Mulry and Cresswell Environmental, Inc.

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FREE PRODUCT DELINEATION ALONG SHUNK ST. SEWER

BELMONT MARKETING TERMINAL
26TH STREET AND PASSYUNK AVENUE
PHILADELPHIA , PA

26 JANUARY 1998

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Draft
Belmont Terminal, Shunk Street Sewer
Separate Phase Hydrocarbon Delineation / Remedial Testing Results
Revised 26 January, 1998

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I) Introduction

The Sun Company (R&M), Sun, Belmont Marketing Terminal is a truck petroleum loading facility adjacent to Sun's Philadelphia refinery located on the south side of Passyunk Avenue at the intersection of 26th Street in South Philadelphia (see Figure I). The Study Area of this report is the portion of the Terminal property through which the City of Philadelphia Shunk Street sewer passes, which is south of the Terminal office building and north of the facility's truck loading rack.

A City of Philadelphia combined storm and sanitary sewer line, the Shunk Street sewer, crosses the Terminal property in an approximately east - west direction and crosses under Passyunk Ave. in the vicinity of the Terminal main gate (see Figure II). The sewer was installed in the early 1900's and is reported thirteen feet in diameter constructed of brick. The top of the sewer is estimated to be approximately twenty feet below the current grade of the terminal parking lots and extends to approximately thirty three feet below this grade. The dimensions of the excavation in which the sewer was constructed, the methods of excavation employed and the nature and extent of fill used in restoring the sewer excavation are not known. In response to reports of hydrocarbon odors in the sewer and a visual inspection of the sewer line under the Terminal property conducted by the City of Philadelphia Water Department which reported hydrocarbon infiltration to the sewer line in this area, Sun contracted Mulry and Cresswell Environmental, Inc. (MCE) to conduct a subsurface investigation of the area.

Between 13 and 19 November 1997 MCE in conjunction with B.L. Myers Bros., Inc., a Pennsylvania certified and licensed drilling company installed seventeen borings on the Terminal property along the Shunk Street sewer, both north and south of the sewer line. Depending on whether or not a boring was to be completed as a temporary two inch diameter well or a permanent four or six inch diameter well, borings were drilled to either thirty five (temporary, 2" diameter) or fifty feet (4" and 6" diameter) below grade. The relative casing elevation of each well was surveyed by transit and rod, depth to water and or separate phase hydrocarbon (product) was measured and product bail-down and recovery tests were performed. Pumping tests were performed on three wells , RW 6, RW 15 and OW 17, and vacuum extraction tests via vacuum truck RW 6) and VR unit (OW 17) were performed on two wells.

This report describes the methods and results of the investigation along the Shunk Street sewer line on the Belmont Terminal property and contains conclusions draw from these results and the results of remdiation feasibility testing conducted at the site.

II) Scope of Investigative Activities Conducted

To delineate the areal extent of separate phase hydrocarbon (free product) on the water table along the Shunk Street sewer, a grid was constructed with nodes spaced at alternating fifty foot intervals, north and south of the sewer along the length of the sewer in the study area. Prior to drilling, the Pennsylvania One Call, Inc. was notified to allow utility owners with potential conflicts to mark out subsurface utilities. All available drawings depicting subsurface features were reviewed and the borings were hand dug to at least four feet below grade prior to drilling with a rig. Fourteen borings were installed from east to west as determined by field monitoring during drilling. All borings were completed as two inch, four inch or six inch diameter wells, again based on field monitoring.

The relative casing elevations of the wells were surveyed by transit and rod and water table elevations in all wells determined. Wells were gauged frequently from 18 November through 19 December 1997 to allow determination of the areal extent of separate phase hydrocarbons and water table gradient. Pumping tests were conducted on RWs 6 and 15 and OW 17 to define aquifer characteristics in the study area and to gather data necessary for devising a remediation strategy. Soil vapor extraction testing, also to aid in formulating a remediation plan, was conducted on RW 6 utilizing a vacuum truck and on RW 15 utilizing a VR3 vapor extraction and thermal oxidizing unit.

The results of the execution of these work items are discussed below.

III) Boring and Well Installation

As depicted on Figure II, the Shunk Street Sewer crosses the Belmont Terminal property from east to west, passing between the Terminal offices and truck loading racks. As mentioned above, the sewer, constructed of brick sometime prior to 1904, is thirteen feet in diameter and extends from approximately twenty to thirty three feet below the grade of the terminal parking areas. A visual inspection of the sewer conducted by the City of Philadelphia Water Department reported separate phase hydrocarbons (product) entering the sewer line somewhere between the two manholes inside the study area. In order to determine if a product plume underlies the study area in the vicinity of or in contact with the sewer line, thirteen borings were installed both north and south of the sewer along the length of the sewer on the Terminal property between 14 and 19 November 1997 and one additional well was drilled on 8 December 1997. Initially borings were installed to total depths of thirty five feet below grade and temporarily fitted with two inch diameter PVC well screen to determine the depth of the water table and allow liquid level gauging for the presence of free product. In areas where free product was encountered, borings were drilled to fifty feet below grade and completed with four inch or six inch schedule 40 PVC well screen (0.02" slot) and solid riser pipe to provide permanent wells. Figure III depicts the location and diameter of the wells installed. As presented on Figure III, a total of fourteen borings were installed and completed as temporary (TW) or permanent (RW or OW) wells: six four inch wells (OWs 2, 12, 13, 14, 16, and 17); two six inch wells (RW 6 and RW 15); and six two inch wells (TWs 3, 5, 8, 9, 10, and 11). The well designations as presented on Figure III are based on a combination of the original proposed boring locations, based on a one hundred foot grid overlying the area where the sewer crosses the terminal property, and the actual order in which borings were drilled which was field determined based on cumulative observations during drilling and well gauging.

