

United States - Ukraine Technical Exchange II Trip Report

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Prepared for the U.S. Department of Energy
Office of Technology Development



Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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ACRONYMS

ALARA	as low as reasonably achievable
DOE	U.S. Department of Energy
EM-50	Office of Technology Development
EML	Environmental Measurements Laboratory
GIS	geographic information system
GM	Geiger Mueller
GPR	ground-penetrating radar
GPS	global positioning system
ISV	in-situ vitrification
MCA	multi-channel analyzer
MDC	minimum detectable count
MR	master receiver
MRDS	mobile radiological data system
NPP	nuclear power plant
PSD	Personal Survey Devices
RF	radio frequency
SAIC	Science Applications International Corporation
SR	stationary receiver
WHC	Westinghouse Hanford Company
US	ultrasonic
USRADS	Ultrasonic Ranging and Data System

ACRONYMS (cont.)

UTM	Universal Transverse Mercator
WGS84	World Geodetic Survey 1984

TRADEMARKS

ARC/INFO	Environmental Systems Research Institute, Inc.
AT&T	American Telephone and Telegraph, Inc.
Eberline HP-270 GM	Eberline Instrument Corp.
Eberline SRM-300	Eberline Instrument Corp.
gamma data reduction (GDR)	EG&G Ortec
GammaVision (software)	EG&G Ortec
Ludlum Model 19	Ludlum Measurements, Inc.
Ludlum model 40-10	Ludlum Measurements, Inc.
Ludlum Model 2221	Ludlum Measurements, Inc.
M-1	EG&G Ortec
NOMAD	EG&G Ortec
NOMAD-2	EG&G Ortec
USRADS	ChemRad Tennessee, Corp.

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EXECUTIVE SUMMARY

During the period of May 15 to 21, 1994, the first technical conference was held at the Hanford Site in Richland, Washington between Ukraine-Chornobyl representatives, under the sponsorship of Chornobyl Union International, and representatives from Westinghouse Hanford Company and Science Applications International Corporation. The purpose of the conference was to exchange technical information and experience gained in the cleanup and stabilization of radioactive contamination at the Hanford and Chornobyl sites. The conference was funded as a part of contract activities for the U.S. Department of Energy (DOE).

A protocol was signed between representatives of both organizations agreeing to pursue a second technical exchange and technology demonstration program in Kiev and near the Chornobyl power plants.

Technical Exchange #2 was held from August 28 to September 9, 1994. The conference was funded by the DOE through Dr. Clyde Frank's Office of Technology Development (EM-50). The technical exchange had three main areas of focus: (1) field demonstration of DOE-Hanford technologies and their application to cleanup of contaminated lands resulting from the Chornobyl accident of 1986; (2) to explore application of other U.S.-DOE technologies; and (3) to observe Ukraine-developed technologies and evaluate their potential application in the U.S.

At the first technical exchange, the Ukraine-Chornobyl delegation identified the man-carried Ultrasonic Ranging and Data System (USRADS) as a qualitative radiological mapping technology that could have several applications for Chornobyl cleanup. They requested that this technology be demonstrated at three geographically different areas near Chornobyl. The U.S. team agreed and also chose to demonstrate a mobile radiological data system (MRDS), which uses a global positioning receiver that obtains signals from a satellite system. This latter method is more precise than the USRADS, but its position accuracy is not as definitive. This type of system was developed at Hanford and is used with mobile platforms, such as a tractor, for surveying large areas. In addition to these systems, the U.S. team brought to Chornobyl a quantitative radiological mapping system, the EG&G NOMAD™ unit, which was successfully demonstrated at one of the three demonstration sites on the last day of field operations at Chornobyl.

The Ukraine-Chornobyl team hosted technical presentations, discussions, and field trips for four and a half days. This provided the U.S. team detailed insight on the scope and magnitude of the Chornobyl problem that faces Ukraine and the rest of the world. The U.S. team presented overviews on DOE technologies that may be applicable to the Chornobyl situation. These included surface and subsurface barriers, radioactive waste handling and disposal methods, characterization tools, soil and groundwater remediation

technologies, quality assurance programs, and management systems. Other areas the Ukrainians requested assistance in included improving agricultural practices and forest management, harvesting, and fire prevention techniques.

The technical tours and discussions led the U.S. team to conclude that Ukrainian scientists and researchers have tremendous talent and have expended considerable energy in attempting to tackle a problem of unprecedented magnitude. The economic and cultural conditions within Ukraine have prevented acquiring the resources to implement basic aspects of characterization and remediation activities. A tremendous amount of research work has been completed, but most publications are printed only in Russian and not easily accessible to the worldwide scientific community. Translation of these papers, plus the resources to carry forward some basic research proposals into bench scale and field demonstration projects, could benefit the DOE complex and other nuclear programs. The hardware and prototype equipment that the Ukrainians have available appeared generally less innovative or reliable than items within the western world.

The U.S. team also concluded that Ukraine is experiencing considerable cultural and economic change. The changes, although evolving slowly, are aimed at stabilizing Ukraine and pushing it more toward a democratic and capitalistic economy. This atmosphere is providing many unique opportunities for private industries to assist in the changes and for DOE and others to apply cleanup technologies. It is essential that close relationships are established between the appropriate ministries and the institutions wishing to work within Ukraine. These relationships will help overcome cultural, political, and technological differences that naturally exist between two distinctly proud countries. Per agreement with Dr. Clyde Frank, no follow-on commitments were made for the DOE. Follow-on opportunities will be the responsibility of private industry working with Ukrainian ministries.

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UNITED STATES - UKRAINE TECHNICAL EXCHANGE II

CHORNOBYL, UKRAINE

AUGUST 28 - SEPTEMBER 9, 1994



Pripyat Ghost Town and Abandoned Amusement Park

**United States Department of Energy
Office of Technology Development**

1.0 INTRODUCTION

1.1 TECHNICAL EXCHANGE #1

A two-step technical exchange program between the United States and Ukraine was planned in April 1994. The first technical exchange was held at the Hanford Site from May 15 to 21, 1994. Ukraine's Chornobyl delegation consisted of five delegates representing Ukrainian Ministries, the Chornobyl exclusion zone, and Chornobyl Union International, which sponsored the delegation. The U.S. representatives, consisting of staff from Westinghouse Hanford Company (WHC) and Science Applications International Corporation (SAIC), and the conference, were funded as part of contract activities for the U.S. Department of Energy (DOE). The exchange introduced the Ukraine delegation to the cleanup problems facing the Hanford Site and the technologies being utilized. Presentations and tours were conducted for a full week so that the Ukrainians could ascertain which technologies could be considered for transfer to remediate the contaminated soil, groundwater, and facilities resulting from the accident at the Chornobyl Unit 4 in April 1986.

Although there are differences in soil types, depth to groundwater, magnitude of contamination, and regulations between Hanford and Chornobyl, the Ukraine-Chornobyl team was eager to pursue further exchanges with the United States. They believed it was imperative that the U.S. team see first-hand the conditions at Chornobyl so that appropriate technologies could be matched to specific applications. The Ukraine team was impressed with the Ultrasonic Ranging and Data System (USRADS) used for radiological mapping at Hanford and requested that the technology be demonstrated at several sites in and around the 30-km exclusion zone.

The exchange concluded with all parties signing a protocol agreeing to pursue future technology transfer opportunities, to demonstrate the USRADS system at Chornobyl, and to hold a second conference in Ukraine.

1.2 TECHNICAL EXCHANGE #2

The second technical exchange was conducted in Kiev and Zeleny Mys, Ukraine from August 28 to September 9, 1994. The technical exchange had three main areas of focus: (1) to demonstrate DOE-Hanford-developed technologies and their application to cleanup of Chornobyl's contaminated lands and facilities; (2) to explore other potential U.S. technology applications; and (3) to observe Ukraine-developed technologies and evaluate their potential application in the United States.

The specific objectives of the technical exchange were to:

- Assess the current logistics, technologies, and approaches used at Chornobyl to determine if DOE-developed technologies can be utilized as is or modified to enhance Chornobyl cleanup
- Demonstrate to the Ukrainian technical staff specific DOE-developed technologies and cleanup approaches
- Assess the broader aspects of Chornobyl's environmental problems for potential U.S. involvement
- Evaluate Ukraine-developed technologies and potential application of those technologies to solve U.S. environmental problems
- Discuss the cultural, economic, and political issues that must be managed for U.S. technologies and industry to be utilized in Chornobyl cleanup and economic recovery
- Report all findings and understandings in a formal trip report to the DOE Office of Technology Development (EM-50).

Per agreement with Dr. Clyde Frank of DOE EM-50, no further commitments for DOE were made; future opportunities will be the responsibility of private industry.

The results of these objectives are documented in this trip report. The daily agenda prepared by the Chornobyl team can be found in Appendix A.

The conference goals and results were summarized and signed by the Ministry of Chornobyl, Chornobyl Union International, and the U.S. team.

2.0 TECHNICAL DISCUSSIONS AND EXCURSIONS RELATIVE TO CHORNOBYL'S PROBLEMS AND SOLUTIONS

This section provides a chronological synopsis of the technical discussions hosted by the Chornobyl delegation at the International Conference Center in Chornobyl, Ukraine (Figure 2-1).

2.1 AUGUST 29, 1994

Five members of the U.S. team were located in the International Conference Center at Zeleny Mys, approximately a 45-minute drive from Chornobyl. Two had arrived in Ukraine several days earlier to assess the site conditions and arrange for logistical support, one would arrive with the demonstration equipment within two days, and other members of the team came several days later to complete the 8-person team. The staggered arrival was to minimize U.S. costs for the technical exchange.

Volodymer Kholosha, Deputy Minister of Chornobyl, gave us an overview tour of the town of Chornobyl, the evacuated city of Pripyat, and the areas around the reactors. We were issued "travel clothes" for travel from Zeleny Mys into the 30-km exclusion zone and the town of Chornobyl. Once there, we changed vehicles and traveled to a change facility in the 10-km exclusion zone where clothes were changed to issued "zone clothes." The two set of clothes are almost identical in design; cotton shirt and cotton/wool pants and jacket (Figure 2-2). Cloth skull caps are issued but not required to be worn. Gloves and breathing protection equipment are neither issued nor required according to Ukrainian safety practices.

The tour was of a general nature to allow us to "get the lay of the land" and help us adjust to the human and emotional aspects of such intense and wide-spread contamination. The city of Pripyat seemed especially eerie. The electronic reader board outside the city indicated dose rates of 74 microrems (μ Rem) at the time of the tour. Although technically a ghost town, many people work within the city in offices, cafeteria, laundry, etc. These people are compensated with special meals, medical care, and additional salary.

The following pages show photographs of various areas within the 10-km exclusion zone (Figures 2-3, 2-4, 2-5, and 2-6).

In the afternoon, Kholosha acted as guide for four team members during a 45-minute helicopter trip that covered the entire Chornobyl site and surrounding areas. We flew over Zeleny Mys, logging operations within the 1992 fire area, the equipment graveyard (Figure 2-7), the medium- and low-level burial grounds (Figure 2-8), Pripyat, the sarcophagus, and the river and surface waters. The trip provided an outstanding opportunity to view the magnitude of the accident and realize that the cleanup will require a tremendous amount of resources and time.

Figure 2-1. Technical Exchange #2 in Session at Chornobyl, Ukraine.

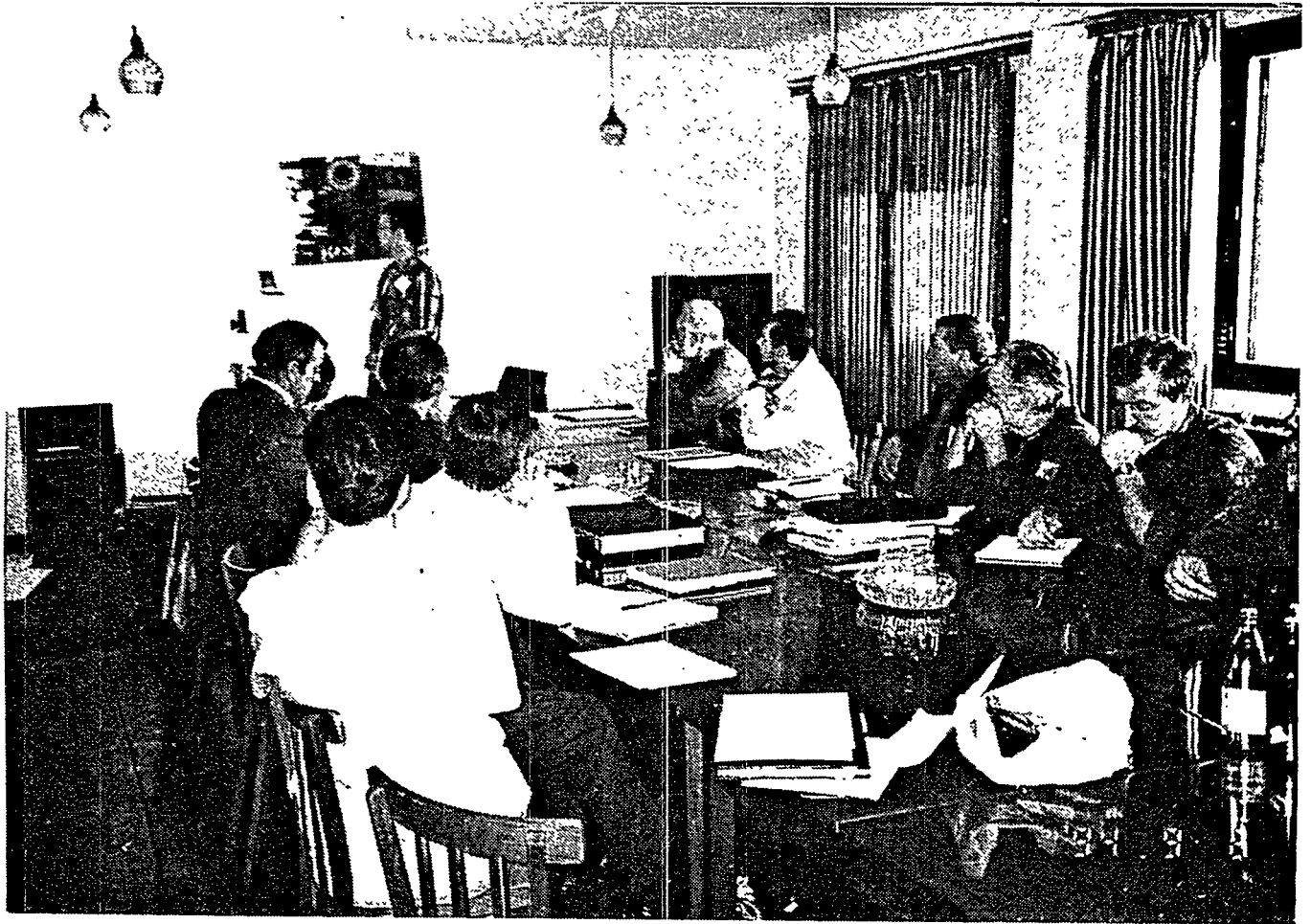


Figure 2-2. The Ukraine and U.S. Teams in Their Work Clothes Outside the Sarcophagus.

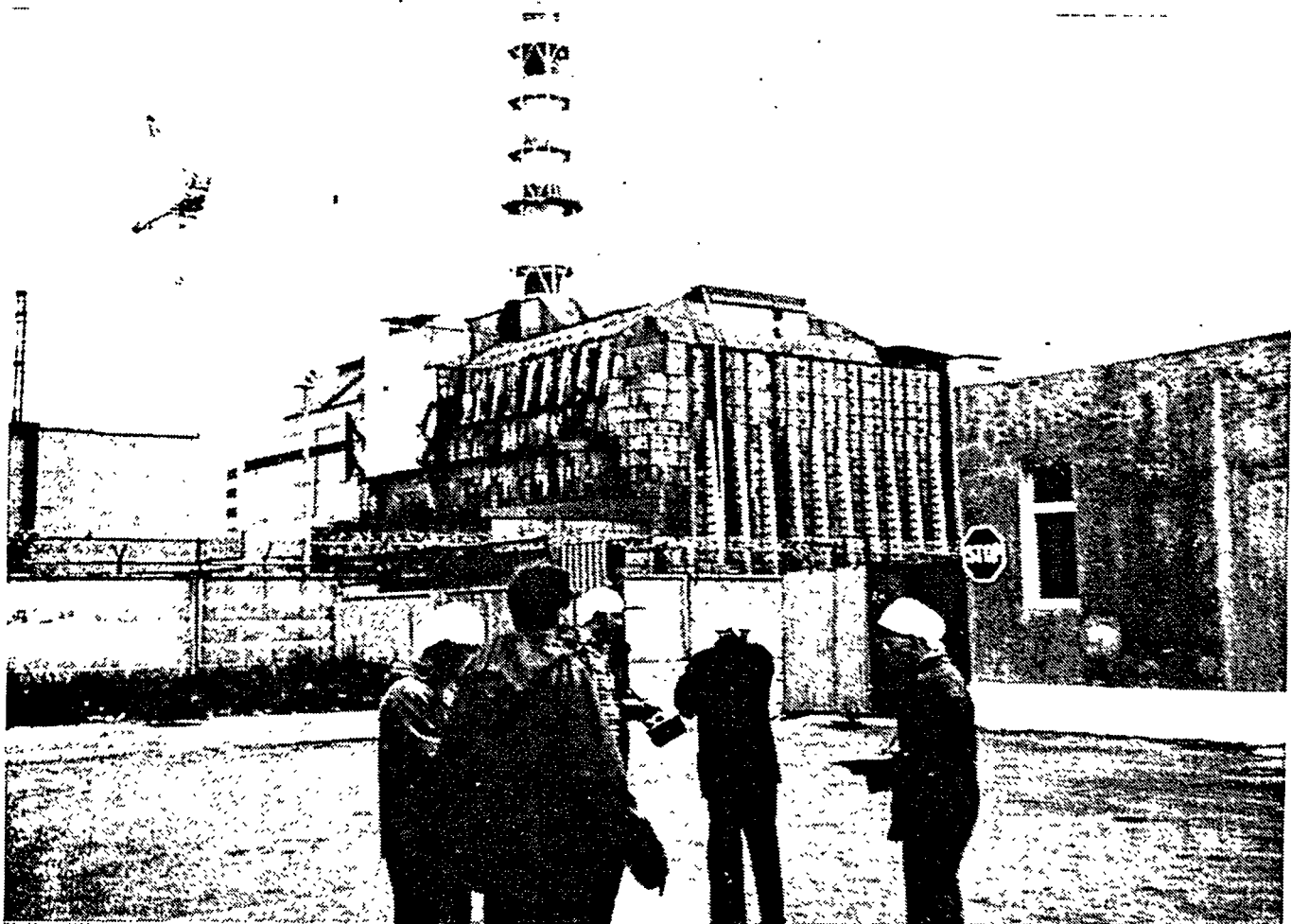


Figure 2-3. The Sarcophagus Covering Unit 4.

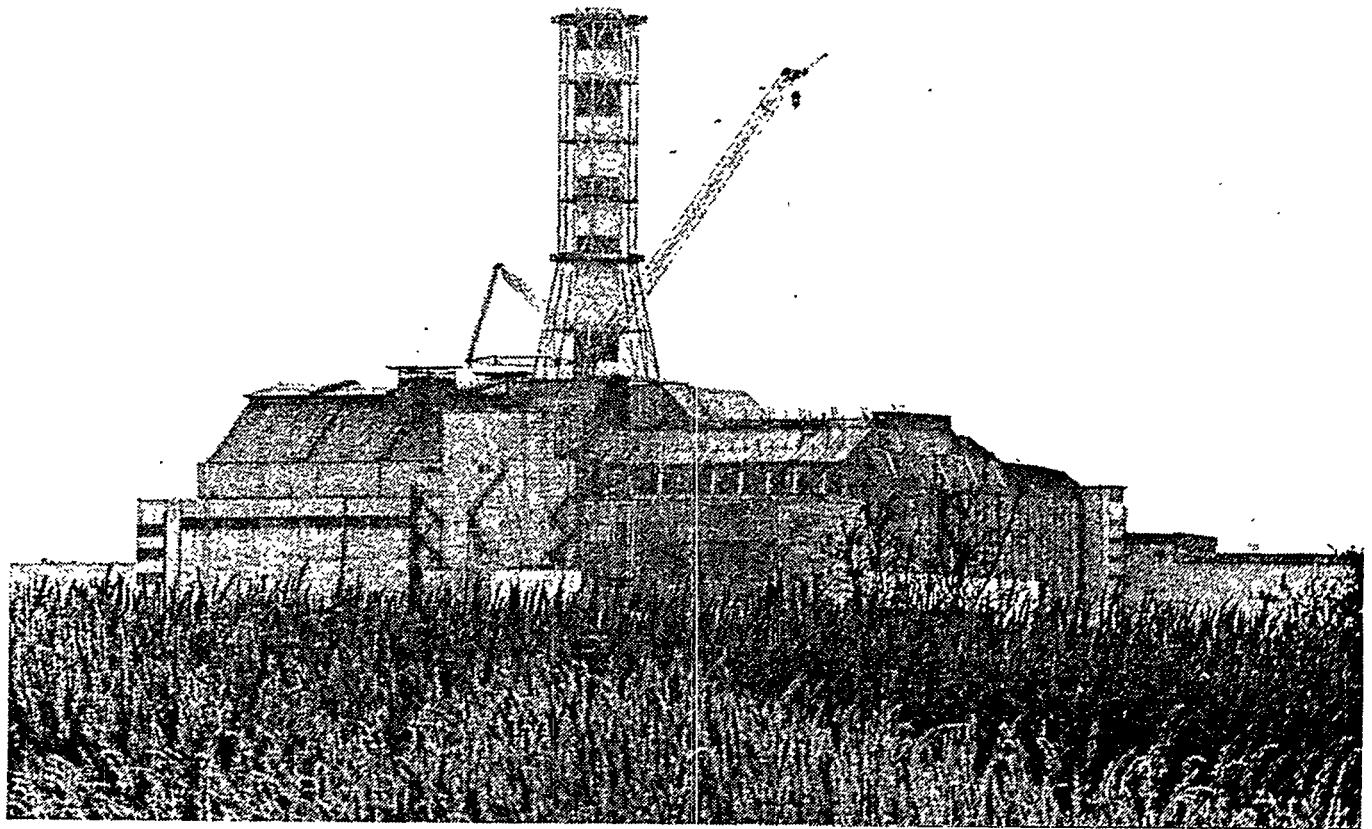


Figure 2-4. The Ghost Town of Pripyat, 1.2 km from the Sarcophagus.



Figure 2-5. The Amusement Park in Pripyat.



Figure 2-6. The Stadium and Hotel in Pripyat.

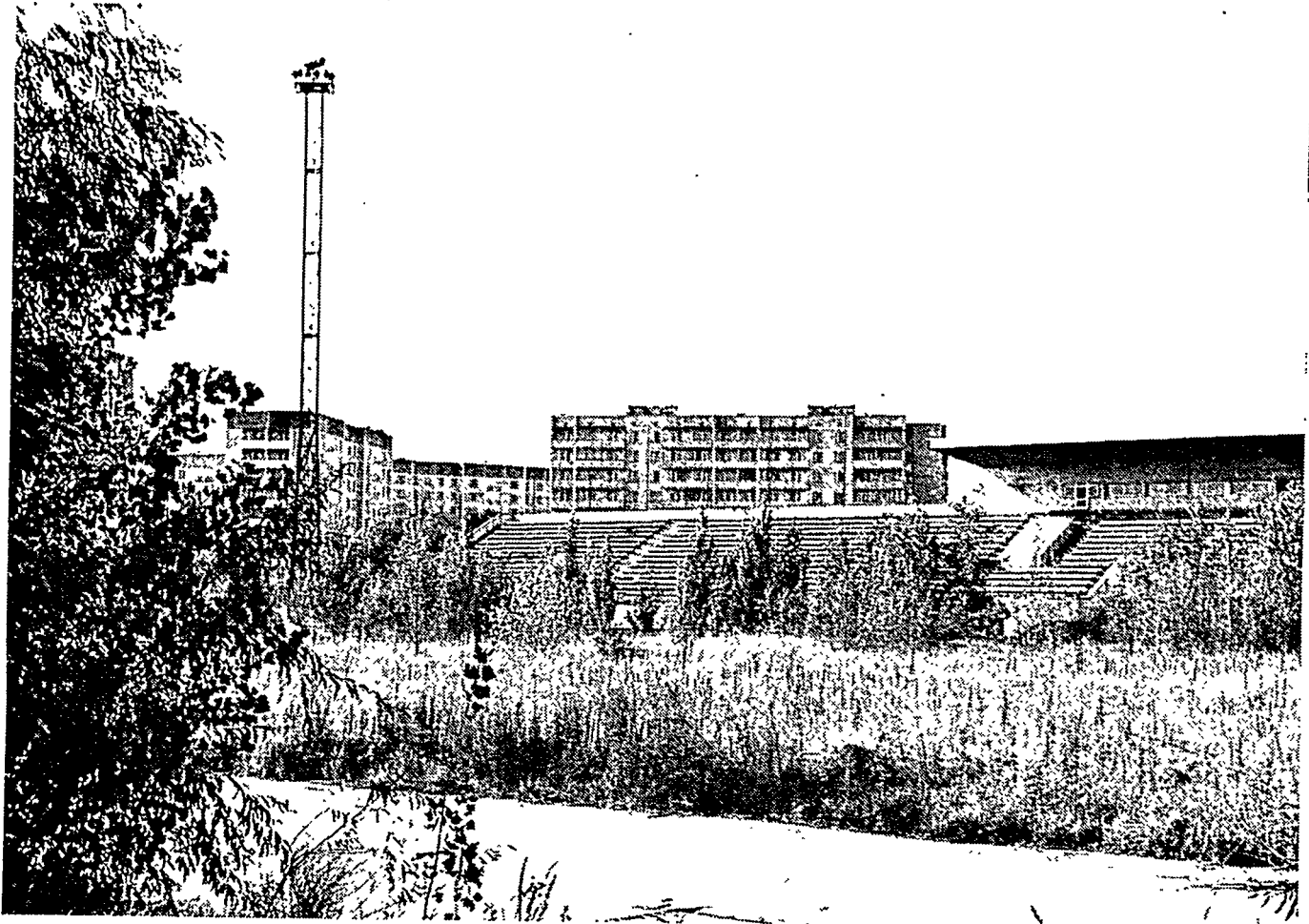


Figure 2-7. A Small Section of the Contaminated Equipment Yard.

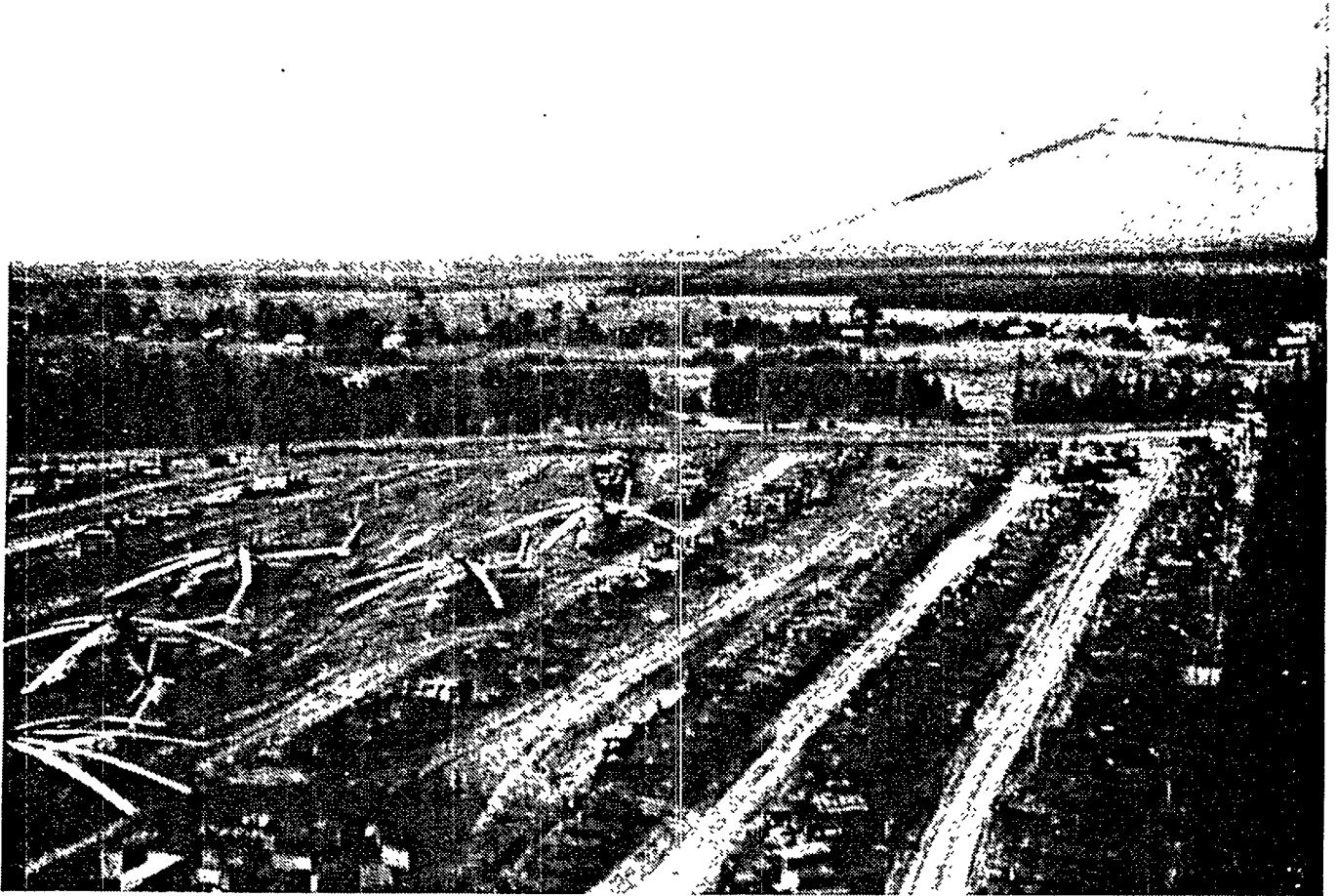


Figure 2-8. The Low- and Medium-Level Burial Grounds.



2.2 AUGUST 30, 1994

The conference convened with Volodymyr Kholosha, Deputy Minister of Chornobyl, as chairperson. Kholosha and Sergey Saversky, Administrator of Technical Services for 30-km exclusion zone, were the leaders of the Ukraine team and our hosts for the exchange. The audience consisted of the U.S. team, the interpreter Alexander Shevechenko, and 15 Chornobyl staff. These staff are the key representatives or heads of all zone activities, including forests, water protection, infrastructure, monitoring, research, and the Pripyat Association. Kholosha introduced his colleagues, and Donald Moak (WHC) introduced the U.S. team. Kholosha presented background on the first technical exchange and discussed the protocol signed in May. The intent of this exchange was to adhere to the actions in the initial protocol; however, Kholosha suggested that some minor perturbations might be necessary because the equipment had not arrived yet, and there were additional members of the U.S. team arriving in several days. He stated that because the United States and Ukraine have different cultures and ways of doing business, the group would need to discuss these and try to understand each other's ways.

The exclusion zone is approximately 2,100 km² with about 110,000 hectares of forest. The Pripyat River and several smaller rivers run through the exclusion zone. Before the accident, the zone had a well-developed infrastructure. There were 84 settlements and towns plus the cities of Chornobyl and Pripyat. After the accident, over 100,000 people had to be resettled (Figure 2-9).

Kholosha described how several measures were taken immediately after the accident, including the construction of approximately 800 temporary burial sites for contaminated material. These sites now contain low- and medium-level wastes, including wastes contaminated with transuranics (see Section 2.4 for a more detailed description). Burial grounds were constructed near villages and near nuclear power plants (NPP) 5 and 6 that were then under construction. Approximately 370,000 curies of radioactivity are in the burial sites. There are estimated to be 250,000 curies of radioactivity in the remainder of the zone, exclusive of that within the sarcophagus. Approximately 150,000 m³ of waste exist within the zone. Since the accident, contamination is spread approximately 83% by flooding and water, 15% by air, and the remainder by human activities and birds.

Within the exclusion zone, NPPs 1 and 3 are in operation. Units 5 and 6 were not completed. Unit 4 is within the sarcophagus, and Unit 2 was shut down in 1991.

Kholosha identified the three priorities within the zone dictated by a draft document issued by the Ministry. This document has several conclusions and ideas that are factual and without argument; others have caused some debate.

Figure 2-9. An Abandoned Settlement Within the 30-km Exclusion Zone.



The three priorities are:

- (1) Stabilize the radioactive waste in the zone by preventing airborne and other releases.
- (2) Ensure that forests, lands, and water are properly managed to prevent fires, airborne releases, and subsurface releases.
- (3) Isolate waste burial sites in which 60 to 70% of the radioactivity is concentrated.

The burial grounds were constructed as "temporary" storage areas, and now, radioactivity from these sites is leaching into the groundwater and waterways. The levels of radioactivity and the inventory of buried material is now being determined.

There are three ways to treat the problem:

- (1) Monitor the existing sites
- (2) Stabilize the burial sites by using various technologies, including those in use at Hanford
- (3) Remove the wastes and transport them to permanent burial sites.

At some temporary burial sites, biomass was used to remove contamination; however, other, more advanced technologies should be applied. Contaminated groundwater migration into the Dnieper River is a major concern because millions of Ukrainians use the Dnieper River as their source of fresh water.

Kholosha concluded the presentation by explaining the Organization Chart of the "Pripyat Association" (Figure 2-10).

The U.S. team presented a generalized overview of the site characteristic methodologies leading to remediation, based on the book *Field Sampling Methods for Remedial Investigations* by Mark Byrnes of SAIC. A presentation was given on the technologies that would be demonstrated over the next several days. These include USRADS, the mobile radiological data system (MRDS), and NOMAD™.

Following lunch, the U.S. team was given a tour of the Radiochemistry Laboratory (Figure 2-11). The laboratory performs analyses for chemical, radiological, and biomedicine research. The laboratory is equipped with liquid scintillation counters, alpha scalars, etc., including an EG&G NOMAD unit. The NOMAD unit was not state of the art and had not been used. The Ukrainians hope to use it in a helicopter survey (which would not be an effective use).

Figure 2-10. Structure of Research - Industrial Association of Pripyat.

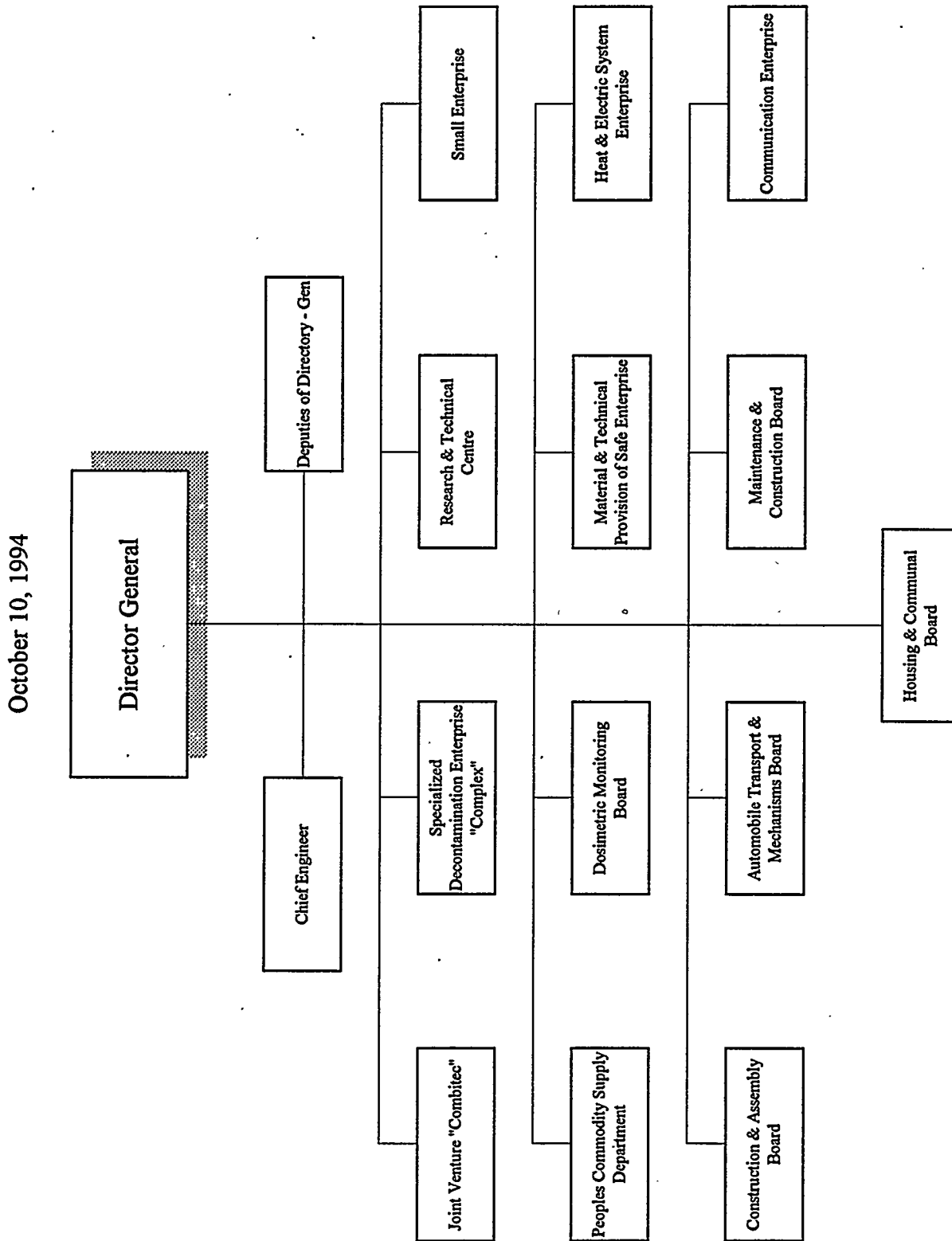
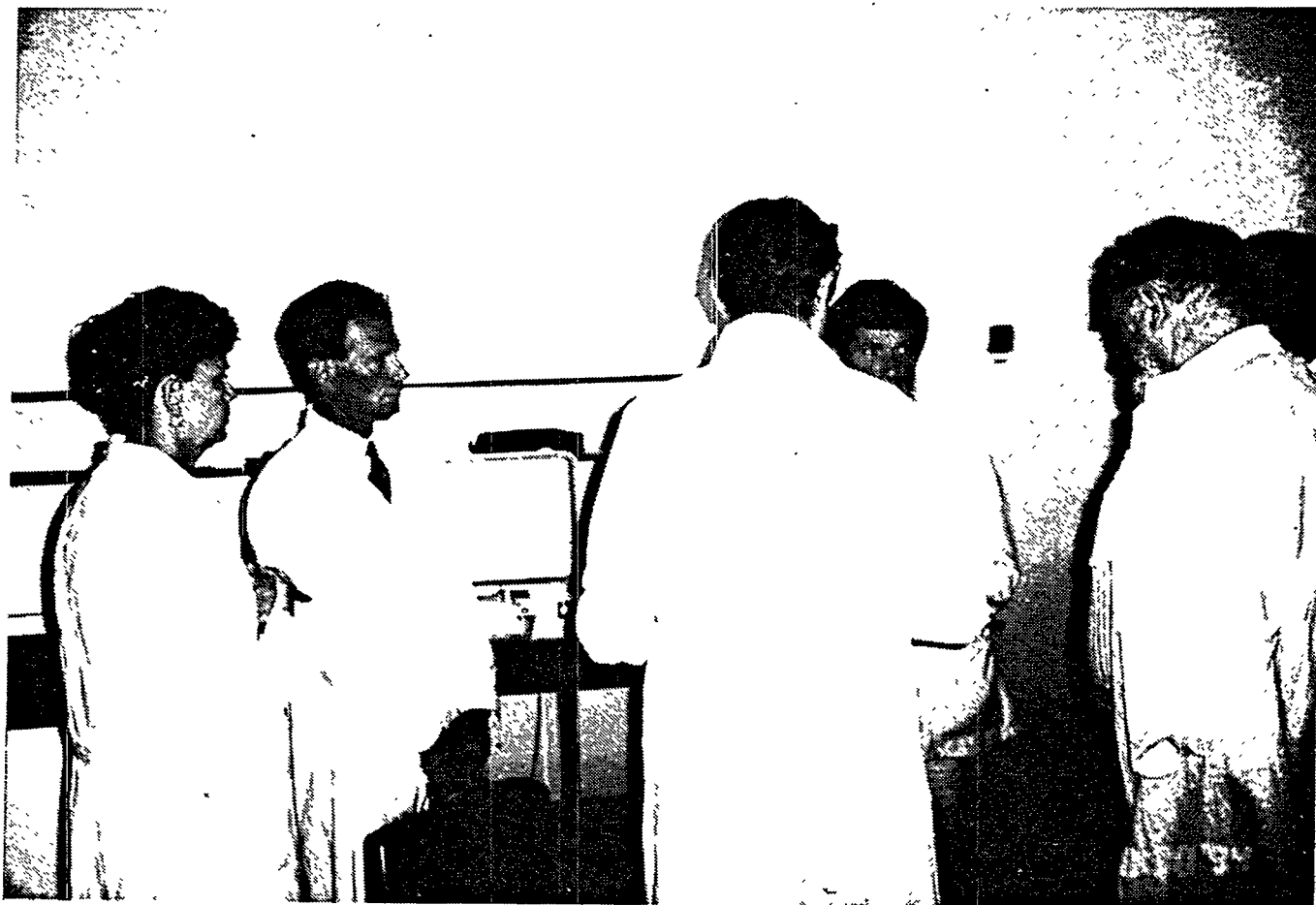


Figure 2-11. Kim Berg (SAIC), Don Moak (WHC), Alexander Shevchenko (Interpreter) an Unidentified Laboratory Technician, and Dr. Nikolay Arkhipov, Scientific and Technical Center Director, Visiting the Radiochemistry Laboratory.



Although the laboratory has good instrumentation, no experiments or analyses were noted. Only one laboratory scientist was present during the tour.

After the laboratory tour, both the Ukraine and U.S. team reconvened for technical discussions. There was considerable discussion, especially at breaks, as to the necessity for further radiological mapping and characterization. Some felt that the mapping of contaminants was nearly complete; others felt that the USRAD/MRDS were essential for further detail. It appeared that maps of 1:200,000 scale with limited data points were available, but detailed 1:25,000 scale was desired by many scientists.

The discussion concluded at 4:00 p.m. and the U.S. team returned to Zeleny Mys to prepare for field work on August 31 and September 1.

2.3 SEPTEMBER 2, 1994

After two days of field work, intermittent rain in the morning forced the postponement of field work for the day. Under the direction of the interpreter, Alexander Shevechenko, the U.S. team toured several facilities in Pripjat and ended the day with an ecology tour.

2.3.1 Facilities Tour

The first was the laboratory for compiling soil and water sample data and the environmental air sampling data acquired from the 21 monitoring sites within the 30-km exclusion zone. Average concentrations of the air sampling data were:

Element	Concentration
Cs ¹³⁷	1E-16 - 1E-17 Ci/L
Ru ¹⁰⁶	1E-20 Ci/L
Pu	1E-22
Sr ⁹⁰	1E-18

The group next visited the field laboratory, which contains a greenhouse and nurseries for growing plants and vegetables. The laboratory, run by Department Head Lydia Loygonova under Dr. Nicholai Anatolov, deals with many issues. These include subsurface leaching problems, food chain problems, and genetics. Over 600 types of plants, such as berries and other fruits, are grown in the greenhouse and outdoors. The greenhouse was built before the accident to grow food for consumption and was planned to open in May 1986. The accident forced postponement of its opening for several months. Plants grown here are from both contaminated and uncontaminated seeds, including some from the Red Forest (the forested area killed by radioactivity from the accident). Genetic effects of

seedlings have been studied for several years. Although we were told that the trees are "grown in decontaminated soil," our instruments indicated that the soil was actually 200 to 400 counts per minute (cpm) above background.

A small plot of fir trees in the laboratory is used to assess morphological changes in irradiated seeds from the Red Forest. We noted some visible effects, including multiple branches from a single node aberrant, needle morphology, and color of the trees. The laboratory plans to continue experiments with second, third, and fourth generation seeds.

Scientists from Sweden, Switzerland, France, Netherlands, and Spain actively participate in this research. We presume that because their areas of Europe were most affected by the accident, these scientists have the strongest interest in research. No U.S. research efforts have been undertaken in this unique laboratory, but we believe that this, and the entire Chornobyl site, presents unique opportunities for many U.S. researchers.

Later in the afternoon, Valeri Kamenica, Acting Chief of Dosimeter Control Department, provided a tour of his operations. He is responsible for radiation safety, individual dose control, health physics, instrument repair, and computers. Anatoly Susko showed us the radiation control monitoring center. This center is the storage area for data from the 21 monitoring/control points within and around the exclusion zone. The data (humidity, atmospheric pressure, temperature, wind, etc.) are transported via modem/radio to the control center. The farthest station is 57 km from the exclusion zone. Effluent monitoring data from the operating Chornobyl plants are also monitored here. The maximum allowable release for the operating power plants is 86 Ci/24 hr, and the normal release is 40 Ci/24 hr. This system was implemented in 1988. No monitoring system existed prior to the accident. Each NPP in Ukraine has a monitoring system such as this, but each site is different and generally monitors only at the immediate plant site. Currently there are 14 operating reactors in Ukraine.

