PRELIMINARY WORKING DRAFT

PROPOSAL FOR ACCELERATED EFFORTS RELATED TO PROJECT INDALO

Reassessment of U.S. (DOE) Commitment to Project Indalo

Prepared by
C. R. Richmond
B. W. Wachholz
P. N. Dean

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CONTENTS

1. INTRODUCTION

Environmental contamination from plutonium in places such as Rocky Flats, Colorado; Mound Laboratory in Ohio; Thule, Greenland; Palomares, Spain; the Irish Sea; and the Bikini and Eniwetok Atolls of the Pacific has generated some concern within the scientific community and elsewhere. In addition to the need to learn more about these specific cases of environmental contamination, it is possible that we may deduce information helpful in a more general sense as regards mechanisms of environmental transport and disposition following accidental releases of plutonium.

The purpose of this document is to provide the Department of Energy (DOE) with information concerning Project Indalo (plutonium dispersal at Palomares, Spain, resulting from accidental release from two thermonuclear weapons in 1966). The principle goal of the expanded Project Indalo effort described in this proposal is unchanged from that established in 1966, namely to determine the impact of the USAF accident on the health of Palomares residents. The detailed tasks required to fulfill this goal are listed in the Hall-Otero Agreement and described in detail elsewhere in this proposal.

In addition to providing background information and presenting previous recommendations, this document:

1. details the project's needs,
2. identifies the resources required,
3. recommends a five-year plan of action, and
4. suggests the need for long-term considerations.

2. ADMINISTRATIVE SUMMARY

Twelve years ago plutonium was released in large quantities from two thermonuclear weapons at Palomares, Spain, as the result of a midair collision of two USAF aircraft. Extensive contamination of Spanish territory occurred. Remedial actions were undertaken and large quantities of contaminated soil were brought to the United States. Civilian populations were exposed to plutonium at the time of the incident and have probably been exposed since 1966 to residual plutonium contamination at Palomares.

Because of the remaining plutonium and the fact that human beings are involved, it is important that the United States actively and adequately support its commitment to the Hall-Otero Agreement (Appendix 1) which details the responsibilities of la Junta de Energia Nuclear (JEN) and the Department of Energy (DOE). This agreement, between John A. Hall of the U.S. Atomic Energy Commission and Sr. D. Jose Maria Otero of the JEN, established the U.S.A.E.C. as the agency responsible for U.S. actions regarding Project Indalo. This responsibility has passed through ERDA to the DOE whose role in the project is to provide Spain with technical advice and assistance and equipment. All field and laboratory work is performed in Spain by JEN personnel. The Department of Defense, although heavily involved in the decontamination and remedial actions taken at the time of the accident, has no direct responsibility in the Project. It does maintain an interest in the Project and is kept informed on its progress.

The present document outlines an expanded effort for the DOE as regards its support for Project Indalo over the next five years. Including the provision for yearly increases in the cost of living in Spain, we estimate a total DOE operating cost of $1,230,000 (approximately 100,000,000 Pesetas). Capital equipment resources for the five-year period are estimated at $175,000 (approximately 14,240,000 Pesetas). The money for capital equipment is needed for Year One of the project.

Currently, the U.S. DOE supplies about 10 to 15% of the total operating costs related to Project Indalo. The operating support envisioned in the expanded five-year program is about 2.8 times larger than the current level and would increase the DOE support to about 30% of the total effort.

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SUMMARY OF PAST, PRESENT, AND PROPOSED STUDIES

A. Past and Present Studies

1. Human

1966: 100 persons of a total resident population of about 2000 received full medical examination and radiological survey - no abnormal medical indications were found and no lung burdens of plutonium were detected, although sensitivity of the counting equipment was poor (minimum detectable activity approximately 40 nCi)

1975-6: small but unknown number of residents surveyed - data essentially useless because of calibration and other problems

1978: chest counting revealed positive activity in some residents - these results have not been confirmed by repeat counting

future: 6 groups of 10 persons per group comprising various potential exposure and control groups; subjects to be identified and monitored annually (contined chest counting, urine radiochemistry, medical examination, radiology, blood and urine chemistry, and chromosome analysis); in addition an effort will continue to be made to examine all Palomares residents

