Department of Energy
Eastern Measurements Office
P.O. Box 380
Suitland, Maryland 20752

January 30, 2001

Orysia Bailey
Nuclear Regulatory Commission
61 Forsyth Street, SW
Atlanta, Georgia 30303

Enclosed please find the information you requested from Dr. Kevin Phoenix. The two tables contain AMS detection sensitivities originally prepared for distribution to parties involved with decommissioning work. Be aware that many factors affect these detection limits. Depth of burial, soil composition and local background radiation levels all have to be considered when discussing aerial detection limits.

Another option available for the location of buried waste sites involves the use of multispectral techniques on an airborne platform. We have also included a technical paper describing the application of airborne multispectral techniques to the search for historical waste burial sites at Los Alamos National Laboratory. This powerful tool is particularly suited to the search for buried waste sites where attenuation of the radiation due to overlying soil limits the application of airborne radiation detectors.

I'd like to extend an invitation for members of your office to visit either of our facilities at Nellis AFB in Nevada or Andrews AFB in Maryland. The Remote Sensing Laboratory at Nellis AFB is the home of DOE's aerial multispectral capability.

Please feel free to contact Dr. Phoenix at (301) 817-3365 with any questions you may have concerning aerial radiation measurements. Dr. Bill Ginsberg at (702) 295-8031 can answer any questions you have regarding the multispectral systems.

Thomas D. Wiard

Thomas D. Wiard
Site Manager

Enclosure: as stated

Minimum Detectable Activity

	Helicopter			
	50 ft.	150 ft.	Kiwi	HPGe[c]
	(pCi/g)[a]	(pCi/g)[a]	(pCi/g)[a]	(pCi/g)[a]
^{137}Cs	0.3	0.4	0.3	0.05
^{60}Co[b]	0.08	0.1	0.05	0.03
^{241}Am	2	5	2	0.4

Site Specific Values May Vary 2X

a) Uniform soil concentration

b) Both lines included

c) 70% N-type, 15 min.

Bechtel Nevada

Minimum Detectable Spot Diameter

	50 ft.	150 ft.	Kiwi	HPGe
	diameter (ft)	diameter (ft)	diameter (ft)	diameter (ft)
^{137}Cs	20	50	2	0.5
^{60}Co	10	30	0.6	0.4
^{241}Am	40	150	4	1.2

Uniform Circular Spot with Concentration of 20 pCi/g

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Remote Sensing Characterization of Selected Waste Sites at the Los Alamos National Laboratory

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ABSTRACT

The paper presents some examples of the use of remote sensing products for characterization of hazardous waste sites. The sites are located at the Los Alamos National Laboratory (LANL) where materials associated with past weapons testing are buried. Problems of interest include the detection and delineation of buried trenches containing contaminants, seepage from old septic drain fields, and location of faults and fractures relative to hazardous waste areas.

Overlays of suspected trench locations on multispectral and thermal images showed correlation between image signatures and trenches. Overlays of engineering drawings on recent and historical photos showed error in trench location and extent. A thermal image showed warm anomalies suspected to be areas of water seepage through an asphalt cap. Overlays of engineering drawings on multispectral and thermal images showed correlation between image signatures and drain fields.

INTRODUCTION

A legacy of the cold war with its emphasis on weapons production has led to environmental problems at the Department of Energy (DOE) sites where nuclear weapons and materials were produced. The present problem is widespread, occurring at sites in 34 states, involving a wide variety of wastes including radionuclides, and hazardous organic and inorganic chemicals. Current efforts are underway to detect, map, characterize, and clean up subsurface contaminants including leakage from landfills and other contaminated plumes, buried objects such as pipes, drums and tanks, old buildings, covered trenches and pits.

Unfortunately, areas of waste disposal at DOE sites are not all documented and located. There are a number of reasons for this situation: records have been lost or destroyed, the locations were not documented, and memories have been lost. The search of large areas at these sites for buried waste and buried waste containers is a difficult and expensive problem when using conventional, ground-based methods. Typical conventional methods involve the drilling of wells/boreholes (point sampling), and interpolation between holes is required to obtain the needed areal information.

Drilling for buried waste is expensive, potentially hazardous, and time-consuming, yet accurate interpolation can require a large number of holes per-unit-area. A similar problem is encountered in gaining current information about the boundaries of toxic waste plumes in the ground, transport pathways, and the composition and concentration of toxic materials.

With drilling operations costing hundreds of thousands of dollars per hole, the reduction in the number of holes is of great concern. And just as importantly, safety must be a principal consideration when drilling to explore for unknown buried waste. Alternatives to conventional ground-based methods need to be evaluated. To consider alternatives an effort was begun to analyze existing remotely sensed data. By using remote sensing methods to reduce the ground area to be considered, the amount of actual drilling needed can be reduced.

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To K. Vlaming	From B. Ginsberg
Co.	Co.
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LANL is the test facility for the collection of remote sensing data from aircraft and satellite. Many of the chosen sites had archival data available for analysis which include aerial photography, multispectral and infrared imagery, radar imagery, and nuclear radiometry. Those data have been collected by commercial and Government sensors, and span an appreciable time interval.

Several known and suspected sites at LANL were chosen as important areas in need of help from remote sensing. Existing imagery from each area was reviewed and site managers collaborated on the concept for solutions. Preliminary processing of imagery was done for many site problems and the most fruitful are being produced in a brochure.

Imagery data used for this project include airborne multispectral Daedalus imagery collected for DOE over Los Alamos by DOE Remote Sensing Laboratory (RSL) in 1994 and coincident natural color aerial photography; LANDSAT TM, SPOT, and 1989 Russian KFA-100 satellite imagery; historical photographs since 1935, ground photos taken during the project and recent orthophotos. Other information includes airborne nuclear (gamma) surveys flown by RSL in 1994, digital map information, and engineering drawings of burial sites.

The Environmental Research Institute of Michigan (ERIM) was contracted by DOE's Morgantown Technology Center (METC) to collect the data, choose sites of focus and perform special processing. The results have been presented to LANL on-site managers for determining the site- specific applications.

SITE SELECTION

Between 3 and 10 sites were sought to demonstrate the use of remote sensing for DOE waste sites. A technical workshop was held in Los Alamos to invite LANL site managers to suggest and review potential sites. Ten sites were selected. Locations of these sites are shown on a SPOT image of LANL, with a preliminary gamma radiation contour obtained in 1994; Figure 1. Other features on Figure 1 will be discussed later in the paper.

