PRE-CONSTRUCTION RADIOLOGICAL ASSESSMENT AND DECONTAMINATION

OF A DEPLETED URANIUM WASTE HANDLING SITE

By: Adam S. Weaver

B.A. Curry College, 1981

Submitted in partial fulfillment of the requirements for the Degree of Masters of Science in Radiological Sciences and Protection, University of Lowell, Lowell, Massachusetts.

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Thesis Supervisor: Dr. Kenneth W. Skrable

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ABSTRACT

This research concerns the pre-construction radiological assessment and subsequent decontamination of a depleted uranium waste handling site. The site was used for almost twenty years to process wastes generated from a depleted uranium manufacturing facility. This site had to be decontaminated prior to construction of a building that would be used for waste processing. The work was conducted in two phases: Phase I involved decontaminating the building site by removing materials; Phase II involved containment of materials for a complete radiological assessment and final decontamination. Techniques for determining concentrations of depleted uranium in soils and detecting contamination on solid materials using gamma solid scintilation detectors and other conventional radiation detection systems are presented. Full details of methods, decision criterion and results also are presented.

DEDICATION

I would like to dedicate this Thesis to my wife, Patricia, and my parents, Thomas and Judith, without whose love, support and assistance I would never have been able to complete the work needed for my Masters of Science Degree.

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There are many people whom I should thank for their help during my studies at the University of Lowell.

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I. INTRODUCTION

In February 1983, a depleted uranium (DU) waste handling facility was to be decontaminated for construction of a 40,000 square foot building which would house radioactive waste processing operations.

As Project Foreman, I had responsibility for all health physics and safety aspects during pre-construction radiological assessment and subsequent decontamination. After an extensive search for literature on methodologies regarding site assessment and decontamination of soil, asphalt, and concrete contaminated with uranium, little information was found. As a result, this project consisted primarily of "on-the-job" training with research and development being pursued continually throughout the project to ensure that the site was decontaminated to specified limits in a safe and efficient manner.

The work was performed in two phases: Phase I included removal of all material above background from the proposed building site; and Phase II consisted of containment of materials for a complete radiological assessment and final decontamination of material isolated during Phase I. The primary purpose for the first phase was to release the site for construction, while Phase II involved waste volume reduction of materials removed during Phase I.

II. PHASE I: ASSESSMENT AND REMOVAL OF MATERIALS FROM BUILDING SITE

A. Site Description

In 1958, Nuclear Metals, Inc. (NMI) constructed its first building on forty acres of land in Concord, Massachusetts (Figure No. 1). Increased production demands led to an augmentation of radioactive waste generation thus requiring addition of a separate waste handling facility, which was constructed in 1964. This predominantly metal building was set on a poured concrete base and floor and was called "Butler III" (B-3). The depleted uranium (DU) wastes were processed for burial both inside and outside of this structure. In 1982, a new building (Building "E") was designed to totally house the waste handling operation with construction planned for the spring of 1983 (Figure No. 2).

NMI fabricates many metal products, most of which are made from depleted uranium. When natural uranium ore is chemically processed during the enrichment of uranium for the U-235 isotope, the long and short-lived daughters from natural uranium are removed. The gaseous enrichment process produces a "waste", one of which is uranium hexafluoride (UF_6) which is later converted into uranium tetrafluoride (UF_4) or greensalt. This greensalt is depleted in weight of the natural U-235 content; 0.2% compared to 0.7% in natural uranium (A183, Wa77).

The DU wastes at NMI can be in the form of machined chips, oxides from melting and casting, magnesium fluoride and contaminated oils and greases. Such wastes were processed in the B-3 building area

for almost twenty years. This waste handling site contained contaminated asphalt, concrete, soil, trees and underground piping systems that had to be removed, decontaminated, or stored for later decontamination.

B. Radiological Assessment

Surveys were conducted on the B-3 building, the temporary B-3 site and the surrounding area during pre-construction assessment of the site. The first area to be assessed was the B-3 temporary area. This site was next to the main facility on a small tree-covered hill. Surveys were conducted well before any outside contractors commenced work in the area in order to assess radiation levels and ensure that contamination was removed.

The B-3 temporary site was surveyed using Geiger Mueller survey meters (GM's) and soil samples were collected and analyzed for their U-238 concentration via gross gamma counting. The results of the area surveys showed that some areas needed to be removed prior to the cutting of trees, removal of stumps and grading of the area by contractors. During the process of getting the B-3 temporary site readied, soil, trees and equipment were removed off site or moved to an unrestricted area following surveys using GM's, wipes and gross gamma counting. Throughout the operation, air samples were collected and ambient radiation levels were monitored in work areas.

The B-3 site and its surrounding area, as expected, had many contaminated areas that had to be decontaminated to unrestricted limits, or the contamination had to be fixed to reduce the possibility

of airborne dispersion before contractors were permitted access to the area. The GM and wipe surveys of this area showed that the asphalt area could be cleaned to reduce the loose contamination on the surface. There were a few high ambient GM survey meter readings of asphalt and soil, which were removed before contractors entered the area. The B-3 metal structure was to be reused as a temporary waste handling facility; therefore, it was cleaned via washings and painted before it was moved. The DU activity concentrations in soil in the B-3 area were well above the limits for an unrestricted area, and therefore it was necessary to remove soil from these contaminated areas before workers were allowed access.

Approximately 150 grams of soil were collected and placed in a properly labeled plastic bag. Soil samples were analyzed via gross gamma counting using a low energy NaI(Tl) detector connected to a scaler and timer that gave digital numerical results. The samples were oven dried at 200°C for approximately five minutes in a glass pyrex dish. Samples were cooled and placed in a homemade Pb-Al-Cu counting chamber directly under the detector and counted for five minutes in a gross gamma counting mode. Soil samples collected from surrounding towns served as a background standard.

C. Radiation Protection

Potential health hazards exist when working with DU. External exposure to DU presents no known radiobiological concern due to its low dose rate. Internal hazards from DU are renal chemical toxicity for the soluble form and the radiation dose to the lung, bone

and large lower intestine for the insoluble form (Be66). Therefore working with uranium requires training and experience to ensure that it does not become an internal hazard to workers and/or members of the public. Working with contaminated soil is not a radiological concern even if the soil becomes suspended in air as a dust at or above the Occupational Safety and Health Administration's (OSHA) respirable nuisance dust loading limit (OSHA81). To show this I used the OSHA dust loading limit and typical soil concentration of U-238 on the site to estimate the maximum amount of U-238 that could be suspended as a dust in air and compared this value to the Maximum Permissible Concentration (MPCa) guideline for this project. This calculation is shown in Appendix A. Estimated air concentrations are compared to the project guideline for U-238 of 5.0 pCi/M^3 which corresponds to the Nuclear Regulatory Commission (NRC) MPCa limit for unrestricted areas. This limit assumes continuous exposure for 168 hours per week, 52 weeks per year and an internal dose limit of 1/10 that of occupationally exposed workers. Thus, this guideline without regard to actual exposure times, indeed, is very conservative.

The acceptable soil activity concentration of U-238 for an individual sample was set at 35 pCi/g per the Environmental Protection Agency (EPA) guideline and adopted by the NRC (US81). The absorbed dose in air at one meter from a uniform U-238 concentration of 35 pCi/g in soil is 0.48 RAD/year (NRCP81). Administrative guidelines for external exposure for contractors working this project were set at 1250 mrem/quarter to the skin or a dose rate of 2 mrem/hr. This quarterly

guideline was used because the contractors were considered radiation workers and the maximum time to remove contaminated materials from the site was estimated to be three months.

Each contractor was issued a whole body, two-chip lithium fluoride thermoluminescent dosimeter (TLD). One chip was shielded such that it only records gamma dose where the other chip is non-shielded and measures beta and gamma dose. The badges were processed approximately weekly, and results were evaluated following readout. TLD's worked well for this project because the housings are rugged and cleanable.

Geiger counters and ion chamber type survey meters were used daily throughout operations to check ambient radiation fields, surface contamination, and possible contamination on outgoing personnel and materials. A GM type survey meter with a pancake probe was used most frequently. Every soil sample that was collected for gross gamma counting was analyzed prior to collection in an effort to correlate GM readings with the gross counting results. Low volume air samples were collected when radioactive dust or fumes could possibly be generated from an operation and were analyzed for gross alpha and gross beta/gamma activity using an internal low background proportional counter. Additionally, hi-volume air samplers located around the plant's perimeter ran continuously throughout the project. Standard wipes of 100 cm^2 areas were taken to measure removable surface contamination. These wipes were also analyzed using the internal low background alpha and beta/gamma proportional counter. Urine samples

were also obtained from contractors working on jobs involving potential exposure and were analyzed for total uranium content.

The GM's with a large pancake probe were used to measure ambient radiation levels in work areas and to assess fixed contamination levels on surfaces. Surveys were taken before work started and throughout the operation. These surveys, in conjunction with the TLD personal monitoring results, ensured that exposures were maintained As Low As Reasonably Achievable (ALARA).

A very important aspect of any decontamination project is the determination of the proper state and federal regulatory limits. Removal and packaging of contaminated material directly in to waste containers was based upon GM surface readings. Materials with GM readings in excess of 1 mrem/hr were packaged in waste containers for subsequent burial while materials reading below 1 mrem/hr were contained in a pile to await Phase II operations. Possible surface contamination levels for materials going off site (i.e., equipment, clothes and/or solid materials) were assessed using a GM survey meter and wipes for removable contamination. The limit used for fixed contamination was 5000 dpm/100 cm^2 beta/gamma average and 11,000 dpm/100 cm^2 maximum at any point. The removable contamination limit was 22 dpm/100 cm^2 alpha and 220 dpm/100 cm^2 beta/gamma. Skin had to be rewashed and rechecked if found above the GM's background reading before workers could leave the site.

The decontamination of contaminated equipment and facilities as well as the removal, packaging, and storage of contaminated

materials was performed by company employees under close supervision. Many of the tasks had not been attempted previously and work proceeded slowly in order to ensure that all procedures worked as anticipated. Contaminated areas of soil or asphalt above the established limit were removed and placed directly into plastic-lined drums with shovels. One of the most difficult tasks involved the removal of underground contaminated pipes, manholes and catchbasins. At times, these pipes were as deep as 20 feet below the surface, and it was essential that a qualified individual be in the hole while the heavy equipment was uncovering the pipe so that it would not be broken, thus causing a more significant contamination problem than presently existed. Once the pipes were uncovered, both they and the soil were monitored using a GM survey meter. If the pipe was contaminated, the open end was pried up, bagged and taped, then the other end was also bagged and taped. The pipe was then raised up using heavy equipment and placed in a box. If soil was contaminated around the pipes, it was placed into a bag, which was then placed into a box. Following removal, a survey was conducted to ensure that the pit was clean before replacing the fill.

