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Subsurface Pulsed Radar Measurements

Beatty, Nevada
October 29 - November 2, 1979

Prepared by R. Beers, R. Morey

Geo-Centers, Inc.

Prepared for
U.S. Nuclear Regulatory
Commission

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Abstract

A ground penetrating radar system was employed at the low-level radioactive waste storage site at Beatty, Nevada to more accurately determine the location of the burial trenches. The survey was conducted after excavation work discovered waste storage drums beyond the known burial boundaries. The survey determined that several of the trenches extend approximately 60 feet further than records indicated.

TABLE OF CONTENTS

List of Figures

List of Tables

Subsurface Pulsed Radar Measurements

1. Introduction

This report describes the measurements and summarizes the results from a subsurface pulsed radar survey conducted at the low-level radioactive waste burial site located near Beatty, Nevada during the week of October 29-November 2, 1979. The work was performed under contract to the United States Nuclear Regulatory Commission (NRC) as part of the NRC's response to a request for assistance from the Department of Human Resources of the State of Nevada.

In the course of excavations being carried out in October, 1979 by the United States Geological Survey (USGS) at the Beatty site, several barrels of low-level radioactive waste were discovered beyond the established boundary of the burial area, although well within the facility's property. This discovery demonstrated an apparent deficiency in the records of the locations of the older waste trenches and indicated the need to quantitatively define these trench boundaries using non-intrusive subsurface survey techniques.

Since the waste has low specific activity and is shielded by the backfill, nuclear detection methods are not fully effective; similarly, traditional geological tools such as seismology, magnetometry, metal detection and resistivity suffer variously from a lack of sensitivity or limited spatial resolution.

A complementary subsurface technique, video pulsed radar, offers the promise of adequate penetration depth coupled with excellent spatial resolution. A demonstration field test of the radar profiling system had just been completed for the NRC; and although the data analysis was incomplete, preliminary results suggested the usefulness of the technique to the assessment of the situation at Beatty.

2. Beatty Waste Storage Site

The Beatty waste storage site, the first such privately operated facility in the United States, is owned by Nuclear Engineering Company (NECO) of Louisville, Kentucky. Established in 1962, the site is located near Beatty, Nevada, more than 100 miles north of Las Vegas. Originally licensed by the United States Atomic Energy Commission (AEC), the facility currently operates under license from the State of Nevada.

By January, 1971 a nuclear burial area consisting of 12 long trenches on the north-central sector of the site had been filled with more than 40,000 curies of low-level waste including approximately 40 Kg of special nuclear material (SNM). As the trenches were excavated and filled, various temporary markers were emplaced to define their extent. In 1975, in an effort to standardize and upgrade the marker system, a new set of permanent monuments was installed at the head and foot of each of these 12 trenches. Table 1 summarizes the dimensions and history of these trenches as described on the monuments. An aerial photograph of the site, taken in 1976, is shown in Figure 1 with an enlargement of the nuclear disposal area shown in Figure 2.

As part of a research effort during October, 1979, the USGS began digging a trench-tunnel complex under the Beatty burial site to measure the potential leaching or migration of buried material. Beginning the excavation from the north and proceeding south under the center of the old burial ground, the USGS team encountered five barrels of low-level waste approximately 50 feet beyond the established burial area and its fenced boundary. Figure 3 is an engineering drawing of the location of the trenches, their monuments, the USGS excavations and the discovered waste barrels.

Therefore, various experimental teams brought in by the USGS, NRC, DOE, the State of Nevada and NECO undertook a variety of measurements in an effort to completely define the real extent of buried waste material.

The remainder of this report discusses the measurements and findings from the subsurface pulsed radar survey conducted under contract to the NRC.

3. System Description

Subsurface radar detection systems have been the object of study for over a decade by both military and environmental agencies. In both applications, the purpose is to locate and, hopefully, identify buried or submerged objects otherwise not detectable.

The principle of operation involves the generation of a pulse train of electromagnetic (EM) radiation in the frequency range of 10-1000 MHz. In accordance with the laws of classical electromagnetism, the wave will propagate, with material dependent attenuation, through a given medium, e.g., the earth. When the wavetrain encounters a material or boundary

Table 1. Nominal Trench Parameters

North Section of Nuclear Burial Site-Beatty, Nevada

Trench #	Depth (feet)	Length (feet)	Width (feet)	Date of Opening	Date of Closing
8	6	300	4	July, 1966	October, 1966
9	6	300	4	March, 1967	May, 1968
11	6	300	4	May, 1968	December, 1968
12	6	300	4	Dec., 1968	June, 1969
13	6	300	4	June, 1969	December, 1969
15	10	300	10	Dec., 1969	January, 1971
3	20	300	40	October, 1963	August, 1964
5	20	300	40	June, 1965	February, 1966
4	20	300	40	Sept., 1964	June, 1965
2	20	300	40	January, 1963	September, 1963
1	20	300	31	October, 1962	January, 1963
6	6	300	4	July, 1965	July, 1966