All borings were installed by hollow stem augering and advanced with collection of split spoon samples at five foot intervals until the desired total depth was obtained. Collected split spoon samples were field screened with a Thermo Environmental Instruments model 580B Organic Vapor Monitor (OVM) which is an intrinsically safe photo ionization detector. Field headspace analysis consisted of transferring sample from the split spoon sample barrel to a "zip-lock" plastic bag, sealing the bag and allowing the sample to equilibrate with the headspace for an approximate duration of two to five minutes. After equilibration, the "zip-lock" was opened just enough to allow insertion of the probe tip of the OVM and the maximum OVM response for each sample was recorded for inclusion in the drilling log (see Appendix A). Well screen and solid pipe were lowered into the boring and for the permanent wells, clean quartz sand pack was poured into the augers to fill the annular space as the augers were retrieved. At least one foot of sand was placed above the screen/solid riser pipe joint. A minimum one foot hydrated bentonite pellet seal was placed over the sand pack and the remaining annular space was filled to grade with drill cuttings. For the temporary wells, the augers were pulled from the boring and the annular space was backfilled with drill cuttings. All permanent wells were capped with locking cap (gripper plug) although only RW 1 (formerly RW 15) outside the fence was fitted with a lock. The temporary wells were sealed with a two inch PVC slip cap. All well heads were finished to grade with a steel manhole. The manholes were not set in concrete as future work will probably require re-accessing many of the wells for plumbing installations.

Drilling logs for all borings and wells recording lithology, OVM responses, construction details and observations for each boring are contained in Appendix A.

IV) Geology

The study area is located in the lowland and intermediate upland section of the Atlantic Coastal Plain Physiographic Province. This Province is characterized by a flat upper terrace surface cut by narrow steep-sided valleys to open, shallow valleys, including the Delaware River floodplain. The underlying deposits are fluvial in origin including glacial meltwater and consist of unconsolidated to poorly consolidated sand and gravel.

From the presence of the sewer line beneath the investigated area it can be inferred that all the borings encountered the backfill of the sewer construction excavation, at least to the suspected depth of the bottom of the sewer line, e.g. approximately thirty three feet below grade. A generalized geologic cross section constructed from all boring logs is attached as Figure V. As depicted on the cross section, obvious anthropogenic fill was observed in most borings to depths of up to twenty feet below grade (RW 6). Sand and gravel was encountered below the fill as the predominant unit in all borings. Exceptions to the undifferentiated sand and gravel with varying amounts of silt and clay were:

- a clay unit of five foot maximum thickness was encountered from approximately fifteen to twenty feet below grade in the western portion of the investigation area in wells TW 8, TW 10, and OW 12;
- a gravel rich unit of a few foot thickness was encountered in all wells except OW 2 and TW 11, dipping to the east. It was encountered at approximately sixteen feet below grade at the western end of the investigation area (RW 15) to a depth of approximately twenty nine feet below grade in the eastern end of the investigation area (OW 14). A hard gravel layer of less than one foot thickness was encountered at approximately seventeen feet below grade in well TW 5 and approximately twenty seven feet below grade in well RW 6;
- a silt unit was encountered for the entire depth of well OW 2.

Although separated into distinct lithologic units on the drilling logs and cross section, it is probable that the entire area is comprised of undifferentiated native sediments utilized as fill. For the purposes of this investigation and subsequent remediation efforts, the entire area can be considered a mixture of sand and gravel with varying silt and clay content. No continuous lithologic units were observed that would be expected to significantly influence the hydraulic characteristics of the subsurface in the area of the Shunk Street sewer line.

V) Hydrogeology

Groundwater at the study area is encountered under water table conditions at approximately twenty six to thirty feet below grade. Regional groundwater flow is expected to be towards the Schuylkill River to the west. From groundwater elevation data collected at another site in the area, the Sunoco Station at 28th and Passyunk, across Passyunk Avenue from the study area, local groundwater flow has been documented as to the south-southwest. Subsurface utilities also can influence local groundwater elevations to the point of creating local gradients that do not conform to the regional gradient. Water distribution and sewer lines often have minor leaks which can influence the local water table gradients. The City sewer systems are known to influence groundwater gradients along 26th Street and Packer Ave. In addition to leaks to or from these utilities, the presence of the backfilled trenches these utilities were constructed in are more permeable than and therefore preferential groundwater flow pathways over the undisturbed native geology. All of these factors could locally change the water table gradient compared to the anticipated regional gradient.

Plots of the groundwater elevation data collected from the wells installed at the Study area, along the Shunk Street sewer are displayed in Figures V through X. A general gradient to the west along the sewer line of approximately 3% to 4% was noted on the static water table plots constructed from data collected on 18 through 25 November. The addition of well OW 17 in December provided water table elevation data somewhat further from the sewer line. The additional data point indicates a gradient towards the sewer from the southwest in addition to the western gradient along the line. Also present with consistency is an area of higher groundwater elevation in the north east corner of the site, encompassing TW 5 and to a lesser extent, TW 9 and OW 2. This groundwater mound may be due to artificial recharge such as leaking water lines or catch basin drain pipes. In contrast to this mound, the water level in OW 14 was anomalously low on several gauging dates (20, 21 and 25 November and 17 December), it is possible the casing elevation of this well is incorrect or also possible that groundwater is infiltrating the sewer line in this location, lowering the water table elevation. This well was resurveyed on 15 January 1998 to eliminate the possibility of an incorrect casing elevation and the surveyed elevation agreed with the previous elevation. The erratic water elevation in OW14 compared to surrounding wells is probable due to a non-groundwater influence, such as the sewer line or similar cultural phenomenon.