2. Air

1966-9: 4 air sampling stations in operation - yearly average activity detected was 40% of proposed EPA screening level (1 fCi/m^3) or below

1969-78: 3 air sampling stations in operation (1 sporadically) - most recent data show activities at or below the lower limit of detection (.01 fCi/m^3)

future: reestablish orginal four air sampling stations plus portable air monitoring units for use at various locations

3. Vegetation

1969-78: 6 plots (other areas added to monitor for redistribution), 9 sampling locations per plot, Pu-239 measured - some high activity levels have been detected but it is not known whether the contamination is internal or external

future: possibly establish additional plots, provide capability to analyze for Am-241, backlog of samples must be reduced to real time analysis (counting of samples as rapidly as they are taken)

4. Soil

1966-9: no samples

1969-77: 5 sampling grids, 9 locations per grid, 5 soil depths per location, replicates of all samples, analysis for Pu-239 - in areas where the soil is cultivated the plutonium has become evenly distributed throughout the sampling zone and now only the top 1 cm of the soil is sampled - although occasional high activities are detected for individual samples the averages over the sample grids are below the proposed EPA screening level

future: reduce large backlog of samples, reassess the number and location of sampling grids, expand capability to analyze for Am-241

B. Proposed New Studies

Ground area survey

A new ground survey is proposed since none has been conducted since 1966; weathering and changing land usage is redistributing the remaining plutonium

Animal sampling program

A sampling program of domestic and native animal tissues for Pu-239 and Am-241 needs to be initiated, together with appropriate training and provision for analytical capability.

Particle-size determination

Initiate studies to determine particle-size distribution of contaminated air and soil samples, together with appropriate training and provision for analytical capability.

Review of program

U.S. and Spanish contacts should review the progress, data, and needs of the program on an annual basis.

C. Financial Support

	Operating Costs	Equipment
1966-75:	$25,000 per year	$ 27,000
1976-8:	$50,000 per year	53,000
1979:	$150,000 (Proposed)	175,000
1980:	$200,000 "	
1981:	$240,000 "	
1982:	$290,000 "	
1983:	$350,000 "	

Major emphasis in the expanded program will be on the medical follow-up of six groups of ten people each from Palomares and Madrid. These individuals will be carefully monitored and studied each year (see A.I. above). A survey of ground contamination in one of the original bomb impact areas will also be undertaken. A new program addition will be the measurement of plutonium-239 and americium-241 in tissues of domestic and wild animals from Palomares. To date, virtually all environmental monitoring has been restricted to air, soil, and vegetation.

The expanded program also calls for periodic reviews of the Project Indalo data by the appointed U.S. and Spanish review teams and preparation of data obtained to date for publication in the easily accessible, widely-read open literature.

It is recommended that the U.S. DOE provide the resources to meet the needs of Project Indalo in keeping with the commitment to the Hall-Otero Agreement and the importance of the information that will accrue from these studies of a "real-world" plutonium contamination event.

It is further recommended that provisions be made to ensure some institutional memory or programmatic continuity so that proper attention will be given this important project beyond the five-year period considered in this document.

3. THE CONTAMINATING EVENT

The incident at Palomares, Spain in 1966, which resulted from an accident involving nuclear weapons, created considerable international attention, as it involved the release of plutonium into the environment of a foreign country.

At 10:30 AM (local time), on January 17, 1966, a USAF B-52 bomber and a USAF KC-135 tanker collided during a refueling operation over the southeastern coast of Spain (Appendix 2). Both aircraft were destroyed in the air. Of the four nuclear weapons aboard, one was recovered intact from the Mediterranean Sea about 5 miles offshore 80 days after the collision and another was recovered intact from the dry Almanzora riverbed just east of Palomares. The primary parachutes did not open for the other two and each underwent high explosive detonation upon impact.

One weapon landed approximately 1 mile west of the village (Impact Point No. 2) and the second landed at the eastern edge of Palomares (Impact Point No. 3) (Appendix 3). Few people were working in the fields, as most villagers were celebrating the festival of Saint Anthony (ironically, the patron saint of Palomares). The population of Palomares at the time was about 1500. However, Pedro Alarcon de la Torre and two of his nieces were thrown to the ground by the high explosive detonation of the weapon at Impact Point No. 3. This explosion broke the windows and cracked the walls of his home.