Worker safety was ensured by giving all contractors a safety orientation prior to the start of work. The safety orientations addressed actual situations that could be encountered, how to identify problems and who to contact when and if questions arose. Before beginning a particular task, a complete survey of the area was performed. If any problems existed, special procedures were implemented and discussed with workers in detail. Contractors were not

allowed to perform any jobs if the ambient radiation field was greater than 2 mrem/hr. These jobs were conducted by company employees who had adequate training and experience in working with radioactive materials. Adequate control of all work activities was ensured by weekly meetings with supervisory personnel directly responsible for the specific work to be accomplished. Schedules were set and followed, thus ensuring that the tasks were done safely, quickly and effectively.

D. Decontamination

The decontamination of the site depended upon the prior site assessment and measurements, which were continually made during the performance of the actual decontamination. A schedule was established considering both construction requirements as well as decontamination needs. Phase I included many different decontamination methods; primary of these was removal of materials from the site for burial or relocation of materials to the containment pile for Phase II.

The first area to prepare was the B-3 temporary site. Removal of some contaminated soil areas on site was performed prior to the contractors being allowed in the area. During the removal of the hill, soil samples and GM ambient readings were taken continually. An old contaminated storage shack which had been buried under about five feet of soil was discovered and the entire area was surveyed with GM's and soil samples. Contaminated pieces and soil were removed and placed into waste containers for burial before work continued.

The next decontamination problem became apparent during the relocation of the B-3 building. Metal beams and walls required hand

washing with a strong detergent to eliminate removable contamination. Following the washing, a survey was conducted to assess the success of the decontamination effort. Results showed a need, in a few areas of the building, for a coat of latex paint to ensure fixation of contamination. The contractors moving the building to the new location were given company uniforms and were closely monitored for possible contamination throughout the operation.

When the building was removed, the concrete walls were cut using air-powered saws that used a considerable amount of water for cooling the blade and to reduce dust. From surveys of asphalt on the site, it was found that most of the areas had contamination that penetrated only the top 1/4 inch. Once the surface had been washed off with a hose and rinse water directed to the holding basin, a road plannar was used to remove this top 1/4 inch of asphalt. This operation was closely monitored for uranium in air generated during removal. The dust was controlled by keeping the asphalt wet with hoses and with the water used by the road plannar for cooling of its cutters. Scarification of the top 1/4 inch of 35,830 square feet of asphalt as well as decontamination of the equipment used took only twenty-four hours, and during this time contractors used company uniforms and respirators. The sucess of this method was verified by GM surveys conducted over the scarified area after completion of the operation.

The concrete floor of the B-3 building was scarified to a depth of 1/8 inch using the road plannar. Surveys conducted indicated

that this depth was sufficient to ensure that the remaining concrete would be below the soil limit of 35 pCi/g. Areas of concrete that the road plannar could not reach were decontaminated with a concrete floor polisher to a 1/8 inch depth as well. The floor polisher used a significant amount of water during removal to reduce the possible problem of uranium release into the air. The only area of concrete removed directly to drums for burial prior to scarification due to high ambient readings was the sink used in B-3 for contaminated liquids.

Following the concrete decontamination, the contractors broke the concrete up into pieces for removal off site. This proved to be a problem when the contractors tried to remove the pieces off site because the soil around the building was still contaminated. The contaminated soil was picked up along with the concrete pieces and when the outgoing truck was surveyed, the error was recognized. Subsequently, the concrete and associated soil were stored in the south parking lot for later separation and final assessment. This proved to be a time-consuming process. We learned that it would have been much easier to cut the concrete into slabs for removal and final assessment.

Once the building and its foundation were removed, the soil needed to be assessed for contamination. Soil from some areas that had a GM survey meter surface reading over 1 mrem/hr had to be removed directly into drums. All other questionable areas were removed to the containment pile. The soil contamination depth was tested prior to work. Every area proved to be different, and decontamination efforts had to be assessed with a GM during the course of all work. Depths of

soil removal ranged from 2 inches up to 1.5 feet.

The final areas to be decontaminated on the site were all underground. There were various networks of pipes that had to be removed before the release of the site to contractors. Some of these pipes and manholes were cited on blueprints while others were not. As a result, it was necessary to question NMI "old timers" regarding the history of the site. The entire process of removing these pipes and manholes was conducted by company employees.

After the site was released to contractors for construction of Building "E", only one more item was necessary for completion of Phase I. The concrete blocks and soil placed in the south parking lot. Concrete pieces were washed off using a fire hose in a backhoe bucket and were surveyed with GM's and wipes. Soil and concrete pieces over the limit were placed in the containment pile while material under the limit was removed off site.

III. PHASE II: FINAL ASSESSMENT AND DECONTAMINATION OF MATERIALS REMOVED FROM BUILDING SITE

A. Location of Work

The containment pile was placed next to the holding basin. A trench was placed down gradient to catch and direct contaminated run off, if any, to the holding basin, which is a neutralized radioactive waste storage pit with restricted access. The area was then finish graded and covered with plastic to prevent the contamination of soil under the pile. The location of the work during Phase II encompassed the entire area around the containment pile.

The location of the containment pile area was selected on the basis of its topographical conditions and its proximity to the Building "E" site. Topographical conditions of the area directed the run off down gradient away from the building site and, with the placement of the trench, directed run off towards the holding basin (Figure 8). This location was secured for restricted use due to the contaminated materials in the pile.

After the building site was decontaminated and contractors were permitted to work in the area, Phase II was initiated. It was decided that the containment pile would not be decontaminated until the summer of 1984 and, therefore, the pile would have to be contained for temporary storage. The shape of the pile was graded to ensure that the run off would enter the holding basin and that the material would remain on the pile and not become an airborne hazard. Loose areas of the pile's contents were covered with a layer of wet hay to reduce the

possibility of contaminated material becoming airborne. The work during Phase II was conducted by myself and other company employees.

B. Radiological Assessment

When the pile was ready for storage it was analyzed for activity. Additionally, locations of material were recorded by making a map that included the type of material present, the specific location of each type, and an estimate of the activity concentration (Figure 9). Before winter, two areas of soil were counted which included one in the trench to evaluate contaminated run off to the holding basin and an area farther down gradient to evaluate containment of run off (Figure 10). The last thing done to the pile before winter was to pour four gallons of Ethylenediamine Tetraacetic Acid (EDTA) aqueous solution over it in order to increase the rain infiltrate leaching of uranium from the pile.

The pile converted to four distinct areas: Area A included scarified hot top and concrete and had a volume of 50 cubic yards; Area B consisted of concrete pieces from the B-3 building's walls and floor and had a volume of 100 cubic yards; Area C included most of the soil that was removed during Phase I and had a volume of 150 cubic yards; and, Area D included the various pieces of contaminated junk, tree stumps, fence posts and concrete steps with a volume of 50 cubic yards. The total volume of all the materials in the pile was about 350 cubic yards.

Assessment of the contamination levels of materials in the pile was accomplished by using GM's, wipes and gamma spectroscopy.

The multi-channel analyzer (MCA) and NaI(Tl) detector are portable so it was possible to count areas in the pile directly. Samples were also collected and analyzed via gamma spectroscopy in a low background shield. The use of this equipment was crucial to the success and completion of Phase II.

The 93 keV gammas from U-238's daughter, Th-234, were used to determine the amount of activity present using gamma spectroscopy. It was assumed that the U-238 and Th-234 were in secular equilibrium, and therefore, the estimated Th-234 activity could be assumed to be equal to the U-238 activity present in the sample. However, if the samples were not in secular equilibrium; that is, if there was unsupported Th-234 in the sample, then the estimated U-238 activity would be conservative. The U-238 and Th-234 reach secular equilibrium in about five months (Th-234 T 1/2 = 24.1 days). Th-234 emits two gamma photons that are so close in energy, only one peak is resolved.

C. Area A: Hot Top

The activity in Area A was estimated from measurements with GM surface readings, gamma spectroscopy, and sampling results determined during Phase I. The activity concentration present in Area A averaged 100 pCi/gram. When the volume and density of the material are taken into consideration, the total U-238 activity present in Area A was estimated to be 4.97 E9 pCi. No decontamination of materials in Area A was attempted because methods would not be cost effective. The scarified asphalt and concrete were assessed and packed in drums for burial.

D. Area B: Concrete

The activity in Area B was measured using GM surface readings and gamma spectroscopy. The estimated activity concentration for this area averaged 40 pCi/gram near the surface of the concrete. Using the volume and density of the concrete in the area, the total U-238 activity present in Area B was estimated to be 7.86 E9 pCi. The contamination on the concrete was fixed on the surface and could be removed by scarification. When a hand scarifier was used to decontaminate the concrete, a large quantity of dust was generated; so, pieces had to be wet in order to reduce the problem. Tasks involving use of the hand scarifier required donning respirators and leather gloves for additional personnel protection. Additionally, a hi-volume air sampler was placed approximately 75 feet down wind of the pile. The contaminated pieces of concrete were placed into a separate work area and scarified together to accomplish the task with greater efficiency.

Decontamination with the hand scarifier worked well on the concrete pieces by reducing a large piece of contaminated concrete to a clean piece of concrete and a small volume of contaminated concrete dust. The dust was surveyed and placed into drums for burial. The concrete block was washed off, rechecked with GM's and wipes, and if below the limit, removed off-site.

E. Area C: Soil

The activity of soil prior to removal of contaminated areas was estimated using GM's, gamma spectroscopy and sampling results

obtained during Phase I. Area C had an activity concentration that ranged from 20 to 100 pCi/gram. When the volume and density of the soil in Area C are considered along with this concentration estimate, the total U-238 activity was estimated to be from 5.90 E9 to 2.95 E10 pCi. Ambient and surface GM readings were taken during the removal of the soil from the pile prior to mixing of the soil with a backhoe over and over to get a uniform concentration of DU.

The 93 keV gamma photon in dry soil has a mean free path of approximately 2.2 centimeters. Only uranium atoms in close proximity to the detector will produce a count in the 93 keV region of interest. A method to estimate the activity concentration in the field was established by assuming a uniform concentration of uranium and comparing labortory results and field measurements of the same soil samples. This method was used to complete the work on Area C.