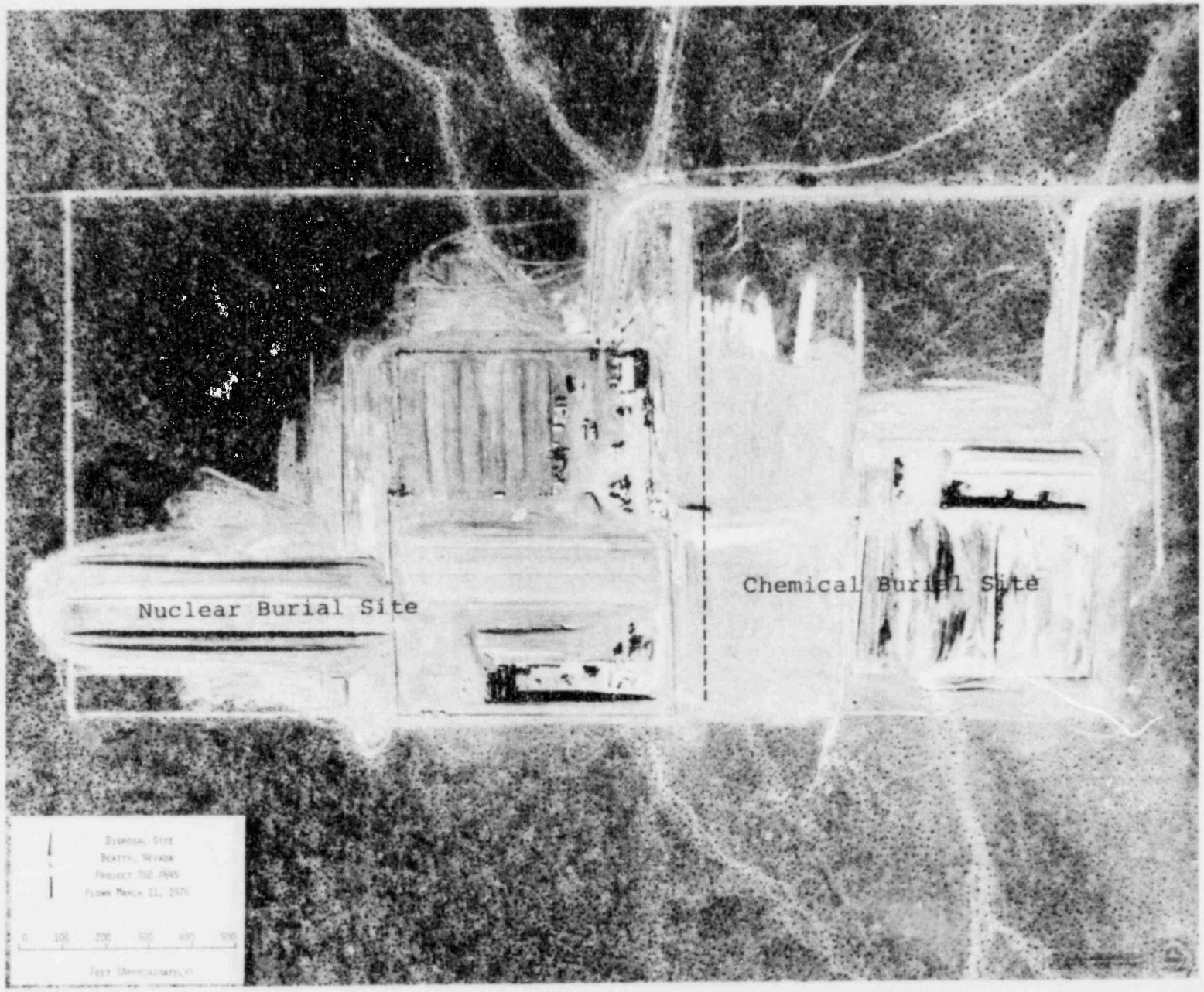

Figure 1: Aerial View of the Waste Disposal Site Near Beatty, Nevada.

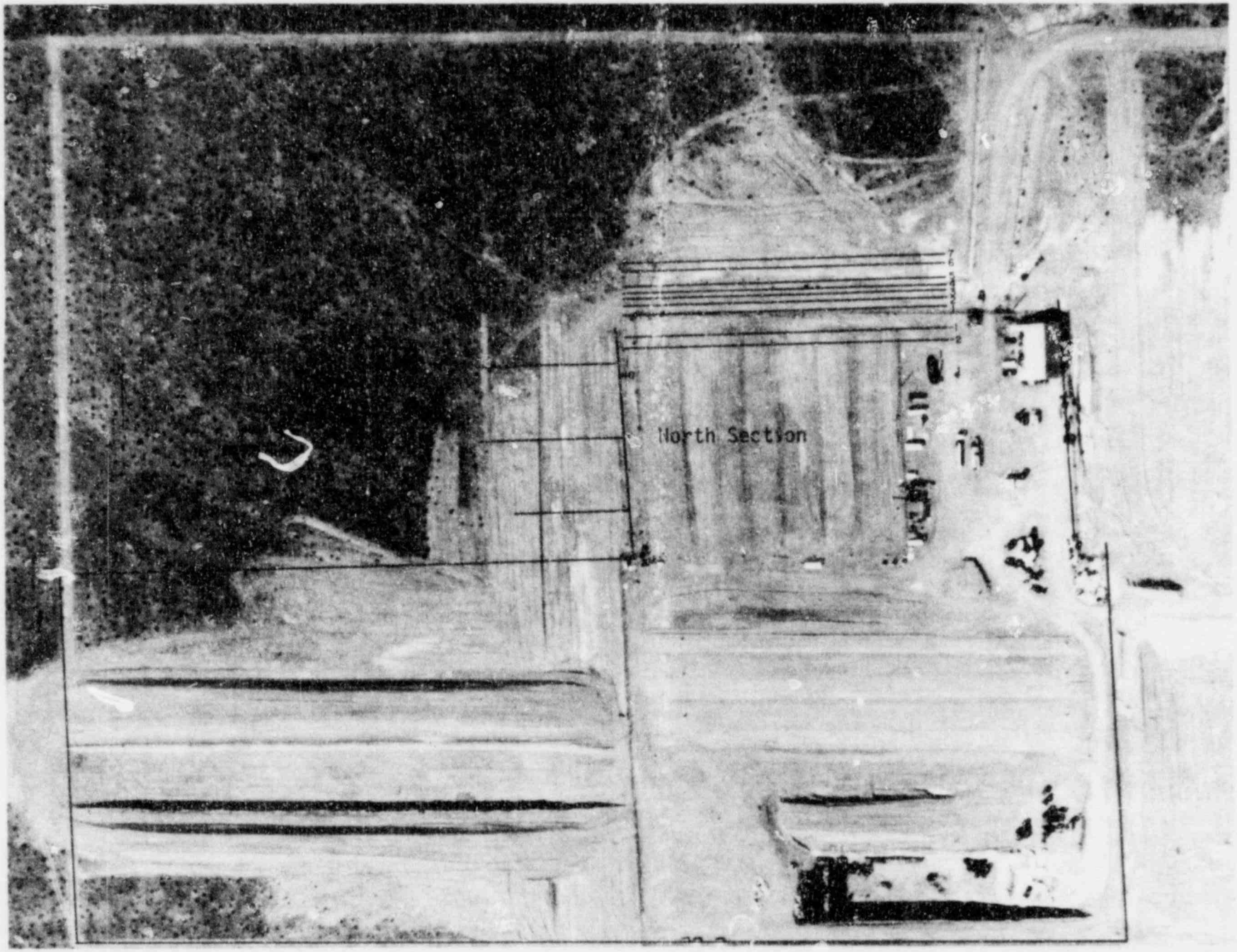

Figure 2 Aerial View of Nuclear Waste Section of Disposal Site Near Beatty, Nevada (survey lines superimposed).