If local groundwater flow on the north side of Passyunk Avenue (Sunoco Station) is towards the southwest and groundwater flow on the south side of the sewer is towards the northwest, the sewer and/or the original excavation the sewer was constructed in is a groundwater discharge feature and local groundwater trough. In this case, any separate phase hydrocarbons in the vicinity of the sewer will migrate to this trough and follow the sewer to the west, providing an opportunity for product migration into the sewer in any areas where the sewer line integrity has been compromised.

VI) Pumping Tests

Three pumping tests were performed on different site wells. Subsequent to development by air lifting, a very brief (two hour) test was conducted on RW 15, a six inch diameter well, on 25 November 1997. A submersible pump with conductivity level controlling probes was deployed near the bottom of the well with the intake at approximately forty eight feet below the top of casing. This well was pumped at approximately 10 gallons per minute for two hours. During that time the product layer in the well increased to as much as 5.1 feet with 7.47 feet of draw down in water elevation. If corrected for the density of the product (assumed to be specific gravity of 0.68), actual draw down would be approximately 4.48 feet. See Figure IX for water and product measurements during the pumping test. The discharge from RW 15 was temporarily piped to a yard drain catch basin which in turn discharges to the refinery waste water collection system. In spite of a separation of approximately fourteen feet between the water/product interface and the pump intake, an oil/water emulsion was observed in the pump effluent and the pump test was terminated. As no exceptional turbulence was anticipated in this well under these pumping conditions, future groundwater pumping from RW 15 or nearby wells should account for the potential of an emulsified discharge.

A longer duration pumping test was conducted on RW 6, a six inch diameter well, also subsequent to development by air lifting on 25 November 1997. A submersible pump capable of producing six gallons per minute (gpm) was deployed near the bottom of the well (50 feet below top of casing (TOC)). Pumping at approximately 6 gpm was conducted for a duration of approximately four hours and forty minutes when the portable generator used to power the pump ran out of gas. Product accumulation, emulsion formation and discharge overflow were not restricting factors in conducting this test. At the pumping rate of approximately 6 gpm, draw down in RW 6 after 285 minutes (four and three quarter hours) was 1.54 feet. Based on a Cooper-Jacob analysis of draw down in nearby observation wells over time, a transmissivity of 1.61×10^{0} ft^2/ min. and hydraulic conductivity of 10^{-2} ft./min. were calculated. While pumping RW 6, draw down was measured in OW 13 (0.17') and TW 3 (0.03') to the west but not OW 2 which actually rebounded by 0.02' during the test. To the east., no draw down was measured in OW 14 or TW 11. North of the sewer TW 5 remained at static and TW 9 fell 0.04'.

A third pumping test was conducted using a four inch well, OW 17, constructed approximately fifty feet south of the sewer, presumably outside the sewer construction excavation. Again the well was developed by air lifting and a submersible pump with conductivity controls was set near the bottom of the well, at approximately forty eight feet below TOC. The initial flow rate was set at six gallons per minute and the discharge was temporarily piped to the nearest yard drain. Pumping at 6 gpm was initiated at 2:59 PM on 17 December 1997 and continued at this rate until 10:08 AM on 18 December when the pump was found to be cycling and the flow rate was reduced to 4 gpm. As with the data from the pump test on RW 6, a Cooper-Jacob distance draw down analysis was conducted for data from observation wells influenced by pumping OW 17. Liquid level changes in response to pumping OW 17 are displayed on Table III. The transmissivity and hydraulic conductivity solutions calculated from the data collected while pumping OW 17 were in excellent agreement for those derived from earlier pump tests, e.g. $T \approx 1.5 \times 10^{0}$ $ft^{2/min.}$ and $k \approx 5 \times 10^{-2}$ ft./min. See Appendix B "Pumping Tests Analyses". From Table III, the decline in water table elevations in wells remote from the pumping well, wells TWs 5, 9, OW 11 and TW 5-73 was 0.06', 0.04', 0.05' and 0.04' respectively. These declines in water levels are considered to be background changes in static levels and not due to pumping effects. All changes of greater magnitude during the pumping test are considered to be in response to the pumping of OW 17. Observed draw down ranged from a maximum in RW 15, not corrected for product thickness increase of 0.88' with a coincidental increase in product thickness of 0.85', to 0.13' in OW 2, more than 260' to the east of the pumping well. If corrected for the increase in product thickness, these declines in water levels still equate to 0.30' in RW 15 and 0.12' in OW 2. While it is uncertain if the cone of depression formed around OW 17 during pumping was adequate to create a gradient away from the sewer line, it is clear that the pumping influence extended to the north side of the sewer line and hundreds of feet along the sewer line. See Figure VIII, the Water Table Elevation plot for 19 December 1997, after more than forty hours of pumping OW 17.