Groundwater sample analysis data are also archived here. Data are routinely obtained from 100 boreholes within the 30-km exclusion zone. We later learned that these data lack sound quality control/quality assurance protocols, and the sampling equipment is quite crude (Figure 2-12).

Dr. Andrej Sukhoruchkin is in charge of radiological data analysis and interpretation. The maps he presented were hand drawn and colored. Data points were often random with large areas of extrapolation. No site-specific or local-scale maps were noted to exist.

Next, we visited the CP Complex for decontamination of small pipes, cables, etc., from the power plants. One decontamination system is a two-step process using lime and natural sorbents. A new facility is under development to minimize secondary wastes. Other decontamination is achieved with acid baths and pressurized steam. The decontamination facility itself was quite contaminated; radiation control practices could be improved to enhance worker safety.

Figure 2-12. Olga Chvesik Obtaining a Water Sample from the Unconfined Aquifer.



2.3.2 Ecology Tour

Our last tour was by bus to view the fields surrounding the sarcophagus. The Red Forest consists of 100,000 hectares of trees killed as a result of the Chernobyl accident. Emergency measures involved cutting the dead trees and burying them in trenches throughout the fields. The bottom of the trenches are very close to the water table. Scientists had recommended that the trees be buried in mounds to protect the groundwater from contaminants, but this was not done except in a small experimental area. The result is that the trees have started to decay and contaminants (especially Sr^{90}) are leaching into the groundwater.

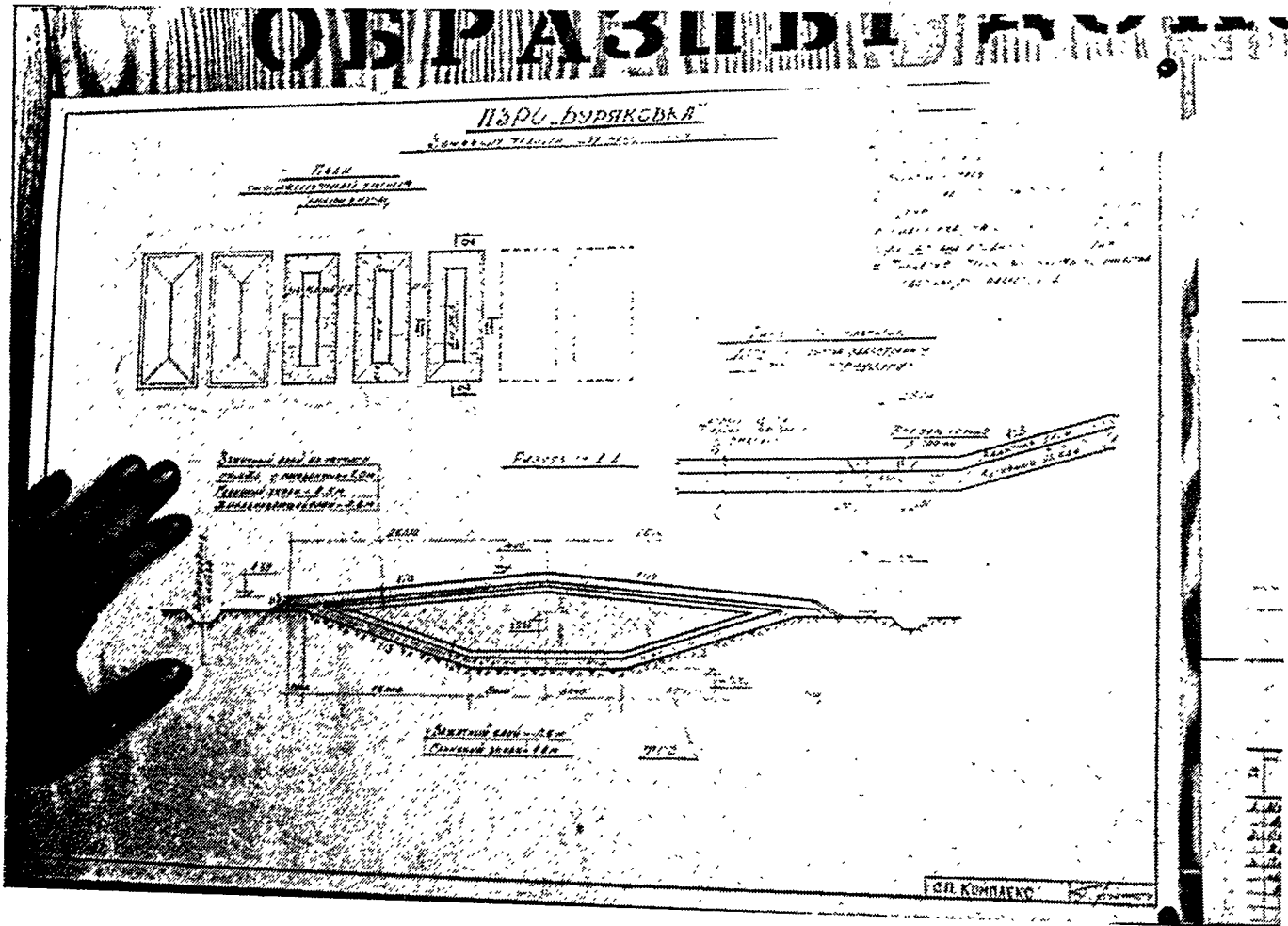
Grass and wheat are growing throughout the fields. Scientists have harvested small grass plots from near the reactor and conducted experiments to determine the amount of radioactivity removed by the plants. This was found to be very ineffective, as less than 1% of the radioactivity was removed each year, or 4% in 5 years. This information seems to contradict a previous study, which claims up to 90% of radioactivity was removed in experiments using alfalfa. However, it also indicates a strong potential for growing crops for consumptive or non-consumptive uses within the 30-km exclusion zone.

2.4 SEPTEMBER 3, 1994

After the morning planning meeting with Sergey Saversky, the field team went to Site 2, not far from the Pripyat River, to begin work. Saversky took D. Moak, J. White, and J. Field on a tour of the low- and medium-level burial grounds, termed "Vector Site." These burial grounds are several kilometers west of the NPPs. The burial ground is planned to accommodate 30 trenches, each having a capacity of 45,000 m^3 . The only compaction or volume reduction is achieved by the use of crawler tractors driving over the waste. The burial grounds were initiated in 1986 to accommodate some emergency burials, and the site is now being upgraded. The trenches have a 1-m-thick clay lining, with a 0.5-m sand-damping layer atop the clay (Figure 2-13). The trench has roughly a 1:3 side slope, and the final clay cover slopes approximately the same so that the entire trench is enclosed. The trench is not covered until completely filled. The trench cover of clay then receives several inches of top soil where grass is planted to stabilize the material.

The waste in the burial grounds contains alpha, beta, and gamma contamination. Although alpha waste technically is not allowed, no methods are available to separate out the alpha waste. While we were there, open-ended dump trucks filled with metal scrap arrived to dump contaminated wastes into the trenches. The truck tires and bed body were surveyed upon entry to the burial grounds, and the truck went through a decontamination (tire wash) facility upon exit. Construction of a dose control/monitor center was underway at the burial ground entrance where we visited.

Figure 2-13. The Design of the Low- and Medium-level Burial Grounds.



The burial grounds have been assessed to be stable for 300 years. They are designed for wastes up to 1 R/hr, but up to 2 R/hr was deposited there only 1 year ago. Generally, waste is 200 to 300 μ R/hr. The groundwater is at approximately 14 m below surface. No contamination migration has been detected to date in the nearby monitoring wells (Figure 2-14). Numerous trenches are awaiting burial material and contain about 1m of standing rain water. The water is pumped from the trench prior to waste disposal (Figure 2-15).

Located near the burial trenches is a storage area under construction for packaged/contaminated radioactive waste. A concrete pad has been poured and a large area cleared, but construction has been terminated due to (1) economic conditions and (2) the waste treatability program was not successful, so the program is being revisited.

Upon completion of the burial ground tour, we returned to Prip'yat to visit several more Chernobyl operations. We toured the contaminated-laundry facility which occupies a two-story building and employs approximately 30 people per shift. Contaminated laundry is divided according to contamination levels. If contamination is greater than 400 mR beta, the laundry is buried. Approximately 800 kg/day of clothes are washed and ironed. We were unable to determine how frequently the workers change their clothes. Since only gauze masks are worn at the NPPs or for remediation, there is no mask cleaning facility. Gauze masks are buried in the low-level waste burial grounds.

We also toured the Jupiter Facility, which is a factory in Prip'yat for fabrication of technical parts for the NPPs and accident cleanup parts. This facility fabricates unique and new technology equipment. It contains numerous lathes, presses, milling machines, etc., but all of the equipment is very old (Figure 2-16). The building is unheated except in a small area. Upgrades to the building are planned; however, bureaucracy has hampered progress, and lack of funds have prevented procurement of modern equipment. Some of the unique pieces of equipment we noted included a wall scrubbing machine for use in the sarcophagus. The machine, designed to be hung from a crane with a 12-ton ballast, chips off wall plaster and then scrubs the wall to decontaminate it. The machine is followed by a second machine that provides a clean coating to the wall.

We saw a gun consisting of 24 6-in.-diameter barrels that were filled with fire suppressant chemicals (Figure 2-17). The gun is designed to shoot the chemicals up to 200 m into a burning building or forest. It is not in production but has been tested in the field.

As measured with our portable instruments, the background contamination in the factory was 200 to 400 cpm, with some higher contamination on the lathes and tables.

Figure 2-14. Dr. Jim Field (WHC) Near a Monitoring Well at the Low- and Medium-level Burial Ground.



Figure 2-15. Standing Rainwater in an Unused Burial Trench.

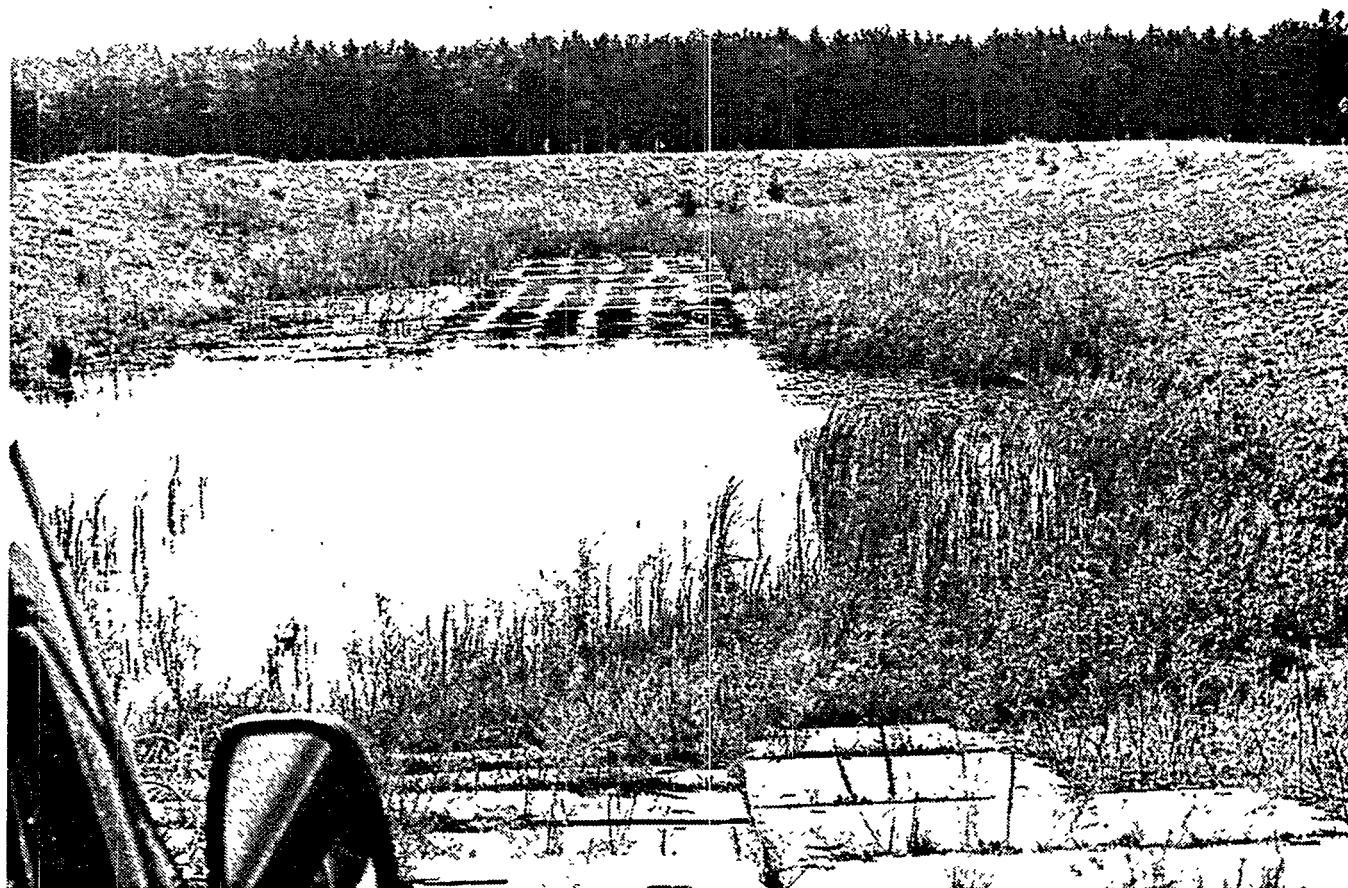


Figure 2-16. The Jupiter Facility.

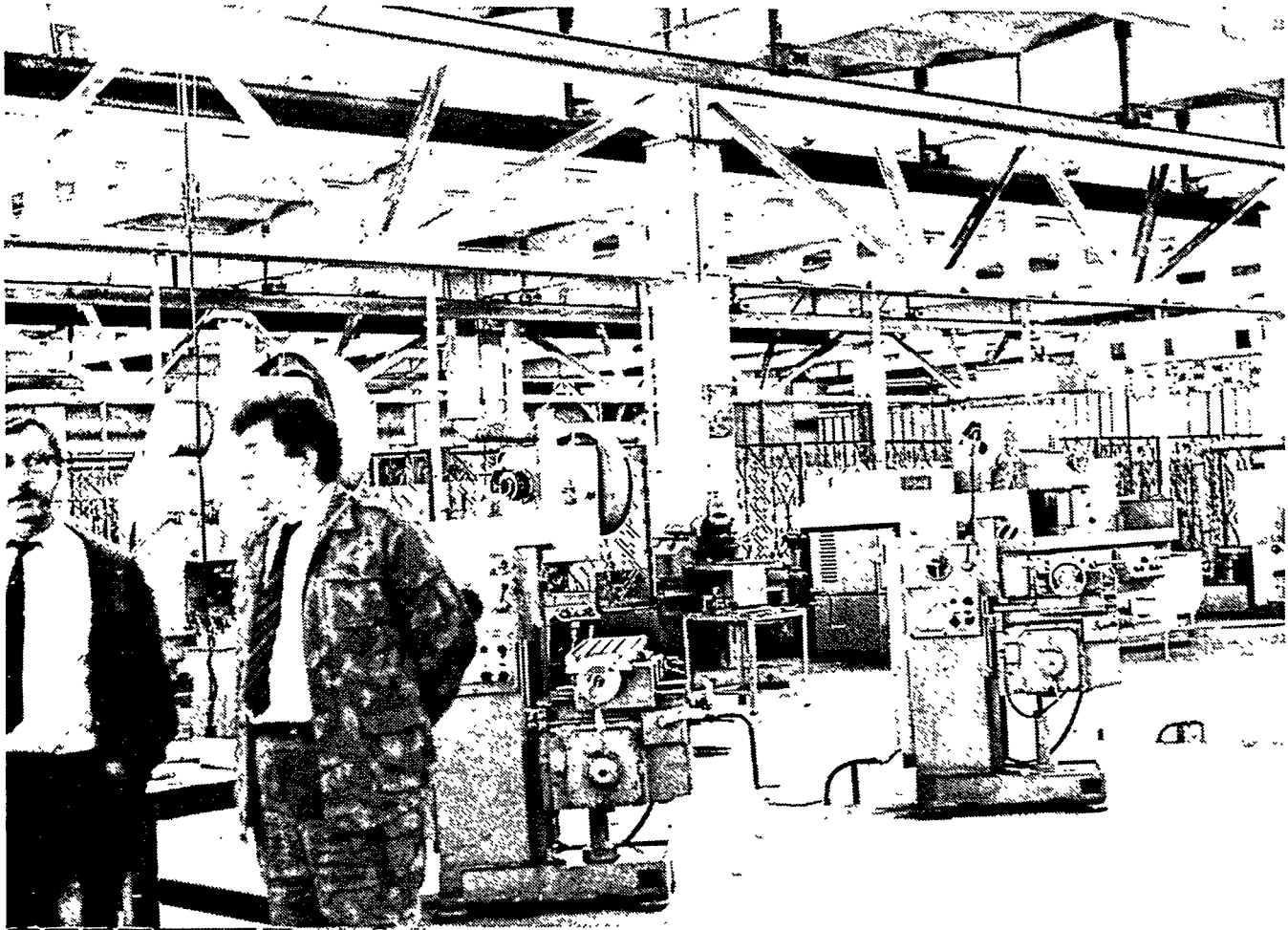
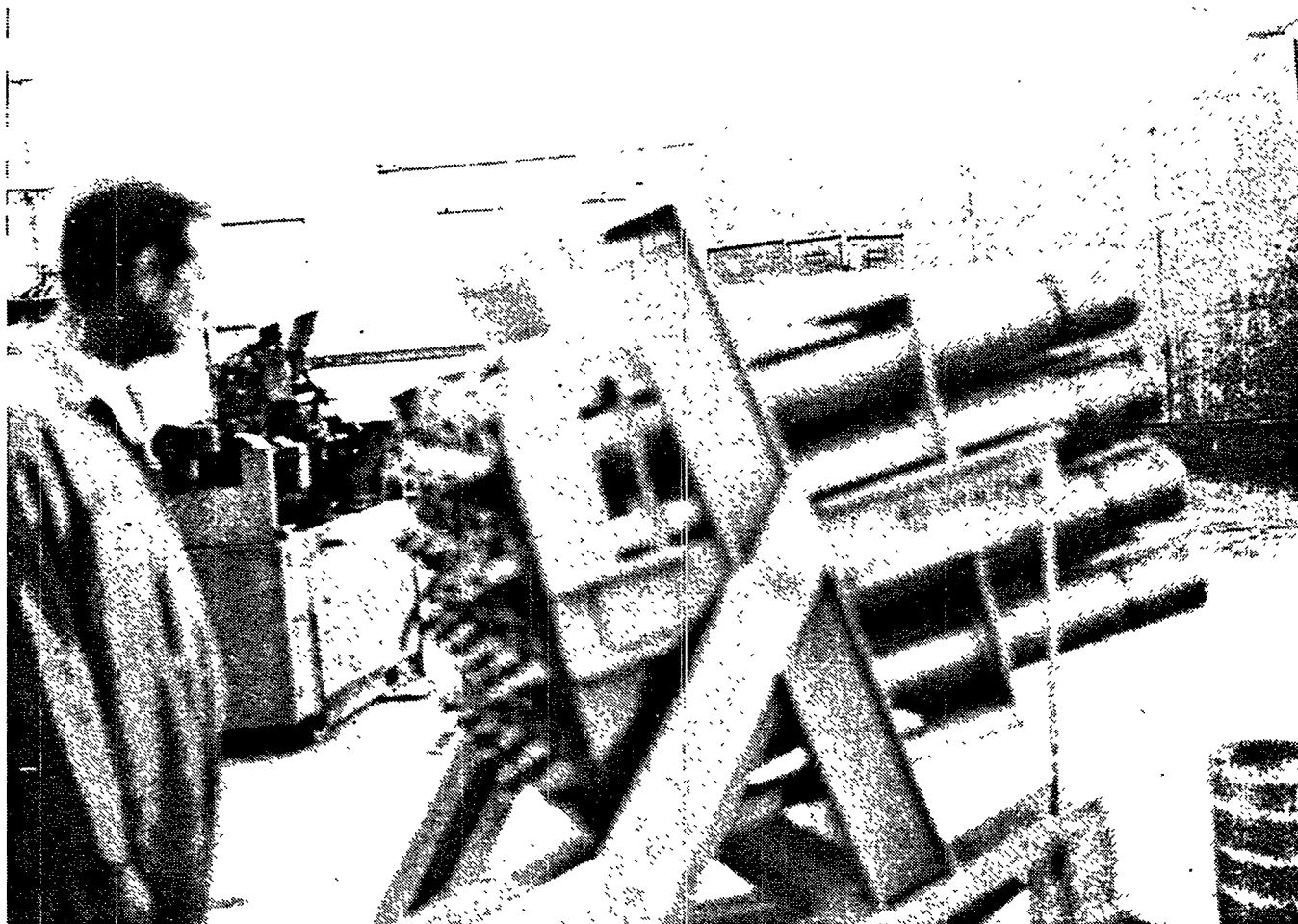


Figure 2-17. Jerry White (SAIC) Viewing the Fire Suppressant Gun.



2.5 SEPTEMBER 5, 1994

The technical discussions were led by Oleg Audeyer of the KORO Scientific Center. KORO was established before democratization to deal with waste and ecological problems of the Ukrainian mining industry. The group was also involved in Cheylabinsk-65 and Lake Karachy problems. After 1991, KORO was incorporated into the Chornobyl Affairs Ministry. The KORO Scientific Center now deals with scientific and design activities for all facets of radioactive waste handling, including old and new burial grounds, within the framework of the Chornobyl Ministry. KORO's main task is the creation of a facility to handle, treat, and bury all radioactive wastes. Wastes are from industry, agriculture, mining, medical, etc., but exclude high-level NPP wastes and fuels.

Mr. Audeyer stated that the Supreme Soviet of Ukraine created a policy in January 1994 dealing with radioactive waste disposal. Two main directions were noted: (1) set up a state-wide system for radioactive waste handling and (2) solve problems directly relating to the 30-km exclusion zone and all other places contaminated by the accident. The design of the burial grounds was governed by three main legislative documents that deal with (1) radiation safety standards, (2) sanitary regulations, and (3) sanitary demands for radioactive waste storage. New laws that include regulations for long-lived isotopes will be issued soon.

The Vector Project at the Chornobyl burial site is the base for the KORO project. This burial ground will be the center for all Ukraine radioactive wastes excluding NPP, uranium, and coal industry wastes. The calculations and design for the burial ground liners and covers were performed by KORO staff. They considered radioactive decay, forecast of radionuclide migration, soil properties, moisture, and emergency scenarios. The design anticipates that the burial ground will last 300 years.

Ukraine has 15 major radioactive burial places in 5 regions of the country. Characterization and study of the burial sites is needed since the material was simply piled into open, unlined pits or natural depressions. Study of burial places in the Zertoma region of Ukraine has begun, but the largest challenge, by far, is locating the currently unknown burial places in the Chornobyl exclusion zone.

Discussion ensued on the disposal of radioactive waste. Some Ukrainian technical staff contend that since material is "decontaminated," it should not be classified as radioactive waste; hence, expensive burial grounds, required by legislation, are not necessary. There appeared to be a terminology problem in determining what is "decontaminated." Based on our observations, waste could be "decontaminated" but still be well above natural background levels.

Contaminated soils are buried in the trenches along with metals. Some contaminated soils resulted from attempts to strip the 5 to 10 cm of contaminated soil throughout the zone. Technical difficulties with the burial equipment generally resulted in stripping up to 30 cm of soil. The KORO staff realizes that other, more modern, equipment is available for soil

removal, but they do not have the financial resources to upgrade or buy new equipment. They believe a super-vacuum type of machine is preferable to a turf or sod cutter. We proposed using a RadRover or backpack equipment to identify discrete areas of contamination, particularly around settlements, and then cut the soil with machines. They thought that this would be a good idea if the resources were available.

Overall, volume reduction/compaction techniques should be used prior to burial of fences, soils, trees, houses, etc. Currently, the only compaction is from heavy equipment. Subsidence problems have been noted but are not considered to be of concern at this time.

KORO is also responsible for decontamination of villages and settlements beyond the 30-km exclusion zone. To date, over 30 settlements in 5 regions have been decontaminated. (Note: Neither the before or after levels of contamination, nor the methodologies used for decontamination, were stated.)

Following Mr. Audeyer's discussion, the U.S. team led discussions on Hanford's history, burial grounds, and the barrier technology. After viewing our conceptual diagrams for subsurface barriers, KORO representatives expressed great interest in subsurface barriers that use horizontal holes to form the barrier. Jet grouting of existing waste sites was also a preferred option to stabilize burial sites. We were unable to provide detailed cost information without answers to our specific questions relative to site conditions, contamination levels, performance requirements, and regulatory issues.

S. Saversky then provided an overview of the Chornobyl high-level waste storage facility. Because the groundwater is only 14 to 18 m below the surface, high-level waste is stored aboveground in 1-m³ containers. These containers reside inside a concrete vault that has soil mounded up along its sides. The waste is lowered in place by remote-operated cranes. After one row of containers are emplaced, they are stabilized with concrete. When the entire vault is filled, it will be covered with soil. Presently, one storage module is 2/3 full and one is approximately 1/3 full. Material stored here is less than 50 R/hr. It includes pieces of the roof from Unit 4 and pieces of the machine room and other buildings. This waste was not pretreated. The site was initially intended for temporary storage, but in the process of constructing the sarcophagus, some waste had to be moved here and it is not prudent to move it again. Although the storage site has monitoring wells and sensors in place to detect leakage, scientists later said that the characterization and monitoring program is less than adequate, but radiation levels are too high to allow access.

After lunch the team reviewed photos and discussed waste site stabilization programs at Hanford and other DOE-complex sites.

Alexander Ledenyers, Department Chief from KORO, discussed temporary burial places and their problems. His organization focuses on waste inventory, hydrogeological evaluations, subsurface subsidence, groundwater plume paths, and travel time and data collection for future decisions.

Mr. Ledenyers stated that more field research work is needed to understand the hydraulic gradient and groundwater travel times. Methods to minimize the flowpaths and travel time must be identified.

Mr. Ledenyers provided some background on the emergency burial grounds and trenches. The geological conditions were not accounted for when emergency burial took place. In some areas, the burial grounds are flooded during springtime. The burial grounds were not identified with a coordinate system, so there are unknown burial sites. His group has examined 15 hectares with penetrators to identify burial ground locations and contamination levels. The 20-mm-diameter penetrator holes are hand driven into the ground to depths of 4 m and then logged with a 14-mm-diameter, sodium iodide (NaI) crystal gamma probe. The initial hole spacing is 4 m and later on 0.5-m centers to define the site boundaries. Over 38 burial places have been identified with this method within the 15 hectares. The total volume of buried material is estimated at 16,400 m³ and 81 Ci of radioactivity. Burial sites will continue to be identified with the labor-intensive method until funds are available for other technologies. The field crew consists of 5 workers per shift in radiation fields up to 3 to 4 mR. The dose rates are monitored closely, and when the dose reaches the international permissible limit, the workers are transferred to an office where they perform data analysis.

Although site-specific data for groundwater modeling programs are sparse, modeling activities continue. It is believed that in 10 to 20 years, contamination levels of Sr⁹⁰ will increase in the Pripyat river to 4×10^{-7} Ci/L.

Saversky gave a short discussion on remediation technologies he that believes could be effective. The Ukrainians have used grouting within burial sites, with special equipment and an electric hammer to allow homogeneous mixing of the grout. The grout mix minimizes leaching of the waste. (We were not shown this equipment.) He believes that a metal melter is necessary for the vast amount of scrap metal that exists onsite. He would like to see in-situ vitrification (ISV) technology improved but be able to use it ex-situ inside a large metal box and potentially melt metal using ISV technology. By melting small volumes of waste, energy consumption would be reduced and the gases to capture would be of a lower volume. We were unsure of the technical merits or viability of this proposal, but Saversky was interested in continued U.S. use and advancement of ISV.

2.6 SEPTEMBER 6, 1994

Some of the U.S. technical team conducted a site background survey at Zeleny Mys, one member went with the KORO group to observe their penetration techniques for site investigation, and three members attended the technical presentations.

The main theme for the presentations was Radiation Monitoring and Resource Protection.

A presentation given by Dr. Sergei Dgepo, Ukrainian National Academy of Sciences, was titled "Problems of Monitoring Radionuclide Contamination of the Ground Water System and Ground Water Protection in the Chornobyl Exclusion Zone." Offsite health risks are caused mainly by the potential for migration of Sr^{90} in hydrologic pathways. The contaminated catchment basins of the Pripyat, Dnieper, and Desna Rivers are secondary sources for radioactive contamination of water reservoirs. Point sources, such as the cooling pond, temporary burial sites, and the sarcophagus are expected to increase subsurface radionuclide transport into the system.

The highest point-source priority is the NPP cooling pond. This unlined pond has contributed up to 28% of the total Sr^{90} contamination to the Pripyat River in the last four years. The burial trenches also contribute to the contamination, especially in areas that become flooded in the spring, like the Red Forest. The contamination from the sarcophagus could come from pieces of the reactor thrown out onto the ground. Site characterization is needed to identify where, if any, of these pieces exist.

The hydrogeology near the plants includes water-bearing horizons of sandy Quaternary deposits with rather low sorption capacity. The groundwater depths range from 1 to 10 m. These hydrogeological conditions favor radionuclide migration to the groundwater system.

The groundwater monitoring program at the Chornobyl area suffers from several shortcomings:

- Insufficient number of wells
- Improper well design
- Improper sampling protocols.

The incompleteness and low reliability of the groundwater monitoring data limits the possibilities to analyze migration processes. There are 94 wells randomly placed into the unconfined aquifer and 17 wells to the confined aquifer. Water sampling is by hand bailer only, and the well is not pumped prior to sampling. The well screen interval is usually quite large, which produces "mixed" samples. Sample analysis is only for radionuclides, although it is known that heavy metals reside in the surface waters and that bacteriological contamination is likely present.

More than 90% of the radioactivity is concentrated in the upper 5 to 10 cm of the soil. The Sr^{90} and Cs^{137} groundwater contamination is 1 to 2 orders of magnitude higher than pre-accident levels. The Sr^{90} and Cs^{137} concentration in the groundwater throughout the zone and adjacent to the reactor either is close to, or exceeds, the drinking water safety limit of 100 pCi/L.

Risk assessments began about 1 1/2 years ago and are still in progress, but inadequate data may lead to erroneous conclusions. Even items like pH meters and bailers are expensive and difficult to access in Ukraine.

A paper was presented from the Ukraine Institute of Geological Science on subsurface and groundwater water protection structures. The first measure implemented after the accident was to prohibit the use of unconfined aquifer wells for potable water. Another measure was to construct dams to sorb the radionuclides because there are many open-channel water collection and irrigation systems that flowed into the Pripjat River. Drainage galleries of up to 300 wells over 15 km in length were installed near Unit 4. There were no reasonable scientific or technical bases for these installations; they were done on an emergency basis but were never used.

Several negative aspects resulted from these measures. After the dams were constructed, flooding took place behind the dams, which caused further spread of contamination. Some irrigation systems were left open, and radionuclide flooding has killed vegetation. The flooding, of course, also caused vertical migration of contaminated surface waters to the unconfined aquifer.

Researchers and scientists were aware of these problems, so last year a new water treatment process was conceptualized and development plans are underway. No specifics on this process were provided. Other remedial measures being discussed include construction of a dike to prevent the right bank of the Pripjat River from breaking out and flooding. Another project being considered will collect and treat contaminated surface water south of the cooling pond prior to discharge into the Pripjat. Drainage galleries that were built just after the accident were not put into service because lowering the groundwater levels near the burial grounds could markedly change the groundwater flow direction.

We inquired if any water treatment measures, such as pump-and-treat or filtration process, had been considered. They stated that these approaches had not been considered recently due to previous failed attempts. In 1986, a facility was designed and built by a Moscow Institute. A zeolite was used to fill 20-m- and 10-m-diameter tanks and then water was pumped into them for cleaning. However, the efficiency was quite low, possibly due to the high levels of radioactivity passing through in suspension. Additionally, the disposal of secondary waste was a large problem, so the project was halted.

Dr. Alexia Shuke, Technical and Scientific Center of Pripjat Association stated that 10 to 15 different organizations have been doing research relative to groundwater protection. There continues to be a problem with coordination, exchange of technical information, and duplicative investigations. The Pripjat Association is developing a general information system whose main objective is a computerized database that includes data from an observational network and a special geographic information system (GIS). Traditional GIS technology is not used at the Technical and Scientific Center. An in-house system called APRIL was developed. Potential collaboration with the Ukraine Institute of Cybernetics would allow them to use the ARC/INFO™ GIS.

J. Field and D. Moak were asked to provide an impromptu presentation on Hanford's groundwater monitoring and contamination problems. Following this discussion, we toured the groundwater protection systems and contaminated surface waters that were discussed in the morning session.

On the tour we noted several burial grounds near the river that flood in the spring. As a result of the accident and the changes it effected, the groundwater has risen 1 to 3 m in places. One of the Chornobyl team told us that, during emergency burial of wastes, he witnessed trenches being dug to the groundwater level. The Ukraine military, who performed this emergency procedure, did not understand the significance and continued to bury the waste.

We saw a portion of the 30-m-deep barrier that was to be constructed over an 8-km length to stop contaminated groundwater flow into the Pripyat. This barrier was built in extremely high radiation fields in 1988. It was apparently designed by engineering staff who had no hydrogeological and little scientific background. Once the contaminated water reached the barrier setting on the aquitard, the waste was to go the cooling pond. However, water levels in the cooling pond are several meters higher than the Pripyat River, and no provisions were made to lift the water or treat it. Fortunately, only 2 km of the barrier was built, but it still affects the local hydrogeology.

2.7 SEPTEMBER 7, 1994

Presentations were hosted by Dr. Proscura. Dr. N. Arkhipov discussed ecological problems. Serge Ehak, Department Head of the Laboratory for Ecology and Animal Radiobiology, discussed effects of radiation on cows and sheep, and Dr. Nikiolai Kuchma discussed forest radioecology. Translation of these sessions was very poor; therefore, information is sparse.

Dr. Arkhipov provided a general overview of his institute and of some ecological problems. He stated that cesium becomes more leachable with time. Based on strontium and cesium decay rates, possibly 55% of the 30-km exclusion zone may now be considered safe for agricultural use. Radioisotope translocation coefficients are highly dependent on soil type. Levels of radioactivity have been reduced by several different practices.

Dr. Arkhipov indicated that many publications of his work are available and that he can compile information presented on the charts, as needed.

Dr. Kuchma's discussion on forestry issues was mostly general and focused on research instead of current forest management practices. Approximately 102,000 hectares of forest are in the 30-km exclusion zone. The zone is 45% forest, which is 1% of the total Ukraine forests. Approximately 600 hectares of forest were killed as a result of the accident.

New trees were planted in this area but only a few random seedlings have taken root possibly because the area was covered with sand after the accident and the sand does not contain the necessary nutrients.

Initially 80% of the radiation in the forest was on the tree limbs and needles. The most contaminated parts of the trees are the cambium layer in the trunk and branches and the young needles. Radioactivity appears to transport from the young cells with age. Needles are shed once every 1 to 3 years. Cs^{137} uptake appears to have stabilized in the young trees, but Sr^{90} levels are still increasing in the young trees.

Now, 80% of the radioactivity in the forest is in the tree litter on the ground. Dr. Kuchma stated that all trees cut in the zone must be used in the zone unless special permission is granted.

In 1992, 15,000 hectares of forest were burned. This one fire equaled 40 to 50 years worth of radioactive migration into the soil due to the destruction of the organic mat that held most of the contamination.

In a normal Ukraine forest, there are approximately 2,000 trees per hectare. In the Red Forest and surrounding area, trees were planted close together, and there are 3,500 to 4,000 trees per hectare. That has resulted in tall trees with small-diameter trunks. Twenty to thirty percent of the trees in the zone are diseased or sick.

A few treatment methods have been highly successful in reducing Cs^{137} levels in wood shavings. Shavings were treated in a water bath with mechanical agitation of the water. Results were as follows:

Hot water	35 to 50% reduction
Hot water changed out	70 to 80% reduction
Hot water and salt changed out	90 to 95% reduction

These reductions are sufficient to commercially use many of the trees in the zone.

Dr. Kuchma briefly discussed concerns about forest fires, but he chose not to discuss specifics. He stated that a new organization, "Chornobylyss," has fire protection as its main charter. Chornobylyss has constructed fire breaks to prevent fires from spreading; new, special techniques and services, such as helicopters for fire detection, are now being used in the zone. Each fire is quickly extinguished. Dr. Kuchma stated that in 1992, over 15,000 hectares burned, but last year only 4 hectares burned, although 200 fires were reported. (Note: Some of this information conflicts with previous information received from the Ministry.)

The last discussion of the day dealt with the status of the sarcophagus (now referred to as The Ukritiye or "shelter"). The Deputy General Director responsible for the sarcophagus stated that the main concern is collapse of the current structure or pieces within the structure. Such collapse would cause airborne releases of radioactive dust, fires, and other unpredictable events. Liquid radioactive wastes and fuel still reside in the lower portions of the sarcophagus. Methods for removal and reprocessing this material are not available. Allowing current cleanup practices to remain in place raises major issues of contaminant migration into the soil and groundwater. Problem solving techniques and methods to clean up a disaster such as Chernobyl is unprecedented. With Ukraine's complicated social and economic state, cleanup actions are even more difficult. The tender to European communities for the design of an ecologically safe encasement and technical solutions to the problem is now complete. A feasibility study will begin within a few months that will provide for an encasement to prevent contamination spread in the air and groundwater. The Deputy General Director showed four films on the construction of the current sarcophagus and of scientific investigations that have taken place inside.

It was not the intent of our exchange to become involved in the reconstruction of the sarcophagus; therefore, this session was only for background information.

2.8 SEPTEMBER 8, 1994

A close-out session was held between the U.S. technical team and seven members of the KORO staff, led by Valadimir Udad. An overview of the Project Plan (Appendix C) and its initial objectives was first presented by the U.S. team. The objectives and characteristics of the sites to be surveyed had been modified since the original plan had been prepared; hence, it was important to set the stage for the following technical discussions. Following an overview of the three technologies demonstrated, preliminary computer-generated maps showing count rates and dose rates on the three sites were presented. Section 3.0 presents details on the acquired data and conclusions that could be reached based on the data.

In summary, the KORO staff would like to use our demonstrated technologies, with our assistance, within all of the contaminated zones. The technologies can be used for several purposes, including identification of some burial grounds, during decontamination of villages and settlements, or assessments of contamination in surrounding areas.

Both teams concluded that technologies developed in the United States, many with DOE funds, are applicable to the cleanup of contaminated lands and facilities at Chernobyl. These range from basic items such as burial boxes and waste drums, to quality assurance and project management programs, to sophisticated decontamination technologies and site characterization tools.

The magnitude of the contamination, and its associated problems, is enormous. Ukrainian staff have a wealth of scientific knowledge but lack the resources and equipment for implementation of many technologies. Because of past social and cultural situations, the staff have not in many cases been exposed to existing or emerging technologies; hence, some of their conceptual efforts have duplicated what currently exists.

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3.0 RADIOLOGICAL MAPPING DEMONSTRATION SURVEY PROJECT

3.1 SCOPE

This chapter summarizes and documents the results of the radiological surveys conducted from August 31 through September 6, 1994 over partial areas of the Chornobyl 30-km exclusion zone near Prypiat, Ukraine. In addition, this report explains the methodology of the technologies used to perform these surveys.

The radiological surveys were conducted by a team composed of WHC and SAIC employees under a DOE contract. The survey methodology was based on utilization of the Ultra Sonic Ranging And Data System (USRADS™) and the Mobile Radiological Data System (MRDS) for qualification of dose rate and counts per minute (cpm) contamination levels, and the NOMAD™ for quantifying various gamma emitting isotopes per square meter.

3.2 OBJECTIVE

The objective was to demonstrate these technologies in three geographic locations with different radiological levels, terrain, and surface vegetation. The demonstrations had a twofold purpose:

- To determine the potential usefulness of the technologies for cleaning up the Chornobyl area
- To create the opportunity for the U.S. and Ukraine teams to jointly evaluate the overall effectiveness of the technologies.

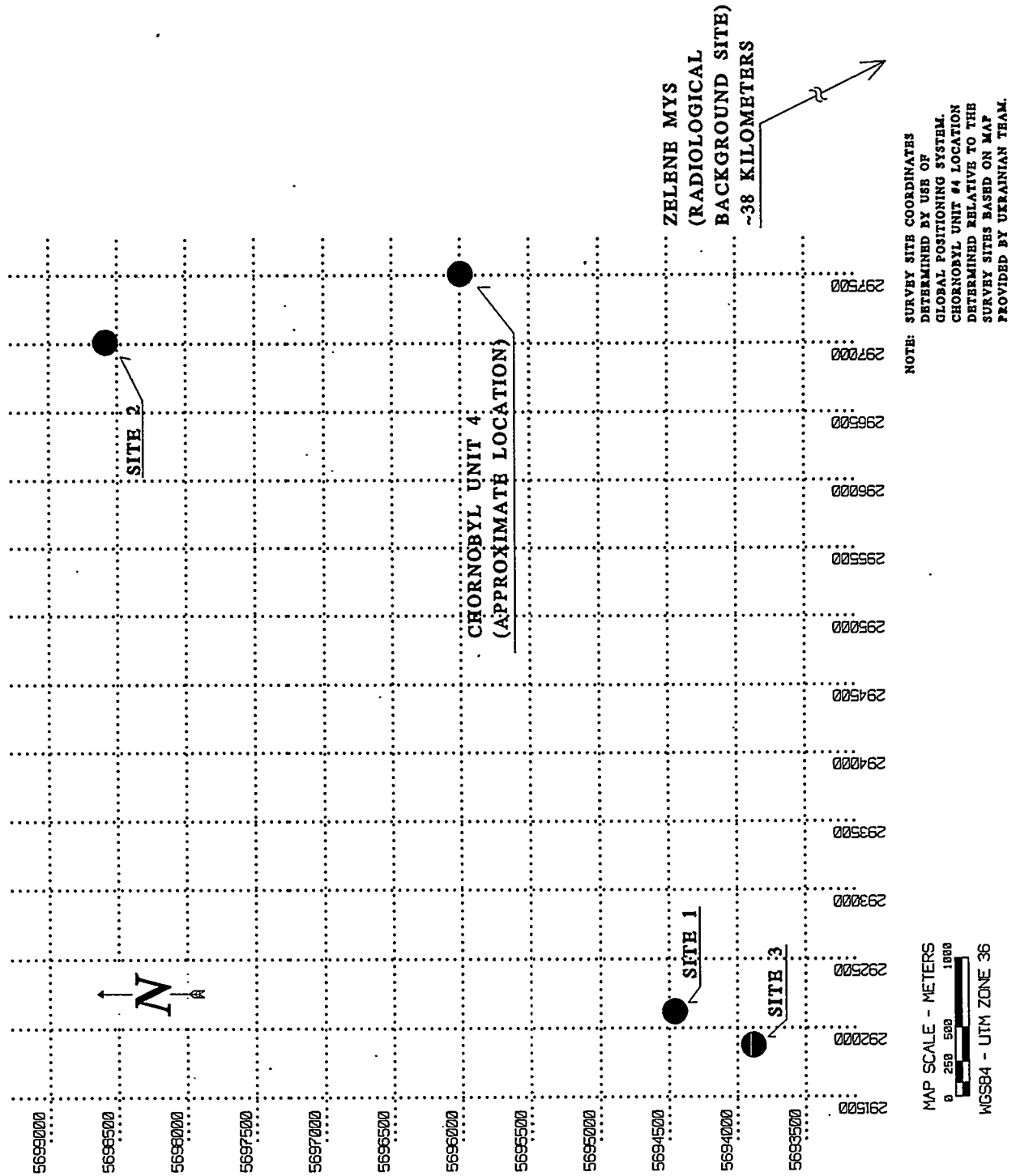
3.3 PROCEDURE

This project was conducted following the guidance contained in the *Project Plan Chornobyl Site Demonstration of Radiological Survey Instrumentation* (Appendix C).

3.4 LOCATION

All the sites surveyed, with the exception of the Background Determination Site, are located within the Chornobyl 30-km exclusion zone, within 6 kilometers of the Chornobyl #4 Reactor Unit (Figure 3-1). The Background Determination Site was located in Zelene Mys, Ukraine, approximately 38 km southeast of Reactor Unit #4.

Figure 3-1. Radiological Mapping Demonstration Project Survey Site Locations.



Coordinates of the locations of these sites were obtained by use of the Global Positioning System (GPS), and the location of Chernobyl Unit # 4 was determined relative to the sites based on a map provided by the Ukrainian team. All coordinate information is reported in World Geodetic Survey 1984 (WGS84) datum and Universal Transverse Mercator (UTM) Zone 36, a metric projection.

3.5 INSTRUMENTATION

The USRADS survey was conducted using a Ludlum Model 2221™ digital count rate meter with a Ludlum Model 44-10™, 5-cm by 5-cm sodium iodide (NaI) detector, and a Ludlum Model 19™ micro Roentgen per hour (μ R) dose rate meter. The MRDS survey was conducted using two Eberline SRM-300™ count/dose rate meters. One meter interfaced to an Eberline HP-270™ Geiger-Mueller (GM) tube for dose rate determination, and the other meter interfaced with an Eberline SPA-3™ NaI detector for cpm readings. These meters were coupled to the individual radiological mapping systems to record the data from the output of the individual detectors, versus the location of that data within the survey area.