To be a final candidate, a site had to satisfy 5 criteria:

1.) The LANL Environmental Restoration Program felt that there was a problem to be solved at the site.
2.) Some problem at the site was amenable to a remote sensing solution, that is, image exploitation was scientifically possible.
3.) A site manager would take an interest in the project, that is, would take the time and had the knowledge to help find a solution.
4.) Good ground truth was available so that the demonstration products would be credible.
5.) Imagery at the right times, wavelengths, resolution, etc., was already available.

Sites were named after the site manager that expressed an interest. Seven out of ten sites were selected:

Rofer-1 Site: Detecting and delineating relatively known and unknown trenches.
Mynard Site: Determining location and extent of seepage for septic drain fields and holes, buried cable and firing pits.

Becker Site: Displaying sampling areas by hydrologic category and contaminant concentration.

Glatzmeier Site: (not selected)

Rofer-2 Site: (not selected)

Koch Site: Evaluating faults and fractures beneath waste disposal areas, assessing vegetative and thermal anomalies.

Hoard Site: Locating pits and comparing to engineering drawings.

Mason Site: Assessing thermal hot spots in an asphalt cap; locating contaminated trenches, shafts and drains.

Whole Lab: Relating gamma radiation contours to known contaminated areas.

Wheat Site: (not selected)

The Glatzmeier Site problem was resolved right after the workshop and was not considered further. At the Rofer-2 Site, ground disruption by recent environmental work severely degraded possibilities for a demonstration area. At the Wheat site only the low resolution lab-wide coverage was available so existing imagery was inadequate to address the problem.

ANALYSIS METHODS

Most of the image processing for this paper concentrated on the Daedalus multispectral imagery. The image pre-processing of bands is described below. Once some basic softcopy multispectral images were constructed, a visual procedure was started, analyzing these images along with SPOT, Russian and Landsat satellite images, historical and concurrent aerial photographs, site maps and other ground truth. The phenomenology of the signature of the particular waste site problem guided the special processing of an image. Signatures of known trenches and objects were compared to those of suspected trenches and objects. Often no additional image processing or image analysis was needed on any one image, but information from more than one image or map needed to be fused to aid the site managers in assessing a problem. This was especially useful at waste sites where there were conflicting information sources concerning buried waste locations. Data fusion is also discussed below.

Multispectral Image Pre-processing: DOE conducts periodic flights over the waste site areas with aircraft operating the Daedalus AADS 1268 Multispectral Scanner and a 70mm aerial framing camera. These data are collected, analyzed and archived by EG&G/EM. The EG&G/EM data base permitted retrieval of flight logs and imagery of the flight lines covering the pre-selected sites.

A set of flight lines were selected from the collection on 24 June 1994. These included both daytime and pre-dawn collections. The daytime imagery contained eight bands. The nighttime imagery contained only thermal bands (high and low gain channels). Flight lines were flown at an altitude of 1000 to 1500 feet AGL yielding a ground resolution of 2.5 to 3.75 feet at Nadir and at 5000 to 5500 feet AGL with resolution of 12.5 to 13.75 feet at Nadir.

The Daedalus scanner AADS 1268 is capable of collecting data in up to 12 spectral bands. The following bands (corresponding to Landsat TM bands) were archived and used for this project:

Daytime Multi-spectral Imagery:

Band 1	0.45-0.52 μm	TM-1
Band 2	0.52-0.60 μm	TM-2
Band 3	0.63-0.69 μm	TM-3
Band 4	0.76-0.90 μm	TM-4
Band 5	1.55-1.85 μm	TM-5
Band 6	2.08-2.35 μm	TM-7
Band 7	8.5-12.5 μm (low gain 0.5)	TM-6
Band 8	8.5-12.5 μm (high gain 1.0)	TM-6

Predawn Thermal Imagery (long wave thermal band only):

Band 1	8.5-12.5 μm (low gain 1.0)	TM-6
Band 2	8.5-12.5 μm (high gain 2.0)	TM-6

Natural color aerial photography was also collected coincident with all flight lines. This provided very high resolution (estimated at 8-12 inches) with sufficient overlap to permit stereo analysis.

The Daedalus imagery was retrieved from 8mm exabyte tape using both ERIM software (ERIPS) and commercial software (ENVI/IDL). The sites of interest were identified on the flight lines in softcopy, and smaller images of the individual sites were taken from the flight lines. This was done to ease the analysis by reducing the amount of data.

Preliminary Visual Image Analysis for Detection Problems: Imagery was examined for signatures indicating the locations of trenches, other buried objects and contamination problems. These features were identified via site maps provided by Los Alamos. It is expected that detectability is driven by a variety of phenomena, including soil moisture, soil compaction, soil type, and vegetation type and vigor. Therefore, the first analysis step was a preliminary review of all data, with emphasis on daytime and nighttime thermal and reflective multispectral. The preliminary analysis was visual, using single images, multiple images in a side-by-side presentation, and multi-band or multi-image composites where appropriate (and where the quality of the registration permits). Data transformations such as Tasselled Cap and Principle Components were applied to the multispectral data, and day/night thermal data was evaluated for thermal inertia effects. Histograms and scatterplots were created and analyzed. Following the preliminary analysis a more detailed analysis was done to better understand the conditions under which the signatures can be detected and to enhance detectability where possible.

Phenomenology: Generally there were three classes of issues:

1.) Locating buried objects or trenches,
2.) Detecting seepage from buried objects, pits or drain fields and
3.) Detecting faults and fractures.

These issues were linked to a set of observables.

Buried objects or trenches usually involve a significant disturbance of the soil which can have a long lasting and often visible effect in the surface. The process of digging up and replacing a large volume of soil creates differences in soil compaction and composition of the disturbed area in contrast to the surrounding undisturbed soil. These differences may result in different drainage over the effected area. Drainage differences result in soil moisture differences which, in turn, may result in vegetation differences (either vigor or type) and thermal differences due to differential evaporative cooling of the surface. In addition, trenches may cause subtle features on the surface either as subsidence due to settling or decay of the buried material or it may leave a mound where excess material is piled on top of the trench.

Seepage from buried objects, pits or drain fields results in soils moisture and nutrient differences which, in turn, may result in vegetation differences (either vigor or type), and thermal differences due to differential evaporative cooling of the surface. When the area has an asphalt cap, thermal differences from cracked spots indicate a possible problem.