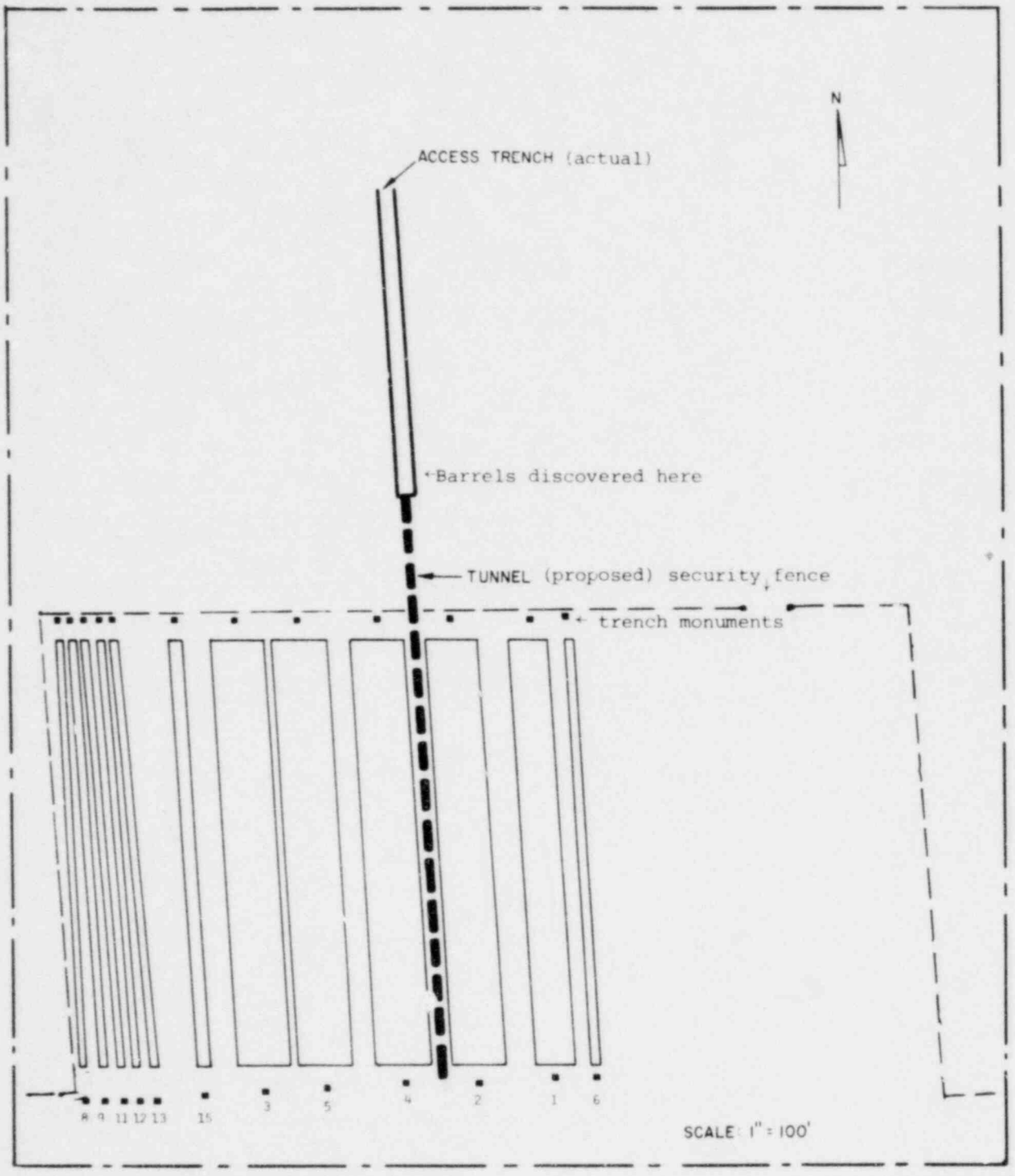

Figure 3: Facility Layout Nuclear Waste Trenches (North Section) at the NECO Site near Beatty, Nevada; Showing USGS Access Trenches and Tunnel Complex.

of different dielectric properties, the wave will be partially reflected. This reflected wave is then detected and the time interval between transmission and detection is recorded. As part of the calibration, the velocity of propagation of the EM wave in the particular medium is measured. Hence, the time interval can be converted to a distance or depth. Depending upon the intensity and phase of the return signal, inference as to the composition of the reflecting material is possible. For example, metallic objects have much different dielectric properties than soils and will therefore give rise to strong reflections and a phase shift; geological interfaces, on the other hand, give relatively weak reflections and no significant phase shift.

A selection of antennas, designed to operate at different frequencies, is available. There is a trade-off between penetration depth achieved at low frequencies, and spatial resolution at higher frequencies. Thus, the system yields better resolution at the expense of penetration depth; conversely, greater penetration is achieved at the expense of resolution.

The particular system used was a Geophysical Survey Systems, Inc. (GSSI) System 7, a block diagram of which is shown in Figure 4. Two antenna Systems were used. The first was a standard GSSI 80 MHz model with penetration depths of 15-20 feet (under soil conditions at Beatty) and spatial resolution of several inches; the second was an experimental model developed by Geo-Centers operating at 10 MHz and having penetration depths of 30 feet or more with a resolution of a few feet. All results presented in this report were derived from the high frequency antenna, which offered adequate penetration and excellent spatial resolution.

The equipment consisted of a portable, gasoline-powered electrical generator, a control unit, a graphic recorder and a tape recorder, which were all mounted in a rented van. The antenna was attached via a harness behind the van at a distance of approximately 20 feet and was pulled across the survey area at a speed of 2-3 miles per hour.

The data were recorded on magnetic tape and on strip chart paper, the latter information being compressed because of the high input data rate. After the field survey, the magnetic tape was played back at a slower speed to generate full resolution hard copy for visual analysis.

4. Operations

A team of four scientists; two from the NRC and two from its technical contractor, Geo-Centers, proceeded to Beatty, Nevada,

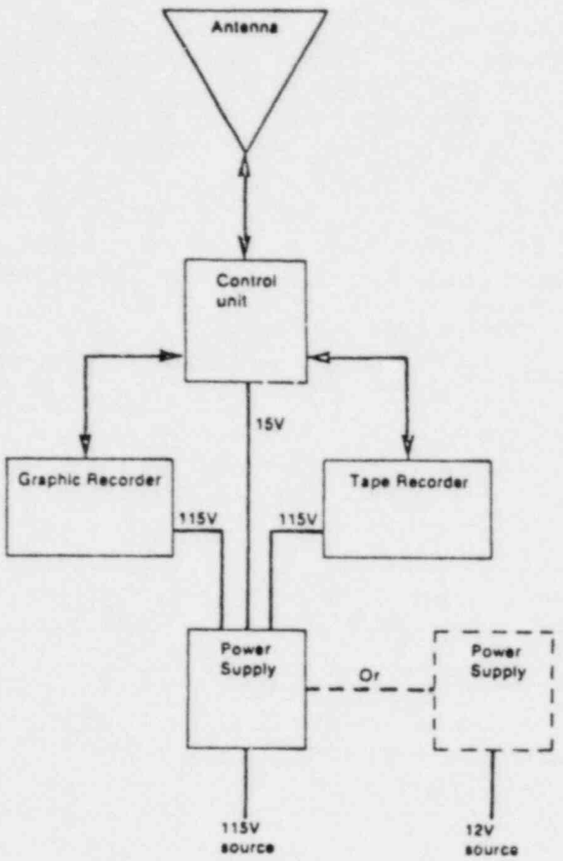

Figure 4 Block Diagram of Subsurface Impulse Radar System.

to conduct the survey, with coordination from a representative of the Department of Human Resources, State of Nevada, and with the cooperation of the NECO management.* The equipment, except for the Geo-Centers' antenna, was made available to the NRC by the USGS from Denver. In fact, Dr. G.Olhoeft of that office participated in the preliminary measurements; and his designate, Mr. D. Nichols, remained on-site during the course of the survey.

The area to be surveyed was established by the consensus of the on-site officials from the State of Nevada, NRC, USGS, and NECO using information contained in aerial photographs and plant records. Of primary importance was a detailed mapping of the logical extension of all the older trenches (where the USGS made its discovery). Of next importance was the area parallel to the older trenches and outside the fence. Lastely, it was deemed worthwhile to perform a complete perimeter scan of the nuclear portion of the Beatty site. Figure 2 shows an aerial view of this nuclear section with the survey lines superimposed. Figure 5 shows an expanded view of the area where the measurements were concentrated and where anomalies were recorded.

The nuclear waste area boundary as shown in Figure 2 was mapped using the GSSI 80 MHz antenna with an estimated penetration depth of 15-20 feet. That area within the temporarily erected fence and over the trenches themselves was surveyed as above and re-surveyed using the Geo-Centers experimental antenna with penetration depths in excess of 30 feet.