Portable gamma spectroscopy surveys were conducted using an Ortec NOMAD Plus™ multi-channel analyzer (MCA), which is a rugged portable MCA designed specifically for field measurements. Also used were a notebook computer, a 40% germanium detector, and a suite of software applications.

3.6 INTRODUCTION

Three individual sites, designated Site 1, Site 2, and Site 3, as well as the Background Determination Site, were surveyed. These sites are described below.

Site 1 (Figure 3-2) was a sparsely vegetated field with some evidence of soil disturbance, most notably two shallow trenches through the area. There was also some evidence in the southwest area (farthest from the paved road) of the application of a surface contamination fixative.

Site 2 (Figure 3-3) was a more heavily vegetated emergency burial ground area. Dose rates within this area were much greater than encountered at Site 1.

Site 3 (Figure 3-4) was an extremely vegetated location. A village that had become heavily contaminated as a result of the Chernobyl accident had been demolished and buried.

A Background Determination Site survey was conducted to establish baseline radiological background conditions in a designated test plot known to have no contamination as the result of the Chernobyl accident, and no history of radiological operations (Figure 3-5). The radiological data collected during the survey of this site is considered

Figure 3-2. The U.S. Team Setting up the Field Demonstrations at Site 1.

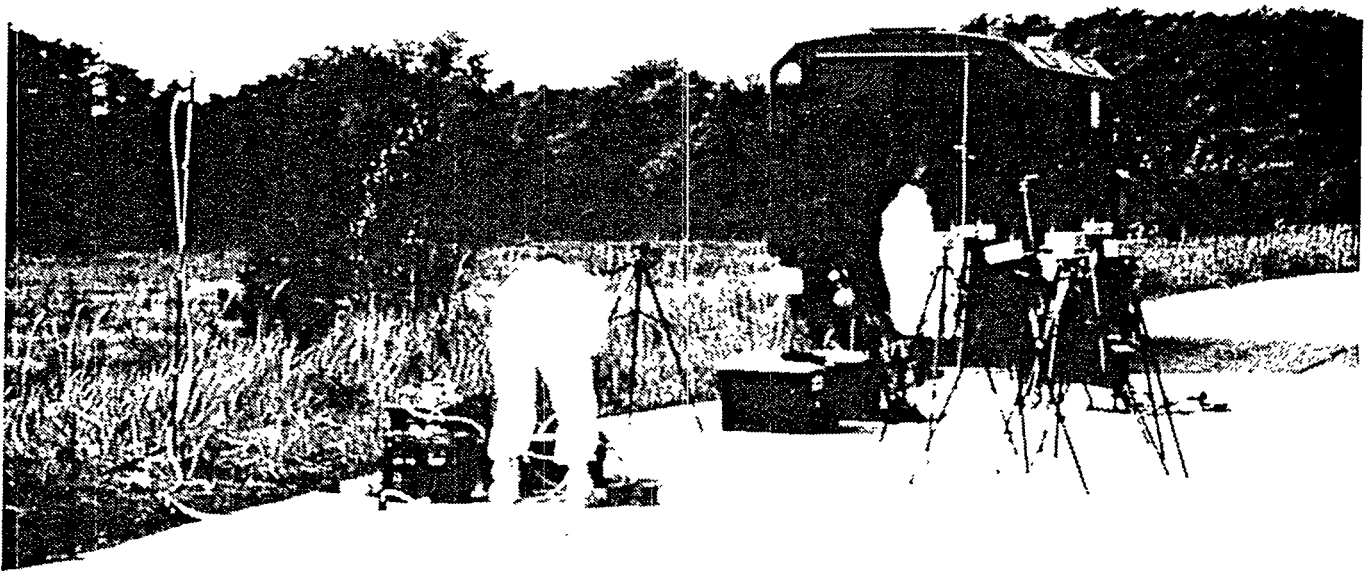


Figure 3-3. Pavet Orchazov (KORO) and Kim Berg (SAIC) at Site 2 Carrying the MRDS and USRADS.



Figure 3-4. A Ukraine Engineer Being Outfitted with the MRDS at Site 3.

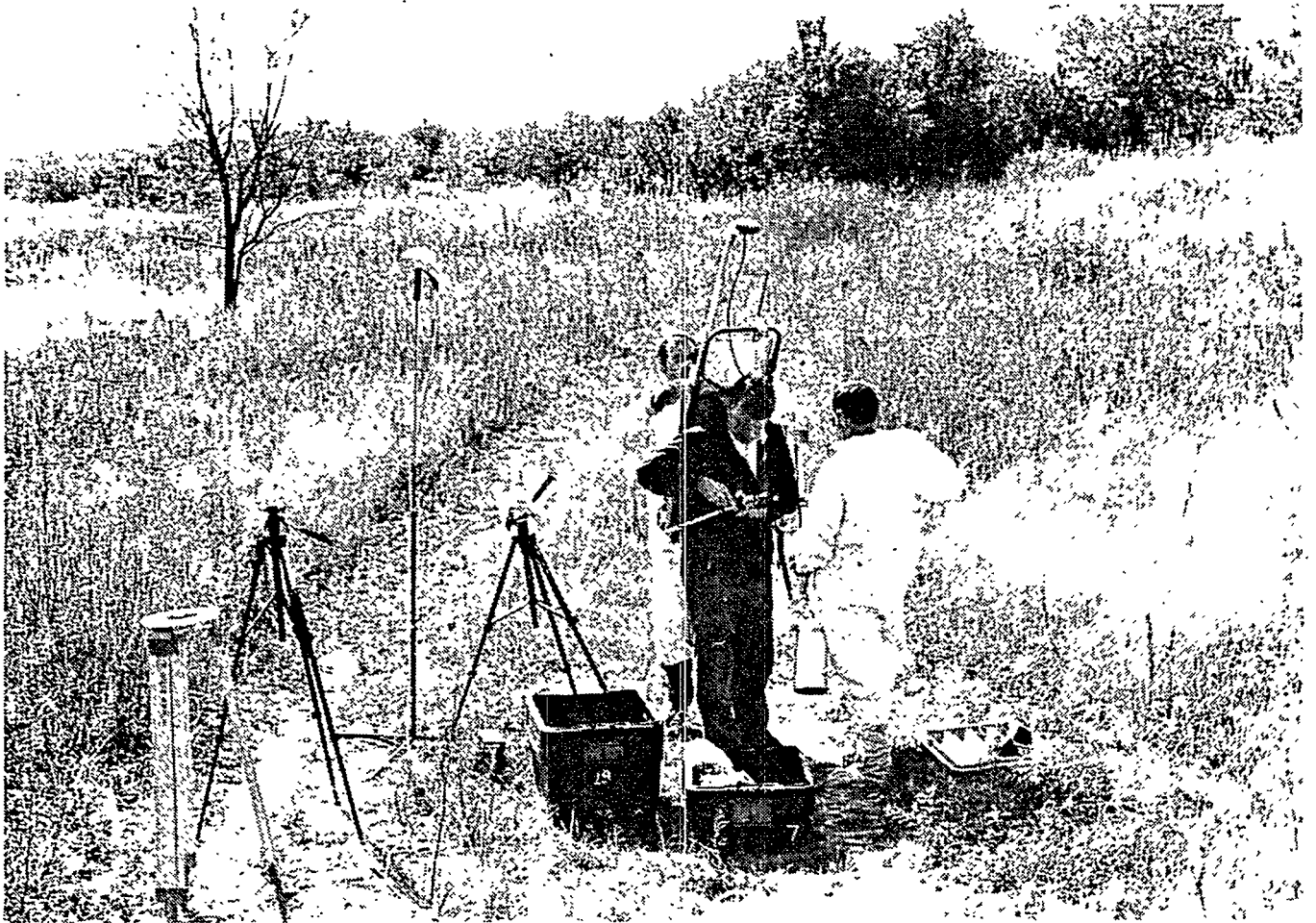


Figure 3-5. Zeleny Mys International Conference Center Where the U.S. Team Stayed and the Background Survey Was Conducted.



representative of the natural radioactivity contained within the soil and cosmic influences within the vicinity of the Chornobyl reactor site.

3.7 USRADS SURVEYS

3.7.1 Overview

The USRADS is a computerized data collection system that enables the user to correlate geographic location with the data gathered at that location. Survey coverage can be verified in the field, the data analyzed onsite, and the survey results graphically illustrated. The USRADS software also allows the data to be exported into other software packages for further enhanced graphical illustration. A two-person team is required for operation. One person acts as the surveyor, moving about the site wearing a specially outfitted backpack containing the electronic data-gathering and telemetry equipment, and the other person handles the base-station host computer and master radio receiver.

For this application, the backpack was outfitted with radiation contamination detection instrumentation; however, any detection device that outputs a digital, analog, or pulse type signal may be interfaced with USRADS. The system is capable of inputting up to six channels of data information at one time, allowing a great deal of information to be gathered simultaneously.

The USRADS employs three different technologies to accomplish its tasks: (1) ultrasonics (US), (2) radio frequency (RF) transmission, and (3) microcomputers. Each second, US transmissions fix the location of the surveyor, RF transmissions provide data-telemetry and system synchronization, and microcomputers calculate the precise position of the surveyor, displaying that information on the computer screen along with the reading(s) of the data collection instrumentation. This makes it possible for the USRADS to collect 3,600 readings per hour of survey time, allowing a very thorough coverage of the area.

3.7.2 USRADS Operation

A US signal of 19.5 kHz is emitted from the surveyor's location once each second. At precisely the same time, an RF transmission is broadcast from the surveyor's location to the master receiver (MR). Since the RF transmission travels at the speed of light, the time delay over the short distance from the surveyor to the MR is essentially non-existent. This RF transmission is used to mark the start time of the US signal. Each SR contains a US receiver and RF transmitter. When an SR receives a US transmission, it transmits an RF signal to the MR. This RF signature is used as the stop signal for the US signal, establishing the length of time it took for the US signal to travel from the surveyor to that SR. Since each SR responds to the US signal, corresponding stop signals are sent and distances determined. Through this method, the location of the surveyor is established each second.

To accomplish the necessary correlation between the surveyor's location and the survey data, the surveyor's RF signal is coded with the survey data collected for the last second. This automatically correlates the measurement to the proper location. As each one-second position is determined by the computer, a corresponding dot is placed on the computer screen, and the survey instruments reading(s) is displayed at the bottom of the screen. The computer operator enters a threshold when initiating the survey, and any data point exceeding this threshold is plotted with a user-defined symbol giving immediate indication of survey site areas of concern. The plotted dots or symbols remain on the screen, offering a track map that can be checked to ensure complete survey coverage. At any time during the survey, the computer operator can alert the surveyor of faulty coverage or elevated instrument readings, allowing for quick correction or additional survey coverage of areas of concern.

Upon completion of the survey, the software included in the USRADS allows running data reduction routines on the computer, compiling statistics for each survey, and allowing the data to be put into the proper format for export into other software packages for enhanced graphical representation or further statistical analysis.

USRADS surveys were successfully conducted at both Sites 1 & 2. Difficulties were encountered at Site 3 that precluded use of the USRADS. These difficulties will be discussed below.

The radiological surveys were conducted using both a digital count rate meter with an NaI detector reporting in cpm and a dose rate meter reporting μR . The count rate meter was set for gross counting, i.e., window "out." The window setting allows detection of low, intermediate, and high-energy photons.

These instruments were connected to a CHEMRAD Tennessee Corporation Series 2000 USRADS. This USRADS equipment is used to record the detector readings versus the location of the readings, generate a map of the survey area, and save the data on computer storage media.

Each survey entailed setting up the USRADS equipment in a grid block, connecting the radiation survey meters to the USRADS Data Pack, calibrating the USRADS equipment, and performing the survey. Calibration of the USRADS is performed prior to starting a survey. The purpose of the calibration sequence is to reestablish the positioning instrumentation after the equipment is moved to a new location.

Every attempt was made to traverse each grid block on a 3-m cross-hatched pattern; however, due to the roughness of the terrain and varying vegetation growth, this was not always possible. The speed of the survey averaged 0.6 m/sec. The gamma detector was maintained approximately 15 cm from the soil surface by suspending the detector from a boom attached to the surveyor's backpack. The dose rate meter was mounted to this boom ~1 m from the soil surface. In this manner, detector geometry remained relatively constant throughout the entire survey.

3.7.3 USRADS Location

Before initiating the USRADS radiological surveys of the two site locations, a grid system was established so that the individual surveys could be controlled and tied together. The survey team placed stakes in a grid. Each grid block was given a unique designator. Figure 3-6 shows the survey grid layout used for the survey of Sites 1 and 2.

3.7.4 USRADS Survey Results

Site 1--10,400 m² of the Site 1 area were surveyed with the USRADS. Statistically elevated radiation/contamination readings were observed in every survey of each grid block. These elevated readings may be due to either radiation from subsurface radioactive material, surface contamination, or a combination of both. All 8,119 data points collected during the survey were greater than the minimum detectable count (MDC) rate (Section 3.9). USRADS survey statistics of this area are summarized in Table 3-1.

Figure 3-7 is a composite track map of the surveyors path. Figures 3-8, 3-9, and 3-10 are graphical representations, or "surface models," of the cpm and dose rate data.

Table 3-1. USRADS Survey Statistics of Site 1.

Grid	Date	Points	Max cpm	Min cpm	Max μ R	Min μ R
1	01/Sept/94	1,998	1,080,540	147,000	1,021	129
2	01/Sept/94	2,506	781,140	203,460	882	288
3	31/Aug/94	1,821	756,000	241,860	998	377
4	31/Aug/94	1,794	715,560	195,840	952	522

cpm = counts per minute
 μ R = microrems per hour.

Site 2--6,950 m² were surveyed in this location. While the variance in radiological levels encountered at Site 2 may have been caused by surface contamination, it is believed that some variance in readings was caused by subsurface radiation emitting from the burial areas. 6,349 data points were collected at Site 2. Survey statistics are summarized in Table 3-2.

Figure 3-6. Demonstration Radiological Survey Projects Grid Block Layout.

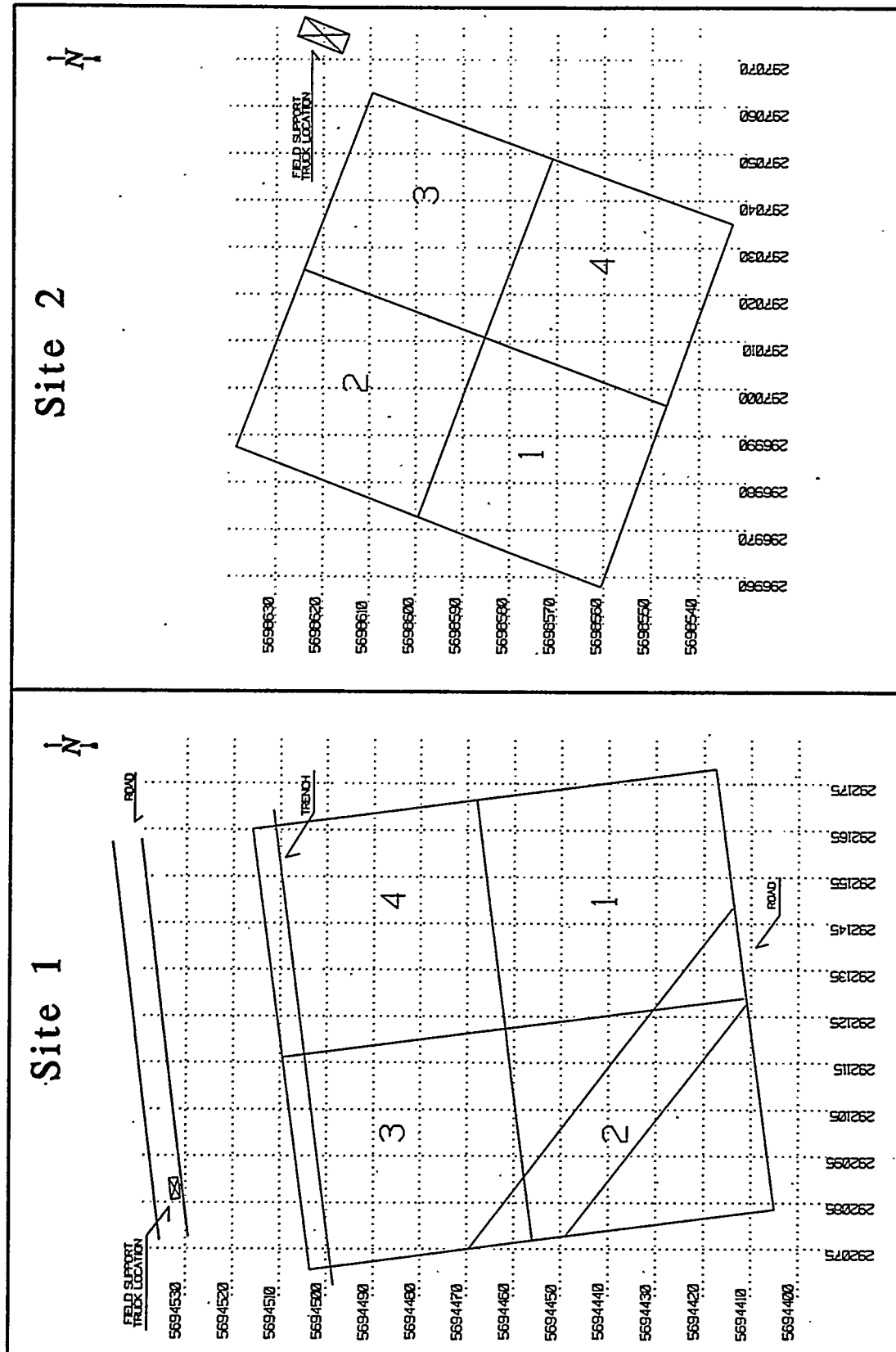


Figure 3-7. Site 1 - Composite Survey Track Map.

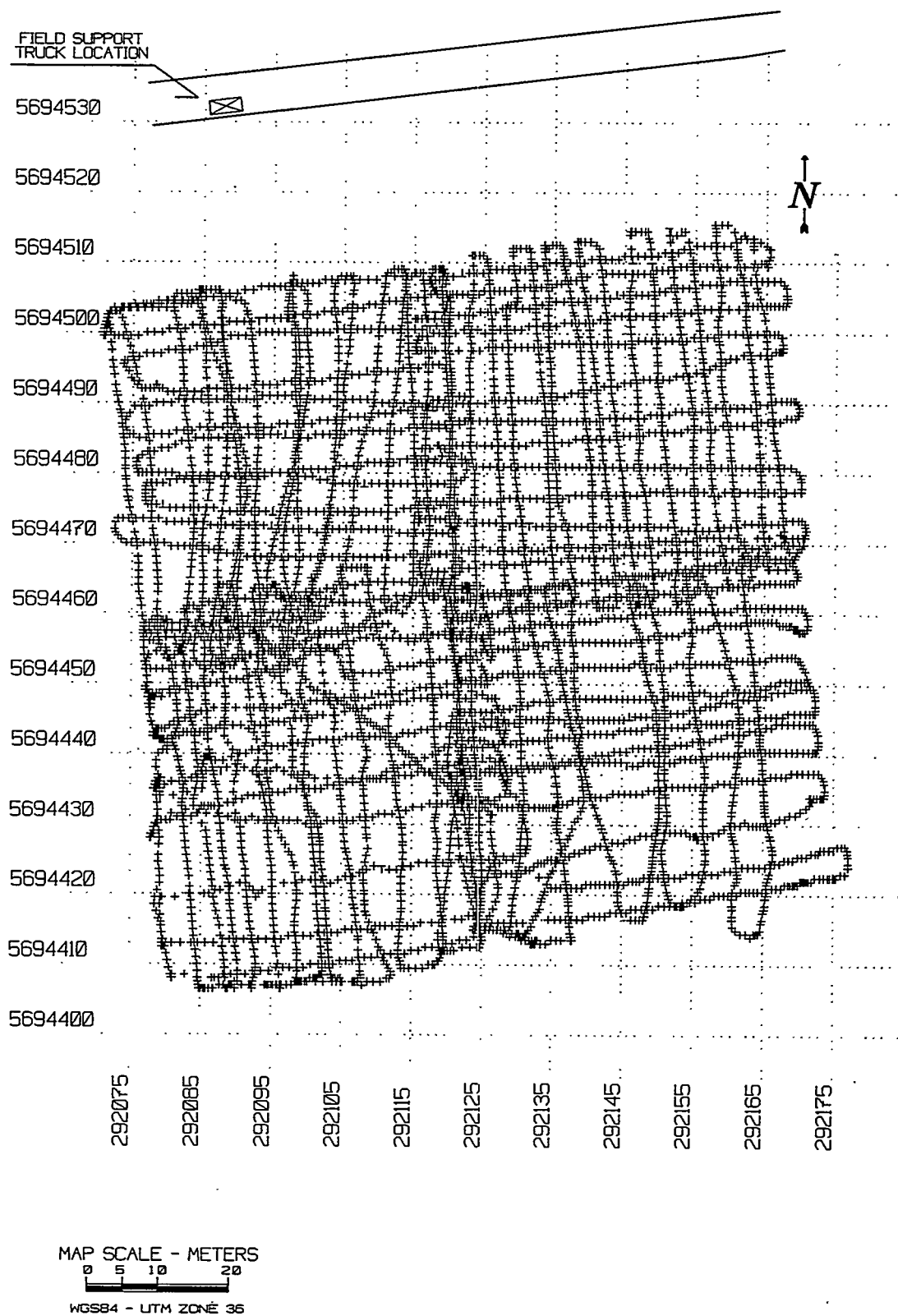
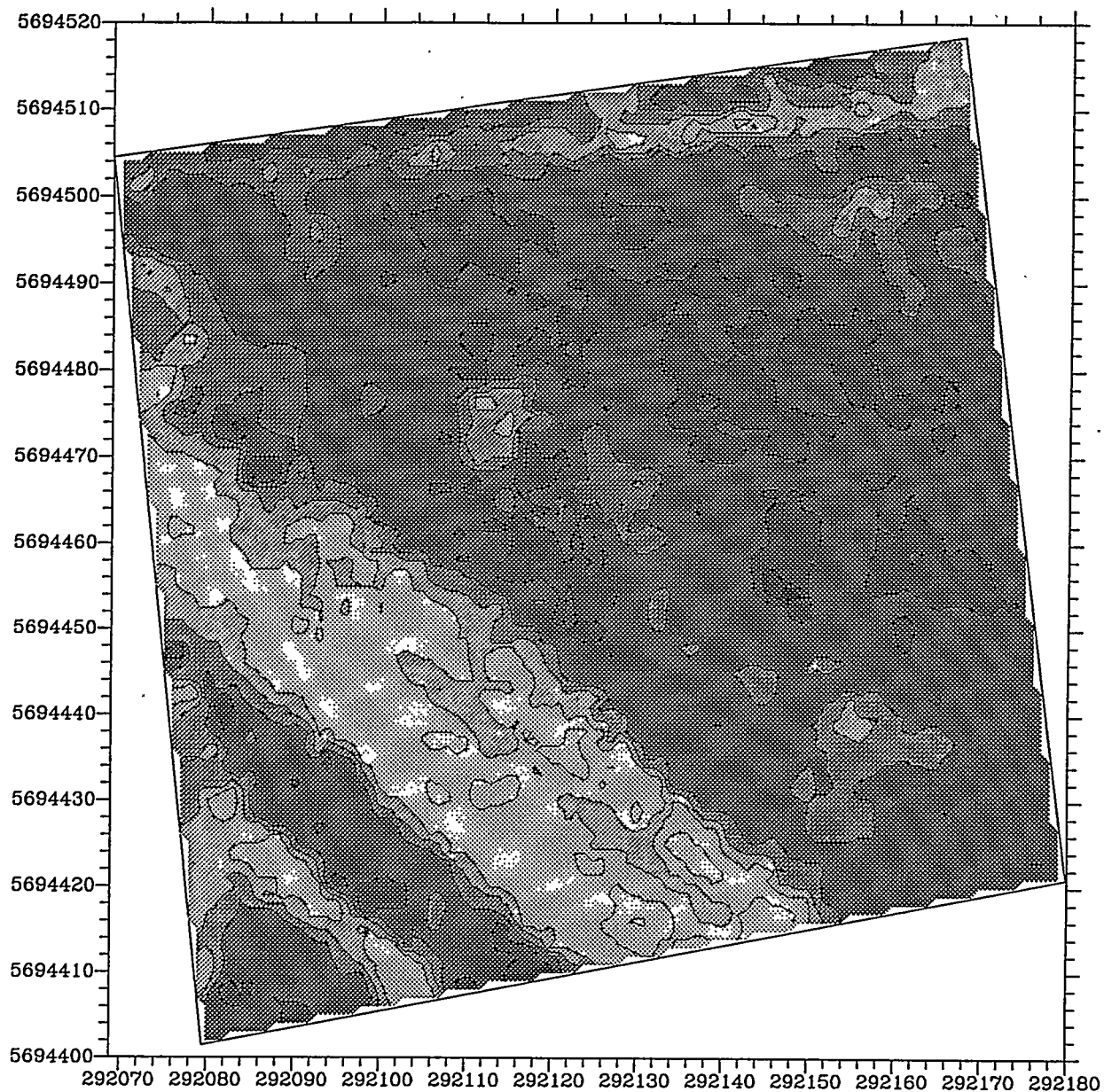
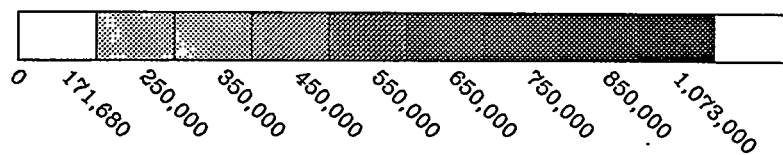


Figure 3-8. Site 1 - Topographical Representation of Count Rate Data



Counts Per Minute - NaI Detector



Map Scale - Meters

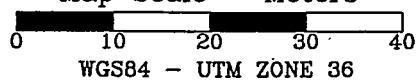
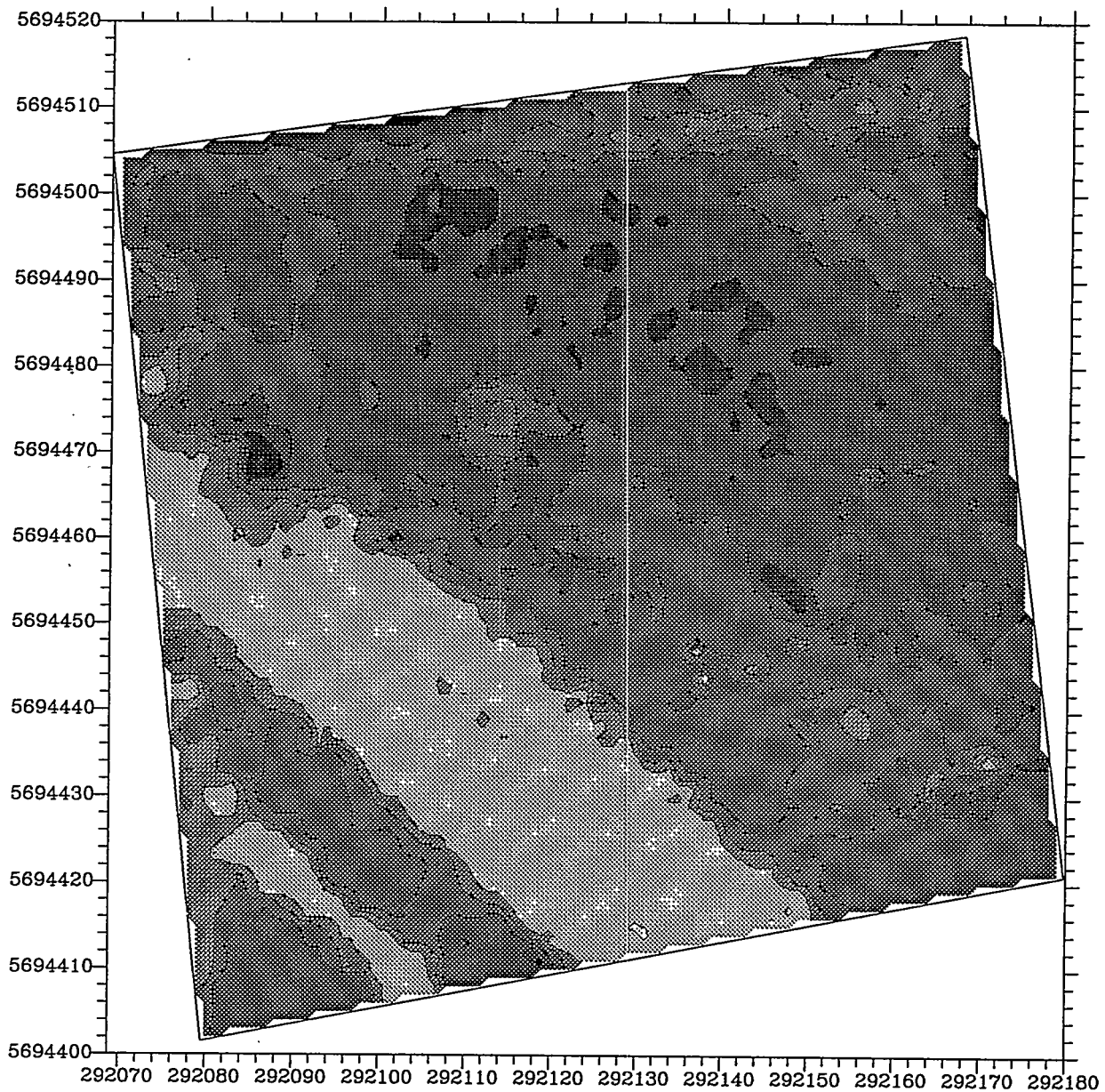
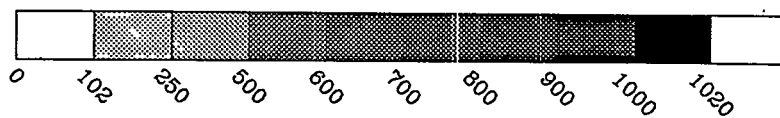


Figure 3-9. Site 1 - Topographical Representation of Dose Rate Data



Dose Rate - $\mu\text{R}/\text{Hr}$



Map Scale - Meters

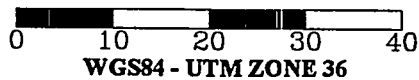


Figure 3-10. USRADS Radiological Dose Rate Profile - Viewed from Northwest

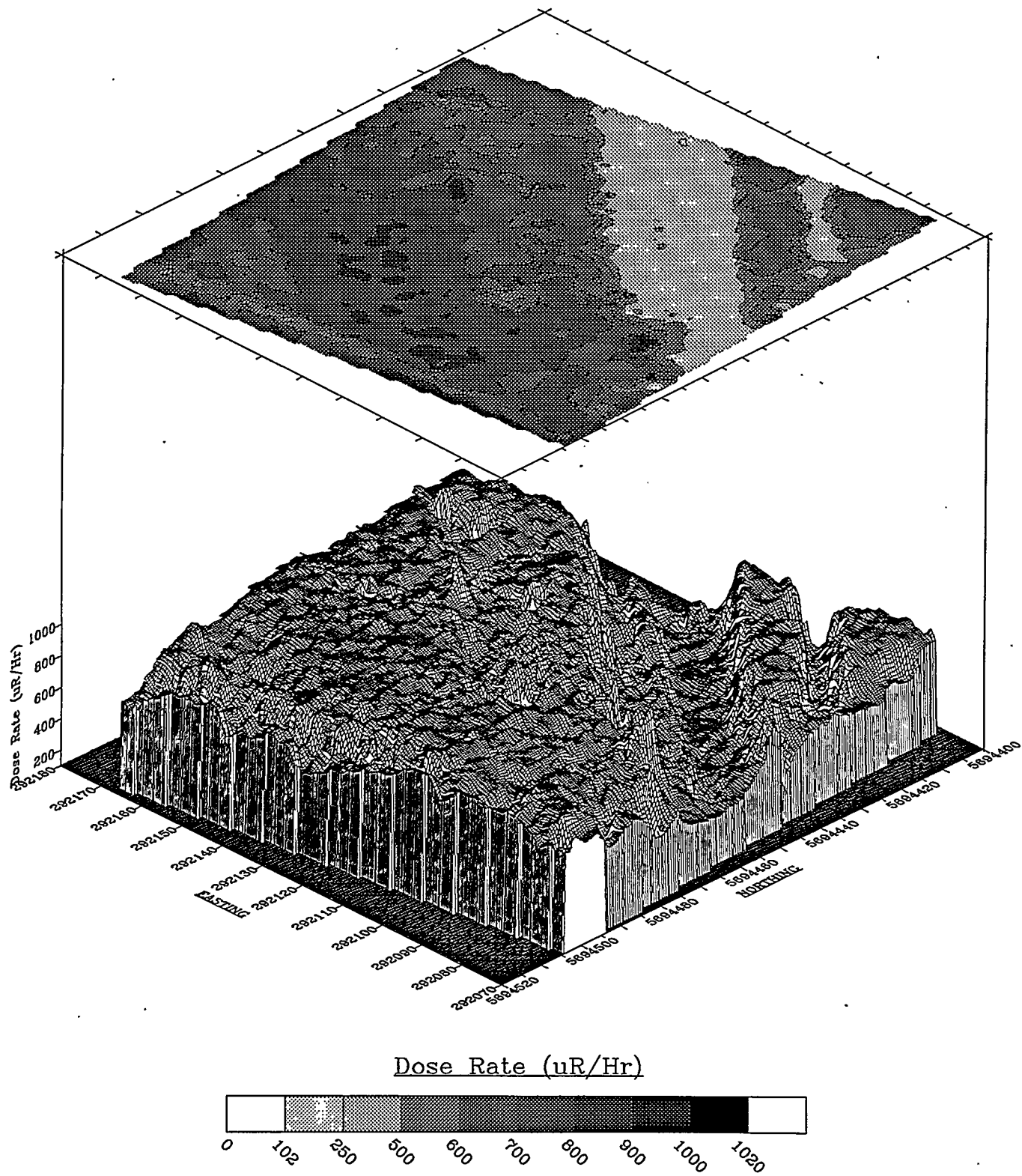


Table 3-2. USRADS Survey Statistics of Site 2.

Grid	Date	Points	Max cpm	Min cpm	Max μ R	Min μ R
1	03/Sept/94	1,733	2,186,580	611,520	3,558	791
2	03/Sept/94	1,835	2,651,460	606,120	4,919	778
3	03/Sept/94	1,254	2,688,180	607,320	5,529	940
4	03/Sept/94	1,527	2,508,780	501,960	5,218	744

cpm = counts per minute

 μ R = microrems per hour.

As with Site 1, every data point collected with the USRADS was statistically elevated over the MDC.

A composite of the USRADS surveyors track for Site 2 is shown in Figure 3-11. Figures 3-12, 3-13, and 3-14 are graphical representations of the radiological data.

Site 3--The USRADS operations were unsuccessful at Site 3 because of the abundance of a Ukrainian katydid. The insect set up an ultrasonic frequency, rendering the ultrasonic generator on the USRADS useless. Operations during the insect's dormant season would likely be effective.

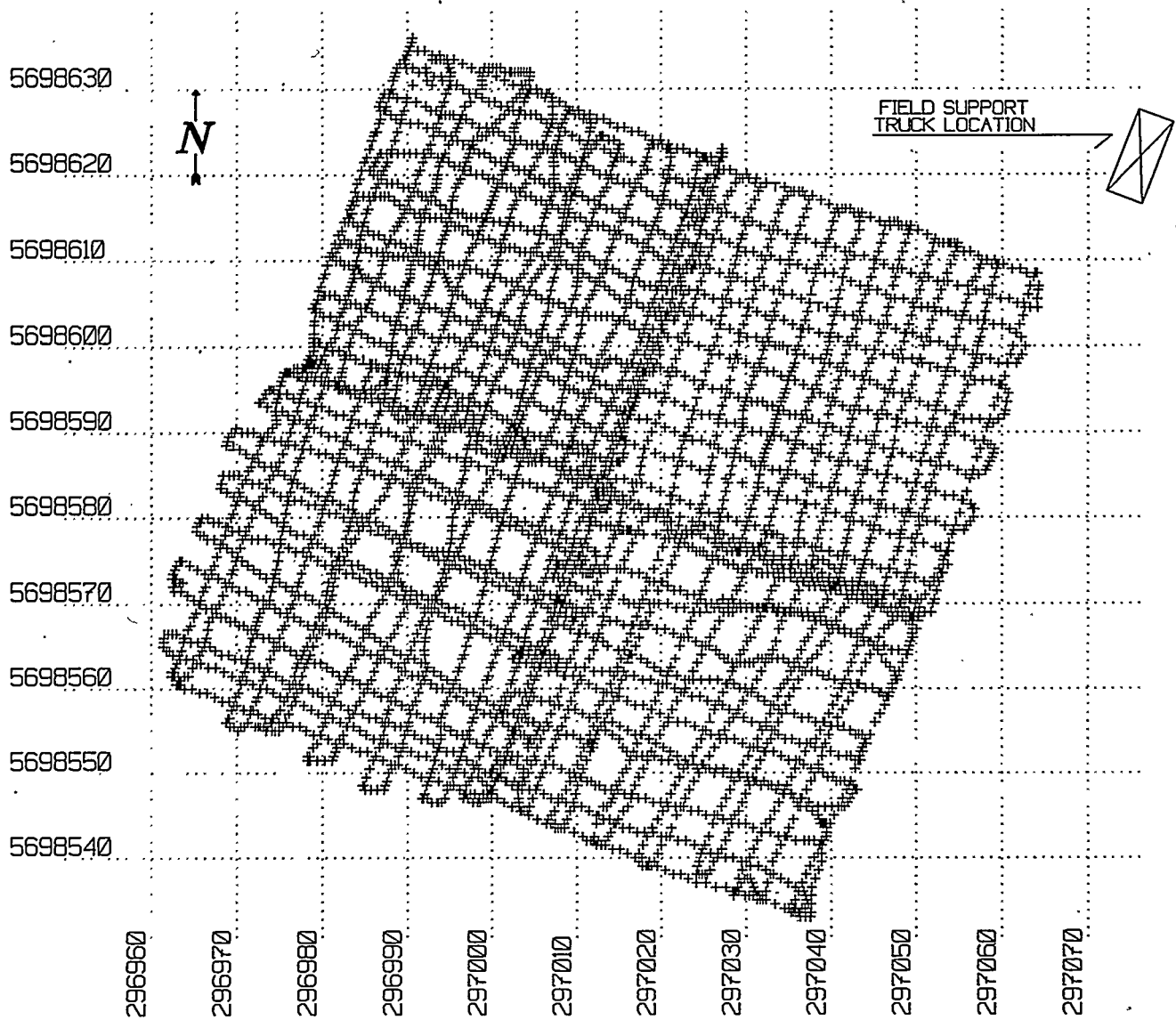
3.8 MRDS SURVEYS

3.8.1 Overview

The MRDS and radiological instrumentation is similar to the USRADS in that it correlates radiological data with location and stores this information in an electronic file once per second. It also provides a cpm reading from a 5 cm by 5 cm NaI detector at ~ 15 cm. from the soil surface and a micro Rem dose rate reading from an energy-compensated GM tube located at approximately waist height.

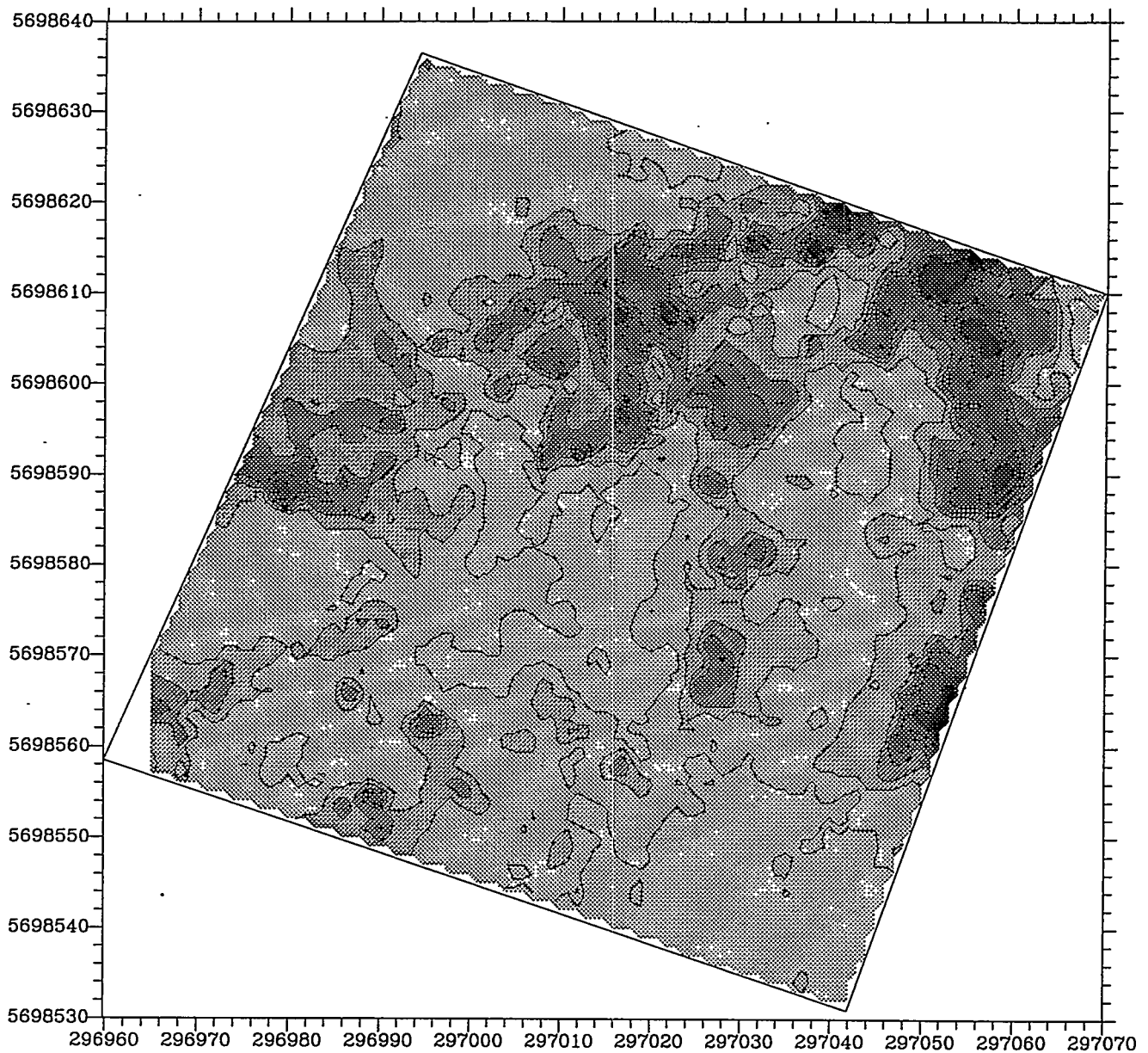
The MRDS is a backpack-based radiological mapping device that correlates radiological readings with position. Position is determined by utilizing the U.S. NAVSTAR (NAVigation Satellite Timing And Ranging) satellite system. In this respect, it differs from the USRADS positional technology. The MRDS requires a lower maintenance and is easier to operate; however, its positional accuracy in normal mode of operation is ~ 2 m, as opposed to the USRADS which is ~ 30 cm.

Figure 3-11. Site 2 - Composite Survey Track Map.