Faults and fractures also result in soil type and soil moisture differences which may be directly or indirectly observed by assessing vegetative differences. Changes in surface temperature due to differences in soil moisture can often be observed in thermal imagery. If the surface is covered by vegetation, the age, type, and relative vigor can sometimes indicate the location of faults and fractures.

Burial Site Analysis: Image of Burial sites were examined for evidence of soil or surface disturbances using a side by side comparison of the following band combinations:

(Bands 4,3,2)	False Color Composite (looking for vegetation differences)
(Bands 6,4,2)	SWIR Composite (looking for soil moisture and vegetation differences)
(Bands 7,6,2)	Thermal Composite (looking for thermal anomalies)
(Band 7 or 8)	Individual Thermal Bands (looking for warm/cool thermal anomalies).

A Principal Components image was created to search for trenches. A three-color image of the first three principle components was examined for groups of pixels with unusually large variances. Also, a Tasseled Cap Transform, a special case of principal components, was used to produce estimates of "greenness" and "wetness". The Tasseled Cap Transform is an established process for analysis of Landsat Thematic Mapper imagery. The Daedalus scanner bands approximately duplicate the Thematic Mapper. One of the outputs of the Tasseled Cap is a "greenness" transform band which has long been used as an indicator of vegetation vigor and "wetness" which is used as an indicator of vegetative and soil moisture.

A comparison of the daytime and nighttime imagery was conducted to evaluate various areas showing unusual thermal inertia properties and vegetation stress. The comparison can by made by registering night image to daytime image. using side by side analysis, or using change or difference images.

Stereo analysis of aerial photography has been performed using the conventional mirror stereo- scope. Some mounds and evidence of subsidence is visible but - difficult to assess due to the vegetation cover.

Analysis of Drain Fields: Images of the drain fields are being studied for evidence of anomalous vegetation vigor or stress and for soil moisture patterns using the same techniques as for buried trenches.

Fault and Fracture Area Analysis: To analyze fault and fracture areas, the multispectral images are registered to the geologic map, then examined for spectral features within the known fracture region. The remaining area is searched for similar features.

A modified Tasseled Cap Transform was applied to produce a "greenness" image. The "greenness" image was evaluated to locate areas of vegetation vigor and stress.

Healthy vegetation tends to maintain a relatively uniform temperature (by evaporation). Stressed vegetation often has difficulty regulating its temperature. Ideally one would like to measure the vegetation's temperature at its minimum and maximum (predawn and mid afternoon). A thermal image of the difference in temperature between these two times of day can provide indications of areas of stressed vegetation. While predawn thermal data is available, the daytime imagery was collected mid-morning. Nevertheless severely stressed vegetation might still show a meaningful temperature difference. To do this, the predawn thermal image is registered to the daytime thermal image, and the predawn image is subtracted from the daytime image. The result is evaluated for vegetated areas with large temperature differences. An overlay is produced registering the results to the geologic map.

Data Fusion to Aid Users: To provide a physiographic representation to the site analysts, layers of information were georeferenced and added. A typical application is to use multiple sources to aid in confirming or denying positions of buried objects. Imagery available in digital form was directly entered as a layer. Maps, diagrams, drawings or photographs not available in digital form were digitized or scanned, depending on the material. Information from georeferenced data bases were added as other layers. Often the layers of information are overlaid on a background image for context and to integrate the geographical features. Commercially available packages were used--TNT MIPS, ERDAS, ARCINFO and ENVI. The choice depended the particular workstation being used and preference of the particular analyst.

RESULTS

A final brochure available in February of 1996 will cover the final remote sensing products that were selected for presentation. Interim products that have been made include the following: delineation of trench and old septic field boundaries using photography, maps and imagery; analysis of thermal signatures in unusual geological strata, asphalt and buried pits; analysis of fault and fracture areas beneath contaminated areas; broad radiological (gamma) data contours overlaid on imagery, compared to site problems; comparison of existing engineering drawings of buried objects with imagery and; use of hydrologic data merged with imagery to aid in soil sampling strategies.

Figures 1-7 show sample products that have been made to date. Two of these images, a comparison of suspected trench locations with thermal image features and an overlay of drian fields on false color composite imagery, are shown in color at the end of the issue.

Figure 1 shows the location and intensity of anomalous, man-made gamma emitters in and around selected METC project sites. A panchromatic SPOT image from 1991 with the LANL boundary, selected METC project sites, and a preliminary map of anthropogenic gamma radiation are shown. The gamma data were acquired by the DOE Remote Sensing Laboratory in April 1994 and the data presented are derived from a preliminary map of man-made gamma radiation. Approximately 90% of LANL was covered. The Hoard Site, TA-33, and portions of the Mason Site, TA-21, were not covered due to flight restrictions. At the Mason site, only the edge of the anomaly in DP Canyon was surveyed and the airport was not covered at all. A subsection of the site-wide image map from the Potrillo Canyon watershed is magnified and shown in the lower left of the figure. Radiation contours coincide with known explosive test firing sites.

Figure 2 is a comparison of suspected trench locations with thermal image features at the Material Disposal Area F (MDA-F) at Technical Area 6 (TA-6), the Rofer site. Three side-by-side images are shown: an overlay of suspected trench locations, a predawn thermal image, and an image composite containing both thermal and reflective bands.

The trench overlay image was produced by scanning a trench map developed at Los Alamos and documented in the reference listed below. This trench map was developed by analyzing historical photos taken since 1946. The exact location of trenches where contaminant waste was buried was not known. The trench map was digitally registered to the Daedalus data, pertinent map features were traced into a new digital overlay, and the new overlay was superimposed on a single-band Daedalus image (visible red). The colors indicate the following:

Color	Interpreted Feature (Date of Photo)
Magenta	Suspected Trench (1958-1972)
White	Disturbed Ground (1946)
Red	Circular Anomaly (1946, 1949)
Yellow	Large Mound (1958)
Sienna	Access Road (1946)
Blue	Fence (1991)

The image in the center is a predawn Daedalus thermal infrared image. The arrows point to a areas for which the apparent temperature is less than that of the surroundings. Many of these "cold spots" coincide with suspected trench or disturbed ground locations. The uppermost and lowermost magenta trenches and the lowermost disturbed ground are particularly good examples. Note also the dark outline corresponding to the long magenta trench in the center of the scene. Part of this may be related to soil disturbance associated with the removal of a fence that was there in 1991. Note, however, that the dark outline extends up into a clearing (fifth arrow from the top) in which there is not apparent surface explanation for this line. Other "cold spots" occur outside of MDA-F in the upper part of the image and within MDA-F in locations that do not correspond with suspected trenches (in particular, see the rectangular patch along the road in the center of the image).

