DOE/MC/32116 -- 5148
(DE96004368)

Imaging Data Analyses for Hazardous Waste Applications

Final Report

Dr. Nancy David
Dr. I.W. Ginsberg

December 1995

Work Performed Under Contract No.: DE-AR21-95MC32116

For

U.S. Department of Energy
Office of Environmental Management
Office of Technology Development
Washington, DC

U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
Environmental Research Institute of Michigan
Ann Arbor, Michigan

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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 delineation of strata for soil sampling, detection and delineation of buried trenches containing contaminants, seepage from capped areas and old septic drain fields, and location of faults and fractures relative to hazardous waste areas.

Merging of site map and other geographic information with imagery was found by site managers to produce useful products. Merging of hydrographic and soil contaminant data aided soil sampling strategists. 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. Analysis of aerial photography and spectral signatures of faults/fractures improved geologic maps of mixed waste areas.

ACKNOWLEDGEMENTS

This research was 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). The authors would like to acknowledge Karl-Heinz Frohne, METC Contracting Officer's Representative (COR) for his technical guidance of this work as well as Richard McQuisten, formerly of DOE/METC for his technical input at project outset.

The Los Alamos National Laboratory (LANL) contributed time of its scientists and funded scientists at DOE's Remote Sensing Laboratory (RSL) as well. The Environmental Restoration Program at LANL also contributed the needed materials and site support for this project. Special thanks go to site managers Naomi Becker, Dorothy Hoard, Richard Koch, Cas Mason, Randy Mynard and Cheryl Rofer.

Report authors and project scientists include Nancy David, Bill Ginsberg, April Lewis, Julie Odenweller, Gary Stahl and Bill Tyler of ERIM. Contributing scientists include Paul Pope and Ed Van Eeckhout of LANL and Lee Balick, David Brickey and Rob Weber of RSL.

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INTRODUCTION AND PURPOSE

A legacy of the cold war with its emphasis on weapons production has led to environmental problems at 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 information committed to memory has been lost or is inaccurate. 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.

LANL is the test facility for this project to collect and analyze existing remotely sensed data from aircraft and satellite. Many of the chosen sites had archival data available for analysis which include aerial photography, multispectral, infrared, and radar imagery. 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. Processing of imagery was done for many site problems and the most fruitful are included in this report.

Imagery data available for this project included airborne multispectral Daedalus imagery collected for DOE over Los Alamos by RSL in 1993 and 1994, 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 digital map information, and engineering drawings of burial sites.

ERIM was contracted by 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.

BACKGROUND

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. Six sites were selected. Locations of these sites are shown on a 1991 SPOT image of LANL; Figure 1. The laboratory boundary is shown in red and the site areas are designated by yellow quadrangles. Images made for this project were developed to be used in color. This report contains black and white versions of the images.

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 took an interest in the project, that is, took 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.

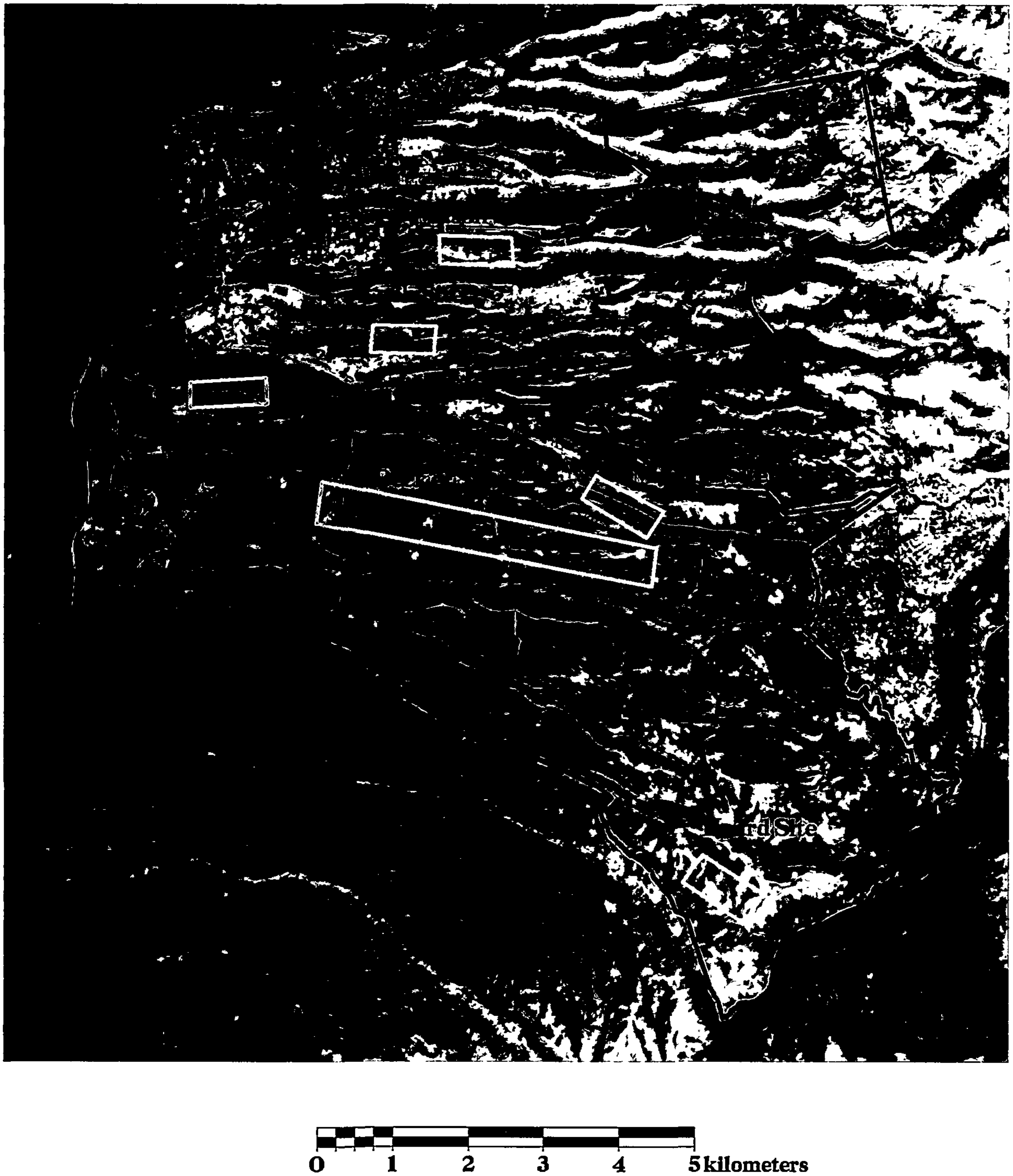
Sites were named after the site manager that expressed an interest. Six sites were selected:

Becker Site: Displaying sampling areas by hydrologic category and contaminant concentration.
Hoard Site: Locating pits and comparing to engineering drawings.
Koch Site: Evaluating faults and fractures beneath waste disposal areas.
Mason Site: Assessing thermal hot spots in an asphalt cap and other areas.
Mynard Site: Determining location and extent of seepage for septic drain fields.
Rofer Site: Detecting and delineating relatively known and unknown trenches.

METHODOLOGY

Most of the image processing for this project 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 existing 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 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 were 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 on the particular workstation being used and preference of the particular analyst.



Sites Selected for Evaluation at the Los Alamos National Laboratory.

Figure 1

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 RSL. The RSL data base permitted retrieval of flight logs and imagery of the flight lines covering the pre-selected sites.