The field counting method used for Area C depended upon having a uniform concentration of DU in the sample. The portable NaI(Tl) detector and MCA were used to estimate the activity concentration in the soil. The front loader bucket on the backhoe, which held a soil volume of 1.25 cubic yards, was used as a counting chamber. This procedure was conducted on sunny days which ensured that the samples were dry. Soil in the bucket was leveled off with a shovel and monitored with the GM survey meter. Three holes were dug into the soil for placement of the NaI(Tl) detector. The detector was then put in each hole and covered with soil. Each of these areas within the bucket was counted for one minute. The area with the highest net

counting rate was then recounted for ten minutes in order to estimate the U-238 content from the Th-234 93 keV gamma photon peak.

The first bucket of soil which was thoroughly mixed, was used to estimate an correction factor such that the net counting rate obtained in the field could be converted to an activity concentration. This was accomplished by comparing the net counting rate from the bucket with the activity concentration determined for a composite soil sample counted in the laboratory. The laboratory count was made on the same NaI(Tl) detector in a shielded laboratory configuration, which had been previously calibrated with a standard U-238 soil sample. The net counting rate obtained in the field divided by the laboratory activity concentration from the first bucket was used as a correction factor for converting field net counting rate measurements to activity concentration. The constancy of this conversion factor was confirmed by collecting a composite soil sample from each bucket for counting in the laboratory. The field and laboratory activity concentration values were compared throughout work on Area C using the same field conversion factor determined from the first bucket. The equations used to estimate soil activity concentration in Area C are given in Appendix B.

F. Area D: Miscellaneous Materials

The activity in Area D was estimated from measurements using GM surface readings. Area D had an average activity concentration of about 40 pCi/gram on the surfaces of the various materials in the area. The total U-238 activity present on materials in Area D was estimated to be 1.53 E9 pCi. Contaminated bark on tree stumps was

removed with a hatchet and placed in drums. The tree stumps were continually resurveyed with a GM and removable wipe measurements until each piece of wood was under the contamination limits. The metal fence posts had concrete bases with a layer of contaminated asphalt on the top, which was removed with a hammer and chisel and placed into drums for burial off-site. The metal and concrete were washed off with a hose, surveyed with GM's and wipes, and if below the limit, removed off site. The concrete steps were scarified in a few areas to remove contaminated spots and were later removed off-site once survey results indicated that they were below contamination limits.

IV. RESULTS AND DISCUSSION

A. Phase I

Soil contamination was present throughout the building site (Table I). Removal depths of soil were estimated by collecting samples on the surface and at various depths using a auger. Results of soil contamination depth testing indicated that it was necessary to recheck every contaminated area following removal of the contaminated soil (Table II). During removal of contaminated soil, a GM surface reading less than or equa to ambient background qualified the area as clean, pending confirmation from the analysis of soil samples. Each contaminated soil area was different; therefore, it was necessary to establish different soil removal depths depending upon the extent of the contamination. For instance, if a shallow removal depth was set for an area with deep contamination, it would be probable that contamination would be missed; whereas, if a deep removal depth was set in an area of limited surface contamination, extra time would be spent in removing more soil than necessary.

The contaminated layers of concrete in B-3 were removed with the road plannar and a floor polisher to a depth of 1/8 inch. Before and after the scarification of the top 1/8 inch, samples of concrete were collected with a hammer and chisel (Table III). Following scarification, the concrete was found to be within limits. The only problem during the work on the B-3 concrete floor and walls was when the concrete had to be broken up for removal. The concrete pieces were moved to the south parking lot for disposition after the Building "E"

site was decontaminated for construction. Soil samples were collected from the south parking lot both prior to the placement of the concrete as well as after completion of work on materials (Table IV).

Before the Building "E" site was released to the contractors, a complete GM survey of the site was performed. Additionally, soil sample activity concentrations were determined to ensure that the site was below the limit. The soil sample results indicated that the area where the building was to be constructed had been decontaminated below the limit (Table V).

Beta and gamma exposures to contractors were monitored using Harshaw two-chip TLD-100 cards and holders. These cards were analyzed using a Harshaw Model 2271 Thermoluminescent Detector/Dosimeter and Identifier. The results of contractors' skin exposures in mrem for the issue period were reviewed following readout. Using the highest skin dose recorded for the issue period and the number of days multiplied by eight hours per day, the skin exposure rate was determined (Table VI).

The DU air concentration in the work area during an operation where dusts or fumes were generated was monitored with stationary low-volume air samplers. Hi-volume air samplers around the facility's perimeter were checked monthly and showed no significant change from previous monthly results. Low volume air samplers were started at the beginning of work for the day and stopped at the completion of work. The estimated air concentrations are compared to the project guideline for U-238 of 5.0 pCi/M^3. The results of air samples collected during the work are shown (Table VII). Urine samples also indicated that the

air concentrations were kept low, with the highest total uranium content found in a contractor's urine sample being 8 µg/l, which is comparable to normal background levels.

Phase I prepared the buildi e for unrestricted use by removing contaminated materials. Furthermore, the internal and external exposures were kept As Low As Reasonably Achievable (ALARA) throughout the work.

B. Phase II

During Phase II a hi-volume air sampler was placed near the containment pile. The sampler was started when the work on the pile first began and was left on continuously until the work was completed. The sample was analyzed off site for total uranium using fluorometric techniques (Table VII).

When the containment pile was prepared for the winter, two areas were analyzed for DU concentration down gradient via the collection of soil samples. One area was in the trench and the other was farther down gradient on the roadway. The activity concentration of the two areas were 5.39 and 4.05 pCi/gram for the trench and roadway, respectively, which are close to natural background values for the New England region. Collection of samples in the same locations after the winter and spring prior to the commencement of work on the pile showed activity concentrations to be 32.78 and 6.47 pCi/gram for the trench and roadway, respectively. This indicates that activity was leached from the pile and that the trench worked in directing the contamination towards the holding basin.

Contaminated concrete pieces were decontaminated using a hand scarifier. It reduced the fixed activity on the surface by removing about 1/8 inch with each pass. Removal of this surface contamination reduced the volume of waste for burial significantly. Wood stumps were decontaminated by removal of the bark which also greatly reduced the volume of waste for burial.

Using Phase I survey results and surveys of the pile, the total range of activity in the pile was estimated. The total range of activity of U-238 in the pile was 20 to 43 mCi. When a contaminated area of the pile was removed for burial, it was surveyed to estimate the activity. Fourteen drums of waste were generated from the work on the pile with a estimated total activity of 19 mCi of U-238. From the product of the mean activity concentration of 6 pCi/g from the soil released from Area C and the volume of soil, the total activity of U-238 released in the soil was estimated to be 17.7 mCi. The total activity estimate of 36.7 mCi was within the range of total activity estimated prior to work. Obviously there is considerable uncertainty connected with these estimates.

Throughout the mixing of the soil for counting in the bucket, the soil was surveyed with a GM survey meter to locate any contaminated materials above a 1 mR/hr surface reading. If such material was found, it was then removed for burial. The field method for determining soil activity concentration compared very well to the laboratory values. A correlation coefficient of 0.93 was calculated from the field and laboratory soil activity concentration results from 56 samples (Table

VIII). The correlation coefficient was determined by using results greater than zero and omitting the lost sample from bucket #21.

V. SUMMARY AND CONCLUSIONS

The methodology used to decontaminate the Building "E" site in two phases proved to be safe and effective. Both internal and external exposures were kept ALARA throughout the project. The Building "E" site was decontaminated to unrestricted limits. The methods used in the radiological assessment of soils and solid materials were effective and can be used again with confidence. Decontamination methods of solid materials reduced the volume of radiological waste generated. The goals set before the project started were met successfully.

The decontamination methodology used for this project was somewhat unique. Contaminated materials above a set criteria limit were removed to one area for a more detailed radiological assessment and subsquent decontamination if nessary. With all of the materials located in one area, assessment and decontamination could be accomplished in a more efficient way. This work proved that contaminated material can be contained over a period of time in a condition that does not become a health hazard to the public. It also proved that the bulk of contaminated material did not have to be removed directly from the site to waste containers for burial, thus reducing project costs.

Four goals were set at the beginning of the project, as follows, in order of importance:

1. Health and safety of the workers.
2. Decontaminating the site to unrestricted limits.

3. Developing methods which could be used for future decontamination projects.
4. Reducing the volume of radiological waste to be buried at a commercial low-level repository.

The radiological assessment and subsequent decontamination of the building site was performed in an acceptably safe manner. Phase I results indicate that all tasks were performed with radiation exposures to workers being ALARA.

The results of surveys from the building site prior to construction showed that the site was within specific limits for an unrestricted area. The worker exposures following site decontamination as determined from personnel dosemeters (TLDs) were consistent with the projected radiation levels expected through proper decontamination. The methods used throughout this project proved to be effective and demonstrated regulatory compliance with respect to activity and radiation limits for unrestricted use.

The waste volume reduction was approximately 90%. This provided for a considerable reduction in the cost for off-site waste disposal.

VI. RECOMMENDATIONS

The radiological assessment of any site needs to include the history of prior uses of the site, whenever possible. Characterizing the types and levels of existing contamination through site radiation measurements and sampling for subsequent analysis is mandatory. The data from this characterization dictates the degree of potential radiation hazards to which workers may be exposed. The radiological assessment database is used to design and develop procedures for safe and effective decontamination.

Specifically, the following guidelines should be considered for similar projects:

1. Estimate the amount of manhours, materials and equipment which will be necessary for decontamination of the site prior to beginning the project.
2. Establish decision criteria based on site assessment data and do not deviate from the plan once the work has begun.
3. Survey all areas before, during and after work.
4. Coordinate activities of outside contractors and plant workers to ensure that work progresses smoothly and provide them with all necessary information prior to the commencement of work.
5. Use only trained, experienced personnel when working with radioactive materials.

