ROCKY FLATS SPPTS
GEOTECHNICAL INVESTIGATION REPORT

Jefferson County, Colorado

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TABLE OF CONTENTS

1.0 INTRODUCTION 1
2.0 CONDITIONS AT THE SPPTS 2
3.0 SPPTS CONSTRUCTION 4
4.0 GEOLOGY AND GROUNDWATER 5
5.0 FIELD INVESTIGATION 7
5.1 Site Visits 7
5.2 Exploratory Borings 7
6.0 LABORATORY TESTING 9
7.0 SUBSURFACE CONDITIONS 11
7.1 Aggregate Base Course 11
7.2 Man-Placed Clay Fill Material 11
7.3 Sandy Clay/Organic Layer 12
7.4 Sandy Gravel/Alluvium/Colluvium 12
7.5 Weathered Bedrock 13
7.6 Claystone Bedrock 13
7.7 Groundwater 13
8.0 CONCLUSIONS 15
9.0 RECOMMENDATIONS 17
9.1 Remove and Replace 17
9.2 Ground Improvement 17
9.3 Piles and Piers 18
10.0 FOUNDATION RECOMMENDATIONS 19
11.0 LIMITATIONS 21
12.0 REFERENCES 22

LIST OF TABLES

Table 1: Summary of Laboratory Test Results
Table 2: Consolidation Swell Test Results
Table 3: Water Level Measurements
Table 4: Factor of Safety for Uplift

LIST OF FIGURES

Figure 1: Rocky Flats Project Vicinity Map
Figure 2: Boring Locations
Figure 3: Cross Section Locations
Figure 4: Cross Section A-A
Figure 5: Cross Section B-B
Figure 6: Cross Section C-C

LIST OF APPENDICES

Appendix A: Borehole Logs
Appendix B: Laboratory Test Results
Appendix C: Geotechnical Calculations

1.0 INTRODUCTION

This report presents the results of a geotechnical investigation by Tetra Tech, Inc. to evaluate the recent, localized settlement at the Solar Ponds Plume Treatment System (SPPTS) located at the U.S. Department of Energy (DOE) Rocky Flats Site. Localized subsurface failures in the vicinity of the water storage sump at the treatment system resulted in sump leakage. The investigation was performed for S.M. Stoller Corporation (Stoller) as part of their DOE contract. Stoller is a Legacy Management contractor for the DOE and provides engineering, operations, and maintenance support from offices in Westminster and Grand Junction, Colorado.

The SPPTS and Rocky Flats are located 16 miles northwest of Denver in northern Jefferson County, Colorado. The general site location and the location of the SPPTS within Rocky Flats are shown on Figure 1.

This report includes a description of the existing site, facilities, and the distress that has occurred, discussion of the geologic and subsurface conditions, descriptions of Tetra Tech's field and laboratory investigations, analysis of the subsurface and geotechnical conditions, and recommendations for feasible mitigation alternatives for the SPPTS Phase II/III and IV facilities.

2.0 CONDITIONS AT THE SPPTS

The SPPTS is located on a north-facing hillside on the south side of North Walnut Creek and the North Walnut Creek Drainage. North Walnut Creek is an intermittent/perennial stream that flows from west to east through the area. Before construction of the SPPTS, extensive regrading had occurred in the area, according to Stoller personnel who have been involved in work at Rocky Flats for many years. The historical fill placement described by Stoller is consistent with geologic mapping by Shroba and Carrara (1996), which shows much of the area to be covered by "artificial fill."

The following history and historical description of site conditions were provided by Stoller. The natural stream channel may previously have been located as close as 20 feet north of the north edge of the original SPPTS treatment cells. During the late 1970s, the streambed was moved north to accommodate security upgrades, a 72-inch-diameter drain was installed to route water from areas west and southwest of the SPPTS to the new streambed, and the existing hillside at and around the SPPTS was constructed. A roughly two-mile network of French drains (the Interceptor Trench System, or ITS) was installed on this hillside to collect and route groundwater from the slope immediately north and east of the former Solar Evaporation Ponds to a sump and pump house (the Interceptor Trench Pump House, or ITPH) located in the North Walnut Creek valley bottom, from which the water was pumped to various locations over the subsequent years. The manner in which this work was performed, the construction practices that were used during backfilling of the previous stream channel, and the level of compaction during fill placement on the hillside are unknown. The ground surface in the area of the original SPPTS treatment cells, including the new Phase II and Phase III components, appears to have been raised by approximately 10 to 15 feet as a result of this work.

Additional disturbance occurred during construction of the original components of the SPPTS in 1999. Because of the depth of the treatment cell structure (approximately 28 feet, plus a 5-foot overexcavation and engineered fill) and associated groundwater intercept trench, a large excavation was required. That excavation likely included much of the ground on which the Phase II/III SPPTS facilities were later constructed. Stoller personnel who observed the construction of the trench have indicated that the excavation was quite large. However, the topographic surface that existed prior to construction of the SPPTS (i.e., after the first phase of regrades described above) was, in the immediate vicinity of the SPPTS, generally very similar to the current topography.

A third, less extensive but locally disruptive regrading effort occurred following installation of the SPPTS just prior to site closure in 2005, when the 72-inch drain was removed, the adjacent functional channel was constructed, and an estimated 2 to 3 feet of fill was placed over parts of the area generally west and northwest of the SPPTS concrete structure to provide a more even surface. The construction methods (in particular, compaction) and the condition of the fill, particularly that used to backfill the removed 72-inch drain, are not known. However, these regrading episodes included placement and compaction of deep fills that have significant potential to impact the Phase II and Phase III upgrades to the SPPTS. One early hypothesis explaining the settlement of the sump was that the backfilled drainage pipe excavation may have settled when loaded by the recently constructed Phase II and III SPPTS facilities, presumably due to inadequate compaction of the associated backfill. The nature and composition of the fill that was encountered in this investigation is described in Sections 4 and 5 of this report.

The current ground surface elevation at the SPPTS is approximately 5,900 feet above mean sea level. The SPPTS treatment facilities occupy approximately 6,000 square feet of land on the hillside above North Walnut Creek. The SPPTS, the approximate location and orientation of the previous 72-inch diameter drain pipe, and the locations of exploratory borings drilled as part of this investigation are shown on Figure 2.

3.0 SPPTS CONSTRUCTION

The SPPTS was constructed in 1999 to treat elevated levels of uranium and nitrate in subsurface water. It includes a groundwater interceptor trench that is approximately 1,100 feet long; an associated manhole; a two-cell, rectangular concrete treatment vault; and a discharge gallery. The groundwater collection trench is immediately upgradient from the treatment cells. The concrete structure that includes the two treatment cells is approximately 46 feet long by 20 feet wide by 28 feet deep, and is believed to have been constructed on native soils or bedrock and 5 feet of engineered fill. The system was upgraded via the addition of a collection well and pump in 2002.

The treatment system previously exhibited no obvious sign of significant physical distress, such as settling or subsidence (Stoller, 2009). However, shortly after Rocky Flats closed and was transferred to the Office of Legacy Management (LM), the concrete structure was excavated to determine the cause of reduced treatment that had been observed since mid-2005. It was found that several of the subsurface valves had malfunctioned, the penetrations through the concrete structure were not adequately sealed, and piping within the first cell had broken. No surface expression of these conditions was evident. Repairs were made and the system resumed normal operation.

Because of the costs and difficulty in performing these repairs, which were generally similar in magnitude to what would be required to change the treatment media, the decision was made to evaluate whether the system could be upgraded to allow maintenance actions to be performed more easily and inexpensively. In late 2008, the first of four phases of upgrades to the system was completed. The Phase I upgrades comprise additional collection and discharge infrastructure in the valley to the north and east.

In May 2009, construction of the Phase II/III upgrades to the SPPTS was completed. The planned (as opposed to as-built) Phase II/III SPPTS facilities layout is shown on Figure 2. Phase II includes a zero-valent iron (ZVI) cell, which is intended to be a long-term component of the treatment system, and Phase III is the pilot-scale nitrate treatment cells (Cells A and B). The Phase III components may be interim facilities or longer-term components of the ultimate treatment system, depending on system performance and various requirements. The SPIN vault supports the entire system, while the metering vault, carbon storage vault, water storage sump, and associated piping and electrical facilities support the Phase II and Phase III structures (Stoller, 2009). Phase IV will be a full-scale nitrate biotreatment facility and is scheduled to be designed and constructed in fiscal year (FY) 2010.

Operation of the Phase II/III SPPTS facilities was initiated on May 28, 2009. On July 4, parts of the system automatically shut down due to unexpected conditions, most notably a sudden drop in the water level in the water storage sump that was unrelated to groundwater availability. Investigations conducted by Stoller in early July revealed that leakage had occurred from the water storage sump, and that a cavity had developed in the shallow subsurface adjacent to the sump. It was found that the water storage sump had settled in an irregular manner, causing the watertight seal between sections of the pre-cast concrete structure to separate and leak.

A geotechnical investigation was designed to investigate the characteristics of the subsoils in accessible locations adjacent to the Phase II/III SPPTS facilities, recommend mitigative measures to reduce the risk of future, similar distress prior to Phase IV design and construction, and provide long-term fixes as necessary for Phase II and III components.

4.0 GEOLOGY AND GROUNDWATER

The geology of the SPPTS site was evaluated by reviewing geologic mapping and reports of the area, site visits by Tetra Tech staff, and by examination of cuttings, bulk samples, and split barrel samples recovered from six exploratory borings drilled at the site on July 27 through 29, 2009. Comprehensive geologic investigations of Rocky Flats and the surrounding area have been completed by others, including a report by EG&G Rocky Flats, Inc. titled *Geologic Characterization Report for the Rocky Flats Environmental Technology Site*, dated March 1995. Tetra Tech examined the EG&G report, a map by Shroba and Carrara titled *Surficial Geologic Map of the Rocky Flats Environmental Technology Site and Vicinity, Jefferson and Boulder Counties, Colorado*, dated 1996; and a map by Colton and Holligan titled *Photo Interpretive Map Showing Areas Underlain by Landslide Deposits and Areas Susceptible to Landsliding in the Louisville Quadrangle, Boulder and Jefferson Counties, Colorado*, dated 1977. Those documents were reviewed for detailed geologic information regarding the SPPTS site and the surrounding area. The following discussion of local geology is presented to provide background specific to the SPPTS site and this investigation.

The Rocky Flats Site is located in a structurally stable area (EG&G, 1995) between the Front Range of the Rocky Mountains to the west and the Denver Basin to the east. The surface of the area is a broad pediment that is covered by a thin mantle of silty topsoil over clay, sand, and gravel deposits of the Quaternary-age Rocky Flats Alluvium. More recent alluvial deposits exist locally and in stream channels and valleys. The Rocky Flats Alluvium is described as reddish-brown, poorly sorted, coarse clayey sand with varying concentrations of pebble and cobble clasts derived from erosion of the mountains to the west. In the vicinity of Rocky Flats, where it caps the flat pediment surface, the thickness is reported by EG&G to average 10 to 25 feet.

The Rocky Flats Alluvium rests unconformably on sedimentary bedrock, and generally provides for infiltration of surface water and recharge (EG&G, 1995). In the immediate vicinity of the SPPTS, infiltration is strongly affected by the extensive series of French drains that forms the ITS, as well as the SPPTS groundwater collection trench. The latter trench is known to extend into the claystone bedrock and intercepts segments of the ITS, receiving the water flowing within those segments. It is assumed that this trench is also effectively intercepting perched groundwater flow from upgradient sources such as the Rocky Flats Alluvium and colluvial and alluvial surface deposits. It is possible that some component of the general groundwater flow pattern to the west of the groundwater collection system has found a preferential pathway in the backfill for the removed 72-inch drainage pipeline. No evidence of such a scenario was encountered during the recent field investigation; however, a localized area adjacent to and south and west of the SPPTS had vegetation consistent with that frequently seen in areas of shallow groundwater. In addition, standing water associated with precipitation events was observed at the ground surface in this area through the wetter spring months of 2009, and a small wetland area fed by shallow groundwater has developed nearby to the west. (Note that seepage on the north-facing hillside southwest of the SPPTS is commonly observed during the spring months, and the heavier precipitation in 2009 led to wet conditions in the flat area west of the SPPTS.)

The bedrock geology consists of comparatively flat-lying claystone and sandstone deposits of the Upper Cretaceous Arapahoe and Laramie Formations. The Arapahoe Formation is a fluvial deposit that locally includes a discontinuous sandstone or pebble conglomerate layer at the base and greenish claystone and siltstone overbank deposits. The thickness has been mapped at 0 to 50 feet locally (EG&G, 1995).

The Upper Laramie Formation is described as a 300- to 500-foot-thick sequence of gray and yellowish-orange kaolinitic claystones with ironstone nodules, and dark-gray to black, carbonaceous claystones, discontinuous coal beds, and lenticular sandstones (EG&G, 1995). Compared to the Arapahoe Formation, the Laramie Formation generally contains more claystone, which tends to weather into clay. Conditions suggesting the presence of expansive clays have been encountered during historical development and reclamation at the Rocky Flats Site (Stoller, 2009).

Tetra Tech investigations at this site and at the Original Landfill (OLF) located south of the SPPTS (Tetra Tech, 2008), support the published literature and geologic mapping.

The hillside underlying the SPPTS is mapped by Colton and Holligan (1977) as a landslide deposit that consists of “masses of earth and rock that have moved downslope as earthflows and slumps.” (Note that the date of this reference suggests this description is of the “original” hillside that was present before the main regrading effort performed in the area in the late 1970s-1980, which relocated North Walnut Creek. Therefore, in addition to the methods of construction and compaction used to create this artificial hillside, the stability of the original materials beneath the regraded hillside is questionable.) Colton and Holligan (1977) explain that these landslide deposits have formed along the margins of gravel-capped mesas (such as those visible on the hillside north of the SPPTS) where springs and seeps have saturated the underlying clayey parts of the Laramie Formation. The landslide deposits have a history of sliding; it is not known if they are actively moving at this time or have ceased movement sometime in the past. However, no evidence of larger-scale, catastrophic slope instability or movement was observed at the SPPTS treatment cells. Further, no occurrences of slope instability or landsliding at the SPPTS have been reported by Stoller personnel familiar with the site and its history. Evidence of slope movement has been observed on the hillside immediately east of the SPPTS treatment cells, downstream and on north- and south-facing slopes near the SPPTS discharge gallery, and on a northeast-facing hillside underlain by the easternmost portion of the ITS. It is likely that the potential for landsliding and/or soil creep in the vicinity of the SPPTS has been reduced by the installation of the groundwater collection systems described above, but these indications of ongoing movement suggest these systems do not completely eliminate the potential for larger-scale slope movement.

5.0 FIELD INVESTIGATION

In an effort to evaluate the cause of the subsurface failure that caused the water storage sump to settle and leak in early July, Tetra Tech conducted field investigations that included site visits on July 16 and 27, and August 4, 2009. Six exploratory borings were drilled between July 27 through 29, 2009. During drilling, soil and bedrock samples were collected, cuttings were logged, and water levels were measured. Penetration resistance measurements were recorded during sampling. The elements of the field investigation are described in more detail below.

5.1 Site Visits

A Tetra Tech senior geotechnical engineer visited the SPPTS site on July 16, July 27, and August 4, 2009, to observe site characteristics, plan the geotechnical investigation, and observe backfill operations in the vicinity of the water storage sump. Stoller personnel provided required safety training and accompanied Tetra Tech staff while on site. Borings were drilled at accessible locations in the field, as close to the planned locations as practical. Several of the planned boring locations were revised slightly based on field conditions and to improve access for the drill rig. With one exception, the actual locations were surveyed by a Stoller subcontractor; the location of boring Tt-3 was not surveyed because this area was regraded during system repair efforts.

At the time of the field investigation, the water storage sump had been removed and an irregularly shaped excavation existed between the ZVI cell and the carbon storage vault. A slight depression in the ground surface was apparent immediately south of Cell B, although no cracking was apparent at the depression. Slight, irregular but generally linear-shaped swales were visible on the ground surface both east and north of the SPPTS treatment structures. These surface irregularities may be associated with fill settlement above existing pipelines, or with general fill settlement associated with one or more of the episodes of construction and/or historical grading operations that were described above, or may represent the as-built topography (i.e., having no relationship to any settlement).

5.2 Exploratory Borings

Six borings (Tt-1 through Tt-6) were drilled at the locations shown on Figure 2 on July 28 and July 29, 2009. At the time of drilling, the sump had been removed, leaving an approximately 10-foot-deep by 12-foot-wide excavation, sloped from the west. The objectives of the drilling program were to obtain comparatively high-quality and undisturbed samples for laboratory testing, determine depth to water, look for weak zones within the fill, and determine the depth to bedrock.

A track-mounted, CME 55 drill rig was used to drill the six borings. Depths ranged from 31 to 36 feet. Each hole was terminated in comparatively unweathered bedrock. Bulk samples were collected by filling a bag or bucket with auger cuttings from a certain depth interval in the hole. A “California-style” split-barrel sampler was driven into the substrata at depths of 2 and 5 feet, then at approximately 5-foot intervals to obtain brass liner samples for laboratory testing. The sampler was driven into the soil using a 140-pound weight repeatedly dropped 30 inches by an automatic “hammer” device on the drill rig. The number of blows required to drive the sampler 12 inches is recorded on the borehole logs (see Appendix A) as the penetration resistance value (N). After drilling, the boreholes were backfilled using the auger cuttings from the hole. In holes where water was encountered (three of the six borings), the water level was initially

measured, then the borehole was left open for up to one day to obtain a second water level measurement before backfilling.

Water was encountered in boring Tt-2 at 22 feet at the time of drilling. When checked 26 hours later, the level of water in the boring had risen to 20 feet below the ground surface. In boring Tt-4 water was encountered at 24 feet. Approximately 4 hours later water was measured at a depth of 25 feet. In boring Tt-6 water was encountered at a depth of 7 feet during drilling, and had risen to a depth of 6 feet when checked approximately 1.5 hours later. According to Stoller, this water level does not correspond to the water level in a “riser pipe” located adjacent to the concrete structure and about 10 feet southeast of Tt-6.

Tetra Tech personnel observed drilling and sampling operations, collected samples, and logged boring lithologies. The Tetra Tech geotechnical engineer was present at the SPPTS periodically during the operations to observe conditions and monitor the progress. Stoller personnel provided health and safety oversight during the drilling and sampling operations.

6.0 LABORATORY TESTING

During drilling, representative bulk samples of the soils encountered were collected by Tetra Tech. "California-style" split-barrel samples were also collected, examined, and logged by Tetra Tech as described above. Geotechnical laboratory testing was performed in Tetra Tech's Fort Collins, Colorado, and Billings, Montana, laboratories. Select samples were tested by Stewart Environmental Consultants, Inc. to determine the amount of water-soluble sulfates and the organic content of the soils. Appendix B provides the laboratory test results.

The bulk and split-barrel samples were arranged according to depth and relative location, and visually classified and compared. Suitable, representative samples of each material sampled were selected for testing of in-situ physical properties (natural water content and dry density) and index testing (particle size analyses, Atterberg limits, and Unified Soil Classification system (USCS). Samples were also described according to the Munsel Color Chart method.

Physical properties, in general, indicate the state of the soil in the ground and are useful for comparison of more dense versus less dense materials, saturated versus unsaturated conditions, and so forth. Index properties are used to classify soils into groups that tend to behave in similar ways, such as clays, sands, and gravels.

Strength testing is used in conjunction with N values (blow counts) to provide an estimate of the relative strength of the soils and the suitability of each for engineering purposes such as support of foundations, excavation slopes, and lateral earth pressures. Unconfined compressive strength tests, direct shear tests, and N values were used in this investigation to identify the bearing capacity and other design criteria needed to specify remedial foundation design methods for the SPPTS structures.

Consolidation/swell tests were conducted to determine the volume change behavior of samples of the fill and bedrock when they were wetted after application of a load similar to overburden pressure. This test can be used to determine short- and long-term settlement, consolidation, or swell behavior of the soils and bedrock.

In most cases, samples observed to be representative of specific soil types were selected and tested rather than performing similar tests on all the samples. In other cases, notably water-soluble sulfate concentration and total organic content, the samples that were tested represented the only samples in which evidence of the properties tested was visible. In some cases, such as the samples selected for consolidation/swell testing, direct shear testing, and unconfined compressive strength testing, engineering judgment was used to select suitable samples that would meet the requirements of the specific test procedure and would be least likely to give unreliable results.

Bulk samples of the SPPTS site fill soil and the aggregate base course were tested according to Standard Proctor methods so that the relative compaction of the in-place fill could be estimated. The results of laboratory testing are presented in Table 1. "Typical" ranges of test results for similar soils are also shown for comparison purposes.

Descriptions of the soils and their properties are provided in the following section of this report.

Table 1. Summary of Geotechnical Laboratory Test Results for Borehole Samples – Rocky Flats SPPTS

Boring No.	Sample Depth[1] (ft)	Sample Type[2]	Water Content (%)	Sat.[3] (%)	Dry Density (pcf)	Material Type	Munsell Color	USCS Soil Class	Atterberg Limits[4] LL/PL/PI (%)	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Total Organic Content (%)	Soluble Sulfates (ppm)	Max. Dry Unit Weight[5] (pcf)	Opt.[5] Water Content (%)	UCS[6] (psf)	Direct Shear[6] (C/Φ) (psf/deg.)	Consolidation/Swell Test[7] Inundation Pressure (psf)	Collapse or Swell (%)	Swell Pressure (psf)
Tt-1	2.75	CA	16.1	91	114.2	Clay Fill	2.5Y 5/2										537 / 21			
	5.75	CA	22.8	92	101.0	Clay Fill	2.5Y 4/4											500	1.6	3,325
	10.75	CA	15.5	70	105.3	Clay Fill	2.5Y 4/2									4,106				
	16.25	CA	21.4	95	104.7	Clay Fill	5Y 7/2											1,000	0.7	3,381
	21.25	CA	22.8	94	101.8	W. Claystone	2.5Y 5/4													
Tt-2	6.25	CA	15.4	71	106.4	Clay Fill	2.5Y 4/3													
	16.25	CA	23.1	80	94.7	Clay Fill	2.5Y 5/3										411 / 29			
	19 – 21	Bulk				Dark Clay	10YR 3/1	CL	47 / 16 / 31		63	5.5								
	21.25	CA	15.3	90	115.4	Dark Clay	10YR 3/2	CL	44 / 15 / 29	88	62							1,500	0.4	3,054
	26.25	CA	5.8	58	132.8	Sandy Gravel	10YR 5/3	GW-GM	Non-plastic	50	11									
	35.75	CA	14.5	98	120.2	Claystone	2.5Y 5/3	CH	52 / 17 / 35		99									
Tt-3	3.25	CA	18.2	89	108.5	Clay Fill	2.5Y 4/3													
	11.25	CA	18.5	94	109.9	Clay Fill	2.5Y 6/4	CH	58 / 19 / 39	100	96									
	35.75	CA	16.3	62	98.7	Claystone	2.5Y 4/1									5,544				
Tt-4	3.25	CA	13.9	81	115.3	Clay Fill	2.5Y 5/2						102							
	6.25	CA	18.6	86	106.3	Clay Fill	2.5Y 4/1									6,029				
	11.25	CA	19.5	88	105.6	Clay Fill	2.5Y 4/1	CH	59 / 20 / 39		99									
	21.25	CA				Clay Fill	7.5YR 4/4					4.0								
	31.25	CA	20.0	99	108.9	Claystone	2.5Y 4/1											2,000	2.5	12,675
Tt-5	3.25	CA	17.0	88	110.8	Clay Fill	10YR 5/2									4,404				
	5 – 15	Bulk				Clay Fill	2.5Y 5/3	CH	62 / 16 / 46	97	83			104.8	18.3					
	11.25	CA	21.2	84	100.2	Clay Fill	2.5Y 5/2													
	26.25	CA	21.9	97	104.6	W. Claystone	2.5Y 5/4						157							
Tt-6	2 – 5	Bulk				Base Course	7.5YR 4/3	SM	Non-plastic	66	17			134.0	8.2					
	6.25	CA	8.7	61	121.6	Base Course	10YR 3/6	SM	Non-plastic	70	20									
	11.25	CA	23.9	102	103.2	Clay Fill	2.5Y 4/3											500	0.6	2,074
	16.25	CA	20.9	96	106.1	Clay Fill										1,936				
	35.75	CA	14.8	88	115.9	Claystone	10YR 4/1													
Expected Range of Parameters			12 – 25	50-100	90 – 115	Clay	-	CL – CH	PI = 10- 60	70 – 100	50 – 100	≤ 5	< 1,000	100 – 115	16 – 20	1-8,000	0-1,000/14-30	-	0 – 12	0 - 36,000
Expected Range of Parameters			5 – 12	30-100	115 -130	Gravelly Sand	-	SM	Non-plastic	51 – 100	0 – 30	NA	< 1,000	120 – 135	7 – 9	-	-	-	-	-
Expected Range of Parameters			1 – 8	20-100	125 -140	Sandy Gravel	-	GW-GM	Non-plastic	0 – 50	0 – 30	NA	< 1,000	130 – 140	5 – 7	-	-	-	-	-

Notes:
1) Sample Depth is the distance from the ground surface to the middle of the sample tested. For the bulk samples, the Sample Depth is the depth range from which the cuttings sample was collected.
2) CA = California Split-Spoon Sample. Bulk = bucket or bag sample of auger cuttings.
3) Sat. = Saturation, in percent, the ratio of the volume of water in a sample to the volume of voids.
4) Atterberg Limits describe an index test used to group soils with similar properties. LL = Liquid Limit, the water content below which soil behaves as a plastic material. PL = Plastic Limit, the moisture content below which soil is non-plastic. PI is the Plasticity Index, the difference between LL and PL.
5) Maximum Dry Unit Weight and Optimum Water Content are obtained from the Standard Proctor compaction test according to ASTM D 698.
6) UCS = Unconfined Compressive Strength, measured in units of pounds per square feet (psf) and Direct Shear. Tests used to define the shear strength of a soil.
7) Consolidation/Swell Test. A one dimensional test in which a sample is loaded vertically to overburden or another load, then inundated and allowed to consolidate or swell.

7.0 SUBSURFACE CONDITIONS

The borings encountered man-placed fill, silty to gravelly sand, low- to high-plasticity clay fill, clay with variable concentrations of organic materials, weathered claystone, and comparatively unweathered claystone to the maximum depths explored. Water was encountered in three of the six borings at depths of 7 to 24 feet at the time of drilling. Graphical and descriptive logs of the borings are presented in Appendix A.

On the basis of field observations, physical examination of the samples, and laboratory analysis, the subsoils were classified into six groups as described below:

- Aggregate base course;
- Man-placed clay fill material;
- Sandy clay/organic layer;
- Sandy gravel/alluvium/colluvium;
- Weathered bedrock; and
- Claystone bedrock.

7.1 Aggregate Base Course

The aggregate base course material generally ranges between 2 and 7 feet thick. The material is moist, reddish-brown sand, gravel, and silt, and has a medium dense consistency. The base course is classified as silty sand with gravel having a maximum size of ¾ inches and a silt and clay content (percent passing the number 200 sieve) of 17 and 20 percent in the two samples tested. This material was placed and compacted around the Phase II/III SPPTS structures and used as an all-weather road surface in the surrounding areas. Although not encountered in borings or tested as part of this investigation, a clean sand was observed in excavations adjacent to the Phase II/III SPPTS structures. This material was used as bedding adjacent to piping.

7.2 Man-Placed Clay Fill Material

Below the aggregate base course in the borings was a layer of clay fill ranging in thickness from 17 to 27 feet. The clay fill was slightly moist to very moist, soft to very stiff with angular sand and gravel inclusions. The colors of the clay fill included mixtures of brown, gray, yellow, and black. This material was generally a variable mixture of clay, claystone fragments, sand, and gravel. Dry density ranged from 94.7 to 115.3 pounds per cubic foot (pcf) and water content ranged from 13.9 to 23.9 percent. Standard Penetration Tests (SPT) performed during sampling indicated N values that ranged from 5 blows per 12 inches to 53 blows per 12 inches. In Tt-1, Tt-6, and Tt-2, the clay fill material was less stiff than in the other borings, as indicated by the blow counts shown on the boring logs included in Appendix C. These results suggest that the material was placed in layers or lifts, and compactive effort was applied. However, the compaction appears to have been variable, such as would be expected from thick lifts, where compaction would be greater in the upper portion of the lift and would decrease towards the lower portion of the lift.

Mechanical particle size analyses run on three samples of the clay fill material indicated a range of silt- and clay-sized particles from 83 to 99 percent. The liquid limits ranged from 58 to 62, and the plasticity index ranged from 39 to 46. The three samples of the clay fill material were classified as high-plasticity clays (CH).

In several of the borings, the amount of angular sand and gravel encountered within the clay fill increased with depth. A sample of the clay fill from Tt-4 that had a mottled, dark-colored zone at 21 feet had a total organic content of 4 percent. This likely represents the previous ground surface that was reworked at the time of the original grading operation. Thin layers of soil with organic concentrations less than 5 percent are typically not problematic in this area from a settlement standpoint.

A sample of the clay fill was also tested for concentration of water-soluble sulfates due to a white precipitate that was noted in the sample. A concentration of 102 parts per million (ppm) was measured, and indicates a negligible risk of damage to concrete elements that are in contact with the site soils.

Consolidation/swell tests were conducted on samples of the clay fill from Tt-1 at 5.75 feet and 16.25 feet, and from Tt-6 at 11.25 feet. When inundated at overburden pressure, the samples swelled 0.6 to 1.6 percent. This amount of swell potential generally represents a low risk of damaging movement of structures with conventional foundation loads, but poses a greater risk for structures that have a comparatively large footprint and a low bearing pressure, such as the SPPTS structures. These results also indicate that at the intervals tested there was no significant risk of settlement, or that settlement/consolidation of these layers has already occurred.

7.3 Sandy Clay/Organic Layer

Under the man-placed clay fill material, only in Tt-2, a 5-foot-thick sandy clay layer with organics was observed. The sandy clay was very moist, very dark grayish brown, and stiff with a slight organic odor. Two samples of the sandy clay from Tt-2 were classified as low-plasticity clays (CL), had 62 and 63 percent silt and clay-sized material, liquid limits of 44 and 47, and a plasticity index of 29 and 31, respectively. A sample tested for total organic content had 5.5 percent organic material. A sample of the sandy clay with organics swelled 0.4 percent when wetted after application of a 1,500 pounds per square foot (psf) confining load, and had a measured swell pressure of 3,054 psf. This layer is likely natural sandy clay soil that existed below the man-placed fill. The organic odor, total organic content, and thickness of the layer suggest it may have been a previous ground surface, an area within the ancestral stream channel, a landslide deposit, or an area where soil containing organics was used as fill or backfill. Consolidation testing does not typically show the true settlement potential for soils such as these, because while the organic layers may compress slightly under load, they will also typically continue to decay over time, causing a decrease in volume and a large potential for settlement. The presence of a five foot thick organic containing clay layer in this boring layer also demonstrates a large amount of variability between boreholes. It is possible that a thin organic layer could have gone undetected while logging cuttings and in samples from discrete intervals in other borings, but it is very unlikely that evidence of a significant thickness of organic material would not have been found if it was present.