A set of flight lines was selected from the collection on 24 June 1994. These included both daytime and nighttime (predawn) 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 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 Thematic Mapper (TM) bands, were archived and used for this project:

Daytime Multi-spectral Imagery:

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

Predawn Thermal Imagery (long wave **thermal band** only):

Band 1 8.5-12.5 mm (low gain 1.0)	TM-6
Band 2 8.5-12.5 mm (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 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 LANL. 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 the trench.

Seepage from buried objects, pits or drain fields results in soil 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: Images 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 TM imagery and the Daedalus scanner bands approximately duplicate Landsat. 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 nighttime to daytime images, using side by side analysis, or using change or difference images. Stereo analysis of aerial photography has also been performed using the conventional mirror stereo-scope. Some mounds and evidence of subsidence was visible but difficult to assess due to the vegetation cover.

Analysis of Drain Fields: Images of the drain fields were 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 were registered to a geologic map, then examined for spectral features within the known fracture region. The remaining area was 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 was available, the daytime imagery was collected mid-morning. Nevertheless severely stressed vegetation will still show a meaningful temperature difference. To do this, the predawn thermal image was registered to the daytime thermal image, and the predawn image subtracted from the daytime image. The result was evaluated for vegetated areas with large temperature differences. An overlay was produced registering the results to the geologic map showing faults and fractures.

RESULTS AND DISCUSSION

The following pages show nine images and a one-page description beside each image. These images and the implications of what they reveal have been discussed with LANL site managers at a second technical workshop. The images were made to be used in color, so some information is not as clear on black and white for this report.

IMAGES AND DESCRIPTIONS

BECKER SITE, Cu, Pb AND U CONTAMINATION

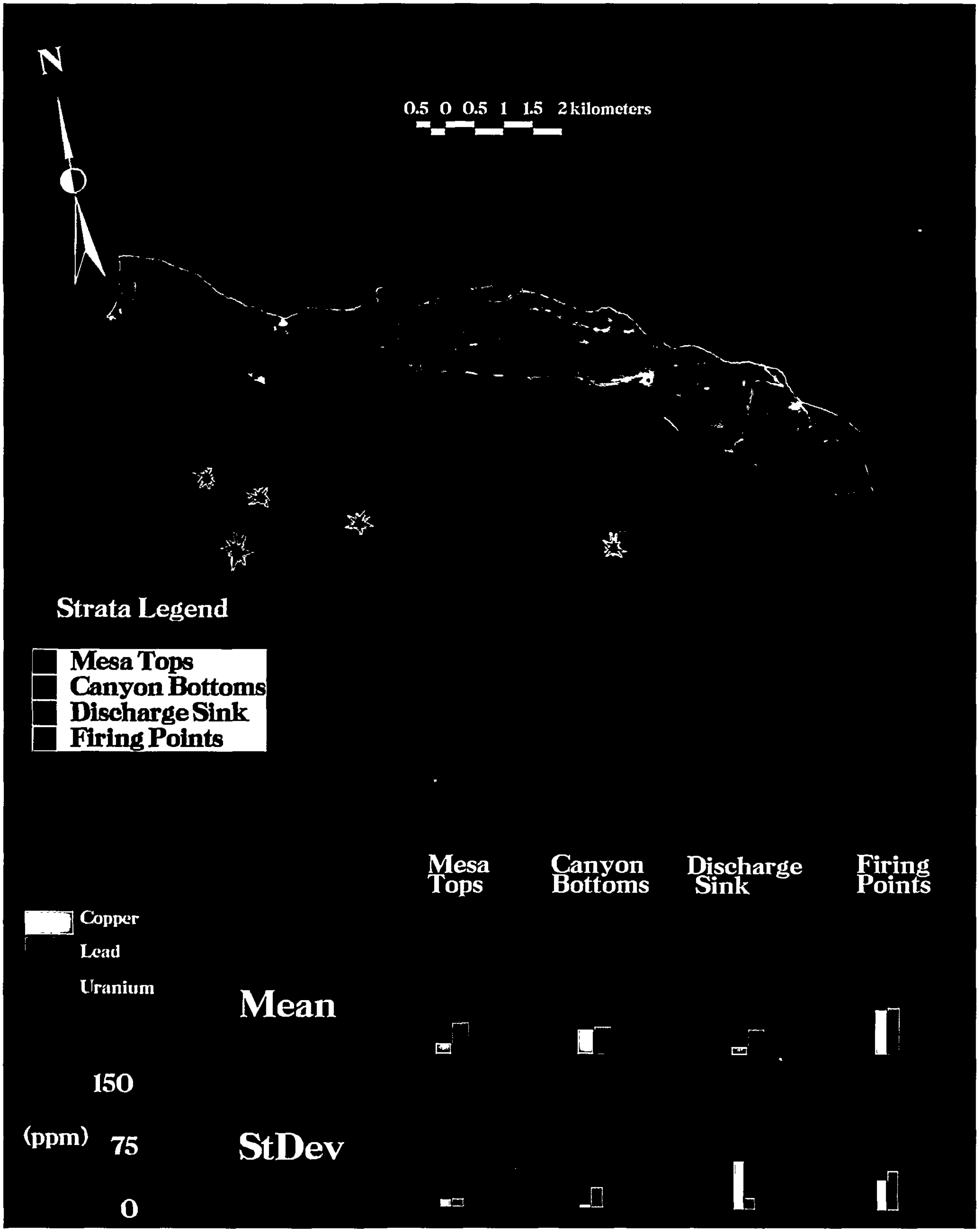
SITE PROBLEM A visual display of the Potrillo Canyon Watershed was needed so that means and standard deviations of strata could be re-calculated as soil sampling stratification strategies and boundaries are changed. Boundaries of soil sampling strata are related to hydrological features of the area.

DESCRIPTION OF IMAGERY The number of samples needed to make estimates of concentrations with a given accuracy is a function of the standard deviation of contamination throughout the watershed. The Potrillo Canyon Watershed was "cut out" from the SPOT image shown in Figure 1. The location of mesa tops, canyon bottoms, a hydrological collection area called a discharge sink and firing points were located and mapped on the SPOT image. The area was divided into these four types of areas used as sampling strata. Means and standard deviations in ppm of Cu, Pb and U are shown in Figure 2.

REMOTE SENSING CONCEPT Imagery can provide an accurate map base to identify potential strata boundaries used for sampling. Strata for this type of problem are a function of hydrological characteristics, identifiable on imagery. Geographic Information Systems (GIS) or GIS-type systems display this information quickly and easily.

INFERENCE Previous samples from an intensive sampling period were geolocated (Becker, 1995) and statistics for the four strata were automatically calculated. These were used to guide the next soil sampling survey in Potrillo Canyon.

SITE ACTIONS/SUGGESTIONS For site sampling plans, boundaries of strata need be changed and statistics recalculated while looking for better strategies for future collections. This would be straightforward now that these strata have been digitally located. After new samples are collected, they can be integrated with other data in the GIS system for trend analysis.