A grid system was established by NECO personnel by driving stakes into the ground on ten foot centers throughout the region of concern. In peripheral areas a coarser system on thirty foot and then one hundred foot centers was established. As the antenna passed over these respective markers, the data tape was indexed. Further indexing was done by referencing the data to permanent markers such as the trench markers and fence posts. Based upon this grid system, the coordinate data are accurate to a few feet.

The coordinate system is shown in Figure 5 and is defined as follows:

1) The fence Line at the north end of the old burial site is labelled line "0".

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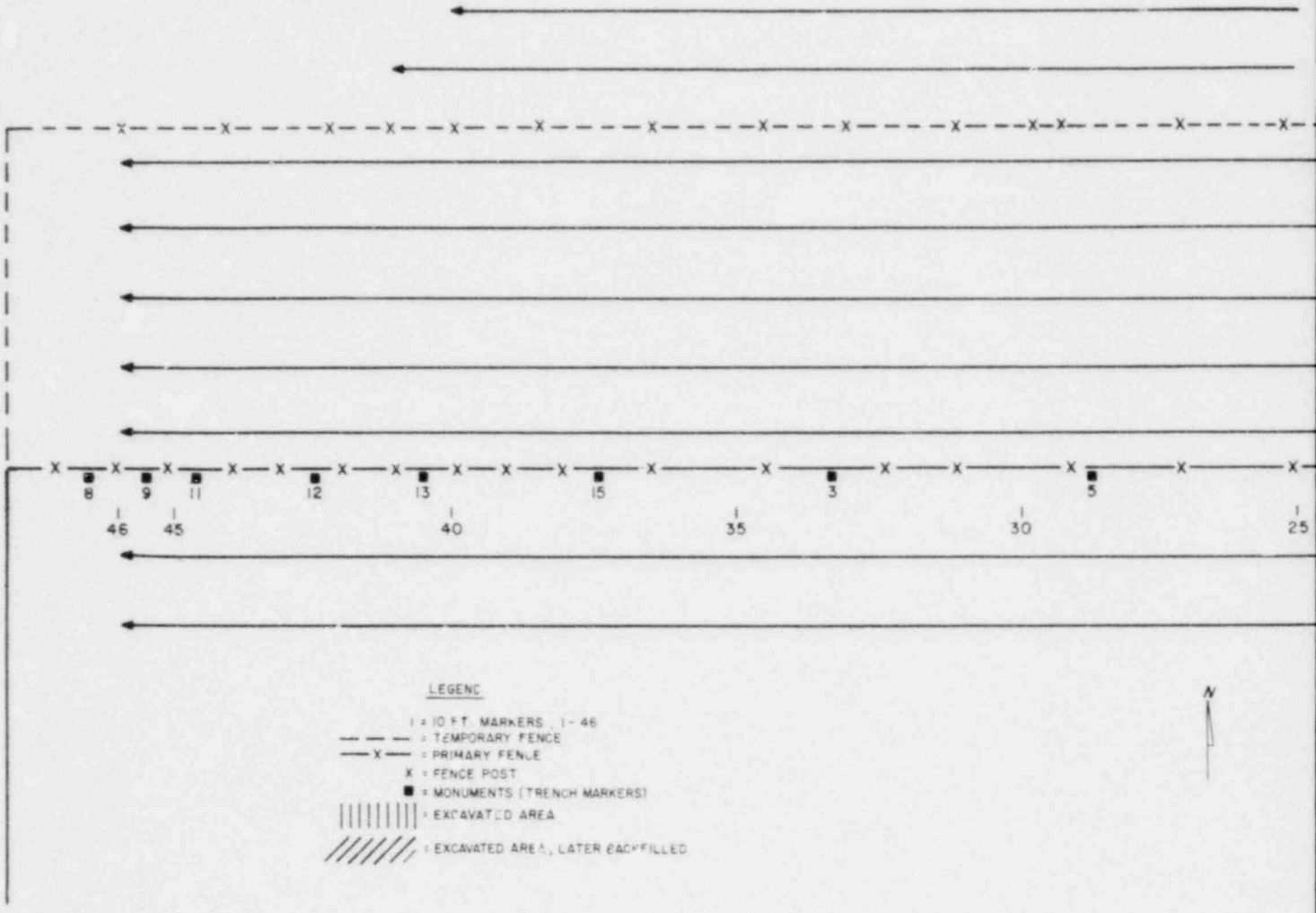
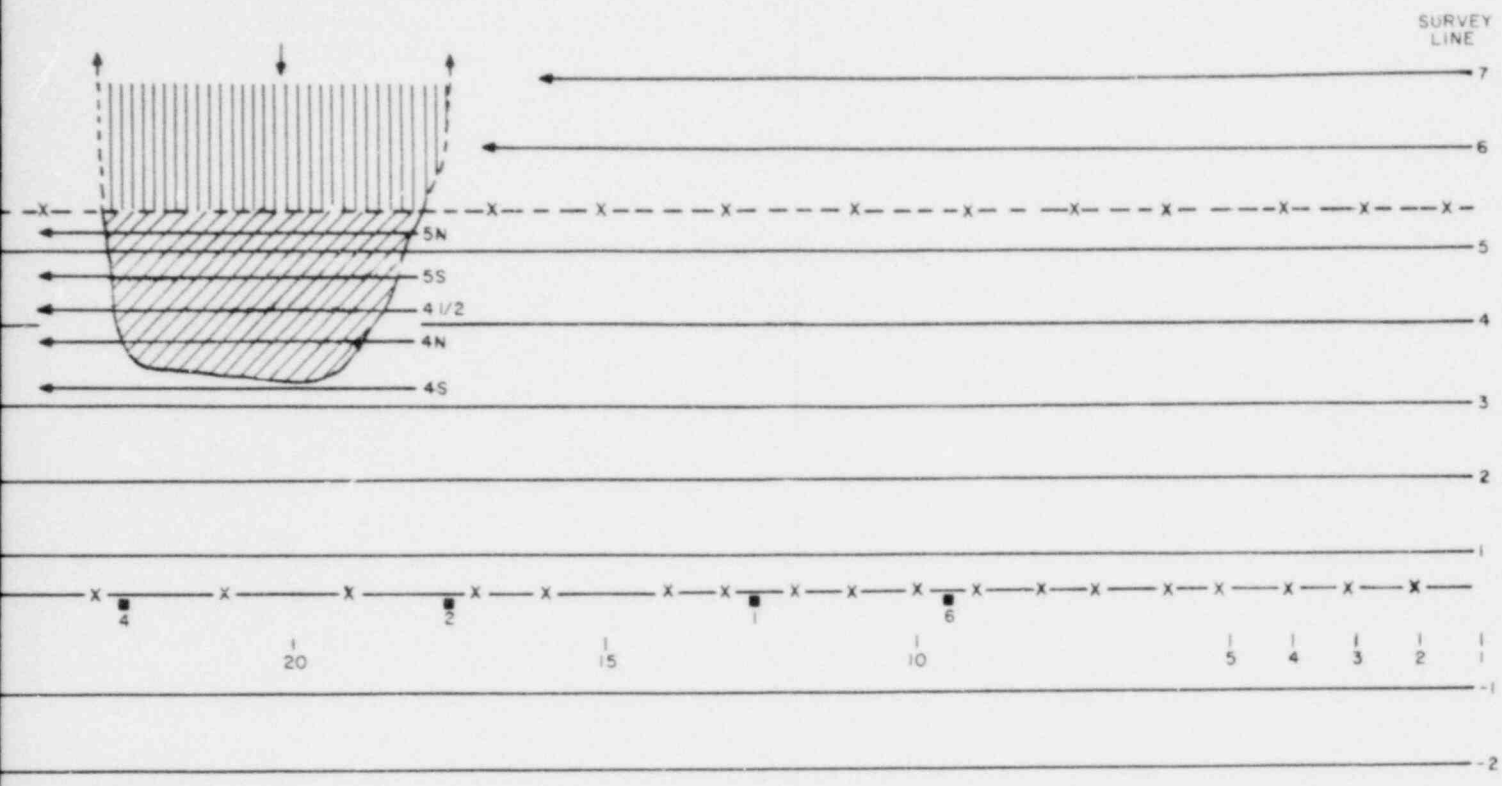
* Messrs. C. Jupiter and J. Thomas of the NRC; Messrs, R. Beers and R. Morey of Geo-Centers; Mr. J. Vaden of Nevada; and Mr. S. Carpenter of NECO.