The image on the right is a Daedalus thermal composite of a daytime-nighttime thermal difference image in red, the far SWIR band in green, and the visible-green band in blue. The thermal difference image was formed by digitally registering the predawn data to the daytime data and subtracting the predawn longwave image from the daytime longwave image. The dark areas of the predawn image are correspondingly bright in the daytime image, resulting in bright thermal difference values that accentuate the suspected trenches and similar areas. In the thermal composite, these areas are bright red or reddish orange. The reddish signature is the result of bright thermal difference values in combination with moderately dark SWIR and visible-green values.

A possible reason that these areas are dark in the predawn thermal image and bright in the daytime thermal image is that the soil is less compacted and hence cools down faster at night and heats up faster during the day. Another possibility is that these signatures are associated with a specific type of vegetation, which may or may not be indicative of earlier burial activity. The darker SWIR response may be the result of increased soil moisture in these areas, or it might be related to difference in surface soil composition caused by previous excavation.

Figure 3 is a nighttime thermal infrared Daedalus image of an asphalt closure cap at TA-21, at the Mason Site. The area was capped to cover a buried contaminated materials area. The image shows warm thermal anomalies. The three upper arrows point to anomalies which can be explained as resulting from dark patch material. The other arrows point to two large anomalies and a few small anomalies which cannot be explained by changes of surface properties. These are suspected to be areas where water has leaked through cracks in the asphalt cap. Site managers are concerned about the potential implications of these anomalies, that the water may be contaminated and or that some other chemical activity is present below the surface.

Figure 4 is a side-by-side comparison of a natural color composite and nighttime thermal image of an old laundry area for contaminated uniforms and an adjacent burial grounds, also at the Mason Site, near the asphalt cap area. The capped asphalt area at the bottom of the image shows some asphalt patches that are visible as dark gray spots in the color image and as warm areas in the thermal image. The former laundry area was dismantled and is now being used as a parking lot. The nighttime thermal image shows the thermal shadows (dark spots) left behind by departed vehicles. These shadows make it difficult to assess this area because they overwhelm the other thermal features at the site. However, the overgrown area contains three old foundations which appear as vegetation patterns in the natural color composite and as slightly warm areas in the thermal image. There is an unexplained rectangular cold spot at the far end of the area that could include a shallow buried object or pit.

The upper portion of Figure 5 contains an orthoreticfied, resampled panchromatic SPOT image of the Potrillo Canyon watershed with a binary mask. The lower portion contains vector layers representing sampling strata. The bargraphs indicate the means and standard deviations of concentrations of the contaminants copper, lead and uranium (in ppm) that were detected in soil samples in each strata. The kind of map is used to guide stratified soil sampling procedures. Strata have evolved based on the geological features and previous sampling data. Where standard deviations are quite different stratum-by-stratum, as in this case, stratified procedures require fewer samples for the same accuracy as random or grid sampling procedures.

Figure 6 shows a 1962 engineering drawing of material disposal trenches at TA-33, the Hoard site, overlaid on a 1994 color aerial photograph coincident with the Daedalus multispectral imagery and a black and white historical photograph from November, 1958. Surface scars in the 1994 photograph extend well beyond the areas drawn for the larger trenches but the smaller trenches are not seen. In the old photograph, one of the trenches is open and is clearly larger than indicated in the engineering drawing.

Engineering drawings of material disposal areas are often incorrect; however, site mangers must reconcile them before remediation can start. Remotely sensed data can help identify errors and supply evidence to help determine more precise location of burial trenches. The color photograph indicates that even the concrete pad was incorrectly mapped. Careful inspection of the trenches (dashed lines) along the short sides of the enclosure (line with circles) suggests that the trenches are considerably longer than mapped. At least the scarring from the trench closure has a greater extent: this does not necessarily mean that the trench is there. The trench along the long "back" edge also appears longer than mapped. That this is so is apparent in the somewhat blurred older aerial photograph. The thin L-shaped trench in the engineering drawing, in the interior of the closure, is not seen in either image and is not referenced in any other current site information.

Figure 7 is an overlay of engineering drawings that are presumed to indicate the boundaries of old contaminated drain fields at the Mynard Site, TA-18. The site manager was interested in the accuracy of these and to look for possible seepage. The engineering drawings are overlaid on subsets of a Daedalus false color composite image containing the near-infrared band in red, the visible-red band in green, and the visible-green band in blue. The line drawings were scanned, and the Daedalus image was registered to them. The drain fields were traced from the scanned line drawings and displayed as an overlay.

There are red areas beneath the drain field overlays (indicated by black on white arrows). In this composite, red results from high reflectance in the near infrared and low reflectance in the visible red, which in turn generally indicates healthy vegetation. These red areas may be linked to better drainage or more abundant nutrients due to the presence of the drain fields. Note also the tree growing near the bend in the drain tile just before it passes under the bridge. Leaks commonly occur at junctions like this and this tree may be benefiting from some seepage. On the right image there is a red linear feature just to the right of the drain tile leading away from the drain field. This may indicate a slight misregistration of the image or that the drain field is misplaced on the map.

APPLICATIONS

Economy: Rather than (or in conjunction with) statistical methods, analysis of remotely sensed data will provide information on where waste is located and on where wells should be drilled in order to obtain definitive characterization of waste sites. This would reduce the expense of exploratory drilling and the necessity for fine-gridded sampling.

Accuracy: Remote sensing's capability to provide (relatively) continuous information would be used to extrapolate conditions between wells/boreholes. This would improve the accuracy of information derived from point-sampling, and also would provide better data for waste-flow models.

Safety: In many situations there are risks associated with inadvertently drilling into containers and in working in areas where hazardous waste has migrated to the surface. Such conditions may not be known beforehand. Remote sensing provides the capability to detect and map such hazardous areas prior to beginning clean-up and mitigation.