VII) Separate Phase Hydrocarbon (free product) and Bailing Tests

Of the fourteen wells installed, no separate phase hydrocarbons were measured on any of the gauging dates in wells TW 5, 8, 9, 11 and OW 14. Three of these wells, 5, 8 and 9, are on the north side of the Shunk Street Sewer. The other two wells, OW 14 and TW 11 are at the eastern end of the studt area. The product thickness in wells with separate phase hydrocarbons was at a maximum for all but RW 15 and OW 2 on 20 December 1997, at the conclusion of the pumping test on OW 17. Product thickness in RW 15 was greater during the short duration pumping test in RW 15 on 25 November 1997 when a separate phase thickness of over five feet was recorded. Product thickness was measured in RW 6 at a maximum of 0.66' on 18 November 1997, prior to over drilling the well to a six inch diameter.

Several product bailing and recovery tests were performed on wells with significant free product layers, particularly OW 3, RW 6 and OW 12. An attempt to quantify the rate of product accumulation in various wells is presented in Table IV. For the wells in the western portion of the study area, TW 10 and OW 12, product accumulation rates of up to 0.27 GPH (≈6.5 gpd) and 0.02 GPH (≈0.5 gpd) were recorded. Much lower rates were observed for the wells tested in the eastern portion of the site; rates for TWs 2, OW 3 and OW 13 were 0.05 GPH (≈1.2 gpd) for 2 and 3 and 0.08 GPH (≈ 1.9 gpd) for OW 13. The greatest observed rate of product accumulation was in RW 15 during the brief pumping test on this well on 25 November 1997. During the two hours of pumping, product thickness accumulated to a maximum of 5.10' at a maximum observed rate of 15.3 gallons per hour (GPH) at the start of the test. After one half hour of pumping, the product accumulation rate was 8.3 GPH. This rate of product accumulation was not maintained and the product thickness in the well actually declined subsequent to reaching the maximum at thirty minutes into the test. Due to the rapid draw down in the water level in the well, the product accumulation is not believed to be representative of a sustainable rate. It can be considered however as evidence that a separate phase plume that could be recovered in the liquid phase is present near RW 15.

The recovery data from product bailing tests on TW 3, OW 6 (twice before the well was over-drilled to six inch diameter) and OW 12 are presented in tables and graphs in Appendix C. The product thickness in a well is deemed to equal the "true" product thickness, that is the thickness of the hydrocarbon layer on the water table outside the well bore, at the inflection point of water table recharge subsequent to the well being bailed down. The inflection point is the point at which the water level in a recharging well ceases to rise and begins to fall as a result of the weight of a floating product layer in the well. Several attempts were made to remove the product from OW 12 by bailing. All the product could not be removed by this method and the recovery tests conducted therefore started with a free product thickness of more than 0.1'. From the consistency of the post bailing product thickness and the recovery data, the true product thickness in the vicinity of this well is estimated to be 0.08' to 0.10'. Similar testing and analysis were applied to obtain estimated true product thicknesses of 0.04' for OW 3 and between 0.06' and 0.40' for RW 6.

VIII) Soil Vapor Extraction Testing

Prior to concluding the pumping test conducted on RW 6 on 25 November 1997, a vacuum truck was employed to withdraw soil vapors from RW 6. During the application of vacuum to the pumping well, vacuum readings (relative to atmospheric pressure) were conducted at surrounding wells. The vacuum applied to RW 6 was varied from a minimum of 5" Hg to a maximum of 16" Hg. Vacuum communication was consistently measured in OWs 2,13 and 14 and TW 5. The magnitude of measured vacuum communication for various wells is depicted on Figures X-XII.

From the field measurements, a vacuum radius of influence for different applied vacuums at the extraction well(s) can be extrapolated. Figure XIII depicts expected radii of vacuum influence for varied applied vacuums. The significance of this figure is the implication that to cover a one hundred foot length of the sewer with a 0.5 inch water vacuum, two vacuum extraction wells, one hundred feet apart would require an applied vacuum of approximately 72 inches of water gauge vacuum. Extraction wells placed on fifty foot centers would require an approximate vacuum of 30 inches of water gauge.

In addition to the "high vacuum" test conducted on RW 6, a VR3 vapor recovery unit (VR) was connected to RW 15 on 18 December 1997, during the second day of the pumping test on OW 17. The VR would run on well gas only but the controls for mixing auxiliary fuel (propane) would not function. The VR carburetor was manually adjusted to keep the unit running at 1700 RPM with no auxiliary fuel. For the unit to continue to operate the extracted well gas (soil gas) would have to contain hydrocarbon concentrations in the range of 1.4%-6.9%. The VR ran for two brief stints of 38 and 48 minutes, and again after some adjustments for a longer period of approximately 28.5 hours without any supplemental auxiliary fuel. As per the manufacturer's specification sheet, during the time of operation, the unit should have processed approximately 14.44 lbs. of hydrocarbon per hour or 411.5 lbs. during the 28.5 hours and another 20 lbs. during the other brief periods of start-up operation. While operating, the VR applies whatever vacuum is necessary to the connected well(s) to satisfy its fuel needs. While drawing from RW15, minimal vacuum (1-4 inches of water gauge) was applied to the well and the corresponding withdrawal rate of soil gas ranged between seven and ten cubic feet per minute. VR operational data are contained in Appendix D.