TABLE I

Soil Sample Results Prior to Work on Site

(Locations Shown on Figure No. 3)

Sample Identification Number	Result (pCi/gram ± 2 σ)
1	14.08 ± 11.67
2	242.56 ± 15.14
3	11.63 ± 7.09
4	10.46 ± 8.87
5	240.61 ± 14.04
6	2.87 ± 7.81
7	3.41 ± 7.69
8	163.60 ± 14.26
9	242.68 ± 16.67
10	78.62 ± 38.00
11	115.18 ± 62.42
12	5.12 ± 9.39
13	251.20 ± 14.87
14	10.51 ± 10.63
15	11.49 ± 9.94
16	20.51 ± 12.46
17	12.95 ± 9.71
18	8.96 ± 9.71
19	18.71 ± 8.34
20	18.16 ± 9.41
21	19.85 ± 10.66
22	14.10 ± 7.91
23	5.44 ± 11.65
24	19.83 ± 10.34
25	12.85 ± 9.80
26	20.17 ± 14.49
27	3.73 ± 9.48

TABLE I (Continued)

Sample Identification Number	Result (pCi/gram ± 2 σ)
28	6.63 ± 9.37
29	9.11 ± 6.89
30	11.25 ± 14.57
31	140.00 ± 23.67
32	187.57 ± 20.52
33	7.19 ± 4.97
34	104.73 ± 8.35
35	220.92 ± 8.46
36	384.99 ± 10.70
37	11.73 ± 12.45
38	14.68 ± 7.54
39	1366.40 ± 18.59
40	724.39 ± 15.96
41	67.48 ± 10.68
42	49.82 ± 8.79
43	795.69 ± 20.07
44	38.47 ± 6.47
45	71.24 ± 11.14
46	22.83 ± 7.60
47	19.28 ± 7.19
48	9.64 ± 6.78
49	112.58 ± 8.33
50	15.23 ± 9.18
51	97.93 ± 8.17
52	21.94 ± 5.17
53	10.75 ± 8.49
54	4.06 ± 5.73
55	4.50 ± 5.28
56	7.89 ± 4.90
57	3.49 ± 5.39
58	14.42 ± 2.23 (Asphalt Sample)
59	53.50 ± 3.41 (Asphalt Sample)

TABLE I (Continued)

Sample Identification Number	Result (pCi/gram ± 2 σ)	
60	63.06 ± 3.83	(Asphalt Sample)
61	30.82 ± 3.34	(Asphalt Sample)
62	7.45 ± 2.84	(Asphalt Sample)
63	170.92 ± 8.47	(Asphalt Sample)
64	34.90 ± 3.77	(Asphalt Sample)
65	25.37 ± 4.08	(Asphalt Sample)
66	348.08 ± 11.08	
67	6.01 ± 4.77	
68	28.97 ± 5.05	
69	7.97 ± 3.17	
70	10.26 ± 3.40	
71	6.17 ± 2.84	
72	99.66 ± 7.26	
73	8.59 ± 2.76	
74	7.39 ± 3.58	
75	7.94 ± 4.06	

TABLE II

The Depth of Contamination in Soil Tests

(Locations Shown on Figure No. 4)

Area	Depth in Inches	Result (pCi/g ± 2 σ)
1	Surface	14.51 ± 6.19
	3	10.06 ± 4.77
	6	14.70 ± 5.46
2	Surface	6340.20 ± 49.64
	3	253.08 ± 12.11
	6	96.96 ± 7.29
3	Surface	21.83 ± 4.74
	3	43.43 ± 5.78
	6	10.85 ± 4.70
4	Surface	579.16 ± 12.94
	3	29.65 ± 5.22
	6	46.19 ± 5.89
5	Surface	270.74 ± 8.40
	3	159.93 ± 6.81
	6	28.73 ± 4.80
6	Surface	1818.94 ± 19.80
	2	358.22 ± 10.52
	4	341.95 ± 10.72
	6	247.91 ± 8.82
7	Surface	2089.57 ± 22.63
	2	644.05 ± 12.07
	4	289.29 ± 9.72
	6	222.75 ± 7.66

TABLE III

B-3 Concrete Sample Results Before and After Scarification

(Locations Shown on Figure No. 5)

A. Before Scarification

Sample Identification Number	Result (pCi/gram ± 2 σ)
1	126.44 ± 12.25
2	102.18 ± 13.37
3	624.12 ± 21.00

B. After Scarification

Sample Identification Number	Result (pCi/gram ± 2 σ)
1	10.57 ± 5.40
2	11.90 ± 6.34
3	19.64 ± 4.90
4	7.87 ± 5.37
5	9.94 ± 5.26
6	34.86 ± 6.31
7	7.40 ± 6.28
8	26.20 ± 9.45

TABLE IV

Soil Results of South Parking Lot Prior to Placement of Concrete Blocks and After Removal

(Locations Shown on Figure No. 6)

A. Before Placement of Concrete Blocks

Sample Identification Number	Result (pCi/gram ± 2 σ)
1	13.26 ± 5.21
2	16.63 ± 4.16
3	20.84 ± 4.46
4	20.17 ± 4.15
5	8.98 ± 4.53

B. After Removal of Concrete Blocks

Sample Identification Number	Result (pCi/gram ± 2 σ)
1	14.27 ± 6.42
2	9.77 ± 4.47
3	22.43 ± 5.62
4	18.56 ± 8.31

TABLE V

Final Soil Samples at Completion of Phase I

Before Construction of Building "E"

(Locations Shown on Figure No. 7)

Sample Identification Number	Result (pCi/gram ± 2 σ)
1	5.94 ± 1.84
2	6.35 ± 2.17
3	8.81 ± 2.34
4	12.89 ± 1.88
5	7.36 ± 0.92
6	11.83 ± 2.05
7	4.85 ± 2.14
8	13.96 ± 2.94
9	21.74 ± 2.65
10	14.38 ± 1.14
11	18.75 ± 2.56
12	13.86 ± 2.85
13	26.46 ± 1.50
14	21.29 ± 2.36

TABLE VI

Contractors' Highest Exposure Results During Phase I

Period	Skin Dose (mrem β/γ)	Dose Rate (mrem/hr)
3/21 through 3/25/83	41	1.03
3/25 through 4/30/83	50	1.25
5/01 through 5/15/83	55	0.49
5/10 through 5/22/83	79	1.41
5/23 through 5/31/83	76	1.06
6/01 through 6/06/83	45	1.13
6/07 through 6/21/83	44	0.42
6/22 through 6/30/83	38	0.59
	$\sum$ = 428	Average = 0.92

After Completion of Phase I

Period	Skin Dose (mrem β/γ)	Dose Rate (mrem/hr)
7/01 through 8/01/83	50	0.20

* Administrative guideline established for this project:

1250 mrem β/γ per quarter and 2.0 mrem per hour

TABLE VII

Air Sampling Results During Phase I and Phase II Operations

PHASE I

Location	Date	Result (pCi/M^3)	% of Limit
B-3 Temp. Work Area	3/25/83	< LLD	-
B-3 Temp. Soil Removal	4/04/83	1.24	2.48
B-3 Temp. Soil Removal	4/04/83	< LLD	-
Bldg. E Work Area	5/06/83	1.15	23.0
Bldg. E Work Area	5/06/83	2.39	47.8
Bldg. E Work Area	5/06/83	2.38	47.6
Scarification	5/12/83	0.48	9.6
Scarification	5/12/83	1.60	32.0
Scarification	5/12/83	2.24	44.8
Scarification	5/12/83	< LLD	-
Scarification	5/13/83	0.31	6.2
Scarification	5/13/83	< LLD	-
Scarification	5/13/83	0.22	4.4
Scarification	5/13/83	< LLD	-
Scarification	5/17/83	0.52	10.4
Scarification	5/17/83	0.49	9.8
Scarification	5/17/83	< LLD	-
LLD	-	0.10	2.0

PHASE II

Location	Date	Result (pCi/M^3)	% of Limit
Hi-Volume Air Sampler Down Wind of Work Area	5/08/84 to 6/28/84	.0005	0.01

TABLE VIII

Laboratory Versus Field Results of Soil

Sample Activity Concentration in Area C

Sample ID Number	Laboratory Result (pCi/gram)	Field Result (pCi/gram)
1	16.84	16.84
2	7.59	7.86
3	10.07	10.08
4	< LLD	< LLD
5	8.69	9.86
6	8.02	10.77
7	12.04	12.59
8	9.49	10.04
9	1.96	2.62
10	10.58	13.01
11	12.00	12.41
12	2.61	5.67
13	< LLD	3.58
14	12.54	14.30
15	< LLD	< LLD
16	< LLD	2.27
17	13.88	16.63
18	13.46	16.99
19	11.54	7.92
20	19.50	13.13
21	Lost Sample	9.31
22	1.78	2.65
23	16.33	15.36
24	18.72	18.21
25	1.61	0.89
26	< LLD	< LLD
27	< LLD	1.73

TABLE VIII (Continued)

Sample ID Number	Laboratory Result (pCi/gram)	Field Result (pCi/gram)
28	14.43	16.72
29	18.27	18.91
30	4.08	3.70
31	2.66	6.03
32	5.78	8.65
33	5.79	10.86
34	6.28	3.47
35	< LLD	< LLD
36	4.75	3.43
37	4.34	3.43
38	3.61	2.58
39	< LLD	0.58
40	< LLD	< LLD
41	6.24	7.85
42	2.53	8.70
43	< LLD	< LLD
44	3.46	5.06
45	3.14	1.80
46	3.91	8.34
47	1.58	2.59
48	< LLD	< LLD
49	6.60	11.48
50	< LLD	0.64
51	< LLD	< LLD
52	4.08	3.61
53	7.76	9.97
54	15.04	19.22
55	12.24	13.95
56	2.66	5.25
57	< LLD	1.90
LLD	1.50	0.50

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NCRP81 National Council on Radiation Protection and Measurements, 1975, "Natural Background Radiation in the United States," NCRP Report No. 45 (Washington, DC: NCRP).