7.4 Sandy Gravel/Alluvium/Colluvium

Below the sandy clay and/or the clay fill in borings Tt-1 and Tt-2 was a 2- to 5-foot-thick sandy gravel layer. The sandy gravel was moist to wet, reddish brown, dense sand and gravel with clay lenses throughout. A sample of the sandy gravel from Tt-2 had 50 percent gravel, 39 percent sand, and 11 percent silt- and clay-sized particles. This material is likely natural alluvial/colluvial material.

7.5 Weathered Bedrock

Below the gravelly sand and/or the clay fill, a zone of weathered bedrock was encountered in the borings. The borings encountered weathered claystone ranging in thickness from 1.5 to 4.5 feet. The weathered claystone was moist to very moist, gray, very stiff, and generally included oxidation. A sample tested for water-soluble sulfate content had a concentration of 157 ppm, which is not considered problematic for concrete, according to the American Concrete Institute (ACI).

7.6 Claystone Bedrock

Comparatively less-weathered claystone was encountered below the weathered claystone zone in all of the borings, and continued to the maximum depth explored of 36 feet. The less-weathered claystone was slightly moist, gray, and hard with traces of lignite and oxidation. Claystone samples had dry densities of 98.7 to 120.2 pcf and water contents of 14.5 to 20.0 percent. A sample used in mechanical grain size analysis had 99 percent silt- and clay-sized particles (passing the number 200 sieve), a liquid limit of 52, and a plasticity index of 35. A sample of the claystone swelled 2.5 percent when inundated after application of a 2,000 psf pressure, and had a measured swell pressure of 12,675 psf. These results indicate a high swell potential that must be considered in the design of foundation elements. Table 2 summarizes the consolidation/swell test results.

Table 2. Consolidation Swell Test Results

Boring ID	Depth	Inundation Pressure	Percent Swell	Swell Pressure
	(ft bgs)	(psf)	(%)	(psf)
Tt-1	5.75	500	1.6	3,325
Tt-1	16.25	1,000	0.7	3,381
Tt-2	21.25	1,500	0.4	3,054
Tt-4	31.25	2,000	2.5	12,675
Tt-6	11.25	500	0.6	2,074

7.7 Groundwater

Water was encountered in boring Tt-2 at 22 feet at the time of drilling. When checked 26 hours later, the level of water in the borehole had risen to 20 feet below the ground surface. In boring Tt-4 water was encountered at 24 feet. Approximately 4 hours later water was measured at a depth of 25 feet. In boring Tt-6 water was encountered at a depth of 7 feet during drilling, and had risen to a depth of 6 feet when checked again approximately 1.5 hours later. The measured water levels are summarized below on Table 3.

Table 3. Water Level Measurements

Boring No.	During Drilling (estimate)		Follow-up Measurement			
	Water Elevation (ft above mean sea level)	Depth to Water[1] (ft)	Elapsed Time (hrs)	Water Elevation (ft above mean sea level)	Depth to Water[1] (ft)	Change in Water Level [2] (ft)
Tt-2	5878	22	26	5880	20	2
Tt-4	5874	24	4	5873	25	-1
Tt-6	5891	7	1.5	5892	6	1

(1) Depth measured from the ground surface.
(2) Positive number denotes an increase in water level.

8.0 CONCLUSIONS

The purpose of the geotechnical investigation at the SPPTS site was three-fold: (1) to explore potential causes of the settlement that occurred at the Phase II/III structures, (2) to identify mitigative measures that can be used to support interim and final SPPTS (Phase II/III facilities and Phase IV) facilities to reduce the likelihood of additional future settlement and distress, and (3) to provide a safe work area for personnel regularly accessing and monitoring the site.

The cause of the sudden settlement and failure of the collection sump at the SPPTS site in July 2009 is not clear cut. However, when the related conditions are considered, it is possible to identify a “most likely” series of events that resulted in the failure of the collection sump. As consolidation of the variable and thick fill occurred, some areas of the fill “bridged” over settling soils, resulting in the formation of voids at depth within the clay fill. As settlement continued and wetting of the soils occurred, voids became larger, until the more-competent lenses of clay fill that had “bridged” over the void collapsed into the void(s). This process of settlement, void formation, wetting, collapse, and settlement gradually progressed upwards through the 17 to 27 feet of fill. When the Phase II/III upgrades to the SPPTS were constructed, the actual weights imposed from the structures were slightly less than the weight of the soils that they displaced. This is due to the fact that the structures were either empty or filled with materials that weigh significantly less than the in-place soils. However, the construction process itself resulted in loads being applied to the soils, and wetting of the soils occurred due to surface drainage and natural wetting processes. These processes likely accelerated the progression of settlement upwards until the failure occurred. The failure at the SPPTS was a localized occurrence that was not evident in the widely spaced borings; however, it is likely that similar conditions exist in many areas of the fill. Because other areas have not been leveled and are not covered by a thick layer of comparatively strong aggregate base course, any settlement that reaches the ground surface is more likely to develop slowly and would be visible as a shallow depression in the ground surface. The following observations and conclusions support the causes of the distress that are described above:

- The investigation confirmed that the Phase II/III SPPTS structures were constructed partially or completely over a 17- to 27-foot-thick layer of man-placed clay fill. This was emplaced during re-grading performed as part of security upgrades and movement of the North Walnut Creek stream channel in the 1970s; backfilling that occurred as part of construction of the SPPTS treatment cells and groundwater intercept trench in 1999; and/or removal of a 72-inch drain culvert and subsequent recompaction of fill that occurred in 2005. It was not feasible to identify which fill originated with which of these events, nor which fill material presented the greatest weakness (least compaction).

- The density, water content, and other physical properties of the fill are variable. A comparison of in-place density of the fill with a maximum density (by standard Proctor methods) indicated a compaction generally 90 percent or greater. However, this is the density that exists now, after consolidation of the fill has occurred to some extent. Further, density of some of the samples may be misleading due to the rock content of the comparatively small brass liner samples. That is, a single rock fragment that was randomly sampled as part of a liner sample would increase the measured density of that sample, while the larger bulk sample used to determine the maximum density for the material according to Standard Proctor methods likely had a lesser concentration of rock fragments. Therefore, some of the actual, in-situ densities may be lower than those

indicated in the data shown on Table 1. The variability of the in-situ material is supported by the generally high water content and degree of saturation of the clay fill samples.

- SPT results (blow counts) are also variable, suggesting inconsistent compaction or thick lifts during construction (i.e., a high degree of compaction in the upper portion of each lift that decreases with depth in each lift). The lowest blow counts were seen in Tt-1 and Tt-6. The blow counts suggest that the clay fill has a bearing capacity adequate to support the SPPTS elements, but variable and localized conditions in the fill resulted in settlement of the overlying structure. Voids that were observed in the base course backfill around and under the collection sump are believed to be the result of a long-term settlement process related to one or more of the fill/backfill processes that occurred previous to the Phase II/III SPPTS construction. The construction activity and subsurface wetting associated with the Phase II/III facilities likely increased the rate at which settlement occurred in the fill as voids worked their way upwards in the fill.

- The presence of an organic layer that varies from 5 feet thick in Tt-2 to not present at all less than 30 feet away suggests a high degree of variability in the natural soils below the fill as well. It is possible that a thin organic layer could have gone undetected while logging cuttings and in samples from discrete intervals in other borings, but it is very unlikely that evidence of a significant thickness of organic material would not have been found if it existed. Settlement in soils with significant organic content can continue over many years, and it is difficult to predict the nature and extent of the settlement. Settlement of an organic layer at the original ground surface could have contributed to settlement and eventually the development of voids higher up in the fill.

- The free water level appears to generally be perched near the surface of the bedrock and/or within alluvial/colluvial materials, but below the man-placed fill. (This is not the case at borehole Tt-6, which is discussed separately below.) This is believed to be controlled by the presence of the groundwater collection system; however, groundwater flow could be occurring around the west end of the collection system and finding preferential pathways along the prior fill/backfill zones.

- Free water was measured 6 feet below the ground surface in Tt-6. The source of the water is most likely leakage from the water storage sump and surface drainage that flowed down the adjacent hill on the north side of the access road. When the surface water encounters the comparatively permeable aggregate base course, a percentage of it percolates into the base course and through the sand bedding until it encounters the much less permeable clay fill.

9.0 RECOMMENDATIONS

Foundation recommendations are needed that will provide a stable bearing condition for elements of the Phase II/III and Phase IV SPPTS facilities. Further, the ground surface surrounding the Phase II/III and IV SPPTS facilities must be protected in the event of additional settlement. The Phase II/III structures are generally lightly loaded. A maximum allowable soil bearing pressure of 1,200 psf should be used for design of any foundation that will bear on the clay fill. This compares with an estimated actual bearing pressure of 700 psf for the previous sump.

Prior to and during the investigation at this site, alternatives that were considered included:

- Removal and replacement of fill and subgrade below and adjacent to the Phase II/III SPPTS structures. This alternative would require removal of the existing structures, excavation to within approximately 3 feet of the base of the fill, replacement and recompaction of the fill in thin lifts, and reconstruction of the SPPTS facilities;
- Methods of ground improvement such as compaction grouting or low-mobility grout injection;
- Conventional concrete piers;
- Piles or micro-piles; and
- Helical piers.

These methods are discussed in more detail below.

9.1 Remove and Replace

This alternative involves reconstructing the facilities according to the design, recognizing that occasional operational pauses may be needed to make similar repairs if and when failures occur. If the Phase II/III SPPTS facilities will be used on an interim basis only, and the separate water storage sump is a critical component of these facilities, this may be the most cost-effective approach, because it is possible that no additional failures will occur within the next several-month period. A variation on this alternative is removal and replacement of fill below the Phase II/III structures. Removal and replacement of these facilities and the underlying fill to some depth would be costly, inconvenient for the operation of the system, and may not solve the problem unless all of the fill were removed to a depth of 20 feet or more.

9.2 Ground Improvement

The performance of a shallow foundation could be improved, and the risk of distress could be reduced by a ground improvement program. This process would involve injection of a cementitious material in a three-dimensional grid system that would encompass the SPPTS Phase II/III area and extend from the ground surface to the claystone bedrock. Compaction grouting or low-mobility grouting would improve the strength and stiffness of the fill material, but the highly plastic and low-permeability nature of the clay fill would decrease the ability of the grout to permeate evenly throughout the material. Further, the creation of a large and comparatively stiff mass of soil would tend to “dam” subsurface water flow, which could increase the risk of slope instability in this slide-prone area. This method also includes a higher degree of inherent risk because a clear and singular causative mechanism has not been identified. Although this method does not appear to be a feasible alternative for foundation support, it does have merit as a means of stiffening the subgrade and filling near-surface voids that could

present safety problems for workers. If this method is chosen in addition to a deep foundation system (to stabilize the shallow subsurface to support pedestrian traffic), the upper 5 feet of the clay fill should be treated by injection of a low-viscosity, cementitious grout injected into the soil on a grid approximately 5 feet by 5 feet square that extends to at least 10 feet beyond the outer edge of the structures. This is typically accomplished by drilling a small diameter hole to a depth of 5 feet and injecting grout as the drill steel is removed. Pressure and grout volume pumped are measured to achieve a degree of uniform grout placement.

9.3 Piles and Piers

A deep foundation alternative would bypass the fill material altogether so that the weight of each element of the SPPTS is borne by the bedrock below the fill at a depth of approximately 30 feet. Conventional concrete piers and micropiles would accomplish this goal; however, the variable nature of the fill and the intermittently encountered sand/gravel layer would complicate pier installation. Any foundation system for this site must consider the effects of possible settlement due to the variable, man-placed fill. It must also consider the potential effects of swelling soils and bedrock that exist at the site. Of the alternatives considered, helical piers (a.k.a. helical piles) are the preferred alternative for this site and this application. Design recommendations for helical piers are presented in the following section of this report.

10.0 FOUNDATION RECOMMENDATIONS

After consideration of several alternatives, helical piers appear to be the best and most cost-effective foundation type to stabilize the components of the treatment cells. Advantages of helical piers include the following:

- Helical piers can be installed without concern for groundwater conditions, unlike a spread footing or concrete pier, both of which require dewatering for placement and would take time to cure.
- The equipment used to install helical piers is typically smaller and more maneuverable than that used in the installation of other foundations. This is also an advantage when installing the piers close to existing structures.
- Helical piers installed in the claystone bedrock underlying the fill have a lower risk of movement due to the expansive nature of the site soils than a shallow foundation.
- Helical piers can be installed in a phased approach to coincide with phased construction of future SPPTS structures. In many cases, helical piers can be removed and reused if desired.

The helical piers recommended for this project are Magnum Helix Foundation piers, Magnum Piering, Inc. To size the helical pier, the weight of the water storage sump (or other component of interest) and the types of soil (both the soil that will support the helix at the base of the pier and the soil that will be penetrated during drilling) must be considered. The foundation pressure due to the storage sump is approximately 700 psf, based on its weight and size. The pier must penetrate the clay fill and claystone, and must resist potential uplift forces due to heave. Magnum Piering, Inc. has sizing recommendations for their piers in their technical reference manual based on Standard Penetration Resistance or blow count (N). Appendix C includes manufacturer's descriptions of their product and sizing recommendations for Magnum Helical piers based on site soil conditions. For this application, the sizing of the pier will be governed by the pier's capacity to penetrate the bedrock because the blow counts for the clay fill are so low.

In order to determine the minimum allowable blade area to resist uplift, the Magnum Piering, Inc. Technical Reference Manual presents a paper entitled, "Summary of Earth Retaining Methods Utilizing Helical Anchors" by Howard A. Perko, March 4, 1999. The paper states that the pull out or uplift capacity is a combination of shear along the cylinder of soil between the blades and bearing capacity of the blade. The following equation is from the paper and was modified from Mitsch and Clemence (1985) and Clemence (1985).

$$(1) \qquad Q_u = 2\pi r L(c + \sigma_v \tan\phi) + A(1.3cN_c + \sigma_v N_q)$$

where Q_u is the pull out capacity, r is the radius of the blade on the helical pier, L is the length of soils that is mobilized between the blades, A is the area of the blade, c is the cohesion, σ_v is the vertical soil stress, and N_c and N_q are bearing capacity factors.

The results of the direct shear test performed on a sample taken from Tt-2 at a depth of 15 feet was used to determine the bearing capacity factors, N_c and N_q. The sample of clay fill from 15 feet below ground surface had a cohesion (c) of 411 psf and an angle of internal friction (φ) of 29°. Using φ = 29° the bearing capacity factors N_c and N_q were 32.5 and 20, respectively (Figure 14.13, Lambe and Whitman, 1969, p. 206). If the helical piers are advanced to a depth of 35 feet, the vertical stress (σ_v) is approximately 4,460.5 psf, assuming 20 feet of clay fill with an average total unit weight of 126.8 pcf over 15 feet of claystone with an average total unit

weight of 128.3 pcf. For 10- and 12-inch-diameter blades the areas are 0.54 and 0.79 feet, respectively.

Given that the structures in the treatment cells are lightly loaded, either a 10- or 12-inch-diameter Magnum helical pier can be used. Both the 10- and 12-inch-diameter piers are adequate to resist the uplift force from potentially swelling soils. Table 4 shows that the calculated factor of safety for uplift is 1.3 for the 10-inch-diameter pier and 1.9 for the 12-inch-diamter pier. The 12-inch-diameter pier with the double-cutting edge will have an advantage in cutting through areas of very hard bedrock.

Table 4. Factor of Safety for Uplift

Pier Blade Diameter	Pier Blade Area	Q_U	Q_A	Uplift Force[1]	Factor of Safety
(in)	(ft)	(lbs)	(lbs)	(lbs)	
10	0.54	518,721	172,907	131,947	1.3
12	0.79	758,870	252,956	131,947	1.9

Note: 1) Calculated based on the swell pressure from sample Tt-4 at 30 feet.

Helical piers should be installed to a minimum depth of 35 feet below the ground surface, and should have a minimum penetration of at least 5 feet into the claystone bedrock. It is assumed that the helical piers would be attached to the SPPTS facilities using a prefabricated bracket fastened to the lower-most segment of each tank or structure. Helical piers can be installed individually for each structure, in a phased approach, or all structures could be underpinned at one time. Installation of the helical piers is normally accomplished using construction equipment that has hydraulic capabilities determined from the soil properties provided on the attached boring logs and test results presented on Table 1.

11.0 LIMITATIONS

This investigation was conducted to ascertain a reasonable picture of subsurface conditions. Variations in the subsoils not indicated in our borings should be considered likely. This report was prepared from data provided by others, information developed during our field exploration, laboratory testing, engineering analysis and experience with similar conditions. Our calculations and recommendations were based on assumptions of ground conditions, interpretation of geologic conditions, and uncertainties that are unavoidable in geologic and geotechnical studies.

If any of the conditions change, or if information becomes available that would alter our assumptions or our calculations, we should be contacted to review the recommendations. We should review plans and specifications during the design, and we should observe the construction to confirm soils are as we anticipated from our borings. If helical piers are constructed, the geotechnical engineer or designated representative should observe the drilling process and document the installation torque. If grouting is performed, the geotechnical engineer or designated representative should observe the grout placement and document installation pressures and grout volume pumped. If subgrade soils are removed and recompacted, the placement and compaction of fill, backfill, subgrade and other fills that will be relied on for support of structural elements should be observed and tested by a qualified geotechnical engineer or their designated representative during construction.

We believe this investigation was conducted in a manner consistent with that level of skill and care ordinarily used by members of the profession currently practicing under similar conditions in the locality of this project. No warranty, express or implied, is made. If we can be of further service in discussing the contents of this report or in the analysis planned project from the geotechnical point of view, please call.

12.0 REFERENCES

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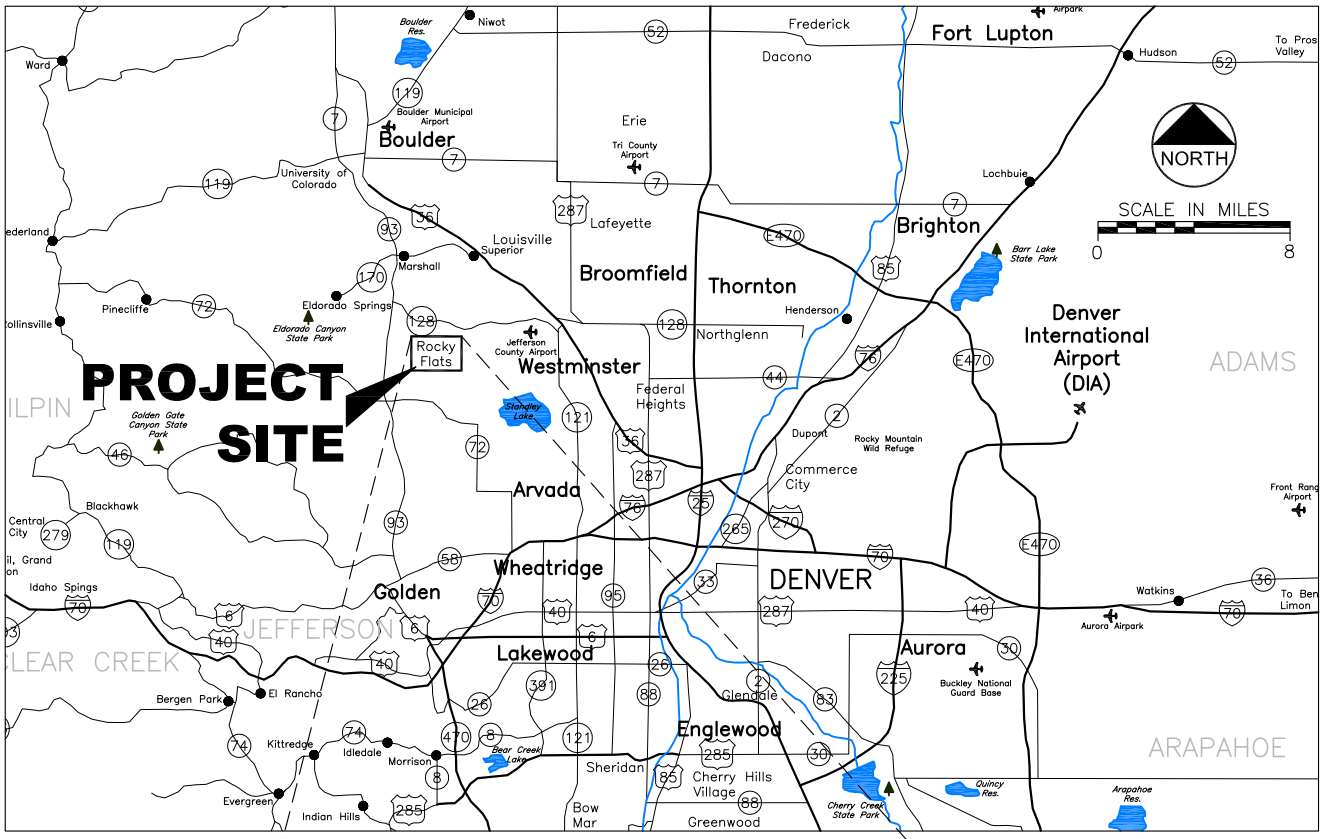
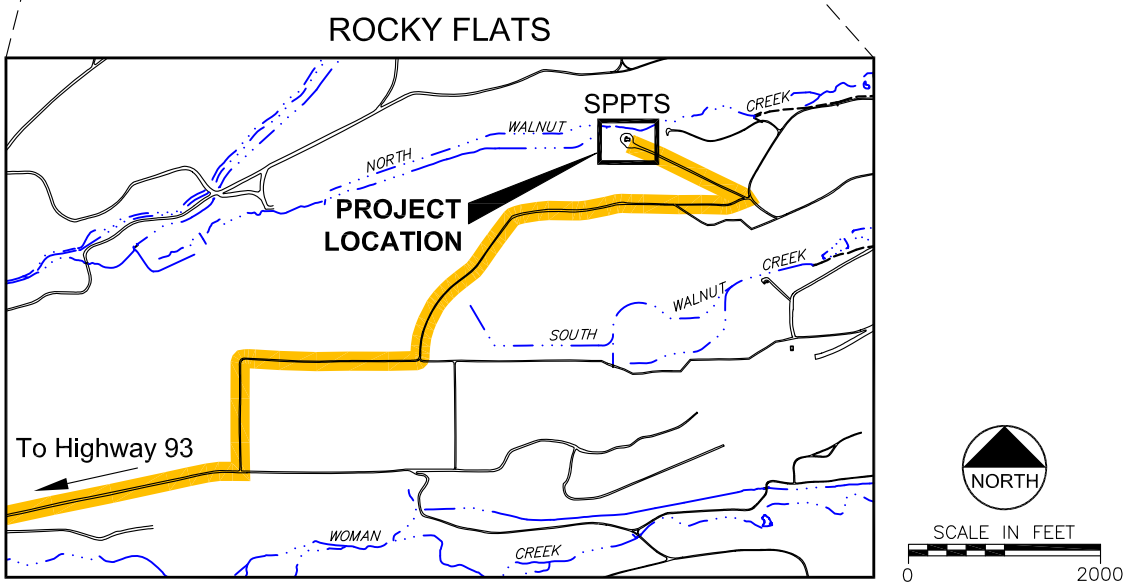
FIGURES





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Project No. 181919

October 2009

Figure 1
Rocky Flats Project Vicinity Map
SPPTS Geotechnical Investigation

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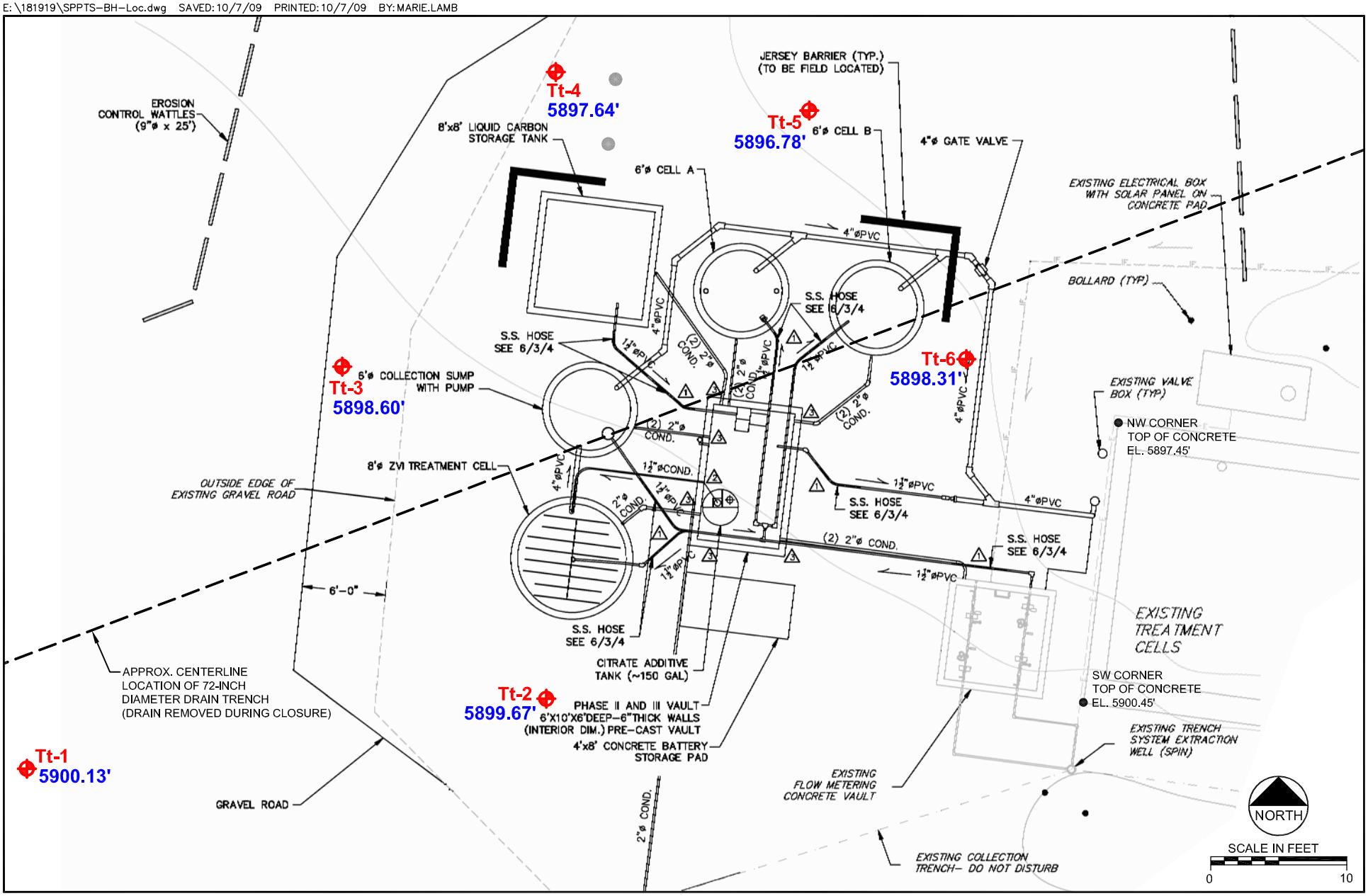

Project No. 181919

October 2009

LEGEND

BORING LOCATION WITH ELEVATION
(NO SURVEY DATA FOR Tt-3, APPROX. LOCATION AND ELEVATION)

BORING LOCATION FOR Tt-4 BEFORE HITTING REFUSAL

Figure 2
Boring Locations

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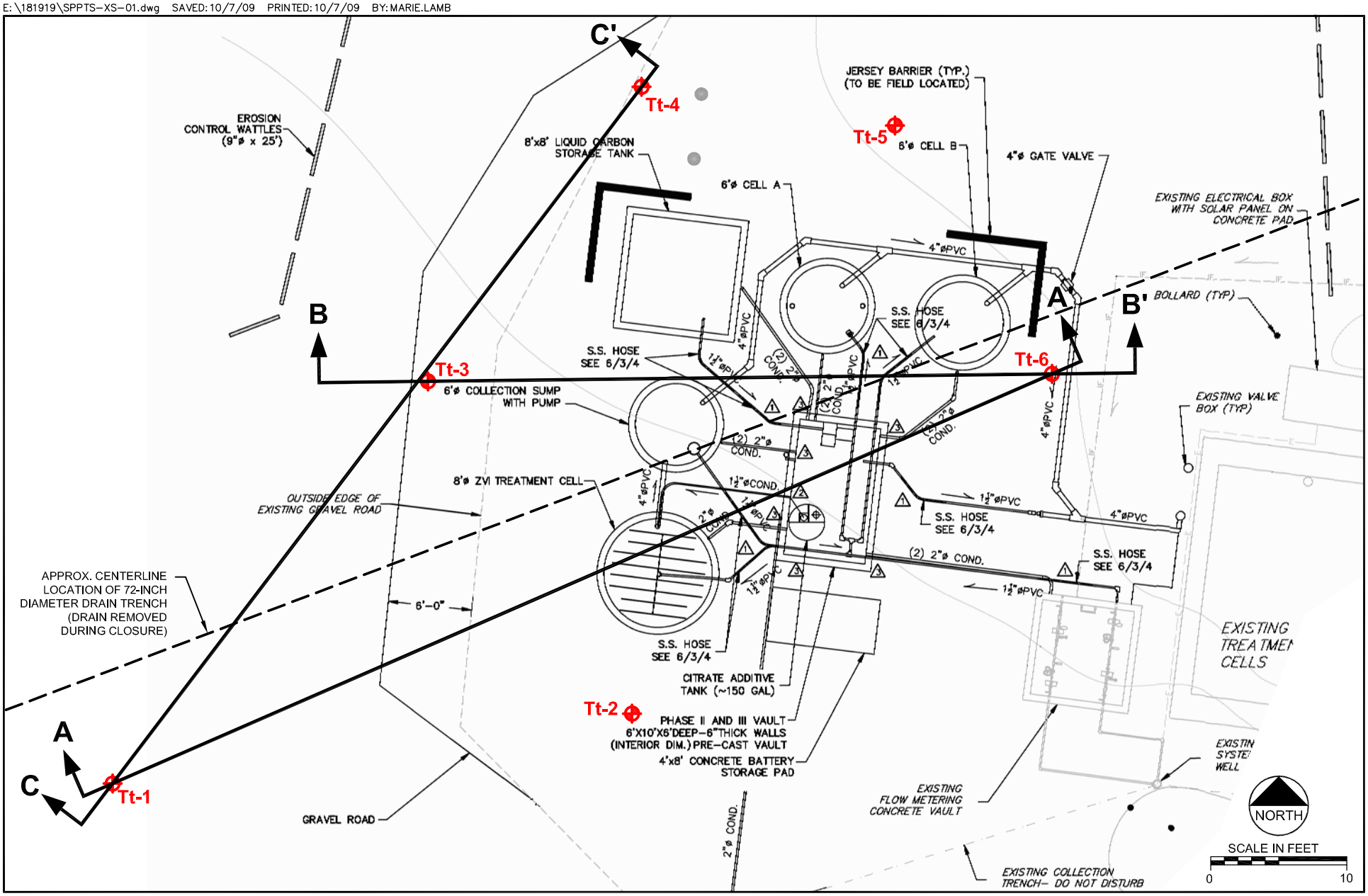