ACKNOWLEDGEMENTS

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The Los Alamos National Laboratory (LANL) is contributing the time of its scientists and is funding RSL scientists as well. The Environmental Restoration Program at LANL also contributed the needed materials and site support for this project. ER project personnel that have been practically helpful are Naomi Becker, Dorothy Hoard, Richard Koch, Cas Mason, Randy Mynard and Cheryl Rofer. Special thanks go to Paul Pope of LANL and David Brickey, of EG&G/EM for their scientific contributions.

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Pope, P., Van Eeckhout, E., Rofer, C., 1995, "Waste Site Characterization Through Digital Analysis of Historical Aerial Photographs," Los Alamos National Laboratory, Technical Report LA-UR-95-812.

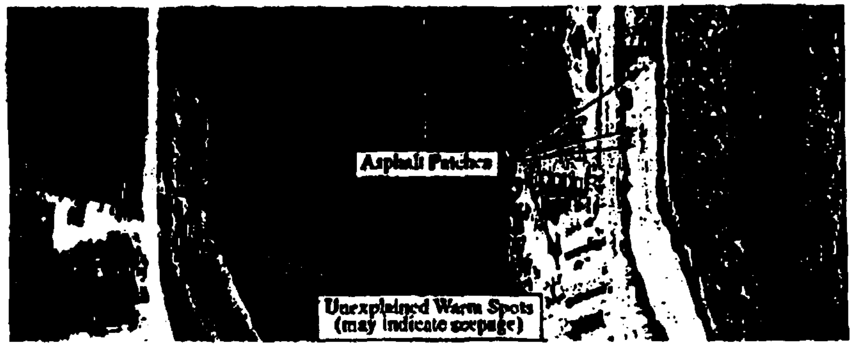


Fig. 4. Comparison of thermal imagery with color.

Mismatches between engineering drawings and historical photos: the Hoard site
Site Managers have to reconcile existing information about their sites before recommending actions. Often the information is incorrect. At the Hoard Site 1962 engineering drawings were overlaid on a 1958 photograph taken while one of the trenches was still open. This trench is clearly larger than the drawing indicates. The 1994 photograph in Fig. 5 shows by the lighter color that some of the trenches are larger and displaced from what the drawings indicate. This portrayal gives the site manager evidence to disregard the drawings when establishing the trench boundaries.

November, 1958 June, 1994

Fig. 5. Engineering drawings on photographs.

For information about this project please contact Karl-Heinz Frohne, METC (304) 285-4412. ERIM contact is Nancy David (505) 982-9180, LANL contact is Ed Van Eeckhout (505) 667-1916 and RSL contact is Lee Balick (702) 295-8603. Site managers were Naomi Becker, Dorothy Hoard, Richard Koch, Cas Mason, Randy Mynard and Cheryl Rofer.

USE OF REMOTE SENSING FOR HAZARDOUS WASTE SITES

Remote sensing is a technology that is well suited to the surveillance of large areas for detecting and locating buried containers as well as detecting the boundaries of toxic plumes. Imagery provides spatially continuous information to achieve accurate interpolations of point sampled data. The Los Alamos National Laboratory (LANL) is a test facility for a project to demonstrate the use of imagery in the environmental clean-up process.

This brochure presents some results of the research, sponsored by the U. S. Department of Energy's (DOE) Morgantown Energy Technology Center (METC) under Contract DE-AR21-95MC32116 with the Environmental Research Institute of Michigan (ERIM). LANL contributed scientific and site support to this project and that of DOE's Remote Sensing Laboratory (RSL)in Las Vegas.

Six sites were chosen to demonstrate the technique. They are shown on Fig. 1--the Becker, Hoard, Koch, Mason, Mynard and Rofer Sites. The figure shows the laboratory boundary and waste site locations overlaid on a recent SPOT satellite image. Nuclear and hazardous materials were buried underground and scattered on the surface at these sites during the testing of nuclear weapons.

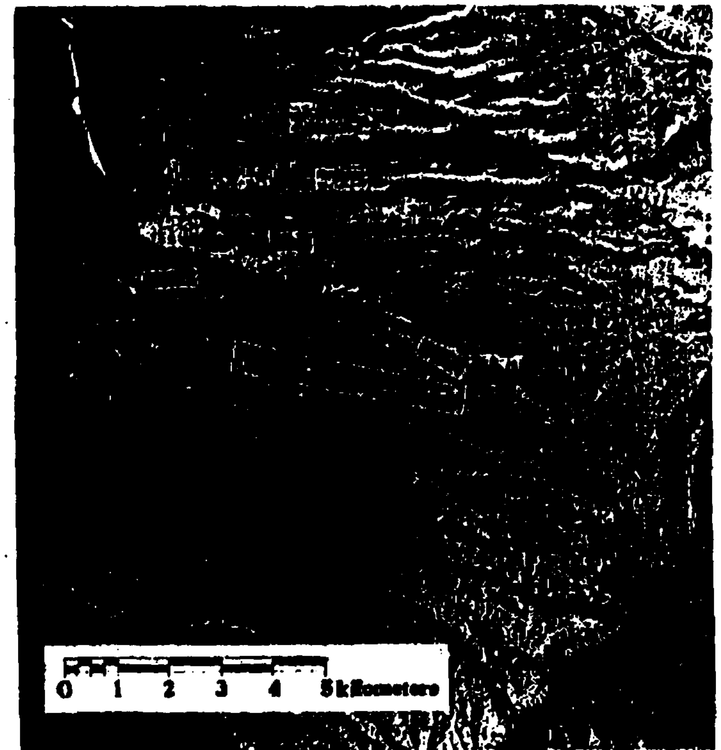


Fig. 1. Sites selected at Los Alamos for study.

Delineation of Sampling Strata: the Becker site

At the Becker Site explosive tests were conducted at firing points in the Potrillo Canyon Watershed where contaminants can flow into the canyon below. Figure 2 shows strata for soil sampling. These were selected on the basis of hydrologic characteristics that are visible on the SPOT imagery. Data on concentrations were merged with the imagery information to portray contamination differences among the strata.