8
9
11
12
13
15
3
5
46
45
40
35
30
25
LEGEND
| = 10 FT. MARKERS, 1 - 46
— — — = TEMPORARY FENCE
—x— = PRIMARY FENCE
x = FENCE POST
■ = MONUMENTS (TRENCH MARKERS)
= EXCAVATED AREA
= EXCAVATED AREA, LATER BACKFILLED
N



Primary fence represents the northern most boundary of the nuclear section of the Beatty Waste Storage Site.

Numbered monuments indicating the northern ends of the burial trenches are shown

Survey lines (-2 & -1) scanned northern ends of the trenches.

Survey lines (+1 through +7) scanned the suspect area to the north of the trenches.

Short survey lines (5N through 4S) scanned the backfilled excavation area where the USGS discovered waste containers.

The temporary fence was erected by NECO after the USGS discovery to enclose the suspect area.

Figure 5: Detailed Survey Grid of the Area to the North of the Old Nuclear Burial Area - Beatty, Nevada (solid lines with arrows represent actual survey lines).

2) Lines to the south of this reference, i.e., within the burial area, are sequentially labelled "-1" and "-2" at approximately 15 and 25 feet, respectively, from the "0" line.

3) Lines to the north are sequentially numbered 1, 2, 3, etc. at 5, 15, 25 feet, etc. from the "0" line.

4) The east end of the survey area was bounded by a temporary fence assigned as grid position "0".

Successive grid markers from east to west are labelled 1, 2, 3, etc. ending at 48 where the western end of the secondary fence was encountered. A typical data line would be identified by line number "X" with grid marks superimposed from 1 through 46 as the antenna passed a set of stakes. Grid markers "0" and "48" are coincident with the fences and could not be recorded; and the length of the truck usually precluded recording "47". Other "missing" data are attributable to inaccessable terrain, e.g., the USGS excavations. After completion of the radar measurements, a crew from REECO, Inc. conducted a land survey to permanently define locations relative to absolute markers.

5. Data Processing

To establish baseline and calibration signatures a series of preliminary scan lines were generated:

1) A baseline run approximately 210 feet from the primary fence (line "0") was made to establish a geological and system background. Signatures were representative of the local geology and exhibited the presence of many subsurface disturbances due to strata and buried rocks. Similarly, the effects of the antenna being jostled over the terrain and other noise contributions were made manifest.

2) To establish characteristic signatures from trenches and buried debris, calibration lines were scanned over the designated burial area (lines "-2" and "-1") and over the backfilled USGS excavation where several waste containers were known to be present. Examples of these calibration data are shown in Figures 6 and 7.

The magnetic tape data were played back and full-scale hard copies of the electrostatic print-out were generated. Data from parallel lines were displayed side-by-side to permit visual correlation. In the absence of computer processing

techniques for filtering and enhancement of effects, the results were visually analyzed and interpreted by a team of six scientists, engineers and geologists.

6. Discussion of Results

Figure 6 shows a portion of a data record taken inside the primary fence (line "-1") over the designated locations of trenches numbers 3, 15, 13 and 12. While in their unprocessed form these data may appear difficult to interpret, some features are apparant:

1) There is a general region of disturbance in the vicinity of the designated location of trench no.3. The disturbance is approximately 40' wide, begins directly beneath the surface, and exhibits smaller anomalies at depths greater than 4'. The centerline of this region is displaced approximately 10' from the trench marker. Referring to the site records (Table 1), trench no. 3 is approximately 40' wide and 20' deep. The radar data appear to resolve the sides of the trench and objects buried within it, but do not resolve the bottom.

2) There are no indications of any signals in the area around trench no.15.

3) In the designated location of trench no. 13 are very strong return signals from two or more objects, judged to be metallic, at a depth of approximately 5'; the width of disturbance is approximately 5'. Again referring to Table 1, trench no. 13 is reported as being 6' deep and 4' wide.

4) In the vicinity of the designated location of trench no. 12, there are no indicators of buried debris, but there does appear to be a disturbance from the side of the trench. While difficult to resolve, the radar data suggest that the trench has sloping sides with a width of 5' - 10'. The records (Table 1) show a trench having a depth of 6' and a width of 4'.

Figure 7 shows a portion of a data record from a scan over the backfilled excavation in which the USGS discovered the waste barrels outside the burial site fence. Unlike the record discussed above, the only anomaly or disturbance is from the isolated barrels. The properties of the host soil exhibit continuous features, i.e., a constant background; against which anomalies are readily detected.