Means and Standard Deviations of Contaminant in ppm for Four Strata (Becker Site, Potrillo Canyon Watershed)

Figure 2

BECKER SITE, POTRILLO AND BIG BUCK WATERSHEDS

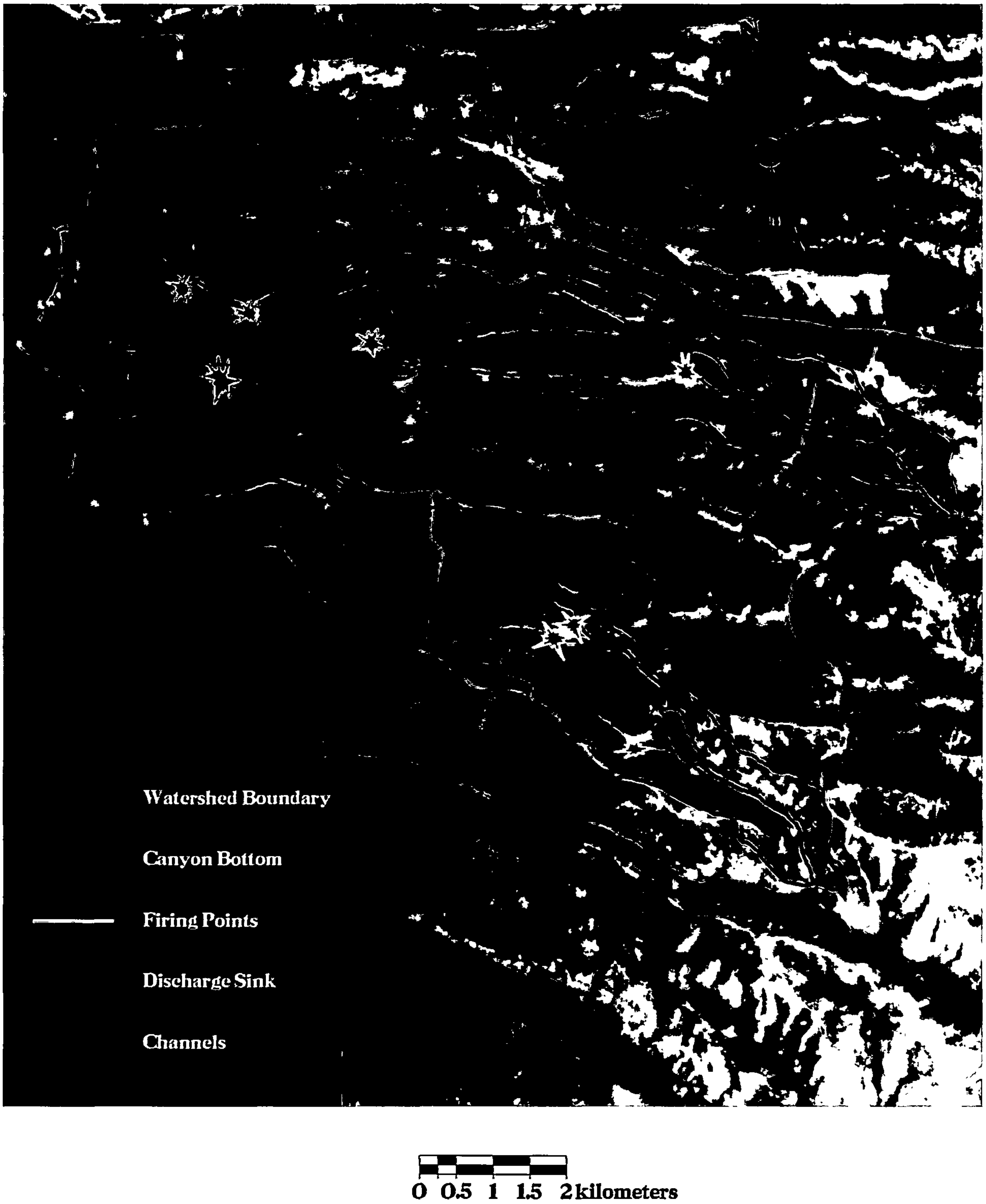
SITE PROBLEM Much was known about the contamination and what sampling strategies were optimal for the Potrillo Canyon Watershed in Los Alamos. A similar canyon watershed, Big Buck, was not so well understood. The problem was to design an optimal sampling strategy for Big Buck Watershed. An optimal strategy will reduce the number of samples needed and thus, reduce cost.

DESCRIPTION OF IMAGERY Boundaries of both watersheds were identified on the SPOT image. The hydrological features that define the strata for Potrillo were marked on both watersheds in Figure 3.

REMOTE SENSING CONCEPT This hydrological representation can be used to compare Big Buck's characteristics to Potrillo, in order to determine whether or not the same strata can be used. Again, the use of remotely sensed imagery in a GIS site information system is accurate and inexpensive.

INFERENCE The hydrological characteristics are similar. Both have firing points that are the source of contamination, both have a discharge sink, and one main channel. Mesa tops surround both canyons. The standard deviations from Potrillo could be used as starting points to determine the number of samples needed in Big Buck.

SITE ACTIONS/SUGGESTIONS The site manager suggests that procedures should be extended to other canyons. There are numerous ones in Los Alamos that are not as well understood as Potrillo. It is also suggested that an evaluation be made of how well the Potrillo strata predicted the optimal Big Buck strata once a new sample is actually collected in the Big Buck Watershed.



Four Strata in two similar Watersheds. (Becker Site, Potrillo and Big Buck).

Figure 3

ROFER SITE, TRENCHES AT TA-6, NATURAL AND FALSE COLOR COMPOSITES

SITE PROBLEM The goal was to understand multispectral signatures of relatively certain trench boundaries and look for similar signatures that might be undiscovered buried objects. The area studied covers the TA-6 trenches at Materials Disposal Area F (MDA-F).

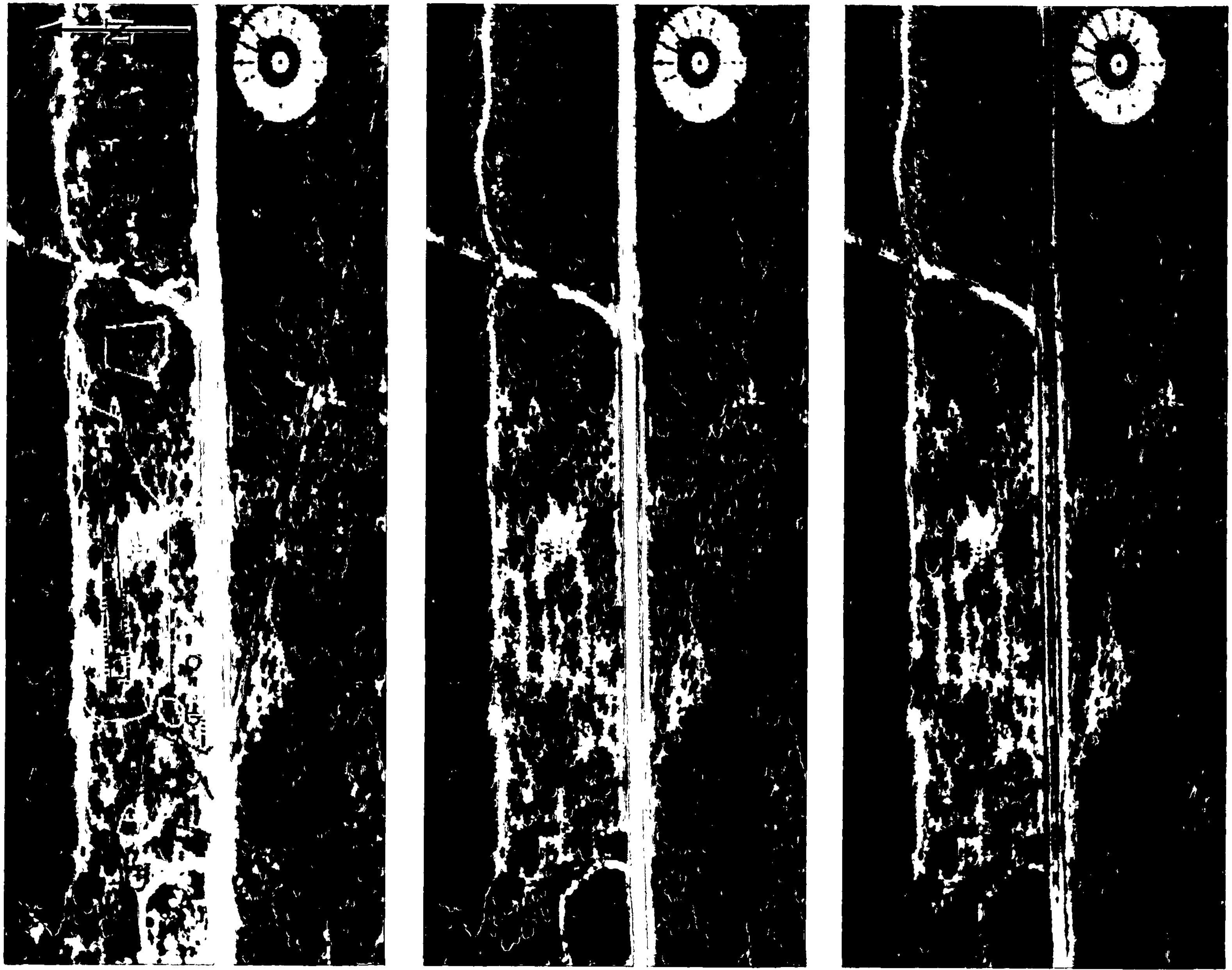
DESCRIPTION OF IMAGERY Left to right in Figure 4, the first image uses data collected by RSL's Daedalus system in 1994. The visible-red band (.63-.69 micrometers) black and white is used for the image. Overlays of "known" feature boundaries were determined from an extensive study of historical photos made by Los Alamos (Pope, 1995). These are shown in color on the image to the left. Suspected trench locations are shown in magenta. The blue dotted lines denote the previous location of a fence, the rust color a dirt road. White encircles disturbed ground, red marks a circular anomaly and yellow denotes a large mound. The center image is a Natural Color Composite from the Daedalus scanner with the visible-red band in red, visible-green band (.52-.60 micrometers) in green and visible-blue band (.45-.52 micrometers) in blue. The right-hand image is a False Color Composite with the Daedalus scanner selected to highlight vegetation differences. It uses the reflected infrared band (.76-.90 micrometers) in red, the visible-red band in green and the visible-green band in blue.