OSHA81 U.S. Department of Labor, Occupational Safety and Health Administration, 1981, General Industry, OSHA 2206, 29 CFR 1910, Table Z-3, page 636 (Washington, DC: OSHA)

US81 U.S. Nuclear Regulatory Commission, 1981, "Standard for Uranium in Soils for Disposal or On-site Storage of Thorium and Uranium Wastes from Past Operations," Federal Register, Volume 46, page 205, (Washington, DC: U.S. NRC)

Wa77 Walker, F.W., Kirouac, G.J., and Rourke, F.M., 1977, "Chart of the Nuclides," Knolls Atomic Power Laboratory, Schenectady, NY, (Educational Relations, General Electric Co. Schenectady, NY)

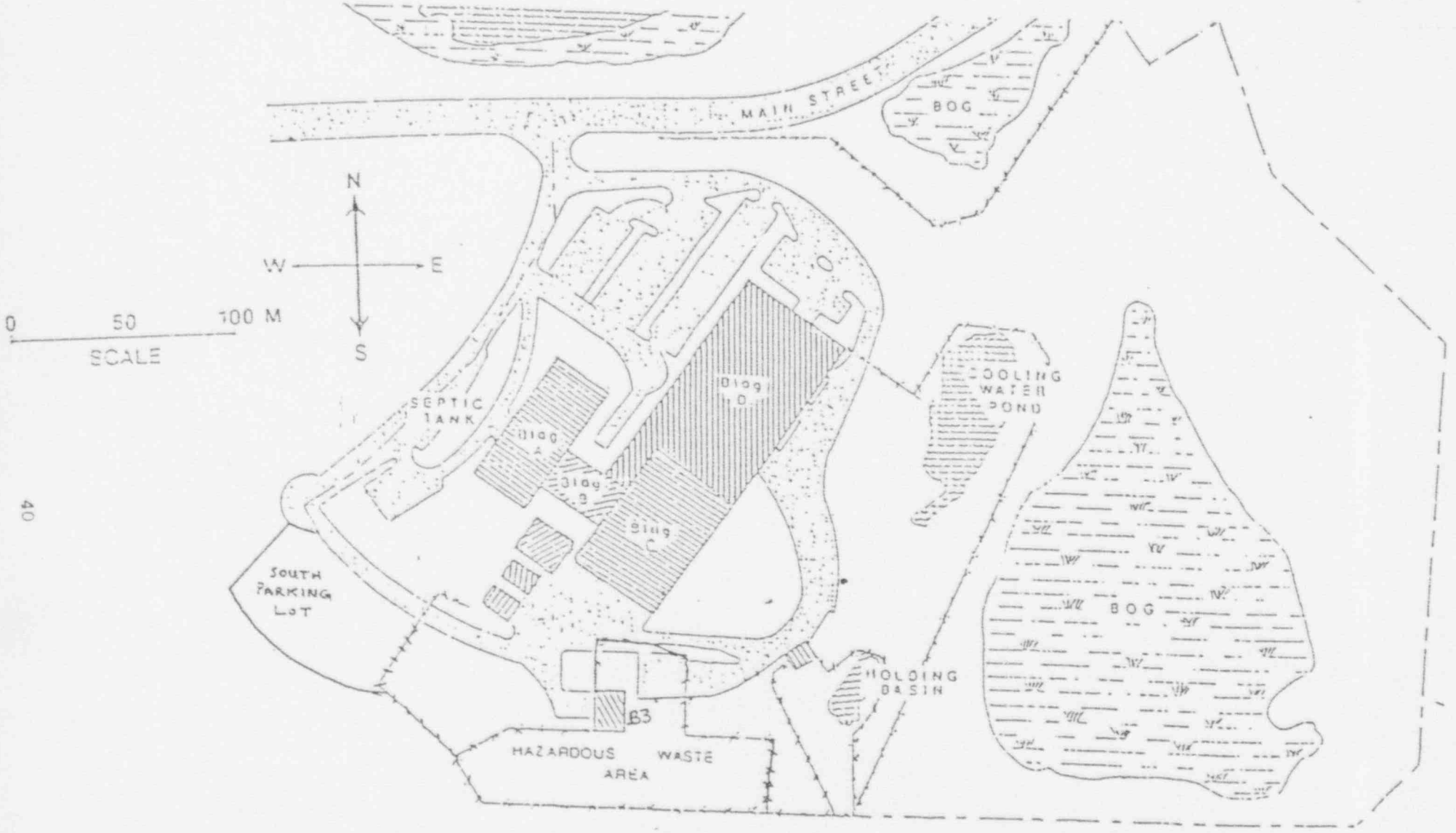


FIGURE No. 1) Plant Location and Buildings in 1983

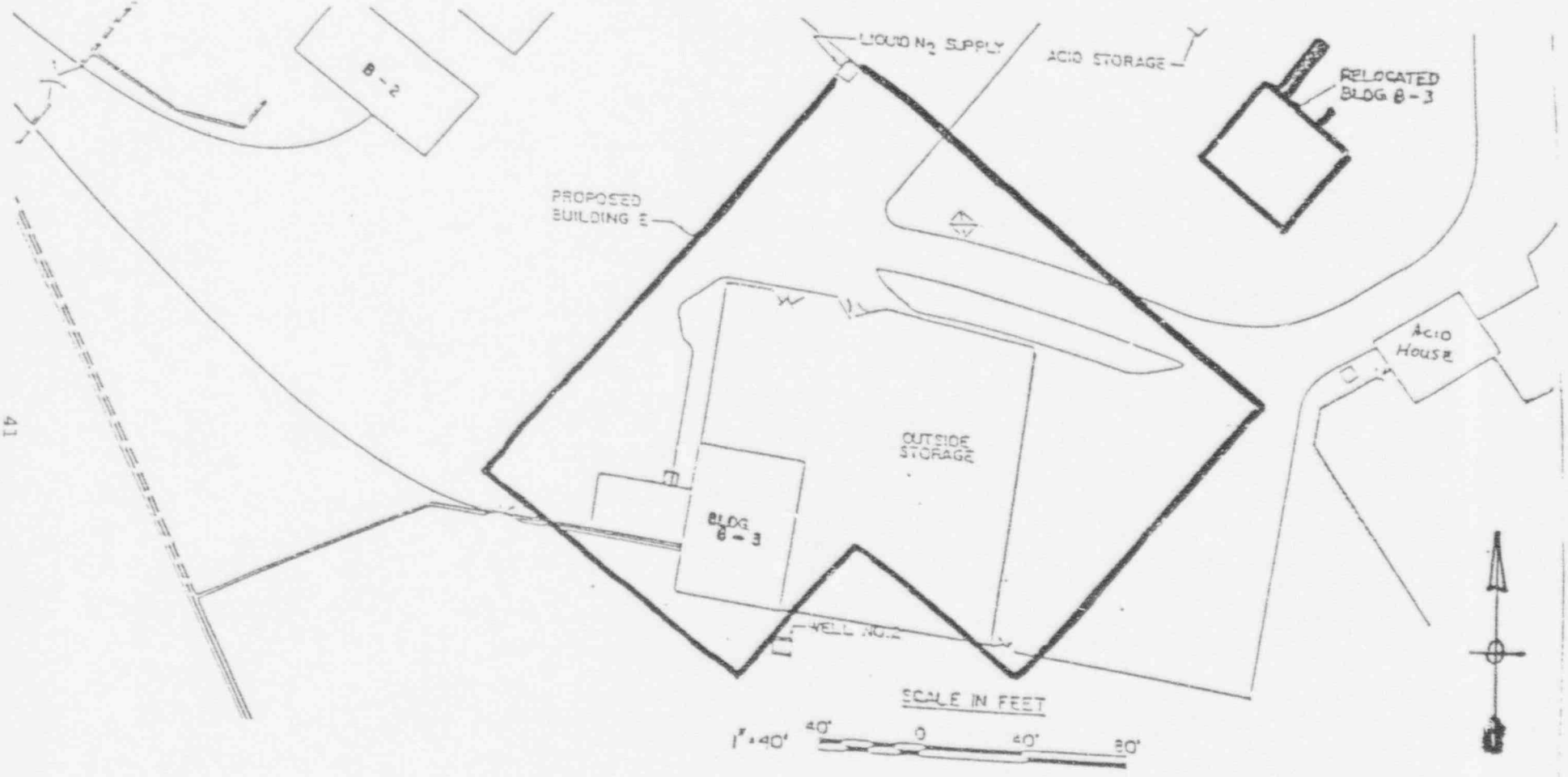


FIGURE No. 2) Building "E" Location Over Existing Conditions Prior to Construction in 1983