Project No. 181919

October 2009

LEGEND

- BORING LOCATION WITH ELEVATION (NO SURVEY DATA FOR Tt-3, APPROX. LOCATION)
- BORING LOCATION FOR Tt-4 BEFORE HITTING REFUSAL

Figure 3
Cross Section Locations
SPPTS Geotechnical Investigation

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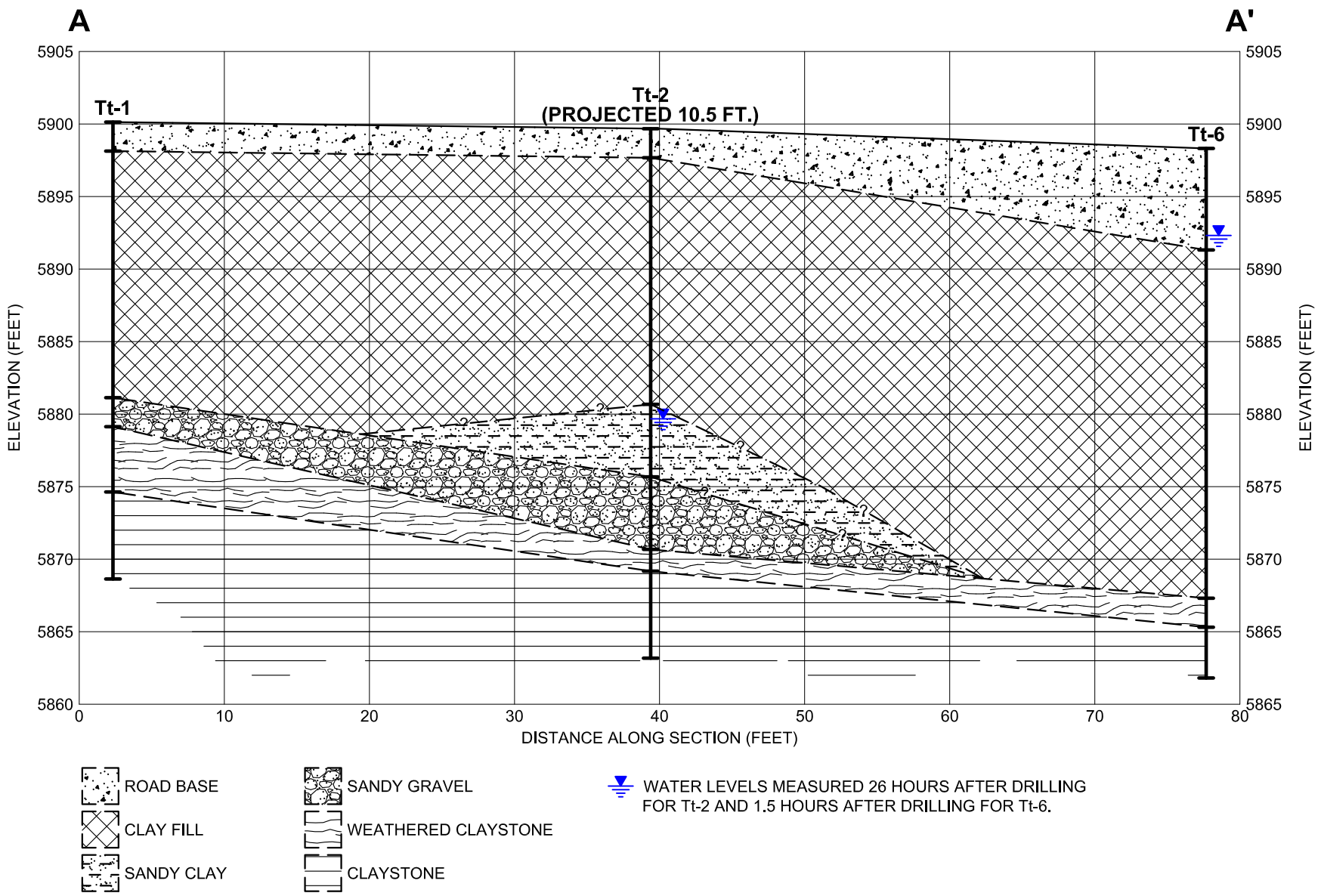

Project No. 181919

October 2009

Figure 4
Cross Section A-A'
SPPTS Geotechnical Investigation

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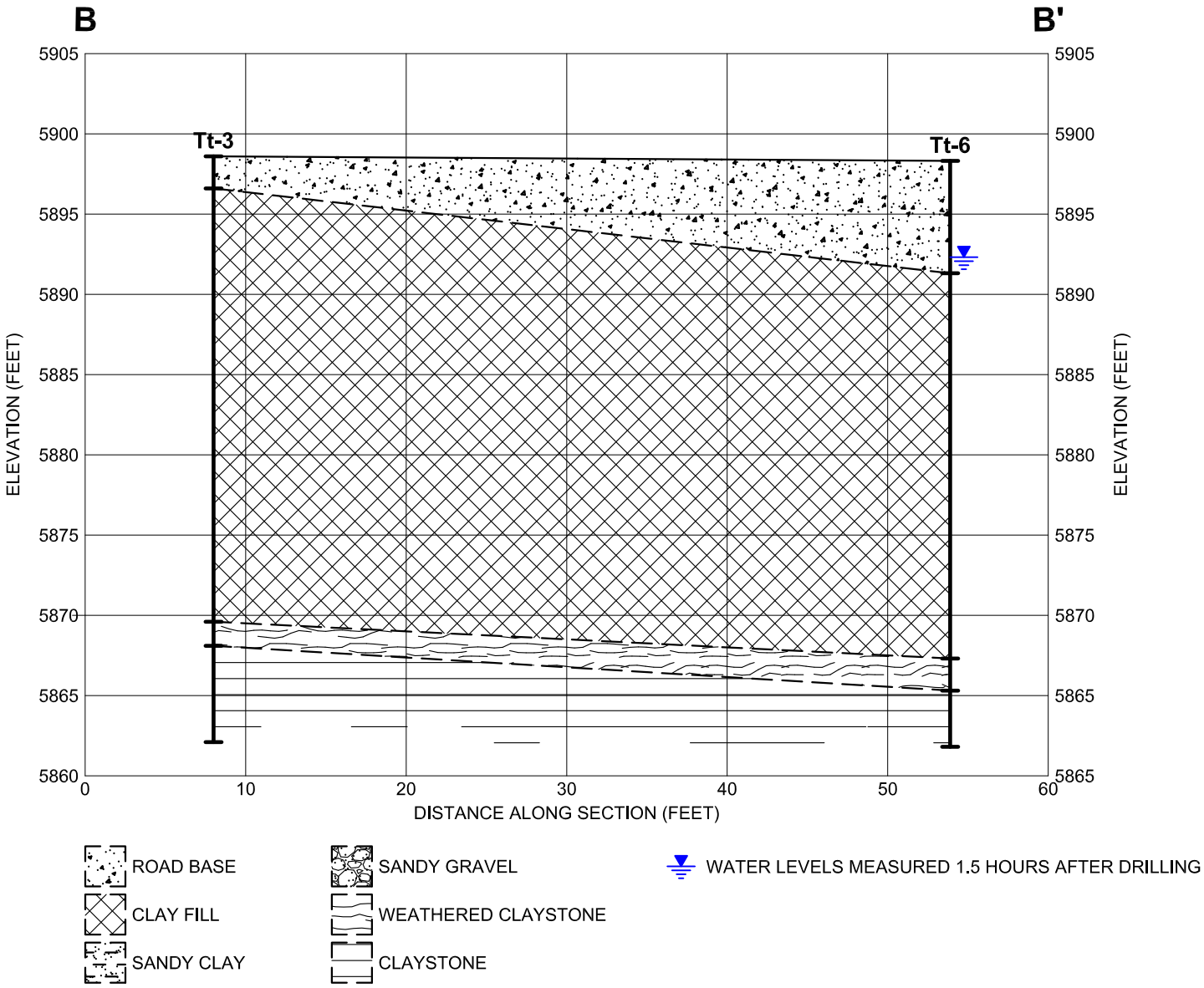

Project No. 181919

October 2009

Figure 5
Cross Section B-B'
SPPTS Geotechnical Investigation

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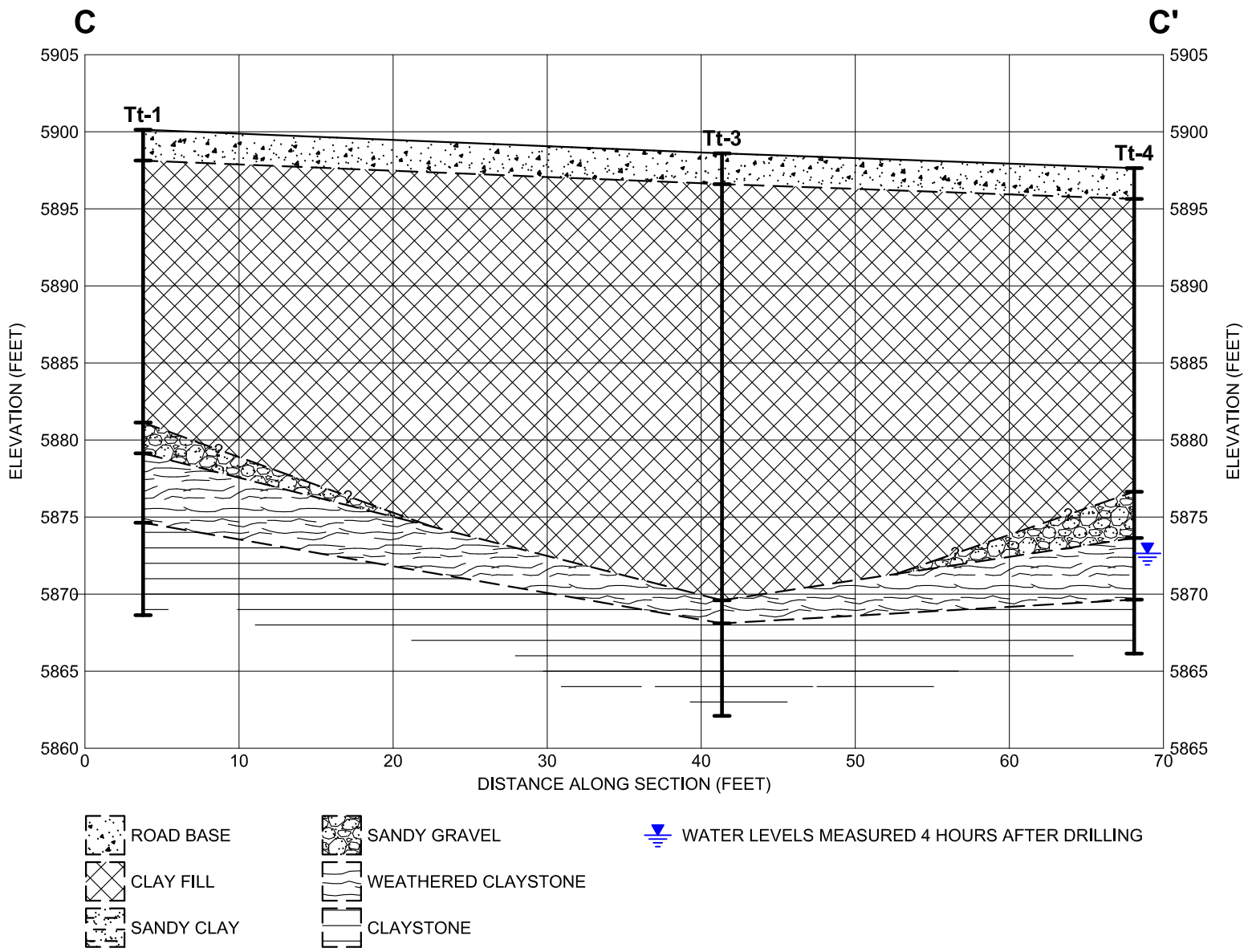

Project No. 181919

October 2009

Figure 6
Cross Section C-C'
SPPTS Geotechnical Investigation

APPENDIX A

BOREHOLE LOGS

BOREHOLE LOG

BOREHOLE NO.: **Tt-1**

PAGE: 1 OF 3

DATE: 7/28/09

PROJECT INFORMATION

PROJECT: SPPTS

PROJECT NO.: 181919

CLIENT: STOLLER

OWNER: D.O.E.

LOCATION: ROCKY FLATS

BOREHOLE LOCATION

LOCATED 17' SOUTH AND 76' WEST OF
SW CORNER OF EXISTING
TREATMENT CELL STRUCTURE
(SEE LOCATION MAP)

FIELD INFORMATION

DATE & TIME ARRIVED: 7/27/09 - 1:30PM (7/28/09 - 7:10AM)

BOREHOLE LOGGED BY: AAS

VISITORS: ---

WEATHER: SUNNY / CLOUDY, 70° F

DRILLING INFORMATION

DRILLING COMPANY: TETRA TECH, INC.

START TIME: 7/28/09 - 7:10AM

BORING DEPTH: 31.5' BORING DIA.: 4" O.D.

DRILLING METHOD: SOLID STEM AUGER WITH CME 55 TRACK RIG

SAMPLING METHOD: CA LINERS (2")

TIME DRILLING COMPLETE: 8:40AM

BOREHOLE COMPLETION / ABANDONMENT INFORMATION

START TIME: --- COMPLETE TIME: ---

INSTRUMENTATION: NONE BACKFILL: BACKFILL CUTTINGS

ELEVATION - TOP OF BORING: 5900.13' RELATIVE TO:

GROUNDWATER CONDITIONS

NO GROUNDWATER WAS ENCOUNTERED DURING DRILLING

FOLLOWING FIELD WORK

TIME OF CLEAN-UP COMPLETE: 7/29/09 - 2:00PM TIME LEFT SITE: 7/29/09 - 2:30PM

NOTES:

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 2 OF 3

PROJECT NO.: 181919 **DATE:** 7/28/09

BOREHOLE NO.: Tt-1

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
							ELEVATION = 5900.13'
0							**ROADBASE (0 TO 2')** MOIST, SILT, SAND, GRAVEL.
1							
2	CA B A	5 8	13	12"			**CLAY FILL (2' TO 19')** MOIST TO VERY MOIST, BROWN AND GRAY, SOFT TO STIFF CLAY FILL WITH SAND AND GRAVEL.
3							
4							
5	CA B A	3 5	8	10"			
6							
7							
8							
9							
10	CA B A	2 3	5	9"			
11							
12							
13							
14							
15	CA B A	3 3 4	7	6"			
16							
17							
18							
19							APPROX. 19' TO 20' - DRILLER SAID "ROCKY" .
20							**SANDY GRAVEL (19' TO 21')** MOIST TO VERY MOIST, REDDISH BROWN, ANGULAR SAND AND GRAVEL, DENSE SANDY GRAVEL WITH CLAY (POSSIBLY THE ROCKY FLATS ALLUVIUM).

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 3 OF 3

PROJECT NO.: 181919 **DATE:** 7/28/09

BOREHOLE NO.: Tt-1

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
20							**SANDY GRAVEL (19' TO 21')** SEE DESCRIPTION ON PREVIOUS PAGE.
	CA B A	4 7 11	18	12"			
21							**WEATHERED CLAYSTONE (21' TO 25.5')** MOIST TO VERY MOIST, GRAY, VERY STIFF WEATHERED CLAYSTONE WITH WHITE PRECIPITATE.
22							
23							
24							
25							
	CA B A	9 22 34	56	14"			
26							**CLAYSTONE (25.5' TO E.O.B.)** SLIGHTLY MOIST, GRAY, HARD CLAYSTONE, SOME SILT AND PLANT FOSSILS, ORANGE OXIDATION.
27							
28							APPROX. 28' - DRILLER SAYS "STIFFER DRILLING".
29							
30							
	CA B A	22 37 55	92	16"			
31							E.O.B. = 31.5'
32							
33							
34							
35							
36							
37							
38							
39							
40							

BOREHOLE LOG

BOREHOLE NO.: **Tt-2**

PAGE: 1 OF 3

DATE: 7/28/09

PROJECT INFORMATION

PROJECT: SPPTS

PROJECT NO.: 181919

CLIENT: STOLLER

OWNER: D.O.E.

LOCATION: ROCKY FLATS

BOREHOLE LOCATION

LOCATED 5.5' SOUTH OF SOUTHERN EDGE OF ZVI TANK, AT CENTER LINE (SEE LOCATION MAP)

FIELD INFORMATION

DATE & TIME ARRIVED: 7/28/09 - 7:00AM

BOREHOLE LOGGED BY: AAS

VISITORS: ---

WEATHER: CLOUDY, 70° F

DRILLING INFORMATION

DRILLING COMPANY: TETRA TECH, INC.

START TIME: 8:55AM

BORING DEPTH: 36.0' BORING DIA.: 8.25" O.D.

DRILLING METHOD: CME 55 TRACK RIG, SOLID STEM AUGER AND HOLLOW STEM AUGER (SEE NOTES BELOW)

SAMPLING METHOD: CA 2" LINERS AND BULK (BUCKET) SAMPLE

TIME DRILLING COMPLETE: 12:00PM

BOREHOLE COMPLETION / ABANDONMENT INFORMATION

START TIME: --- COMPLETE TIME: ---

INSTRUMENTATION: NONE BACKFILL: CUTTINGS ON 7/29/09

ELEVATION - TOP OF BORING: 5899.67' RELATIVE TO:

GROUNDWATER CONDITIONS

GROUNDWATER WAS ENCOUNTERED AT 22' B.G.S. DURING DRILLING (MEASURED AT 20' AT 1:00PM, 7/29/09, ELAPSED TIME 26 HRS.)

FOLLOWING FIELD WORK

TIME OF CLEAN-UP COMPLETE: 7/29/09 - 2:00PM TIME LEFT SITE: 7/29/09 - 2:30PM

NOTES: 10:30 TO 11:00 - SOLID STEM 4" O.D. AUGER REPLACED WITH HOLLOW STEM 8.25" O.D. AUGER SINCE HOLE WAS CAVING.

11:15AM - DRILLING AGAIN (AT 30').

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 2 OF 3

PROJECT NO.: 181919 **DATE:** 7/28/09

BOREHOLE NO.: Tt-2

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
							ELEVATION = 5899.67'
0							**ROADBASE (0 TO 2')** MOIST AT SURFACE.
1							
2							**CLAY FILL (2' TO 19')** MOIST TO VERY MOIST, BROWN AND GRAY, STIFF TO VERY STIFF CLAY FILL WITH ANGULAR SAND, GRAVEL.
3	CA B A	4 8 10	18	10"			
4							
5							
6	CA B A	7 8 10	18	10"			APPROX. 6' - DRILLER SAYS LIGHTER COLOR OF GRAY.
7							
8							
9							
10							
11	CA B A	4 9 9	18	12"			
12							
13							
14							
15							
16	CA B A	5 8 9	17	12"			
17							
18							
19					BKT 19-21'		**SANDY CLAY (19' TO 24')** VERY MOIST, DARK BROWN, STIFF SANDY CLAY WITH ORGANICS AND A SLIGHT ODOR (POSSIBLE OLD TOPSOIL).
20							

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 3 OF 3

PROJECT NO.: 181919 **DATE:** 7/28/09

BOREHOLE NO.: Tt-2

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
20					BKT 19-21'		**SANDY CLAY (19' TO 24')** SEE DESCRIPTION ON PREVIOUS PAGE.
21	CA B A	4 7 11	18	12"			
22							APPROX. 22' - GROUNDWATER ENCOUNTERED DURING DRILLING AT APPROX. 11:00AM. WATER LEVEL MEASUREMENT TAKEN APPROX. 26 HOURS LATER TO BE 20' BELOW GROUND SURFACE).
23							
24							**SANDY GRAVEL (24' TO 29')** WET, BROWN, ANGULAR SAND AND GRAVEL, DENSE SANDY GRAVEL WITH CLAY LENSES (POSSIBLY THE ROCKY FLATS ALLUVIUM).
25	CA B A	16 21 25	46	12"			
26							
27							
28							APPROX. 28' - SWITCHED TO HOLLOW STEM AUGER
29							**WEATHERED CLAYSTONE (29' TO 30.5')** MOIST, GRAY, VERY STIFF WEATHERED CLAYSTONE WITH OXIDATION.
30	CA B A	14 20 31	51	12"			**CLAYSTONE (30.5' TO E.O.B.)** SLIGHTLY MOIST, GRAY, HARD CLAYSTONE.
31							
32							
33							
34							
35	CA B A	24 50/5"	74/11"	10"			
36							E.O.B. = 36.0'
37							
38							
39							
40							

BOREHOLE LOG

BOREHOLE NO.: **Tt-3**

PAGE: 1 OF 3

DATE: 7/28/09

PROJECT INFORMATION

PROJECT: SPPTS

PROJECT NO.: 181919

CLIENT: STOLLER

OWNER: D.O.E.

LOCATION: ROCKY FLATS

BOREHOLE LOCATION

SEE LOCATION MAP

FIELD INFORMATION

DATE & TIME ARRIVED: 7/28/09 - 7:00AM

BOREHOLE LOGGED BY: AAS

VISITORS: ---

WEATHER: CLOUDY, 70° F

DRILLING INFORMATION

DRILLING COMPANY: TETRA TECH, INC.

START TIME: 12:35PM

BORING DEPTH: 36.0' BORING DIA.: 8.25" O.D.

DRILLING METHOD: CME 55 TRACK RIG, HSA

SAMPLING METHOD: CA 2" LINERS AND BULK (BAG) SAMPLE

TIME DRILLING COMPLETE: 3:00PM

BOREHOLE COMPLETION / ABANDONMENT INFORMATION

START TIME: --- COMPLETE TIME: ---

INSTRUMENTATION: NONE BACKFILL: CUTTINGS

ELEVATION - TOP OF BORING: 5898.60' RELATIVE TO:

GROUNDWATER CONDITIONS

NO GROUNDWATER WAS ENCOUNTERED DURING DRILLING

FOLLOWING FIELD WORK

TIME OF CLEAN-UP COMPLETE: 7/29/09 - 2:00PM TIME LEFT SITE: 7/29/09 - 2:30PM

NOTES:

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 2 OF 3

PROJECT NO.: 181919 **DATE:** 7/28/09

BOREHOLE NO.: Tt-3

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
							ELEVATION = 5898.60'
0							**ROADBASE (0 TO 2')** MOIST AT SURFACE.
1							
2							**CLAY FILL (2' TO 29')** SLIGHTLY MOIST TO MOIST, BROWN AND GRAY, STIFF TO VERY STIFF CLAY FILL WITH SAND AND GRAVEL.
3	CA B A	4 6 7	13	12"			
4							
5							APPROX. 5' TO 15' - CONTAINS MOSTLY CLAYSTONE AND SLIGHTLY MOIST.
6	CA B A	8 11 13	24	12"			
7							
8							
9							
10							
11	CA B A	8 14 19	33	14"			
12							
13							
14							
15							
16	CA B A	7 11 13	24	14"			
17							
18							
19							
20							

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 3 OF 3

PROJECT NO.: 181919 **DATE:** 7/28/09

BOREHOLE NO.: Tt-3

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
20							**CLAY FILL (2' TO 29')** SLIGHTLY MOIST TO MOIST, BROWN AND GRAY, VERY STIFF CLAY FILL WITH CLAYSTONE, SAND,GRAVEL, ORANGE IRON OXIDATION.
21	CA B A	8 10 15	25	15"			
22							
23							
24							
25							FROM 25' DRIVE - NO RECOVERY, DRILLED TO 27' TO SAMPLE.
26	CA	18 15 24	39	N.R.			
27							27' - SAMPLE IS HEAVILY DISTURBED (RETAINED FOR OBSERVATION, NOT TESTING).
28	CA A	14 23 30	53	2"			
29							- ROCK AT BOTTOM OF HOLE.
30							**WEATHERED CLAYSTONE (29' TO 30.5')** MOIST, GRAYISH BROWN, VERY STIFF WEATHERED CLAYSTONE WITH IRON OXIDATION.
31	CA B A	10 20 34	54	10"			**CLAYSTONE (30.5' TO E.O.B.)** SLIGHTLY MOIST, GRAY, HARD CLAYSTONE.
32							
33					BAG 32-35'		32' TO 35' - BAG SAMPLE, 1 GAL. ZIPLOC.
34							
35	CA B A	18 50	68	8"			
36							E.O.B. = 36.0'
37							
38							
39							
40							

BOREHOLE LOG

BOREHOLE NO.: **Tt-4**

PAGE: 1 OF 3

DATE: 7/29/09

PROJECT INFORMATION

PROJECT: SPPTS

PROJECT NO.: 181919

CLIENT: STOLLER

OWNER: D.O.E.

LOCATION: ROCKY FLATS

BOREHOLE LOCATION

LOCATED 4.5' NORTH OF CENTER OF NORTH SIDE OF SQUARE-SHAPED (8'x8') LIQUID CARBON STORAGE TANK. (SEE LOCATION MAP)

FIELD INFORMATION

DATE & TIME ARRIVED: 7/29/09 - 6:45AM

BOREHOLE LOGGED BY: AAS

VISITORS: ---

WEATHER: PARTLY CLOUDY, 75° F

DRILLING INFORMATION

DRILLING COMPANY: TETRA TECH, INC.

START TIME: 7:05AM

BORING DEPTH: 31.5' BORING DIA.: 4" O.D.

DRILLING METHOD: CME 55 TRACK RIG, SOLID STEM AUGER (SSA)

SAMPLING METHOD: CA 2" LINERS

TIME DRILLING COMPLETE: 9:30AM

BOREHOLE COMPLETION / ABANDONMENT INFORMATION

START TIME: --- COMPLETE TIME: ---

INSTRUMENTATION: NONE BACKFILL: CUTTINGS

ELEVATION - TOP OF BORING: 5897.64' RELATIVE TO:

GROUNDWATER CONDITIONS

GROUNDWATER WAS ENCOUNTERED AT 24' B.G.S. DURING DRILLING (MEASURED AT 25' AT 1:00PM ON 7/29/09, ELAPSED TIME 4 HRS.)

FOLLOWING FIELD WORK

TIME OF CLEAN-UP COMPLETE: 7/29/09 - 2:00PM TIME LEFT SITE: 7/29/09 - 2:30PM

NOTES: AT APPROX. 8:00AM, MOVED BORING LOCATION APPROX. 5' NORTH OF PREVIOUS Tt-4 BORING LOCATION.

AT APPROX. 8:20AM, MOVED BORING APPROX. 5' TO THE WEST AFTER HITTING REFUSAL AT BOULDER AT APPROX. 15' B.G.S.

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 2 OF 3

PROJECT NO.: 181919 **DATE:** 7/29/09

BOREHOLE NO.: Tt-4

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
							ELEVATION = 5897.64'
0							**ROADBASE (0 TO 2')** MOIST AT SURFACE.
1							
2							**CLAY FILL (2' TO 21')** SLIGHTLY MOIST TO MOIST, BROWN, STIFF TO VERY STIFF CLAY FILL WITH ANGULAR ARKOSIC SAND, GRAVEL, AND TRACE BOULDERS.
3	CA B A	4 6 10	16	16"			
4							
5							
6	CA B A	7 8 10	18	14"			
7							
8							
9							
10							APPROX. FROM 10' TO 12' - MOSTLY SLIGHTLY MOIST, GRAY, CLAYSTONE WITH LIGNITE.
11	CA B A	7 12 17	29	14"			
12							
13							
14							
15							APPROX. 15' - QUARTZ ROCK STUCK IN SHOE OF SAMPLE BARREL.
16	CA B A	7 16 31	47	9"			
17							
18							
19							
20							APPROX. 20' - DARK BROWN ORGANIC SOIL IN THE "B" SAMPLE AT 20'.

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 3 OF 3

PROJECT NO.: 181919 **DATE:** 7/29/09

BOREHOLE NO.: Tt-4

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
20	CA B A	10 50/4"	60/10"	9"			**CLAY FILL (2' TO 21')** SEE DESCRIPTION ON PREVIOUS PAGE. HOLE MOVED 5' TO THE NORTH (GRANITE BOULDER AT 21').
21							**SANDY GRAVEL (21' TO 24')** MOIST TO WET, REDDISH BROWN, DENSE SANDY GRAVEL WITH CLAY (POSSIBLY THE ROCKY FLATS ALLUVIUM).
22							
23							APPROX. 24' - GROUNDWATER ENCOUNTERED DURING DRILLING AT APPROX. 9:00AM. WATER LEVEL MEASUREMENT TAKEN APPROX. 4 HOURS LATER TO BE 25' BELOW GROUND SURFACE).
24							**WEATHERED CLAYSTONE (24' TO 28')** MOIST, GRAY, STIFF WEATHERED CLAYSTONE.
25	CA B A	8 5 9	14	14"			
26							
27							27' - SAMPLE IS HEAVILY DISTURBED (RETAINED FOR OBSERVATION, NOT TESTING).
28							**CLAYSTONE (28' TO E.O.B.)** SLIGHTLY MOIST, GRAY, HARD CLAYSTONE WITH TRACE LIGNITE, TRACE GYPSUM CRYSTAL, OXIDATION.
29							
30	CA B A	10 21 44	65	14"			
31							E.O.B. = 31.5'
32							
33							
34							
35							
36							
37							
38							
39							
40							

BOREHOLE LOG

BOREHOLE NO.: **Tt-5**

PAGE: 1 OF 3

DATE: 7/29/09

PROJECT INFORMATION

PROJECT: SPPTS

PROJECT NO.: 181919

CLIENT: STOLLER

OWNER: D.O.E.

LOCATION: ROCKY FLATS

BOREHOLE LOCATION

10' NORTH AND 12' EAST OFF NE CORNER OF SQUARE-SHAPED (LIQUID CARBON STORAGE TANK) (SEE LOCATION MAP)

FIELD INFORMATION

DATE & TIME ARRIVED: 7/29/09 - 6:45AM

BOREHOLE LOGGED BY: AAS

VISITORS: ---

WEATHER: CLOUDY, 65° F

DRILLING INFORMATION

DRILLING COMPANY: TETRA TECH, INC.

START TIME: 9:40AM

BORING DEPTH: 31.5' BORING DIA.: 4" O.D.