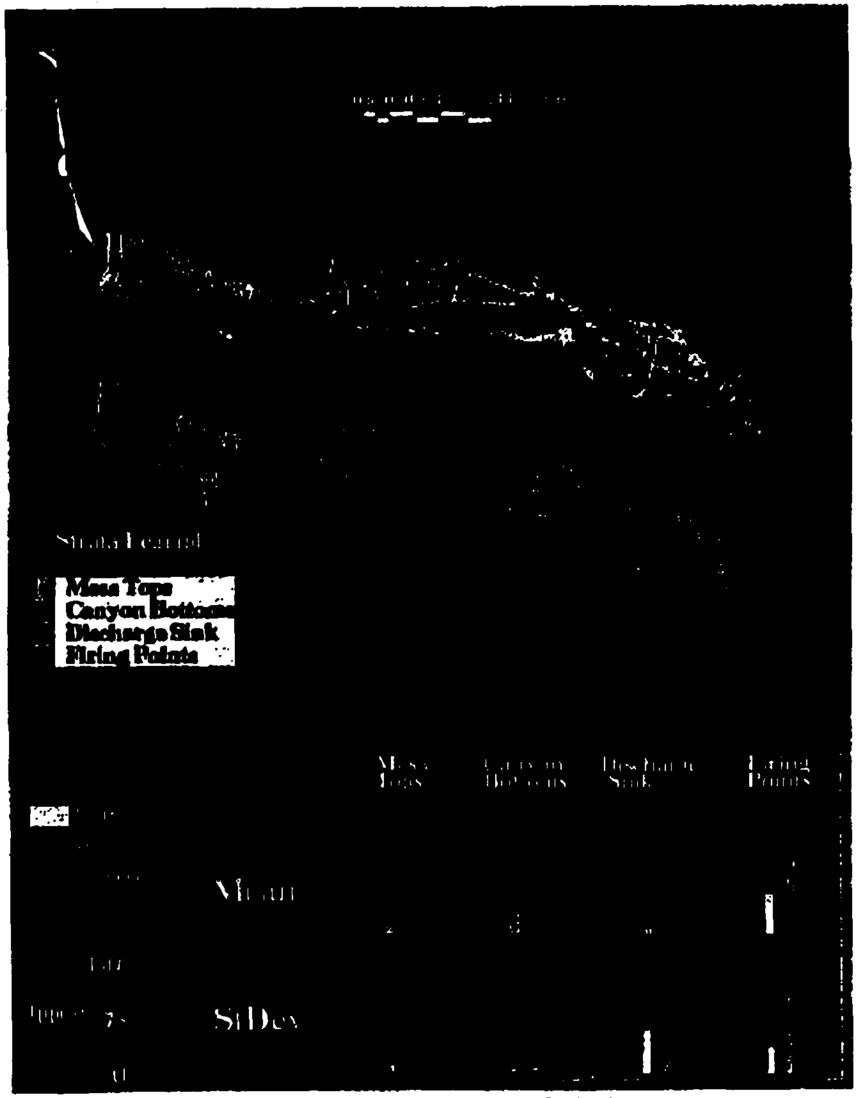


Fig. 2. Contamination by strata on a SPOT image.

Thermal signatures over trenches: the Rofer site

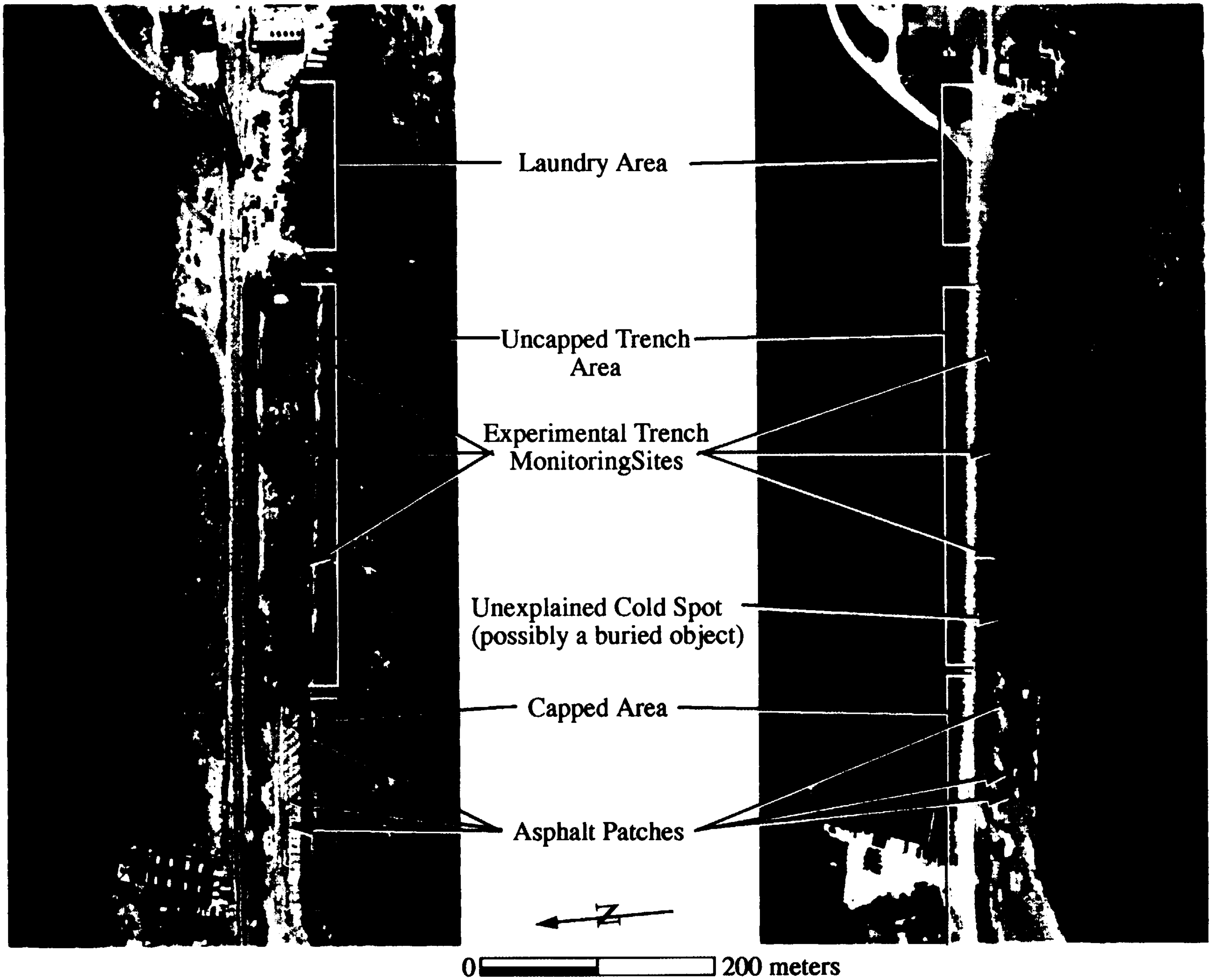
A number of trenches were filled with contaminated material and covered with soil at the Rofer Site. Since that time, vegetation has covered the trenches. From historical aerial photographs, the boundaries of some trenches were reconstructed and are shown in magenta on the image to the left in Fig. 3. Other features are shown in other colors. The middle image uses thermal data collected in 1994 from RSL's airborne Daedalus scanner. The image to the right is a composite of thermal and other multispectral information in the infrared and visible ranges. Arrows point to where trenches are now suspected and to other similar signatures. Three new suspicious areas are seen at the top of the scene and a possible extension of the previously found trench is indicated by the top arrow on the right of the images.