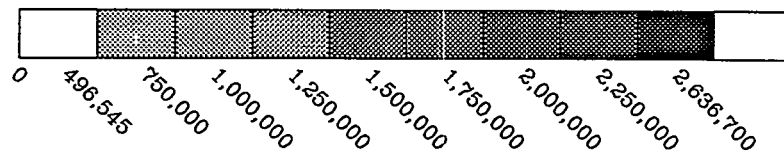


MAP SCALE - METERS
 0 5 10 20
 WGS84 - UTM ZONE 36

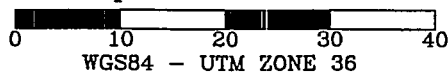
Figure 3-12. Site 2 - Topographical Representation of Count Rate Data



Counts Per Minute - NaI Detector

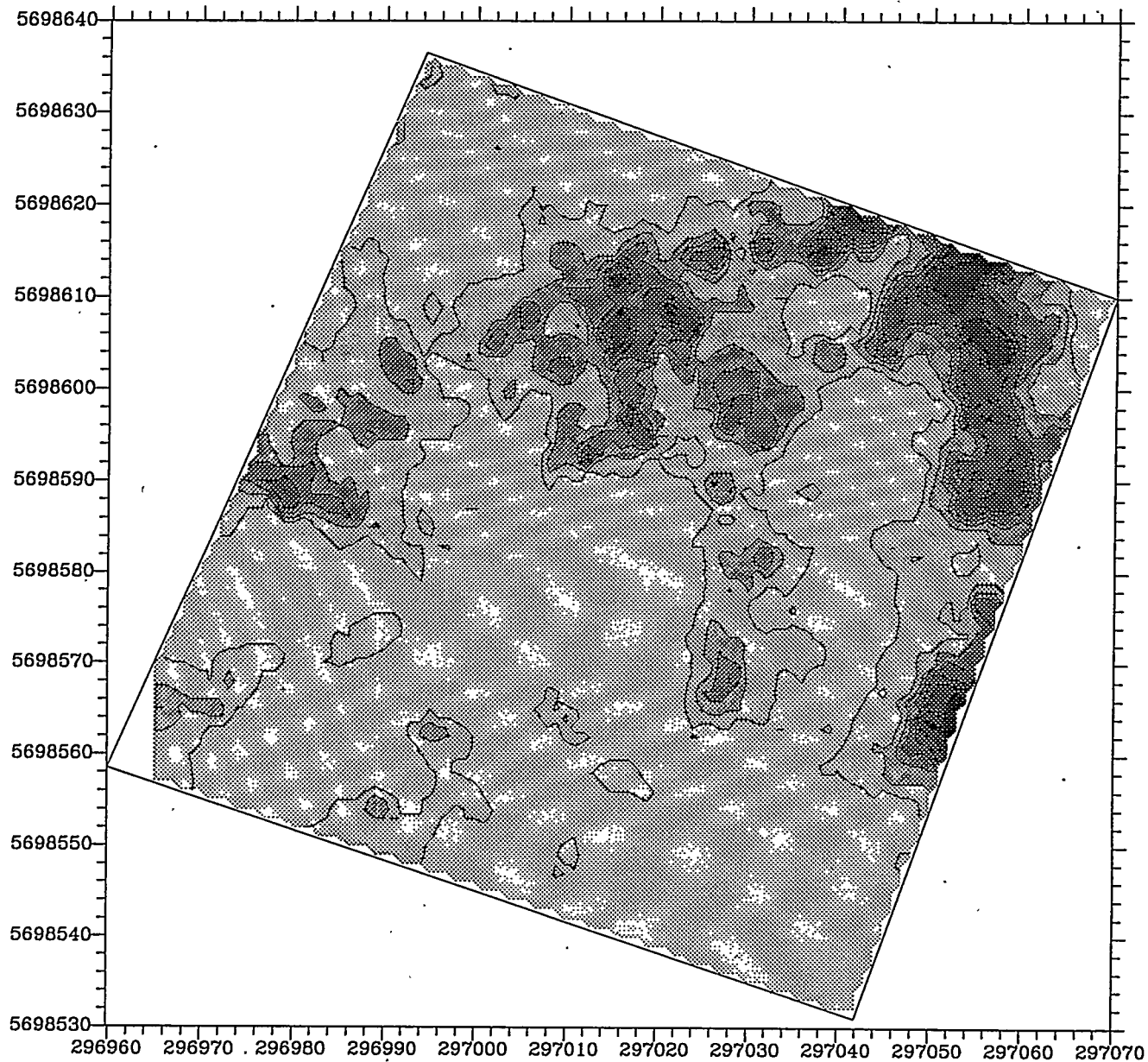
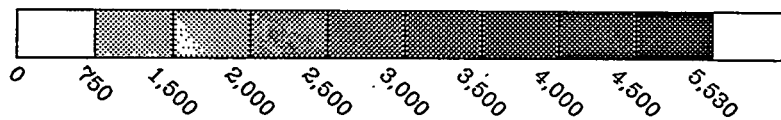


Map Scale - Meters



WGS84 - UTM ZONE 36

Figure 3-13. Site 2 - Topographical Representation of Dose Rate Data

Dose Rate - $\mu\text{R}/\text{Hr}$ 

Map Scale - Meters

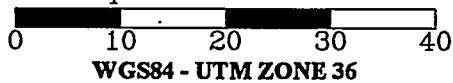
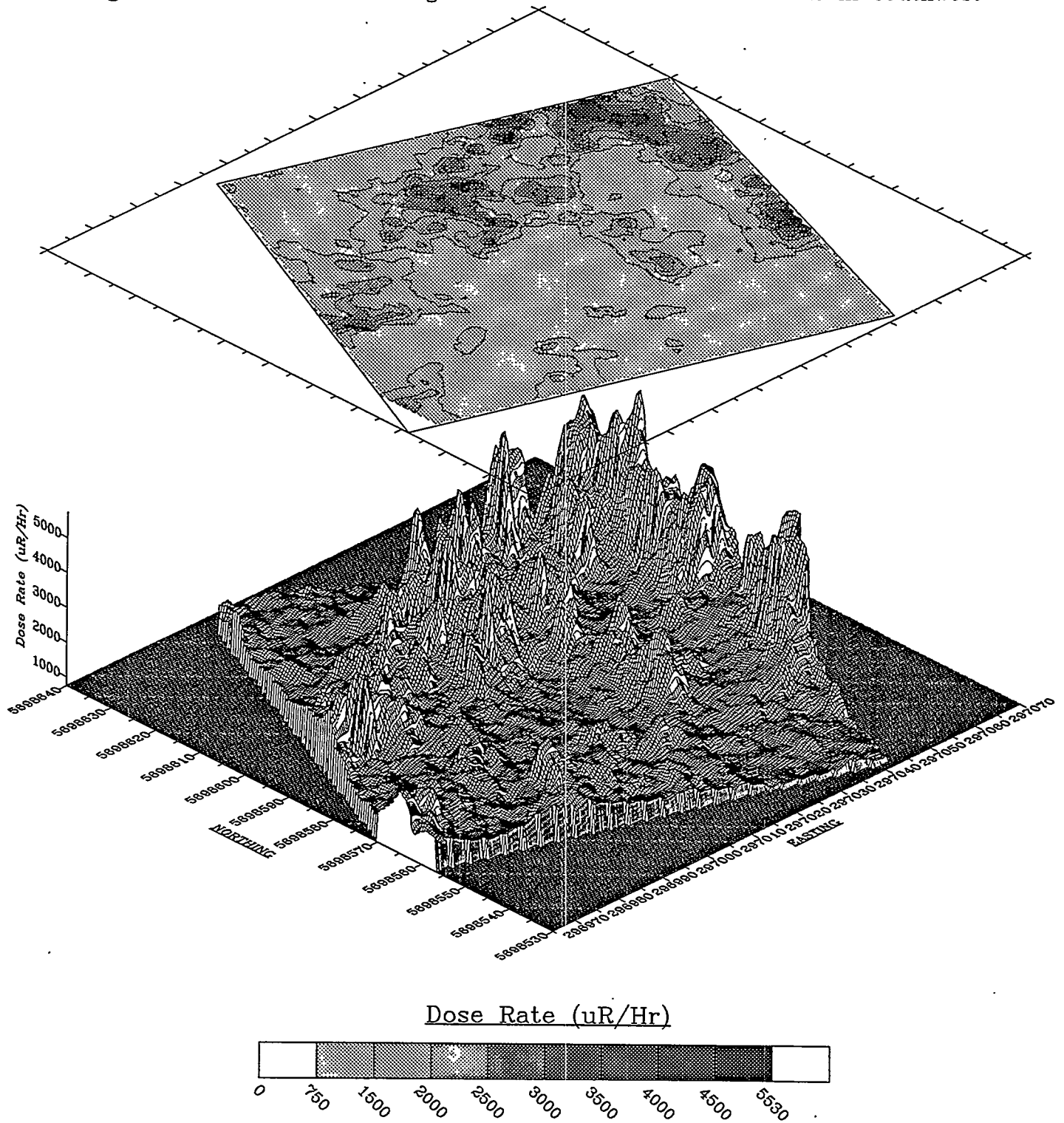


Figure 3-14. USRADS Radiological Dose Rate Profile - Viewed from Southwest



The surveyor dons a backpack unit that contains the radiological detection and GPS gear to perform the survey. The acquired data are stored in electronic format within a computer mounted on the backpack and may also be transmitted via data radio to a base station staged in a vehicle in the vicinity of the surveyor. This base station includes a computer and a monitor that displays a background map of the area to be surveyed, as well as the surveyor's track highlighted with the radiological data. The second person in charge of the base station may be in voice radio contact with the surveyor to ensure adequacy of survey coverage and correctness of data acquired. The MRDS stores a point-per-second update of the surveyor's position and radiological data for later down loading to other software packages that allow further analysis and graphical representation.

3.8.2 MRDS Survey Location

The MRDS was used to survey grid blocks # 1 and # 2 of Site 1 and the entire area of Site 2 and Site 3.

3.8.3 MRDS Survey Results

Site 1--The MRDS recorded 4,342 data points in the ~4884 m² of Site 1.

Every radiological data point collected was statistically elevated above MDC. These elevated readings may be due to either radiation from subsurface radioactive material, surface contamination, or a combination of both. MRDS Survey statistics of this area are summarized in Table 3-3.

Table 3-3. MRDS Survey Statistics of Site 1.

Grid	Date	Points	Max cpm	Min cpm	Max μ R	Min μ R
1	01/Sept/94	2,296	1,301,632	226,088	558.5	36.73
2	01/Sept/94	2,046	1,057,728	205,848	556.6	55.9

cpm = counts per minute

μ R = microrems per hour.

Figure 3-15 is a composite track map. Counts per minute and dose rate data are shown graphically in Figures 3-16, 3-17, and 3-18.

Site 2--Radiological readings collected with the MRDS were much greater in this location than at Site 1. At Site 2, 6,950 m² were surveyed, collecting 5,408 data points. Variations in radiological levels encountered at Site 2 may have been caused by surface contamination and/or subsurface radiation emitting from the burial areas.

Figure 3-15. Site 1 - MRDS Demonstration Survey Project Composite Survey Track Map.

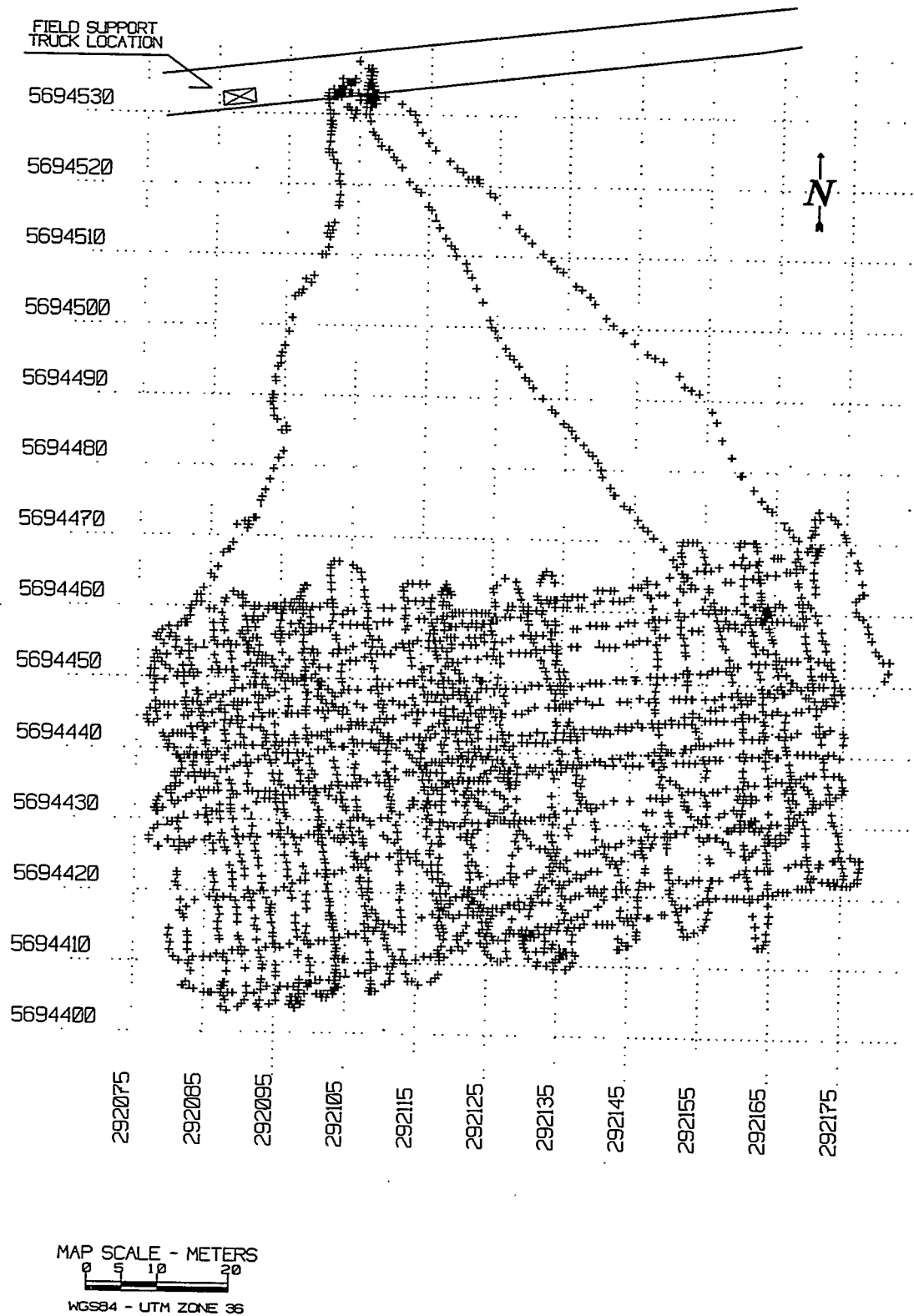
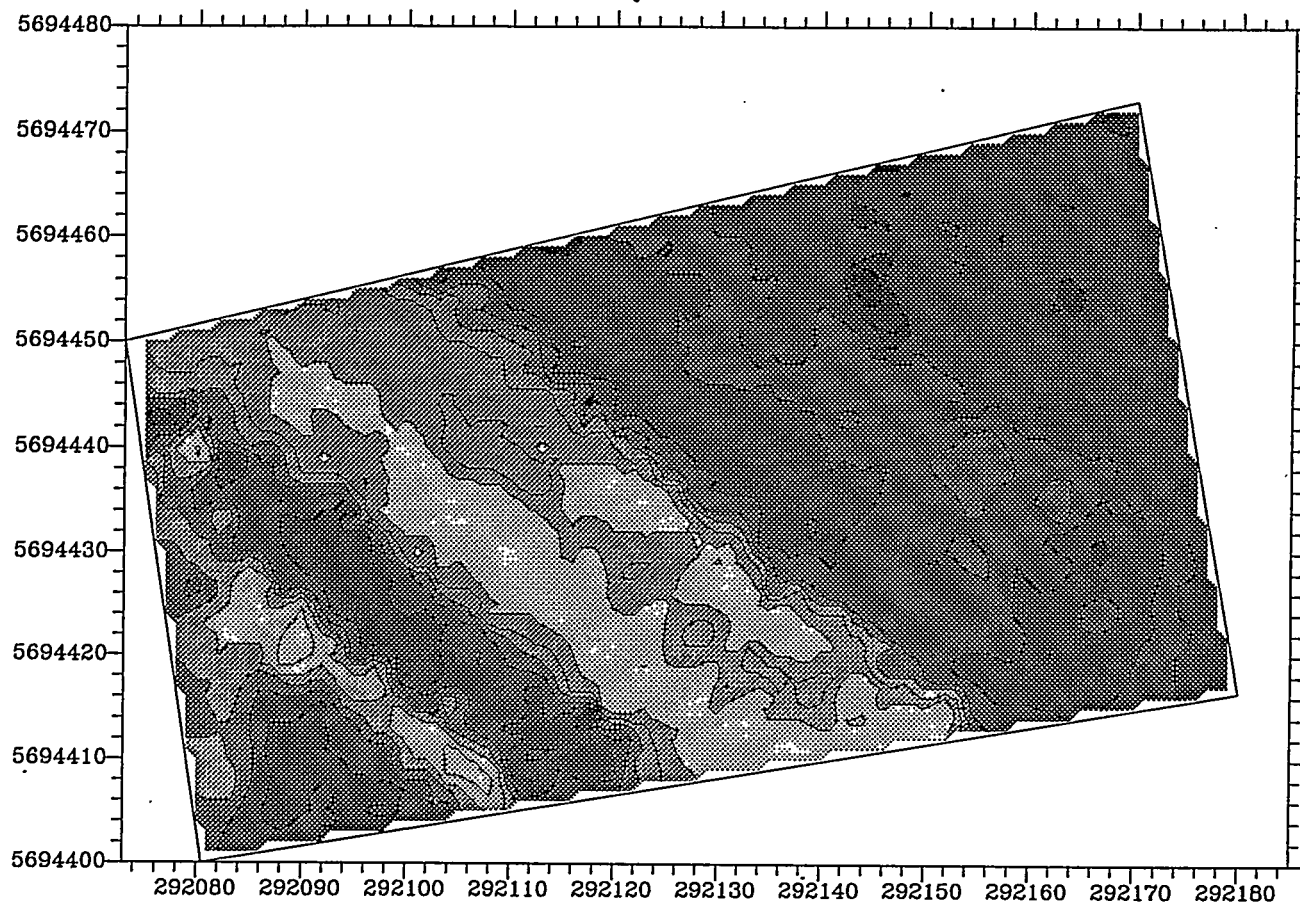
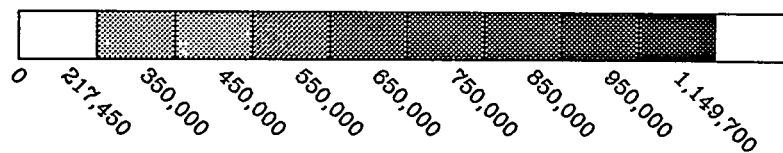


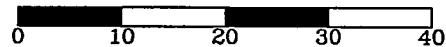
Figure 3-16. Site 1 - Topographical Representation of MRDS Count Rate Data



Counts Per Minute - NaI Detector

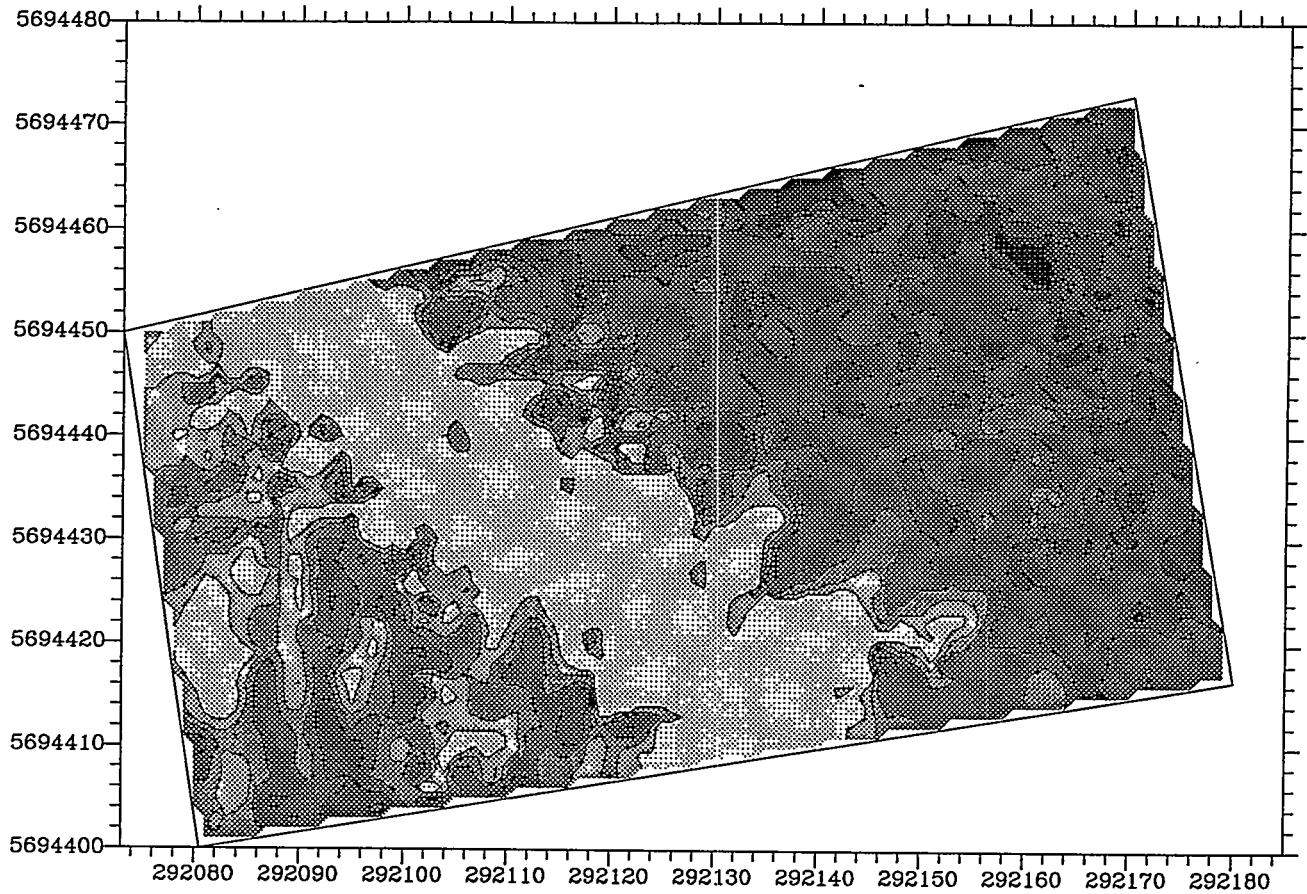


Map Scale - Meters



WGS84 - UTM ZONE 36

Figure 3-17. Site 1 - Topographical Representation of MRDS Dose Rate Data



Dose Rate - $\mu\text{R}/\text{Hr}$



Map Scale - Meters

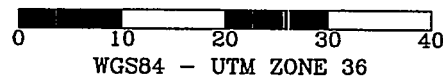
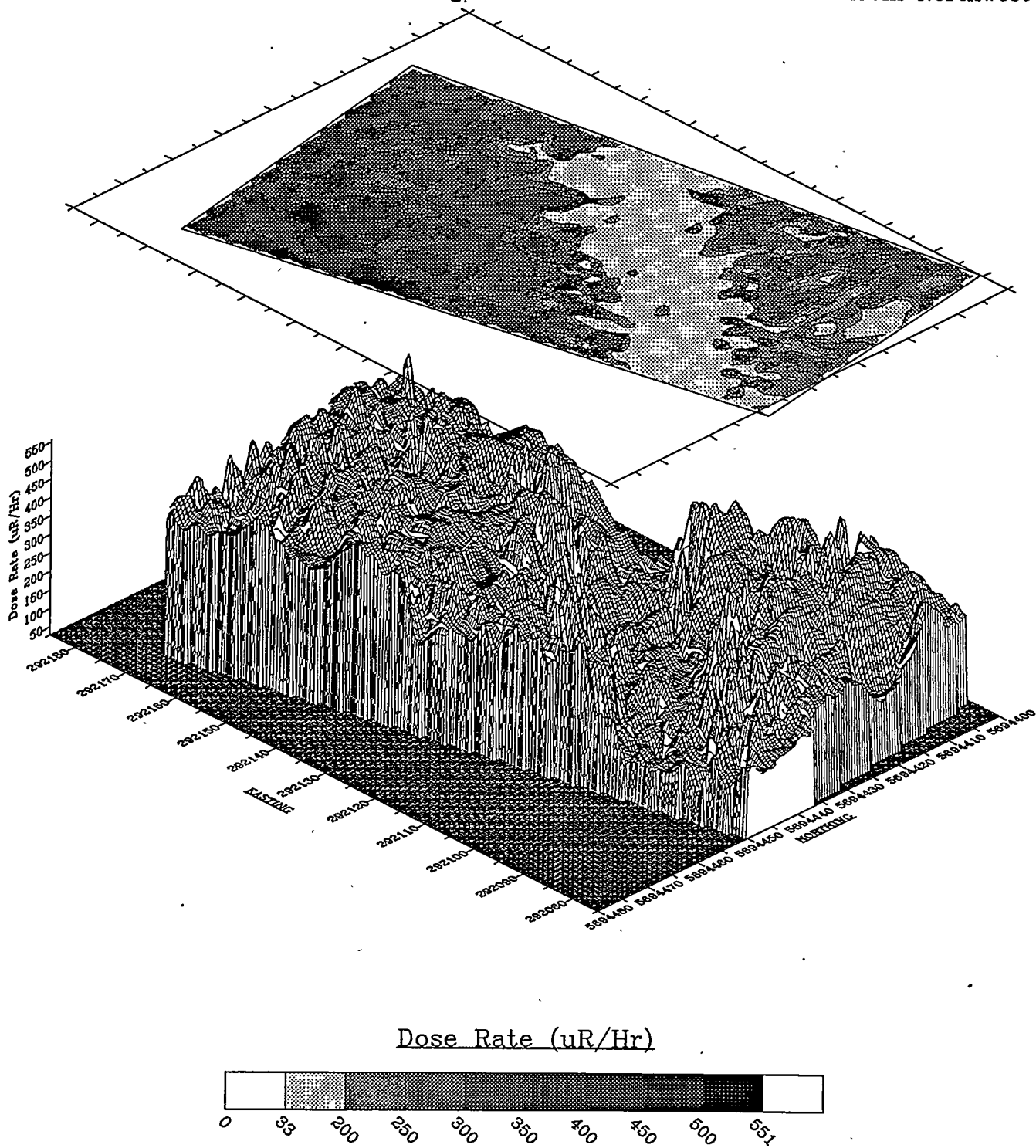


Figure 3-18. Site 1 - MRDS Radiological Dose Rate Profile - Viewed from Northwest



Survey statistics are summarized in Table 3-4.

Table 3-4. MRDS Survey Statistics of Site 2.

Grid	Date	Points	Max cpm	Min cpm	Max μ R	Min μ R
1	03/Sept/94	1,958	2,888,000	666,000	2,469.1	143.1
2	03/Sept/94	1,353	2,854,464	796,080	1,608	159
3	03/Sept/94	989	2,843,328	777,360	2,011	191.1
4	03/Sept/94	1,108	2,862,592	692,336	2,139.3	141.6

cpm = counts per minute
 μ R = microrems per hour.

A composite track map of the surveyors path acquired by the MRDS is shown in Figure 3-19. Figures 3-20, 3-21, and 3-22 are graphical representations or "surface models" of the radiological data.

Site 3--Due to time constraints, only 2,103 m² were surveyed. 1,113 data points were collected at Site 3. Table 3-5 summarizes the data collected, Figure 3-23 is a track map, and Figures 3-24, 3-25, and 3-26 are graphical representations, or "surface models," of the data.

Table 3-5. MRDS Survey Statistics of Site 3.

Grid	Date	Points	Max cpm	Min cpm	Max μ R	Min μ R
Site 3	05/Sept/94	1,113	287,632	90,246	145.4	9.2

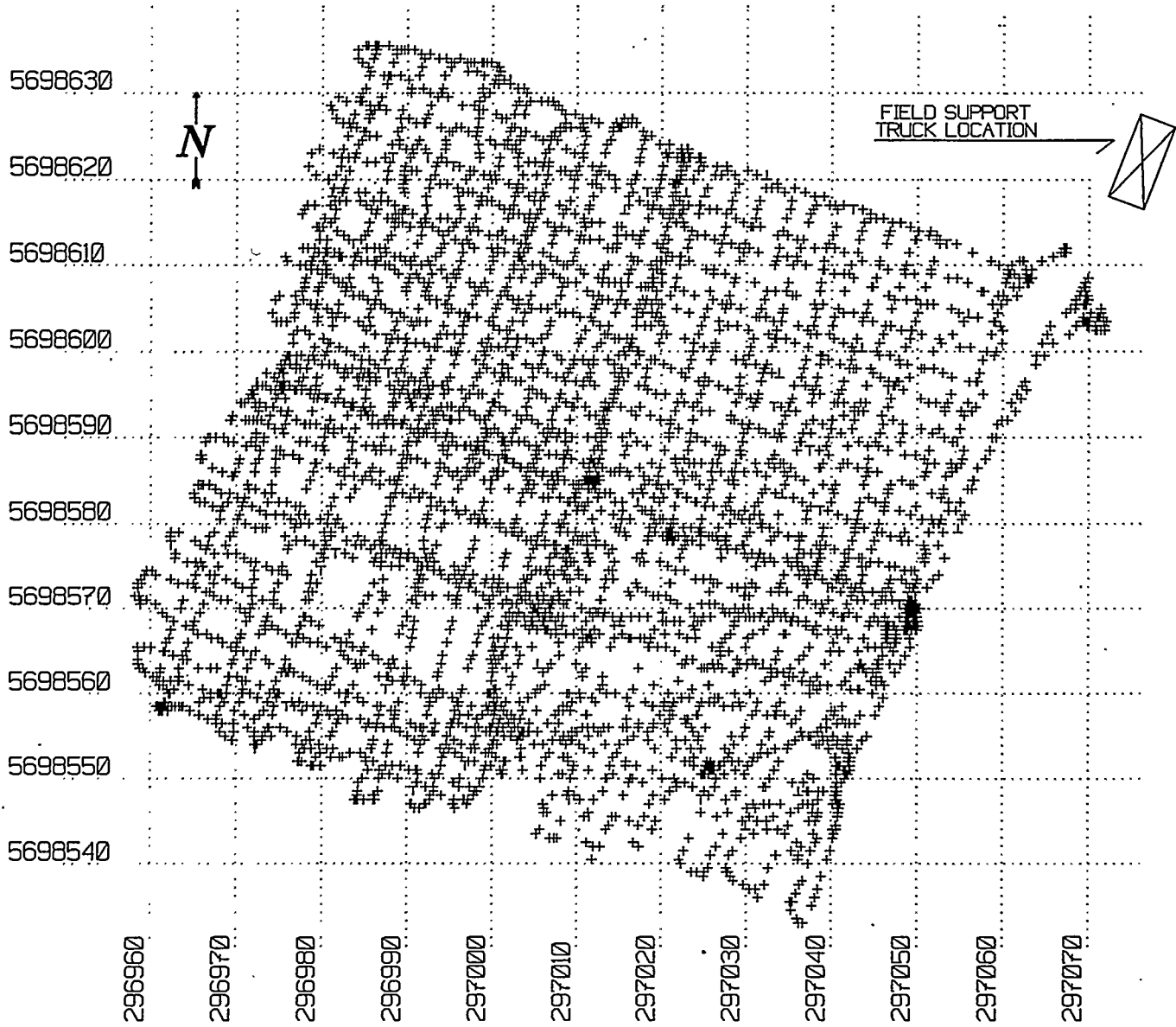
cpm = counts per minute
 μ R = microrems per hour.

3.9 RADIATION BACKGROUND DETERMINATION SURVEY

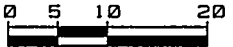
3.9.1 Introduction

A radiation survey was conducted to establish baseline radiological background conditions in a designated test plot known to have no contamination as the result of the Chernobyl accident and no history of radiological operations. The radiological data collected during this survey are considered representative of the natural radioactivity contained within the soil and cosmic influences within the vicinity of the Chernobyl reactor site. The survey was conducted on September 6, 1994.

Figure 3-19. Site 2 - MRDS Composite Survey Track Map.

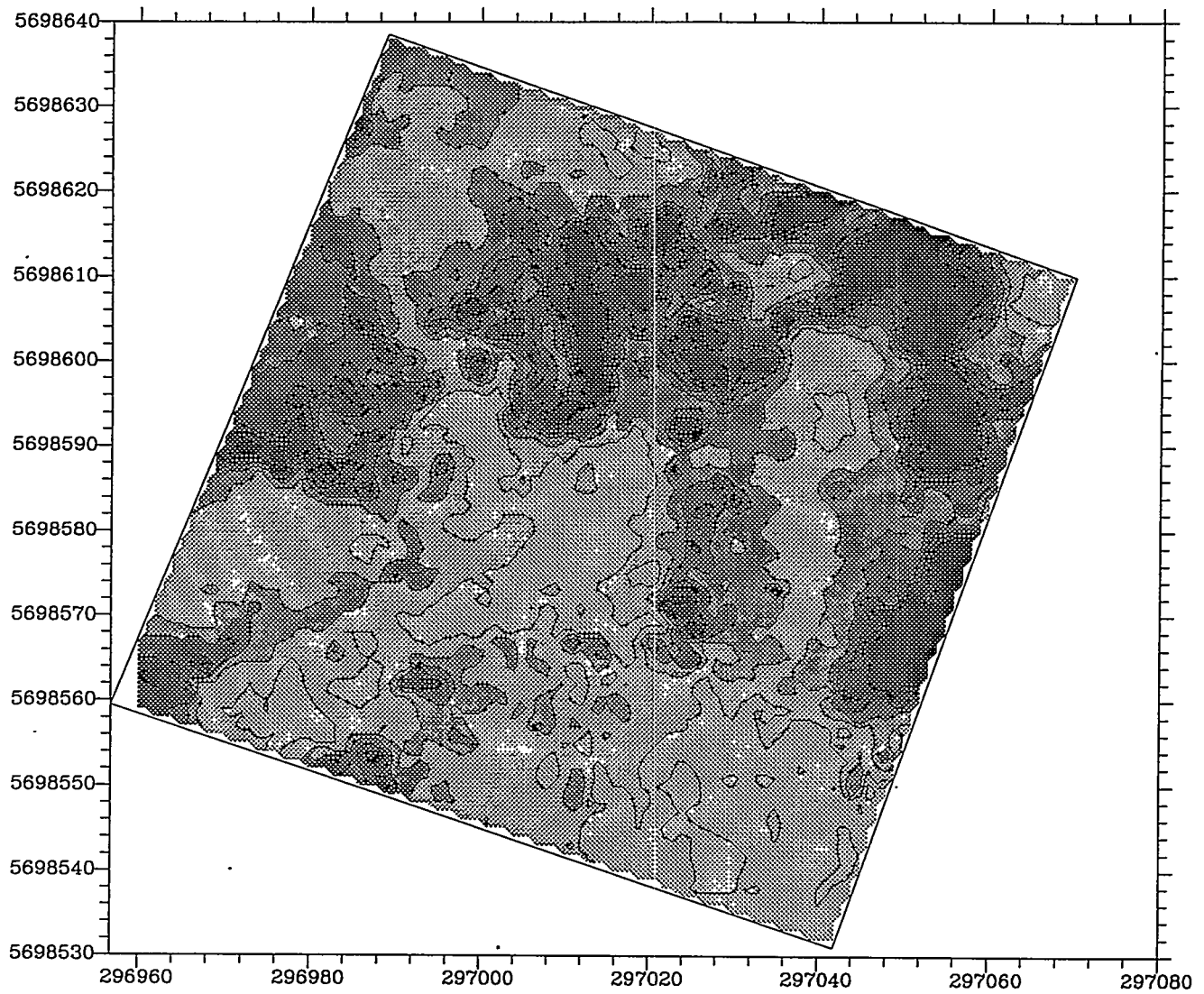


MAP SCALE - METERS

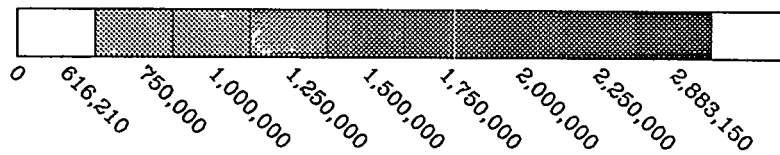


WGS84 - UTM ZONE 36

Figure 3-20. Site 2 - Topographical Representation of MRDS Count Rate Data



Counts Per Minute - NaI Detector



Map Scale - Meters

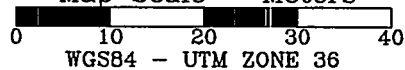
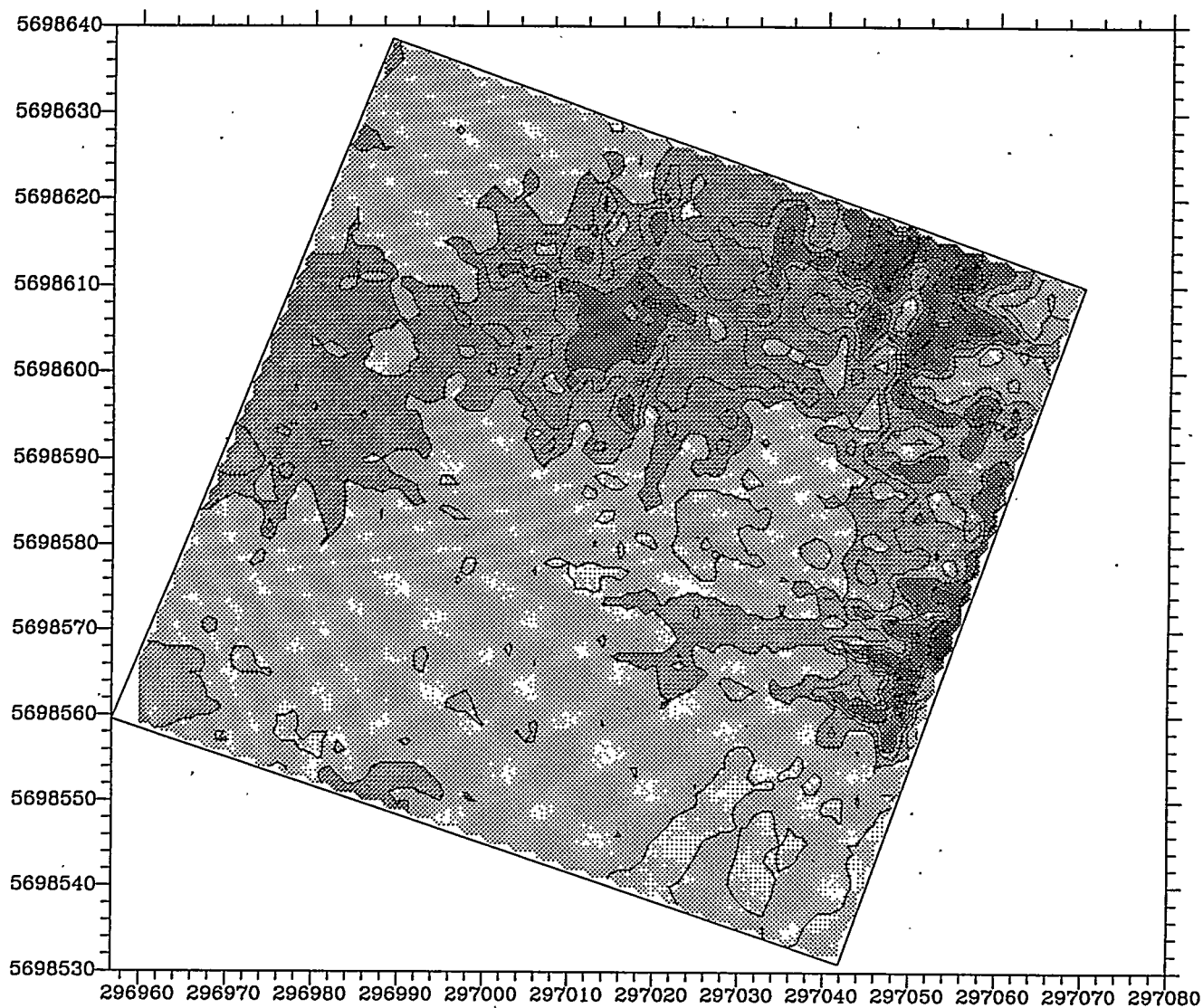
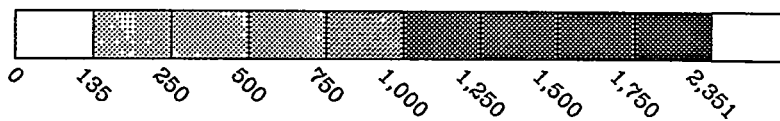


Figure 3-21. Site 2 - Topographical Representation of MRDS Dose Rate Data

Dose Rate - $\mu\text{R}/\text{Hr}$ 

Map Scale - Meters

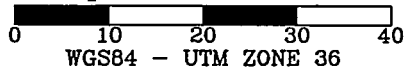


Figure 3-22. Site 2 - MRDS Radiological Dose Rate Profile - Viewed from Southwest

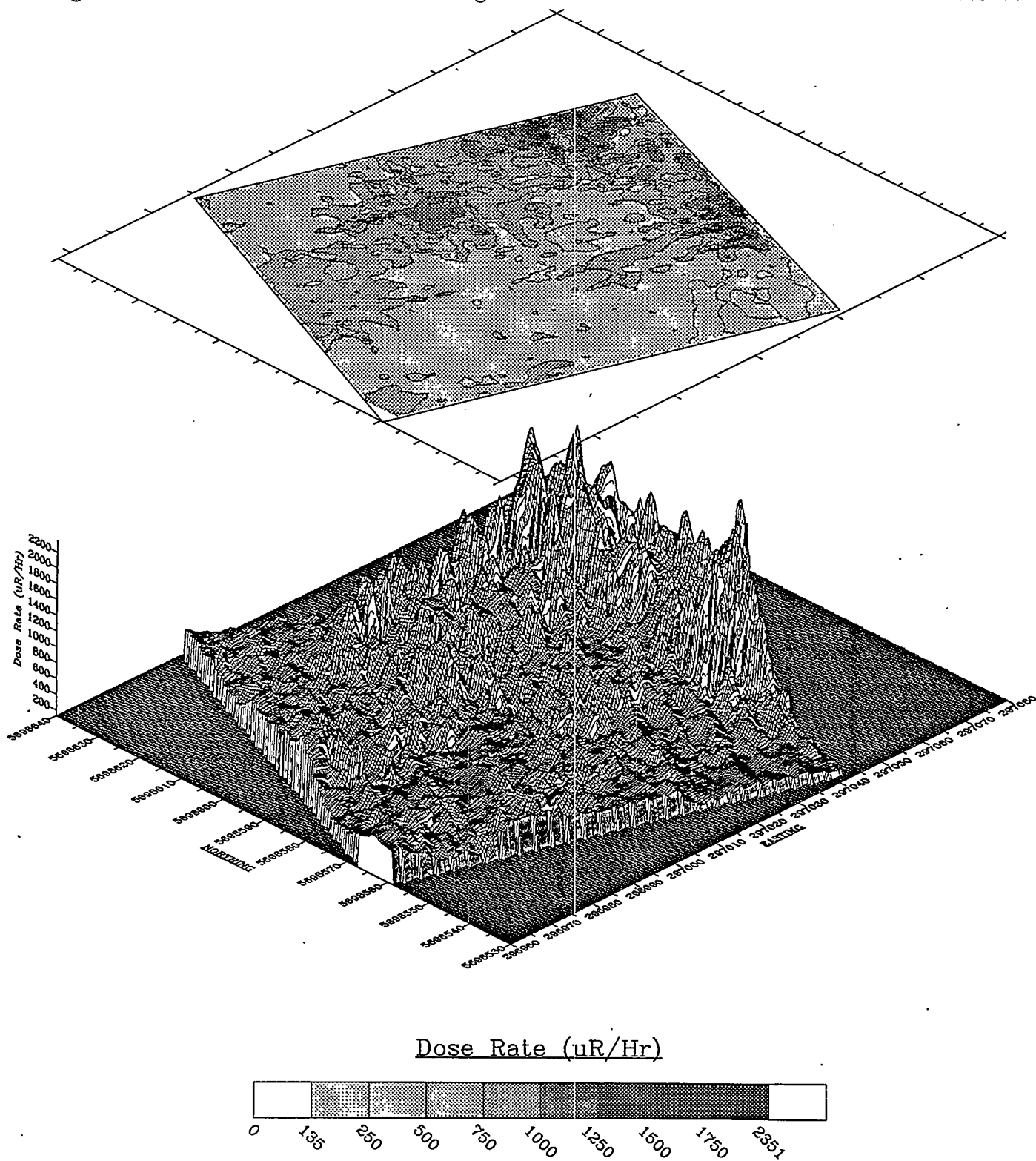
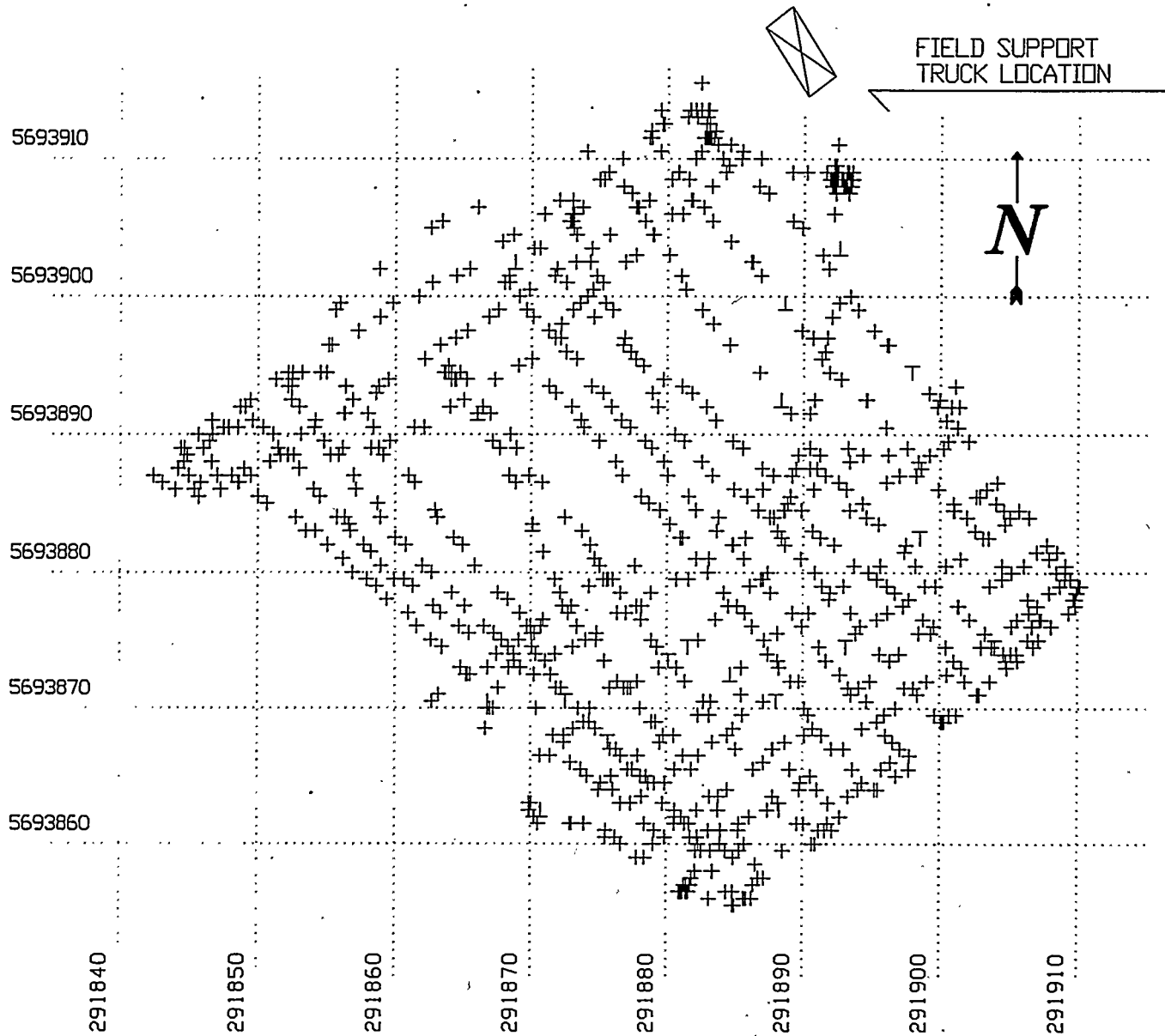


Figure 3-23. Site 3 - MRDS Composite Survey Track Map.