DRILLING METHOD: CME 55 TRACK RIG, SOLID STEM AUGER (SSA)

SAMPLING METHOD: CA 2" LINERS, BUCKET (BULK)

TIME DRILLING COMPLETE: 11:00AM

BOREHOLE COMPLETION / ABANDONMENT INFORMATION

START TIME: --- COMPLETE TIME: ---

INSTRUMENTATION: NONE BACKFILL: CUTTINGS

ELEVATION - TOP OF BORING: 5896.78' RELATIVE TO:

GROUNDWATER CONDITIONS

NO GROUNDWATER WAS ENCOUNTERED DURING DRILLING

FOLLOWING FIELD WORK

TIME OF CLEAN-UP COMPLETE: 7/29/09 - 2:00PM TIME LEFT SITE: 7/29/09 - 2:30PM

NOTES:

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 2 OF 3

PROJECT NO.: 181919 **DATE:** 7/29/09

BOREHOLE NO.: Tt-5

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
							ELEVATION = 5896.78'
0							**ROADBASE (0 TO 2')** MOIST AT SURFACE.
1							
2							**CLAY FILL (2' TO 24')** SLIGHTLY MOIST TO MOIST, BROWN AND GRAY, STIFF TO VERY STIFF CLAY FILL WITH ANGULAR ARKOSIC SAND, GRAVEL, AND TRACE SMALL COBBLES.
3	CA B A	4 5 9	14	16"			
4							
5							APPROX. FROM 5' TO 15' - BULK (3 GAL. BUCKET) SAMPLE OF CLAY FILL.
6	CA B A	6 8 9	17	14"			
7					BKT 5'-15'		
8							
9							
10							
11	CA B A	9 13 15	28	10"			
12					BKT 5'-15'		
13							
14							
15							
16	CA B A	5 11 9	20	11"			
17							
18							
19							
20							

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 3 OF 3

PROJECT NO.: 181919 **DATE:** 7/29/09

BOREHOLE NO.: Tt-5

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
20							**CLAY FILL (2' TO 24')** SEE DESCRIPTION ON PREVIOUS PAGE.
	CA B A	17 25 16	41	15"			
21							
22							
23							
24							**WEATHERED CLAYSTONE (24' TO 27')** SLIGHTLY MOIST TO MOIST, DARK GRAY, VERY STIFF WEATHERED CLAYSTONE WITH WHITE CALCIUM CARBONATE PRECIPITATE.
25							
	CA B A	9 11 16	27	15"			
26							
27							**CLAYSTONE (27' TO E.O.B.)** SLIGHTLY MOIST, GRAY WITH YELLOWISH BROWN HARD CLAYSTONE.
28							
29							
30							
	CA B A	22 30 48	78	14"			
31							E.O.B. = 31.5'
32							
33							
34							
35							
36							
37							
38							
39							
40							

BOREHOLE LOG

BOREHOLE NO.: **Tt-6**

PAGE: 1 OF 3

DATE: 7/29/09

PROJECT INFORMATION

PROJECT: SPPTS

PROJECT NO.: 181919

CLIENT: STOLLER

OWNER: D.O.E.

LOCATION: ROCKY FLATS

BOREHOLE LOCATION

SEE LOCATION MAP

FIELD INFORMATION

DATE & TIME ARRIVED: 7/29/09 - 6:45AM

BOREHOLE LOGGED BY: AAS

VISITORS: ---

WEATHER: CLOUDY, 70° F

DRILLING INFORMATION

DRILLING COMPANY: TETRA TECH, INC.

START TIME: 11:30AM

BORING DEPTH: 36.25' BORING DIA.: 4" O.D.

DRILLING METHOD: CME 55 TRACK RIG, SOLID STEM AUGER (SSA)

SAMPLING METHOD: CA 2" LINERS, BULK (BAG) SAMPLE

TIME DRILLING COMPLETE: 1:10PM

BOREHOLE COMPLETION / ABANDONMENT INFORMATION

START TIME: --- COMPLETE TIME: ---

INSTRUMENTATION: NONE BACKFILL: CUTTINGS

ELEVATION - TOP OF BORING: 5898.31' RELATIVE TO:

GROUNDWATER CONDITIONS

GROUNDWATER WAS ENCOUNTERED AT 7' B.G.S. DURING DRILLING (MEASURED AT 6' AT 1:30PM ON 7/29/09, ELAPSED TIME 1.5 HRS)

FOLLOWING FIELD WORK

TIME OF CLEAN-UP COMPLETE: 7/29/09 - 2:00PM TIME LEFT SITE: 7/29/09 - 2:30PM

NOTES:

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 2 OF 3

PROJECT NO.: 181919 **DATE:** 7/29/09

BOREHOLE NO.: Tt-6

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
							ELEVATION = 5898.31'
0							**ROADBASE (0 TO 7')** SLIGHTLY MOIST TO WET, REDDISH BROWN, MEDIUM DENSE SAND AND GRAVEL.
1							
2							APPROX. 2' TO 5' - BAG SAMPLE (1 GAL. ZIPLOC).
3	CA B A	10 11 13	24	14"	BAG 2'-5'		
4							
5							
6	CA B A	9 5 6	11	12"			APPROX. 7' - GROUNDWATER ENCOUNTERED DURING DRILLING AT APPROX. 12:00PM. WATER LEVEL MEASUREMENT TAKEN APPROX. 1.5 HOURS LATER TO BE 6' BELOW GROUND SURFACE).
7							**CLAY FILL (7' TO 31')** VERY MOIST TO WET, BROWN AND GRAY, MEDIUM STIFF TO VERY STIFF CLAY FILL WITH CLAYSTONE FRAGMENTS, SAND, GRAVEL (ANGULAR), AND TRACE COBBLES.
8							
9							
10							APPROX. FROM 5' TO 15' - BULK (3 GAL. BUCKET) SAMPLE OF CLAY FILL.
11	CA A	3 4 4	8	6"			
12							
13							
14							
15							
16	CA B A	4 4 5	9	6"			
17							
18							
19							
20							

BOREHOLE LOG

PROJECT: RF.SPPTS **PAGE:** 3 OF 3

PROJECT NO.: 181919 **DATE:** 7/29/09

BOREHOLE NO.: Tt-6

DEPTH (FT)	DRIVE SAMPLES: SAMPLE TYPE	BLOWS (PER 6")	SPT (N) BL/12"	RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
20							**CLAY FILL (7' TO 31')** SEE DESCRIPTION ON PREVIOUS PAGE.
21	CA A	5 6 9	15	6"			APPROX. 20' - LESS SAND AND GRAVEL IN THE 20' DRIVE SAMPLE (MOSTLY CLAY).
22							
23							
24							APPROX. 24' TO 31' - INCREASE IN SAND AND GRAVEL FROM 24' TO 31'.
25	CA B A	22 18 25	43	15"			APPROX. 25' - IN THE CA SAMPLE OF THE 25' DRIVE, MOIST TO VERY MOIST, BROWN CLAY FILL, CONTAINS ANGULAR QUARTZ SAND, ROUNDED GRAVEL, AND IRON OXIDATION.
26							
27							
28							
29							
30	CA A	11 15 23	38	2"			APPROX. 30' - POOR SAMPLE (POSSIBLE LARGE GRAVEL OR COBBLE IN THE HOLE.
31							**WEATHERED CLAYSTONE (31' TO 33')** MOIST, GRAYISH BROWN, HARD WEATHERED CLAYSTONE WITH TRACE LIGNITE.
32							
33							**CLAYSTONE (33' TO E.O.B.)** SLIGHTLY MOIST, GRAY, HARD CLAYSTONE.
34							
35	CA B A	18 40 50/3"	90/9"	8"			
36							E.O.B. = 36.25'
37							
38							
39							
40							

APPENDIX B
LABORATORY RESULTS

In-Place Density and Moisture Content Test Results

In-Place Density and Moisture Content Test Form

Tetra Tech, Inc. (970) 223.9600

Project Information

Project Name	Rocky Flats-SPPTS
Project Number	181919A
Date	7/31/2009
Remarks	
Remarks	
Remarks	
Tested By	CK

Assumed Gs= 2.70

Laboratory Testing Determinations

Sample ID	Tt-1	Tt-1	Tt-1	Tt-1			
Sample Location	2'A	5'A	15'A	20'A			
Remarks	**Fill**	**Fill**	**Fill**				
Soil Description	Sandy Claystone, Clay lenses, tr. Gravel, Brown Grey	Clay, w/Gravel & Sand, olive	Sandy Clay, Claystone frag., tr. Gravel, Sandy lenses, Olive Grey	Silty Sandy Clay, tr. Gravel, CaCo3, Olive Rust			
Mass of soil + cylinder (g)	147.65	487.82	400.12	436.75			
Mass of cylinder (g)	0	106.89	109.52	119.61			
Drying Pan ID	10.00	kd8	6.00	12.00			
Mass of Drying Pan (g)	15.96	15.75	15.70	15.63			
Mass of Wet Soil + Pan (g)	165.70	320.40	304.05	395.90			
Mass of Dry Soil + Pan (g)	144.95	263.85	253.28	325.18			
Average Samp. Diam. (in)	1.930	1.930	1.937	1.927			
Average Samp. Height (in)	1.450	4.000	2.957	3.313			
Volume of cyl. (in^3)	4.24	11.70	8.71	9.66	0.00	0.00	0.00

Calculated Results

Moist Density (lb/ft^3)	**132.6**	**124.0**	**127.0**	**125.0**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Dry Density (lb/ft^3)	**114.2**	**101.0**	**104.7**	**101.8**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Moisture Content	**0.161**	**0.228**	**0.214**	**0.228**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Moisture Content (%)	**16.1**	**22.8**	**21.4**	**22.8**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Saturation (%)	**91%**	**92%**	**95%**	**94%**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

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In-Place Density and Moisture Content Test Form

Tetra Tech, Inc. (970) 223.9600

Project Information

Project Name	Rocky Flats-SPPTS
Project Number	181919A
Date	7/31/2009
Remarks	
Remarks	
Remarks	
Tested By	CK

Assumed Gs= 2.70

Laboratory Testing Determinations

Sample ID	Tt-2	Tt-2	Tt-2	Tt-2	Tt-2		
Sample Location	5'A	15'A	20'A	25'A	35'A		
Remarks	**Fill**	**Fill**					
Soil Description	Sandy Clay, w/Gravel, Claystone frag., Olive	Silty Clay, Claystone Frag., tr. Gravel, Olive	Silty Clay, w/ Gravel, tr. Sand, Organic odor, Dk. Brown black	Clayey, Gravelly Sand, Brown	Silty Claystone, Olive, Grey		
Mass of soil + cylinder (g)	292.88	131.55	516.45	560.63	533.17		
Mass of cylinder (g)	119.64	0.00	109.80	120.07	107.65		
Drying Pan ID	3	9	8	111	108		
Mass of Drying Pan (g)	15.68	15.68	13.35	235.86	232.46		
Mass of Wet Soil + Pan (g)	379.83	146.96	200.44	480.12	475.58		
Mass of Dry Soil + Pan (g)	331.30	122.36	175.62	466.81	444.75		
Average Samp. Diam. (in)	1.919	1.935	1.925	1.950	1.936		
Average Samp. Height (in)	1.858	1.462	4.000	4.000	4.000		
Volume of cyl. (in^3)	5.37	4.30	11.64	11.95	11.77	0.00	0.00

Calculated Results

Moist Density (lb/ft^3)	**122.8**	**116.6**	**133.1**	**140.5**	**137.7**	**#DIV/0!**	**#DIV/0!**
Dry Density (lb/ft^3)	**106.4**	**94.7**	**115.4**	**132.8**	**120.2**	**#DIV/0!**	**#DIV/0!**
Moisture Content	**0.154**	**0.231**	**0.153**	**0.058**	**0.145**	**#DIV/0!**	**#DIV/0!**
Moisture Content (%)	**15.4**	**23.1**	**15.3**	**5.8**	**14.5**	**#DIV/0!**	**#DIV/0!**
Saturation (%)	**71%**	**80%**	**90%**	**58%**	**98%**	**#DIV/0!**	**#DIV/0!**

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In-Place Density and Moisture Content Test Form

Tetra Tech, Inc. (970) 223.9600

Project Information

Project Name	Rocky Flats-SPPTS
Project Number	181919A
Date	7/31/2009
Remarks	
Remarks	
Remarks	
Tested By	CK

Assumed Gs= 2.70

Laboratory Testing Determinations

Sample ID	Tt-3	Tt-3					
Sample Location	2'A	10'A					
Remarks	**Fill**	**Fill**					
Soil Description	Sandy Clay, Claystone Frag., Olive	Clay, tr. Sand, Olive Grey					
Mass of soil + cylinder (g)	507.26	518.77					
Mass of cylinder (g)	109.36	119.21					
Drying Pan ID	dc17	110					
Mass of Drying Pan (g)	13.31	233.72					
Mass of Wet Soil + Pan (g)	410.91	465.58					
Mass of Dry Soil + Pan (g)	349.58	429.36					
Average Samp. Diam. (in)	1.939	1.929					
Average Samp. Height (in)	4.000	4.000					
Volume of cyl. (in^3)	11.81	11.69	0.00	0.00	0.00	0.00	0.00

Calculated Results

Moist Density (lb/ft^3)	**128.3**	**130.2**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Dry Density (lb/ft^3)	**108.5**	**109.9**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Moisture Content	**0.182**	**0.185**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Moisture Content (%)	**18.2**	**18.5**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Saturation (%)	**89%**	**94%**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

In-Place Density and Moisture Content Test Form

Tetra Tech, Inc. (970) 223.9600

Project Information

Project Name	Rocky Flats-SPPTS
Project Number	181919A
Date	7/31/2009
Remarks	
Remarks	
Remarks	
Tested By	CK

Assumed Gs= 2.70

Laboratory Testing Determinations

Sample ID	Tt-4	Tt-4	Tt-4				
Sample Location	2'A	10'A	30'A				
Remarks	**Fill**	**Fill**					
Soil Description	Silty Clay, Claystone Frag., Sandy Clay lenses, tr. Gravel, Olive	Silty Clay, Claystone Frag., Lignite Frag. Grey	Claystone, Gypsum Crystals, Lignite Frag., Grey Brown				
Mass of soil + cylinder (g)	521.47	445.27	518.48				
Mass of cylinder (g)	109.41	119.20	119.94				
Drying Pan ID	4	109	dc14				
Mass of Drying Pan (g)	15.73	240.08	13.43				
Mass of Wet Soil + Pan (g)	214.86	428.51	327.54				
Mass of Dry Soil + Pan (g)	190.56	397.82	275.13				
Average Samp. Diam. (in)	1.951	1.925	1.923				
Average Samp. Height (in)	4.000	3.385	4.000				
Volume of cyl. (in^3)	11.96	9.85	11.62	0.00	0.00	0.00	0.00

Calculated Results

Moist Density (lb/ft^3)	**131.3**	**126.1**	**130.7**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Dry Density (lb/ft^3)	**115.3**	**105.6**	**108.9**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Moisture Content	**0.139**	**0.195**	**0.200**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Moisture Content (%)	**13.9**	**19.5**	**20.0**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Saturation (%)	**81%**	**88%**	**99%**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

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In-Place Density and Moisture Content Test Form

Tetra Tech, Inc. (970) 223.9600

Project Information

Project Name	Rocky Flats-SPPTS
Project Number	181919A
Date	7/31/2009
Remarks	
Remarks	
Remarks	
Tested By	CK

Assumed Gs= 2.70

Laboratory Testing Determinations

Sample ID	Tt-5	Tt-5					
Sample Location	10'A	25'B					
Remarks	**Fill**						
Soil Description	Silty Clay, Claystone Frag., Olive	Weathered Claystone, CaCo3, Olive					
Mass of soil + cylinder (g)	480.37	468.50					
Mass of cylinder (g)	104.72	115.66					
Drying Pan ID	kd30	dc23					
Mass of Drying Pan (g)	15.87	13.30					
Mass of Wet Soil + Pan (g)	389.32	165.24					
Mass of Dry Soil + Pan (g)	323.95	137.94					
Average Samp. Diam. (in)	1.937	1.924					
Average Samp. Height (in)	4.000	3.626					
Volume of cyl. (in^3)	11.79	10.54	0.00	0.00	0.00	0.00	0.00

Calculated Results

Moist Density (lb/ft^3)	**121.4**	**127.5**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Dry Density (lb/ft^3)	**100.2**	**104.6**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Moisture Content	**0.212**	**0.219**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Moisture Content (%)	**21.2**	**21.9**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Saturation (%)	**84%**	**97%**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

In-Place Density and Moisture Content Test Form

Tetra Tech, Inc. (970) 223.9600

Project Information

Project Name	Rocky Flats-SPPTS
Project Number	181919A
Date	7/31/2009
Remarks	
Remarks	
Remarks	
Tested By	CK

Assumed Gs= 2.70

Laboratory Testing Determinations

Sample ID	Tt-6	Tt-6	Tt-6	Tt-6	Tt-6	Tt-6	Tt-6
Sample Location	5'A	10'A	35'A				
Remarks	**Fill**						
Soil Description	Clayey, Gravelly Sand, Brown	Silty Clay, Gypsum Crystals, Olive	Silty Claystone, Olive				
Mass of soil + cylinder (g)	473.64	451.74	531.66				
Mass of cylinder (g)	104.47	120.13	117.53				
Drying Pan ID	dc11	xz	kd29				
Mass of Drying Pan (g)	13.56	13.46	15.93				
Mass of Wet Soil + Pan (g)	346.04	283.50	428.94				
Mass of Dry Soil + Pan (g)	319.34	231.44	375.76				
Average Samp. Diam. (in)	1.935	1.925	1.943				
Average Samp. Height (in)	3.618	3.394	4.000				
Volume of cyl. (in^3)	10.64	9.88	11.86	0.00	0.00	0.00	0.00

Calculated Results

Moist Density (lb/ft^3)	**132.2**	**127.9**	**133.0**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Dry Density (lb/ft^3)	**121.6**	**103.2**	**115.9**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Moisture Content	**0.087**	**0.239**	**0.148**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Moisture Content (%)	**8.7**	**23.9**	**14.8**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Saturation (%)	**61%**	**102%**	**88%**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

Munsell Color Classification

Munsell Color Classification

Tt-1 @2'A	Grayish Brown, (2.5Y/5/2)
Tt-1 @ 5'A	Olive Brown, (2.5Y/4/4)
Tt-1 @ 10'A	Dark Grayish Brown, (2.5Y/4/2)
Tt-1 @ 15'A	Light Gray,(5Y/7/2)
Tt-1 @ 20'A	Light Olive Brown, (2.5Y/5/4)
Tt-2 @ 5'A	Olive Brown, (2.5Y/4/3)
Tt-2 @ 15'A	Light Olive Brown, (2.5Y/5/3)
Tt-2 @ 19-21'	Very Dark Gray, (10YR/3/1)
Tt-2 @ 20'A	Very Dark Grayish Brown, (10YR/3/2)
Tt-2 @ 25'A	Brown, (10YR/5/3)
Tt-2 @ 35'A	Light Olive Brown, (2.5Y/5/3)
Tt-3 @ 2'A	Olive Brown, (2.5Y/4/3)
Tt-3 @ 10'A	Light Yellowish Brown, (2.5Y/6/4)
Tt-3 @ 35'A	Dark Gray, (2.5Y/4/1)
Tt-4 @ 2'A	Grayish Brown, (2.5Y/5/2)
Tt-4 @ 5'A	Dark Gray, (2.5Y/4/1)
Tt-4 @ 10'A	Dark Gray, (2.5Y/4/1)
Tt-4 @ 20'A	Brown, (7.5YR/4/4)
Tt-4 @ 30'A	Dark Gray, (2.5Y/4/1)
Tt-5 @ 2'A	Grayish Brown, (10YR/5/2)
Tt-5 @ 5-15'	Light Olive Brown, (2.5Y/5/3)
Tt-5 @ 10'A	Grayish Brown, (2.5Y/5/2)
Tt-5 @ 25'B	Light Olive Brown, (2.5Y/5/4)
Tt-6 @ 2-5'	Brown, (7.5YR/4/3)
Tt-6 @ 5'A	Dark Yellowish Brown, (10YR/3/6)
Tt-6 @ 10'A	Olive Brown, (2.5Y/4/3)
Tt-6 @ 35'A	Dark Gray, (10YR/4/1)

Atterberg Limits Test Results

Atterberg Limits Test
ASTM D 4318

Tetra Tech, Inc. (970) 223.9600

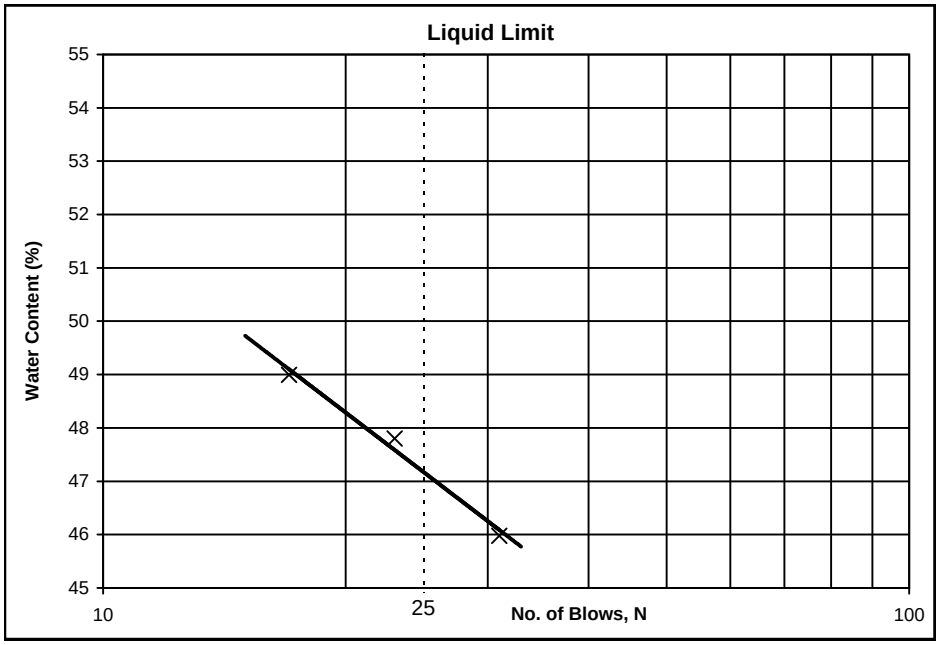
Sample Identification	Tt-2 @ 19'-21'

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	8/6/2009
Sample Type	Bulk
Soil Description	
Remarks	
Tested By	CK
Sieved on #40 (Yes or No)	Yes
Preparation (Wet or Dry)	Dry

Liquid Limit Determination

Goal for range of blows	25-35	20-30	15-25
No. of blows, N	31	23	17
Drying Can No.	b5	a2	c4
Mass of can (g)	11.08	10.99	10.92
Mass of wet soil + can (g)	29.78	30.50	28.68
Mass of dry soil + can (g)	23.89	24.19	22.84
Water content (%)	46.0	47.8	49.0



Plastic Limit Determination

Drying Can No.	a4	b8
Mass of can (g)	11.13	11.10
Mass of wet soil + can (g)	20.14	20.52
Mass of dry soil + can (g)	18.88	19.22
Water content (%)	16.3	16.0

Results		***Adj.***
Liquid Limit	47.2	47
Plastic Limit	16.1	16
Plasticity Index	31.0	31

Atterberg Limits Test
ASTM D 4318

Tetra Tech, Inc. (970) 223.9600

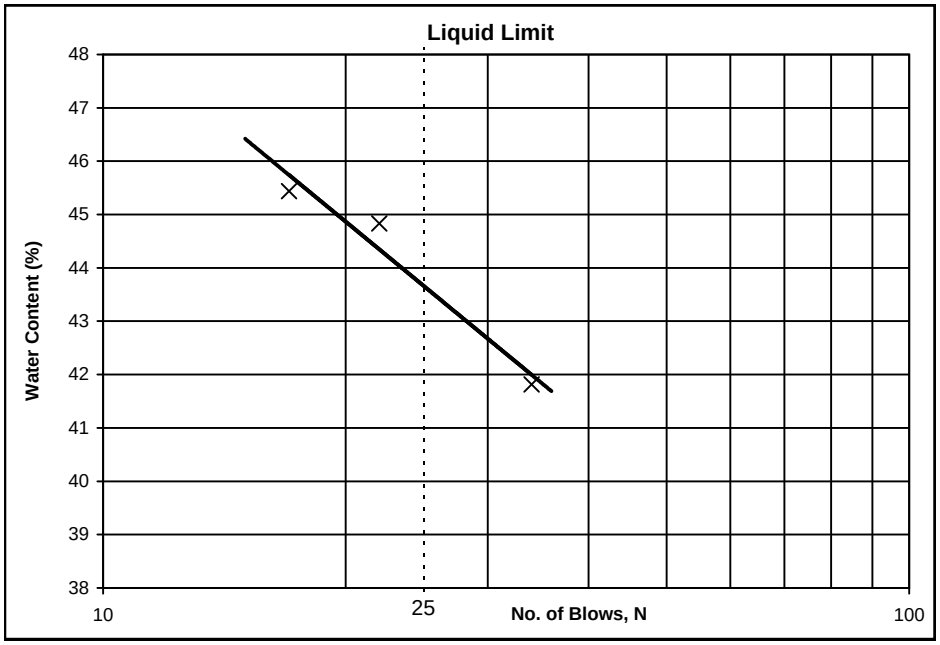
Sample Identification	Tt-2 @ 20'B

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	8/6/2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK
Sieved on #40 (Yes or No)	Yes
Preparation (Wet or Dry)	Dry

Liquid Limit Determination

Goal for range of blows	25-35	20-30	15-25
No. of blows, N	34	22	17
Drying Can No.	c11	b1	d36
Mass of can (g)	11.00	11.15	11.18
Mass of wet soil + can (g)	31.45	31.34	29.36
Mass of dry soil + can (g)	25.42	25.09	23.68
Water content (%)	41.8	44.8	45.4



Plastic Limit Determination

Drying Can No.	d35	b9
Mass of can (g)	11.12	11.11
Mass of wet soil + can (g)	19.26	18.44
Mass of dry soil + can (g)	18.23	17.51
Water content (%)	14.5	14.5

Results		***Adj.***
Liquid Limit	43.7	44
Plastic Limit	14.5	15
Plasticity Index	29.2	29

Atterberg Limits Test
ASTM D 4318

Tetra Tech, Inc. (970) 223.9600

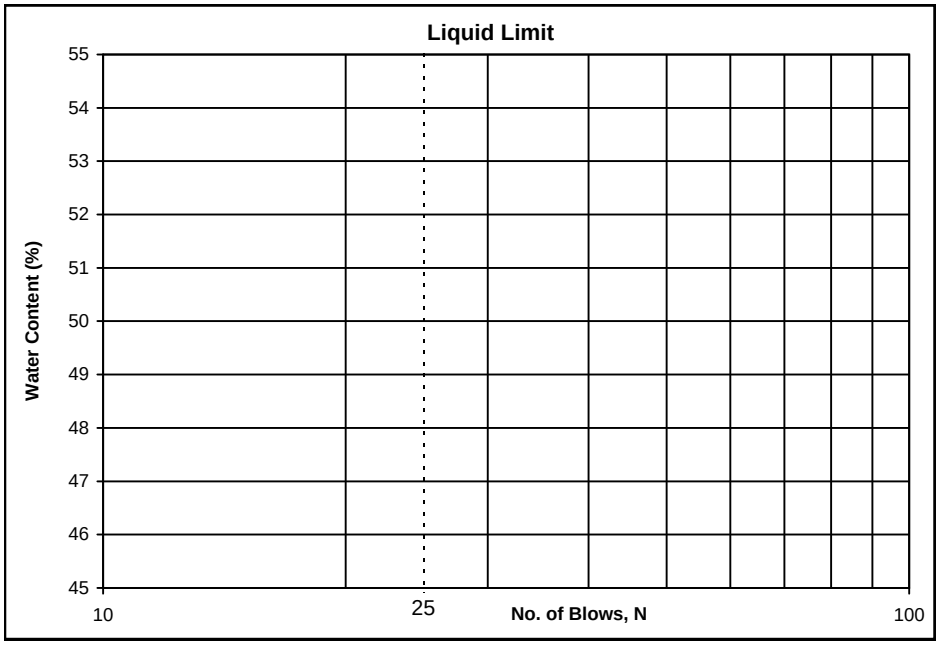
Sample Identification	Tt-2 @ 25'A

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	8/6/2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK
Sieved on #40 (Yes or No)	Yes
Preparation (Wet or Dry)	Dry

Liquid Limit Determination

Goal for range of blows	25-35	20-30	15-25
No. of blows, N			
Drying Can No.			
Mass of can (g)			
Mass of wet soil + can (g)			
Mass of dry soil + can (g)			
Water content (%)			



Plastic Limit Determination

Drying Can No.		
Mass of can (g)		
Mass of wet soil + can (g)		
Mass of dry soil + can (g)		
Water content (%)		

Results		***Adj.***
Liquid Limit		NLL
Plastic Limit		NPL
Plasticity Index		NPI

Granular, Non-plastic

Atterberg Limits Test
ASTM D 4318

Tetra Tech, Inc. (970) 223.9600

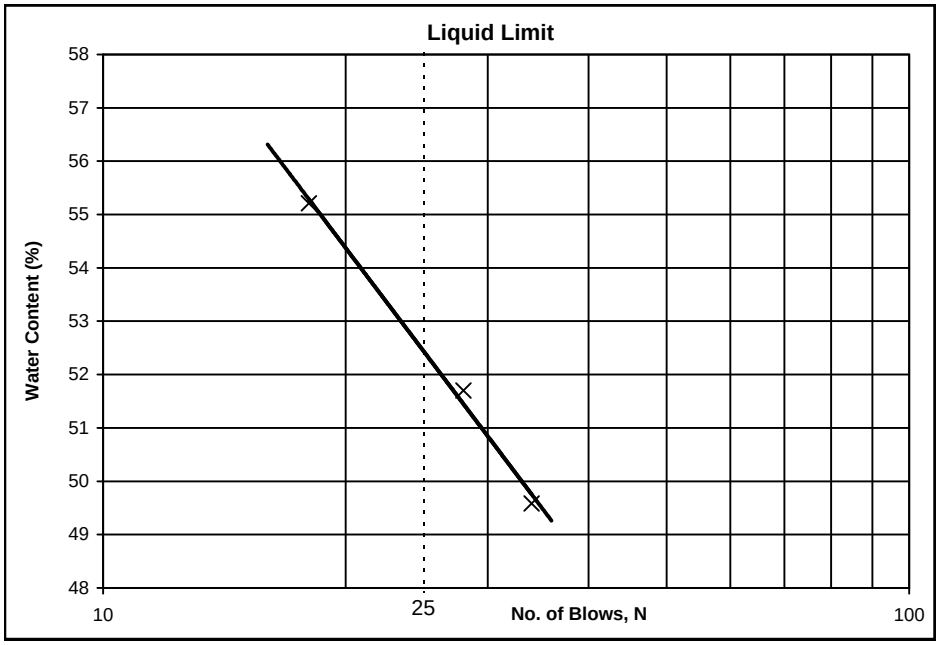
Sample Identification	Tt-2 @ 35'A

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	8/6/2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK
Sieved on #40 (Yes or No)	Yes
Preparation (Wet or Dry)	Dry

Liquid Limit Determination

Goal for range of blows	25-35	20-30	15-25
No. of blows, N	34	28	18
Drying Can No.	a7	a8	b2
Mass of can (g)	11.07	11.13	11.14
Mass of wet soil + can (g)	30.74	30.32	31.10
Mass of dry soil + can (g)	24.22	23.78	24.00
Water content (%)	49.6	51.7	55.2