REMOTE SENSING CONCEPT Trenches would be expected to have differences in vegetation vigor and type because of the differences in soil moisture, compaction, vegetation growth stage and successional state, compared to the surrounding area. Differences could also be caused by composition differences in the soil and contamination from buried material. This kind of spectral coverage of a large area is only practical with remote sensing from aircraft or satellite. Ground sampling would take too long and be too costly.

INFERENCE It is seen that some of the trenches appear bluish-green in the Natural Color Composite and appear red in the False Color Composite. More analysis of these images continues with Figure 5.

SITE ACTIONS/SUGGESTIONS In late 1993 and 1994 there was considerable Los Alamos Environmental Restoration Program ground activity at this location. It would be worthwhile to analyze the June 1993 Daedalus imagery as well.

Suspected Trench Location Overlay with Natural Color and False Color Composites (Rofer Site, TA-6)



Trench Overlay

Natural Color Composite

False Color Composite

Figure 4

ROFER SITE, TRENCHES AT TA-6, THERMAL IMAGES

SITE PROBLEM The goal was to understand thermal signatures of relatively certain trench boundaries and look for similar signatures that might be undiscovered buried objects. The area studied covers the TA-6 trenches at MDA-F.

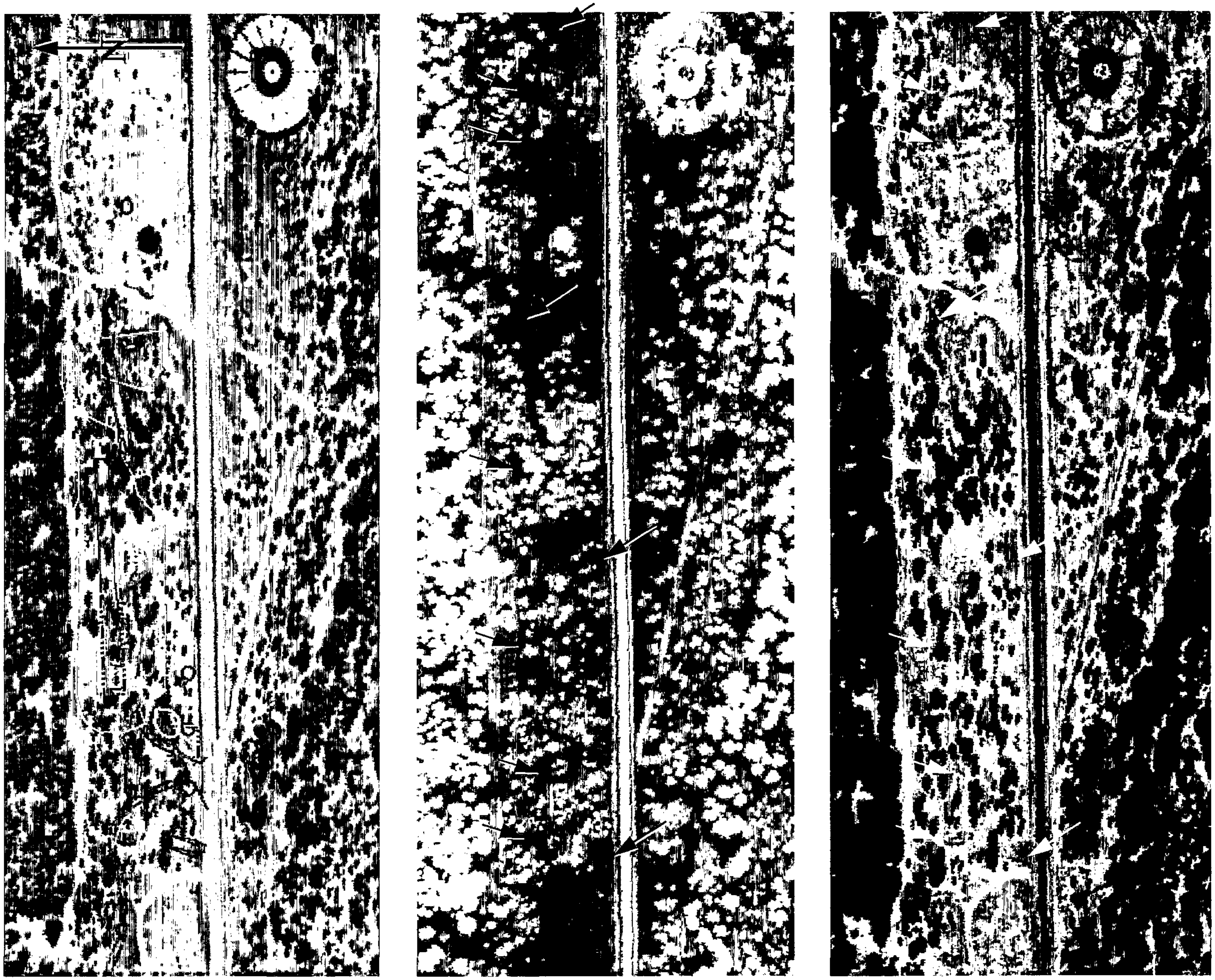
DESCRIPTION OF IMAGERY The image to the left in Figure 5 is the same trench overlay that was previously shown in Figure 4. The image in the center is a Daedalus nighttime thermal infrared band 6 (8.5-12.5 micrometers) image. Colder areas appear darker on this image. A number of cold spots are marked with arrows. The image on the right is a Thermal Composite from the Daedalus scanner where red is the thermal difference between two images collected within several hours--night versus day. In addition to the thermal difference, two other Daedalus bands were used for this image: a SWIR band (2.08-2.35 micrometers) in green and a visible-green band in blue. The bright reddish-orange signature is the result of large thermal differences between the two imaging times in combination with moderately dark SWIR and moderate dark visible-green band signatures.