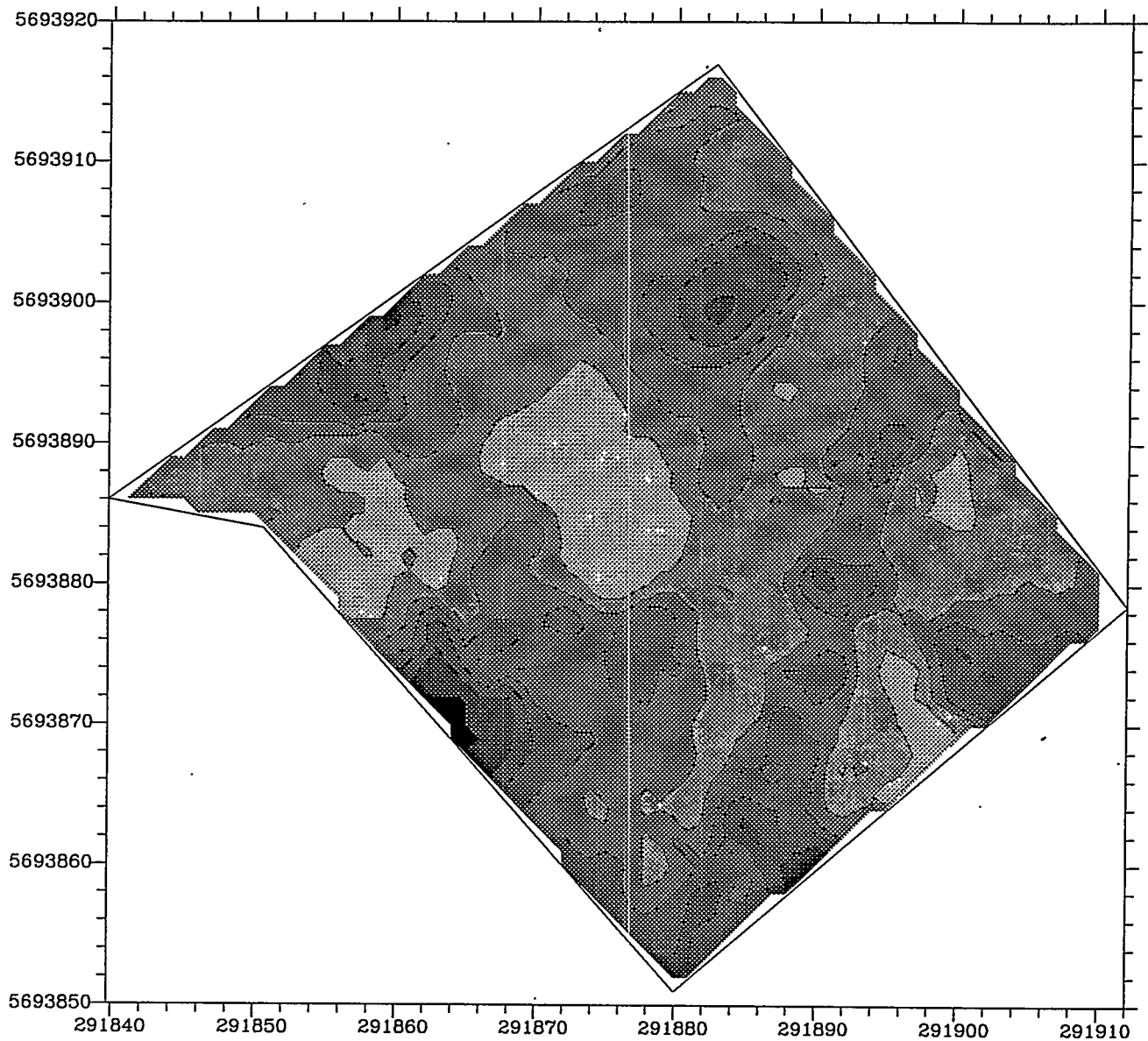
MAP SCALE - METERS

0 5 10 15

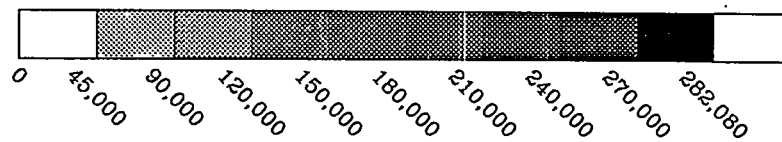


WGS84 - UTM ZONE 36

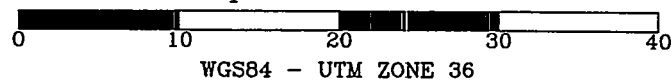
Figure 3-24. Site 3 - Topographical Representation of MRDS Count Rate Data



Counts Per Minute - NaI Detector

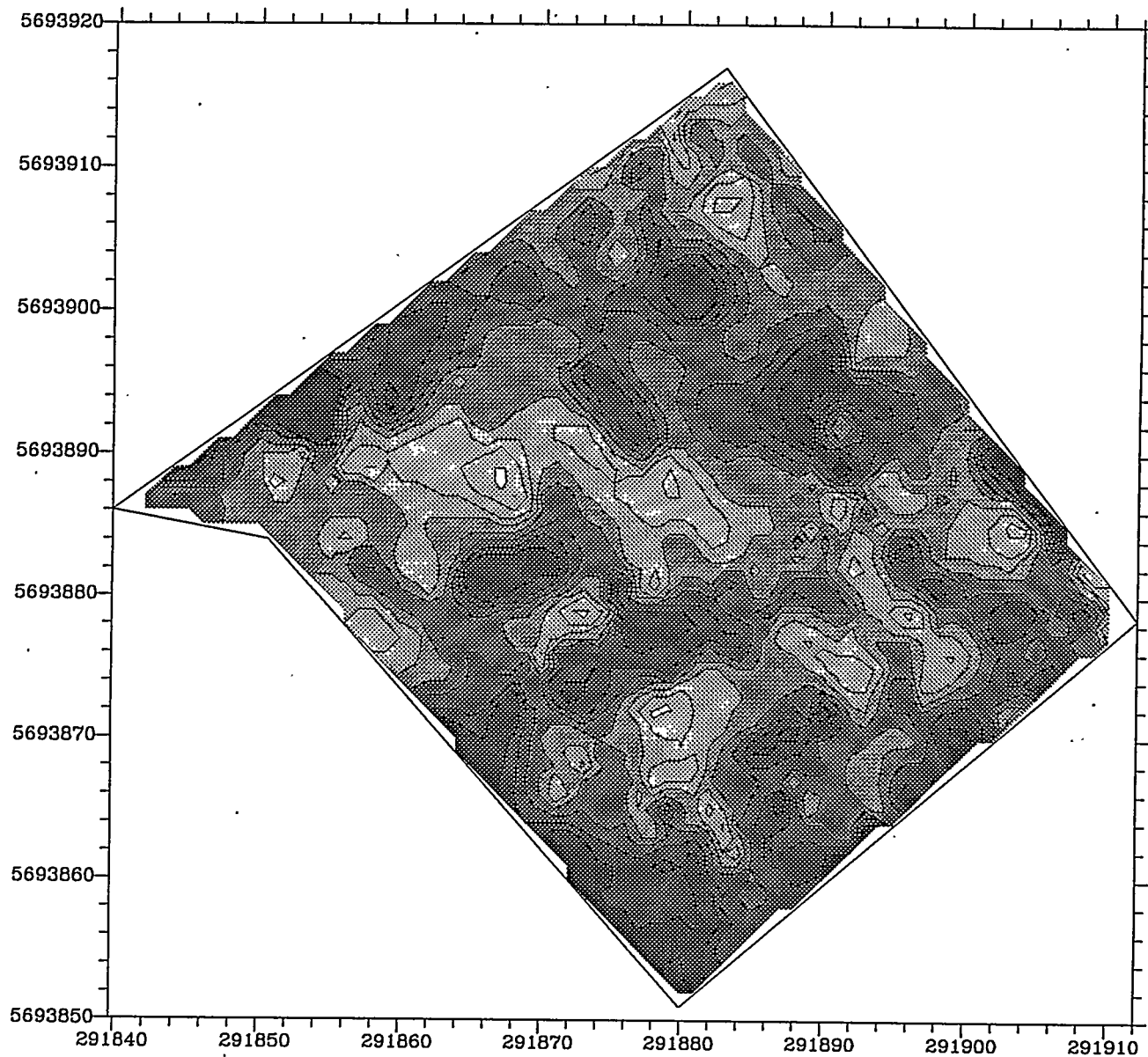


Map Scale - Meters

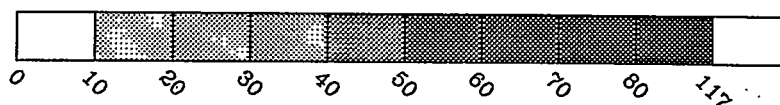


WGS84 - UTM ZONE 36

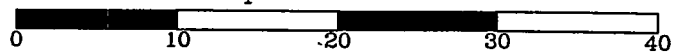
Figure 3-25. Site 3 - Topographical Representation of MRDS Dose Rate Data



Dose Rate - $\mu\text{R}/\text{Hr}$

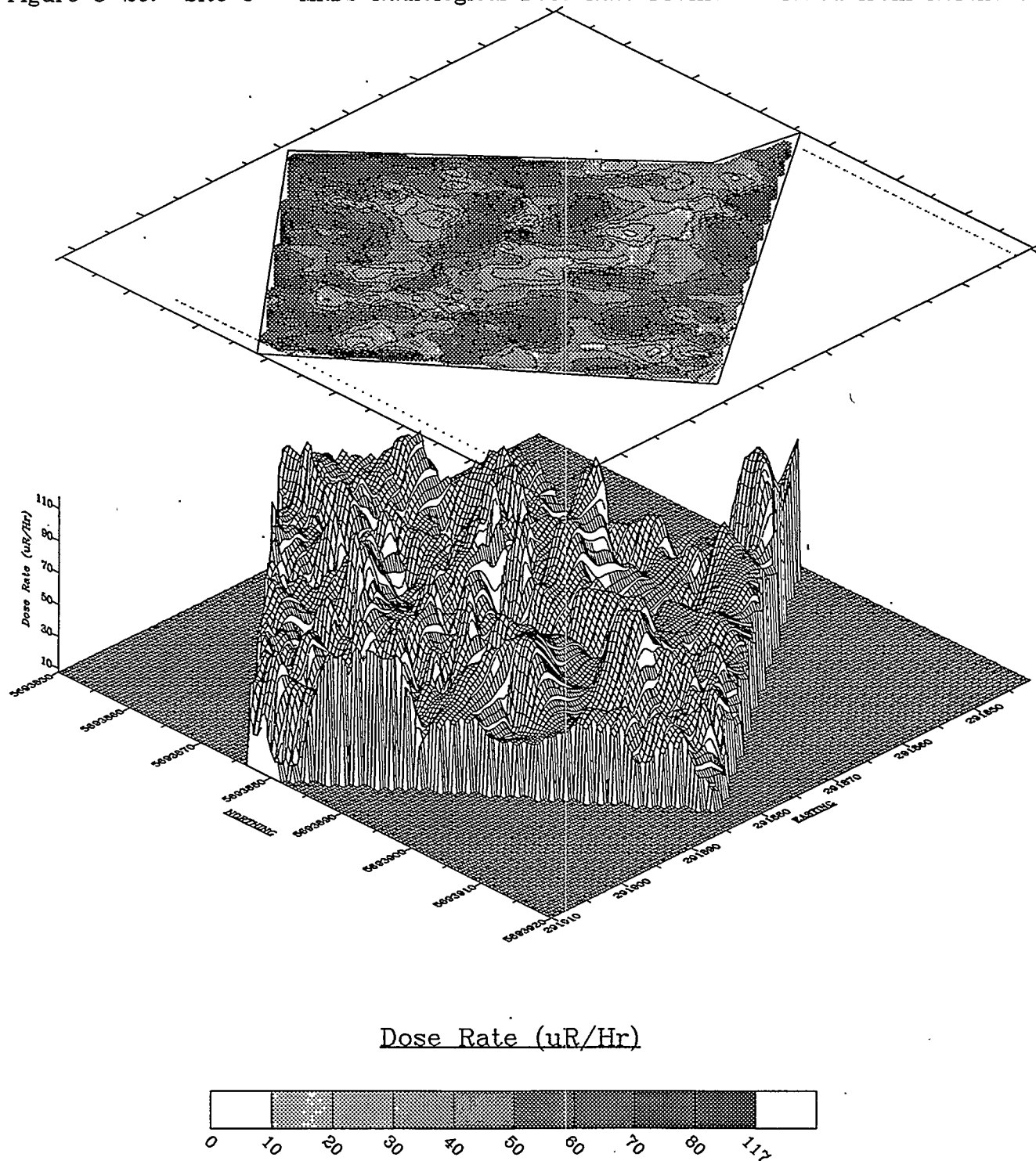


Map Scale - Meters



WGS84 - UTM ZONE 36

Figure 3-26. Site 3 - MRDS Radiological Dose Rate Profile - Viewed from Northeast



3.9.2 Location

The test plot was located in the courtyard of the International Compound of the Zelene Mys Facility, Ukraine. The surveyed area measured 35 m by 35 m.

3.9.3 Discussion

The USRADS survey was conducted using Ludlum Model 2221 digital count rate meter with a Ludlum Model 44-10, 5cm by 5 cm NaI detector and also a Ludlum Model 19 μ R dose rate meter. The MRDS survey was conducted using two Eberline SRM-300 count/dose rate meters, one interfaced to an Eberline HP-270 GM tube for dose rate determination and the other interfaced with an Eberline SPA-3 NaI detector for cpm readings. These meters were coupled to the individual radiological mapping systems for the purpose of recording the data from the output of the individual detectors verses the location of the data within the survey area.

Two separate surveys, one with the USRADS and one with the MRDS, were performed to cover the 1,225 m² site. A total of 769 data points were collected with the USRADS, and 360 data points were collected with the MRDS within this site. A summary of the survey results is found in Table 3-6. Track maps of the surveyed area are shown in Figures 3-27 and 3-28.

Table 3-6. Summary Survey Statistics of the Background Determination Site.

Type	Data points	Min cpm	Max cpm	Mean cpm	Min μ R	Max μ R	Mean μ R
USRADS	769	3,900	9,060	6,638.7	2.12	11.72	6.85
MRDS	360	6,173	10,903	7,868.3	0.8	34.57	9.45

cpm = counts per minute

μ R = microrems per hour.

The USRADS average background count rate at the Background Determination Site was 6638.7 cpm. The average dose rate was 6.85 μ R/hr. For the MRDS, these figures were 7868.3 cpm and 9.45 μ R.

Figure 3-27. USRADS Background Determination Site.

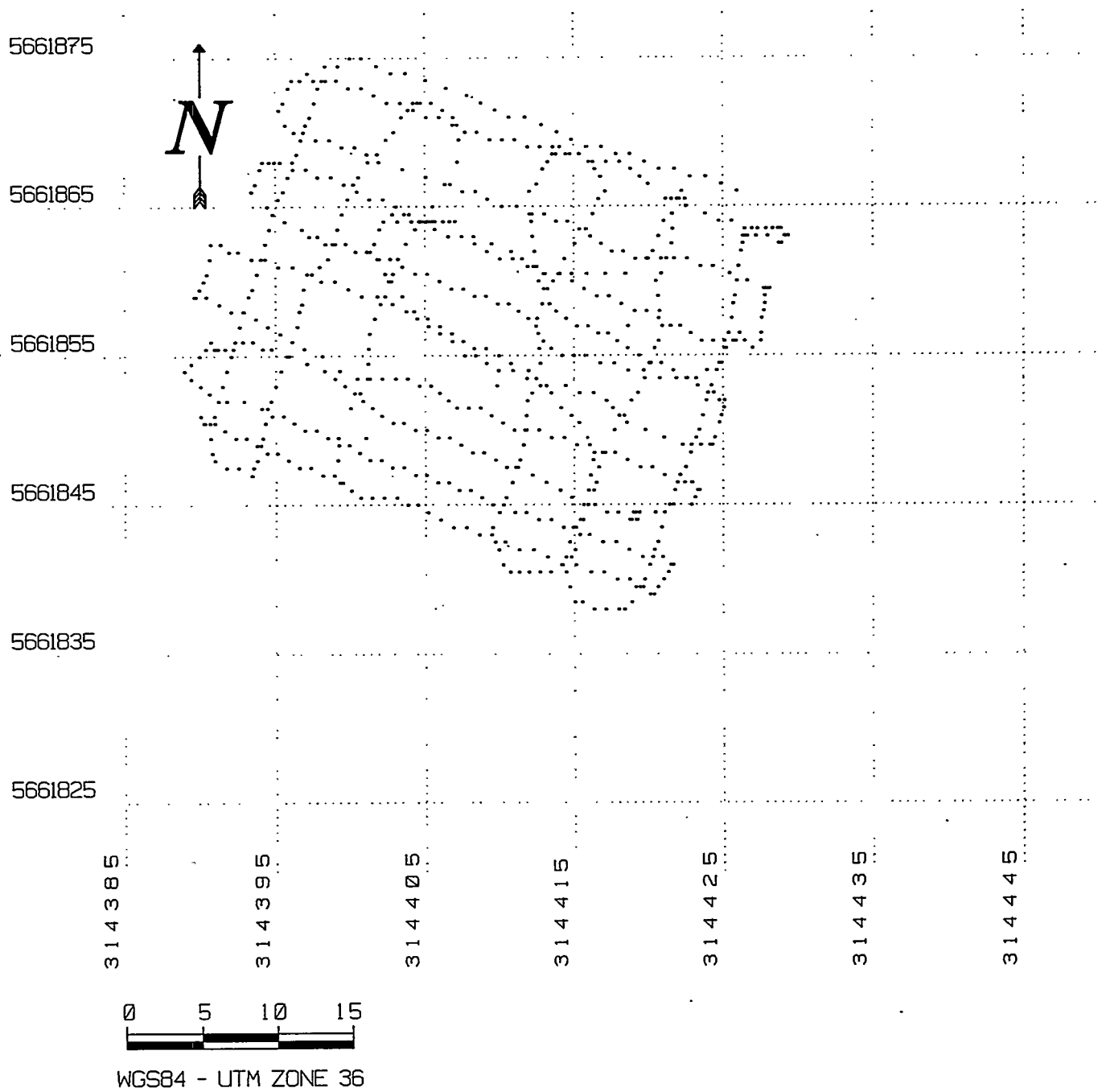
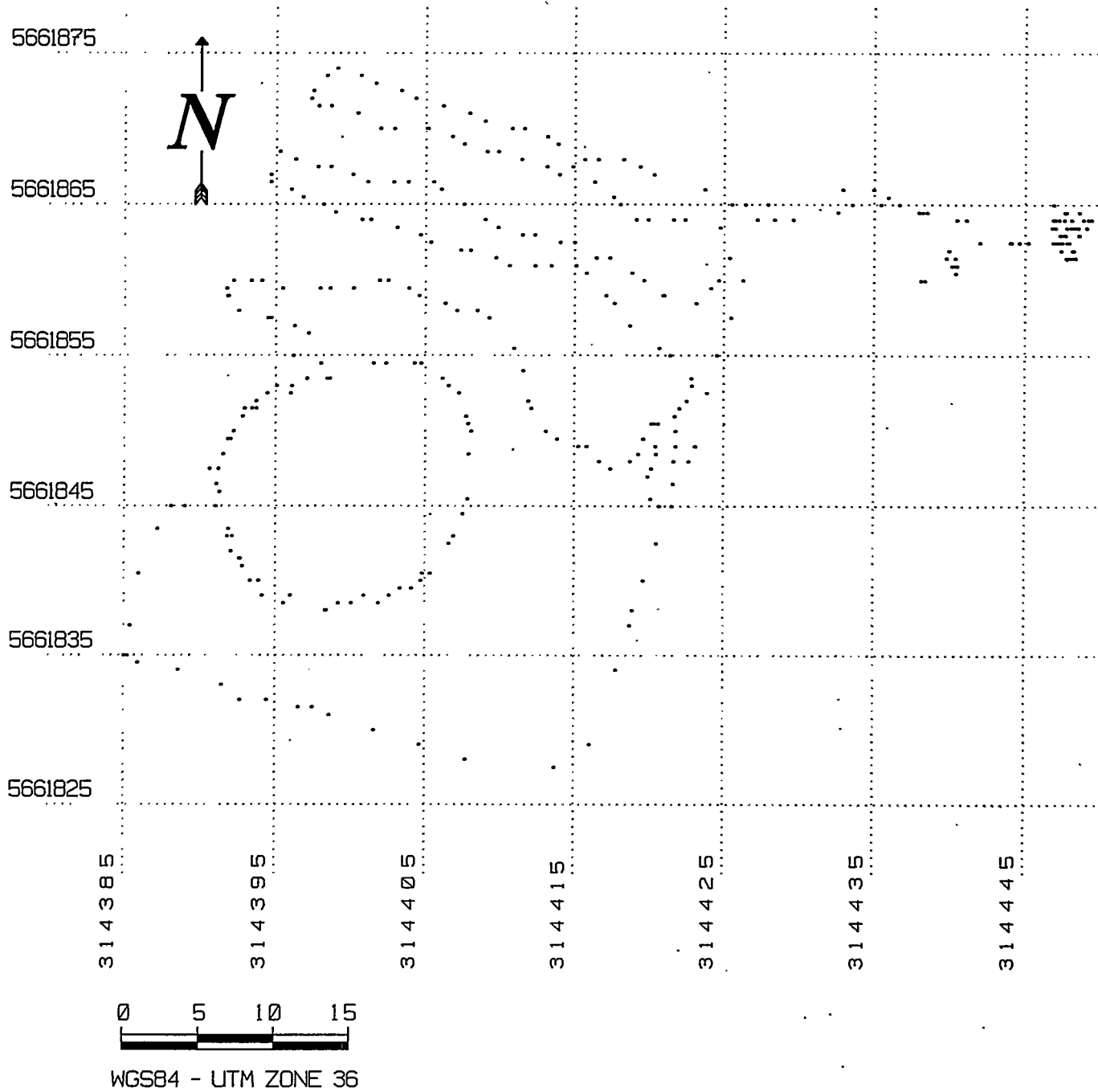


Figure 3-28. MRDS Background Determination Site.



3.9.4 Minimum Detectable Count Rate Calculation

The minimum detectable count rate (MDC) was calculated by equation 1 (Gollnick 1988).

$$[1] \quad MDC = 60 \left(4.66 \sqrt{\frac{Rb}{60}} \right) + Rb$$

where: Rb = background count rate in cpm

Based on this equation, the minimum detectable count rate for USRADS was 9,580 cpm and for the MRDS the MDC was 11,070 cpm.

3.10 SUMMARY OF RADIOLOGICAL MAPPING SYSTEMS SURVEYS

3.10.1 Comparative Variance in Dose Rate Reported

The Ludlum Model 19 meter used with the USRADS systems utilizes an NaI detector and factors the events registered into a dose rate number. A crystalline detector inherently over responds to low-energy gamma radiation, causing the dose rate reported by the USRADS to be overly conservative. The Eberline HP-270 (MRDS) gives a more linear dose rate report; however, due to the small size of the GM tube and relatively short count times, it has a tendency to become unstable in very low dose rate fields. Dose rate numbers reported by the GM tube are much closer to actual dose rate at the surveyed sites. From a qualitative perspective, dose rate surface models from data obtained by both systems are extremely similar.

3.10.2 Radiological Results

Site 1--While Site 1 was found contaminated over the entire area surveyed, the higher levels were found in a band running from northwest to southeast across the site. The areas of soil disturbance, i.e., trenches and dirt roadway, were contaminated to a much less extent, nearly an order of magnitude, than the remainder of the area.

Site 2--The objective expressed by the Ukraine team in the Site 2 survey of was to determine if these systems would locate radiological burial grounds within a contaminated area. This was a partial success, locating 3 of the 5 burials thought to be within the area. Site 2 radiological readings obtained by the systems were higher than at the other two site surveyed (Sites 1 and 3). The highest readings were found in the northeast corner of the area.

Site 3--A relatively small area was surveyed at this location. Because of this, it is difficult to develop a pattern of contamination/radiation at this site. Four areas showed readings generally higher than the rest of the site, but it is difficult to make a valid judgement as to the extent of the radiological problem at this location.

3.10.3 Applicability and Overall Effectiveness for Chornobyl Cleanup Use

Both radiological mapping systems demonstrated were judged by the Hanford team as well as the Ukrainians to be extremely useful tools to assist with the Chornobyl cleanup mission. The MRDS, with its GPS positional technology, was judged to be both easier to operate and more reliable than the USRADS system. The Ukrainians showed interest in outfitting a small all-terrain vehicle with MRDS technology to provide greater productivity and ease of user operation. It was noted that while the systems only found 3 of the 5 burial grounds at Site 2, a modification of the MRDS system to integrate a subsurface characterization device, such as ground penetrating radar or ground conductivity instrumentation, should be extremely effective to map unknown burial ground areas. Overall, the demonstration of USRADS and MRDS in the Chornobyl 30-km exclusion zone was successfully completed by both the Hanford and Ukraine teams.

3.11 NOMAD FIELD GAMMA SPECTROSCOPY

3.11.1 Overview

The NOMAD is a portable gamma spectroscopy system designed to perform in situ measurements. Measurements may be taken using two different methods. The first method is a qualitative identification of the gamma emitting isotopes present based on the position of their photopeaks in the gamma energy spectrum. The second is a quantitative analysis performed using the Environmental Measurements Laboratory (EML) 1-m method originally developed by the DOE's EML (Beck et al. 1972). This technique, described in Section 3.11.5, determines the average activity of natural and man made radionuclides distributed on the surface and within the soil matrix over a finite area.

This method has limitations. With the exception of ^{241}Am , most transuranic isotopes are generally not detectable in the presence of other radionuclides because of their extremely long half-lives and relatively low branching ratios for gamma radiation. Pure beta emitters, such as ^{90}Sr , also cannot be detected by gamma spectroscopy. Because separations activities did not take place at the Chornobyl reactor site, those radionuclides not detectable by gamma spectroscopy are assumed to be always associated with other fission and activation products that are readily detectable.

3.11.2 System Description

The portable gamma spectroscopy system consists of an Ortec NOMAD Plus MCA, a notebook computer, germanium detectors, and a suite of software applications. The MCA is portable and is designed specifically for field measurements. The unit can be powered by a variety of external sources and is capable of eight hours continuous operation using internal batteries. The NOMAD's front-end electronics are composed of a spectroscopy amplifier, analog-to-digital convertor, digital spectrum stabilizer, and a detector bias supply. The amplifier can be configured for either high count rate or high-resolution applications. The analog-to-digital convertor is a successive approximation type with a fixed conversion time of 5 μ S and a resolution of 16,384 channels. The digital spectrum stabilizer circuit is used to correct zero and gain shifts during long counting intervals. The high-voltage power supply provides 0 to 5,000 volts DC for detector bias.

The notebook computer communicates with the NOMAD Plus system via a dual-port memory interface. The computer controls spectrum acquisition, determines amplifier, digital stabilizer, and high-voltage power supply settings, and provides a real-time display of spectral data. Gamma spectra obtained with the system can be analyzed immediately in the field or saved to a disk file for archival purposes or more in-depth analysis.

The detectors used with the NOMAD Plus system are high-purity germanium (HPGe) types that have been specially configured for field applications.

3.11.3 Calibrations

Prior to use in the field, the NOMAD system is operationally checked and calibrated. A gamma emitting radioactive source is used to determine the energy calibration coefficients, peak shape coefficients, and pole zero setting for the detector. A detector efficiency calibration is not performed because it is not required for gamma peak identification.

A separate energy/peak shape analysis is performed using the gamma data reduction (GDR) software. The detector efficiency calibration curves for the EML 1-m method are derived by the M-1™ software using calibration factors developed at the EML (Hefler and Miller 1988). The only information required are the detector's specifications (relative efficiency, germanium crystal dimensions, etc.) supplied by the detector's manufacturer.

3.11.4 Qualitative Analysis

Many radionuclides emit characteristic gamma rays as part of their radioactive decay schemes. These radionuclides can be identified by gamma spectroscopy provided that the gamma rays they emit are of sufficient energy and intensity to be detected.

Qualitative identification of the gamma emitting radionuclides present is accomplished with the EG&G Ortec GammaVision™ software package. This package provides an MCA emulation capability for hardware control, data acquisition, and spectrum display. The peak search and peak identification components of the package are used to locate and identify the gamma photopeaks in the spectrum. The calibration component of the package is used to create and maintain energy calibration parameter files for each of the detectors used with the NOMAD-2™ system. Gamma energy spectra recorded with the system can be analyzed in the field, but are generally saved in a disk file for later analysis.

3.11.5 EML Method (Quantitative Analysis)

The NOMAD Plus portable system has been equipped with the EG&G Ortec M-1 software package. The M-1 software is essentially a commercial implementation of the in situ quantitative analysis technique commonly referred to as the EML 1-m method. For these measurements, the germanium detector is mounted on a tripod with the face of the detector nominally 1 m above the ground and looking downward. At this height, the detector sees a circular area with a radius of approximately 10 m and a depth of 15 to 30 cm (depending on the source energy).

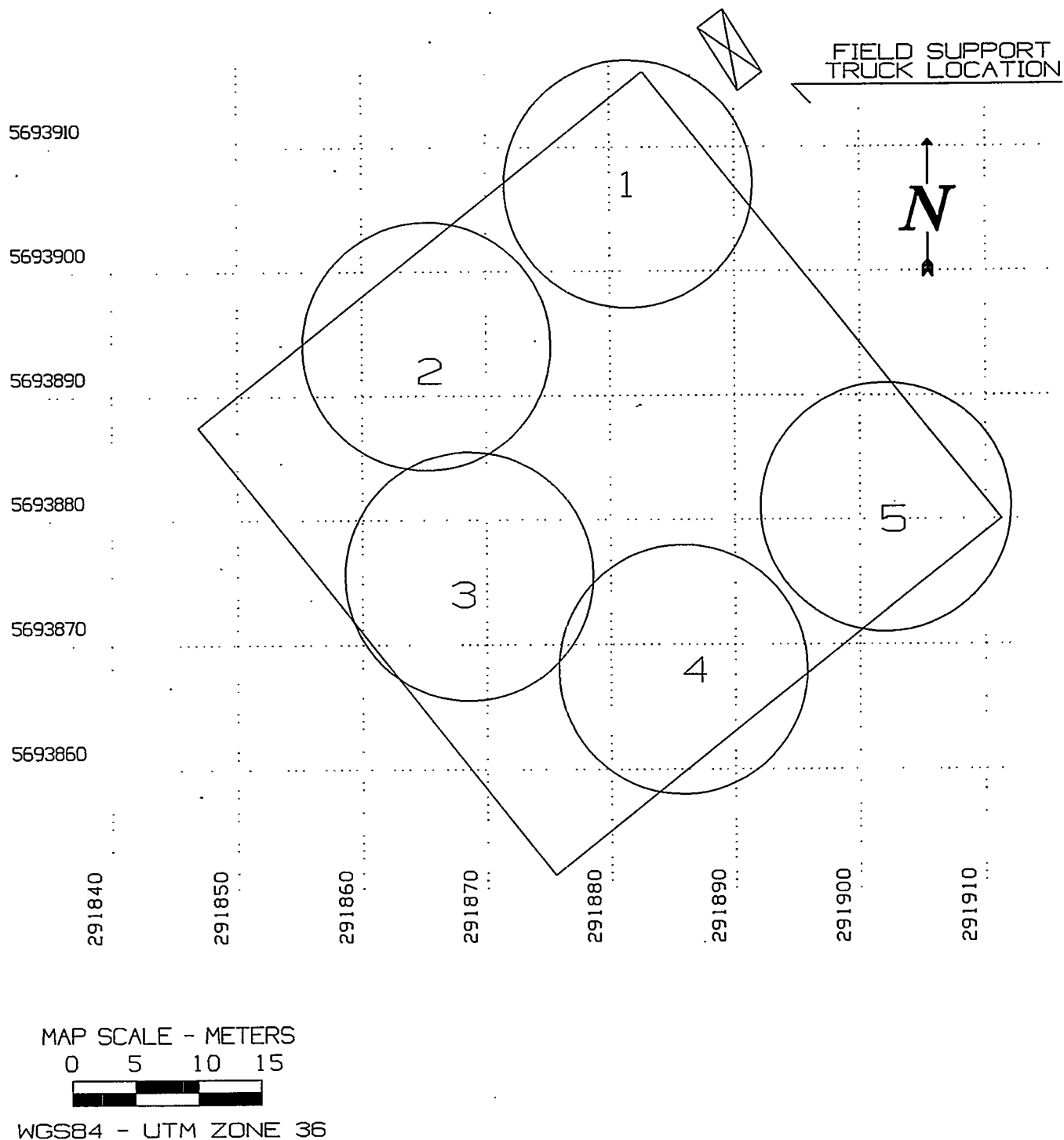
An important parameter affecting the accuracy of the in situ measurements using the EML method is determination of the alpha/rho factor for the site. The alpha/rho factor is a function of the density, moisture content, and distribution of radionuclides in the soil. Lacking this detailed knowledge, there are two general models for the distribution of radionuclides that can be applied in most situations: (1) uniform distribution and (2) negative exponential distribution for both aged and new fallout.

The uniform distribution model is applied to naturally occurring radionuclides and to manmade radionuclides where uniform distribution can be assumed. For the uniform distribution model, the M-1 software reports the radionuclides' concentrations in activity units per gram of soil. The exponential distribution model applies to radioactive fallout that may result from above-ground nuclear detonations, accidents, or routine releases from nuclear facilities. The aged-fallout case is used for radionuclides that were deposited on the surface at some point in the past, as from the Chornobyl accident, which have since migrated deeper into the soil matrix. The new-fallout case is only applicable to recent depositions in which the contamination is distributed on an undisturbed surface. This case assumes that 63 % of the activity is in the top 1 mm of soil. For either case of the exponential distribution model, the M-1 software reports the concentration in activity units per square meter.

3.11.6 NOMAD Location

The NOMAD was set up at 5 locations within Site 3. This covered most of the site (Figure 3-29).

Figure 3-29. Site 3 - NOMAD Field Gamma Spectrograph/Locations.



3.11.7 NOMAD Results

The NOMAD system collected data for ten minutes at each location. Longer count times would reveal results of other contamination nuclides that exist at much lower levels. Gamma spectrograph results are summarized in Table 3-7 and Figures 3-30 through 3-34. Complete results are included in Appendix D.

Table 3-7. NOMAD Field Gamma Spectrograph Results.

Location ID #	Isotopes	Micro curies/meter (10 m radius)
1	Cs ¹³⁷	15.7 ± 0.090
	Cs ¹³⁴	0.584 ± 0.017
2	Cs ¹³⁷	12.9 ± 0.082
	Cs ¹³⁴	0.475 ± 0.015
3	Cs ¹³⁷	21.5 ± 0.108
	Cs ¹³⁴	0.796 ± 0.020
4	Cs ¹³⁷	11 ± 0.0781
	Cs ¹³⁴	0.364 ± 0.016
5	Cs ¹³⁷	11 ± 0.080
	Cs ¹³⁴	0.385 ± 0.015
Average	Cs ¹³⁷	14.42 ± 0.088
	Cs ¹³⁴	0.5208 ± 0.017

3.11.8 NOMAD Applicability and Overall Effectiveness for Chernobyl Cleanup

Field gamma spectroscopy, particularly utilizing the 1-m method, was found to be extremely interesting and useful by the Ukrainian delegation. Most of their reporting of contamination levels is in curies per kilometer and is based on taking soil samples in a large grid. This technique introduces a wide extrapolation of analysis results. The NOMAD allowed a rapid, more accurate analysis of surface contamination gamma emitting isotopes within an area. It would be possible to integrate a GPS receiver with the NOMAD to provide an even more useful tool to assist in environmental radiological mapping efforts.

Figure 3-30. NOMAD Field Gamma Spec Demonstration Project Site 3 - Location 1.

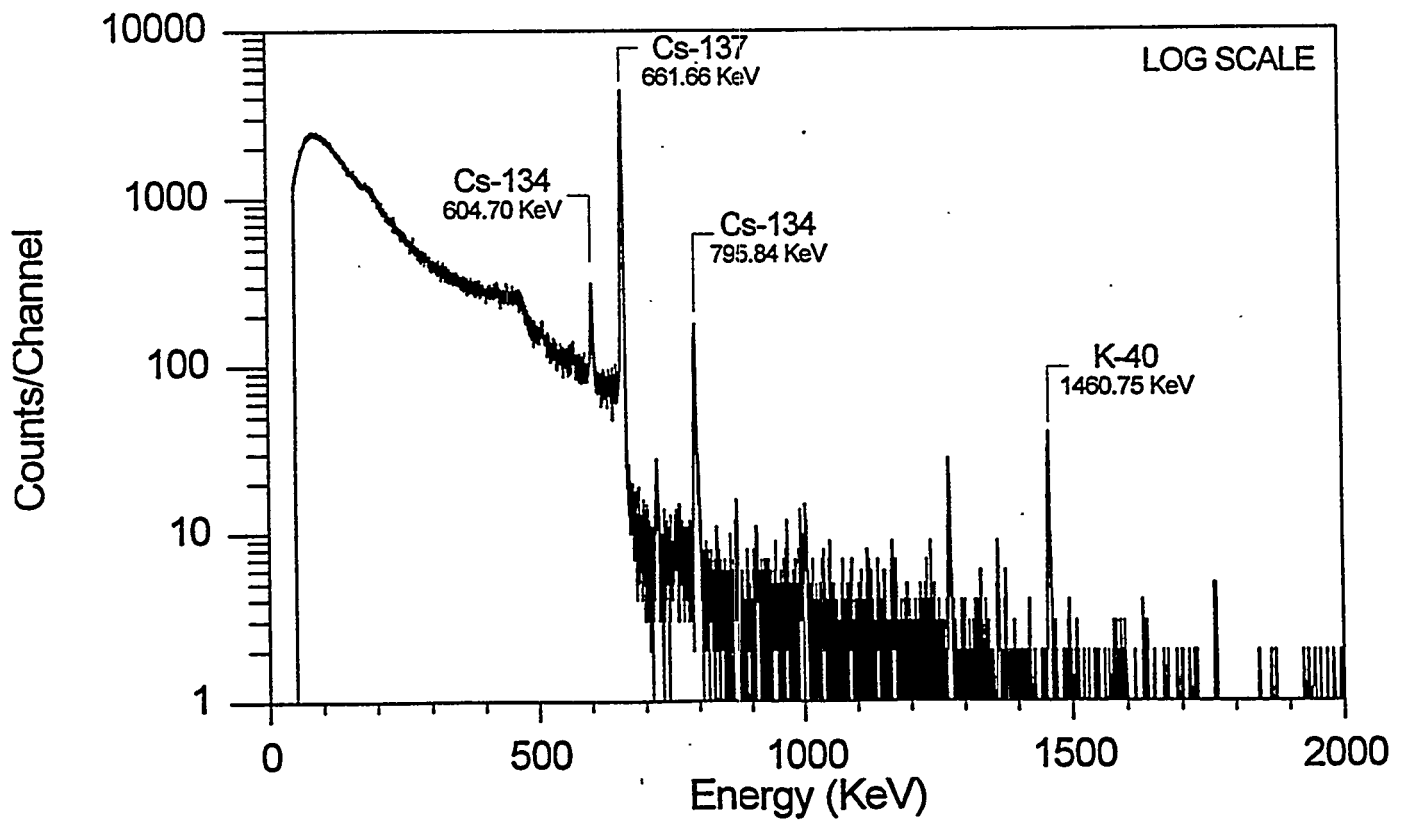
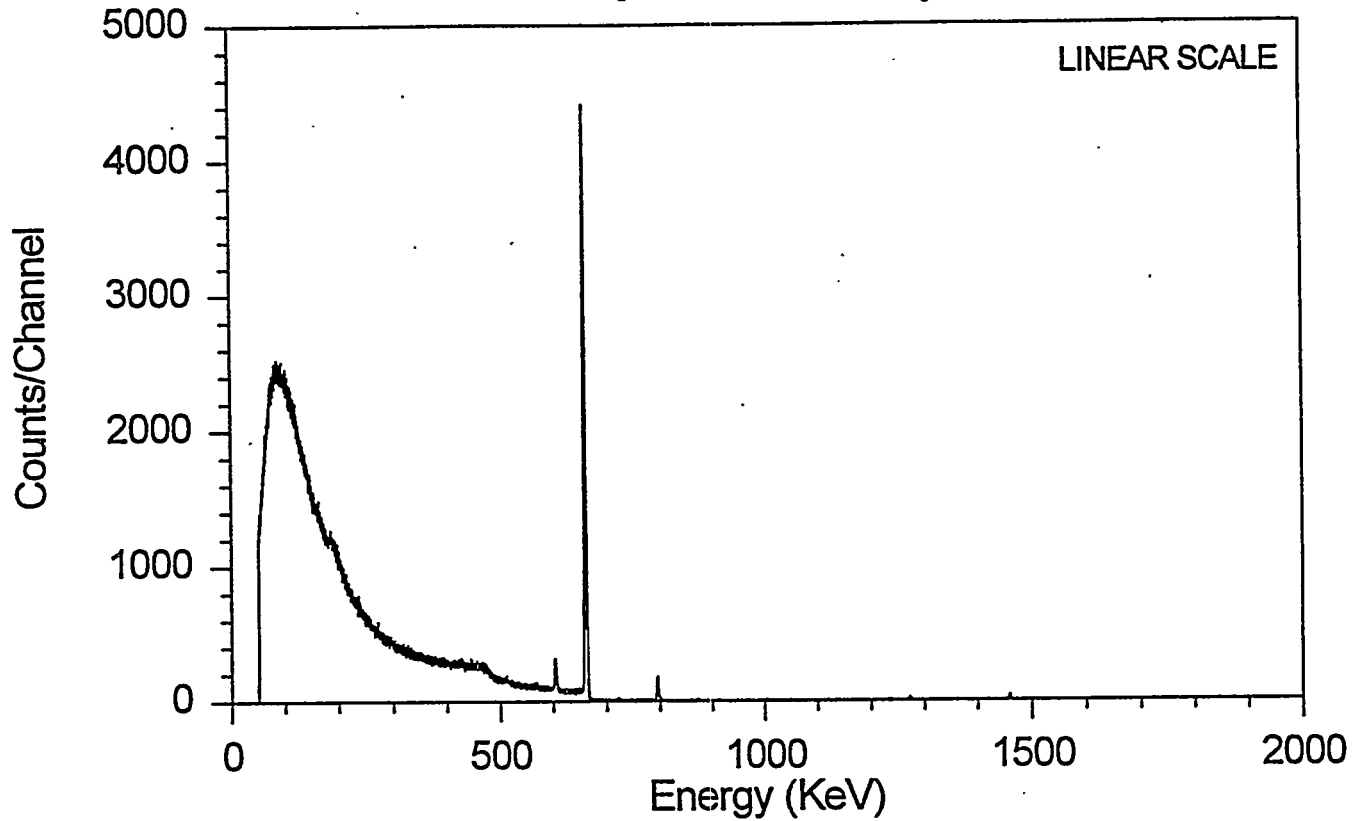


Figure 3-31. NOMAD Field Gamma Spec Demonstration Project Site 3 - Location 2.