Plastic Limit Determination

Drying Can No.	d7	d24
Mass of can (g)	11.23	11.10
Mass of wet soil + can (g)	17.21	19.10
Mass of dry soil + can (g)	16.34	17.92
Water content (%)	17.0	17.3

Results		***Adj.***
Liquid Limit	52.4	52
Plastic Limit	17.2	17
Plasticity Index	35.3	35

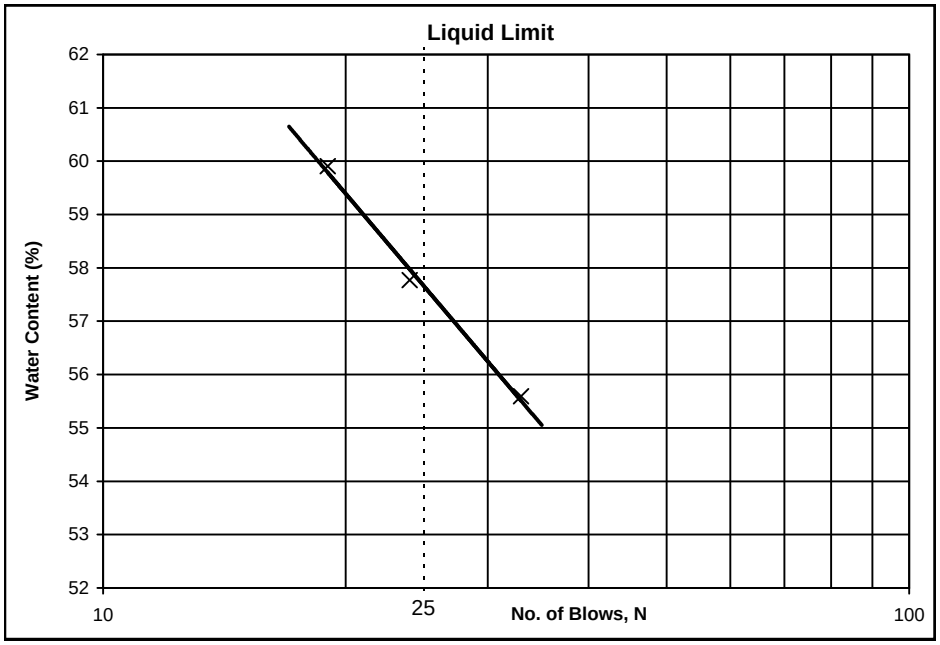
Atterberg Limits Test
ASTM D 4318

Tetra Tech, Inc. (970) 223.9600

Sample Identification	Tt-3 @ 10'A

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	8/7/2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK
Sieved on #40 (Yes or No)	Yes
Preparation (Wet or Dry)	Dry



Liquid Limit Determination

Goal for range of blows	25-35	20-30	15-25
No. of blows, N	33	24	19
Drying Can No.	a12	d8	d3
Mass of can (g)	11.03	11.20	11.17
Mass of wet soil + can (g)	28.13	29.88	31.43
Mass of dry soil + can (g)	22.02	23.04	23.84
Water content (%)	55.6	57.8	59.9

Plastic Limit Determination

Drying Can No.	d29	d32
Mass of can (g)	11.22	11.08
Mass of wet soil + can (g)	20.10	19.79
Mass of dry soil + can (g)	18.70	18.43
Water content (%)	18.7	18.5

Results		***Adj.***
Liquid Limit	57.7	58
Plastic Limit	18.6	19
Plasticity Index	39.1	39

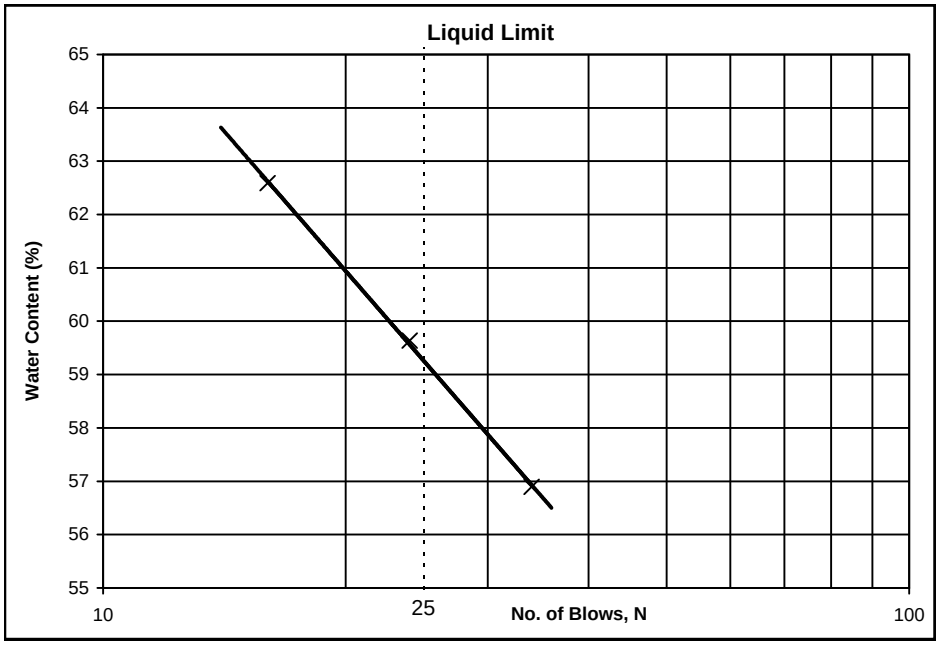
Atterberg Limits Test
ASTM D 4318

Tetra Tech, Inc. (970) 223.9600

Sample Identification	Tt-4 @ 10'A

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	8/7/2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK
Sieved on #40 (Yes or No)	Yes
Preparation (Wet or Dry)	Dry



Liquid Limit Determination

Goal for range of blows	25-35	20-30	15-25
No. of blows, N	34	24	16
Drying Can No.	a9	d33	c5
Mass of can (g)	11.18	11.14	11.04
Mass of wet soil + can (g)	29.16	27.87	29.12
Mass of dry soil + can (g)	22.64	21.62	22.16
Water content (%)	56.9	59.6	62.6

Plastic Limit Determination

Drying Can No.	d10	d31
Mass of can (g)	11.21	11.09
Mass of wet soil + can (g)	16.22	17.10
Mass of dry soil + can (g)	15.41	16.11
Water content (%)	19.3	19.7

Results		***Adj.***
Liquid Limit	59.3	59
Plastic Limit	19.5	20
Plasticity Index	39.8	39

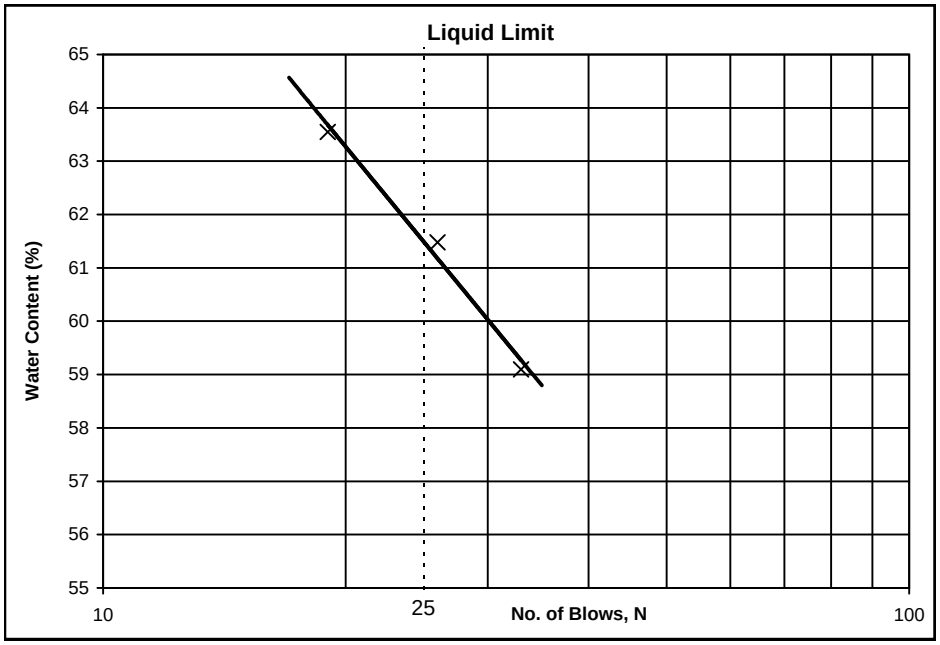
Atterberg Limits Test
ASTM D 4318

Tetra Tech, Inc. (970) 223.9600

Sample Identification	Tt-5 @ 5'- 15'

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	8/7/2009
Sample Type	Bulk
Soil Description	
Remarks	
Tested By	CK
Sieved on #40 (Yes or No)	Yes
Preparation (Wet or Dry)	Dry



Liquid Limit Determination

Goal for range of blows	25-35	20-30	15-25
No. of blows, N	33	26	19
Drying Can No.	d28	a3	b11
Mass of can (g)	11.11	10.91	11.08
Mass of wet soil + can (g)	29.39	28.35	29.25
Mass of dry soil + can (g)	22.60	21.71	22.19
Water content (%)	59.1	61.5	63.5

Plastic Limit Determination

Drying Can No.	a5	b6
Mass of can (g)	10.90	10.72
Mass of wet soil + can (g)	17.32	16.66
Mass of dry soil + can (g)	16.43	15.83
Water content (%)	16.1	16.2

Results		***Adj.***
Liquid Limit	61.5	62
Plastic Limit	16.2	16
Plasticity Index	45.3	46

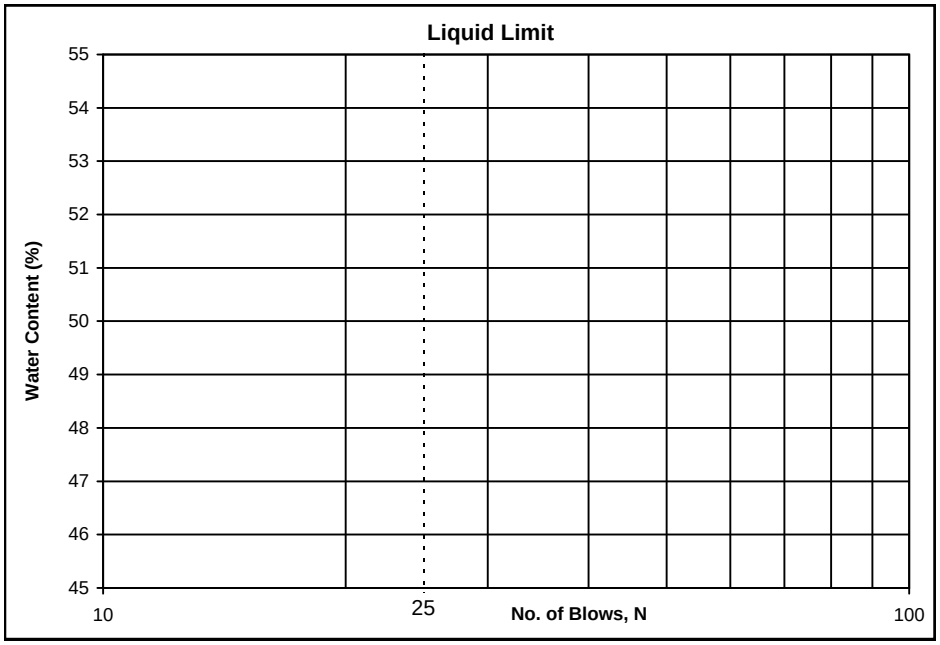
Atterberg Limits Test
ASTM D 4318

Tetra Tech, Inc. (970) 223.9600

Sample Identification	Tt-6 @ 2'- 5'

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	8/7/2009
Sample Type	Bulk
Soil Description	
Remarks	
Tested By	CK
Sieved on #40 (Yes or No)	Yes
Preparation (Wet or Dry)	Dry



Liquid Limit Determination

Goal for range of blows	25-35	20-30	15-25
No. of blows, N			
Drying Can No.			
Mass of can (g)			
Mass of wet soil + can (g)			
Mass of dry soil + can (g)			
Water content (%)			

Plastic Limit Determination

Drying Can No.		
Mass of can (g)		
Mass of wet soil + can (g)		
Mass of dry soil + can (g)		
Water content (%)		

Results		***Adj.***
Liquid Limit		NLL
Plastic Limit		NPL
Plasticity Index		NPI

Granular, Non-plastic

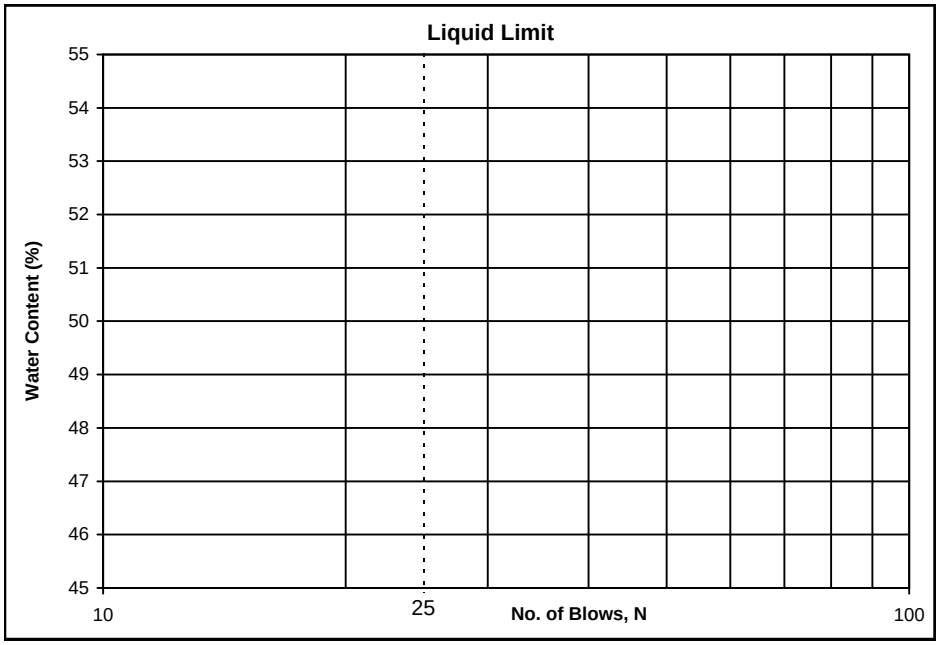
Atterberg Limits Test
ASTM D 4318

Tetra Tech, Inc. (970) 223.9600

Sample Identification	Tt-6 @ 5'A

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	8/7/2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK
Sieved on #40 (Yes or No)	Yes
Preparation (Wet or Dry)	Dry



Liquid Limit Determination

Goal for range of blows	25-35	20-30	15-25
No. of blows, N			
Drying Can No.			
Mass of can (g)			
Mass of wet soil + can (g)			
Mass of dry soil + can (g)			
Water content (%)			

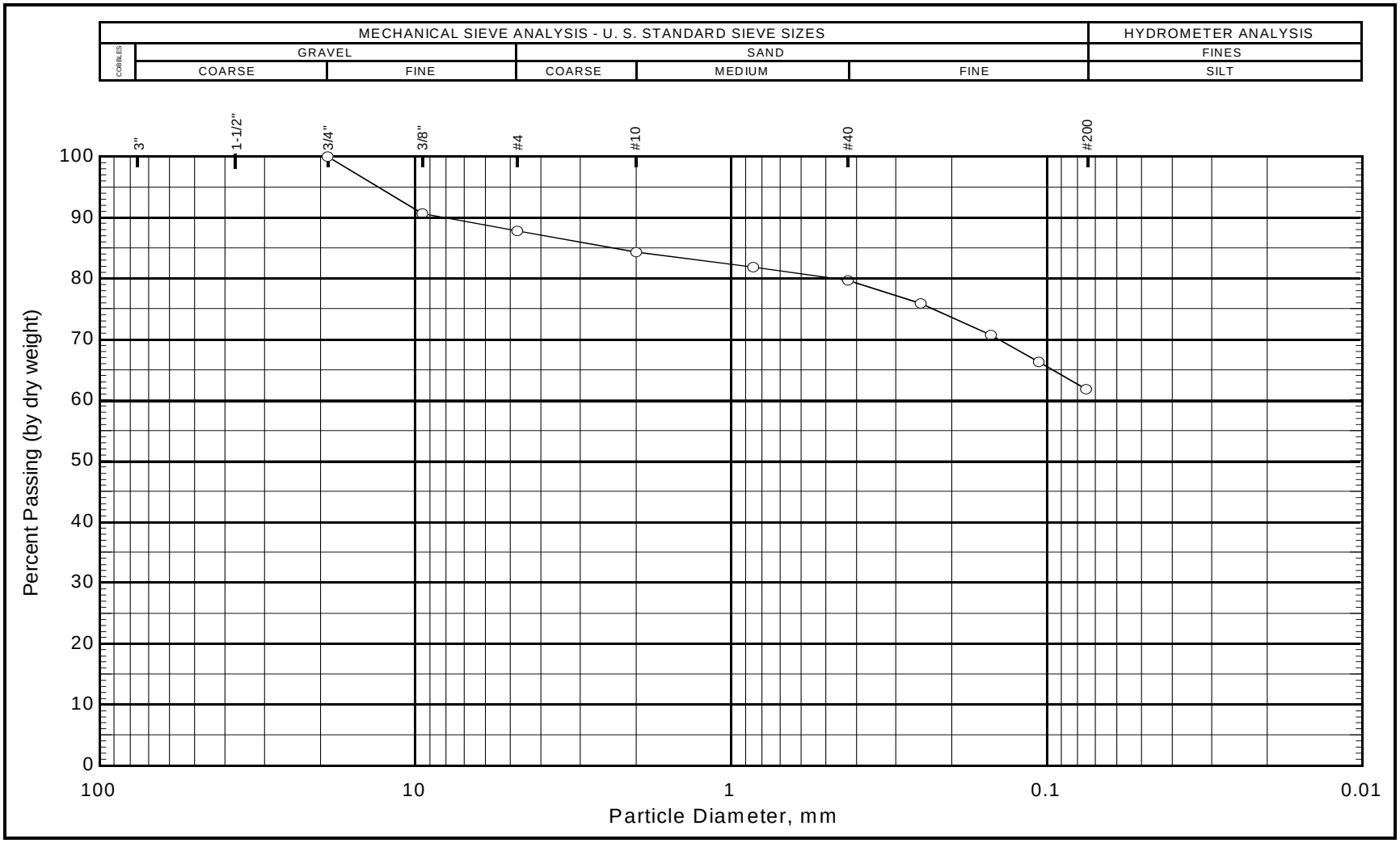
Plastic Limit Determination

Drying Can No.		
Mass of can (g)		
Mass of wet soil + can (g)		
Mass of dry soil + can (g)		
Water content (%)		

Results		***Adj.***
Liquid Limit		NLL
Plastic Limit		NPL
Plasticity Index		NPI

Granular, Non-plastic

Mechanical Grain Size Analysis (Gradation) Results



Particle-size Distribution for
Tt- 2 at 20 feet

Mechanical Grain Size Analysis

Tetra Tech, Inc. 970.223.9600

Sample Identification	Tt-2 @ 20'B

Project Information

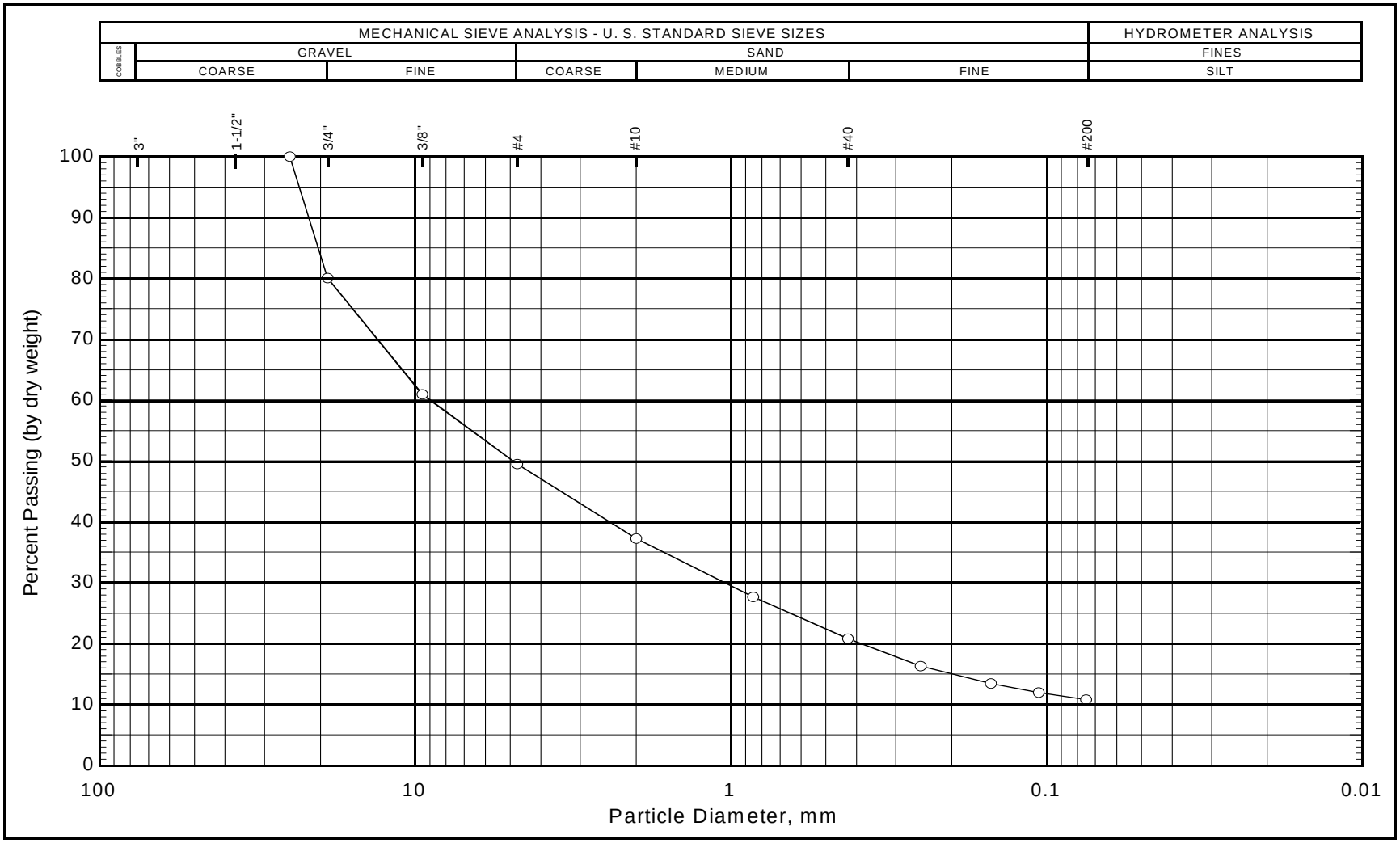
Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	July 31, 2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK

Drying Pan ID	N
Mass Drying Pan (g.)	236.88
Mass Pan + Dry Sample Before Wash (g.)	407.91
Mass of Dry Sample Before Wash (g.)	171.03

Sieve Size (mm)	Sieve #	Individual Mass Retained (g.)	Individual % Retained	Cumulative % Passing
19.0	3/4"		0.0	100.0
9.5	3/8"	15.91	9.3	90.7
4.75	#4	4.90	2.9	87.8
2.00	#10	6.11	3.6	84.3
0.850	#20	4.18	2.4	81.8
0.425	#40	3.69	2.2	79.7
0.250	#60	6.43	3.8	75.9
0.150	#100	8.85	5.2	70.7
0.106	#140	7.50	4.4	66.3
0.075	#200	7.76	4.5	61.8
0.00	Pan	0.55		
TOTAL				

For Use When Washing Wet Sample

Moisture Content (%)		*Wet Soil*	
Tare ID		Tare ID	
Tare Mass (g)		Tare Mass (g)	
Wet Soil + Tare (g)		Wet Soil + Tare (g)	
Dry Soil + Tare		Wet Soil (g)	
Moisture Content (%)	#DIV/0!	Dry Soil (g)	#DIV/0!
		Dry Soil + Tare (g)	#DIV/0!



Particle-size Distribution for
Tt- 2 at 25 feet

Mechanical Grain Size Analysis

Tetra Tech, Inc. 970.223.9600

Sample Identification	Tt-2 @ 25'A

Project Information

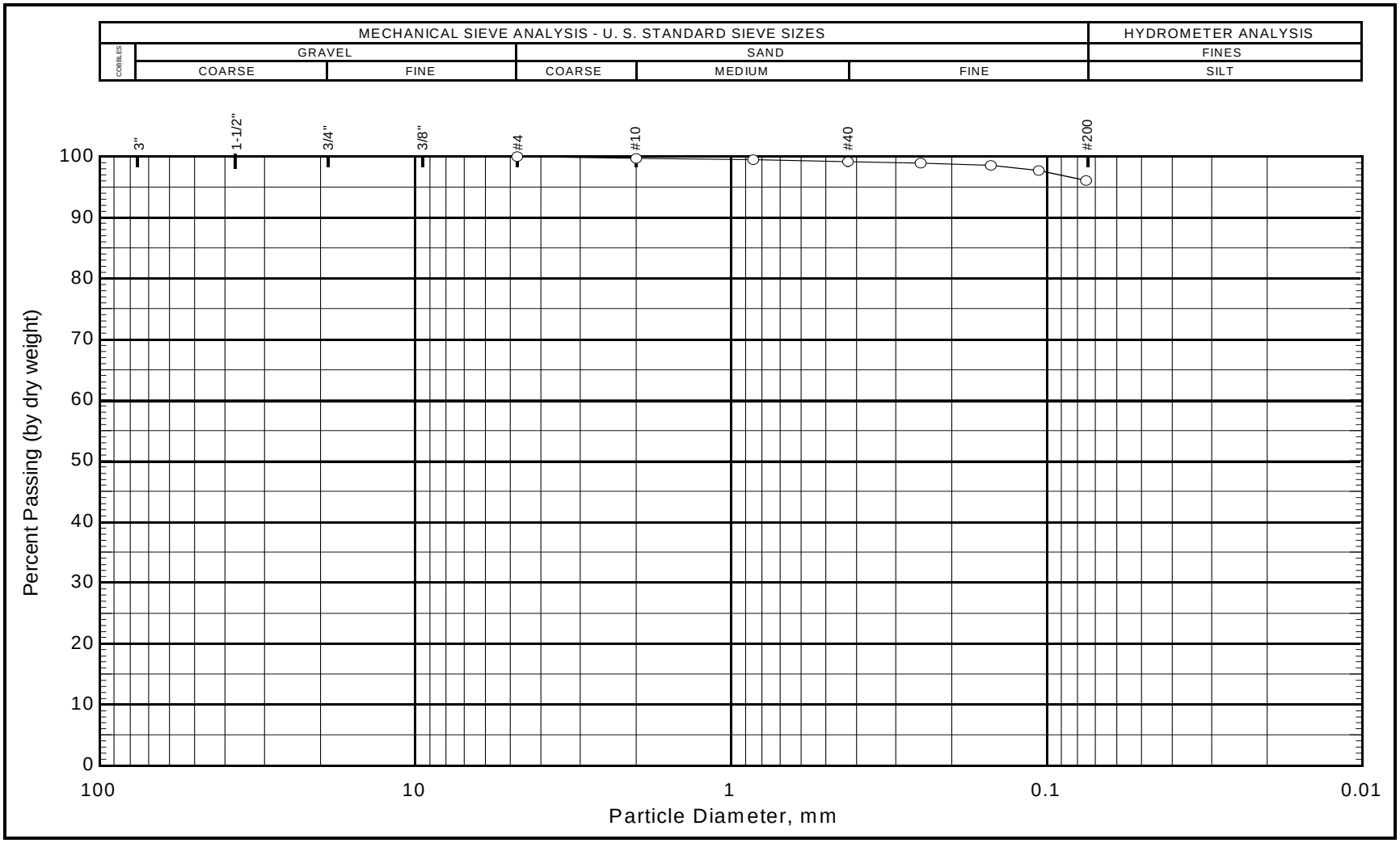
Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	July 31, 2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK

Drying Pan ID	111
Mass Drying Pan (g.)	235.86
Mass Pan + Dry Sample Before Wash (g.)	466.81
Mass of Dry Sample Before Wash (g.)	230.95

Sieve Size (mm)	Sieve #	Individual Mass Retained (g.)	Individual % Retained	Cumulative % Passing
25.0	1"		0.0	100.0
19.0	3/4"	45.85	19.9	80.1
9.5	3/8"	44.23	19.2	61.0
4.75	#4	26.45	11.5	49.5
2.00	#10	28.31	12.3	37.3
0.850	#20	22.04	9.5	27.7
0.425	#40	16.00	6.9	20.8
0.250	#60	10.49	4.5	16.3
0.150	#100	6.36	2.8	13.5
0.106	#140	3.40	1.5	12.0
0.075	#200	2.94	1.3	10.8
0.00	Pan	0.34		
TOTAL				

For Use When Washing Wet Sample

Moisture Content (%)		***Wet Soil***	
Tare ID		Tare ID	
Tare Mass (g)		Tare Mass (g)	
Wet Soil + Tare (g)		Wet Soil + Tare (g)	
Dry Soil + Tare		Wet Soil (g)	
Moisture Content (%)	#DIV/0!	Dry Soil (g)	#DIV/0!
		Dry Soil + Tare (g)	#DIV/0!