IX) Conclusions

- The study area is underlain by predominantly sand and gravel with varying amounts of silt and clay. No continuos confining layers were encountered, nor were any units noted that would be expected to create preferential groundwater flow patterns;
- groundwater at the study location occurs under water table conditions at approximately twenty-six to thirty feet below grade;
- groundwater gradient along the Shunk Street Sewer is generally to the west in the study area;
- an area of elevated groundwater (mound) exists on the north side of the sewer line in the eastern portion of the area (TWs 5 and 9);
- the water elevation in OW 14, on the south side of the sewer in the eastern portion of the study area was much lower than surrounding wells on several gauging events;
- separate phase hydrocarbons were measured in all wells south of the sewer from RW 6 west to RW 15;
- pumping tests were conducted on three wells the results of which indicate:
- calculated aquifer characteristics were nearly identical for wells very close to the sewer line (RWs 6 and 15) and a well approximately twenty five feet south of the sewer line;
- Transmissivity was calculated as between 1.32×10^0 and 4.99×10^0 ft^2/min.;
- Hydraulic conductivity was calculated as between 1.33×10^{-1} and 5.39×10^{-2} ft/min.;
- separate phase hydrocarbon thickness increased in the pumping well and surrounding wells as the water table was drawn down;
- Vapor extraction testing conducted on wells RW 6 and RW 15 indicates a subsurface vacuum can be transmitted for tens of feet from an extraction well under a few inches of mercury vacuum;

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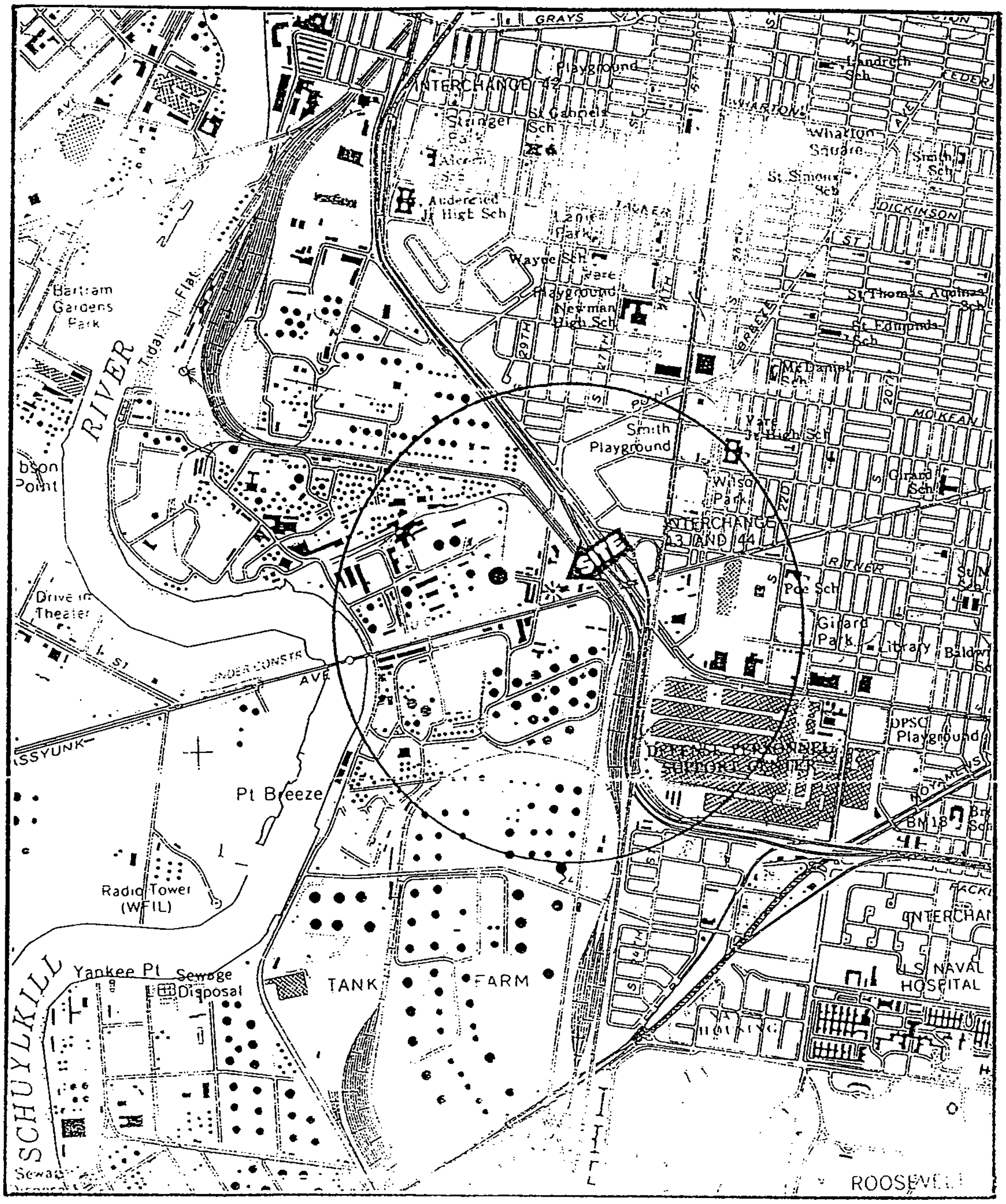