REMOTE SENSING CONCEPT Given that trenches and the surrounding area have the same moisture content, trenches could be expected to cool faster at night and heat faster during the day because the soil is less compacted than in the surrounding area. Differences in temperature could also be caused by differences in vegetation, and soil moisture. These differences would be detected in the SWIR and visible green bands. Without remote sensing, ground temperature, vegetation and moisture measurements would have to be made over large areas, which would be very costly.

INFERENCE Note that the well-studied magenta trenches are indeed dark (cold) on the center nighttime thermal image. They were also bluish-green in the Natural Color and red in the False Color Composite shown in Figure 4. The right-hand image in Figure 5 shows bright reddish-orange in these trenches which is likely due to larger thermal differences (night versus day) in the trenches compared to background. The bright reddish-orange is also due to differences in soil moisture, soil composition and/or vegetation type/vigor shown in the SWIR band, and vegetation differences shown in the visible green band. The three arrows shown at the top of the thermal images point to areas with signatures similar to the magenta trenches. They indicate the possibility of previously unsuspected buried material at these locations. Also, the top arrow on the right hand side of the thermal images shows a continuation of the signature of the large trench. This indicates that the trench might be larger than inferred from just historical photos. These newly suspected areas are also bluish-green in the Natural Color and red in the False Color Composite, shown in Figure 4.

SITE ACTIONS/SUGGESTIONS The site manager suggests that each of these areas be reviewed. This would eliminate false alarms due to utility lines, clearings, etc. Review is in progress. The site manager also suggests that there could be undiscovered trench locations adjoining this MDA-F area and in the nearby areas named MDA-J and MDA-H. The color and thermal signatures developed at MDA-F would be used as a training set for these additional areas. Finally, there is another problem in this area where remote sensing could be used. Because of the volcanic history of Los Alamos, there are blast surge deposit holes in the Mesita Del Burey area that runs through TA-6. Some are noticeable on the ground and some are not. They are important because they could block or redirect underground movement of contaminants.

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



Trench Overlay

Nighttime Thermal

Thermal Composite

Figure 5

MASON SITE, ASPHALT CAP AT TA-21

SITE PROBLEM An asphalt closure cap covering a contaminated area at TA-21 was suspected of having the potential for seepage.

DESCRIPTION OF IMAGERY A Daedalus thermal band nighttime image of the cap shows anomalous areas. Next to it is a daytime, Natural Color Composite of the same area. Both are shown in Figure 6.

REMOTE SENSING CONCEPT Warm thermal anomalies appear light or bright on the image. Warm areas could be caused by a variety of things such as water or other material seeping through cracks in the asphalt, by having different surface material such as patching, or from other causes below the surface. Again, taking a thermal image of this area is much less expensive than taking numerous ground temperature samples. In a Natural Color Composite image, patching from different material would show but differences only in temperature would not.

INFERENCE The top three arrows point to warm spots that are easily explained by different patch material added to the asphalt. The other arrows point to anomalies for which nothing unusual is present on the ground. RSL overflew this cap several times over a period of days in 1994 and the anomalies were consistently seen. Thus, it is suspected that these are areas where water has leaked through cracks in the cap. The patches are visible in the Natural Color Composite and the thermal image, but there is nothing visible in the Natural Color Composite image to explain the "anomalous warm spots".

SITE ACTIONS/SUGGESTIONS The site manager is concerned about the possible implications of this. A subsequent ground review of the area showed nothing visibly detectable to explain these anomalies. A review of any other imagery at this area is recommended.

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

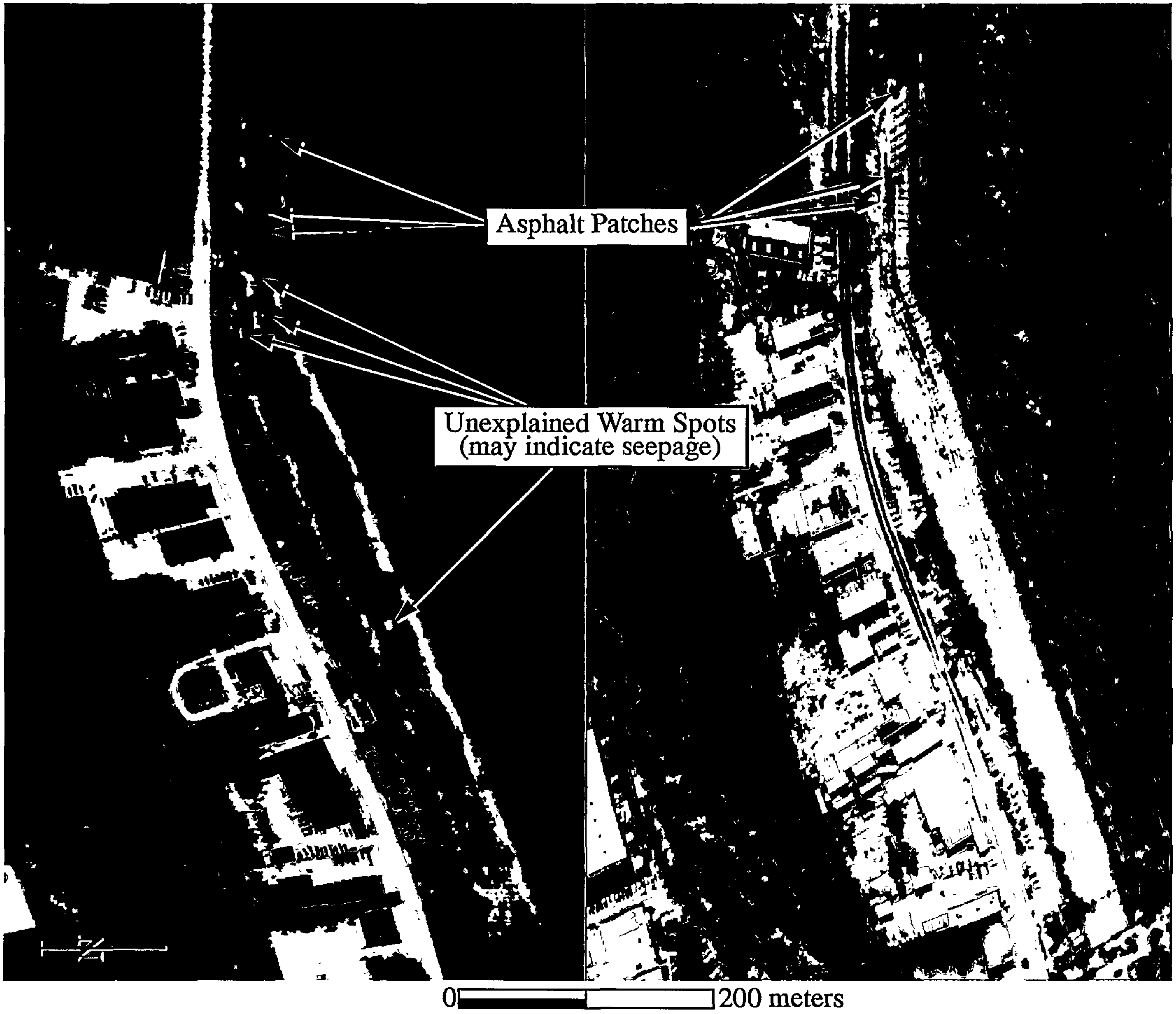


Figure 6

MASON SITE, OLD LAUNDRY AND BURIAL AREAS AT TA-21

SITE PROBLEM The area at TA-21 had contaminated buildings and work areas that have been demolished. They are being monitored for signs that contamination is spreading or is appearing in previously unsuspected areas.