Particle-size Distribution for
Tt- 3 at 10 feet

Mechanical Grain Size Analysis

Tetra Tech, Inc. 970.223.9600

Sample Identification	Tt-3 @ 10'A

Project Information

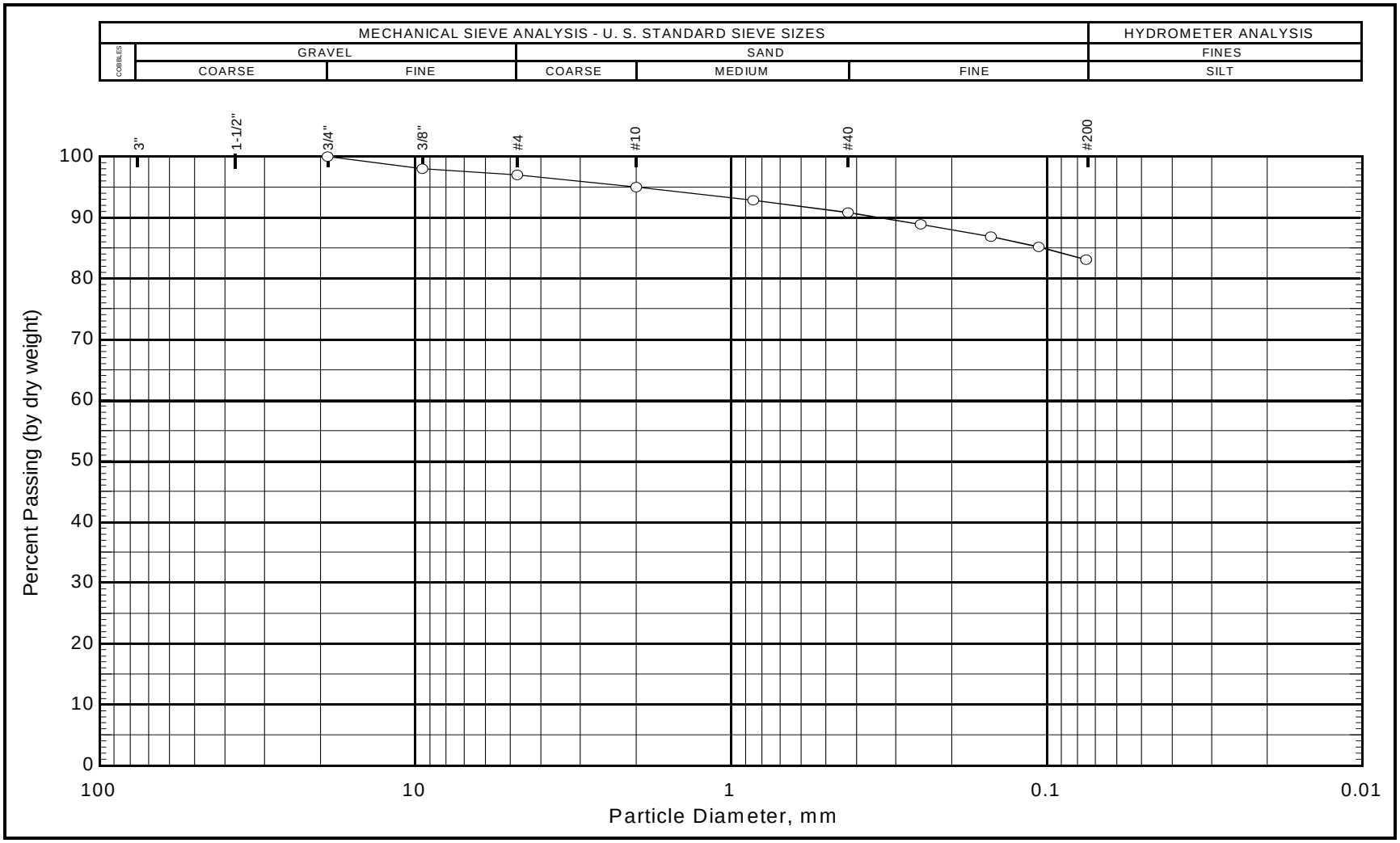
Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	July 31, 2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK

Drying Pan ID	110
Mass Drying Pan (g.)	233.7
Mass Pan + Dry Sample Before Wash (g.)	429.39
Mass of Dry Sample Before Wash (g.)	195.69

Sieve Size (mm)	Sieve #	Individual Mass Retained (g.)	Individual % Retained	Cumulative % Passing
4.75	#4	0.00	0.0	100.0
2.00	#10	0.59	0.3	99.7
0.850	#20	0.49	0.3	99.4
0.425	#40	0.51	0.3	99.2
0.250	#60	0.40	0.2	99.0
0.150	#100	0.81	0.4	98.6
0.106	#140	1.71	0.9	97.7
0.075	#200	3.21	1.6	96.1
0.00	Pan	0.23		
TOTAL				

For Use When Washing Wet Sample

Moisture Content (%)		***Wet Soil***	
Tare ID		Tare ID	
Tare Mass (g)		Tare Mass (g)	
Wet Soil + Tare (g)		Wet Soil + Tare (g)	
Dry Soil + Tare		Wet Soil (g)	
Moisture Content (%)	#DIV/0!	Dry Soil (g)	#DIV/0!
		Dry Soil + Tare (g)	#DIV/0!



Particle-size Distribution for
Tt- 5 at 5 feet to 15 feet

Mechanical Grain Size Analysis

Tetra Tech, Inc. 970.223.9600

Sample Identification	Tt-5 @ 5'- 15'

Project Information

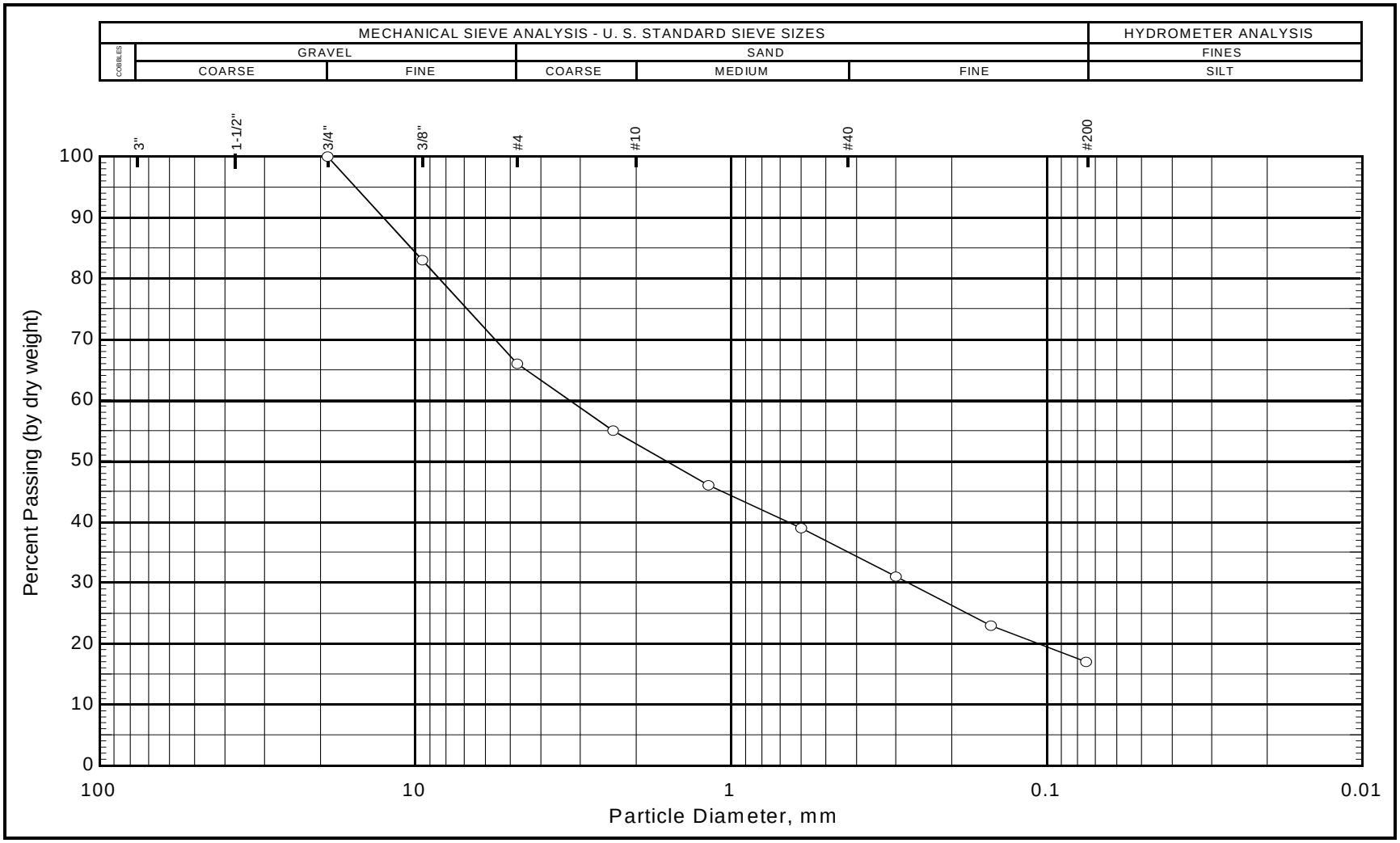
Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	August 3, 2009
Sample Type	Bulk
Soil Description	
Remarks	
Tested By	CK

Drying Pan ID	107
Mass Drying Pan (g.)	234.23
Mass Pan + Dry Sample Before Wash (g.)	611.42
Mass of Dry Sample Before Wash (g.)	377.19

Sieve Size (mm)	Sieve #	Individual Mass Retained (g.)	Individual % Retained	Cumulative % Passing
19.0	3/4"		0.0	100.0
9.5	3/8"	7.49	2.0	98.0
4.75	#4	3.91	1.0	97.0
2.00	#10	7.50	2.0	95.0
0.850	#20	8.41	2.2	92.8
0.425	#40	7.53	2.0	90.8
0.250	#60	7.01	1.9	88.9
0.150	#100	7.58	2.0	86.9
0.106	#140	6.50	1.7	85.2
0.075	#200	7.80	2.1	83.1
0.00	Pan	0.35		
TOTAL				

For Use When Washing Wet Sample

Moisture Content (%)		***Wet Soil***	
Tare ID		Tare ID	
Tare Mass (g)		Tare Mass (g)	
Wet Soil + Tare (g)		Wet Soil + Tare (g)	
Dry Soil + Tare		Wet Soil (g)	
Moisture Content (%)	#DIV/0!	Dry Soil (g)	#DIV/0!
		Dry Soil + Tare (g)	#DIV/0!



Particle-size Distribution for
Tt- 6 at 2 feet to 5 feet

Mechanical Grain Size Analysis

Tetra Tech, Inc. 970.223.9600

Sample Identification	Tt-6 @ 2'- 5'

Project Information

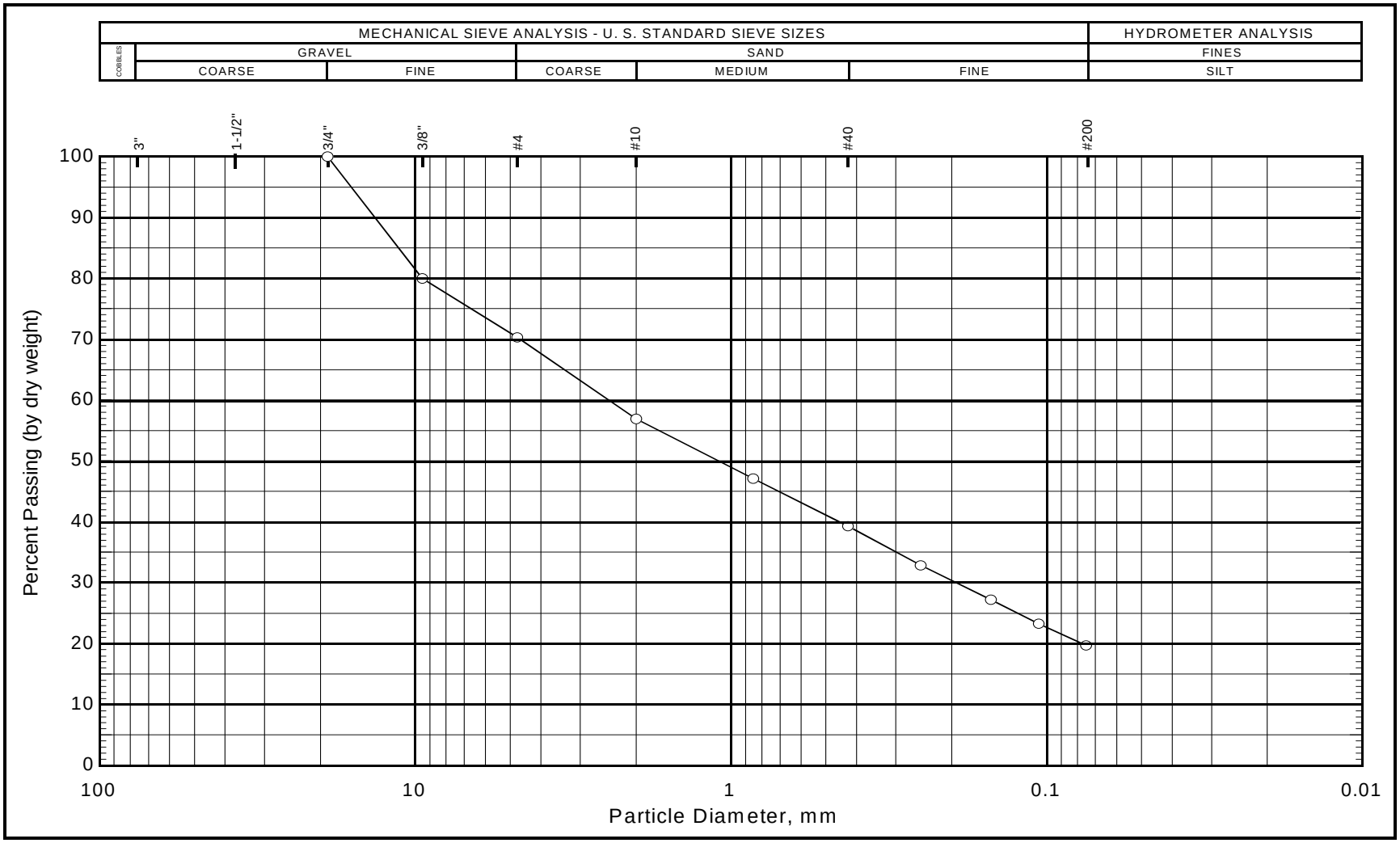
Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	August 3, 2009
Sample Type	Bulk
Soil Description	
Remarks	
Tested By	CK

Drying Pan ID	102
Mass Drying Pan (g.)	235.5
Mass Pan + Dry Sample Before Wash (g.)	1273.29
Mass of Dry Sample Before Wash (g.)	1037.79

Sieve Size (mm)	Sieve #	Individual Mass Retained (g.)	Individual % Retained	Cumulative % Passing
19.0	3/4"		0.0	100
9.5	3/8"	172.49	16.6	83
4.75	#4	184.71	17.8	66
2.36	#8	108.07	10.4	55
1.18	#16	90.76	8.7	46
0.600	#30	80.55	7.8	39
0.300	#50	81.14	7.8	31
0.150	#100	76.62	7.4	23
0.075	#200	65.16	6.3	17
0.00	Pan	6.92		
TOTAL				

For Use When Washing Wet Sample

Moisture Content (%)		***Wet Soil***	
Tare ID		Tare ID	
Tare Mass (g)		Tare Mass (g)	
Wet Soil + Tare (g)		Wet Soil + Tare (g)	
Dry Soil + Tare		Wet Soil (g)	
Moisture Content (%)	#DIV/0!	Dry Soil (g)	#DIV/0!
		Dry Soil + Tare (g)	#DIV/0!



Particle-size Distribution for
Tt- 6 at 5 feet

Mechanical Grain Size Analysis

Tetra Tech, Inc. 970.223.9600

Sample Identification	Tt-6 @ 5'A

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	August 3, 2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK

Drying Pan ID	104
Mass Drying Pan (g.)	284.96
Mass Pan + Dry Sample Before Wash (g.)	411.14
Mass of Dry Sample Before Wash (g.)	126.18

Sieve Size (mm)	Sieve #	Individual Mass Retained (g.)	Individual % Retained	Cumulative % Passing
19.0	3/4"		0.0	100.0
9.5	3/8"	25.22	20.0	80.0
4.75	#4	12.26	9.7	70.3
2.00	#10	16.87	13.4	56.9
0.850	#20	12.36	9.8	47.1
0.425	#40	9.87	7.8	39.3
0.250	#60	8.05	6.4	32.9
0.150	#100	7.25	5.7	27.2
0.106	#140	4.86	3.9	23.3
0.075	#200	4.53	3.6	19.7
0.00	Pan	0.66		
TOTAL				

For Use When Washing Wet Sample

Moisture Content (%)		***Wet Soil***	
Tare ID		Tare ID	
Tare Mass (g)		Tare Mass (g)	
Wet Soil + Tare (g)		Wet Soil + Tare (g)	
Dry Soil + Tare		Wet Soil (g)	
Moisture Content (%)	#DIV/0!	Dry Soil (g)	#DIV/0!
		Dry Soil + Tare (g)	#DIV/0!

Minus #200 Sieve Only

-200 Sieve Only

Tetra Tech, Inc. 970.223.9600

Sample Identification	Tt-2 @ 19'- 21'

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	July 31, 2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK

Drying Pan ID	M
Mass Drying Pan (g.)	238.09
Mass Pan + Dry Sample Before Wash (g.)	560.52
Mass of Dry Sample Before Wash (g.)	322.43

Sieve Size (mm)	Sieve #	Individual Mass Retained (g.)	Individual % Retained	Cumulative % Passing
0.075	#200	119.59	37.1	62.9

For Use When Washing Wet Sample

Moisture Content (%)		*Wet Soil*	
Tare ID		Tare ID	
Tare Mass (g)		Tare Mass (g)	
Wet Soil + Tare (g)		Wet Soil + Tare (g)	
Dry Soil + Tare		Wet Soil (g)	
Moisture Content (%)		Dry Soil (g)	
		Dry Soil + Tare (g)	

-200 Sieve Only

Tetra Tech, Inc. 970.223.9600

Sample Identification	Tt-2 @ 35'A

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	July 31, 2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK

Drying Pan ID	108
Mass Drying Pan (g.)	232.46
Mass Pan + Dry Sample Before Wash (g.)	444.75
Mass of Dry Sample Before Wash (g.)	212.29

Sieve Size (mm)	Sieve #	Individual Mass Retained (g.)	Individual % Retained	Cumulative % Passing
0.075	#200	2.32	1.1	98.9

For Use When Washing Wet Sample

Moisture Content (%)		*Wet Soil*	
Tare ID		Tare ID	
Tare Mass (g)		Tare Mass (g)	
Wet Soil + Tare (g)		Wet Soil + Tare (g)	
Dry Soil + Tare		Wet Soil (g)	
Moisture Content (%)		Dry Soil (g)	
		Dry Soil + Tare (g)	

-200 Sieve Only

Tetra Tech, Inc. 970.223.9600

Sample Identification	Tt-4 @ 10'A

Project Information

Project Name	Rocky Flats SPPTS
Project Number	181919A
Date	July 31, 2009
Sample Type	California Tube
Soil Description	
Remarks	
Tested By	CK

Drying Pan ID	109
Mass Drying Pan (g.)	240.08
Mass Pan + Dry Sample Before Wash (g.)	397.82
Mass of Dry Sample Before Wash (g.)	157.74

Sieve Size (mm)	Sieve #	Individual Mass Retained (g.)	Individual % Retained	Cumulative % Passing
0.075	#200	1.48	0.9	99.1

For Use When Washing Wet Sample

Moisture Content (%)		*Wet Soil*	
Tare ID		Tare ID	
Tare Mass (g)		Tare Mass (g)	
Wet Soil + Tare (g)		Wet Soil + Tare (g)	
Dry Soil + Tare		Wet Soil (g)	
Moisture Content (%)		Dry Soil (g)	
		Dry Soil + Tare (g)	

Total Organics Content and Water Soluble Sulfate

Laboratory Report

Client:
TetraTech
3801 Automation Way, Ste. 100
Fort Collins CO 80525
Attn: Charlie Klapproth

Date Sampled: 8/1/2009 9:30:00 AM
Date Received: 8/3/2009
Batch No: 2733
Laboratory ID: S092151054
Matrix: Solid Grab
Sample Name: Tt-5@25'B

Project # 1573-017

Analysis	Results	Units	MRL	Method	Analysis Date	Analyst	Sent Out	Laboratory
Sulfate	157	ppm	0.5	EPA 300.0	8/5/2009	CMB	☐	

Stewart Environmental Consultants, Inc.
3801 Automation Way, Suite 200 ♦ Fort Collins, CO 80525
Phone 970-226-5500 ♦ Fax:970-226-4946

Client:
TetraTech
3801 Automation Way, Ste. 100
Fort Collins CO 80525
Attn: Charlie Klapproth

Date Sampled: 8/1/2009 9:30:00 AM
Date Received: 8/3/2009
Batch No: 2733
Laboratory ID: S092151055
Matrix: Solid Grab
Sample Name: Tt-2@19'-21'

Project # 1573-017

At 750°C

					Analysis		Sent
Solids/Total	84.1	%	1	SM 2540 C	8/10/2009	TML	☐
Solids/Total Volatile	5.45	%	1	SM 2540 G	8/11/2009	TML	☐

Stewart Environmental Consultants, Inc.
3801 Automation Way, Suite 200 ♦ Fort Collins, CO 80525
Phone 970-226-5500 ♦ Fax:970-226-4946

Client:
TetraTech
3801 Automation Way, Ste. 100
Fort Collins CO 80525
Attn: Charlie Klapproth

Date Sampled: 8/1/2009 9:30:00 AM
Date Received: 8/3/2009
Batch No: 2733
Laboratory ID: S09215105A
Matrix: Solid Grab
Sample Name: Tt-4@2'A

Project # 1573-017

Analysis	Results	Units	MRL	Method	Analysis Date	Analyst	Sent Out	Laboratory
Sulfate	102	ppm	0.5	EPA 300.0	8/5/2009	CMB	☐	

Stewart Environmental Consultants, Inc.
3801 Automation Way, Suite 200 ♦ Fort Collins, CO 80525
Phone 970-226-5500 ♦ Fax:970-226-4946

Client:
TetraTech
3801 Automation Way, Ste. 100
Fort Collins CO 80525

Attn: Charlie Klapproth

Date Sampled:	8/1/2009	9:30:00 AM
Date Received:	8/3/2009	
Batch No:	2733	
Laboratory ID:	S092151105	
Matrix:	Solid	Grab
Sample Name:	Tt-4@20'B	

Project # 1573-017

At 750°C

					Analysis		Sent
Solids/Total	86	%	1	SM 2540 C	8/10/2009	TML	☐
Solids/Total Volatile	4	%	1	SM 2540 G	8/11/2009	TML	☐

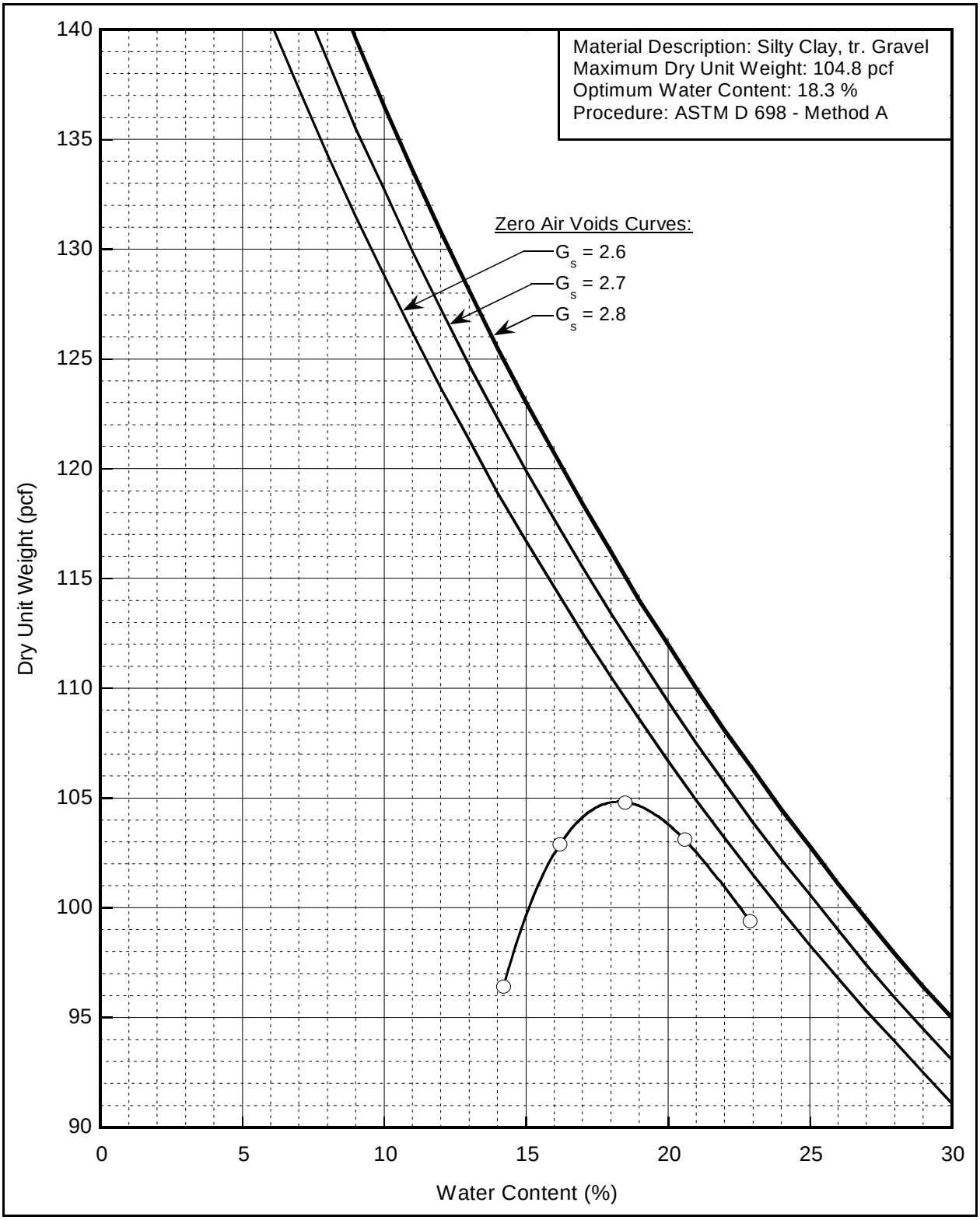
Results Approved by: M. Glavanovich

Michael Glavanovich, Laboratory Manager

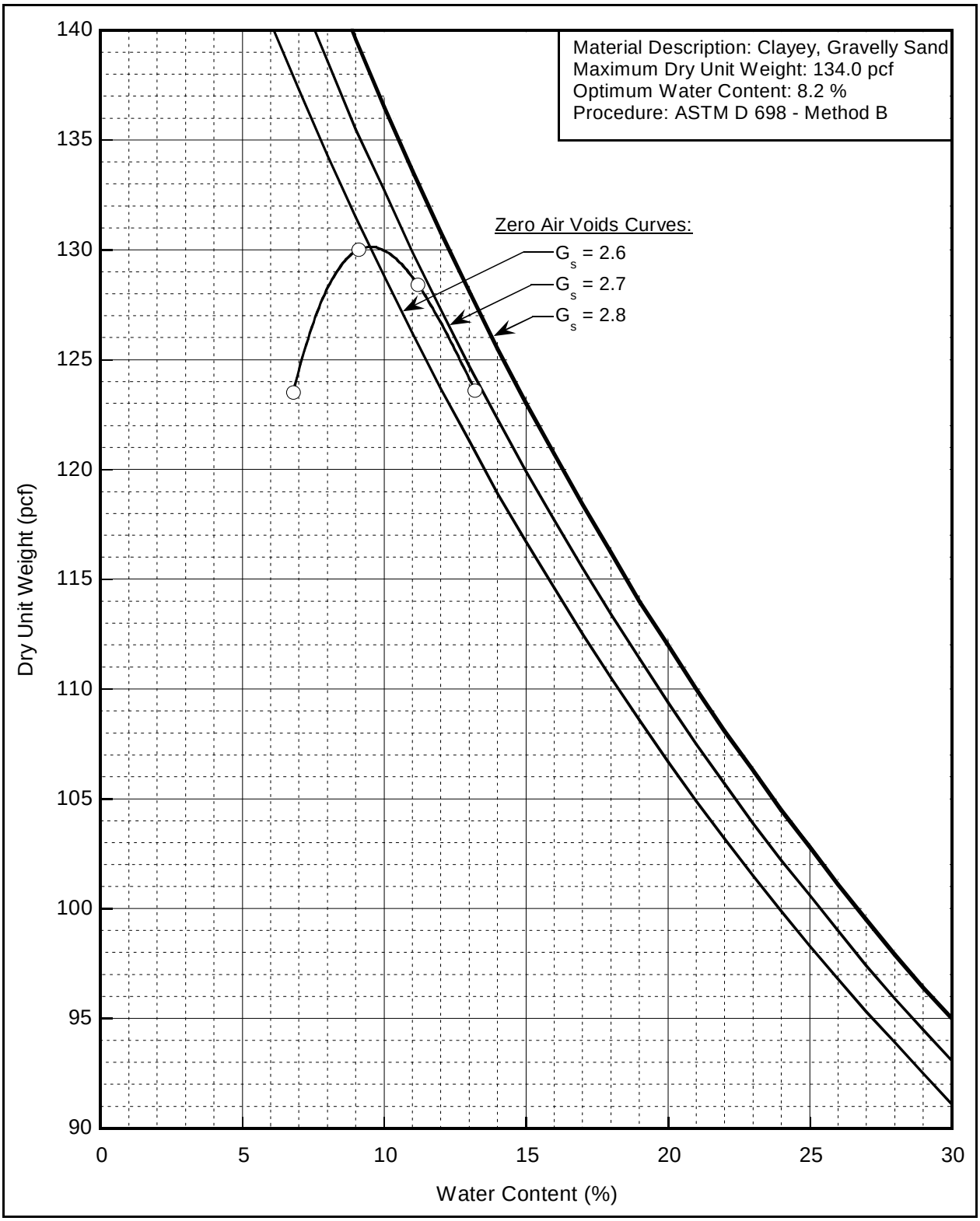
Date Reported: **8/12/2009**

Stewart Environmental Consultants, Inc.
3801 Automation Way, Suite 200 ♦ Fort Collins, CO 80525
Phone 970-226-5500 ♦ Fax:970-226-4946

Standard Proctor Laboratory Compaction Test Results



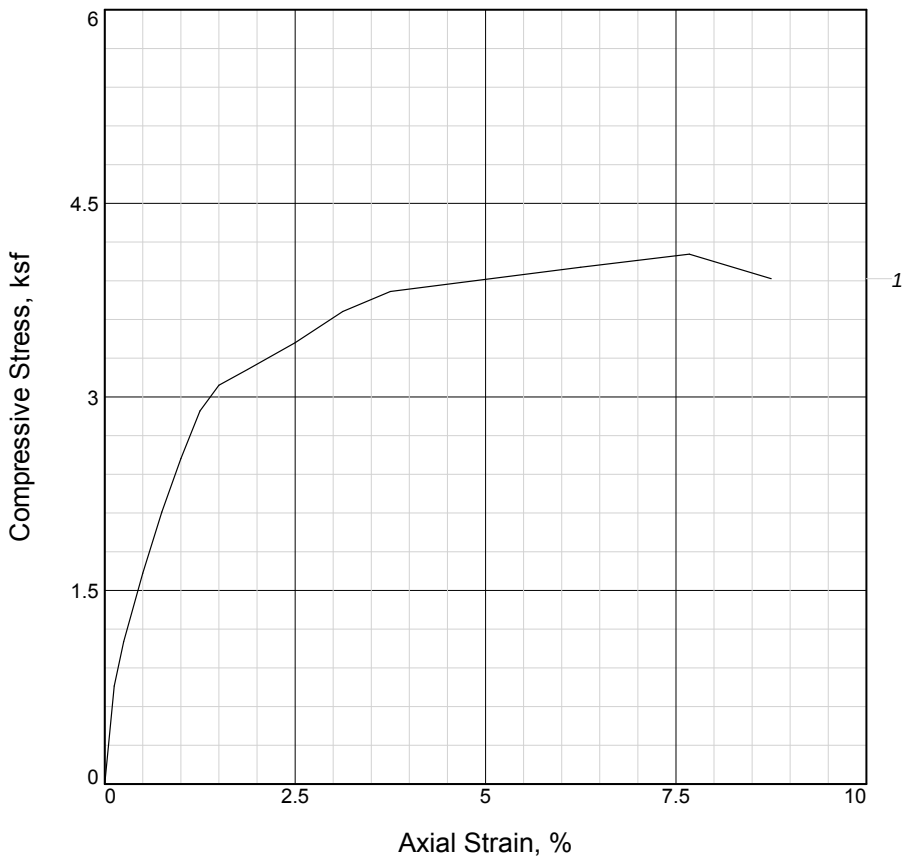
Laboratory Compaction Curve for Tt-5 at 5-15 feet



Laboratory Compaction Curve for Tt-6 at 2-5 feet

Unconfined Compression and Direct Shear Test Results

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, ksf	4.106			
Undrained shear strength, ksf	2.053			
Failure strain, %	7.7			
Strain rate, in./min.	0.020			
Water content, %	15.5			
Wet density, pcf	121.7			
Dry density, pcf	105.3			
Saturation, %	69.8			
Void ratio	0.6002			
Specimen diameter, in.	1.940			
Specimen height, in.	4.000			
Height/diameter ratio	2.06			

Description:

LL =	**PL =**	**PI =**	**Assumed GS=** 2.70	**Type:** Undisturbed

Project No.: 114-181919A

Date Sampled:

Remarks:

Client: Stoller

Project: Rocky Flats-SPPTS

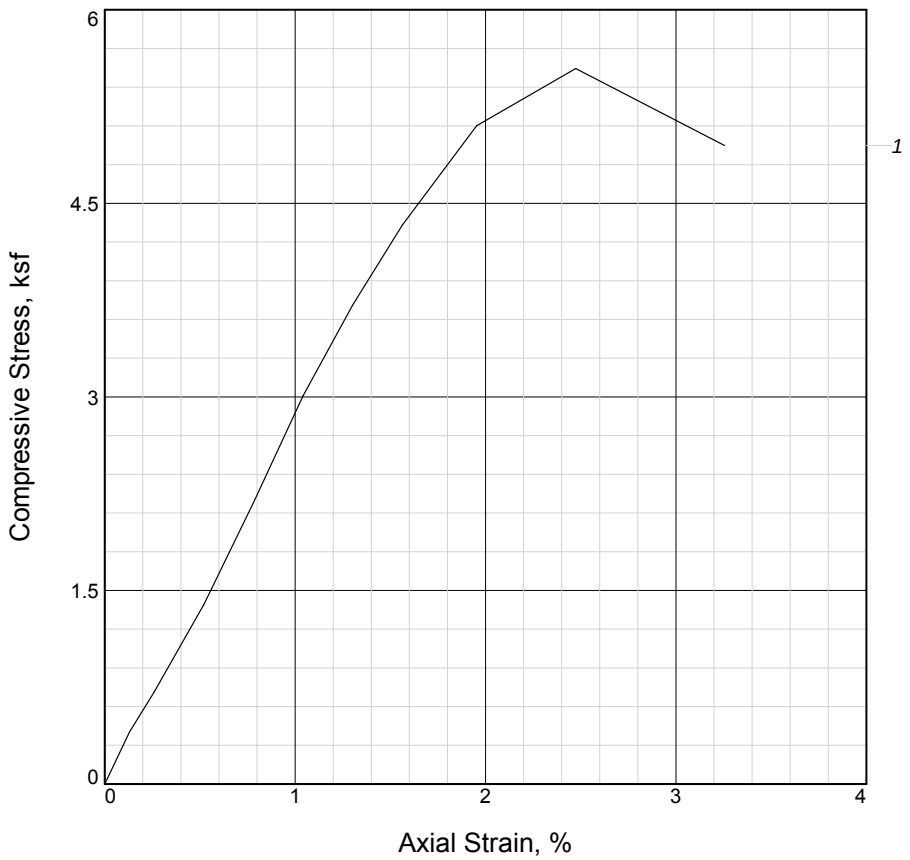
Source of Sample: Tt-1 **Depth:** 10'A

UNCONFINED COMPRESSION TEST

Figure B1

Tetra Tech, Inc.