FIGURE I
SITE LOCATION
SUNOCO A- PLUS
2751 PASSYUNK AVENUE
PHILADELPHIA, PENNSYLVANIA

NORTH

SCALE IN FEET
0 2000 4000

SOURCE : USGS. PHILADELPHIA, PA QUADRANGLE 1967
PHOTOREVISED 1985

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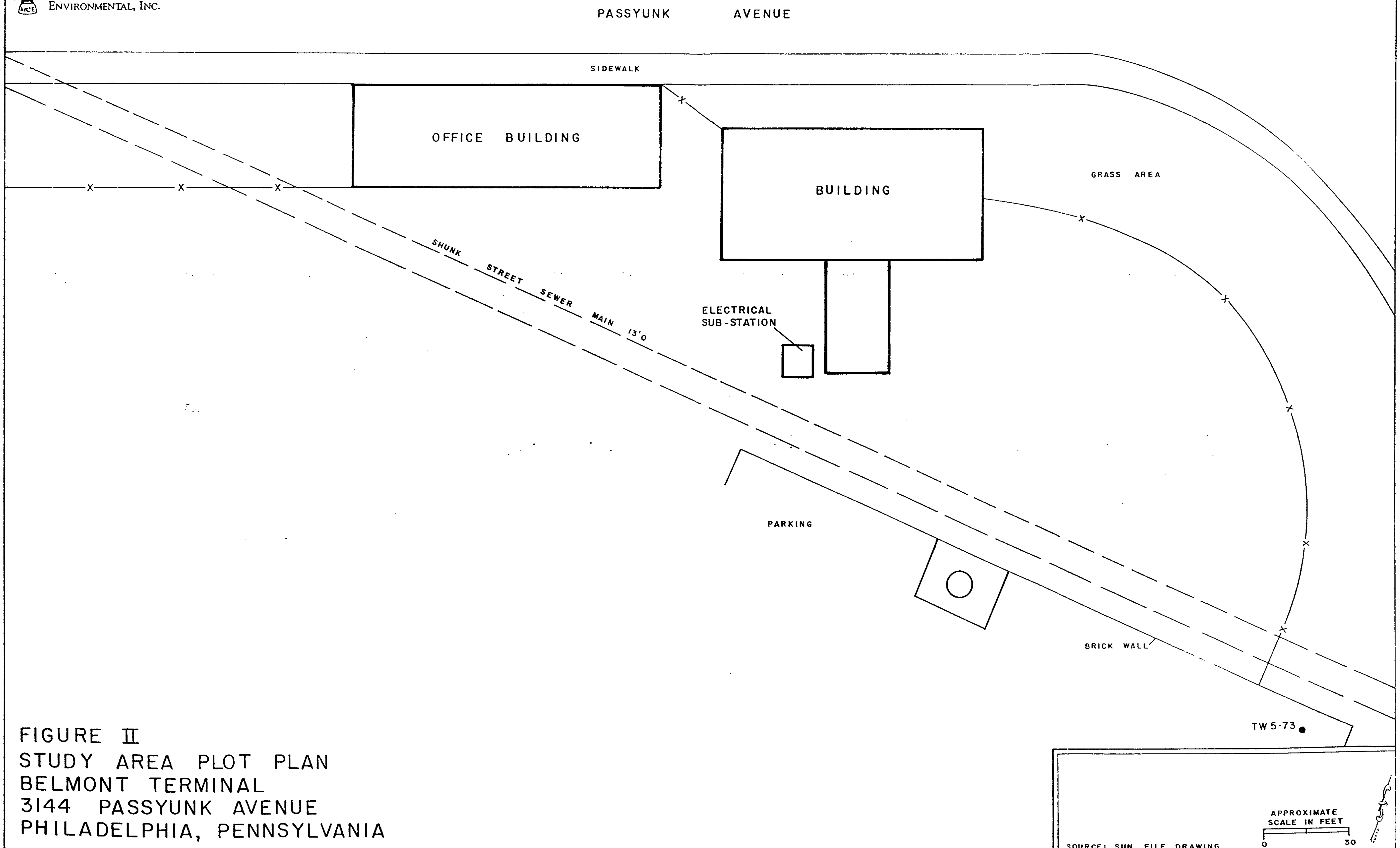