DESCRIPTION OF IMAGERY The image on the left of Figure 7 is a Natural Color Composite and the image on the right is a thermal image, both from the Daedalus scanner.

REMOTE SENSING CONCEPT Unusual signs of vegetation differences in Natural Color Composites or unusual signs of temperature differences in thermal images can be indicators of contamination. These might be present in MDA-V, the former laundry for plutonium contaminated clothing. Contamination could also be present near the uncapped trenches shown below the old laundry area. It is also possible that there are undocumented burials in this area.

INFERENCE No anomalies are seen near the old laundry or in the uncapped area. One unexplained cold spot was found in a clearing. This could indicate the location of a buried object of some sort. The mechanism behind this signature would be the same as for the Rofer Site, TA-6. The asphalt patching that produced the anomalies previously seen are shown at the bottom of these images.

SITE ACTIONS/SUGGESTIONS The site manager suggests a ground review of the cold anomaly as was done for the warm anomalies in the capped area. Also, other multispectral bands and historical imagery should be reviewed for evidence of causation for the cold spot. The site manager also suggests that nearby MDA-A, MDA-T and MDA-U should also be examined. Side-by-side thermal images and Natural Color Composites could be examined as in TA-6 to search for signs of contamination.

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

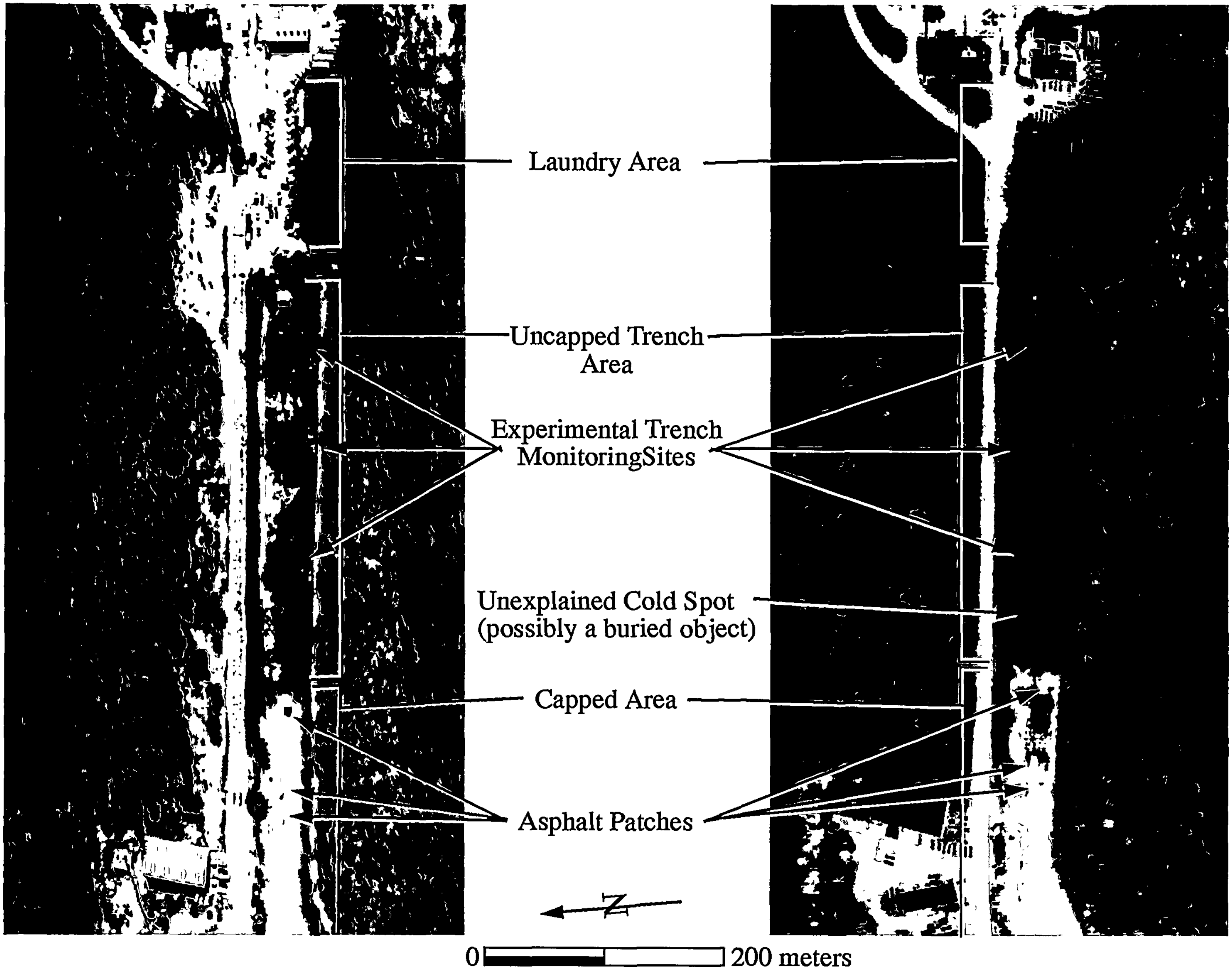


Figure 7

HOARD SITE, ENGINEERING DRAWINGS OF TRENCHES AT TA-33

SITE PROBLEM Historical engineering drawings are often incorrect and conflicting information must be reconciled by a site manager. The site manager at TA-33 hoped that overhead imagery would provide evidence to support or refute the engineering drawings at that site.

DESCRIPTION OF IMAGERY Engineering drawings from 1962 locate materials disposal trenches (dashed lines) and a concrete pad with interior entrance door (solid lines) inside a fenced area (lines with circles). The image on the left of Figure 8 is a black and white photograph from 1958 showing one of the trenches open. The image on the right is a 1994 color photograph taken along with the Daedalus spectral imagery. The drawings from 1962 were registered to the two images.