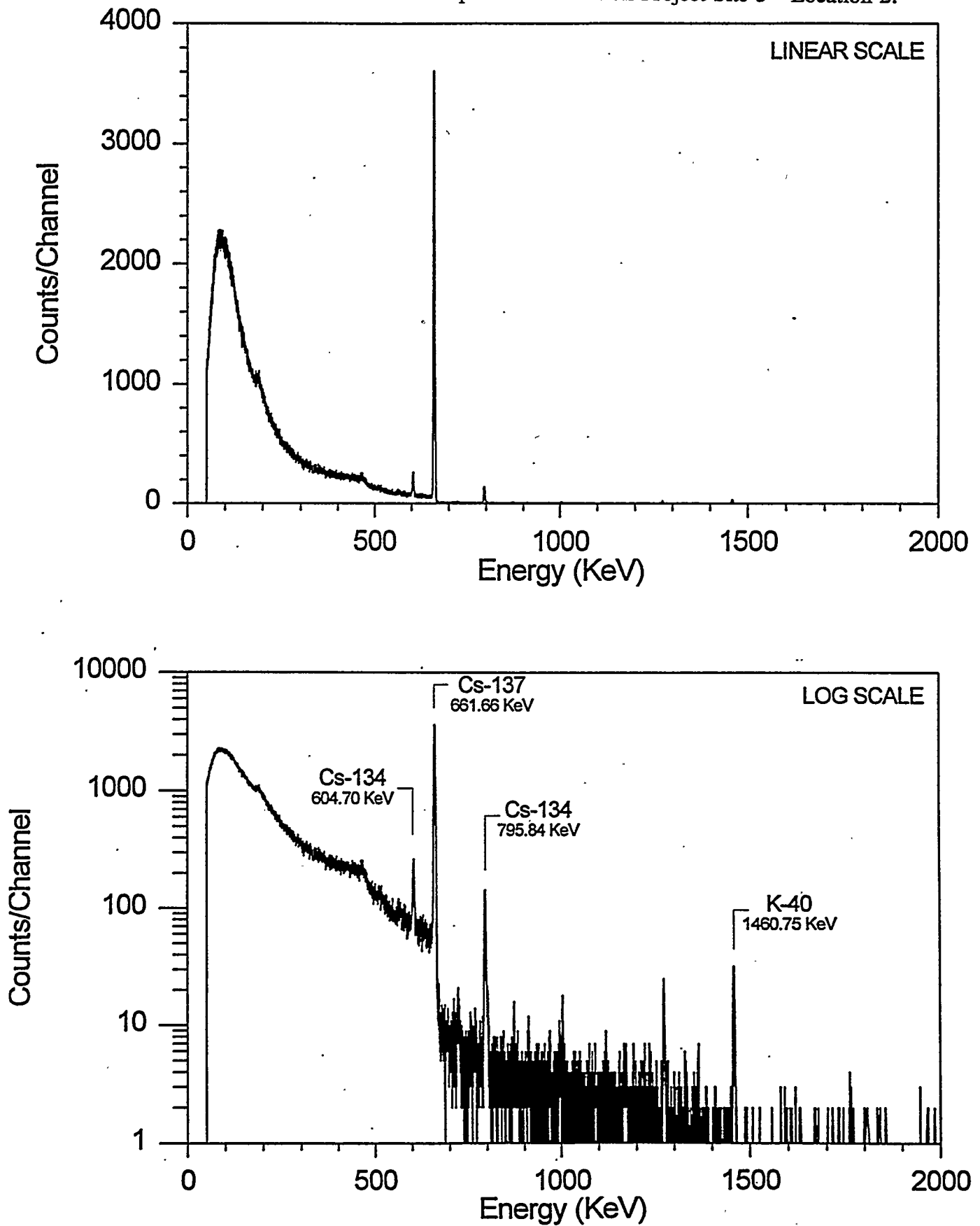


Figure 3-32. NOMAD Field Gamma Spec Demonstration Project Site 3 - Location 3.

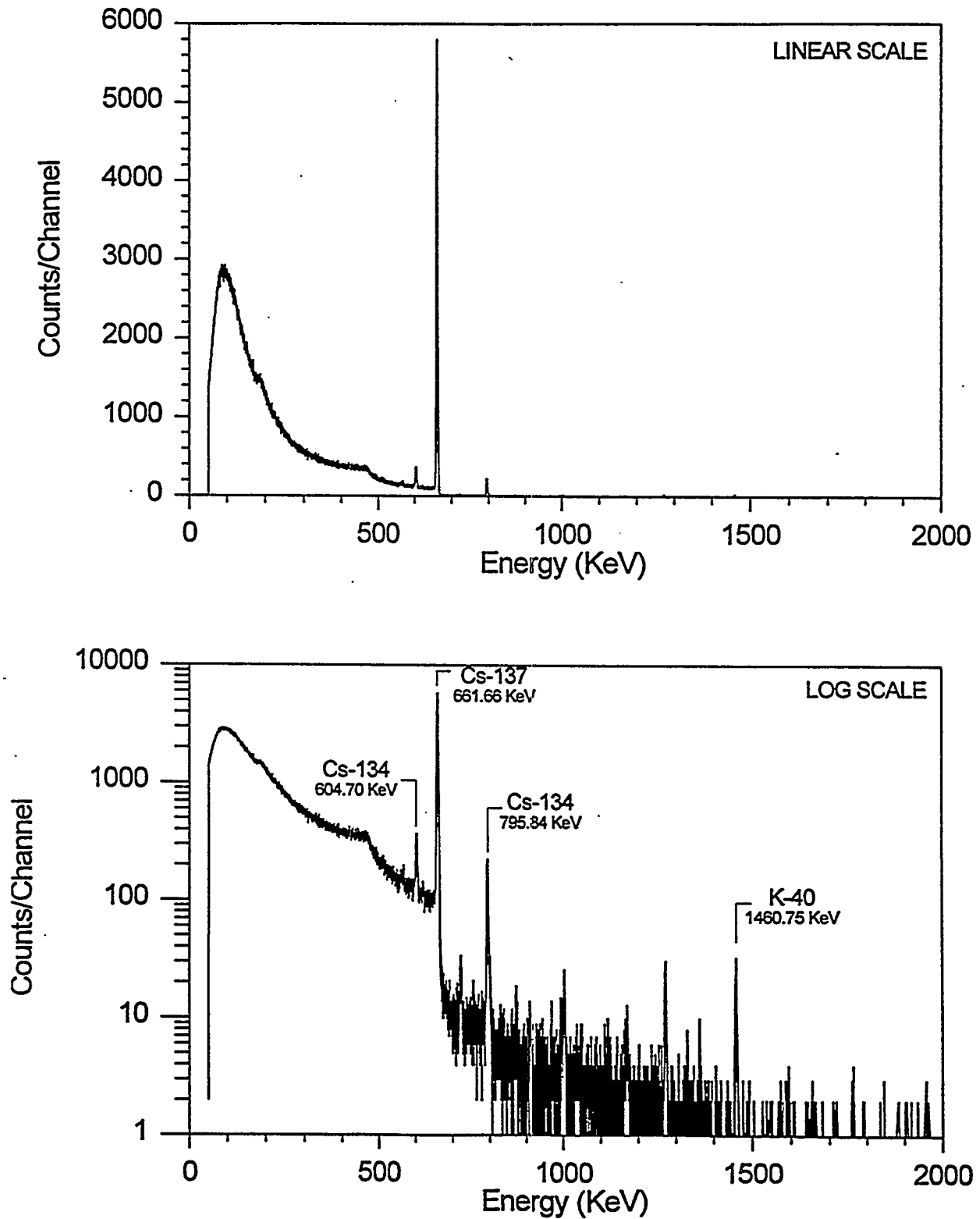


Figure 3-33. NOMAD Field Gamma Spec Demonstration Project Site 3 - Location 4.

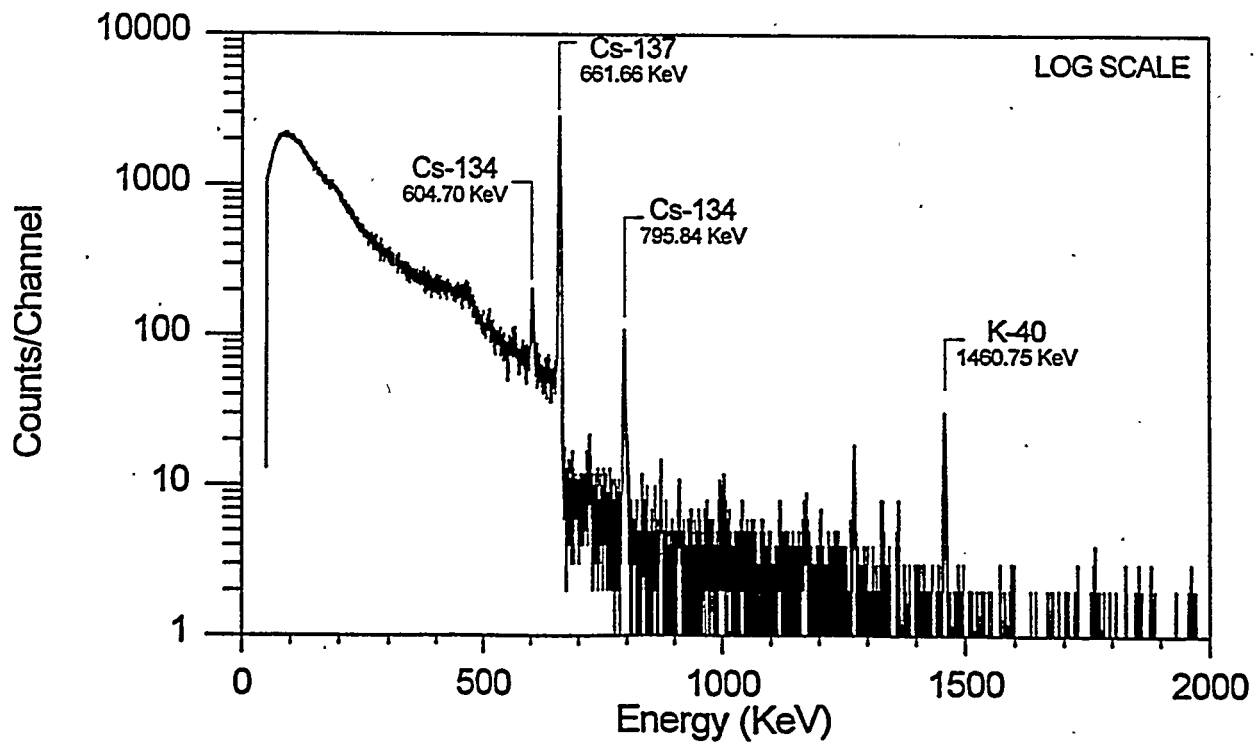
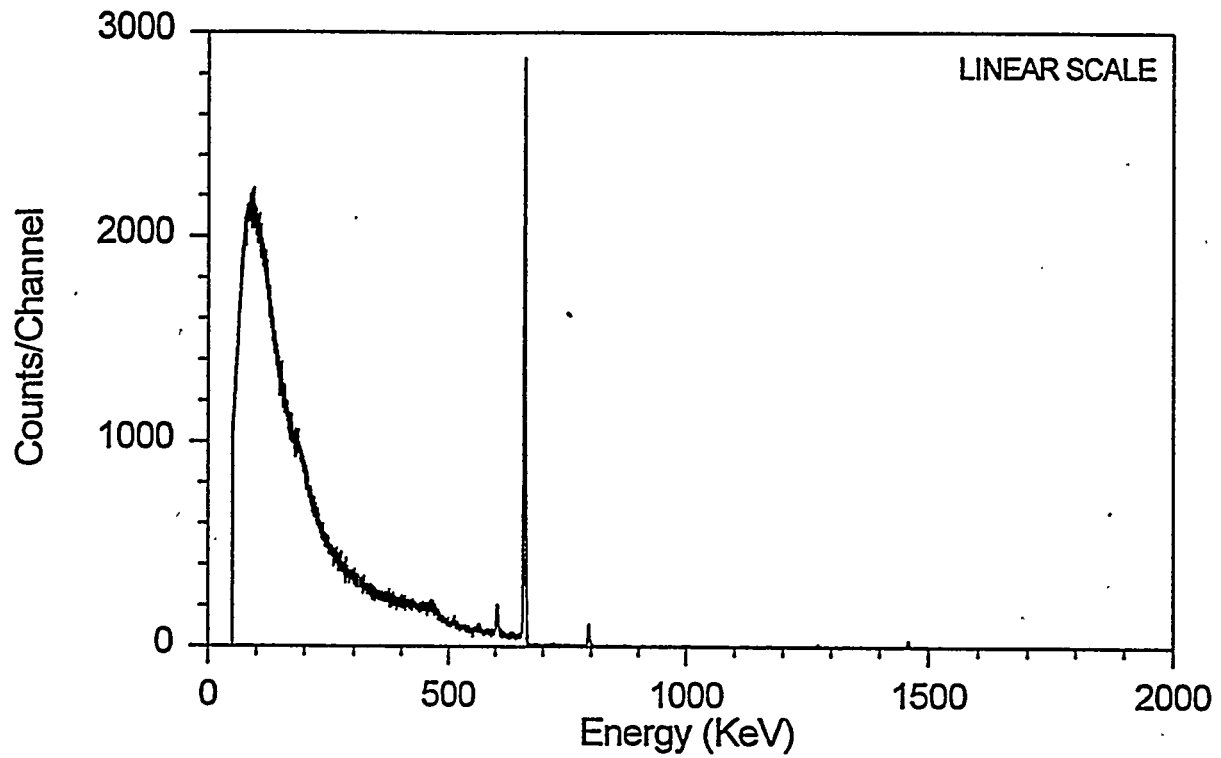
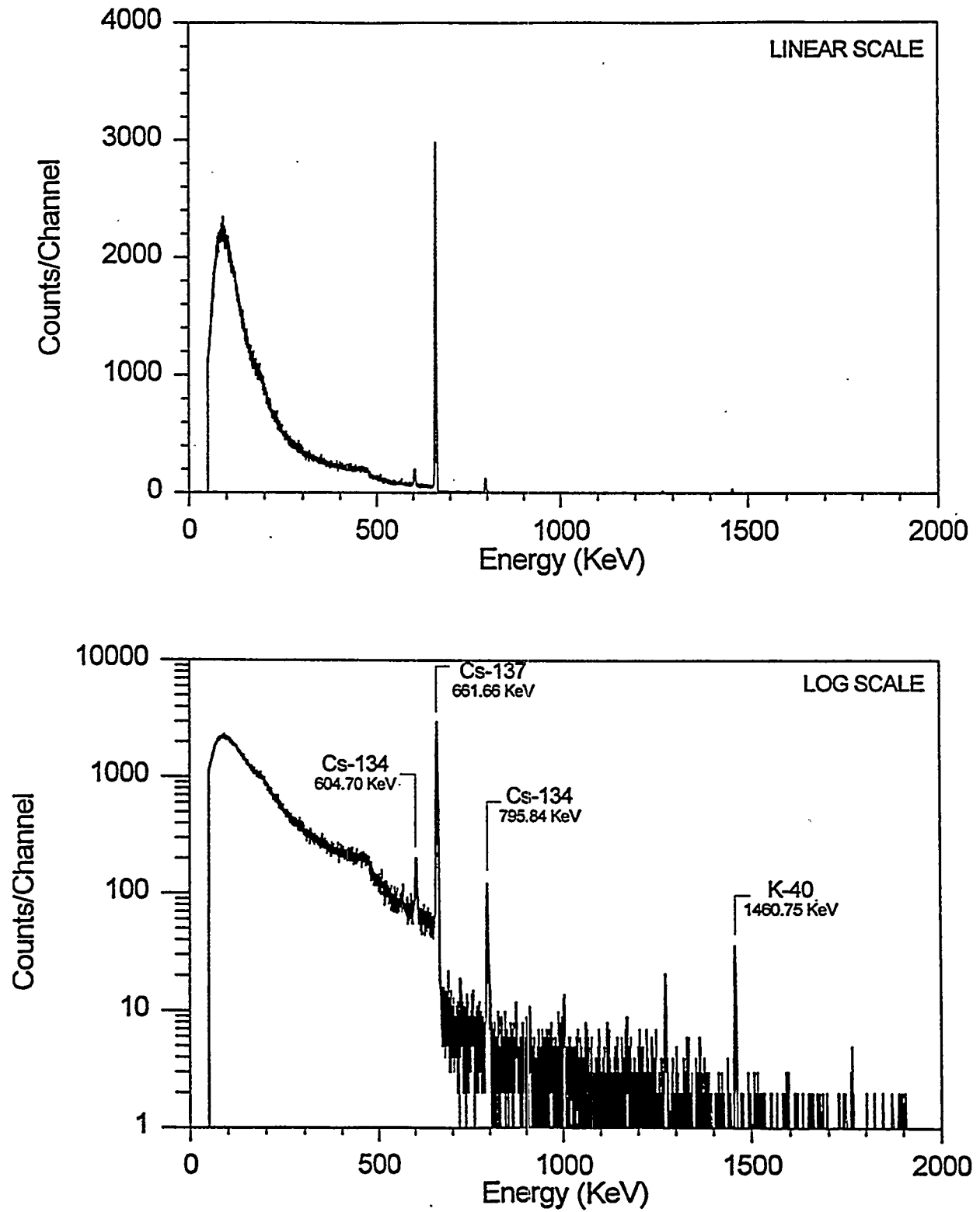


Figure 3-34. NOMAD Field Gamma Spec Demonstration Project Site 3 - Location 5.



4.0 POTENTIAL TECHNOLOGY TRANSFER AND WORK OPPORTUNITIES

4.1 TECHNOLOGIES AND EXPERTISE UKRAINE OFFERS TO THE DOE

The most valuable asset that Ukraine offers the DOE is a vast laboratory of information on the effects of radioactivity on plants, soil, groundwater, animals, and humans. The Ukrainians are maintaining records and closely monitoring health effects to scientists and victims who received high doses of radioactivity as a result of the accident. They have extensive scientific programs to assess the effects of radioactivity on plants and animals. Cooperative work in this area could be invaluable. Many papers are available that could be translated to English and distributed to a wide audience.

Scientists and engineers working near Chornobyl offer a wealth of experience and research regarding radioactivity and the effects of radioactivity. In particular, research regarding the low levels of plant and animal uptake in the zone, and methods to reduce radioactivity in wood shavings and animal tissue, indicate that radioactive lands could be safely used to produce consumable and non-consumable products. Further cooperative work and investigations in this regard are recommended.

Failures in removing Sr^{90} and Cs^{137} using an ion exchange (zeolite) treatment seem to have caused scientists, engineers, and administrative officials within Ukraine to dominate the possibility of treating cesium- and strontium-contaminated groundwater. They have investigated and are preparing to implement many groundwater control measures. The United States may be able to learn from the experiences of the Chornobyl scientists and save money in research and implementation of ineffective treatment methods. On the other hand, we may be able to offer them new technologies they are not aware of to treat contaminated groundwater.

The Ukrainian Academy of Sciences has developed software (APRIL) for GIS mapping that runs reasonably quickly on a personal computer (PC). This software may be useful to the DOE.

A potential joint venture between Ukraine and the DOE, or a private corporation, would be the sponsorship of an annual international environmental and economic reform conference on Chornobyl. Research and communication with the scientists at Chornobyl indicates that numerous papers have been published, and even some small, focused conferences have been held on Chornobyl. However, much of the research is difficult to access or is printed only in Russian or Ukrainian, which makes dissemination difficult. An annual conference would provide international focus to the continued legacy of Chornobyl, provide updates on the progress of the cleanup, provide appropriate recognition and peer review to the international scientific and research efforts, provide a platform for economic infusion into the region, and demonstrate a strong partnering effort toward resolution of the Chornobyl accident.

4.2 TECHNOLOGIES AND EXPERTISE THE UNITED STATES COULD PROVIDE TO UKRAINE

The United States could provide invaluable technical understanding and technical resources to enable Chornobyl officials to move forward on planned projects. In addition, the United States could help develop systematic approaches to cleanup and ensure quality control of projects performed.

Ukraine scientists and management were interested in the following types of technologies that the United States could demonstrate and/or provide:

- Surface mapping. Faster technologies, such as a landrover, using real-time detectors and positioning instrumentation, such as the GPS, for radioactivity surface mapping.
- Locating burial grounds. They are very interested in ground-penetrating radar (GPR), magnetometer, gradiometer, and other geophysical techniques to locate underground burial grounds more quickly than the methods currently employed (e.g., driving probes and manually reading detectors placed in each probe).
 - GPR. A company in Ukraine manufactures GPR equipment. This is scheduled for demonstration in the fall of 1994. However, personnel are not currently available at Chornobyl with expertise in GPR. Without highly skilled operators, the effectiveness of GPR can be very limited. The United States has personnel with exceptional skill at performing and interpreting GPR.
 - Cone Penetrometer/Geoprobe. A hydraulic penetration unit would be useful in performing both intrusive evaluation of burial trenches and sampling and monitoring groundwater. These activities are currently performed using hand labor and "homemade" equipment. A rough estimate is that a geoprobe unit would speed operations by a factor of 10X. Additionally, the quality of groundwater data would be greatly improved due to advanced equipment.

Speeding data collection would be a great asset for two reasons: (1) the data are vitally important in mitigating contamination to the Pripyat river; data are a limiting factor in containment of the burial trenches that are leaching through groundwater to the river and (2) personnel exposure is often significant during data collection, and speeding data collection would reduce personnel exposure.

 - Other technologies. Other technologies that should be evaluated for use at Chornobyl to assist in the primary task of locating burial trenches include infrared imagery and magnetic survey techniques.

- Removing a thin uniform layer of soil. Many areas may require removal of a 10-cm uniform layer of soil for disposal to low-level burial grounds. The current technologies utilized remove 30 cm to 50 cm. U.S.-mechanized equipment can remove thin layers of soil rather uniformly.

This technology should also remove the contaminated tree litter quickly with minimal potential for exposure in a very dense forested area.

- Stabilize low-level burial grounds and minimize subsidence. The main priority of the exclusion zone is to prevent transport of radioactive contaminants from the zone. As disposal trenches are located, they must be moved or stabilized. The method of stabilization has not been selected at this time. Stabilization technology has been extensively studied at the Hanford Site and implemented at DOE sites. Our process of technology selection may provide valuable assistance, as would our experience in implementation.
- Containment for burial grounds. Chornobyl staff are interested in subsurface containment of burial grounds to prevent leaching to the groundwater. This would be especially useful for the emergency trenches where trees and other debris are buried near the water table. Such a technology could reduce the need to relocate materials placed in the trenches. For example, interest was shown in the possibility of combining horizontal drilling and grout injection to construct watertight underground containment in the use of ISV and jet-grouting.
- Soil and groundwater treatment methods. No treatment of soils or groundwater are currently being practiced near Chornobyl because previous attempts have been ineffective. Treatment would help reduce cesium and strontium contaminant levels flowing to the river. Feasibility tests could be conducted to demonstrate the effectiveness of the treatment methods and methods of dealing with any secondary waste that is generated.
- Computer systems. Most of the Ukraine computer systems capabilities could be greatly enhanced with faster computers with more memory and improved software.
- Converting biomass to fuel. Fuel shortage is a problem in the Ukraine. Lands that cannot be used to produce food could be utilized to produce biomass crops for methane fuel. Farm equipment could be modified to utilize methane. The fuel could then be used to improve agricultural production capability or to power other types of equipment.
- Paper production. There are currently no paper mills in the Ukraine, and there is a shortage of paper. Trees inside the zone could be harvested for paper if a small mill was built.

- Macro engineering. The Chornobyl area appears to be a nearly ideal site for application of macro engineering such as proposed for implementation at the Hanford Site. Some of the characteristics of Chornobyl that make the concept viable include:
 - Widespread contamination
 - Shallow location of contamination
 - Easily excavated soil
 - Coarse soil texture, minimizing dust
 - Abundant natural precipitation for revegetation.

Factors that need resolution to make macro engineering viable include sandy, infertile soil that is a challenge for revegetation and future beneficial use.

Ecologists at Chornobyl are concerned that large-scale removal of soil, as in macro engineering, would result in decertification of the zone. The subsoil is sand, with little residual fertility. This is evidenced in the "emergency burial grounds." At the emergency burial grounds, the surface was scraped away, trenches dug, contaminated surface soil placed in trenches, and covered with soil from the excavation. Trenches can often be identified by grass growing densely, 1 m high. Between trenches, sparse grass grows 10 to 20 cm high.

This illustrates the lack of fertility of the subsoil. However, inter-trench areas are vegetated, albeit sparsely. This has been accomplished without addition of artificial fertilizer. Planned revegetation with soil-building plants, together with application of minimum artificial fertilizer, should be investigated as a means of stabilization.

In summary, the United States can offer a number of technologies and management practices that could provide valuable support in resolution of the Chornobyl problem. The U.S. team identified a number of opportunities and established a relationship that could lead to effective teaming with Ukraines.

5.0 CONSIDERATIONS FOR PLANNING FUTURE WORK

5.1 CONTAMINATION LEVELS AND "AS LOW AS REASONABLY ACHIEVABLE" (ALARA) PRINCIPLES

Radioactive contamination within the Chernobyl 30-km exclusion zone is extremely widespread. With a few exceptions, such as decontaminated offices and dining areas, everything has either some fixed or smearable contamination. Pancake GM tube readings range from just slightly above detectable to off scale. Contaminants are etched into the concrete and paved surfaces, making for an enormous decontamination task.

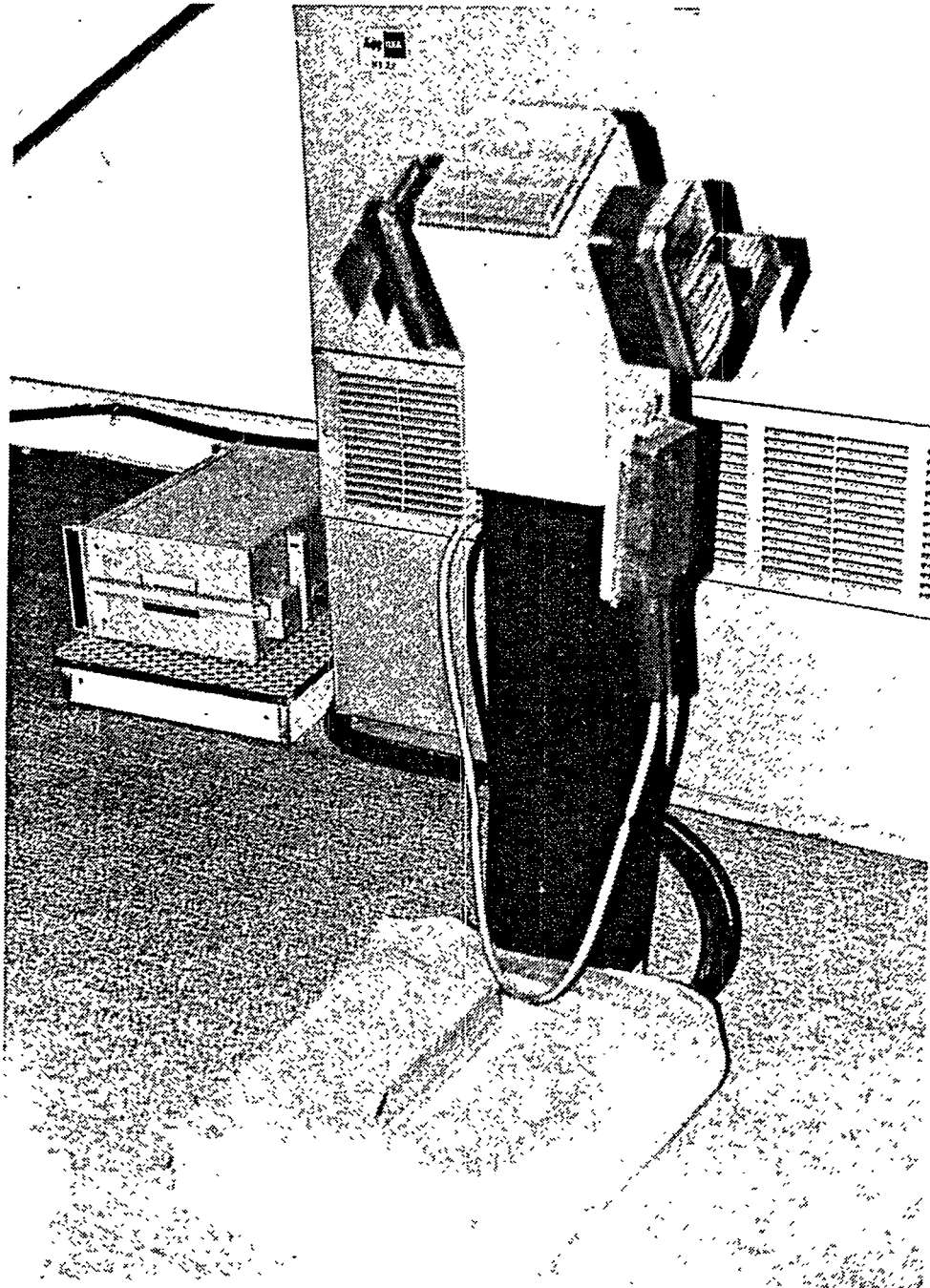
The U.S. team's field activities were conducted under the supervision of a health physics engineer. Daily prejob safety meetings were held to discuss planned events for the day and proper safety precautions. Radiological work permits and an ALARA management plan were prepared before the trip. Personnel wore personal protective equipment during the field demonstrations and as appropriate during field trips. Hand-carried radiological detection equipment and dose rate meters were used by the U.S. team. Employees wore pencil dosimeters and thermoluminescent dosimeter badges during the conference. Employees were given whole body counts at the conclusion of the trip, and no internal radioactivity was detected.

Control of skin contamination for Ukraine workers is an area of concern. Several areas were noted that had Personnel Survey Devices (PSDs) (Figure 5-1). These PSDs were sometimes ignored and bypassed by the workers. Even when used, it appeared that the PSD technology should be improved. The whole body portal types seen were of a hard-wall GM tube design, making them virtually ineffective for beta detection. The half body counters and hand and foot counters were thin window GM tubes. These detectors failed to locate and alarm on a 20,000 d/m speck that was fixed into the insole seam of one issued work shoe.

Workplace air monitoring appeared to be nonexistent. The Ukrainians do have an environmental air sampling program with 21 fixed sampling stations near the reactor site; however, this is on a regional scale and is used primarily to detect reactor emissions or problems.

Electronic reader boards are located in several locations within Pripyat, Ukraine. These boards show the current dose rate in microrems per hour. These readings would change during the day by as much as 10 μ R/hr. There may be many reasons for this varying dose rate. One reason of note may be the redistribution of contaminants by the wind. The reader boards are the only radiological posting. Once inside the exclusion zone no postings were noted except at the high-level (<50R) waste storage facility. The dosimetric technicians, when used at a job-site, are to warn people of high dose rates.

Figure 5-1. A Personnel Survey Device at Chornobyl.



This is not to say that ALARA principles are unknown to the Ukrainians. However, "reasonable" is directly related to cost, and the Ukrainians have few resources to draw upon. For the most part, what is acceptable work and contamination control practices at Chornobyl would be unacceptable by today's standards within the DOE complex.

Two different observations occurred to contrast this. While conducting setup for the field demonstrations at Site 2, the Ukrainian team was very concerned with the placement of a portable generator in a location with twice the dose rate as the surrounding area. It took much discussion to convince them that this area was not going to be occupied by personnel and therefore was not an exposure concern. Another contrasting observation was the release survey of the DOE equipment that had been used during the field demonstration. The Ukrainian equivalent of a Radiological Control Technician did an outstanding job, taking the time to check all accessible surfaces of everything used within the exclusion zone area. This survey was conducted in an area of low background radiation and was the only thorough search of vehicles or equipment noted during our 11-day stay.

In conclusion, for future work activities, it is recommended that disposable protective equipment, dosimetry, and instruments be supplied for field participants by the company performing the work. This, coupled with diligent radiological contamination control protocols, will mitigate the potential for radiological contamination. Staff members must know the radiological conditions and practice ALARA concepts as appropriate. Continued use of western ALARA practices will begin to heighten the awareness of the need and methodologies to minimize contaminant spread to the Chornobyl work force. Personnel should understand that practices at Chornobyl are unlike those used at DOE facilities.

5.2 LOGISTICS

The U.S. team had considerable logistical problems, not the least of which was the Ukraine Customs system. As much equipment as possible should be purchased in Ukraine both to support the local economy and to minimize problems with Customs.

Another step in minimizing customs problems would be to negotiate with Customs, in advance, a simple approach for handling the shipments. A very big part of the problem is that different types of equipment and material are normally taxed at different rates. A flat declaration/customs fee in and out of the country can be legally negotiated. A flat rate fee would cut 50% of the declaration paperwork alone.

Also, not everything that comes into the country leaves the country. Negotiations should allow a company to sell or trade equipment and not have to ship everything back. Without negotiated options, a company could be charged customs and shipping fees that could total more than the item is worth. Advanced understanding of Ukraine Customs, and knowing how to properly complete the declaration forms, can save days of expensive time.

All equipment and support material was packaged in 28 footlocker-size boxes weighing less than 80 lb each. Three companies were identified that ship the size and volume of material required for our trip into Ukraine. For future work, it would be beneficial to test all three companies with small shipments before choosing one for a larger scale effort.

Establishment of a local bank account would also ease customs problems. All customs fees are paid by a bank transfer form or similar mechanism. For example, when we paid the exit declaration, it was not considered paid until someone from Ufit Transport Company, Ltd. had deposited money and made a transfer to declaration programs. One phone call to the bank would have done the same thing. Use of a local bank account would also establish a long-term business commitment.

5.3 COMMUNICATIONS

Personal communication with AT&T™ staff in Kiev indicated that Kiev has five major telephone switch centers. All were at, or exceeded, their capacity. The centers use 1950-60 technology hard wire. The system is easily, and often, overloaded. Kiev has only a limited amount of long distance capacity, which is consistently overloaded at peak hours each day, generally from 9:00 to 11:00 a.m. and 2:00 to 5:30 p.m. Long distance is defined as any call outside of the area of the five switch centers in Kiev. One could easily spend 30 minutes just to get a local or long distance line.

There are some alternatives to normal communications.

1. Ufit Transport Company, Ltd. has a direct line to Helsinki, Finland. All calls on that line go through a Helsinki switch. Research should determine how Ufit obtained that line. They let another company use the phone several times a week to send status reports back to the main office. A company could make a similar agreement until a permanent solution is found.
2. Cellular phones should be used for communications within Kiev. Three operating companies provide total coverage of Kiev. Some research of the companies would have to be done, but coverage seems to be very efficient.

Two of the companies are striving to get communication links to Moscow and Odessa. The estimated time of completion is unknown.

3. AT&T is installing a satellite system with direct linkage to New York City, New York. The estimated completion is January 1995.

5.4 CULTURE

The success of doing business in foreign countries is often more dependent on understanding and overcoming cultural and social differences and less dependent on ability, experience, or cost effectiveness. Success requires understanding the culture, being aware of how individuals function in that culture, and being able to accept the culture.

Ukrainians have had little exposure to the West and Western business practices. Consequently, to be successful in Ukraine, it is important to understand that there is a learning process that must take place on both sides before progress can be made. A team approach of working together serves to educate, motivate, and build cohesiveness. For our mission, bringing the Ukrainians to the United States for the first technical exchange gave them a perspective on how we do things and served as a model for them to set up the second technical exchange. This approach was very successful and served to create a bond and a common goal that now can be expanded on in the future.

Our team found that standard American business practices (e.g., networking, information gathering from multiple sources, and obtaining references) are new to the Ukrainians and must be approached cautiously. We found that building a long-term and solid relationship with a key individual(s) was critical to the success of our project.

Our overall business manner, the projection of self-confidence, enthusiasm, a high degree of commitment to a project, and focused task orientation, was initially overwhelming to the Ukrainians and created some apprehension. The individual relationships we formed provided the opportunity to work through these problems and eventually develop a strong camaraderie with the Ukraine team.

In conclusion, we believe that we were very successful in overcoming the cultural barriers that we encountered during our mission. Our team invested time in learning as much about Ukraine as possible. We structured our program to create an integrated team with Ukrainians and Americans working together toward common goals. We attempted to be aware and sensitive about what they did not know, or understand, about our business practices and we asked questions, offered suggestions, and allowed them to draw conclusions as to how we could work together to accomplish the goals that we had jointly agreed upon as priorities. We are convinced that this approach can allow U.S. companies to build effective relationships that allow beneficial technical work to be accomplished.

5.5 POLITICAL AND ECONOMICAL CONSIDERATIONS

Ukraine is a country struggling to survive the transition from a former Soviet Republic to an independent nation. For Ukraine to flourish as a productive member of the world community, its administration must provide strong and effective leadership to devise and implement a program of comprehensive economic reforms and foreign investments. These changes are in progress and the results will need to be monitored over the coming months.

Chornobyl continues to drain Ukraine's economic resources. Approximately 14% of the national budget is for expenditures directly related to Chornobyl. These expenses include monitoring and containment of the exclusion zone and costs related to continued resettlement and compensation. Additionally, subsidies for the purchase of clean food products for those who live in the contaminated areas within the zone, pensions to Chornobyl invalids, and medical care and treatment for former cleanup workers, their families, and evacuees from the exclusion zone add to the costs. The direct costs are unknown but include medical costs for those effected by Chornobyl, sickpay, and the loss of production due to absenteeism, depression, etc.

Working in Chornobyl on joint projects and programs provides professionals in Ukraine the opportunity to become acquainted with Western business and management practices. This will improve their capability to effectively participate in the international environmental markets. This is important, in that nowhere besides Ukraine are there professionals who have a greater understanding or more hands-on experience with actively dealing with a major nuclear accident. Their experience, knowledge, and expertise can be an invaluable resource to the United States and to the international nuclear community in the planning and design of prevention, risk management, occupational safety, and training.

Chornobyl may be the site of the world's worst nuclear accident, but it can also be considered a living laboratory for nuclear research. The environment provides unique conditions for conducting studies and experimentation. There is an invaluable wealth of basic scientific knowledge to be assimilated into the current body of knowledge of nuclear physics, nuclear medicine, risk management, and nuclear education.

Chornobyl is not only an economic factor in Ukraine but also a political and social one. The primary Ukrainian government offices associated with Chornobyl include the Ministry of Chornobyl, Ministry of Ecology, Ministry of Atomic Energy, Ministry of Health, and Ministry of Social Welfare. Politicians on all levels of government--the executive parliament as well as local and regional officials--are involved in the Chornobyl problem. The Chornobyl problem transcends party affiliations, unites political rivals, and is possibly the only issue that transcends all political differences.

For U.S. companies to work effectively in Ukraine and on the Chornobyl cleanup, companies must understand both the political status of Ukraine and the overall impact of Chornobyl. Funding for cleanup work will be tied to how individual tasks impact the overall solution to Chornobyl and the redevelopment of Ukrainian economy.

6.0 WORKING WITH UKRAINE INFRASTRUCTURE

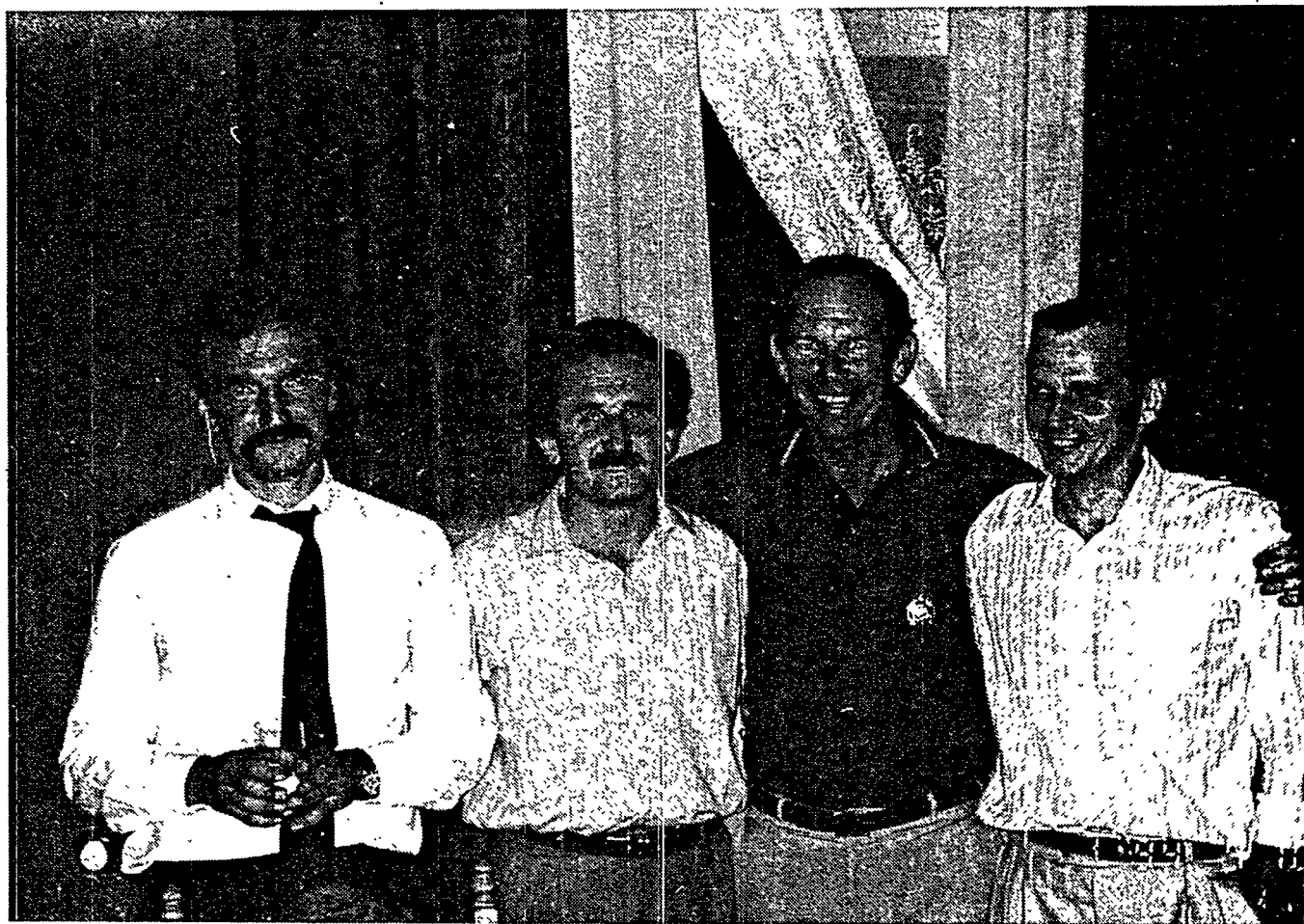
As noted in Chapter 5.0, Sections 5.4 and 5.5, working in Ukraine (and probably in other former Soviet Union countries) will require very different approaches to those normally practiced in the United States.

Development of trust relationships, while difficult, is critical to doing business in Ukraine. These relationships must be developed both at the government and scientific level. Ukrainian experience thus far has been for foreign companies to provide expensive studies, sell them expensive tools, and then leave counting their money without providing tangible benefit to Chornobyl cleanup or the Ukraine economy. The Ukrainians are very concerned that cleanup from Chornobyl be accompanied by actions or benefits that support economic recovery.

Our experience at Chornobyl indicates that U.S. capabilities and technologies can provide tremendous benefit to resolution of the Chornobyl problem. Our efforts also indicate that potential U.S. and international funding can be available to support appropriate cleanup proposals. The major caveat is that funding for Chornobyl cleanup must be coupled with support for Ukraine economic recovery.

For these supporting actions to occur, any company must develop the relationships that will cause the political, administrative, and scientific communities to accept Western technology and support. The U.S. team involved in this technology exchange mission devoted extensive time and effort to developing effective relationships with the Ukraine administration and scientific team. As a result, within a relatively short time, the relationship has matured to the point of eliminating cultural barriers and differences as an inhibitor to working relationships. The Ukraine and U.S. teams worked together effectively in the field and shared information in a manner that would have been impossible only a few weeks earlier. We believe that our efforts have demonstrated an approach that could allow the United States to play a significant role in solving one of the world's most significant environmental and political problems (Figure 6-1).

Figure 6-1. Sergey Saversky, Administrator of Technical Services for the 30-km Exclusion Zone; Volodymer Shovkoshytny, Chornobyl Union President; Jerry White, SAIC; and Volodymer Kholosha, Deputy Minister of Chornobyl.



7.0 REFERENCES

- Beck, H. L., J. De Campo, and C. V. Gogolak, 1972, *In Situ Ge(Li) and Na(Tl) Gamma-Ray Spectrometry*, HASL-258, U. S. Department of Energy, Environmental Measurements Laboratory, New York.
- Gollnick, D. A., 1988, *Basic Radiation Protection Technology*, 2nd Edition, Pacific Radiation Corporation, Altadena, California.
- Hefler, I. K. and K. M. Miller, 1988, "Calibration Factors for Ge Detectors used for Field Spectrometry," *Health Physics*, Vol. 55, No. 1, pp 15-29.

