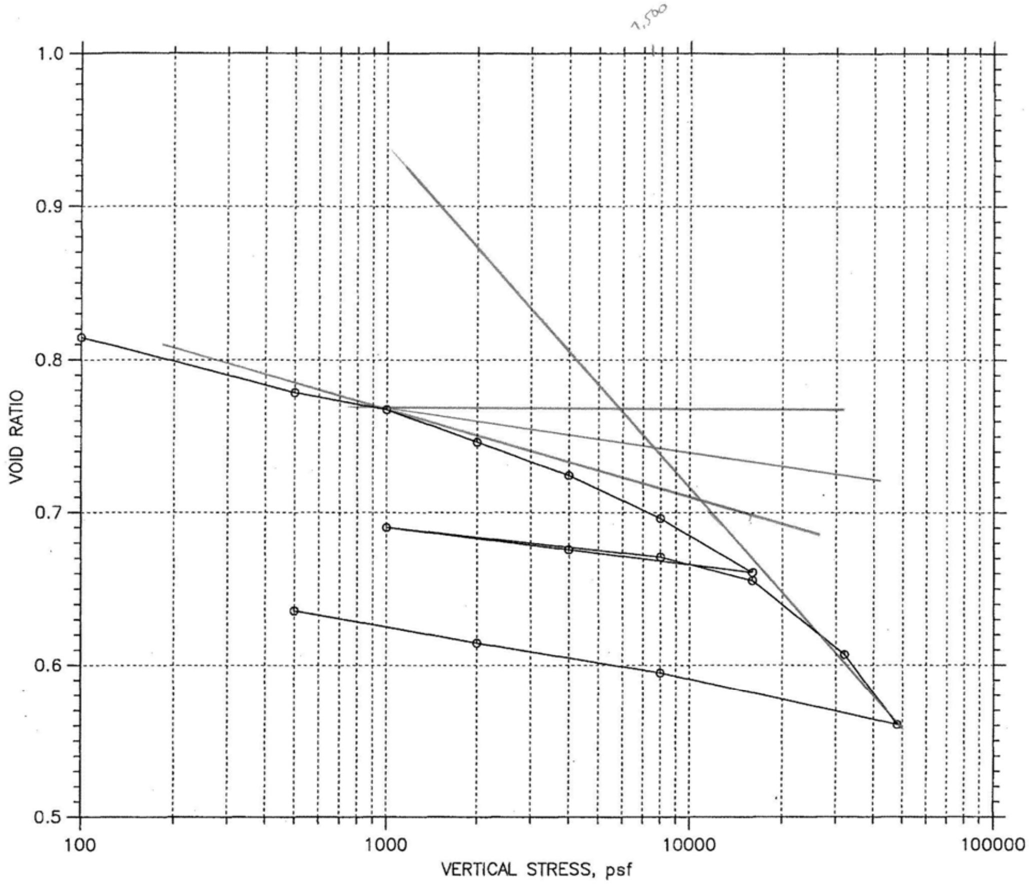
MACTEC	Project: PDC Soft Zone Samples	Location: K-PDC-B05	Project No.: 6155080031
	Boring No.: K-PDC-B05	Tested By: JW	Checked By: JGJ
	Sample No.: FP01	Test Date: 5/3/11	Depth: 113.9-115.8
	Test No.: 10855C1-4.0	Sample Type: UD	Elevation: N/A
	Description: Pale Yellow Silty Sand (SM)		
	Remarks: ASTM D2435-04		

Tue, 17-MAY-2011 15:26:17

SRS147 Page 38 of 55

CONSOLIDATION TEST DATA

SUMMARY REPORT



C_c = 0.226

P_c: 7,500 psf

					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	27.25	23.78
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	91.47	102.3
Compression Index: 0				Saturation, %	88.09	100.24
Diameter: 4 in		Height: 1.005 in		Void Ratio	0.83	0.64
LL: 55	PL: 34	PI: 21	GS: 2.68			

MACTEC			
	Project: PDC Soft Zone Samples	Location: K-PDC-B05	Project No.: 6155080031
	Boring No.: K-PDC-B-05	Tested By: JW	Checked By: JEJ
	Sample No.: FP01	Test Date: 5/3/11	Depth: 113.9-115.8
	Test No.: 10855C2-4.0	Sample Type: UD	Elevation: N/A
	Description: Pale Yerllow Silty Sand (SM)		
	Remarks: ASTM D-2435-04		

Tue, 17-MAY-2011 15:32:36