Fig. 3. Trenches seen on multispectral imagery.

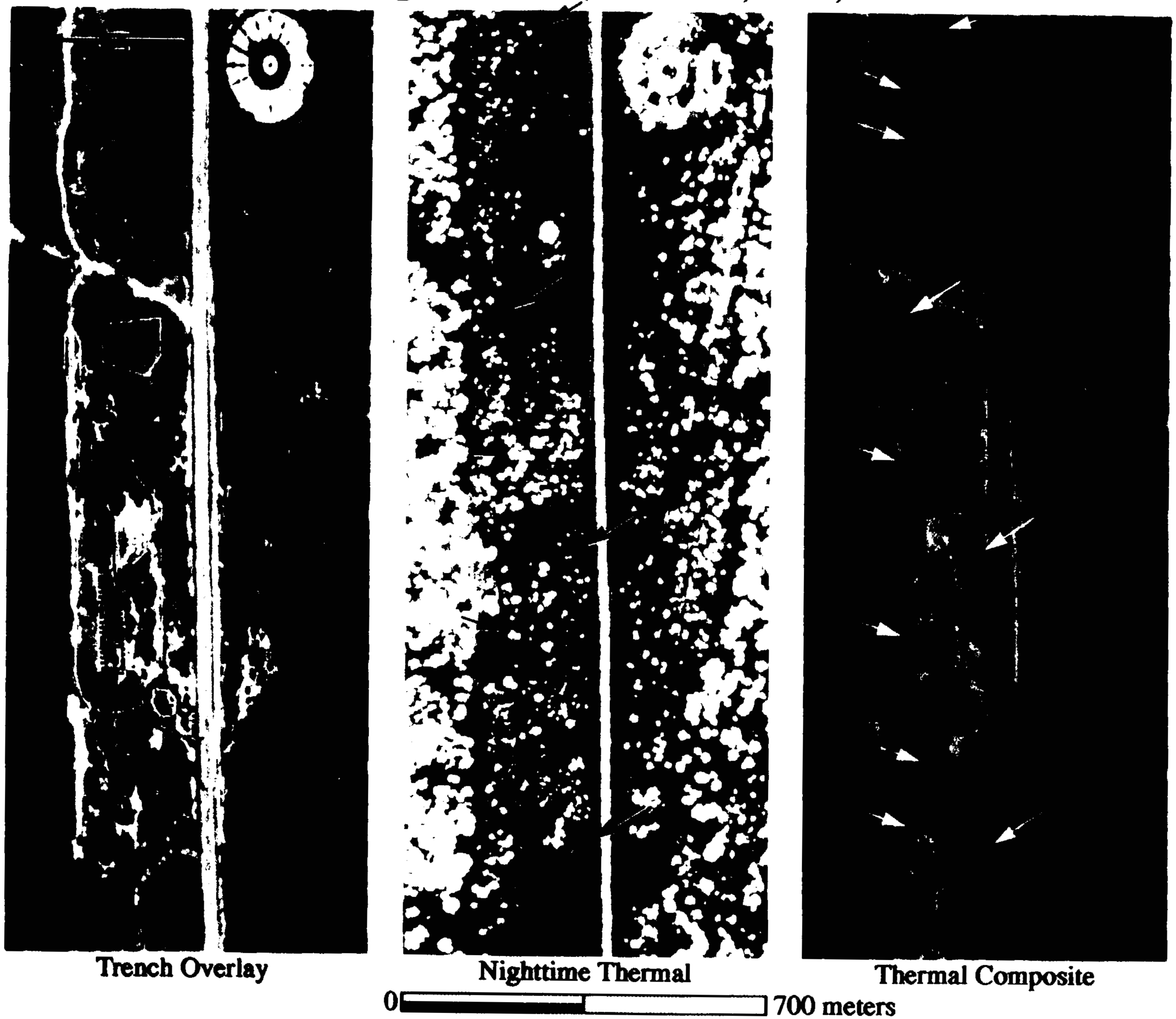
Thermal signatures over asphalt caps: the Mason site

At the Mason Site is an asphalt cap covering old contaminated work areas. Figure 4 shows the cap area on multispectral imagery that was also collected from the Daedalus scanner. The thermal image on the left shows warm spots as light. The warm spots at the top are patching with different material, as seen on the natural color image to the right. The other spots cannot be explained and could indicate seepage.

Natural Color Composite and Nighttime Thermal Image of Laundry Area and Adjacent Burial Areas (Mason Site, TA-21)