FIGURE II
STUDY AREA PLOT PLAN
BELMONT TERMINAL
3144 PASSYUNK AVENUE
PHILADELPHIA, PENNSYLVANIA

SOURCE: SUN FILE DRAWING

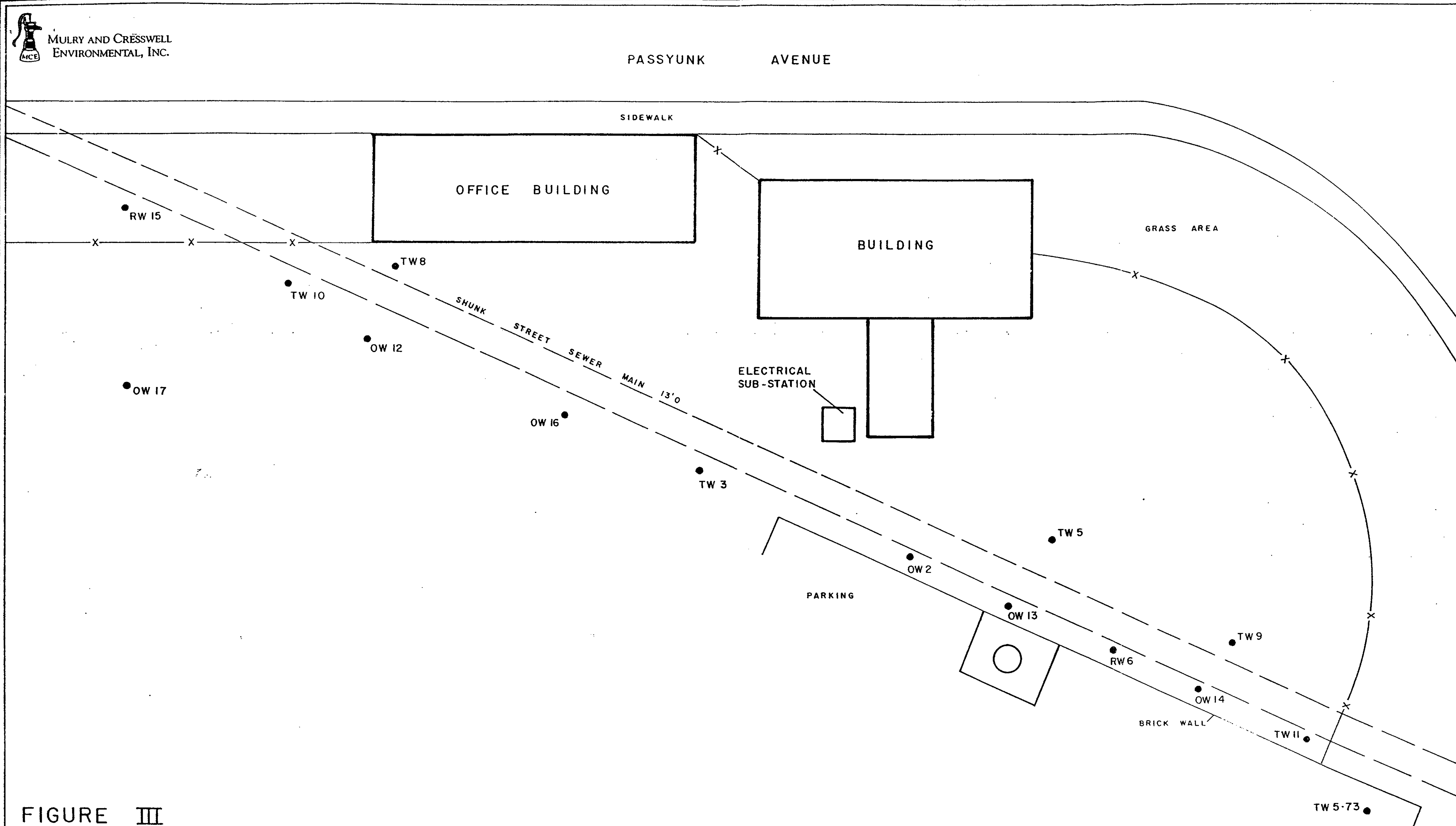

FIGURE III
BORING / WELL INSTALLATION LOCATIONS
BELMONT TERMINAL
3144 PASSYUNK AVENUE
PHILADELPHIA, PENNSYLVANIA

● OBSERVATION WELL
TW= 2" WELL
OW= 4" WELL
RW= 6" WELL

APPROXIMATE SCALE IN FEET
0 30