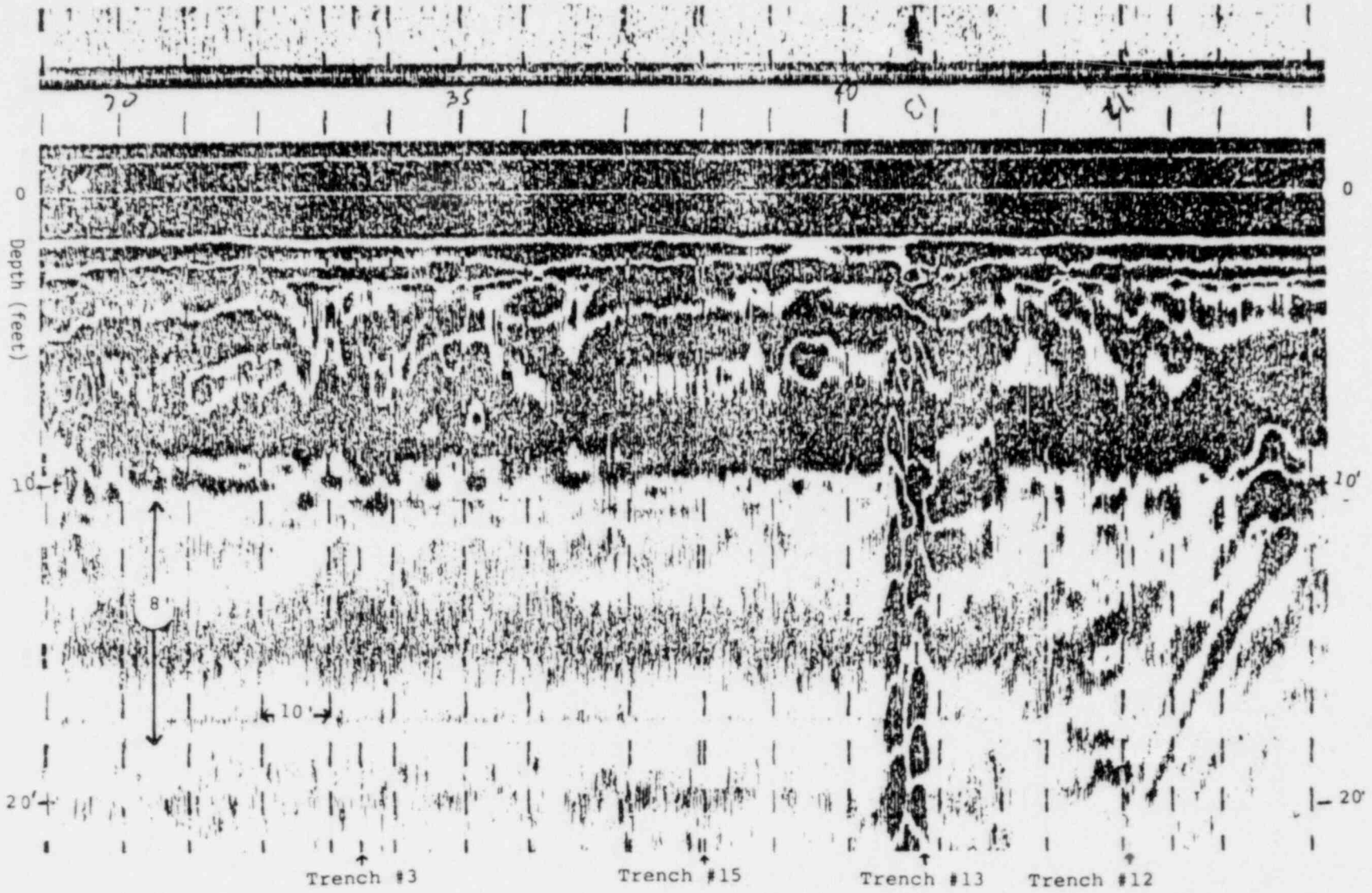


Figure 6: Radar Reflection Data, Inside Fence, Line -1, Showing Disturbances at the Location of Trenches 3, 13, and 12. Metallic object is evident in Trench 13.

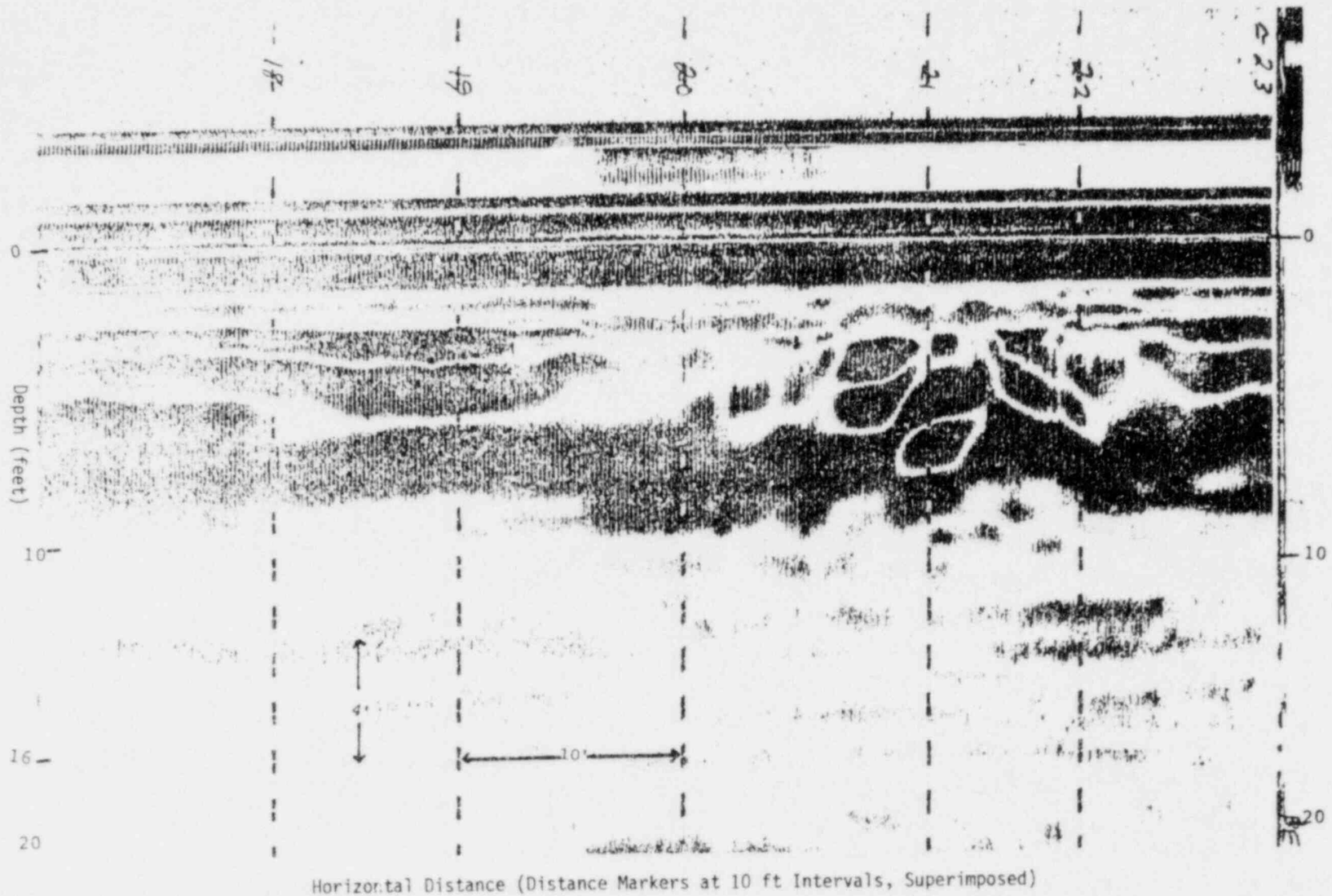


Figure 7: Radar Reflection Data, Excavation Area, Line 4S, Showing Signals from Buried Barrels Near Markers 21-22.

With these characterized signatures on record, the remaining data were visually examined for similar features. Further, since the line spacing between adjacent scan lines was only 10 feet, the field of view of the radar generated overlapping records that permitted data correlation. While all data, both from inside and outside the fence were examined, particular attention was paid to records to the north of the designated burial area. A typical data record from this area is shown in Figure 8. Among the items of interest from this record are:

1) There is a very strong near surface reflection from a thin metallic object whose signature strongly resembles that from a utility pipe or a section of accidentally buried fence post.

2) Nearby the projections of the designated locations of trenches no. 15 and 13, there appears to be a series of disturbances across a width of 30 feet. The reflections are judged to be from metallic objects at a depth of 9'.

3) In the area of the projected extensions of trenches no. 12, 11 and 9, there appears to be more general clutter, generally near the surface, but with no obvious metallic objects.

For the purposes of presentation, subsurface disturbances have been divided into three general categories: near surface disturbances (2' or less), subsurface disturbances (greater than 2'), and subsurface metallic objects. The data were analyzed as described above, anomalies were designated and sorted into one of the three categories, and the results summarized in Figure 9.