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APPENDIX A

AGENDA

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AGENDA

US/CHORNOBYL TECHNICAL EXCHANGE #2

Monday August 29, 1994

10:00 Meet with zone administration
10:30 Meet Ukrainian participants of USRADS
11:00 Visit work station/Pripiat/discuss logistics, etc.
2:00 Tour of Zone

Tuesday, August 30, 1994

10:00 Opening of Conference - Kholosha
Presentation of Project/Priorities in the Zone
Presentation from Problem to Solution/Hanford - Moak
USRAD Overview - Wendling
2:00 Excursion to Chornobyl Lab overview of research projects

Wednesday, August 31, 1994

8:00 Pripiat/SP Complex - USRADS

USRADS - All Day - Complete Team

Thursday, September 1, 1994

8:00 Pripiat/SP Complex - USRADS/Field work USRADS

USRADS - Field Team - All Day

Non-Field Team - Excursion
Low/mid level waste sites
Radiological and biological research

Note: This agenda was not followed verbatim but changed as conditions warranted

Friday, September 2, 1994

8:00 Pripyat/SP Complex - USRADS

Excursions for Non-Field Team
CP Complex - Decontamination Facility
Ecology Tour

Saturday, September 3, 1994

8:00 USRADS Field Work

Field Team - Site 2

Excursions for Non-Field Team
Contaminated Laundry
Jupiter Facility
Burial Ground

Sunday, September 4, 1994

Office Work
Pripyat River Excursion

Monday, September 5, 1994

USRADS Field Work

Field Team - Site 3

Technical Discussions - Non-Field Team

- Handling of Radioactive Waste in the Zone
 - . Cleanup of Ecological Hazards of Waste in Temporary Burial Sites
 - . Technology and Technical Equipment to Prevent Migration of Radionuclides in Areas of Temporary Storage
 - . Technologies for the Decontamination of Natural and Man Made Objects
 - . Handling of Radioactive Waste in the Zone

Note: This agenda was not followed verbatim but changed as conditions warranted

Tuesday, September 6, 1994

Partial Team - Packed and Prepared Equipment to leave zone for Kiev

Partial Team - Technical Discussions

- . The Question of Monitoring Radioactivity, Safety and Cleanup of the Zone

- . Water Monitoring

Partial Team - Baseline Survey Completed at Zeleny Mys

Wednesday, September 7, 1994

Partial Team - Technical Discussions

- . The Question of Radioecology of Forests and Agricultural Areas and the Development of Clean production Capabilities in the Zone

Partial Team - Pack

Partial Team - Prepare Data for Closeout

Thursday, September 8, 1994

Closing Sessions - Zeleny Mys

Note: This agenda was not followed verbatim but changed as conditions warranted

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APPENDIX B

LIST OF PARTICIPANTS

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APPENDIX B
LIST OF PARTICIPANTS

Sergey Saversky	Administrator of Technical Services for 30-km zone
Volodymer Shovkoshytny	Chornobyl Union President
Volodymer Kholosha	Deputy Minister of Chornobyl

Experts that participated in Field Survey or technical sessions:

V. F. Zub	KORO
L. V. Yerdokimar	KORO
Dr. Nikolay Kuchma	R.I.A. Pripyat "Forest Department"
Dr. Lydia Loginova	R.I.A. Pripyat "Scientific Center Department of Radiology and Land Recovery"
Dr. Andre Arkhipov	Scientific and Technical Center
Olga Chvesik	HTU KORO
Pavet Ovchazov	HTU KORO
Alexandr Ledenjov	HTU KORO
Vladimir Udod	WTZ KORO
Oleg Awdejew	WTZ KORO
Sergey Maruchnerko	WTZ KORO
Leonid Erdonximov	WTZ KORO

R.I.A Pripyat - Ukraine's Ministry For Chornobyl

Gennadiy N. Krasnozhon	Deputy Head Engineer
Dr. Anderj K. Sukhoruchkin	Deputy Chief Engineer, Dosimetric Control Board
Vladimir G. Siroshstan	Chief of International Ties and Information Department
Vladmimir N. Fedunov	Deputy Chief of International Ties and Information Department
Dr. Sergei P. Dgepo	Chief of the Laboratory of Groundwater Monitoring Institute of Geological Sciences, Ukrainian National Academy of Sciences
Dr. Alexander Skalsky	Senior Researcher, Institute of Geological Sciences, Ukrainian National Academy of Sciences
Dr. Dmitri Bugai	Senior Scientist, Institute of Geological Sciences, Ukrainian National Academy of Sciences
Dr. Vadim Gouezenko	Senior Research Worker, Institute of Geological Sciences, Ukrainian National Academy of Sciences
Oleg K. Avdeev	Deputy
Mykola Ivanovitch Proskura	Head of the Department of Coordination of the scientific, researching-experimental and constructional works
Dr. Nikolay P. Arkipov	Scientific and Technical Centre, Director of Center

U.S. Participants

Robert L. Ferguson	Corporate Vice President, SAIC
Jerry D. White	Vice President, SAIC
K. Ulana Kushner	Interpreter
Kim M. Berg	SAIC; Technical Staff
Donald J. Moak	Manager, WHC; Technical Staff Leader
Marc A. Wendling	WHC; Technical Staff
Richard C. Roos	WHC; Technical Staff
Dr. James G. Field	WHC; Technical Staff
E. W. (Pappy) Papin	WHC; Technical Staff

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APPENDIX C

DEMONSTRATION PROJECT PLAN

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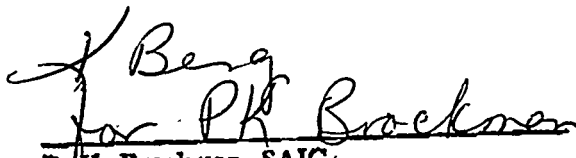
**PROJECT PLAN
CHORNOBYL SITE DEMONSTRATION
OF RADIOLOGICAL SURVEY
INSTRUMENTATION**

August/September 1994

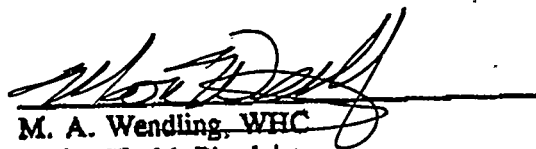
**PROJECT PLAN
CHORNOBYL SITE DEMONSTRATION
OF RADIOLOGICAL SURVEY
INSTRUMENTATION**

APPROVALS

Prepared By:


P. K. Brockman, SAIC

7/14/94
Date

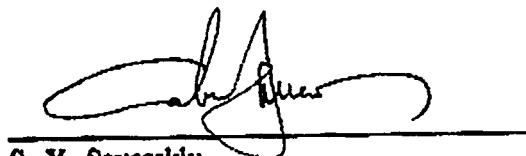

M. A. Wendling, WHC
Senior Health Physicist

7/14/94
Date

Approved By:


D. J. Moak, WHC
Geotechnology and Landfill Technology

7-14-94
Date


S. Y. Saverskiy
Ministry of Chernobyl
Chief of Department

7/16/94
Date

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- 2.0 BACKGROUND**
 - 2.1 PURPOSE AND SCOPE**
 - 2.2 SITE SELECTION**
 - 2.3 PROJECT DESCRIPTION**
- 3.0 PROJECT OBJECTIVES**
 - 3.1 DATA OBJECTIVES**
 - 3.2 DATA REQUIREMENTS**
 - 3.3 DATA ASSIMILATION**
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 - 4.2 PILOT PROJECT DESIGN**
- 5.0 ROLES AND RESPONSIBILITIES**
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- 8.0 PROJECT SCHEDULE**
- 9.0 RECORD KEEPING**
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- 8.1 Demonstration Project Schedule**

1.0 INTRODUCTION

This project plan describes the objectives, specifications, responsibilities and procedures to be followed in order to conduct radiological surveys at pre-determined pilot locations adjacent in the Chornobyl 30 KM exclusion zone. The pre-determined locations have been provided by the Ukrainian delegation and will serve as a cross section of effected surface areas within and adjacent to the Chornoybl exclusion zone. These sites will include a clear site relatively free of dense undergrowth and scrubs, a heavily vegetated site, a wetter area and a baseline control site. These differing sites were chosen to provide a cross section of the types of contaminated areas within and around the Chornobyl exclusion zone. This will demonstrate the Ultra Sonic Ranging and Data System (USRADS) and the Mobile Radiological Data System (MRDS) surface radiation detection survey equipment. A quantitative system, the EG&G NOMAD system will also be demonstrated at one of these sites.

The objective of these surveys is to evaluate and demonstrate the applicability of this technology for use in the Ukraine. If the technology is successful through the proposed demonstrations, application of these technology could potentially assist in returning significant portions of previously contaminated lands into reusable national assets. As envisioned, the survey technology will be used to screen selected areas which will then be field characterized for the identification of hot spot areas of concern which could then be remediated, thus allowing the return of the affected properties for other uses.

2.0 BACKGROUND

The use of radiation detection devices for the screening and identification of radioactive contaminates in the environment have been in place for several decades within government and commercial industries. These devices range from the standard hand held monitors used for the detection of beta/gamma emitting sources to the use of self reading integrated devices utilizing ion chambers and sodium iodine for the detection of alpha/beta/gamma sources. The specific field detection equipment which will be used during the demonstration project in the Ukraine includes the USRADS and MRDS systems which are currently being utilized at the DOE Hanford Site in Eastern Washington. These instruments are currently being used as screening devices for the determination of radioactive contamination prior to a more detailed characterization study for final remediation alternatives of the land .

The USRADS and MRDS survey systems were chosen as the instruments of choice for the demonstration project in the Ukraine. These systems were chosen for their ease of operation, data acquisition and mobile operation capabilities which will be required in the Ukraine. Both survey systems are computerized data collection systems which enable the user to correlate geographic location with data acquisition at that

location. Survey coverage can be verified in the field, data analyzed on-site and survey results graphically illustrated. The systems software allows this data to be exported into other software packages for graphical illustration. For field applications, the USRADS and MRDS are attached to a backpack along with site specific radiation detection instrumentation, however, any detection device that outputs digital, analog or pulse type signals may be interfaced with these systems. The system is capable of accepting information from several sensors at one time, allowing for simultaneous assimilation of information.

The USRADS employs three separate technologies to accomplish its tasks which include 1.) Ultrasonics 2.) Radio Frequency Transmission and 3.) microcomputers. Each second ultrasonic transmissions fix the location of the surveyor, radio frequency transmissions provide data-telemetry and system synchronization and microcomputers calculate the precise position of the surveyor and display the information on the computer screen along the reading(s) of the data collection instrument. This makes it possible for the USRADS to collect 3600 readings per hour of survey time. The USRADS system consists of stationary receivers, backpack mounted detection instrumentation and data acquisition/assimilation microcomputers as shown in schematic form in Figure 1-1.

The MRDS system is similar to the USRADS in that it also ties the radiological readings to their location every second and stores this data in electronic format. The MRDS uses a Global Positioning Receiver (GPS) receiving signals from the United States NAVSTAR satellite system. This method is more reliable than the USRADS methodology but does have some drawbacks, notably the positional accuracy is somewhat less than the USRADS. Due to the fact that the surveyor must have a relatively clear view of the sky for radio satellite reception, the MRDS may be less effective for use in forested areas. The MRDS consists of the GPS receiver, backpack mounted radiological detection equipment and data acquisition/assimilation microcomputers as shown in schematic form in Figure 1-2.

As part of the Ukraine demonstration, three sites have been identified for the demonstration of the USRADS and MRDS systems. The first site will consist of a relatively flat area, the second site will consist of a heavily vegetated area and the third site will consist of softer ground. These three sites represent the makeup of the Chernobyl affected areas and will provide the backdrop for the proof of principal demonstrations utilizing Hanford developed technology application.

2.1 PURPOSE AND SCOPE

Surface contamination surrounding the Chernobyl Site requires additional detailed characterization to determine the extent and levels of radioactive contamination. Existing surveys of the affected areas will be used to support remediation of contaminated areas and allow these areas to be returned to productive use (i.e.

inhabitation, agriculture, industry, etc.) The purpose of the project is to demonstrate existing radiation screening equipment currently being utilized at the Hanford on three pre-determined pilot locations which have been chosen by the Chernobyl staff.

The scope of the demonstrations will involve the radiological survey of three pre-determined locations on the perimeter of the Chernobyl exclusion zone. These sites are believed to be contaminated with both mixed fission and mixed activation products from the Chernobyl accident. The surveys will attempt to correlate the data with Ukrainian data and further identify the extent and qualitative levels. The objective of the demonstrations will be to provide to the Ukraine field proven site screening technologies which could be utilized in the future by the Ukraines as a support tool for the reclamation of contaminated lands.

2.2 SITE SELECTION

The site selection process is a requests of the requires of Ukraine people to reclaim contaminated lands as a result of the 1986 Chernobyl accident. The sites represent a cross section of the natural terrain in the Chernobyl affected area. Based on this natural terrain, the first site chosen will be in a relatively flat, sparsely vegetated portion, the exclusion, the second site will be in a wooded portion of the site and the third in a marshy bog area. These areas will allow for the evaluation and on-site testing of the survey technologies for potential future applications.

The three sites which will be used as part of the demonstration effort will be identified jointly by the WHC/Ukraine technical staff in the Ukraine. It is envisioned that each site will encompass approximately 2 acres (0.8 hectares) per site. It is anticipated that these sites have been contaminated with low levels of radioactive materials based on background information provided by the Ukrainian staff. Based on these background levels, it is anticipated that the levels of existing radioactive exposure is well within the permissible worker exposure range of 300 mR/wk. The level of contamination currently present at the demonstration sites is low enough to ensure worker safety from exposure, yet high enough for detection by the proposed survey equipment.

FIGURE 1.1

ULTRA SONIC RANGING AND DATA SYSTEM COMPONENTS

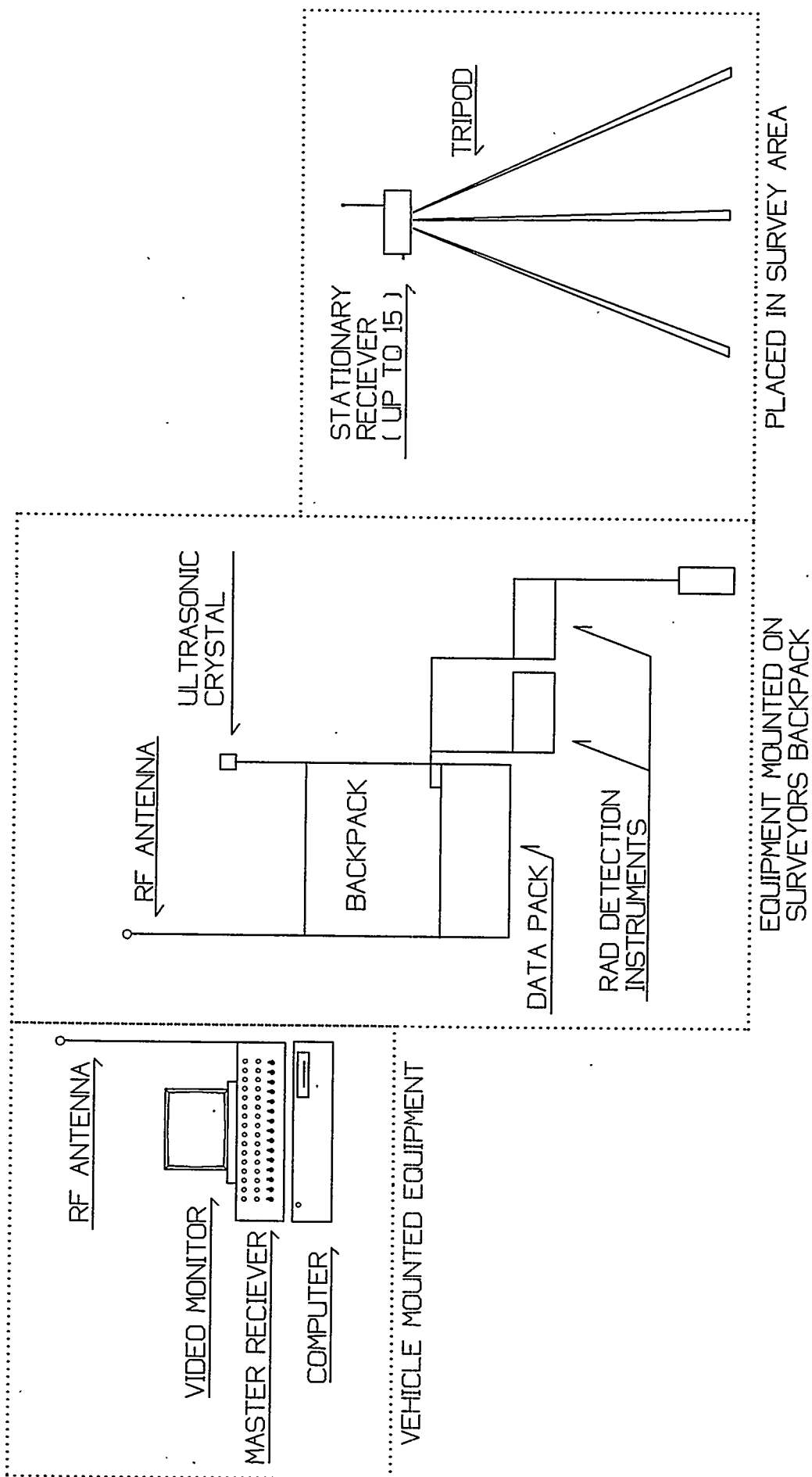
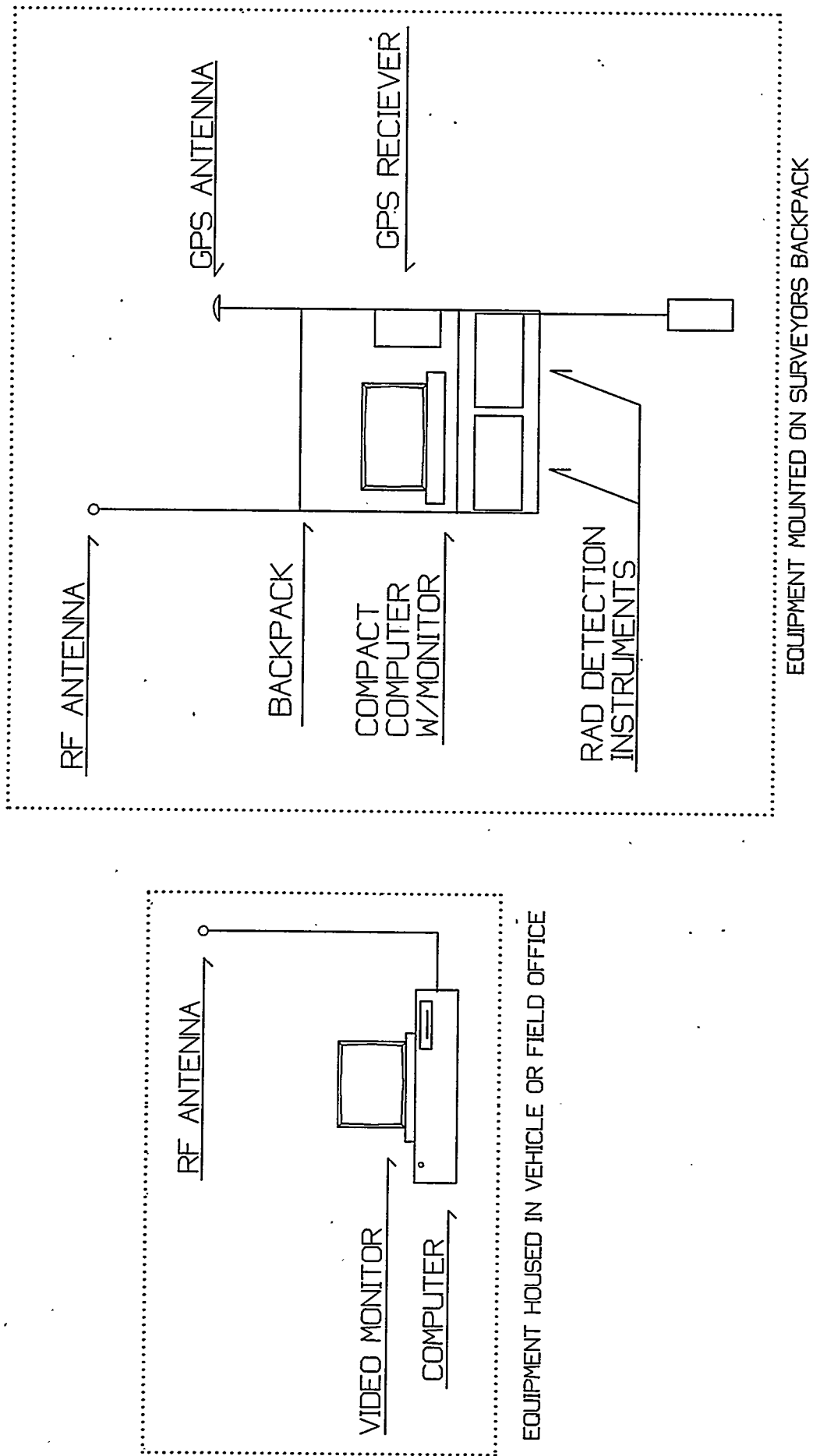


FIGURE 1-2

GLOBAL POSITIONING SYSTEM-RADIOLOGICAL MAPPING DEVICE COMPONENTS



Based on the previously provided background levels of existing radiation contamination at the proposed pilot sites, the initial site surveys will focus on the screening of proposed sites for the identification of high activity areas which would be documented in the final site survey report. Locally identified high activity areas may be further characterized utilizing field testing methods during a subsequent phase of the project should additional quantifiable site specific data be required.

2.3 PROJECT DESCRIPTION

Three site specific surveys (and one control site survey) will be performed as part of the demonstration. The demonstration project will involve the design and field implementation of an area screening survey for the qualitative detection of radioactive contaminants within the perimeter of the Chernobyl exclusion zone. The initial phase of the project will involve a joint survey (i.e. Ukraine technicians/observers and WHC technical staff) of the sites to provide a proof of concept for the proposed survey equipment and will also serve as a training exercise for the Ukraine technicians and observers. Subsequent phases of the project could involve field methods which would provide quantitative analytical results of localized areas of potential concern. The survey methodology is based on the utilization of the USRADS and the MRDS for automatic recording of the gross gamma radiation levels at or near 6 inches and at 3 feet from the surface soils.

Site surveys will be conducted utilizing the USRADS and MRDS systems in a consecutive manner to provide a demonstration of both potentially available technologies. In order to establish a baseline to work from, survey personnel will establish site specific background measurement which will be used to calibrate the field equipment. This background data will serve as the baseline for future site survey activities. As envisioned, the surveys will take place at three separate locations which have been pre-determined by the Ukrainian staff. These sites which measure approximately 2 acres (approximately 0.8 hectares) will be divided into section grids to support mapping of the survey.

Each survey will consist of three stages. The first stage will entail the establishment of the site specific low background levels which will set the baseline for the survey. The radiological data collected during this survey will be considered representative of the undisturbed soil surfaces at the pilot sites. The second stage will include the performance of the actual radiological survey at each location. The survey will be conducted within the previously established site grids. The field survey technician carries the backpack containing the calibrated instrument. After assisting the engineer in setting the grid, the surveyor walks the grid from side to side at transects approximately 9 feet (3 meters) apart. The surveyor's path is directed (left, right, slower, faster) via hand held radio directions from the engineer. The rate of each traverse is approximately 3 feet (1 meter) per second. The survey will provide a qualitative analysis of the existing site radiological levels and can be used as the basis for identification of high activity

areas for future characterization. The third stage will involve the assimilation of the site specific data which will be used to develop a statistical evaluation of the radiation/contamination readings which were observed during the survey(s).

For comparative purposes, the survey information provided from both the USRADS and MRDS systems respectively will be evaluated to determine the performance of each of these systems. Performance measurements will contain as a minimum; data accuracy, data assimilation, detector sensitivity, data reliability and equipment ease of operation and durability.

3.0 PROJECT OBJECTIVES

3.1 DATA OBJECTIVES

The primary objective of the surveys as stated by the Chernobyl delegation on May 18, 1994 will be to provide:

- 1) an opportunity to demonstrate the USRADS/MRDS equipment in the Chernobyl environment
- 2) the determination of specific requirements in their environment for future utilization
- 3) the ability to ascertain if the USRADS/MRDS systems can, or should be used as standard equipment in the exclusion zone

Survey information will be gathered to:

- assess existing radiological conditions at each site
- determine higher activity locations within the survey areas

Based on these demonstrations, the site specific survey information can be used to assess the existing levels of contamination located within the sites to support future restoration activities.

3.2 DATA REQUIREMENTS

Both the USRADS and MRDS will interface two types of radiological detectors. A counts per minute (CPM) reading will be obtained from a 2" by 2" Sodium Iodide (NaI) detector at ~ 15 cm. from the soil surface. Dose rate readings will be obtained at ~1 meter from the soil surface. Both systems will tie the radiological readings obtained to the specific coordinate of that location, display the surveyors location along with the

radiological reading in "real time on a video monitor, store this data in electronic format on the computers hard drive, and can output these files for post survey analysis. The two systems differ in the methodology used to obtain positional information.

The USRADS uses ultrasonic sound and radio to determine the surveyors location within a specific grid relative to the X,Y origin of the grid. This is a local coordinate system and two control points must be within the vicinity of the survey area in order to transform these local (USRADS) coordinates to any other coordinate system. The advantages of using the USRADS positional system is it's accuracy, $\sim \pm 15$ cm and its ability to function under a canopy such as in wooded areas.

The MRDS uses the Navstar Global Positioning System to determine it's location. This system is based upon real world coordinates and has the ability to use a number of specific datums and projections. The MRDS will include a differential correction global positioning receiver (DGPS) in addition to the GPS receiver contained within the surveyors backpack. This provides a higher degree of positional accuracy than with one GPS receiver in a stand alone operation, but even with the use of DGPS, the positional accuracy of the MRDS is $\sim \pm 2$ meters.

3.3 DATA ASSIMILATION

The survey file obtained from either system is analyzed to obtain the maximum, minimum, and standard deviation of both the CPM and dose rate readings. This data is loaded into a spreadsheet program for use in the final report. The file is then exported out in a format that contains the X and Y coordinate as well as the radiological readings. If necessary, at this time an offset is added to the X and Y positions to tie the position to real world coordinates. This data is then analyzed in a bridging routine that formats the data for import into a mapping software program and assigns differing colors to the radiological readings. The mapping software is used to overlay this color coded survey track map onto an existing site feature map for graphical representation of the radiological conditions of the area. The survey data file may also be loaded into a surface modeling software package that also color codes the radiological data and treats it as a Z axis, creating three dimensional graphic representation of the radiological conditions as well as contours.

4.0 PROJECT DESIGN

4.1 PROJECT PARAMETERS

Based on information provided during Technical Exchanges with the Ukrainian delegation it was agreed that the maximum levels of contaminates within the survey areas is not expected to exceed 5 milli rem at contact. Based on these levels, the radiological detection instrumentation will obtain readings from gamma emitting

radionuclides only. It has been assumed that no separations of nuclides would have occurred in the environment to cause a test area to be contaminated with pure beta emitters, but all locations will have a gamma emitting "tag" isotope which could be analyzed in the subsequent stages of the project.

4.2 PROJECT DESIGN

The radiological surveys will be conducted utilizing both a digital count rate meter with a sodium iodide detector reporting in counts per minute (CPM) and a dose rate meter reporting micro Roentgen per hour (uR). The count meter will be set for gross counting in the "window out" position. This window setting allows detection of low, intermediate and high energy photons. This instrumentation will be connected to the survey systems to record detector readings versus site locations of the readings in order to generate a map of the survey area and retain this data on computer storage media.

Prior to initiating the pilot surveys a site specific grid system will be established. The size and configuration of the grids will be determined based on actual site conditions. The grid system will allow for the detailed mapping of individual grids which will then be consolidated. Each grid within the survey will be assigned a unique number for reference. A baseline location will be established as a control reference and tied to individual and collective surveys.

Radiation survey equipment will be calibrated prior to initiation of individual site surveys and will be checked at the beginning of each days operation to insure proper instrument response. This will be accomplished by placing a radioactive check source next to the detector and observing the instruments response.

5.0 ROLES AND RESPONSIBILITIES

The field surveys will be conducted and documented under the technical direction of Mr. Marc Wendling of WHC. Mr. Wendling will also be responsible for the health and safety of the field team. Field support will be provided primarily by the WHC field team, with on-site assistance being provided by the Chernobyl team upon completion of a project briefing and appropriate site training which will be provided by WHC representatives

6.0 PROJECT SAFETY

To insure personnel safety and efficient work practices during the performance of the individual pilot surveys the following measures will be implemented:

- daily pre-job safety briefings which will include discussions of that days field activities
- development of a job specific Radiation Work Procedure which will specify the operating limits of the surveys, personnel permissible exposures, protective clothing and dosimetry requirements, contaminants in the area and will specify special site entry requirements.
- development of an ALARA Management Worksheet which will include site and job specific considerations to insure that work practices and methodologies are conducted safely.
- establish pre/post medical monitoring program for involved personnel. All US field personnel will be trained radiation workers.
- work activities will be performed in accordance with applicable industrial work practices for activities involving lifting, use of electrical equipment, etc.

The project safety officer, Mr. Marc Wendling is assigned to oversee daily field activities to insure that personnel safety is maintained and radiation exposures are maintained to the lowest possible levels.

7.0 PROJECT DELIVERABLES

Upon completion of the site surveys, a site survey test report will be prepared which will include at minimum the following:

- procedural reference for the basis of the surveys which includes types of survey instrumentation used, calibrations, and background radiation levels used for calibration of the equipment.
- introduction and background which will establish the basis for the surveys.
- methodology used during the surveys
- survey results of radiation contamination as defined statistically for each location. Additionally, site specific maps, grid layout plots, composite survey maps, radiological contours indicating readings above background levels and 3D radiological profiles will be provided.

An example of anticipated report outputs for USRADS/MRDS surveys for composite tracking, radiological contour and radiological profile are shown in Figures 7.1, 7.2 and 7.3.

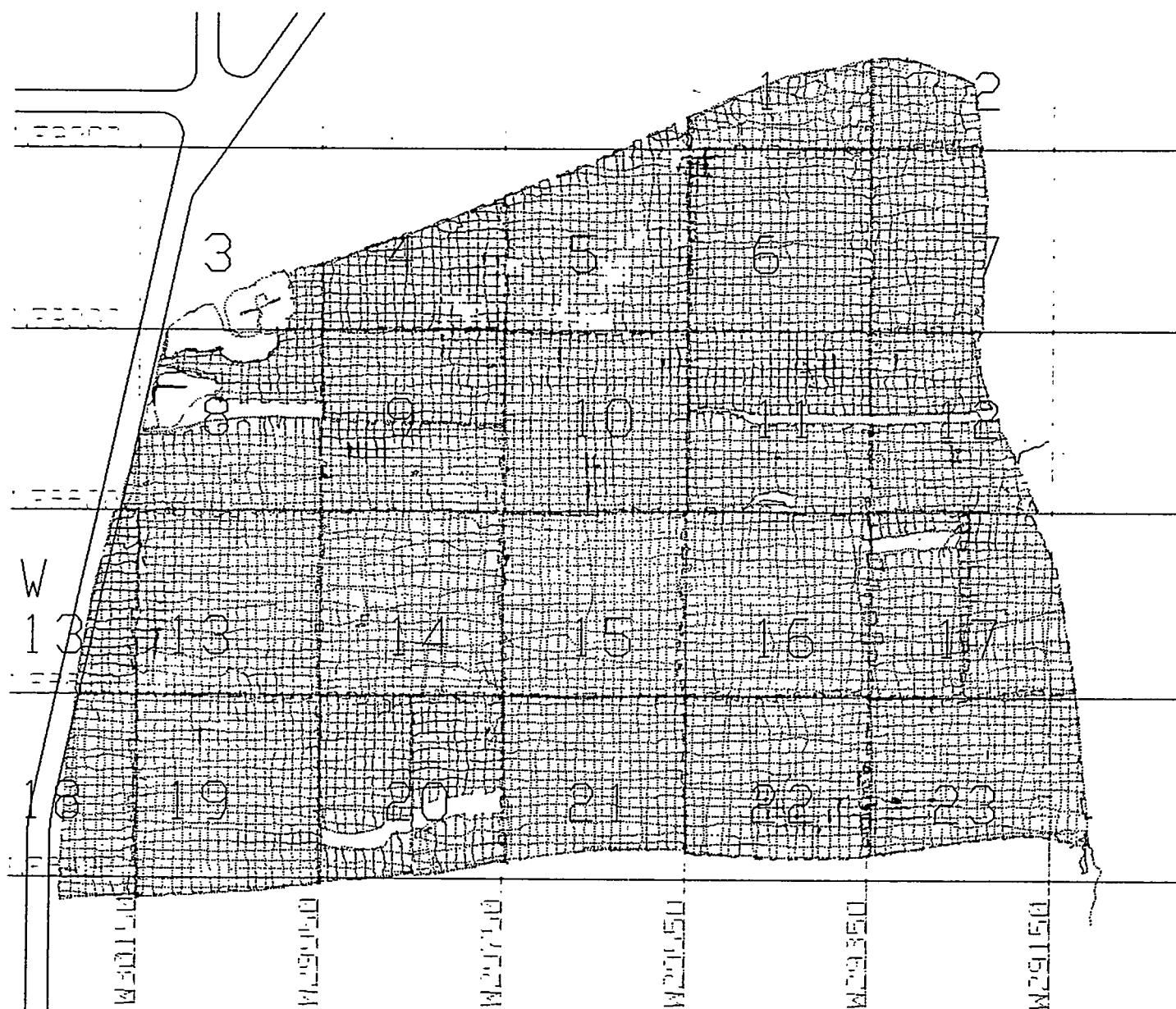
8.0 PROJECT SCHEDULE

Figure 8.1 provides the proposed project schedule. This schedule has been developed to include project planning, field implementation and reporting for the demonstration surveys. It is noted that only Phase I activities have been included in the project schedule. Subsequent field activities will be evaluated as a result of Phase I activities to determine if, and to what extent Phase II activities are required. If time permits, and the Chernobyl staff requests, an additional technology, the NOMAD system will be demonstrated. This system will provide for the acquisition of quantitative radiological data at a chosen location.

9.0 RECORD KEEPING

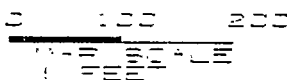
Records of field activities conducted during the investigations will be maintained as part of the project record. Field personnel will take notes sufficient to recreate all

SAMPLE USRADS COMPOSITE TRACK MAP



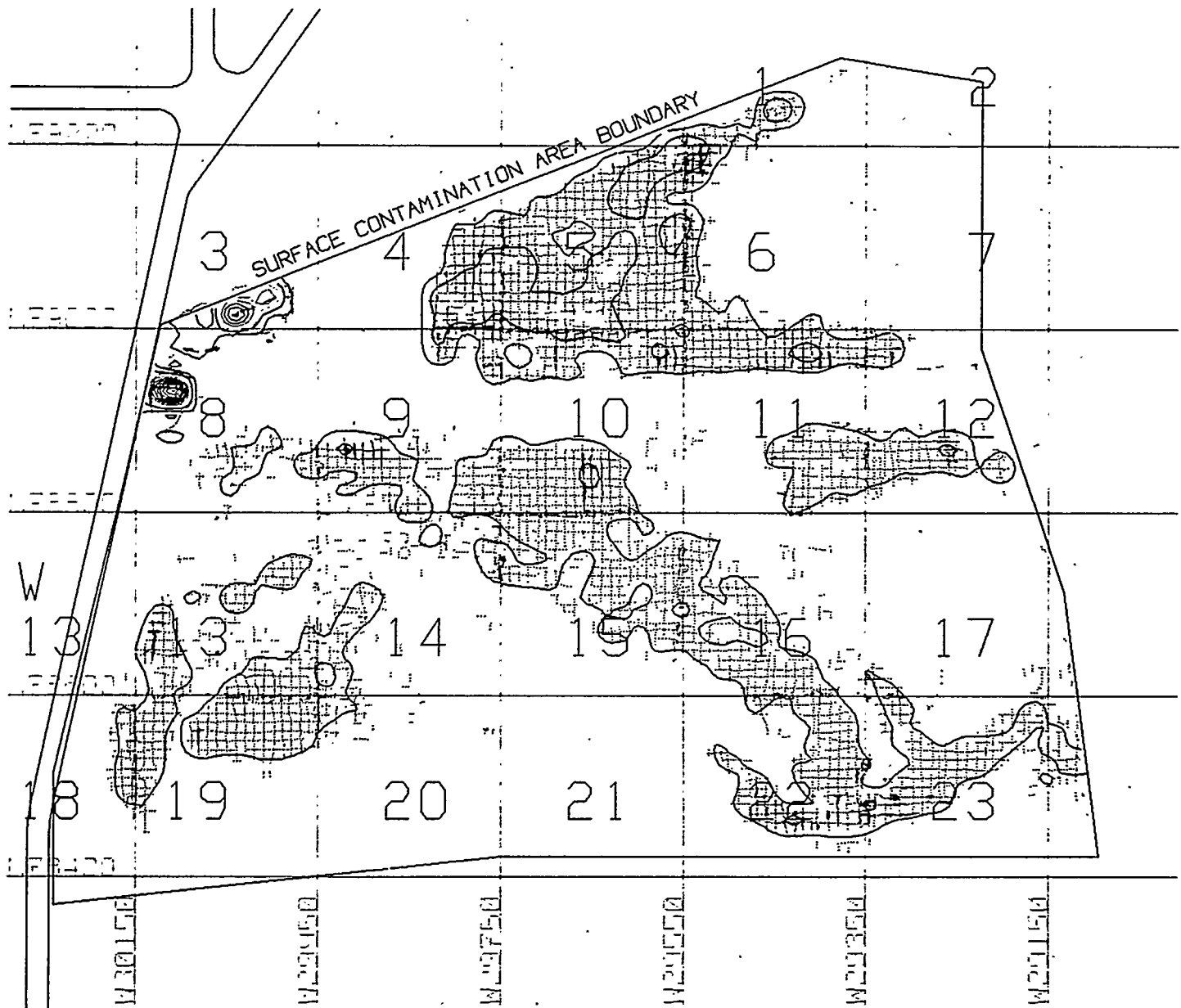
COLOR KEY (CPM)

	<10K (<MDC)
	10K-20K
	20K-30K
	30K-40K
	40K-50K
	>50K



USRADS SURVEYS
ERT/State Investigation Surveys

SAMPLE USRADS RADIOLOGICAL CONTOUR



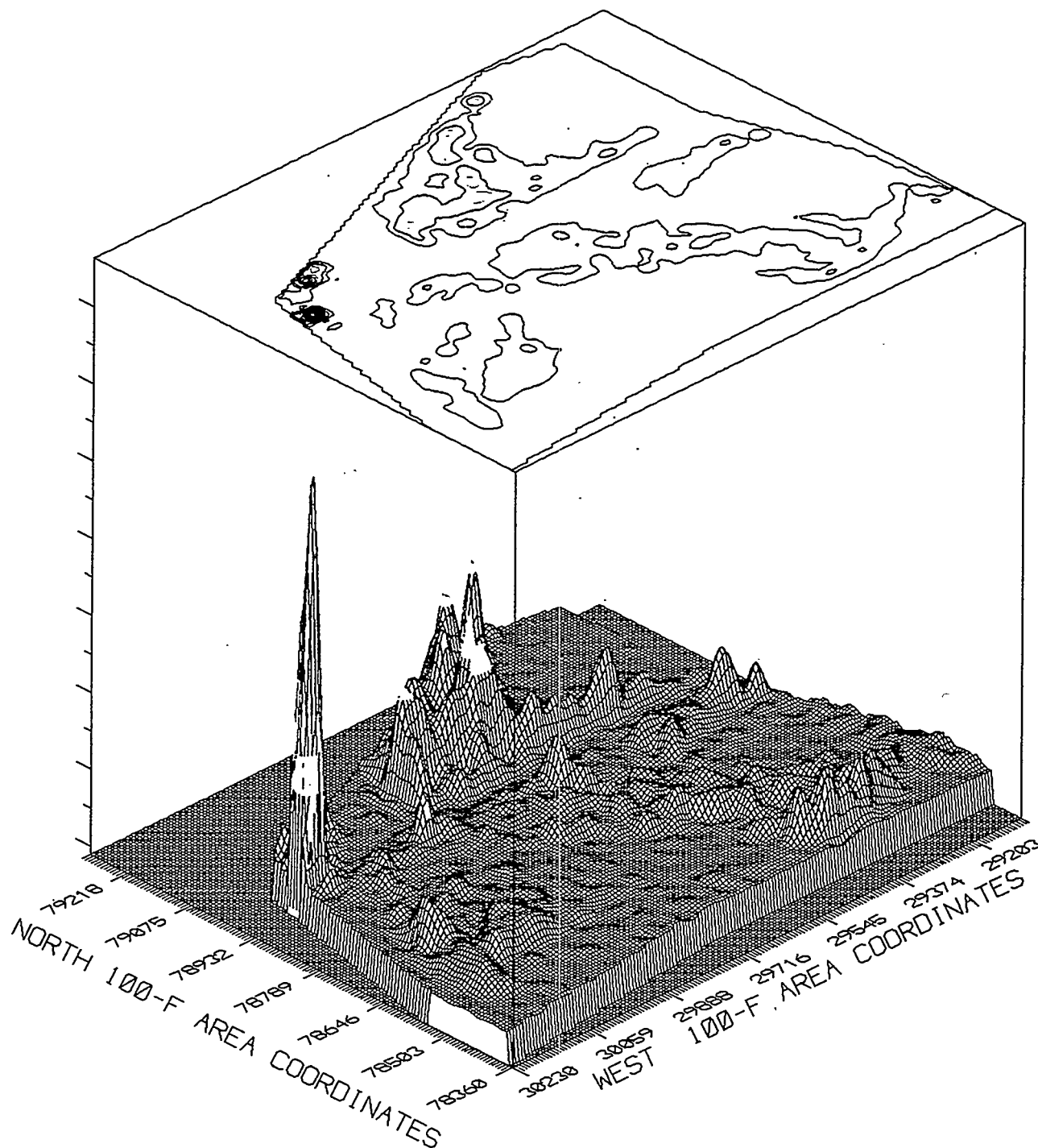
COLOR KEY (CPM)

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	20K-30K
	30K-40K
	40K-50K
	>50K

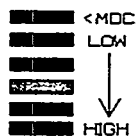
0 100 200
HORIZONTAL SCALE
(FEET)

USRADS SURVEYS
DDE/State Investigative Groups

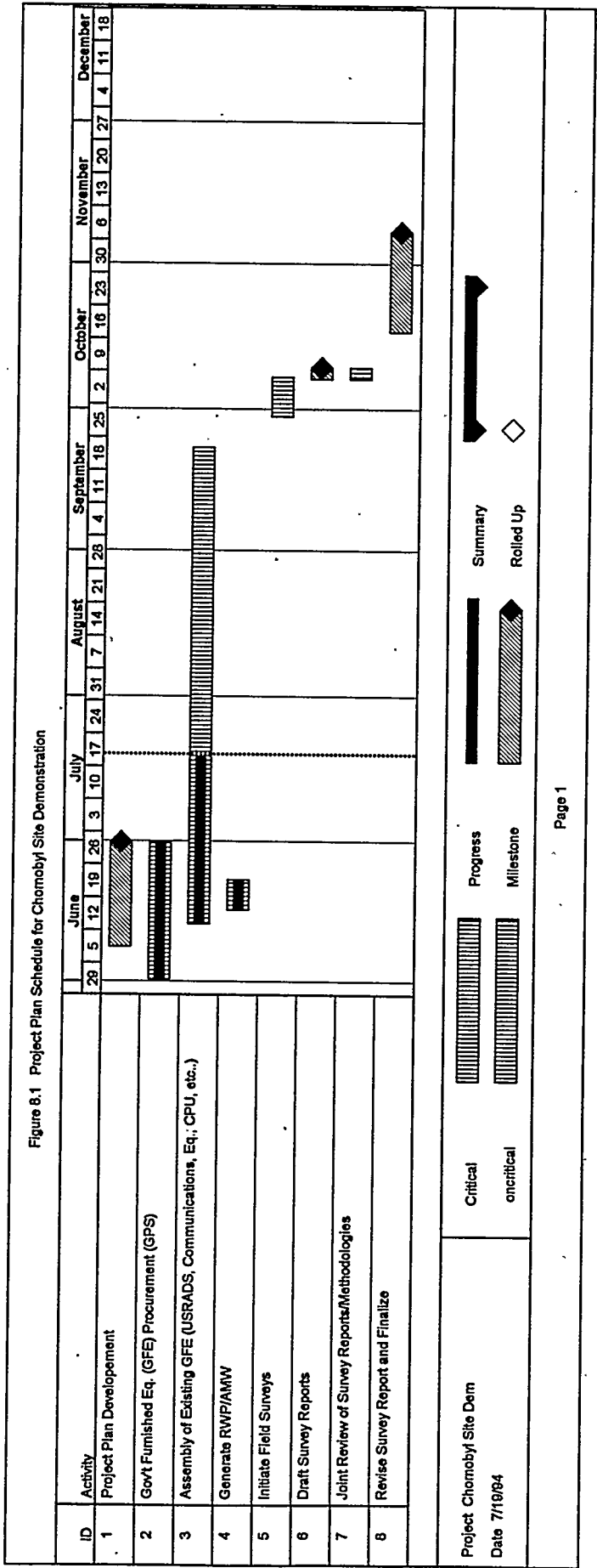
SAMPLE USRADS RADIOLOGICAL PROFILE



COLOR KEY (CPM)



USRADS SURVEYS
EMF/Site Investigation Surveys



activities and provide documentation for later data evaluation. All field activities will be recorded in into the computer compiled in the field. Field results will be recorded in notebooks and/or weather-resistant field notebooks. All databases will be maintained on floppy disks. Whenever specialized forms for recording data of calculations are used, the forms will be maintained as part of the overall project record:

All records will be made in black ink, unless inclement weather requires the use of pencils. Corrections will be made by drawing a single line through the incorrect data, inserting the correct information, and initialing the correction. Incomplete and unused pages will be filled by a single "Z" line and initialed by the recorder.