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, ksf	5.544			
Undrained shear strength, ksf	2.772			
Failure strain, %	2.5			
Strain rate, in./min.	0.020			
Water content, %	16.3			
Wet density, pcf	114.8			
Dry density, pcf	98.7			
Saturation, %	62.2			
Void ratio	0.7083			
Specimen diameter, in.	1.940			
Specimen height, in.	3.840			
Height/diameter ratio	1.98			

Description:

LL =	**PL =**	**PI =**	**Assumed GS=** 2.70	**Type:** Undisturbed

Project No.: 114-181919A

Date Sampled:

Remarks:

Client: Stoller

Project: Rocky Flats-SPPTS

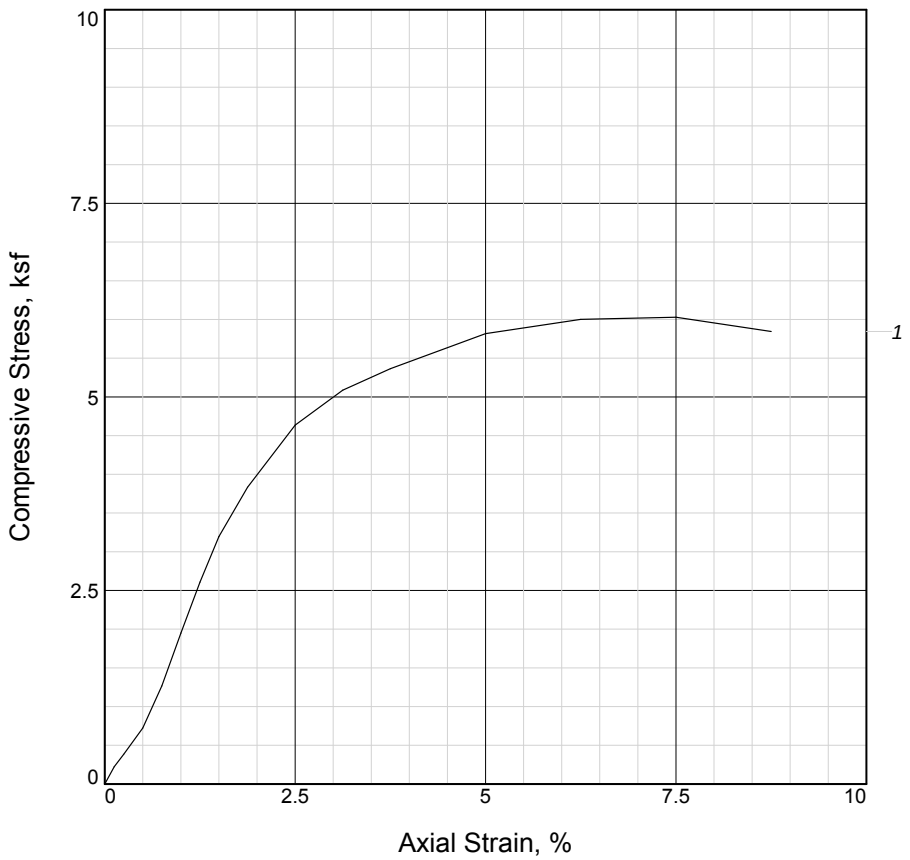
Source of Sample: Tt-3 **Depth:** 35'A

UNCONFINED COMPRESSION TEST

Figure B2

Tetra Tech, Inc.

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, ksf	6.029			
Undrained shear strength, ksf	3.015			
Failure strain, %	7.5			
Strain rate, in./min.	0.020			
Water content, %	18.6			
Wet density, pcf	126.1			
Dry density, pcf	106.3			
Saturation, %	85.9			
Void ratio	0.5856			
Specimen diameter, in.	1.940			
Specimen height, in.	4.000			
Height/diameter ratio	2.06			

Description:

LL =	**PL =**	**PI =**	**Assumed GS=** 2.70	**Type:** Undisturbed

Project No.: 114-181919A

Date Sampled:

Remarks:

Client: Stoller

Project: Rocky Flats-SPPTS

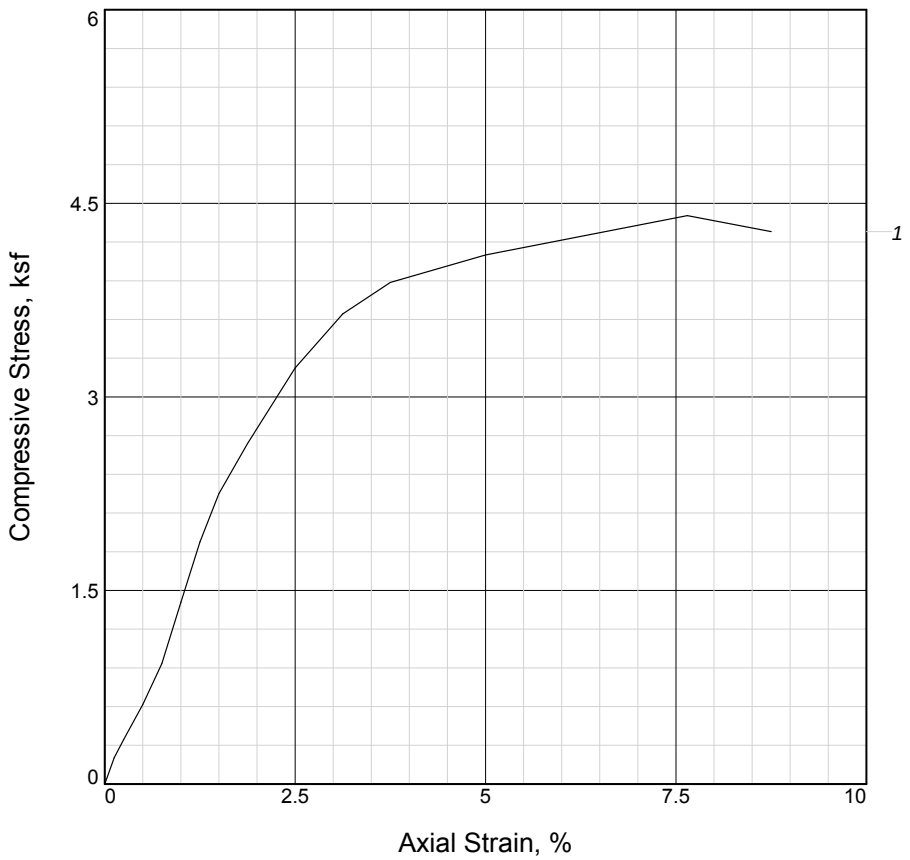
Source of Sample: Tt-4 **Depth:** 5'A

UNCONFINED COMPRESSION TEST

Tetra Tech, Inc.

Figure B3

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, ksf	4.404			
Undrained shear strength, ksf	2.202			
Failure strain, %	7.6			
Strain rate, in./min.	0.020			
Water content, %	17.0			
Wet density, pcf	129.5			
Dry density, pcf	110.8			
Saturation, %	87.8			
Void ratio	0.5219			
Specimen diameter, in.	1.940			
Specimen height, in.	4.000			
Height/diameter ratio	2.06			

Description:

LL =	**PL =**	**PI =**	**Assumed GS=** 2.70	**Type:** Undisturbed

Project No.: 114-181919A

Date Sampled:

Remarks:

Client: Stoller

Project: Rocky Flats-SPPTS

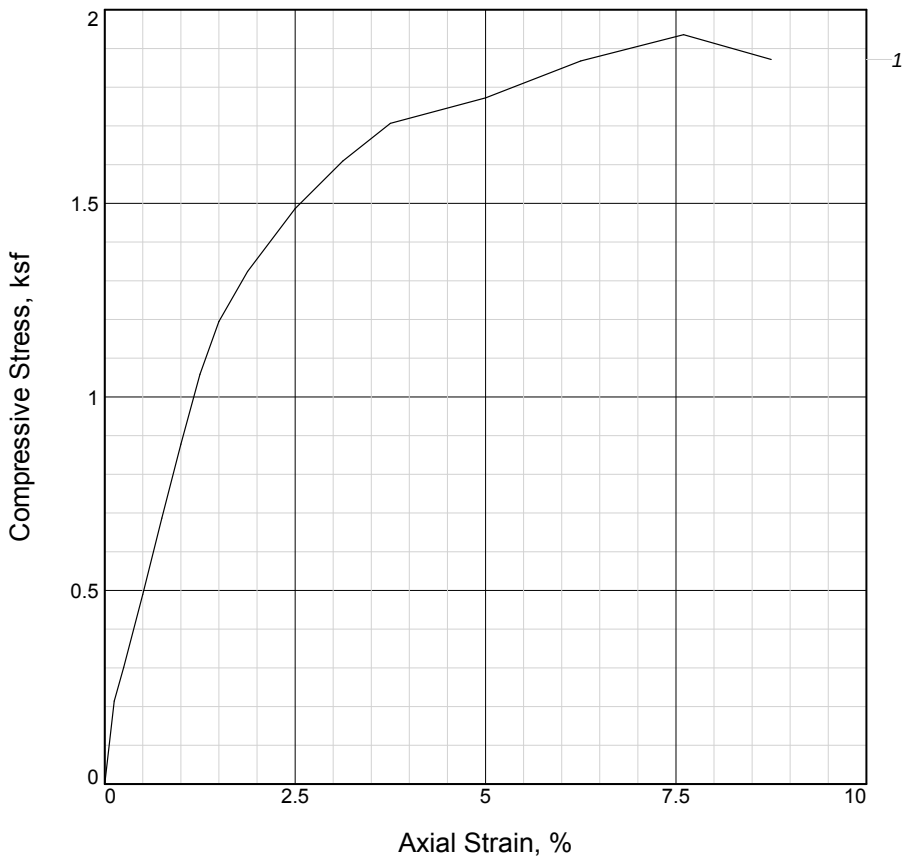
Source of Sample: Tt-5 **Depth:** 2'A

UNCONFINED COMPRESSION TEST

Figure B4

Tetra Tech, Inc.

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, ksf	1.936			
Undrained shear strength, ksf	0.968			
Failure strain, %	7.6			
Strain rate, in./min.	0.020			
Water content, %	20.9			
Wet density, pcf	128.2			
Dry density, pcf	106.1			
Saturation, %	95.7			
Void ratio	0.5889			
Specimen diameter, in.	1.940			
Specimen height, in.	4.000			
Height/diameter ratio	2.06			

Description:

LL =	**PL =**	**PI =**	**Assumed GS=** 2.70	**Type:** Undisturbed

Project No.: 114-181919A

Date Sampled:

Remarks:

Client: Stoller

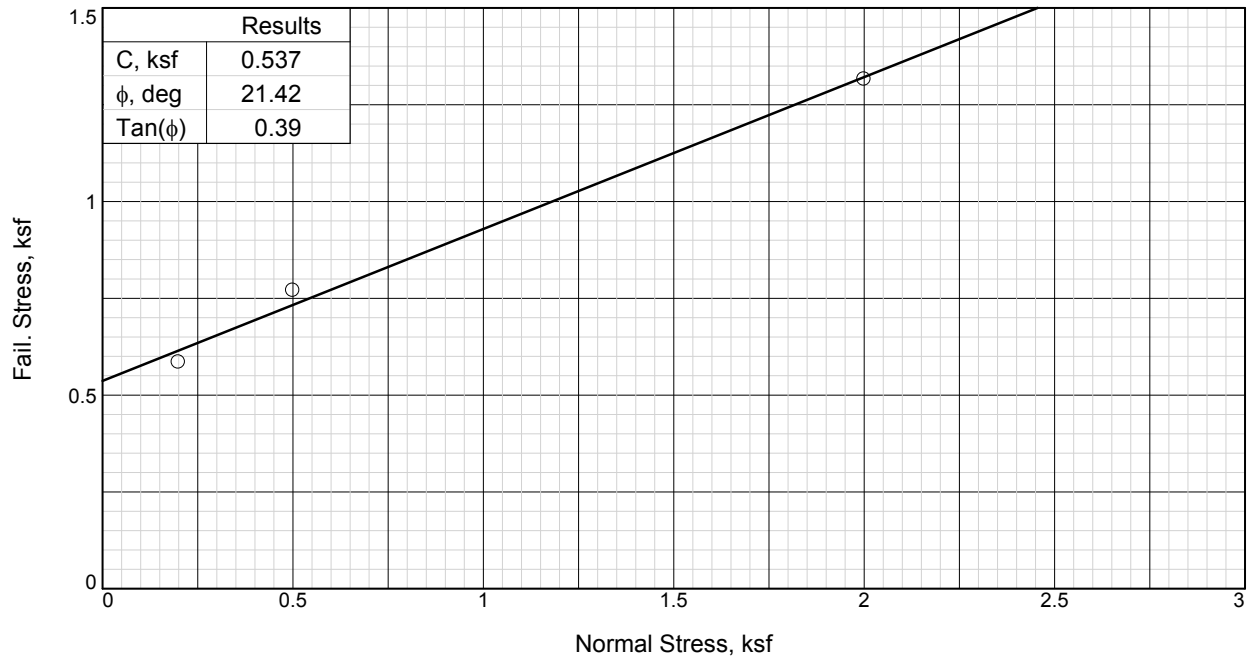
Project: Rocky Flats-SPPTS

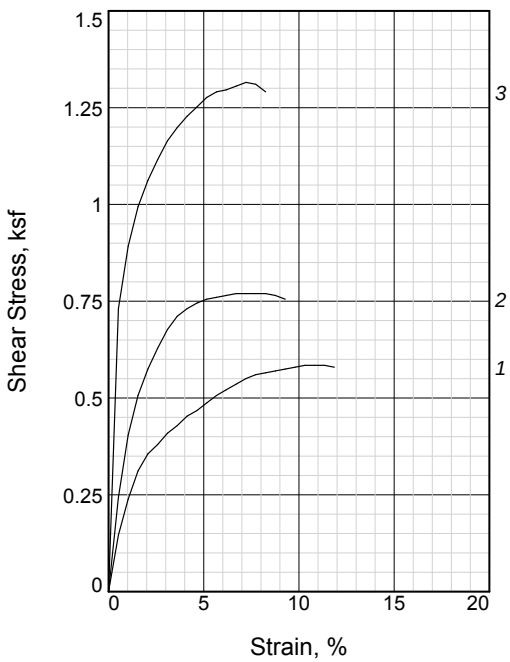
Source of Sample: Tt-6 **Depth:** 15'A

UNCONFINED COMPRESSION TEST

Tetra Tech, Inc.

Figure B5





Sample No.		1	2	3
Initial	Water Content, %	15.2	15.2	15.2
	Dry Density, pcf	117.7	113.4	110.9
	Saturation, %	94.9	84.3	78.8
	Void Ratio	0.4318	0.4860	0.5196
	Diameter, in.	1.940	1.940	1.940
	Height, in.	0.500	0.500	0.500
At Test	Water Content, %	25.2	24.1	23.7
	Dry Density, pcf	117.4	112.4	108.2
	Saturation, %	156.4	130.0	114.7
	Void Ratio	0.4358	0.5000	0.5576
	Diameter, in.	1.940	1.940	1.940
	Height, in.	0.501	0.505	0.512
Normal Stress, ksf		0.200	0.500	2.000
Fail. Stress, ksf		0.585	0.770	1.315
Strain, %		10.3	6.7	7.2
Ult. Stress, ksf				
Strain, %				
Strain rate, in./min.		0.004	0.004	0.004

Sample Type: Undisturbed
Description:

Assumed Specific Gravity= 2.70
Remarks:

Figure B6

Client: Stoller

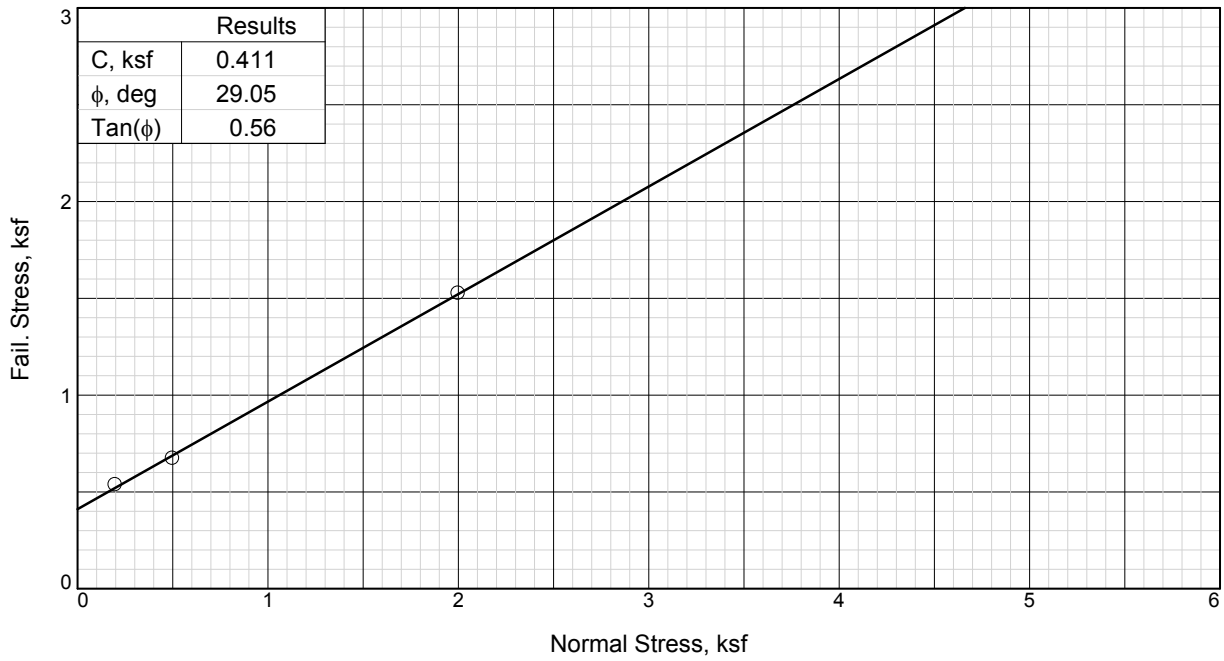
Project: Rocky Flats-SPPTS

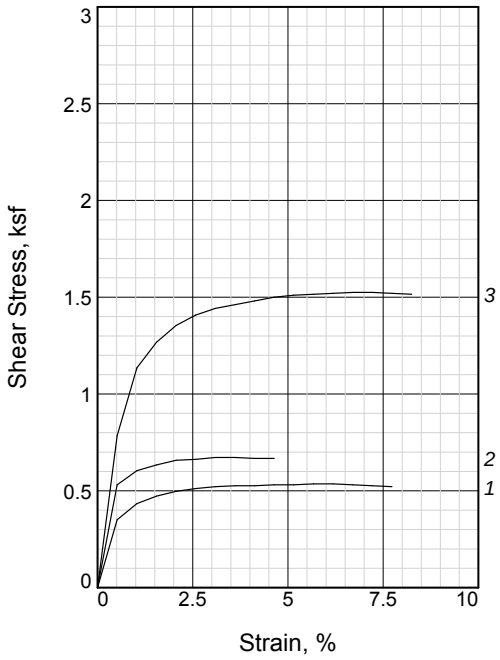
Source of Sample: Tt-1 **Depth:** 2'B

Proj. No.: 114-181919A **Date Sampled:**

DIRECT SHEAR TEST REPORT

Tetra Tech, Inc.





Sample No.		1	2	3
Initial	Water Content, %	19.4	19.4	19.4
	Dry Density, pcf	99.7	100.3	103.0
	Saturation, %	76.0	77.1	82.3
	Void Ratio	0.6906	0.6804	0.6360
	Diameter, in.	1.940	1.940	1.940
	Height, in.	0.500	0.500	0.500
At Test	Water Content, %	30.6	29.5	27.8
	Dry Density, pcf	99.3	98.9	98.6
	Saturation, %	118.3	113.3	105.6
	Void Ratio	0.6970	0.7036	0.7099
	Diameter, in.	1.940	1.940	1.940
	Height, in.	0.502	0.507	0.523
Normal Stress, ksf		0.200	0.500	2.000
Fail. Stress, ksf		0.536	0.672	1.525
Strain, %		5.7	3.1	6.7
Ult. Stress, ksf				
Strain, %				
Strain rate, in./min.		0.004	0.004	0.004

Sample Type: Undisturbed
Description:

Assumed Specific Gravity= 2.70
Remarks:

Figure B7

Client: Stoller

Project: Rocky Flats-SPPTS

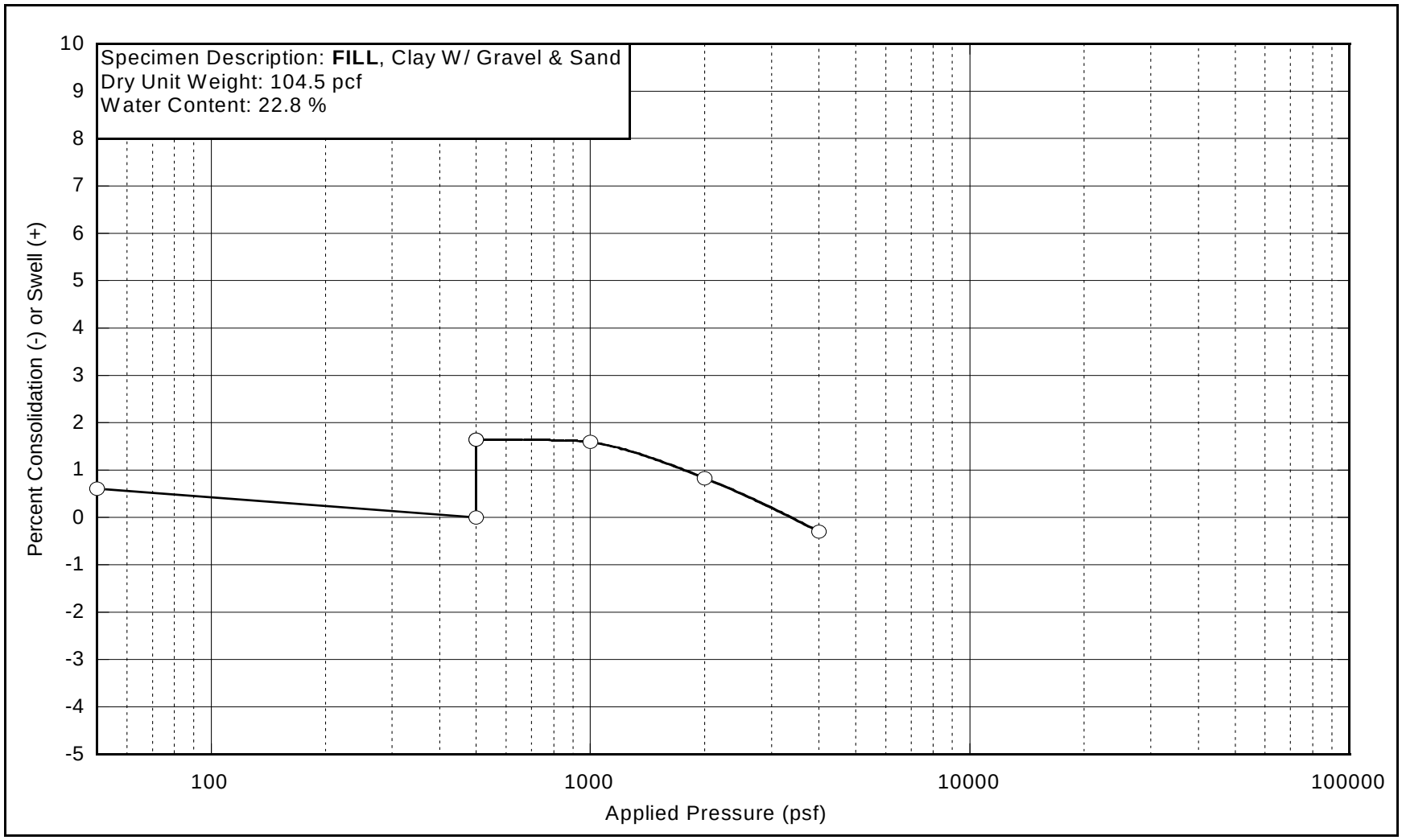
Source of Sample: Tt-2 **Depth:** 15'A

Proj. No.: 114-181919A **Date Sampled:**

DIRECT SHEAR TEST REPORT

Tetra Tech, Inc.