These results make a strong case for the probable mismarking of the northern limits of the burial trenches. It appears that most, if not all of the trenches west of and including no.4 extend 50-60 feet beyond the trench markers. Further, many of these trenches contain metallic debris, some of which are certainly barrels. Lastly, the centerlines of these trenches do not necessarily line up with the trench monuments.

On the other hand, there are no data to suggest that these trenches or any other burials exist beyond these limits. All anomalies appear to be confined to within the 480' X 60' area immediately to the north of the trenches, which had been enclosed by the temporary fence. Specifically, there were no indicators of any anomalies around the perimeter of the nuclear burial site or to the west of these trenches.

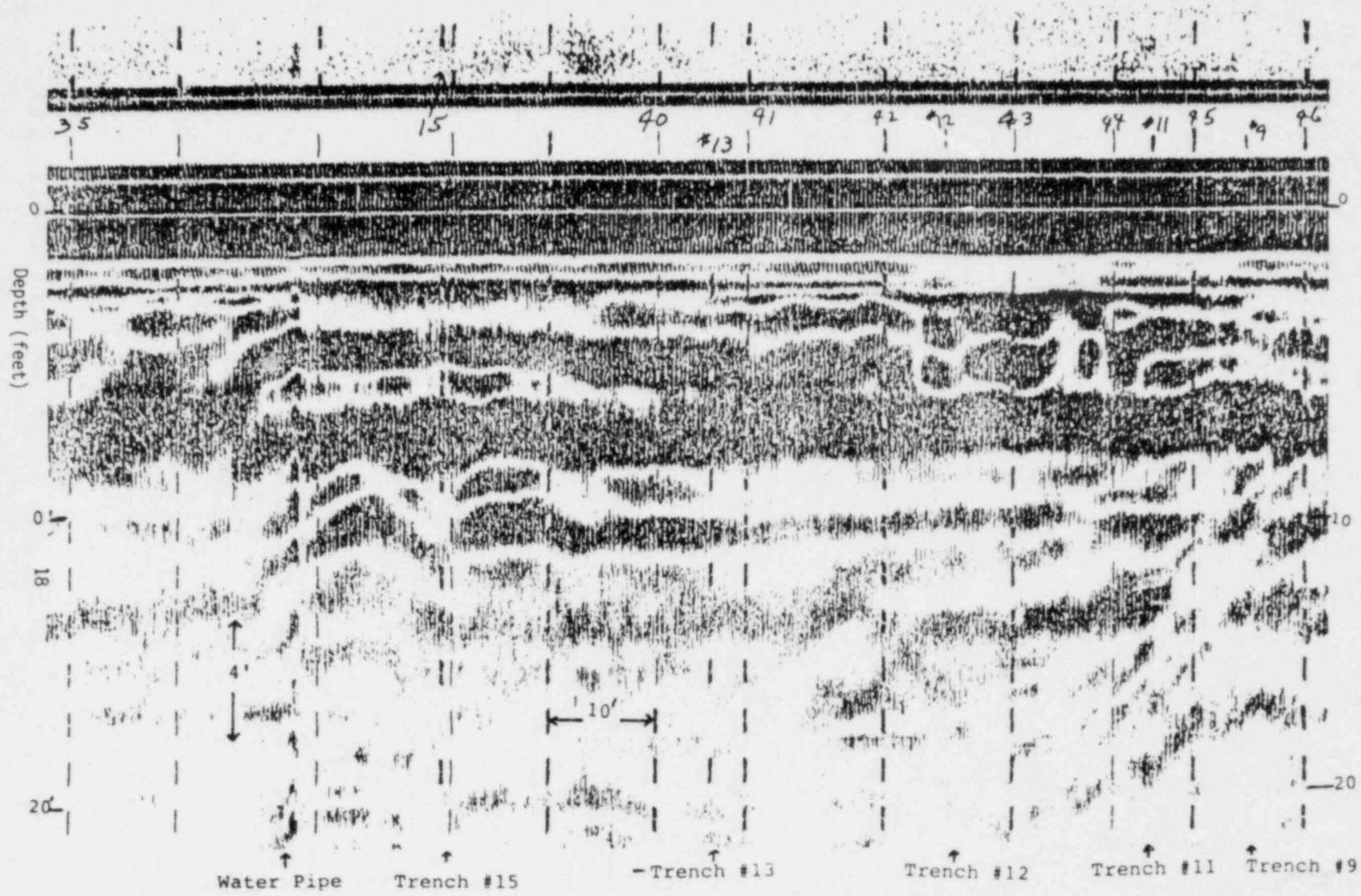
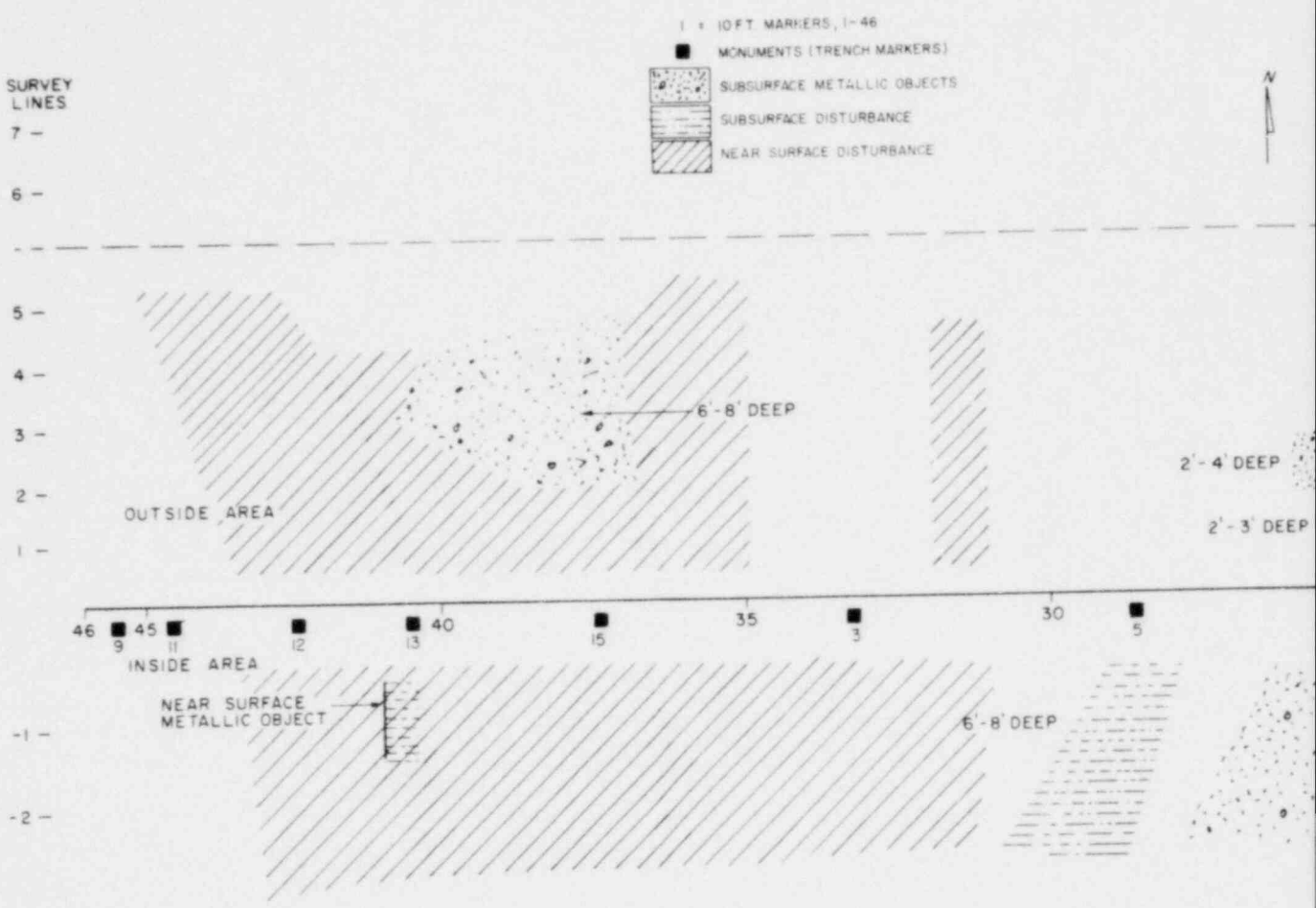
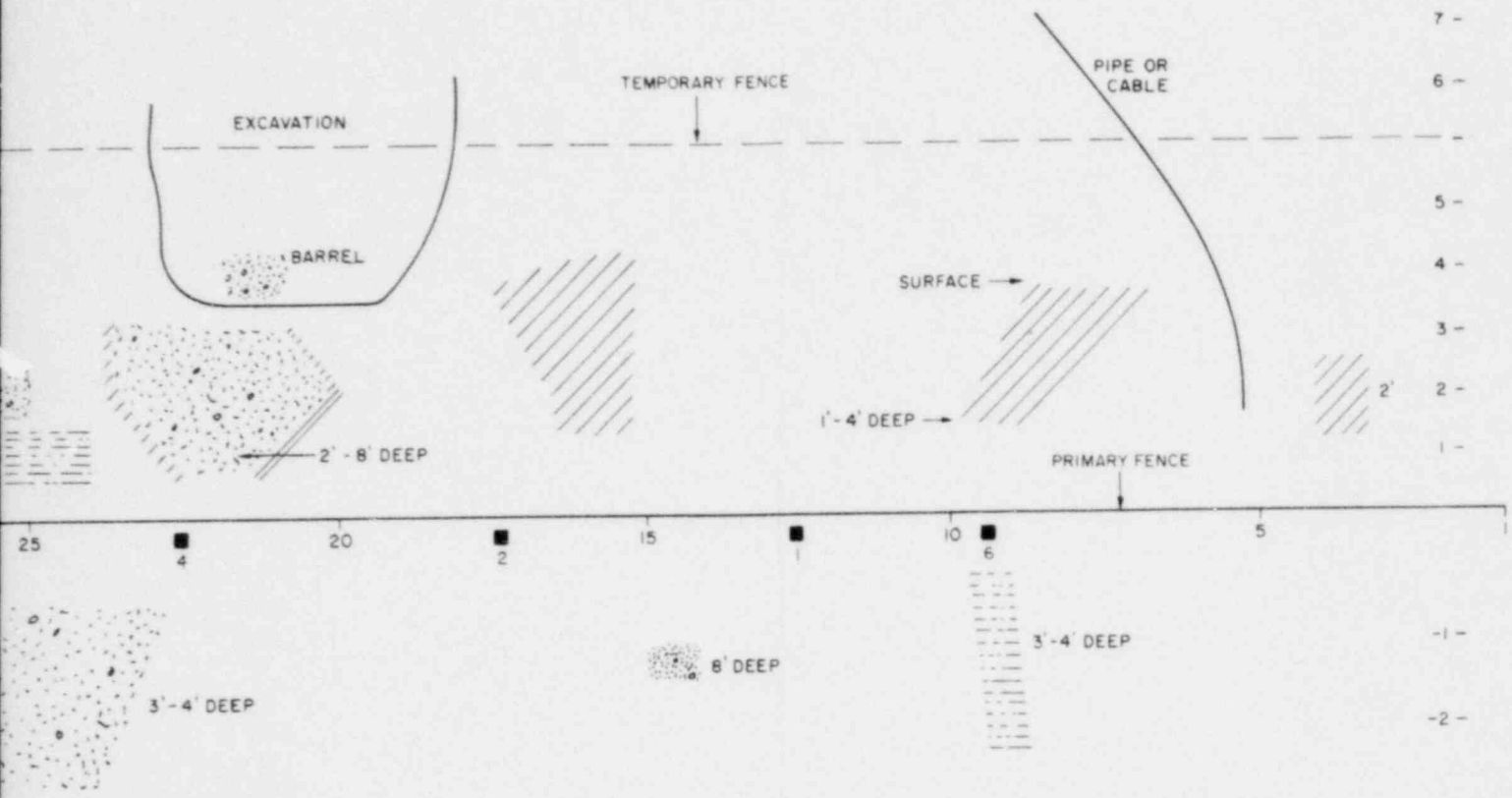