SOURCE: SUN FILE DRAWING

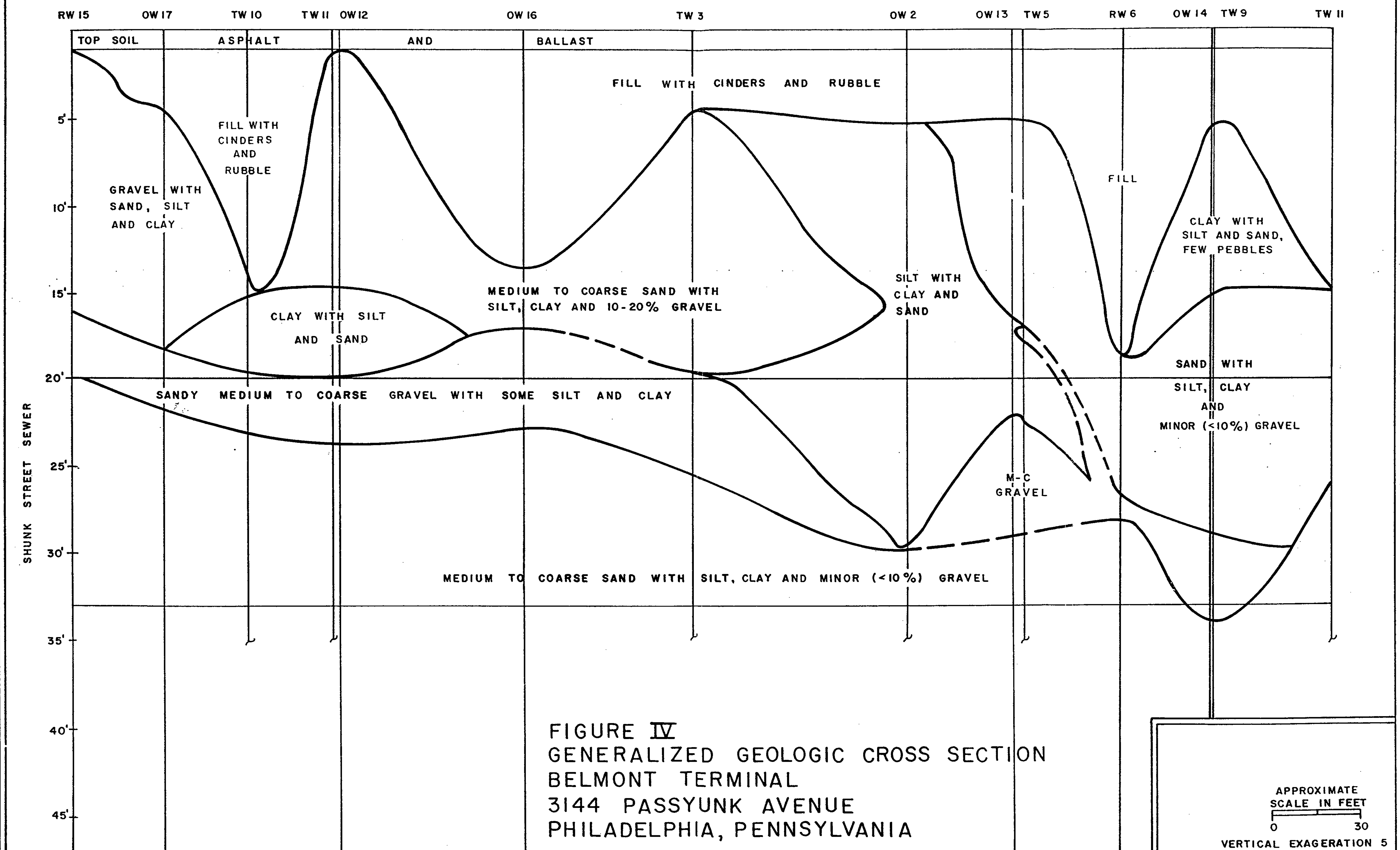

FIGURE IV
GENERALIZED GEOLOGIC CROSS SECTION
BELMONT TERMINAL
3144 PASSYUNK AVENUE
PHILADELPHIA, PENNSYLVANIA

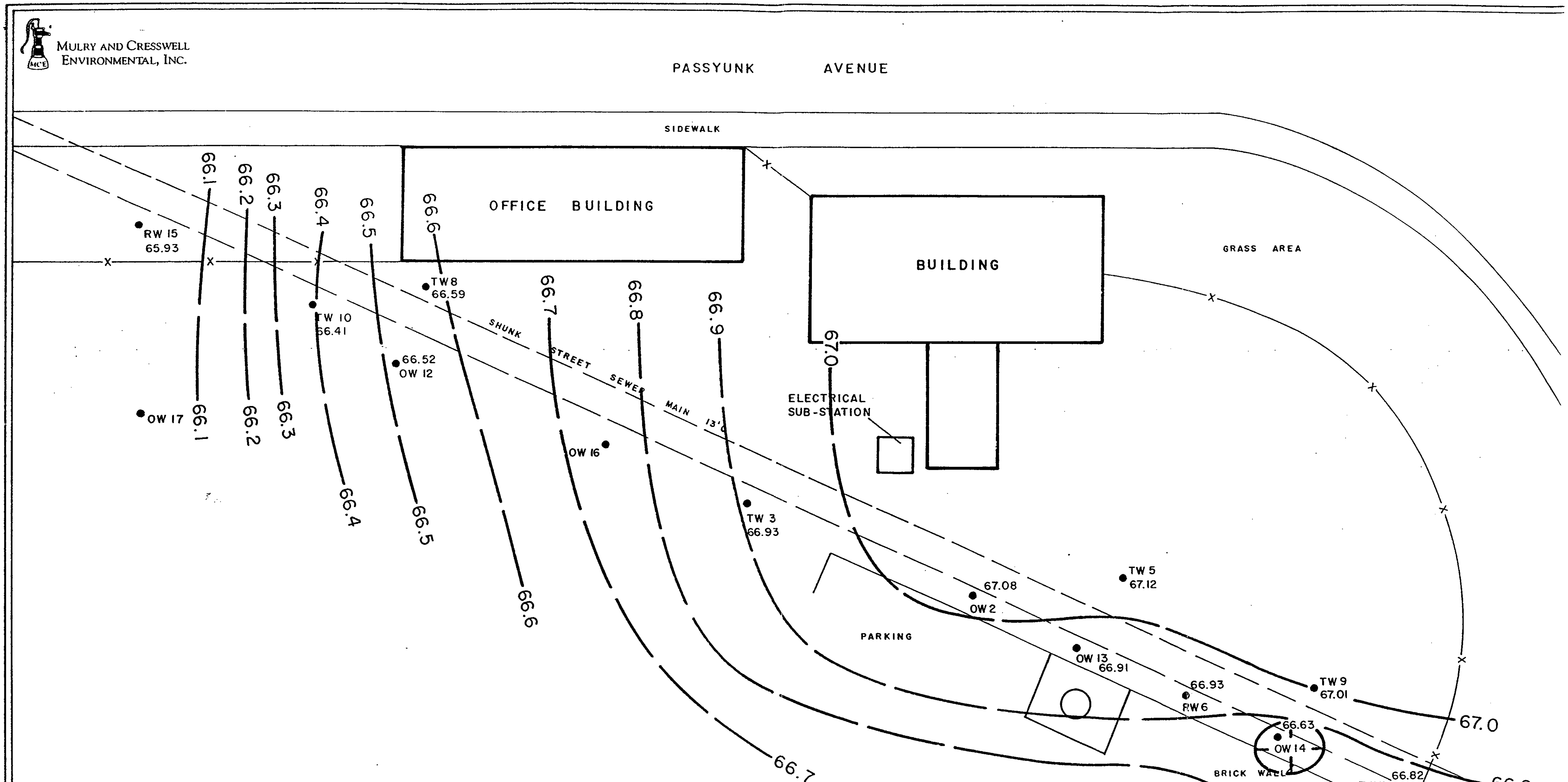

FIGURE V
CORRECTED STATIC WATER TABLE ELEVATION (FEET)
PRIOR TO PUMP TEST ON RW6
25 NOVEMBER 1997
BELMONT TERMINAL
3144 PASSYUNK AVENUE
PHILADELPHIA, PENNSYLVANIA