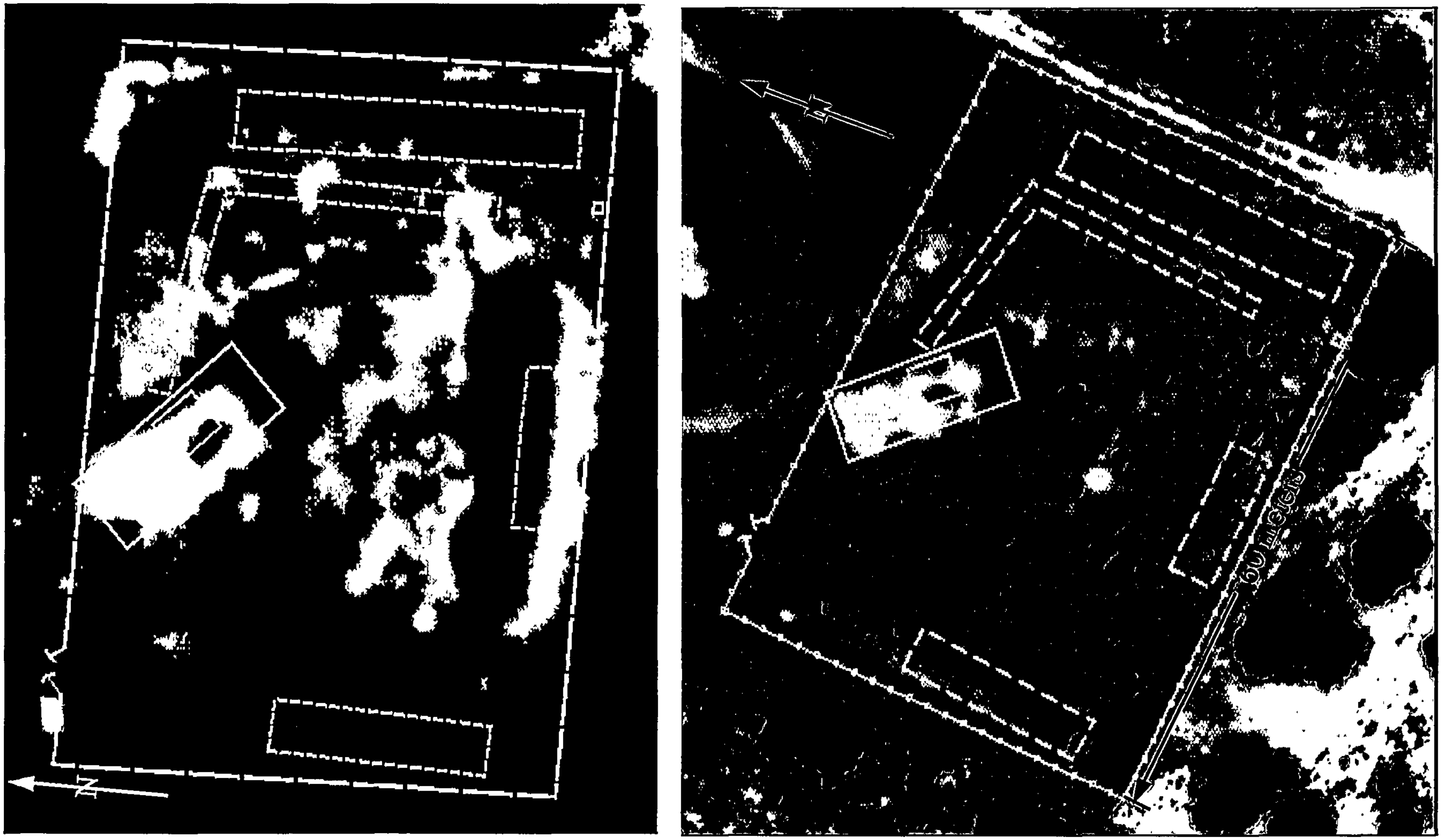
REMOTE SENSING CONCEPT Remotely sensed data can help identify errors and supply evidence to improve the precision of estimated buried trench boundaries. The site manager suggested that a quantitative technical approach such as digital merging of information would provide credible evidence for site documentation.

INFERENCE In the old photo, the trench on the right is shown open and is clearly larger than the drawing indicates. The upper and lower trenches are shown to be lighter and greener than the surrounding area on the recent photo. They also appear to be longer than in the drawings. The drawing of an L-shaped trench is not supported by signatures from the imagery. Both images show that the concrete pad and entrance door are misdrawn. The waste hole on the upper right shows no clear marks on the imagery. Thus, there is reason for the site manager to be concerned about the validity of these drawings.

SITE ACTIONS/SUGGESTIONS The site manager has conducted a ground review of the area that confirms the errors displayed here. A review of historical imagery and other information available could determine whether there is better historical evidence than these engineering drawings. It would also be useful to investigate spectral signatures of the trenches as was done at TA-6. Use of stereo photogrammetry to help refine information is also suggested.

Figure 8

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



November, 1958

June, 1994

MYNARD SITE, CONTAMINATED SEPTIC FIELDS AT TA-18

SITE PROBLEM There are a number of old contaminated septic fields in the Kivas and Central Area at TA-18. Engineering drawings of these were thought to be fairly accurate but a check on these was desired. Also, whether or not there was any seepage outside the fields was of interest.

DESCRIPTION OF IMAGERY The image shown in Figure 9 is a Daedalus False Color Composite. Engineering drawings for two drain fields were overlaid on the image.

REMOTE SENSING CONCEPT In a False Color Composite, red results from high reflectance in the near infrared and reduced reflectance in the visible red, indicating healthy vegetation. These red areas may be linked to better drainage or more abundant nutrients from septic material. This information about vegetation is efficiently obtained by using remotely sensed data. Cost per area is low compared to taking and analyzing soil moisture or vegetation samples.

INFERENCE Red areas are seen beneath the drain field overlays, as would be expected. These are shown by black on white arrows. The field on the left shows unusual amounts of vegetation (indicated by red) near the bend in the drain tile just before it passes under the bridge. Leaks commonly occur at junctions like this and the vegetation may have benefitted from some seepage, which unfortunately was contaminated. The field on the right shows a red linear feature parallel to the drawing of the drain tile leading away from the drain field. This may indicate that the drain field is misplaced on the drawings.

SITE ACTIONS/SUGGESTIONS The site manager has requested a ground review of this area, comparing the imagery to what is seen. This action is in progress. The site manager suggests that there are several other drain fields in this area that should be similarly displayed and analyzed. There are a number of other important contamination issues in this area. In particular, there are a number of contaminated firing pits that have not been properly located. Remote sensing methods could be used to attempt to locate these.