Figure 8: Radar Reflection Data, Outside Fence, Line 2 Showing Man-Made Disturbances along Projections of Several Trenches.


1 = 10 FT. MARKERS, 1-46
MONUMENTS (TRENCH MARKERS)
SUBSURFACE METALLIC OBJECTS
SUBSURFACE DISTURBANCE
NEAR SURFACE DISTURBANCE
N
SURVEY LINES
7
6
5
4
3
2
1
-1
-2
6'-8' DEEP
2'-4' DEEP
2'-3' DEEP
OUTSIDE AREA
INSIDE AREA
NEAR SURFACE METALLIC OBJECT
46
9
45
11
12
13
40
15
35
3
30
5



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Survey lines (-2 & -1) scanned northern ends of the trenches.

Survey lines (+1 through +7) scanned the suspect area to the north of the trenches.

The temporary fence was erected by NECO after the USGS discovery to enclose the suspect area.

Figure 9: Survey Results Showing Measured Subsurface Anomalies and Buried Material.

The unpublished results of resistivity and radioactivity measurements have corroborated the radar findings.

Resistivity measurements show general disturbances in the western half of the 480' X 60' area to the north of the trenches. These results show less resolution and detail than the radar results, but are nonetheless, in good agreement.

Radioactivity measurements were made after the radar measurements and concentrated on areas that had been designated as "suspect". These measurements too showed definite anomalous readings in the western half of the 480' X 60' sector. Particular isotopes identified were Cs^{137} and Co^{60}. Count rates at the surface at the energies characteristic of these isotopes were as much as 10-100 times background, definitive proof of the existence of radionuclides, but representing no health hazard.

7. Summary

A subsurface pulsed radar scanning system was used to survey peripheral areas around the nuclear burial grounds of a low-level waste storage site near Beatty, Nevada. Conducted during a one week period immediately following the accidental discovery of buried material outside the designated burial area, the results of the survey indicate that several trenches extend beyond their stated boundaries. On the other hand, the limits of this extension are within 60 feet of the stated boundaries, which are well within the plant properties and currently protected by a security fence.

While unpublished at this time, results from resistivity and radioactivity measurements have confirmed these results.

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16. ABSTRACT (200 words or less)

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