A record of signatories and initials of project staff performing data recording activities will be maintained as part of the project record. At the end of the project, all records will be maintained by WHC. Copies of records will be available for preparation of the final report.

9.1 CHANGES AND AMENDMENTS

Technical revisions made to this plan will be conducted by the designated WHC lead engineer and the Chornobyl lead. If changes are required during the conduct of the demonstration itself, changes will be noted and justified in a controlled logbook. Both the WHC and Chornobyl leads will acknowledge approval of the change by both signing their names next to the entry in the logbook.

HANFORD RADIOLOGICAL WORK PERMIT				Contractor: WESTINGHOUSE HANFORD COMPANY	
General Job Specific ☐ [X]		Tech. Document No. ☐ [X] N/A	Location Code ☐ [X] N/A	EAN ☐ [X] N/A	RWP Number TECHX-01
Start Date 7/7/94		End Date 9/30/94	Termination Date Extended To:		By
Responsible Organization Technology Projects					
Job Location Chornobyl 30 kilometer exclusion zone, Ukraine					
Job Description and Type of Area: Field demonstration of Hanford radiological mapping technologies, tours and inspections of area.					
Primary Isotope(s): ☐ [X] MFP ☐ [X] MAP ☐ [] Cs ☐ [] Sr ☐ [] H-3 ☐ [] U ☐ [] Pu ☐ [] Other					
Radiation Emitted ☒ [X] Alpha ☒ [X] Beta ☒ [X] Photons ☐ [] Neutrons		Estimated Dose Rate 5 mrem/h General Area: 2 mrem/h Maximum Contact: 2 mrem/h 5 mrem/h		Contamination Levels Beta-gamma: <1M dpm/100 cm² Alpha: <2K dpm/100 cm²	
				Radiological Worker Training Req. I ☐ [] II ☒ [X]	
Internal Dosimetry Requirements (for routine work under this RWP, except those entering for observation only) ☒ [X] Annual Whole Body Count ☐ [] Lung Count ☐ [] Urinalysis Isotopes to Test for (if any):					
MINIMUM RADIOLOGICAL PROTECTION REQUIREMENTS			SPECIAL INSTRUCTIONS (SI)		
HPT Coverage ☐ [] Continuous ☒ [X] Intermittent ☒ [X] Start of Job ☒ [X] End of Job ☒ [X] Self Survey (if qualified) ☐ [] HPT Survey Required ☐ [] Auto. Survey Device		Dosimetry ☒ [X] Multipurpose TLD ☐ [] Basic TLD ☐ [] Pocket Dosimeter ☐ [] Electronic Dosimeter ☐ [] Finger Rings ☐ [] Time Keeping ☐ [] WRAH Access ☐ [] See SI# 3		1. These are the minimum protective clothing requirements. These requirements may be upgraded by the PIC and or HP. 2. Mandatory pre and post job meetings to be conducted daily. 3. Special Whole Body Counts to be performed on all individuals working under the jurisdiction of this RWP, both prior to start of work and after project completion. 4. HP may waive protective clothing requirements for personnel performing tours and inspections under this RWP.	
MINIMUM PROTECTIVE EQUIPMENT					
☒ [X] Coveralls ☐ [] Lab Coat ☐ [] Waterproof Suit ☐ [] Gortex Suit ☐ [] Cap ☐ [] Hood ☒ [X] Surgeon's Gloves ☒ [X] Leather Gloves ☐ [] Canvas & Surgeon's Gloves ☐ [] Waterproof Gloves ☐ [] No Personal Outer ☒ [X] Modesty Clothing ☐ [] See SI# 4		☒ [X] Shoe Covers ☐ [] Canvas Boots ☐ [] Rubber Overshoes ☒ [X] Rubber Boots ☐ [] Full Face Respirator ☐ [] PAPR ☐ [] Supplied Air Respirator ☐ [] SCBA ☐ [] Undressing Assistance			
ALARA Review: Class 2		Pre-Job Briefing: YES ☒ [X] NO ☐ []		Post-Job ALARA Review Required YES ☒ [X] NO ☐ []	
RWP Prepared By: Marc Wendling		Phone: 3-4063		HPT Phone: 3-4063	
Line Management Don Moak		Phone 6-2312		Date 6-17-94	
Health Physics Supervisor Marc Wendling		Phone 3-4063		Date 6/17/94	
Acknowledged By:				Date:	
RWP Change Approvals:				Date:	

ALARA MANAGEMENT WORKSHEET (AMW)

RWP Number

TECHX-01

Date

6/16/94

Page 1 of 2

PART I PRE-JOB INFORMATION

Work Package No. or Equivalent

Project Plan, Chernobyl Site
Characterization/Evaluation
Demonstration

Area/Facility/Location

Chernobyl 30 kilometer exclusion zone, Ukraine.

Job Title/Description:

Field demonstration of Hanford radiological mapping technologies, tours
and inspections of area.

ALARA
Review Class
Check One

1	2	3
	X	

PART II ALARA REVIEW

PART IIA ESTIMATED COLLECTIVE DOSE

<.1 PERSON/REM

PART IIB PROTECTIVE MEASURES

YES

NO

Reference/Explanation

A. Can any or all phases of the work be moved to an area with lower exposure levels?

X

Area of concern is
contaminated soil

B. Can the item or work area be decontaminated to reduce risk?

X

See A

C. Can additional shielding be used to reduce dose rates?

X

Job is to perform
radiological survey of
area. Shielding would
not be effective for
proper job
performance.

D. Can time saving procedures, techniques, or mock ups be used?

X

Training for all
workers will be
conducted in non
radiological areas.

E. Can Best Available Technology (BAT) alternatives be employed (i.e., special tools,
ventilation systems, temporary containment structures, equipment)?

X

BAT is being used to
perform the
radiological mapping
survey.

F. Can all hazards, conditional changes or variables that affect the work be planned for?

X

All known hazards have
been addressed in the
work plan

G. Can method for waste minimization, segregation, removal and/or disposal be planned for?

X

All workers will be
briefed in Waste
Minimization
techniques

H. Can the number of personnel entering the work location be reduced?

X

Minimum number of
personnel determined
by work evolutions

I. Can existing material, tools, or equipment currently at the job location be used to complete
the job (i.e., previously contaminated tools)?

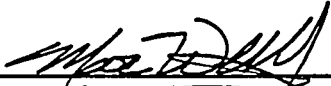
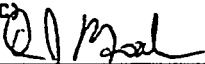
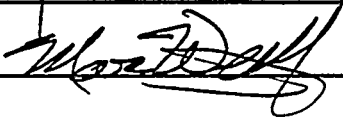
X

Radiologically
contaminated equipment
is not allowed entry
in Ukraine.

J. Can alternate entry and egress routes be identified and planned for prior to initiating work?

X

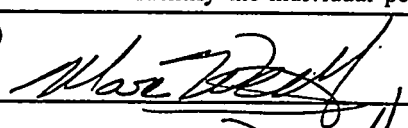
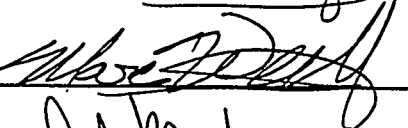
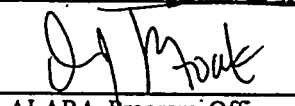
Workers will be
briefed in pre-job
meetings daily.

PART IIC ESTIMATED CORRECTED COLLECTIVE DOSE		<.1 PERSON/REM					
PART III POST JOB REVIEW							
Is Post ALARA Review (PAR) required?		Check One	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; text-align: center;">YES</td> <td style="width: 50%; text-align: center;">NO</td> </tr> <tr> <td style="text-align: center;">X</td> <td></td> </tr> </table>	YES	NO	X	
YES	NO						
X							
PART IV AMW REVIEW							
AMW Preparer M.A. Wendling 		Date 6/16/94					
The PIC, Cognizant Engineer, or designee shall review the AMW and sign documenting the review in Part IV below. The completed AMW shall be forwarded to the locations/personnel listed in the distribution portion of this form as soon as possible.							
Person in Charge (PIC) Don Moak 		Date 6-20-94					
Cognizant Engineer M.A. Wendling 		Date 6/16/94					
Other		Date					

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 Facility ALARA Team Chair

ALARA Program Office
 Work Package

POST ALARA REVIEW

RWP No. TECHX-01	Work Package No. Project Plan Chernobyl Site Demonstration of Radiological Survey Instrumentation	Area N/A	Facility N/A	Specific Job Location Chernobyl Exclusion Zone
Job Title Hanford - Ukraine Technical Exchange II		Job Description Demonstration of Hanford Radiological Mapping Technologies		
Describe any modifications made to the original work plan to <u>increase</u> , <u>decrease</u> , or <u>change</u> the following:				
1. Dosimetry		Added Pencil Dosimeters		
2. Respiratory Protection		No change		
3. Protective Clothing		No change		
4. Time/Distance/Shielding		No change		
5. Personnel		Reduced by one after first phase of survey project		
Evaluate the effectiveness of the hazardous substance exposure controls that were implemented. List dose reduction savings, decontamination factors achieved, and installed engineering applications which attributed to reduction.				
N/A				
Describe any problems encountered, abnormal events, or situations that required the use of stop work authority.				
N/A				
List <u>Lessons Learned</u> and <u>corrective actions</u> taken to prevent recurrence.				
N/A				
(If more space is needed, use continuation page)				
Estimated Collective Dose < 0.1 Person/Rem		Actual Collective Dose 0.030 (Shallow Dose) Person/Rem		Corrected Dose Savings/Difference 0.07 Person/Rem
Identify the individual performing the Post ALARA Review				
Person in Charge (PIC) Marc Wendling 			Date 9/29/94	
Cognizant Engineer Marc Wendling 			Date 9/29/94	
Other Donald Moak 			Date 9/29/94	

Distribution: Original - ALARA Program Office Copy - Work Package Copy - Facility ALARA Team Chair

APPENDIX D

**NOMAD FIELD GAMMA SPECTROSCOPY
SITE # 3**

Table D-1 lists the isotopes that the NOMAD system will identify. Tables D-2 through D-6 are copies of the actual printouts provided by the NOMAD system, including all gamma energy peaks found.

Table D-1. Gamma Emitting Isotopes Identifiable by the NOMAD System. (sheet 1 of 3)

Pk. #	Energy (keV)	Isotope Name	2ndary Pk #	Type	Gamma Fraction	Half-life	NONE (uCi/ml)	Calc Cntr	Sbtr Cntr
1	10.80	Pb-214	17	I.D.	0.1360	2.6800e+001 M	0.00e+000	N	Y
2	10.80	Pb-210	14	I.D.	0.2430	1.0720e+007 M	0.00e+000	N	Y
3	12.65	Pa-231	9	I.D.	0.0620	1.7200e+010 M	0.00e+000	N	Y
4	13.00	U-238	15	I.D.	0.0870	4.7000e+009 Y	0.00e+000	N	Y
5	13.30	Th-234	19	I.D.	0.0980	3.4704e+004 M	0.00e+000	N	Y
6	13.30	Th-231	11	I.D.	0.9200	1.5307e+003 M	0.00e+000	N	Y
7	13.60	Pa-234	44	I.D.	1.1400	6.7000e+000 H	0.00e+000	N	Y
8	13.60	U-234	16	I.D.	0.1040	2.4800e+005 Y	0.00e+000	N	Y
9	15.70	Pa-231	10	I.D.	0.0780	1.7200e+010 M	0.00e+000	N	Y
10	18.50	Pa-231	12	I.D.	0.0200	1.7200e+010 M	0.00e+000	N	Y
11	26.64	Th-231	32	I.D.	0.1817	1.5307e+003 M	0.00e+000	N	Y
12	27.36	Pa-231	3	I.D.	0.9300	1.7200e+010 M	0.00e+000	N	Y
13	39.86	Bi-212	64	I.D.	0.0110	6.0550e+001 M	0.00e+000	Y	Y
14	46.52	Pb-210	2	QUANT	0.0400	1.0720e+007 M	0.00e+000	Y	Y
15	48.00	U-238	4	I.D.	0.0008	4.7000e+009 Y	0.00e+000	Y	Y
16	53.10	U-234	8	I.D.	0.0012	2.4800e+005 Y	0.00e+000	N	Y
17	53.20	Pb-214	24	I.D.	0.0110	2.6800e+001 M	0.00e+000	N	Y
18	59.00	Th-232	0	QUANT	0.0019	7.4100e+015 M	0.00e+000	Y	Y
19	63.29	Th-234	22	QUANT	0.0390	3.4704e+004 M	0.00e+000	Y	Y
20	67.73	Th-230	0	I.D.	0.0038	7.7000e+004 Y	0.00e+000	Y	Y
21	72.80	Bi-208	26	QUANT	0.1900	1.9340e+011 M	0.00e+000	Y	Y
22	73.92	Th-234	23	I.D.	0.0001	3.4704e+004 M	0.00e+000	N	Y
23	74.00	Th-234	30	I.D.	0.0004	3.4704e+004 M	0.00e+000	N	Y
24	74.80	Pb-214	28	I.D.	0.0633	2.6800e+001 M	0.00e+000	N	Y
25	74.81	Pb-212	27	I.D.	0.0960	6.3840e+002 M	0.00e+000	N	Y
26	74.97	Bi-208	34	I.D.	0.3500	1.9340e+011 M	0.00e+000	N	Y
27	77.11	Pb-212	37	I.D.	0.1750	6.3840e+002 M	0.00e+000	N	Y
28	77.11	Pb-214	36	I.D.	0.1070	2.6800e+001 M	0.00e+000	N	Y
29	81.07	Ra-226	31	I.D.	0.0017	8.4100e+008 M	0.00e+000	N	Y
30	83.30	Th-234	42	I.D.	0.0007	3.4704e+004 M	0.00e+000	N	Y
31	83.78	Ra-226	45	I.D.	0.0031	8.4100e+008 M	0.00e+000	N	Y
32	84.21	Th-231	41	I.D.	0.0800	1.5307e+003 M	0.00e+000	N	Y
33	84.40	Th-228	53	I.D.	0.0119	1.9130e+000 Y	0.00e+000	N	N
34	84.80	Bi-208	38	I.D.	0.1200	1.9340e+011 M	0.00e+000	N	Y
35	86.45	Eu-155	47	QUANT	0.3274	4.9600e+000 Y	0.00e+000	Y	Y
36	87.20	Pb-214	39	I.D.	0.0370	2.6800e+001 M	0.00e+000	N	Y
37	87.20	Pb-212	40	I.D.	0.0630	6.3840e+002 M	0.00e+000	N	Y
38	87.30	Bi-208	21	I.D.	0.0350	1.9340e+011 M	0.00e+000	N	Y
39	89.80	Pb-214	61	I.D.	0.0103	2.6800e+001 M	0.00e+000	N	Y
40	89.80	Pb-212	50	I.D.	0.0175	6.3840e+002 M	0.00e+000	N	Y
41	89.95	Th-231	6	I.D.	0.0125	1.5307e+003 M	0.00e+000	N	Y
42	92.38	Th-234	43	I.D.	0.0257	3.4704e+004 M	0.00e+000	N	Y
43	92.80	Th-234	49	I.D.	0.0300	3.4704e+004 M	0.00e+000	N	Y
44	94.67	Pa-234	46	I.D.	0.1550	6.7000e+000 H	0.00e+000	N	Y
45	94.70	Ra-226	56	I.D.	0.0011	8.4100e+008 M	0.00e+000	N	Y
46	98.44	Pa-234	48	MDA	0.2510	6.7000e+000 H	0.00e+000	Y	Y
47	105.31	Eu-155	35	QUANT	0.2180	4.9600e+000 Y	0.00e+000	Y	Y
48	111.00	Pa-234	52	I.D.	0.0855	6.7000e+000 H	0.00e+000	N	Y

Table D-1. Gamma Emitting Isotopes Identifiable by the NOMAD System. (sheet 2 of 3)

Pk. #	Energy (keV)	Isotope Name	2ndary Pk #	Gamma Type	Fraction	Halflife	NONE (uCi/ml)	Calc Cntr	Sbtr Cntr
49	112.81	Th-234	54	I.D.	0.0025	3.4704e+004 M	0.00e+000	N	Y
50	115.18	Pb-212	59	I.D.	0.0058	6.3840e+002 M	0.00e+000	N	N
51	123.10	Eu-154	108	QUANT	0.4046	8.5000e+000 Y	0.00e+000	Y	Y
52	131.28	Pa-234	76	I.D.	0.2000	6.7000e+000 H	0.00e+000	N	Y
53	131.62	Th-228	57	I.D.	0.0011	1.9130e+000 Y	0.00e+000	N	Y
54	184.80	Th-234	5	I.D.	0.0001	3.4704e+004 M	0.00e+000	N	Y
55	185.72	U-235	0	QUANT	0.5400	7.0400e+008 Y	0.00e+000	Y	Y
56	185.99	Ra-226	29	I.D.	0.0328	8.4100e+008 M	0.00e+000	N	Y
57	215.94	Th-228	33	I.D.	0.0027	1.9130e+000 Y	0.00e+000	N	N
58	236.00	Th-227	0	QUANT	0.1120	2.6640e+004 M	0.00e+000	Y	Y
59	238.63	Pb-212	66	MDA	0.4310	6.3840e+002 M	0.00e+000	Y	Y
60	241.00	Ra-224	0	QUANT	0.0390	5.2704e+003 M	0.00e+000	Y	Y
61	241.92	Pb-214	65	I.D.	0.0747	2.6800e+001 M	0.00e+000	N	Y
62	277.36	Tl-208	78	I.D.	0.0650	3.1000e+000 M	0.00e+000	N	N
63	284.30	I-131	69	QUANT	0.0605	1.9296e+002 H	9.00e-009	Y	Y
64	288.08	Bi-212	70	I.D.	0.0033	6.0550e+001 M	0.00e+000	N	N
65	295.22	Pb-214	68	I.D.	0.1920	2.6800e+001 M	0.00e+000	N	Y
66	300.90	Pb-212	25	I.D.	0.0327	6.3840e+002 M	0.00e+000	N	Y
67	338.40	Ac-228	97	I.D.	0.1201	3.6780e+002 M	0.00e+000	N	Y
68	351.99	Pb-214	90	MDA	0.3710	2.6800e+001 M	0.00e+000	Y	Y
69	364.48	I-131	81	QUANT	0.8120	1.9296e+002 H	9.00e-009	Y	Y
70	452.83	Bi-212	84	I.D.	0.0035	6.0550e+001 M	0.00e+000	N	N
71	477.56	Be-7	0	MDA	0.1030	7.6896e+004 M	0.00e+000	Y	Y
72	497.08	Ru-103	0	QUANT	0.8900	9.4440e+002 H	8.00e-008	Y	Y
73	510.00	Rn-222	0	I.D.	0.0008	3.8230e+000 D	0.00e+000	N	N
74	522.65	I-132	88	QUANT	0.1610	2.3000e+000 H	2.00e-007	Y	Y
75	537.32	Ba-140	0	QUANT	0.2500	3.0694e+002 H	4.00e-008	Y	Y
76	569.26	Pa-234	99	I.D.	0.1040	6.7000e+000 H	0.00e+000	N	Y
77	569.31	Cs-134	79	QUANT	0.1543	1.8076e+004 H	1.00e-008	Y	Y
78	583.14	Tl-208	95	MDA	0.8610	3.1000e+000 M	0.00e+000	Y	Y
79	604.70	Cs-134	91	QUANT	0.9760	1.8076e+004 H	1.00e-008	Y	Y
80	609.32	Bi-214	87	MDA	0.4609	1.9900e+001 M	0.00e+000	Y	Y
81	636.97	I-131	63	QUANT	0.0726	1.9296e+002 H	9.00e-009	Y	Y
82	661.62	Cs-137	0	MDA	0.8462	3.0100e+001 Y	0.00e+000	Y	Y
83	724.18	Zr-95	85	QUANT	0.4370	1.5365e+003 H	3.00e-008	Y	Y
84	727.17	Bi-212	89	MDA	0.1180	6.0550e+001 M	0.00e+000	Y	Y
85	756.72	Zr-95	83	QUANT	0.5530	1.5365e+003 H	3.00e-008	Y	Y
86	765.79	Nb-95	0	QUANT	0.9981	8.4144e+002 H	1.00e-007	Y	Y
87	768.36	Bi-214	98	I.D.	0.0489	1.9900e+001 M	0.00e+000	N	Y
88	772.61	I-132	100	QUANT	0.7620	2.3000e+000 H	2.00e-007	Y	Y
89	785.42	Bi-212	96	I.D.	0.0200	6.0550e+001 M	0.00e+000	N	Y
90	785.95	Pb-214	1	I.D.	0.0109	2.6800e+001 M	0.00e+000	N	Y
91	795.84	Cs-134	77	QUANT	0.8540	1.8076e+004 H	1.00e-008	Y	Y
92	803.00	Po-210	0	MDA	0.0000	1.9927e+005 M	0.00e+000	Y	Y
93	815.85	La-140	112	QUANT	0.2350	4.0220e+001 H	1.00e-007	Y	Y
94	818.50	Cs-136	102	QUANT	0.9970	3.1584e+002 H	2.00e-007	Y	Y
95	860.47	Tl-208	62	I.D.	0.1200	3.1000e+000 M	0.00e+000	N	N
96	893.39	Bi-212	103	I.D.	0.0066	6.0550e+001 M	0.00e+000	N	N

Table D-1. Gamma Emitting Isotopes Identifiable by the NOMAD System. (sheet 3 of 3)

Pk. #	Energy (keV)	Isotope Name	2ndary Pk #	Gamma Type	Fraction	Halflife	NONE (uCi/ml)	Calc Cntr	Sbtr Cntr
97	911.07	Ac-228	101	MDA	0.2900	3.6780e+002 M	0.00e+000	Y	Y
98	934.05	Bi-214	104	I.D.	0.0362	1.9900e+001 M	0.00e+000	N	Y
99	946.00	Pa-234	7	I.D.	0.2000	6.7000e+000 H	0.00e+000	N	Y
100	954.55	I-132	74	QUANT	0.1810	2.3000e+000 H	2.00e-007	Y	Y
101	968.90	Ac-228	67	I.D.	0.1746	3.6780e+002 M	0.00e+000	N	Y
102	1048.07	Cs-136	106	QUANT	0.7960	3.1584e+002 H	2.00e-007	Y	Y
103	1078.62	Bi-212	113	I.D.	0.0097	6.0550e+001 M	0.00e+000	N	N
104	1120.28	Bi-214	107	I.D.	0.1504	1.9900e+001 M	0.00e+000	N	Y
105	1173.22	Co-60	109	MDA	1.0000	4.6210e+004 H	9.00e-009	Y	Y
106	1235.34	Cs-136	94	QUANT	0.1970	3.1584e+002 H	2.00e-007	Y	Y
107	1238.11	Bi-214	110	I.D.	0.0592	1.9900e+001 M	0.00e+000	N	Y
108	1274.80	Eu-154	51	QUANT	0.3550	8.5000e+000 Y	0.00e+000	Y	Y
109	1332.49	Co-60	105	MDA	1.0000	4.6210e+004 H	9.00e-009	Y	Y
110	1377.65	Bi-214	114	I.D.	0.0402	1.9900e+001 M	0.00e+000	N	Y
111	1460.75	K-40	0	MDA	0.1070	6.7280e+014 M	0.00e+000	Y	Y
112	1596.49	La-140	93	QUANT	0.9549	4.0220e+001 H	1.00e-007	Y	Y
113	1620.56	Bi-212	13	I.D.	0.0275	6.0550e+001 M	0.00e+000	N	N
114	1729.60	Bi-214	115	I.D.	0.0305	1.9900e+001 M	0.00e+000	N	Y
115	1764.51	Bi-214	80	I.D.	0.1592	1.9900e+001 M	0.00e+000	N	Y

Table D-2. Gamma Spectroscopy Results for Site 3 - Location 1. (sheet 1 of 3)

M1/PC	Hanford-Ukraine Technical Exchange II	Ver. 1.00a
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Spectrum ID : jer1

Location: Chornobyl - 30k Zone

Counting Start. 09-05-94 02:05 | Spectrum File SITE31.SPC

Decay Date. 00-00-00 00:00 | Live Time 600 Sec

Current Date. 10-19-94 13:58 | Real Time 696 Sec

Detector #: 1

Energy(keV)= $0.37 + 0.250 \cdot \text{Ch} + 0.00\text{e}+000 \cdot \text{Ch}^2 + 0.00\text{e}+000 \cdot \text{Ch}^3$ 09-05-94 01:55FWHM(keV) = $-0.10 + 0.118 \cdot \text{En} + 2.18\text{e}-003 \cdot \text{En}^2 + 0.00\text{e}+000 \cdot \text{En}^3$ 08-07-94 09:09

Where En = Sqrt(Energy in keV)

Sensitivity 0.20 | Search Start / End. 0 / 8191

Sigma Multiplier. 1.00 |

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
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1	604.88	2418.21	2466	133	258	2946	3.52	
2	661.85	2646.11	59262	338	494	9995	3.44	
3	795.95	3182.55	2145	74	120	615	3.35	
4	1274.83	5098.19	276	26	42	79	3.44	
5	1460.88	5842.42	163	33	62	234	1.47	
6	1970.18	7879.75	4	2	0	0	0.47	

Table D-2. Gamma Spectroscopy Results for Site 3 - Location 1. (sheet 2 of 3)

M1/PC Hanford-Ukraine Technical Exchange II Ver. 1.00a

1-Meter NUCLIDE ACTIVITY SUMMARY

Spectrum ID: jer1

Location: Chornobyl - 30k Zone

Counting Start. 09-05-94 02:05 | Spectrum File SITE31.SPC
Decay Date 00-00-00 00:00 | Decay Time [OFF]. 0.00e+000 Hrs
Current Date. 10-19-94 13:59 |

Library File. 1-Meter.lib | ID. 1 Meter Analysis Library

Aspect Ratio = ...1.0 | Orientation = ...DOWN
Detector Efficiency 40.0 % | Alpha/Rho File aged.rho

Gamma Fraction Limit > = . . . 80.00 % | Decay Limit < = . . . 8.000 Halflives
Library Energy Tolerance. . . 2.00

FINAL ACTIVITY REPORT

Nuclide	Energy (keV)	Conc +/- 1.00sigma	Halflife (hrs)	Peaks Found
Cs-134	Average: 5.84e-001	+/-1.69e-002 uCi/m2	1.81e+004	2 of 3
	604.70	5.50e-001 +/-2.97e-002		
	795.84	6.00e-001 +/-2.06e-002		
Cs-137	661.62	1.57e+001 +/-8.96e-002 uCi/m2	2.64e+005	1 of 1
K-40	1460.75	1.80e-006 +/-3.66e-007 uCi/gm	1.12e+013	1 of 1
Pa-234	98.44	< 3.25e-006 uCi/gm	6.70e+000	MDA
Pb-212	238.63	< 1.82e-006 uCi/gm	1.06e+001	MDA
Pb-214	351.99	< 1.89e-006 uCi/gm	4.47e-001	MDA
Be-7	477.56	< 6.33e-006 uCi/gm	1.28e+003	MDA
Tl-208	583.14	< 5.49e-007 uCi/gm	5.17e-002	MDA
Bi-214	609.32	< 1.37e-006 uCi/gm	3.32e-001	MDA
Bi-212	727.17	< 1.67e-006 uCi/gm	1.01e+000	MDA
Po-210	803.00	< 2.22e-003 uCi/gm	1.00e+012	MDA
Ac-228	911.07	< 4.23e-007 uCi/gm	6.13e+000	MDA
Co-60	1173.22	< 7.36e-008 uCi/gm	4.62e+004	MDA
Co-60	1332.49	< 5.93e-008 uCi/gm	4.62e+004	MDA

Table D-2. Gamma Spectroscopy Results for Site 3 - Location 1. (sheet 3 of 3)

UNKNOWN PEAKS						
Energy (keV)	Centroid Channel	Net Counts	Un- Certainty	C.L. Counts	Bkg. Counts	FWHM (keV)
1274.83	5098.19	276	26	42	79	3.44
1970.18	7879.75	4	2	0	0	0.47

Table D-3. Gamma Spectroscopy Results for Site 3 - Location 2. (sheet 1 of 3)

M1/PC Hanford-Ukraine Technical Exchange II Ver. 1.00a

Spectrum ID : jer2

Location: Chornobyl - 30k Zone

Counting Start. 09-05-94 02:18 | Spectrum File SITE32.SPC

Decay Date. 00-00-00 00:00 | Live Time 600 Sec

Current Date. 10-19-94 14:23 | Real Time 682 Sec

Detector #: 1

Energy(keV)= 0.37 + 0.250*Ch + 0.00e+000*Ch^2 + 0.00e+000*Ch^3 09-05-94 01:55

FWHM(keV) = -0.10 + 0.118*En + -2.18e-003*En^2 + 0.00e+000*En^3 08-07-94 09:09

Where En = Sqrt(Energy in keV)

Sensitivity 0.20 | Search Start / End. 0 / 8191
Sigma Multiplier. 1.00 |

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM COUNTS (keV)	FLAG
1	605.01	2418.72	1955	120	233	2392	3.98	
2	661.86	2646.15	48565	308	454	8451	3.54	
3	795.90	3182.33	1769	67	110	500	3.83	
4	1005.49	4020.74	84	21	38	86	1.57	
5	1274.57	5097.12	139	25	44	111	2.14	

Table D-3. Gamma Spectroscopy Results for Site 3 - Location 2. (sheet 2 of 3)

M1/PC	Hanford-Ukraine Technical Exchange II	Ver. 1.00a
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1-Meter NUCLIDE ACTIVITY SUMMARY

Spectrum ID: jer2

Location: Chornobyl - 30k Zone

Counting Start. 09-05-94 02:18 | Spectrum File SITE32.SPC
 Decay Date 00-00-00 00:00 | Decay Time [OFF]. 0.00e+000 Hrs
 Current Date. 10-19-94 14:24 |

Library File. 1-Meter.lib | ID. 1 Meter Analysis Library

Aspect Ratio = ... 1.0 | Orientation = ... DOWN
 Detector Efficiency 40.0 % | Alpha/Rho File aged.rho

Gamma Fraction Limit > = . . . 80.00 % | Decay Limit < = ... 8.000 Halflives
 Library Energy Tolerance. . . 2.00

FINAL ACTIVITY REPORT

Nuclide	Energy (keV)	Conc +/- 1.00sigma	Half-life (hrs)	Peaks Found
=====				
Cs-134	Average:	4.75e-001 +/- 1.54e-002 uCi/m2	1.81e+004	2 of 3
	604.70	4.36e-001 +/- 2.67e-002		
	795.84	4.95e-001 +/- 1.88e-002		
Cs-137	661.62	1.29e+001 +/- 8.18e-002 uCi/m2	2.64e+005	1 of 1
Pa-234	98.44	< 3.09e-006	uCi/gm	6.70e+000 MDA
Pb-212	238.63	< 1.70e-006	uCi/gm	1.06e+001 MDA
Pb-214	351.99	< 1.72e-006	uCi/gm	4.47e-001 MDA
Be-7	477.56	< 5.60e-006	uCi/gm	1.28e+003 MDA
Tl-208	583.14	< 4.62e-007	uCi/gm	5.17e-002 MDA
Bi-214	609.32	< 1.28e-006	uCi/gm	3.32e-001 MDA
Bi-212	727.17	< 1.39e-006	uCi/gm	1.01e+000 MDA
Po-210	803.00	< 1.96e-003	uCi/gm	1.00e+012 MDA
Ac-228	911.07	< 2.93e-007	uCi/gm	6.13e+000 MDA
Co-60	1173.22	< 9.41e-008	uCi/gm	4.62e+004 MDA
Co-60	1332.49	< 6.27e-008	uCi/gm	4.62e+004 MDA
K-40	1460.75	< 1.11e-006	uCi/gm	1.12e+013 MDA

Table D-3. Gamma Spectroscopy Results for Site 3 - Location 2. (sheet 3 of 3)

UNKNOWN PEAKS						
Energy (keV)	Centroid Channel	Net Counts	Un- Certainty	C.L. Counts	Bkg. Counts	FWHM (keV)
1005.49	4020.74	84	21	38	86	1.57
1274.57	5097.12	139	25	44	111	2.14

Table D-4. Gamma Spectroscopy Results for Site 3 - Location 3. (sheet 1 of 3)

M1/PC	Hanford-Ukraine Technical Exchange II	Ver. 1.00a
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Spectrum ID : site33

Location: Chornobyl - 30k Zone

Counting Start. 09-05-94 02:34 | Spectrum File site33.SPC

Decay Date. 00-00-00 00:00 | Live Time 600 Sec

Current Date. 10-19-94 14:24 | Real Time 719 Sec

Detector #: 1

Energy(keV)= $0.37 + 0.250 \cdot \text{Ch} + 0.00\text{e}+000 \cdot \text{Ch}^2 + 0.00\text{e}+000 \cdot \text{Ch}^3$ 09-05-94 01:55FWHM(keV) = $-0.10 + 0.118 \cdot \text{En} + 2.18\text{e}-003 \cdot \text{En}^2 + 0.00\text{e}+000 \cdot \text{En}^3$ 08-07-94 09:09

Where En = Sqrt(Energy in keV)

Sensitivity 0.20 | Search Start / End. 0 / 8191

Sigma Multiplier. 1.00 |

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	605.04	2418.86	3428	161	316	4086	3.82	
2	661.92	2646.36	80872	406	614	14868	3.60	
3	722.38	2888.24	126	34	65	258	2.74	
4	796.12	3183.20	2901	87	146	807	3.45	
5	1271.95	5086.64	23	10	19	22	1.05 a	
6	1274.36	5096.29	388	38	73	117	3.81 b	
7	1958.81	7834.25	4	2	0	0	0.31	

Table D-4. Gamma Spectroscopy Results for Site 3 - Location 3. (sheet 2 of 3)

M1/PC Hanford-Ukraine Technical Exchange II Ver. 1.00a

1-Meter NUCLIDE ACTIVITY SUMMARY

Spectrum ID: site33

Location: Chornobyl - 30k Zone

Counting Start. 09-05-94 02:34 | Spectrum File site33.SPC

Decay Date 00-00-00 00:00 | Decay Time [OFF]. 0.00e+000 Hrs

Current Date. 10-19-94 14:24 |

Library File. 1-Meter.lib | ID. 1 Meter Analysis Library

Aspect Ratio = ...1.0 | Orientation = ...DOWN

Detector Efficiency 40.0 % | Alpha/Rho File aged.rho

Gamma Fraction Limit >= . . .80.00 % | Decay Limit <= 8.000 Halflives

Library Energy Tolerance. . .2.00

FINAL ACTIVITY REPORT

Nuclide	Energy (keV)	Conc +/- 1.00sigma	Halflife (hrs)	Peaks Found
Cs-134	Average: 7.96e-001	+2.02e-002 uCi/m2	1.81e+004	2 of 3
	604.70	7.64e-001 +/-3.59e-002		
	795.84	8.11e-001 +/-2.44e-002		
Cs-137	661.62	2.15e+001 +/-1.08e-001 uCi/m2	2.64e+005	1 of 1
Pa-234	98.44	< 3.52e-006	uCi/gm 6.70e+000	MDA
Pb-212	238.63	< 2.04e-006	uCi/gm 1.06e+001	MDA
Pb-214	351.99	< 2.17e-006	uCi/gm 4.47e-001	MDA
Be-7	477.56	< 7.43e-006	uCi/gm 1.28e+003	MDA
Tl-208	583.14	< 6.46e-007	uCi/gm 5.17e-002	MDA
Bi-214	609.32	< 1.58e-006	uCi/gm 3.32e-001	MDA
Bi-212	727.17	< 1.78e-006	uCi/gm 1.01e+000	MDA
Po-210	803.00	< 2.60e-003	uCi/gm 1.00e+012	MDA
Ac-228	911.07	< 3.53e-007	uCi/gm 6.13e+000	MDA
Co-60	1173.22	< 1.05e-007	uCi/gm 4.62e+004	MDA
Co-60	1332.49	< 6.27e-008	uCi/gm 4.62e+004	MDA
K-40	1460.75	< 1.21e-006	uCi/gm 1.12e+013	MDA

Table D-4. Gamma Spectroscopy Results for Site 3 - Location 3. (sheet 3 of 3)

UNKNOWN PEAKS						
Energy (keV)	Centroid Channel	Net Counts	Un- Certainty	C.L. Counts	Bkg. Counts	FWHM (keV)
722.38	2888.24	126	34	65	258	2.74
1271.95	5086.64	23	10	19	22	1.05
1274.36	5096.29	388	38	73	117	3.81
1958.81	7834.25	4	2	0	0	0.31

Table D-5. Gamma Spectroscopy Results for Site 3 - Location 4. (sheet 1 of 3)

M1/PC	Hanford-Ukraine Technical Exchange II	Ver. 1.00a
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Spectrum ID : site34

Location: Chornobyl - 30k Zone

Counting Start. 09-05-94 02:47 | Spectrum File site34.SPC

Decay Date. 00-00-00 00:00 | Live Time 600 Sec

Current Date. 10-19-94 14:25 | Real Time 677 Sec

Detector #: 1

Energy(keV)= $0.37 + 0.250 \cdot \text{Ch} + 0.00\text{e}+000 \cdot \text{Ch}^2 + 0.00\text{e}+000 \cdot \text{Ch}^3$ 09-05-94 01:55FWHM(keV) = $-0.10 + 0.118 \cdot \text{En} + -2.18\text{e}-003 \cdot \text{En}^2 + 0.00\text{e}+000 \cdot \text{En}^3$ 08-07-94 09:09

Where En = Sqrt(Energy in keV)

Sensitivity 0.20 | Search Start / End. 0 / 8191

Sigma Multiplier. 1.00 |

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM COUNTS (keV)	FLAG
1	604.78	2417.80	1761	123	243	2338	3.54	
2	661.84	2646.05	41489	294	451	7743	3.76	
3	796.00	3182.75	1254	68	123	621	3.40	
4	1274.13	5095.37	62	24	45	127	1.79	
5	2002.57	8009.33	7	5	7	6	1.00	NET <CL

Table D-5. Gamma Spectroscopy Results for Site 3 - Location 4. (sheet 2 of 3)

M1/PC Hanford-Ukraine Technical Exchange II Ver. 1.00a

1-Meter NUCLIDE ACTIVITY SUMMARY

Spectrum ID: site34

Location: Chornobyl - 30k Zone

Counting Start. 09-05-94 02:47 | Spectrum File site34.SPC
Decay Date 00-00-00 00:00 | Decay Time [OFF]. 0.00e+000 Hrs
Current Date. 10-19-94 14:25 |

Library File. 1-Meter.lib | ID.. . . . 1 Meter Analysis Library

Aspect Ratio = ... 1.0 | Orientation = ... DOWN
Detector Efficiency 40.0 % | Alpha/Rho File aged.rho

Gamma Fraction Limit > = . . . 80.00 % | Decay Limit < = ... 8.000 Halflives
Library Energy Tolerance. . . 2.00

FINAL ACTIVITY REPORT

Nuclide	Energy (keV)	Conc +/- 1.00sigma	Half-life (hrs)	Peaks Found
Cs-134	Average: 604.70 795.84	3.64e-001 +/-1.57e-002 uCi/m2 3.93e-001 +/-2.73e-002 3.51e-001 +/-1.91e-002	1.81e+004	2 of 3
Cs-137	661.62	1.10e+001 +/-7.81e-002 uCi/m2	2.64e+005	1 of 1
Pa-234	98.44	< 3.06e-006	uCi/gm	6.70e+000 MDA
Pb-212	238.63	< 1.61e-006	uCi/gm	1.06e+001 MDA
Pb-214	351.99	< 1.66e-006	uCi/gm	4.47e-001 MDA
Be-7	477.56	< 5.46e-006	uCi/gm	1.28e+003 MDA
Tl-208	583.14	< 4.57e-007	uCi/gm	5.17e-002 MDA
Bi-214	609.32	< 1.14e-006	uCi/gm	3.32e-001 MDA
Bi-212	727.17	< 1.46e-006	uCi/gm	1.01e+000 MDA
Po-210	803.00	< 2.16e-003	uCi/gm	1.00e+012 MDA
Ac-228	911.07	< 3.02e-007	uCi/gm	6.13e+000 MDA
Co-60	1173.22	< 9.41e-008	uCi/gm	4.62e+004 MDA
Co-60	1332.49	< 7.48e-008	uCi/gm	4.62e+004 MDA
K-40	1460.75	< 1.23e-006	uCi/gm	1.12e+013 MDA

Table D-5. Gamma Spectroscopy Results for Site 3 - Location 4. (sheet 3 of 3)

UNKNOWN PEAKS						
Energy (keV)	Centroid Channel	Net Counts	Un- Certainty	C.L. Counts	Bkg. Counts	FWHM (keV)
1274.13	5095.37	62	24	45	127	1.79

Table D-6. Gamma Spectroscopy Results for Site 3 - Location 4. (sheet 1 of 3)

M1/PC	Hanford-Ukraine Technical Exchange II	Ver. 1.00a
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Spectrum ID : suite 35

Location: Chornobyl - 30k Zone

Counting Start. 09-05-94 03:00 | Spectrum File site35.SPC

Decay Date. 00-00-00 00:00 | Live Time 600 Sec

Current Date. 10-19-94 14:25 | Real Time 680 Sec

Detector #: 1

Energy(keV)= $0.37 + 0.250 \cdot \text{Ch} + 0.00\text{e}+000 \cdot \text{Ch}^2 + 0.00\text{e}+000 \cdot \text{Ch}^3$ 09-05-94 01:55FWHM(keV) = $-0.10 + 0.118 \cdot \text{En} + -2.18\text{e}-003 \cdot \text{En}^2 + 0.00\text{e}+000 \cdot \text{En}^3$ 08-07-94 09:09

Where En = Sqrt(Energy in keV)

Sensitivity 0.20 | Search Start / End. 0 / 8191

Sigma Multiplier. 1.00 |

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L.	BKG COUNTS	FWHM COUNTS (keV)	FLAG
1	604.99	2418.65	1581	124	248	2520	3.42	
2	661.88	2646.21	41285	302	473	8541	3.60	
3	795.90	3182.35	1429	66	113	521	3.26	
4	944.24	3775.73	23	11	18	25	1.01	
5	1459.74	5837.85	234	30	56	101	2.13 a	
6	1462.15	5847.48	181	26	48	87	2.49 b	

Table D-6. Gamma Spectroscopy Results for Site 3 - Location 4. (sheet 2 of 3)

M1/PC Hanford-Ukraine Technical Exchange II Ver. 1.00a

1-Meter NUCLIDE ACTIVITY SUMMARY

Spectrum ID: suite 35

Location: Chornobyl - 30k Zone

Counting Start. 09-05-94 03:00 | Spectrum File site35.SPC
 Decay Date 00-00-00 00:00 | Decay Time [OFF]. 0.00e+000 Hrs
 Current Date. 10-19-94 14:25 |

Library File. 1-Meter.lib | ID. 1 Meter Analysis Library

Aspect Ratio = ...1.0 | Orientation = ...DOWN
 Detector Efficiency 40.0 % | Alpha/Rho File aged.rho

Gamma Fraction Limit >= . . . 80.00 % | Decay Limit <= 8.000 Halfives
 Library Energy Tolerance. . . 2.00

FINAL ACTIVITY REPORT

Nuclide	Energy (keV)	Conc +/- 1.00sigma	Halflife (hrs)	Peaks Found
Cs-134	Average: 604.70 795.84	3.85e-001 +/-1.53e-002 uCi/m2 3.53e-001 +/-2.77e-002 4.00e-001 +/-1.83e-002	1.81e+004	2 of 3
Cs-137	661.62	1.10e+001 +/-8.01e-002 uCi/m2	2.64e+005	1 of 1
K-40	1460.75	2.00e-006 +/-2.89e-007 uCi/gm	1.12e+013	1 of 1
Pa-234	98.44	< 3.10e-006 uCi/gm	6.70e+000 MDA	
Pb-212	238.63	< 1.68e-006 uCi/gm	1.06e+001 MDA	
Pb-214	351.99	< 1.68e-006 uCi/gm	4.47e-001 MDA	
Be-7	477.56	< 5.63e-006 uCi/gm	1.28e+003 MDA	
Tl-208	583.14	< 4.87e-007 uCi/gm	5.17e-002 MDA	
Bi-214	609.32	< 1.18e-006 uCi/gm	3.32e-001 MDA	
Bi-212	727.17	< 1.34e-006 uCi/gm	1.01e+000 MDA	
Po-210	803.00	< 2.03e-003 uCi/gm	1.00e+012 MDA	
Ac-228	911.07	< 3.75e-007 uCi/gm	6.13e+000 MDA	
Co-60	1173.22	< 8.45e-008 uCi/gm	4.62e+004 MDA	
Co-60	1332.49	< 7.48e-008 uCi/gm	4.62e+004 MDA	

Table D-6. Gamma Spectroscopy Results for Site 3 - Location 4. (sheet 3 of 3)

UNKNOWN PEAKS						
Energy (keV)	Centroid Channel	Net Counts	Un- Certainty	C.L. Counts	Bkg. Counts	FWHM (keV)
944.24	3775.73	23	11	18	25	1.01
1459.74	5837.85	234	30	56	101	2.13

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