Consolidation / Swell Test Results



Consolidation/Swell Test for Tt-1 at 5'A

Project Name	Rocky Flats SPPTS
Project Number	181919A
Initial Date of Test	August 3, 2009
Date of Test Completion	August 10, 2009
Sample ID	Tt-1 @ 5'A
Consol. Machine No.	21

= Input Cells
= Calculated Values

Sample Dimensions

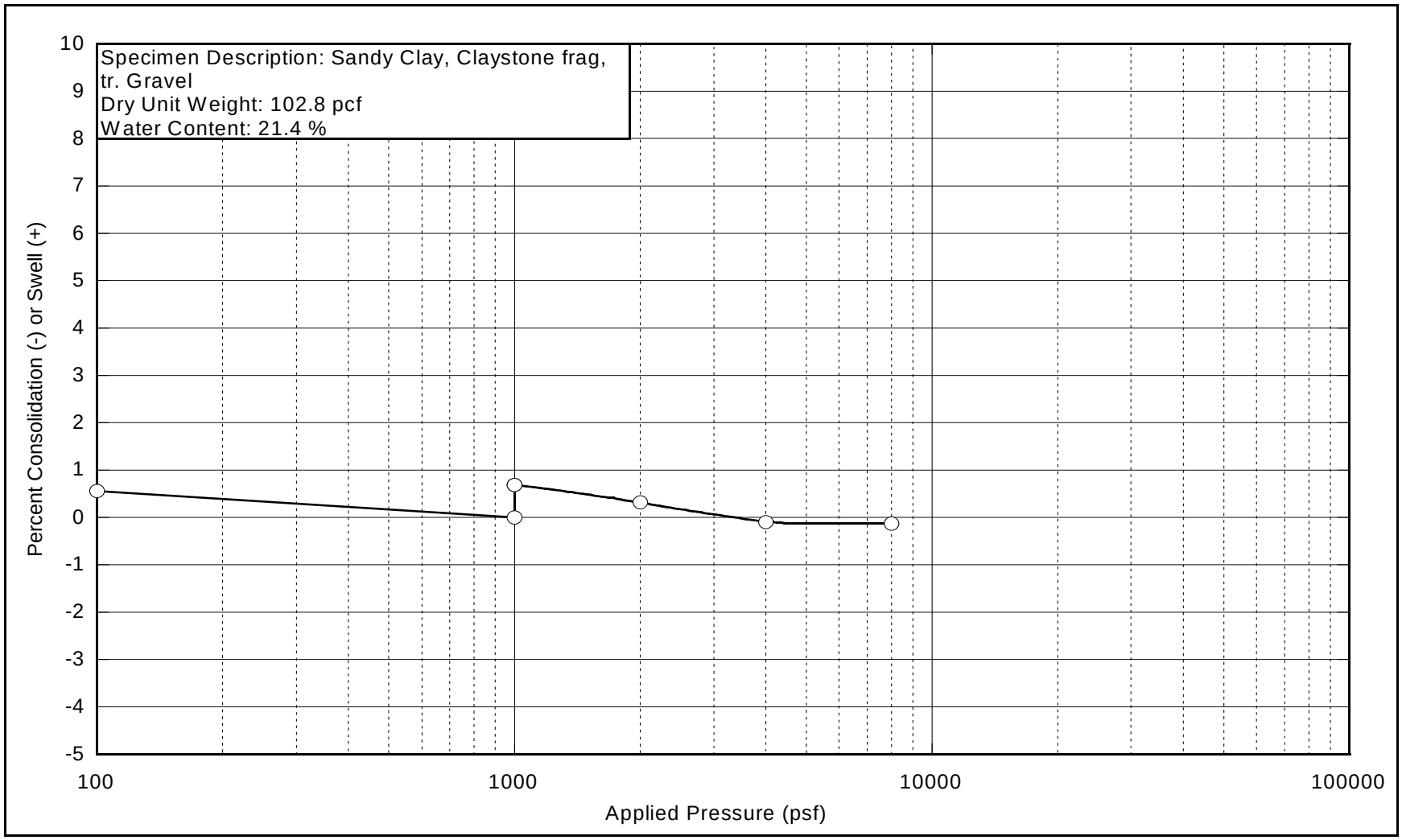
Diameter (in)	1.927
Ring Height (in)	1.003
Spacer Thickness (in)	0.207
Specimen Height (in)	0.796
Area (in^2)	2.92
Specimen Volume (in^3)	2.32

Soil Information

Assumed G_s	2.7
Dry Density (lb/ft^3)	104.5
Moisture (%)	22.8
H_{total} (in)	0.796
H_{solids} (in)	0.494
H_{voids} (in)	0.302
Initial void ratio	0.6122

Moisture	as-received	as-received	saturated	saturated	saturated	saturated	saturated	saturated	saturated
Load Desc.	pre-loading	seating	inundate	loading 1	Loading 2	Loading 3	Loading 4	Loading 5	unloading
Load (pcf)	50	500	500	1000	2000	4000	4000	4000	
Machine Rebound									
Machine Deflection	0	-29	-38	-50	-67	-86	-86	-86	-86
D_0		1837	1760	1882	1866	1788	1679	1679	1679
D_{100}	1837	1760	1882	1866	1788	1679	1679	1679	
D_0 corrected		1837	1789	1920	1916	1855	1765	1765	1765
D_{100} corrected	1837	1789	1920	1916	1855	1765	1765	1765	86
ΔH (in)	0.0000	-0.0048	0.0083	0.0079	0.00180	-0.00720	-0.0072	-0.0072	
Strain (%)	0.0000	-0.6030	1.0427	0.9925	0.2261	-0.9045	-0.9045	-0.9045	#VALUE!
Norm. Strain (%)	0.603	0.000	1.646	1.595	0.829	-0.302	-0.302	-0.302	#VALUE!
void ratio	0.6122	0.6025	0.6291	0.6282	0.6159	0.5977	0.5977	0.5977	

Percent Swell	**1.6**
Swell Pressure (psf)	**3,325**



Consolidation/Swell Test for Tt-1 at 15'A

Project Name	Rocky Flats SPPTS
Project Number	181919A
Initial Date of Test	August 3, 2009
Date of Test Completion	August 7, 2009
Sample ID	Tt-1 @ 15'A
Consol. Machine No.	22

= Input Cells
= Calculated Values

Sample Dimensions

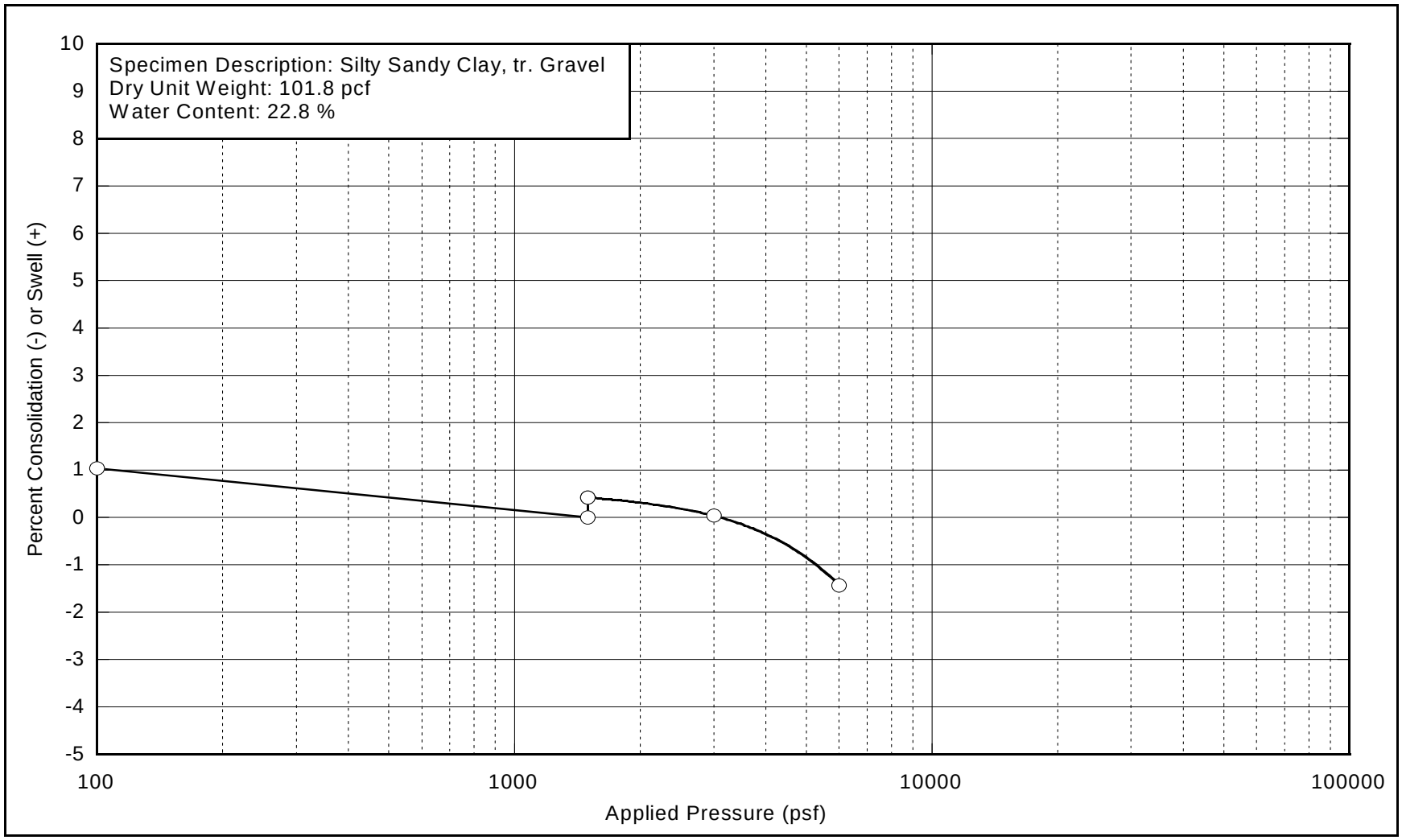
Diameter (in)	1.932
Ring Height (in)	1.01
Spacer Thickness (in)	0.207
Specimen Height (in)	0.803
Area (in^2)	2.93
Specimen Volume (in^3)	2.35

Soil Information

Assumed G_s	2.7
Dry Density (lb/ft^3)	102.8
Moisture (%)	21.4
H_{total} (in)	0.803
H_{solids} (in)	0.490
H_{voids} (in)	0.313
Initial void ratio	0.6389

Moisture	as-received	as-received	saturated	saturated	saturated	saturated	saturated	saturated	saturated
Load Desc.	pre-loading	seating	inundate	loading 1	Loading 2	Loading 3	Loading 4	Loading 5	unloading
Load (pcf)	100	1000	1000	2000	4000	8000	8000	8000	
Machine Rebound									
Machine Deflection		-48	-61	-81	-93	-111	-111	-111	-111
D_0		1595	1502	1544	1494	1449	1428	1428	1428
D_{100}	1595	1502	1544	1494	1449	1428	1428	1428	
D_0 corrected		1595	1550	1605	1575	1542	1539	1539	1539
D_{100} corrected	1595	1550	1605	1575	1542	1539	1539	1539	111
ΔH (in)	0.0000	-0.0045	0.0010	-0.0020	-0.00530	-0.00560	-0.0056	-0.0056	
Strain (%)	0.0000	-0.5604	0.1245	-0.2491	-0.6600	-0.6974	-0.6974	-0.6974	#VALUE!
Norm. Strain (%)	0.560	0.000	0.685	0.311	-0.100	-0.137	-0.137	-0.137	#VALUE!
void ratio	0.6389	0.6297	0.6410	0.6348	0.6281	0.6275	0.6275	0.6275	

Percent Swell	**0.7**
Swell Pressure (psf)	**3,381**



Consolidation/Swell Test for Tt-2 at 20'A

Project Name	Rocky Flats SPPTS
Project Number	181919A
Initial Date of Test	August 3, 2009
Date of Test Completion	August 7, 2009
Sample ID	Tt-2 @ 20'A
Consol. Machine No.	23

= Input Cells
= Calculated Values

Sample Dimensions

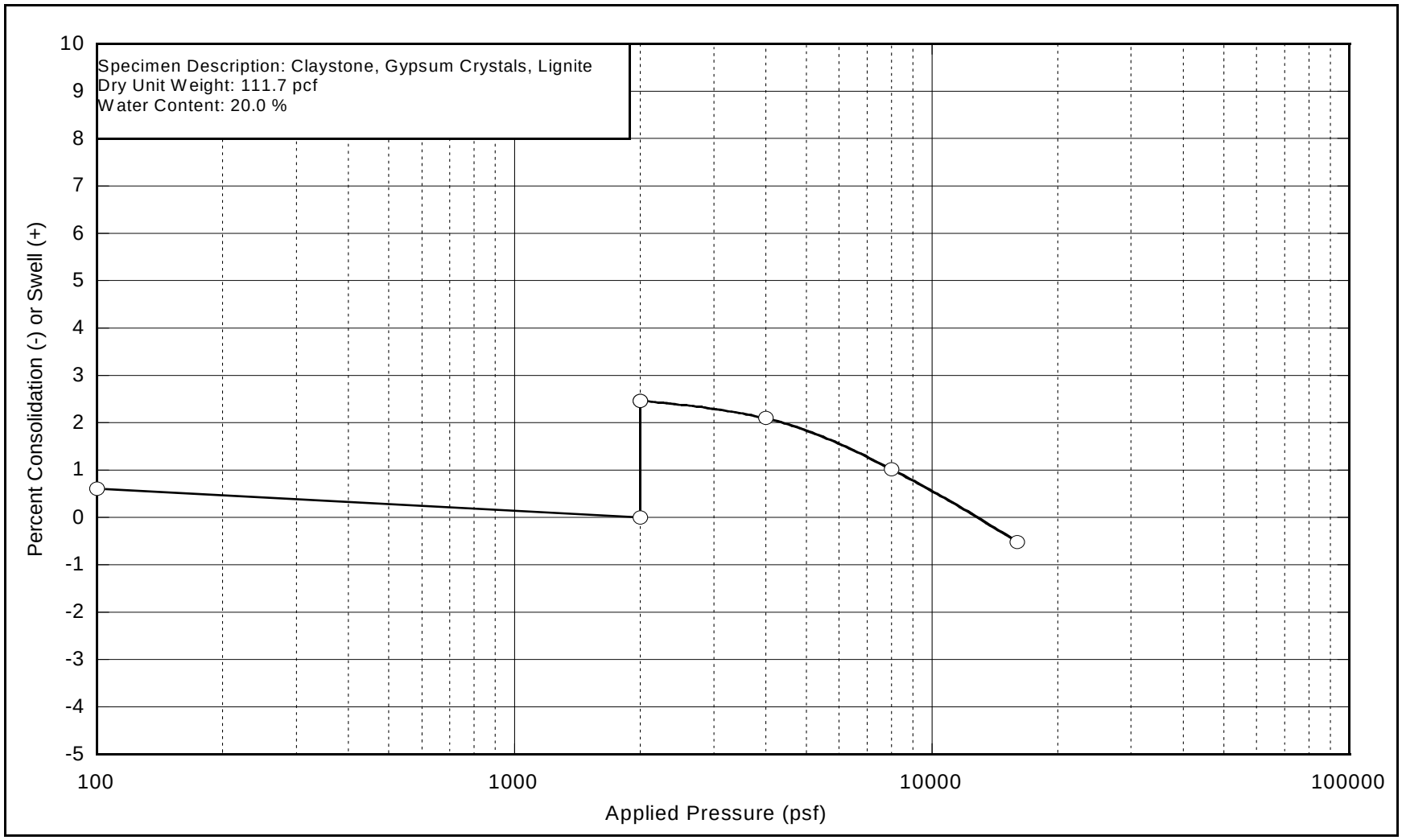
Diameter (in)	1.926
Ring Height (in)	1.001
Spacer Thickness (in)	0.207
Specimen Height (in)	0.794
Area (in^2)	2.91
Specimen Volume (in^3)	2.31

Soil Information

Assumed G_s	2.7
Dry Density (lb/ft^3)	111.2
Moisture (%)	15.3
H_{total} (in)	0.794
H_{solids} (in)	0.524
H_{voids} (in)	0.270
Initial void ratio	0.5151

Moisture	as-received	as-received	saturated	saturated	saturated	saturated	saturated	saturated	saturated
Load Desc.	pre-loading	seating	inundate	loading 1	Loading 2	Loading 3	Loading 4	Loading 5	unloading
Load (pcf)	100	1500	1500	3000	6000	6000	6000	6000	
Machine Rebound									
Machine Deflection		-22	-24	-40	-59	-59	-59	-59	-59
D_0		5072	4968	4999	4953	4817	4817	4817	4817
D_{100}	5072	4968	4999	4953	4817	4817	4817	4817	
D_0 corrected		5072	4990	5023	4993	4876	4876	4876	4876
D_{100} corrected	5072	4990	5023	4993	4876	4876	4876	4876	59
ΔH (in)	0.0000	-0.0082	-0.0049	-0.0079	-0.01960	-0.01960	-0.0196	-0.0196	
Strain (%)	0.0000	-1.0327	-0.6171	-0.9950	-2.4685	-2.4685	-2.4685	-2.4685	#VALUE!
Norm. Strain (%)	1.033	0.000	0.416	0.038	-1.436	-1.436	-1.436	-1.436	#VALUE!
void ratio	0.5151	0.4995	0.5058	0.5000	0.4777	0.4777	0.4777	0.4777	

Percent Swell	**0.4**
Swell Pressure (psf)	**3,054**



Consolidation/Swell Test for Tt-4 at 30'A

Project Name	Rocky Flats SPPTS
Project Number	181919A
Initial Date of Test	August 3, 2009
Date of Test Completion	August 10, 2009
Sample ID	Tt-4 @ 30'A
Consol. Machine No.	21

= Input Cells
= Calculated Values

Sample Dimensions

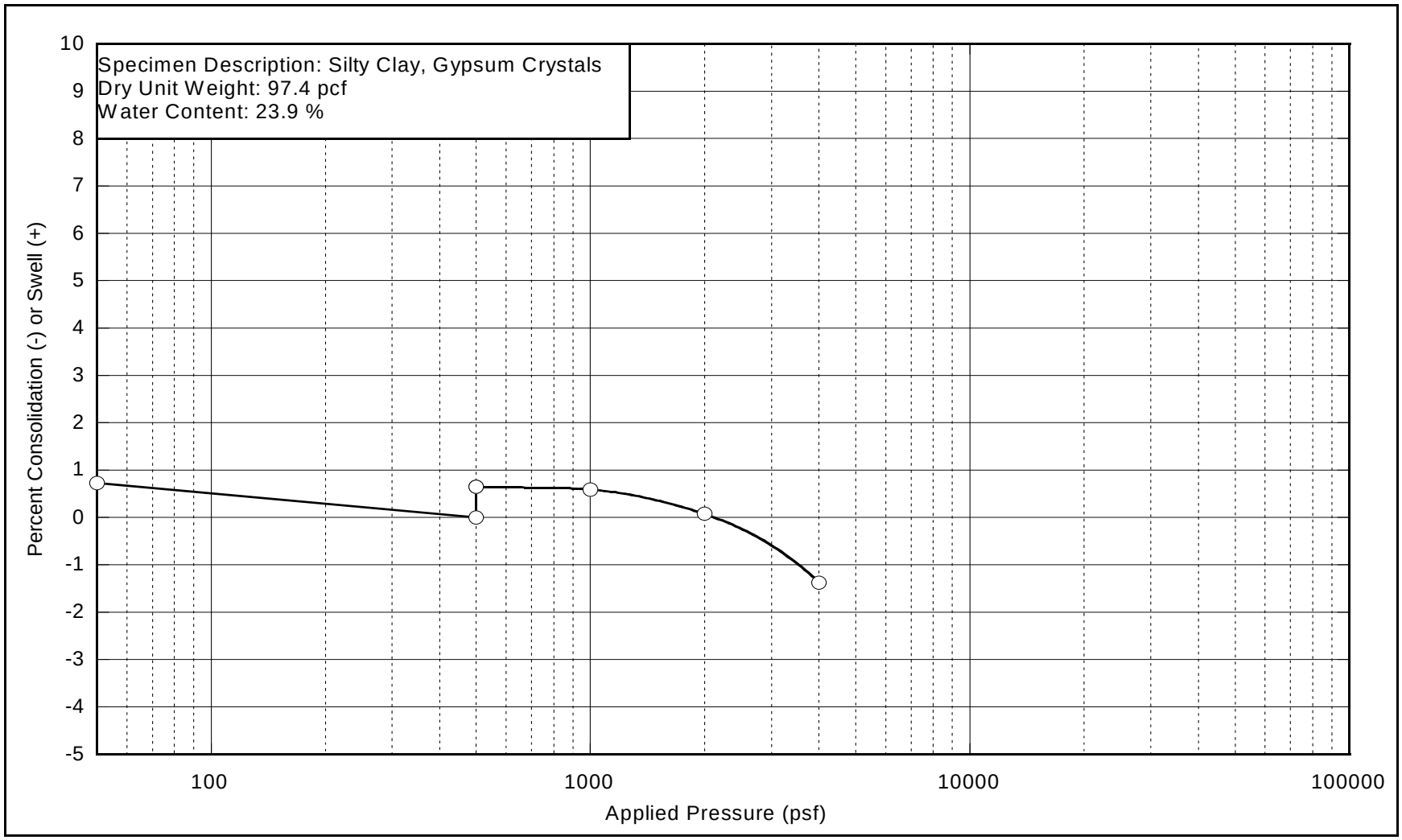
Diameter (in)	1.927
Ring Height (in)	1.003
Spacer Thickness (in)	0.207
Specimen Height (in)	0.796
Area (in^2)	2.92
Specimen Volume (in^3)	2.32

Soil Information

Assumed G_s	2.7
Dry Density (lb/ft^3)	104.5
Moisture (%)	22.8
H_{total} (in)	0.796
H_{solids} (in)	0.494
H_{voids} (in)	0.302
Initial void ratio	0.6122

Moisture	as-received	as-received	saturated	saturated	saturated	saturated	saturated	saturated	saturated
Load Desc.	pre-loading	seating	inundate	loading 1	Loading 2	Loading 3	Loading 4	Loading 5	unloading
Load (pcf)	100	2000	2000	4000	8000	16000	16000	16000	
Machine Rebound									
Machine Deflection	0	-15	-17	-29	-39	-48	-48	-48	-48
D_0		7557	7494	7688	7647	7551	7420	7420	7420
D_{100}	7557	7494	7688	7647	7551	7420	7420	7420	
D_0 corrected		7557	7509	7705	7676	7590	7468	7468	7468
D_{100} corrected	7557	7509	7705	7676	7590	7468	7468	7468	48
ΔH (in)	0.0000	-0.0048	0.0148	0.0119	0.00330	-0.00890	-0.0089	-0.0089	
Strain (%)	0.0000	-0.6030	1.8593	1.4950	0.4146	-1.1181	-1.1181	-1.1181	#VALUE!
Norm. Strain (%)	0.603	0.000	2.462	2.098	1.018	-0.515	-0.515	-0.515	#VALUE!
void ratio	0.6122	0.6025	0.6422	0.6364	0.6189	0.5942	0.5942	0.5942	

Percent Swell	**2.5**
Swell Pressure (psf)	**12,675**



Consolidation/Swell Test for Tt-6 at 10'A

Project Name	Rocky Flats SPPTS
Project Number	181919A
Initial Date of Test	August 3, 2009
Date of Test Completion	August 10, 2009
Sample ID	Tt-6 @ 10'A
Consol. Machine No.	25

= Input Cells
= Calculated Values

Sample Dimensions

Diameter (in)	1.929
Ring Height (in)	1
Spacer Thickness (in)	0.207
Specimen Height (in)	0.793
Area (in^2)	2.92
Specimen Volume (in^3)	2.32

Soil Information

Assumed G_s	2.7
Dry Density (lb/ft^3)	97.4
Moisture (%)	23.9
H_{total} (in)	0.793
H_{solids} (in)	0.458
H_{voids} (in)	0.335
Initial void ratio	0.7298

Moisture	as-received	as-received	saturated	saturated	saturated	saturated	saturated	saturated	saturated
Load Desc.	pre-loading	seating	inundate	loading 1	Loading 2	Loading 3	Loading 4	Loading 5	unloading
Load (pcf)	50	500	500	1000	2000	4000	4000	4000	
Machine Rebound									
Machine Deflection	0	-10	-13	-33	-60	-91	-91	-91	-91
D_0		5084	5016	5064	5040	4972	4826	4826	4826
D_{100}	5084	5016	5064	5040	4972	4826	4826	4826	
D_0 corrected		5084	5026	5077	5073	5032	4917	4917	4917
D_{100} corrected	5084	5026	5077	5073	5032	4917	4917	4917	91
ΔH (in)	0.0000	-0.0058	-0.0007	-0.0011	-0.00520	-0.01670	-0.0167	-0.0167	
Strain (%)	0.0000	-0.7314	-0.0883	-0.1387	-0.6557	-2.1059	-2.1059	-2.1059	#VALUE!
Norm. Strain (%)	0.731	0.000	0.643	0.593	0.076	-1.375	-1.375	-1.375	#VALUE!
void ratio	0.7298	0.7171	0.7282	0.7274	0.7184	0.6933	0.6933	0.6933	

Percent Swell	**0.6**
Swell Pressure (psf)	**2,074**

APPENDIX C

GEOTECHNICAL CALCULATIONS

Table C.1 Helical Pier Sizing Recommendations (Magnum Piering, Inc.)

Boring ID	Depth	Soil Type	Blow Count	Circular Helix Diameter of Pier[1]	Ultimate Foundation Capacity[1]	Circular Helix Diameter of Pier[2]	Ultimate Foundation Capacity[2]
	(ft bgs)		N	(in)	(kips)	(in)	(kips)
Tt-1	2	**Clay Fill**	**13**	**10**	**5**	**12**	**6**
Tt-1	5	Clay Fill	8	**10**	**3**	**12**	**4**
Tt-1	10	Clay Fill	5	**10**	**2**	**12**	**2**
Tt-1	15	**Clay Fill**	7	**10**	**3**	**12**	**4**
Tt-1	20	Gravelly Sand	18	**10**	**10**	**12**	**10**
Tt-1	25	Claystone	56	**10**	**45**	**12**	**47**
Tt-1	30	Claystone	92	**10**	**72**	**12**	**74**
Tt-2	2	Clay Fill	18	**10**	**10**	**12**	**10**
Tt-2	5	Clay Fill	18	**10**	**10**	**12**	**10**
Tt-2	10	Clay Fill	18	**10**	**10**	**12**	**10**
Tt-2	15	Clay Fill	17	**10**	**9**	**12**	**9**
Tt-2	20	Sandy Clay	16	**10**	**9**	**12**	**8**
Tt-2	25	Gravelly Sand	46	**10**	**38**	**12**	**39**
Tt-2	30	Weathered Claystone	51	**10**	**40**	**12**	**43**
Tt-2	35	Claystone	50/5”	**10**	**40**	**12**	**43**
Tt-3	2	Clay Fill	13	**10**	**5**	**12**	**6**
Tt-3	5	Clay Fill	24	**10**	**12**	**12**	**12**
Tt-3	10	Clay Fill	33	**10**	**18**	**12**	**17**
Tt-3	15	Clay Fill	24	**10**	**12**	**12**	**12**
Tt-3	20	Clay Fill	25	**10**	**13**	**12**	**13**
Tt-3	25	Clay Fill	39	**10**	**20**	**12**	**20**
Tt-3	27	Clay Fill	53	**10**	**42**	**12**	**44**
Tt-3	30	Weathered Claystone	54	**10**	**43**	**12**	**44**
Tt-3	35	Claystone	68	**10**	**27**	**12**	**57**

Table C.1 Continued. Helical Pier Sizing Recommendations (Magnum Piering, Inc.)

Boring ID	Depth	Soil Type	Blow Count	Circular Helix Diameter of Pier[1]	Ultimate Foundation Capacity[1]	Circular Helix Diameter of Pier[2]	Ultimate Foundation Capacity[2]
	(ft bgs)		N	(in)	(kips)	(in)	(kips)
Tt-4	2	**Clay Fill**	**16**	**10**	**9**	**12**	**8**
Tt-4	5	Clay Fill	18	**10**	**10**	**12**	**10**
Tt-4	10	Clay Fill	29	**10**	**15**	**12**	**16**
Tt-4	15	**Clay Fill**	47	**10**	**38**	**12**	**23**
Tt-4	20	Clay Fill	50/4”	**10**	**40**	**12**	**43**
Tt-4	25	Weathered Claystone	14	**10**	**6**	**12**	**7**
Tt-4	30	Claystone	65	**10**	**50**	**12**	**54**
Tt-5	2	Clay Fill	14	**10**	**6**	**12**	**7**
Tt-5	5	Clay Fill	17	**10**	**9**	**12**	**9**
Tt-5	10	Clay Fill	28	**10**	**15**	**12**	**14**
Tt-5	15	Clay Fill	20	**10**	**11**	**12**	**12**
Tt-5	20	Clay Fill	41	**10**	**32**	**12**	**21**
Tt-5	25	Weathered Claystone	27	**10**	**13**	**12**	**13**
Tt-5	30	Claystone	78	**10**	**62**	**12**	**66**
Tt-6	10	Clay Fill	8	**10**	**3**	**12**	**4**
Tt-6	15	Clay Fill	9	**10**	**4**	**12**	**5**
Tt-6	20	Clay Fill	15	**10**	**6**	**12**	**8**
Tt-6	25	Clay Fill	43	**10**	**35**	**12**	**22**
Tt-6	30	Clay Fill	38	**10**	**31**	**12**	**20**
Tt-6	35	Claystone	50/3”	**10**	**40**	**12**	**43**

Note: 1) Circular Helix Pier

2) Circular Helix Pier with double cutting edge

Magnum Helical Pile System

Magnum offers superior round shaft helical piles ranging in load capacities from 16 Tons to 200 Tons.

The helical pile product line includes:

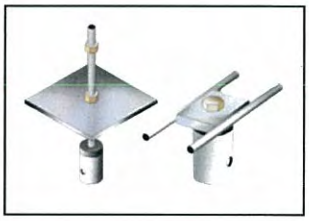
- 3" O.D. - 4 products ranging from 16 Ton to 50 Ton ultimate capacity
- 4.5" O.D. - 4 products ranging from 70 Ton to 97 Ton ultimate capacity
- 5.72" O.D. - 6 products ranging from 92 Ton to 200 Ton ultimate capacity

(see ProductSpecifications for detailed information)

There are many applications for the Magnum Helical Piles including:

- Deep Foundation Piles for New Construction
- Concrete-Less Foundations for Light Construction
- Concrete Slab Lifting & Stabilization
- Temporary & Permanent Shoring
- Underpinning Commercial & Residential Structures
- Tiebacks & Wall Anchors
- Earth Anchors for Slope Stabilization
- Temporary & Reusable Tilt-Up Wall Anchors
- Boardwalks & Pedestrian Bridges
- Sea Walls & Bulkheads
- Pipeline & Utility Tie Downs

Helical piles have significant load bearing capacity and are used in both compression (downward) and tension (uplift) applications. When a helical pier is installed into suitable soil, the load of the structure is transferred to the bearing plates welded to the shaft.



The primary benefits of Magnum Helical Piles are:

- ***Fast Installation*** – 30 to 40 a day (depending upon depth) with a single installation device & one 3 man crew
- ***Pre-Engineered System*** – capacity-to-torque ratio produces completely predictable installation results
- ***Variety of Piles & Capacities*** – capacities ranging from 8 tons to 200 tons; wide selection of products to match capacity requirement
- ***No Soil Spoils*** – eliminates removal costs; perfect for environmentally sensitive sites
- ***Small Maneuverable Installation Equipment*** – minimal equipment costs; no vibration
- ***Dual Cutting Edge Blades*** – patented design enables superior pier installation through cobbles, tightly compacted clay soils & dense fill materials
- ***Single Bolt Connection for 3" Product Line*** – for fast & efficient installation

Magnum installers have installed our helical piles across the country from Manhattan to the mountains of Colorado and West Virginia to the waterways and swamplands in Florida.

Patent #6,058,662
Magnum® Dual Cutting Edge (DCE) Blade™

Patent # 6,058,662
Magnum® Dual Cutting Edge (DCE) Blade™ This revolutionary patented blade design enables Magnum Helical Piles to penetrate difficult soils including very dense gravel, soils laden with occasional cobbles and even fill soils containing trash like trees, concrete debris, small to medium rocks, etc.

The patented DCE Blade can even penetrate sedimentary bedrock with standard penetration test (SPT) blow counts of up to 50 blows for 6 inches.

Read what Magnum installers are saying about the Magnum DCE Blade.

Mr. Joe Loudermilk
Partner – Extreme Technology's, Atlanta, GA
"Magnum's Helical Piles with the DCE Blade are the best helical piles I've ever installed. The blade design virtually eliminates any side-to-side (wobble) motion and the piers advance in our dense clay soils just like a screw into wood."

Mr. Ross Kirk
Owner – Marco Concrete Lifting, Charleston, WV
"Hands down the best blade design for penetrating our dense West Virginia clay soils. The Magnum DCE blade even allows us to penetrate our shale formations without deflection or failure. The DCE blades are great!"

Mr. Jerry Lipe
Owner – Lipe Brothers Construction, Duluth, MN
"Our crews specify the Magnum DCE blades for our helical piles because the blade is able to penetrate the Laurentian Shield formations in our region. Often times we encounter these layers at very shallow depths, and the DCE blades will cut through it so we can get below frost depths and into good tight clays."

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