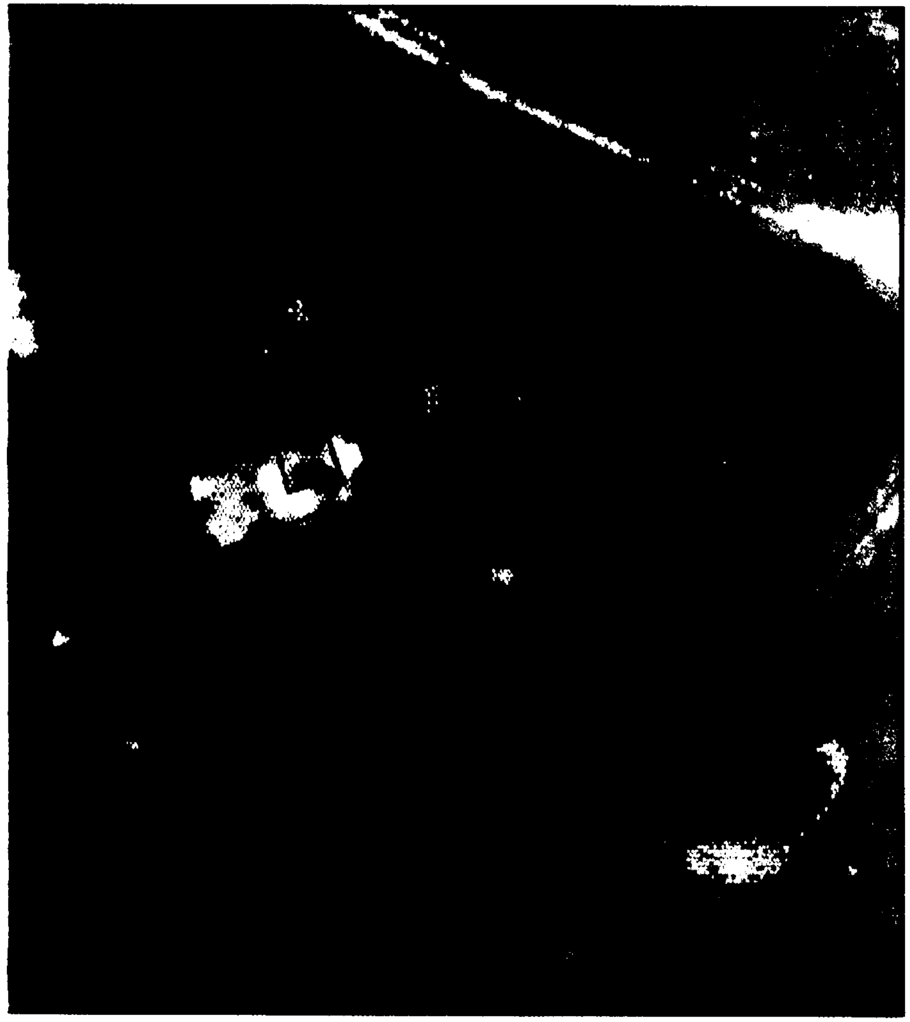


Comparison of Suspected Trench Locations with Thermal Image Features (Rofer Site, TA-6)



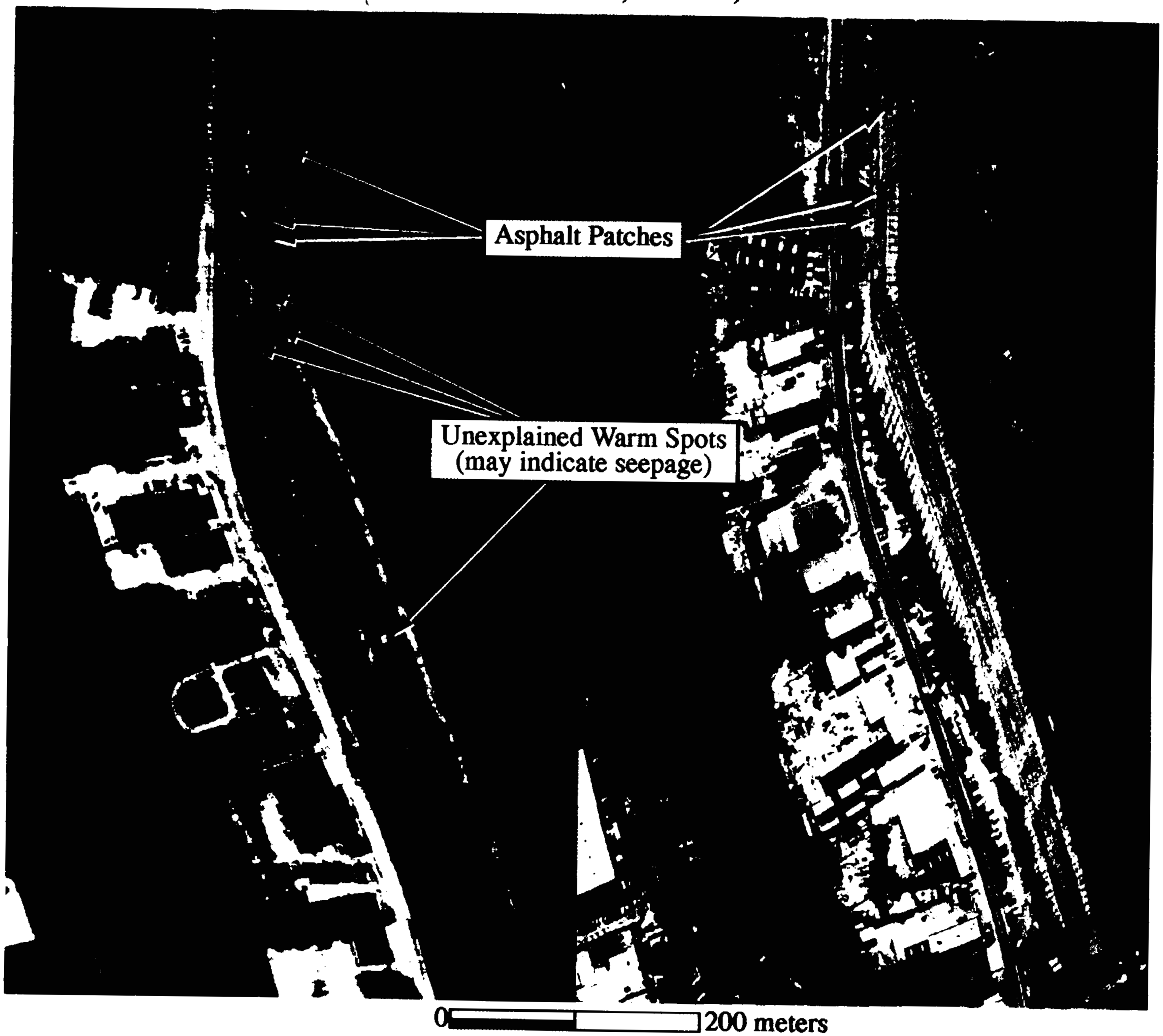
Engineering Drawings from 1962 Overlaid on Historical and Current Aerial Photographs of Materials Waste Pit (Hoard Site, TA-33)

November, 1958



June, 1994

Nighttime Thermal & Daytime Images of Asphalt Closure Cap
(Mason Site, TA-21)



Overlay of Drain Fields on False Color Composites of Kivas/Central Area (Mynard Site, TA-18)