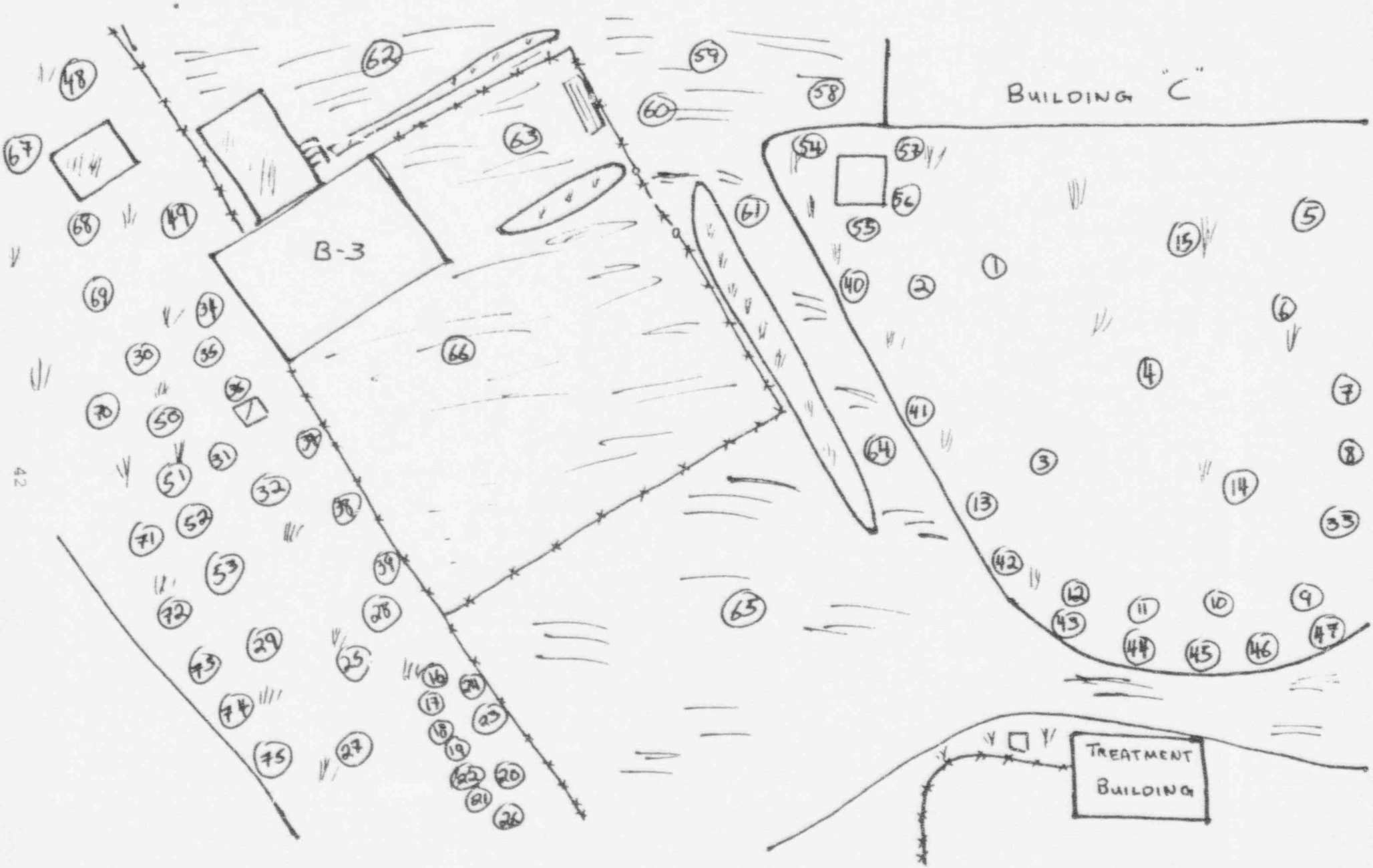


FIGURE No. 3) Locations of Soil Samples Prior to Work

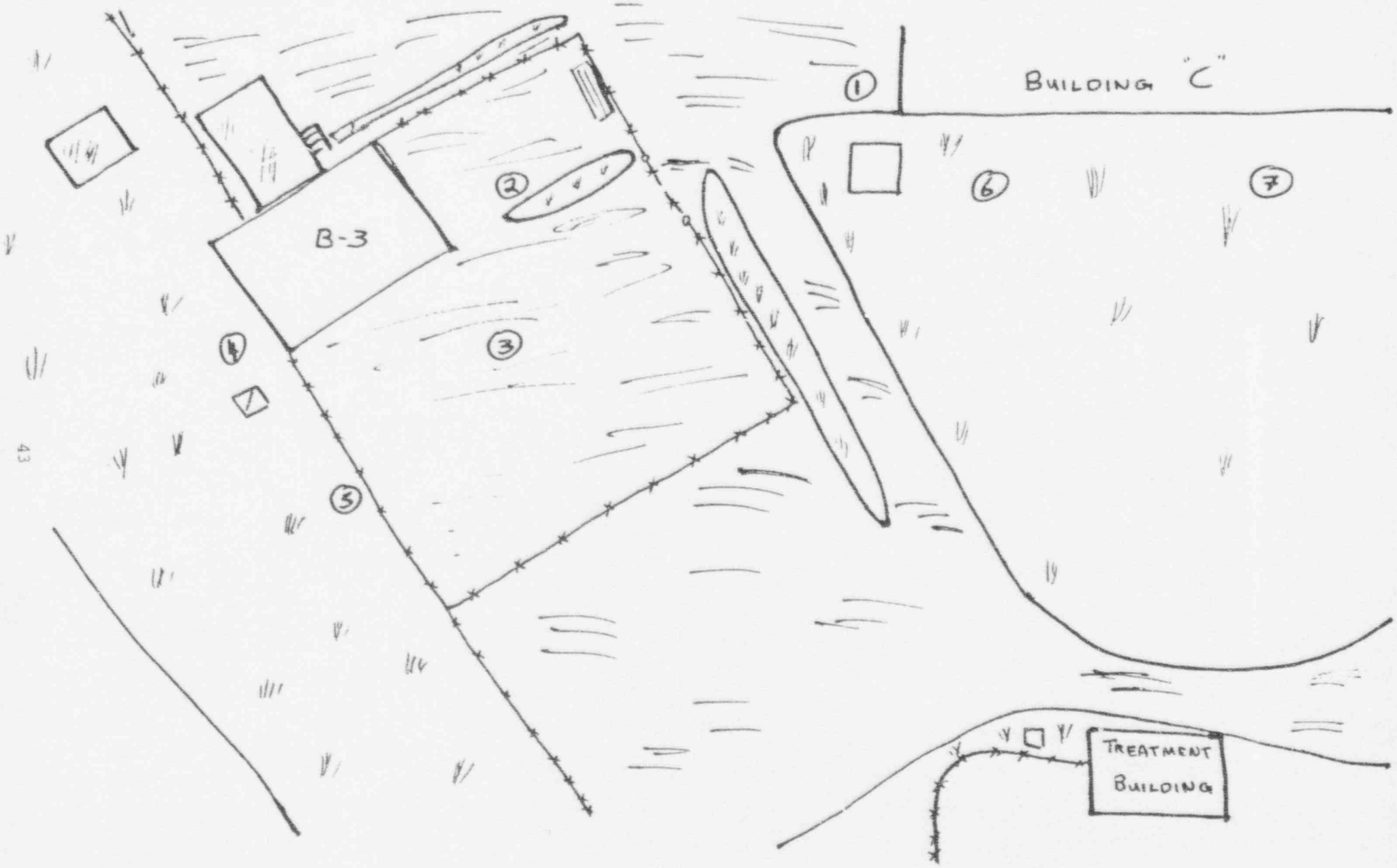
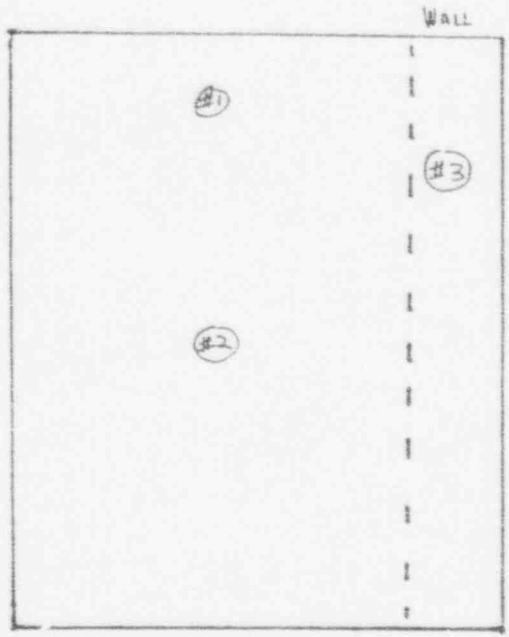
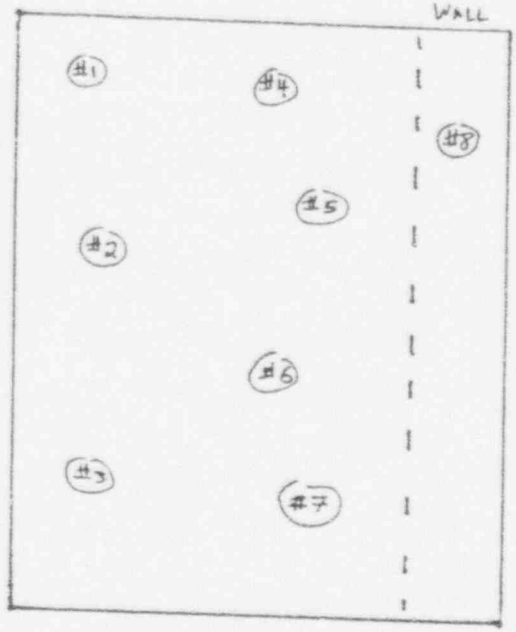


FIGURE No. 4) Locations of Soil Contamination Depth Tests

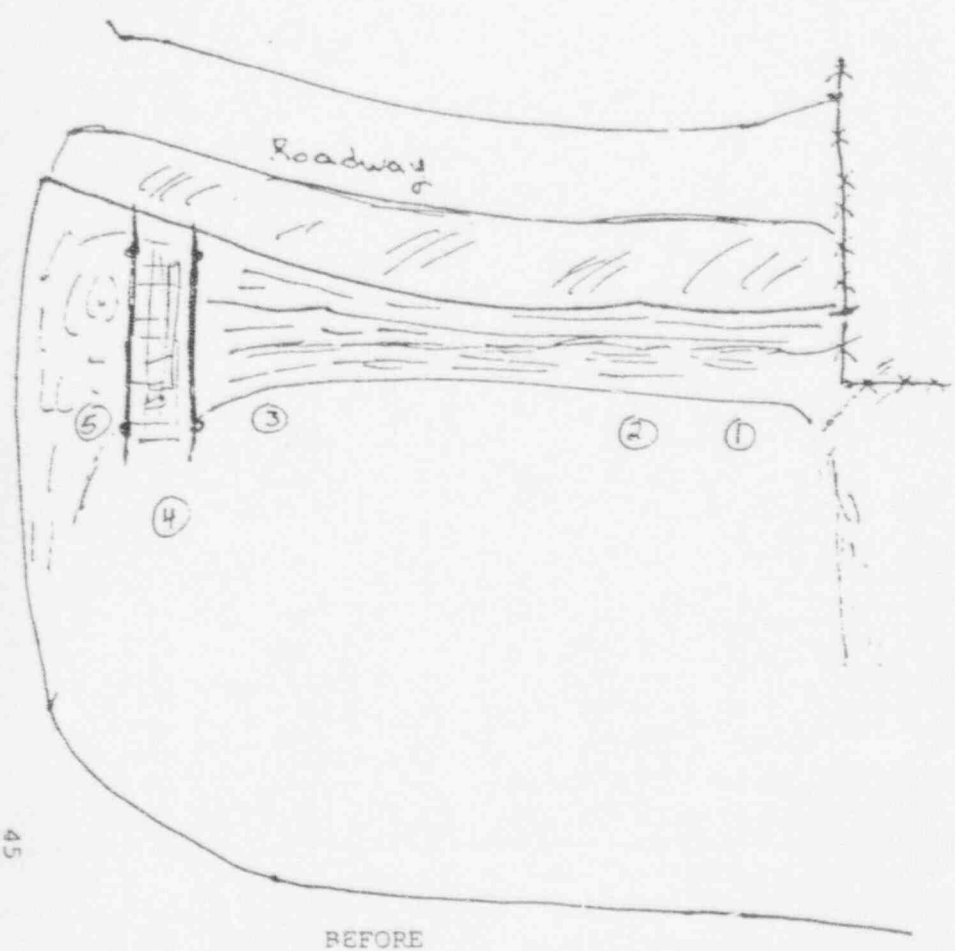


BEFORE



AFTER

FIGURE No. 5) Locations of Samples from the Concrete Walls and Floor of B-3 Before and After Scarification