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

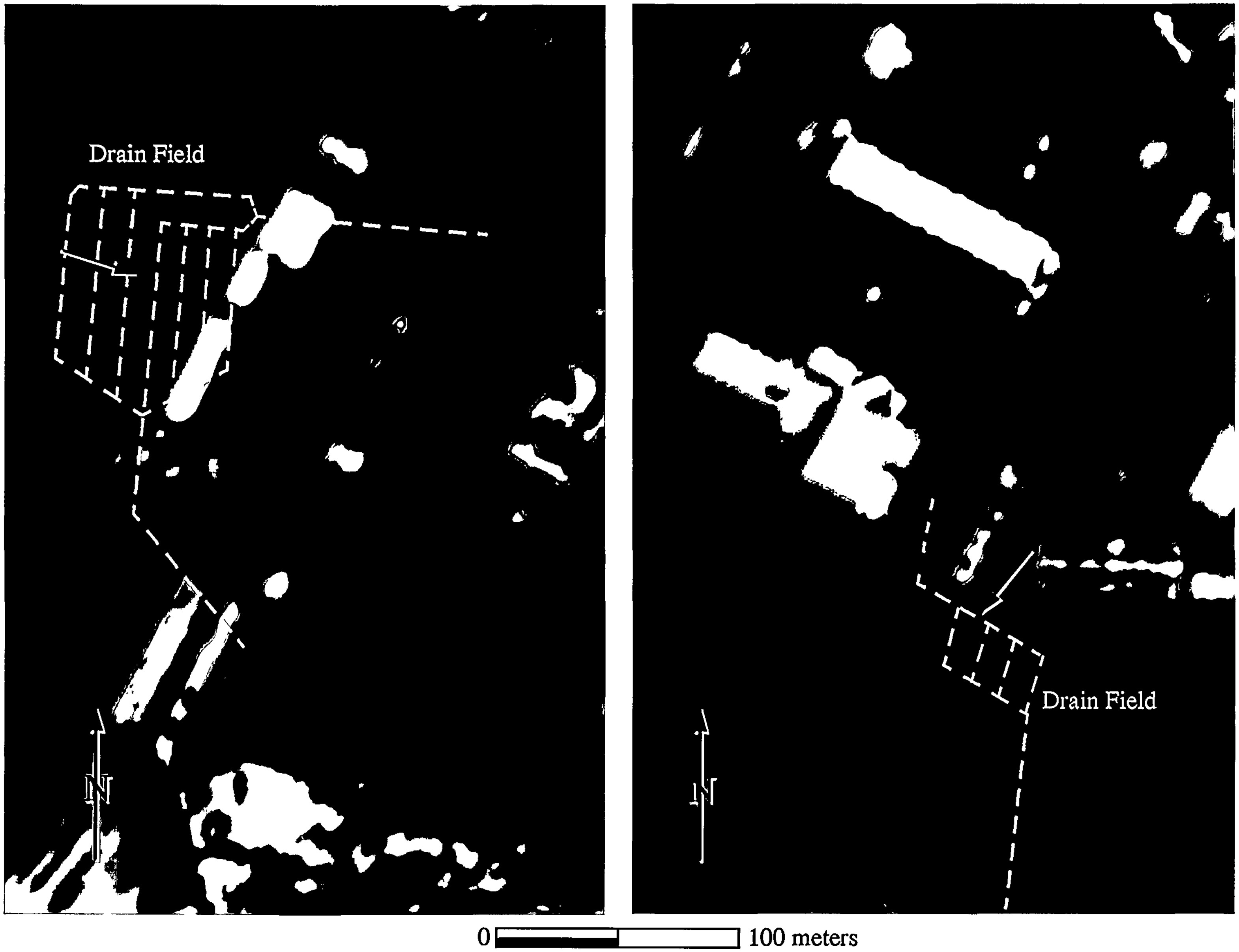


Figure 9

KOCH SITE, FAULTS AND FRACTURES IN MORTANDAD CANYON

SITE PROBLEM In the area between TA-48 and TA-50 in Mortandad Canyon a geologic map was made showing faults and fractures in the area. Knowing locations of faults and fractures is useful for determining potential pathways for contaminant migration from the potential release sites, mixed waste disposal areas in the vicinity. Some areas on the existing map are known to be only approximate.

DESCRIPTION OF IMAGERY The geologic map is shown on the left of Figure 10 with faults shown as black dotted lines and fractures as brown areas. To its right is a Daedalus False Color Composite of the area between TA-48 and TA-50. After analyzing signatures of the faults and fractures using several band combinations, revised estimates from the geologic map were made. These are shown on the False Color Composite in white (fault times) and yellow (fracture areas).

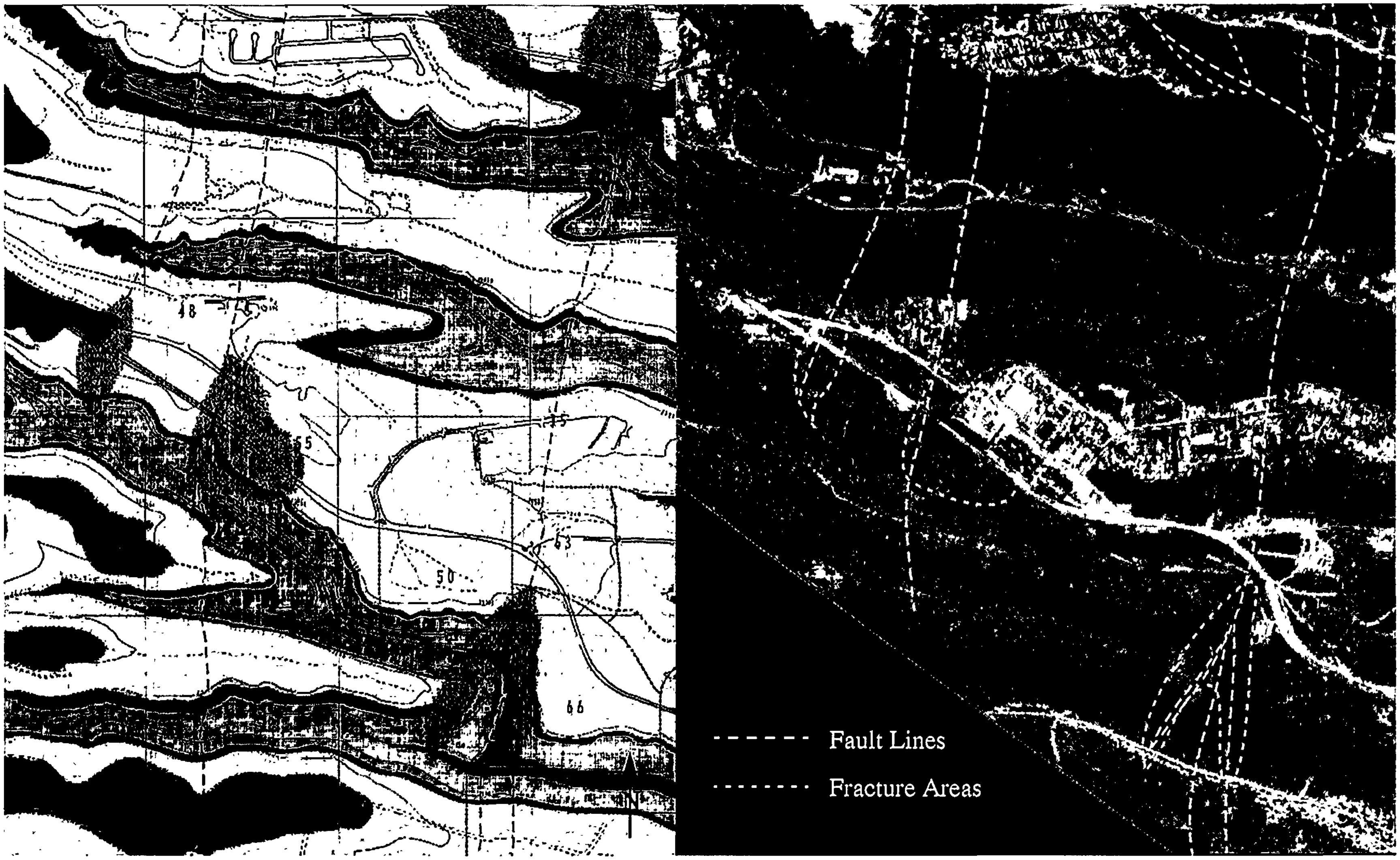
REMOTE SENSING CONCEPT Except where buildings are present, faults and fractures are normally visible on imagery using the various Daedalus bands collected in 1994 and are normally visible on aerial photography as well. The addition of spectral imagery to analysis normally done with aerial photography is known to increase accuracy and speed in making such maps. The resolution of the data collected was adequate for detection, however the image shown in Figure 10 is of lower resolution than was used for detection, to permit display of revised lines on a larger area.

INFERENCE The fault and fracture lines shown on the geologic map were mostly verified on the imagery. There were a few minor corrections that can be seen by comparing the graphics, left-to-right.

SITE ACTIONS/SUGGESTIONS The site manager recommends that this analysis be expanded lab-wide, especially in areas where faults/fractures cross contaminant disposal or handling areas. Another suggested application of remote sensing concerns the sediment traps near this area. There are bedrock faults and/or fractures in this area and contaminants could be collecting in the traps. Vegetative anomalies related to disturbance or stress and thermal anomalies in shallow ground water could indicate problems in the area.

Figure 10

Comparison of Daedalus Imagery to Geologic Map of Mortandad Canyon (Koch Site, TA-48)



Geologic Map

Registered False Color Composite

0 2000 feet

CONCLUSIONS

Highlights of the results are that:

- Information merges in a GIS-type system allowed site managers to evaluate different soil sampling strategies to reduce the number of samples needed.
- Overlays of suspected trench locations on multispectral and thermal images showed correlation between image signatures and the trenches. They also show possible new trench areas.
- Overlays of engineering drawings on recent and historical photos showed errors in previous recordings of trench location and extent.
- Thermal images showed warm anomalies suspected to be areas of water seepage through an asphalt cap and show cold anomalies suspected to be buried material.
- Overlays of engineering drawings on multispectral and thermal images showed correlation between image signatures and drain fields. They also point to possible leaks.
- Use of multispectral and standard photography improved the accuracy of locating faults and fractures compared to existing geologic maps.

Remote sensing was found to be a contributor to hazardous waste applications with the following implications.

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.

REFERENCES

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