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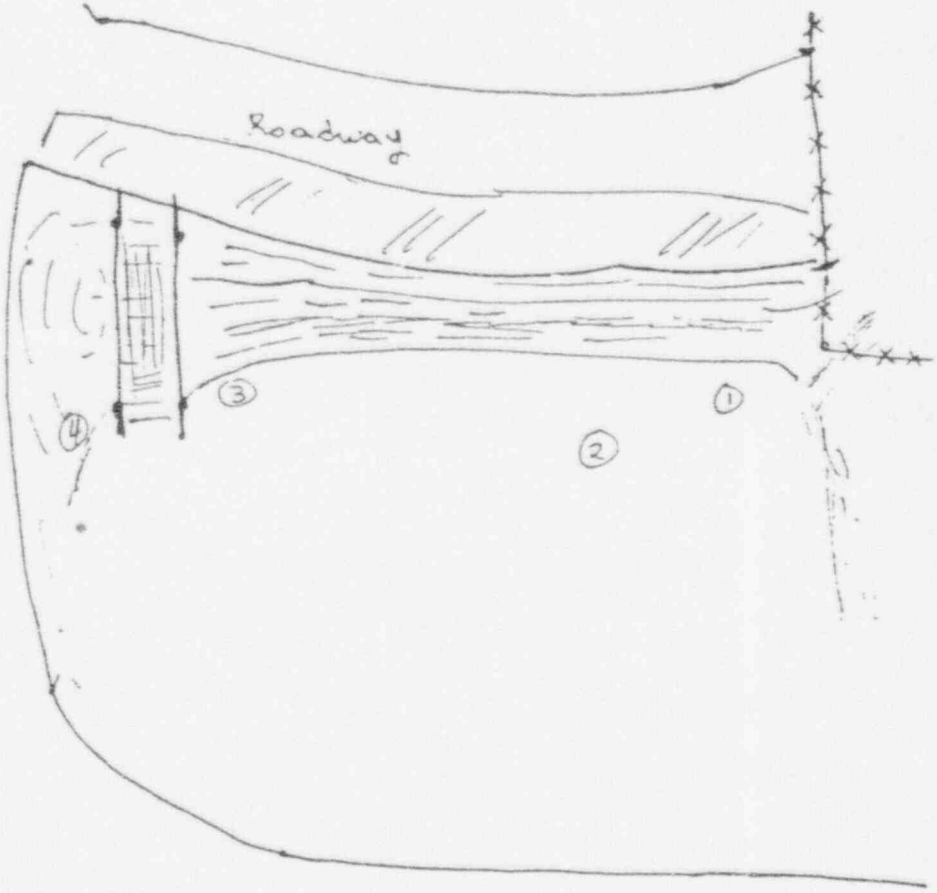


AFTER

FIGURE No. 6) Locations of Soil Samples Before and After Concrete Block Placement in South Parking Lot

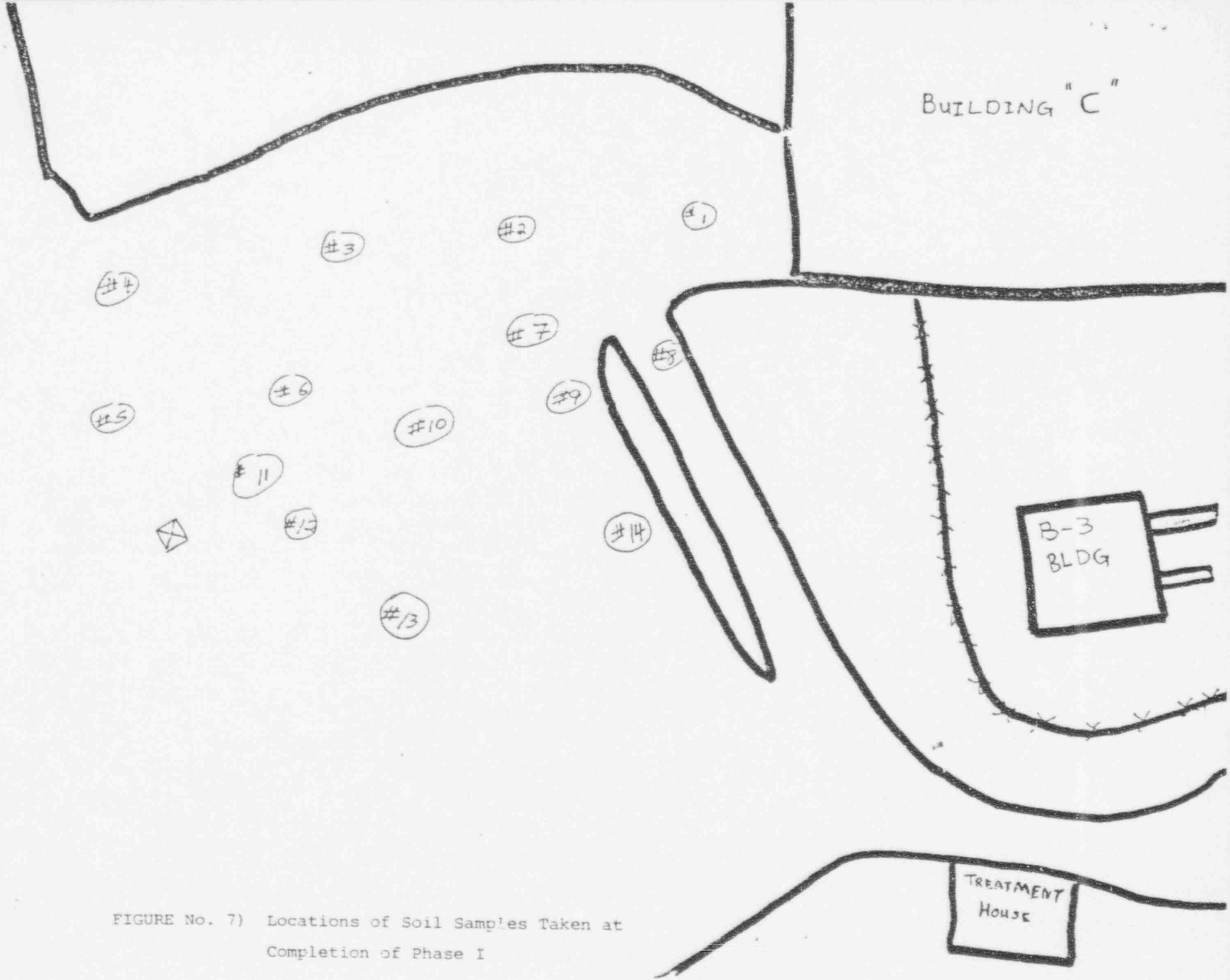


FIGURE No. 7) Locations of Soil Samples Taken at Completion of Phase I

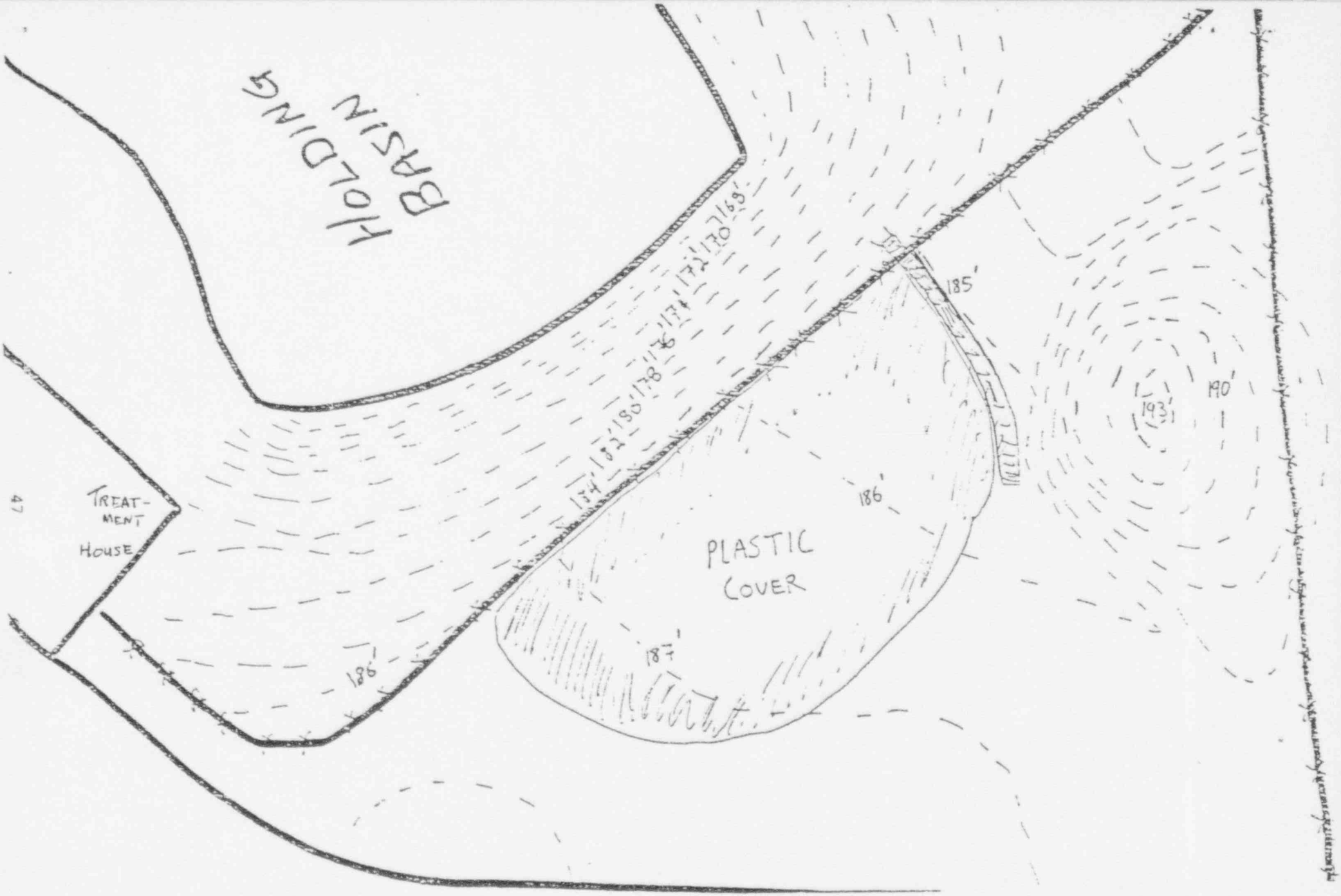
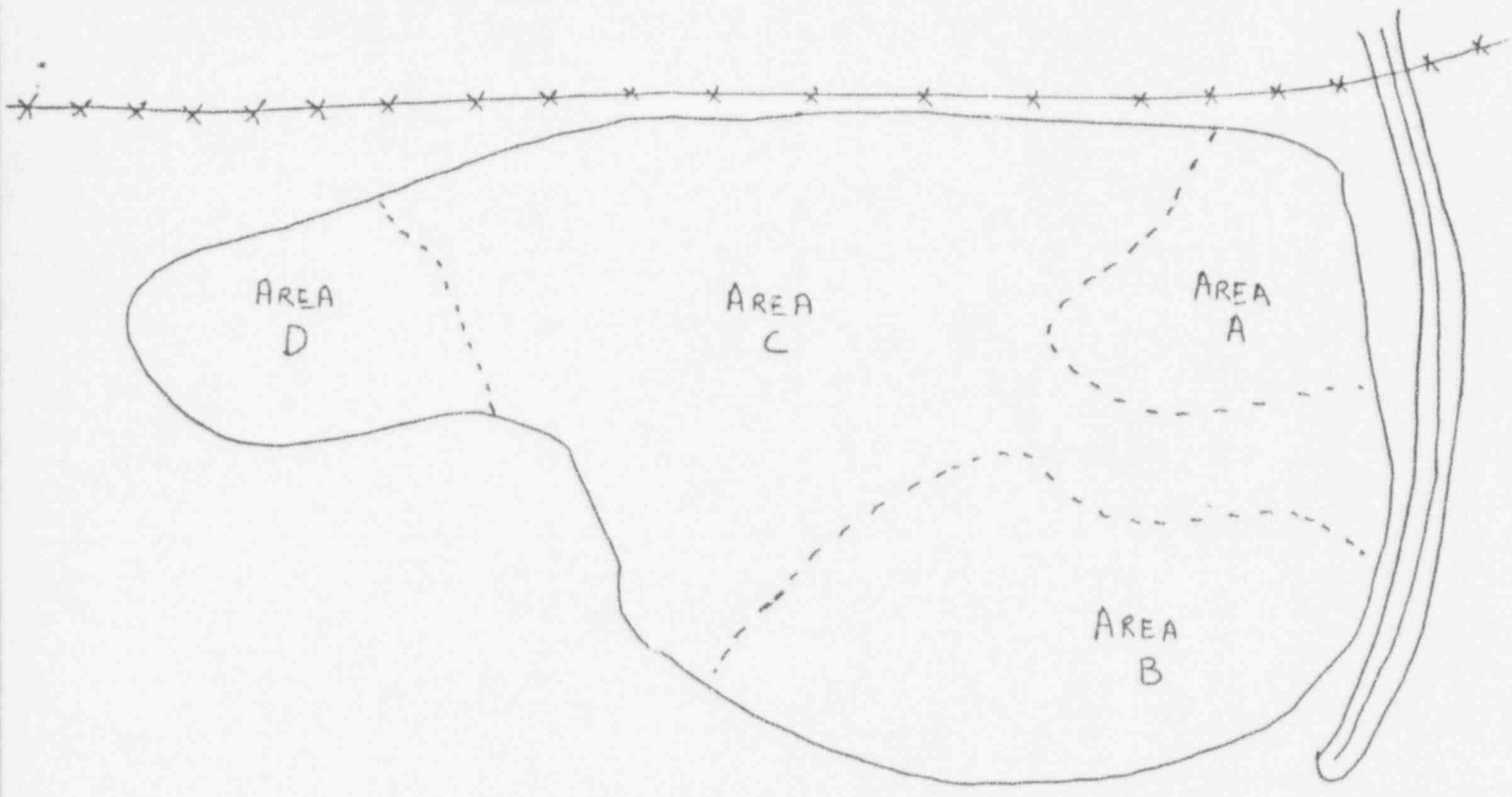


FIGURE No. 8) Topographic Map of Area Showing Location of the Containment Pile



Area A Scarified hot top and concrete

Area B Concrete pieces

Area C Soil

Area D Contaminated junk.

FIGURE No. 9) Building "E" Containment File

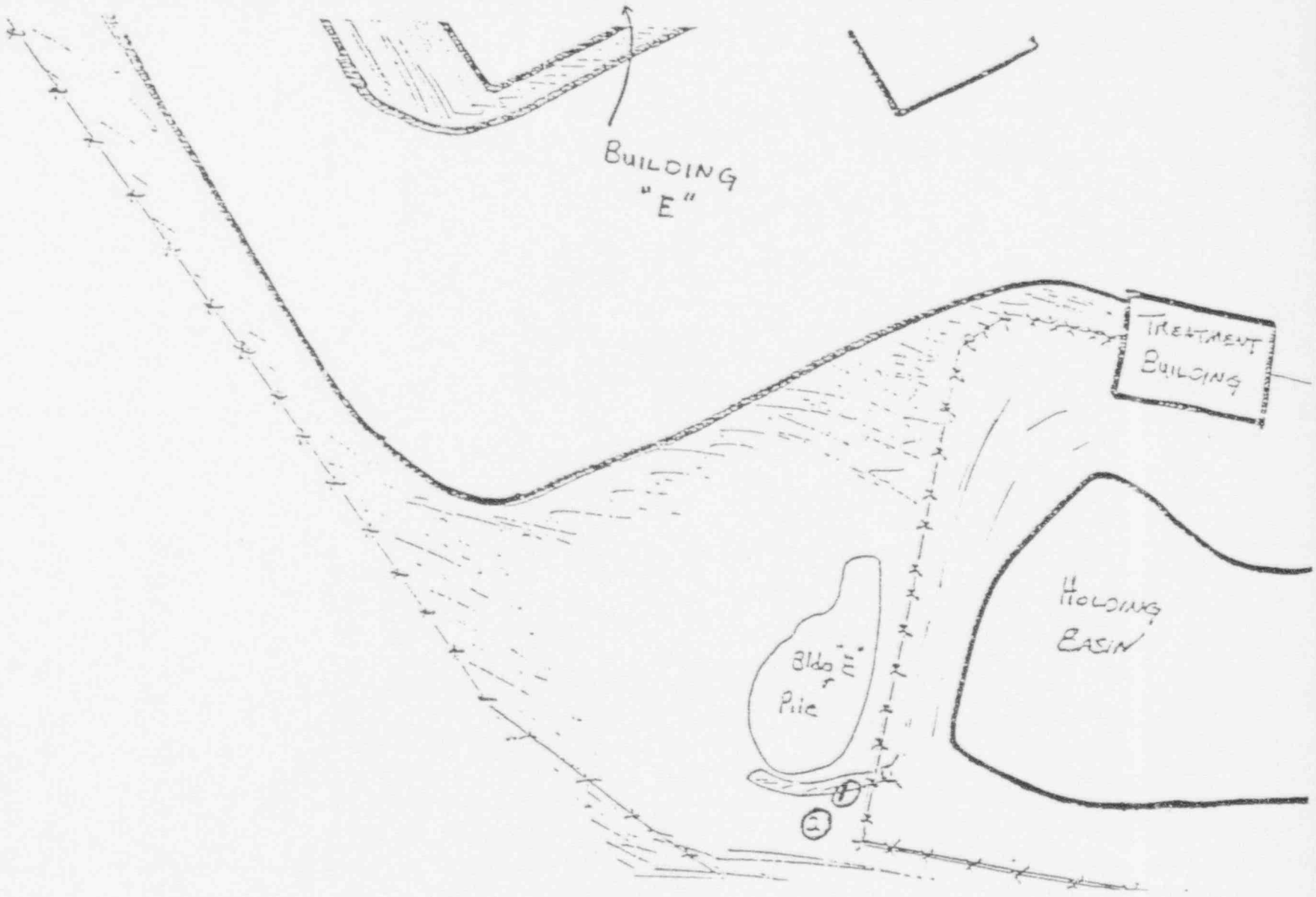


FIGURE No. 10) Pile location On Site and Locations of Areas Where Soil Samples Were Collected When Pile was Prepared for Winter and Prior to Work in the Summer

APPENDIX A: CALCULATION TO ESTIMATE MAXIMUM AIR CONCENTRATION OF URANIUM FROM CONTAMINATED SOIL

Let : $C_L \equiv$ OSHA dust loading limit, 5 mg/M^3,

$C_S \equiv$ typical concentration of U-238 in soil, 50 pCi/g

and,

$C_A \equiv$ concentration of U-238 in air at C_L and C_S, pCi/M^3.

Therefore: $C_A = C_L \cdot C_S$, or

$C_A = 5\ mg/M^3 \cdot 50\ pCi/g \div 1\ E3\ mg/g = 0.25\ pCi/M^3$.

Comparing to the project MPC_a guideline for U-238, 5 pCi/M^3:

$$\frac{0.25\ pCi/M^3}{5\ pCi/M^3} = 5.0\%\ \text{of}\ MPC_a.$$

APPENDIX B: EQUATIONS USED FOR ESTIMATING SOIL ACTIVITY CONCENTRATIONS IN AREA C

Let: $R_F \equiv$ net counting rate of field sample from backhoe bucket, cpm, and

$C_F \equiv$ field determined activity concentration of soil sample in bucket, pCi/gram.

The conversion factor E_F was estimated for field measurements by

$$E_F = \frac{R'_F}{C'_L},$$

where $R'_F \equiv$ net counting rate of bucket number 1, cpm, and where $C'_L \equiv$ lab determined activity concentration of a composite soil sample collected from bucket number 1, pCi/g.

The conversion factor E_F is used to estimate the activity concentration C_F of soil in the bucket:

$$C_F = \frac{R_F}{E_F}, \text{ or } \frac{R_F}{R'_F} C'_L .$$

BIOGRAPHICAL SKETCH OF AUTHOR

Adam S. Weaver was born, the last of four children, to Thomas E. and Judith C. Weaver on April 6, 1958 in Concord, Massachusetts. He grew up in Concord where he attended Concord public schools. After graduation from high school in June 1977, the author attended Curry College in Milton, Massachusetts where he earned a Bachelor of Arts Degree in Biology. He was awarded Curry College's Science Award in 1981.

Upon graduation from Curry College in 1981, Mr. Weaver began working at Nuclear Metals, Inc. in Concord, Massachusetts as a Hazardous Waste Technician. He is currently still employed by Nuclear Metals, Inc. and now works in their Health Physics Department with primary responsibility to the Environmental Affairs group.

Mr. Weaver married Patricia A. Sciore on July 2, 1983 and they currently live in their own home in Lancaster, Massachusetts.

With an increased interest in Health Physics applications, in September 1982 the author entered the University of Lowell's Radiological Sciences and Protection Program leading to a Masters of Science Degree.

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NAME: NUCLEAR METALS, INC. EXPIRATION DATE: 19890531
DEPT/BUREAU: _____
BUILDING: _____
STREET: 2229 MAIN STREET
CITY: CONCORD STATE: MA ZIP: 01742
ATTN: FRANK J. VUMBACO, VICE PRES.

MAIL CONTROL NO: 117780 RECEIPT DATE: 930219 (YYMMDD) ACTION TYPE: 4
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Date: Tuesday, September 13, 1994 12:54 pm
Subject: NUDOCS document that sent back to you

I am returning it to you, with the advice from JSurmeier and MWeber that perhaps it should be forwarded to John Kinneman, Region I, as they are project manager for Nuclear Metals, Inc. that is mentioned in this report and let them decide. But no one in DWM knows about this and even why it should go to NUDOCS. Thanks, Janette

Cindy Poland 9/15/94

Cheryll,
See attached note.
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