The impact, high explosive detonation, and burning of weapon number two (Area 2) produced a plutonium-bearing dust cloud which was blown by a 30-knot westerly wind across cultivated fields and the northern edge of the village (Appendices 3, 4, and 5). The cockpits of both aircraft landed within about 1/4 mile of Impact Point No. 2. The cloud from Impact Point No. 2 traveled down a small valley in a northeasterly direction and then past the northern edge of the village. The end of the valley nearest the impact point had once been used for dry farming but, because of inadequate rainfall, had not been cultivated for many years. The portion of the valley nearest the village was irrigated and under cultivation at the time of the accident. Appendices 3 and 4 show the location of Impact Points 2 and 3 relative to houses in the village. Appendix 5 shows Impact Point No. 2

relative to aircraft wreckage, cultivated areas, and houses. Appendix 6 shows Impact Point No. 3 relative to some B-52 wreckage, the cultivated fields east of the village, and the Almanzora. The plutonium-bearing cloud produced by the weapon that fell in the eastern edge of the village (Impact Point No. 3) traveled away from Palomares but across the prime cultivated (irrigated) fields used for growing tomatoes, beans, and alfalfa. Several tomato crops are produced each year; at the time of the accident, the last tomato crop of the season was ready for harvest.

Camp Wilson (see Appendix 5) was established as the general headquarters during the search for the weapon which fell into the Mediterranean and for the clean-up operation. Approximately 2000 Americans were at Camp Wilson for about 40 days.

Following the accident, a survey of the surface distribution of plutonium was conducted to determine the extent of ground contamination. The isopleths describing the surface plutonium contamination within weeks of the accident are shown in Appendix 7. About 226 hectares (558 acres) were contaminated with plutonium and uranium. No surveys have been made since that time.

Soil contaminated to levels above 32 Ci/m^2 (approximately 0.32 $Ci/100\ cm^2$ or 500 g/m^2) of plutonium was placed into steel drums and shipped to the United States for disposition. Topsoil was removed from 5 1/2 acres and vegetation was removed from 600 acres, which were subsequently plowed. Soils contaminated to levels between 0.32 and 32 Ci/m^2 of plutonium were plowed to a depth of at least 10 inches. No long-term remedial actions (beyond wetting) were taken for areas with less than 0.32 Ci/m^2 of plutonium. However, areas too rough to plow but contaminated to the extent of 3.2 Ci/m^2 or more were worked into the surface by hand. For reference, the proposed U.S. Environmental Protection Agency (EPA) screening level for environmental contamination from plutonium is 0.2 Ci/m^2. The amount of soil removed has been given by various sources as 1600 tons, 4900 barrels, or 1500 cubic yards.

Because drinking water is trucked into Palomares from a distance of 50 kilometers (30 miles), there is no concern about drinking water as a pathway by which plutonium contamination could reach man.

The code name Indalo has been used in connection with the Palomares incident. "Indalo" is the ancient Iberian name for the stick figures found in Cro-Magnon caves behind the playa on which Palomares is located. The area is highly mineralized, there being ancient Phoenician lead, silver, and iron mines. This mineralization results in a high radiation background level from the uranium-thorium series.

4. HALL-OTERO AGREEMENT

The initial interaction between the United States and Spain resulted in an agreement between the United States Atomic Energy Commission (AEC) and the Spanish Junta de Energia Nuclear (JEN) which set up a four-point follow-up program designed to collect additional information on the Palomares accident. This program was to be conducted under the direction of the JEN, Division of Protection and Medicine (under the guidance of Dr. Eduardo Ramos), with equipment and technical advice and assistance supplied by the U.S. AEC (now the DOE). The four-point follow-up program included the following:

1. collection of information on the uptake and retention of plutonium and uranium by representative members of the population group who were potentially exposed to plutonium oxide by inhalation;
2. measurement of the temporal and seasonal fluctuations in the plutonium air concentrations above the plutonium-oxide-contaminated agricultural area that was subjected to the decontamination procedures following the accident;
3. serial measurements of contamination levels (both by plant uptake from the soil and by wind dispersal) of agricultural products produced in the contaminated area subsequent to decontamination; and
4. studies of the temporal migration and redistribution of plutonium oxide in soil, which had been decontaminated by deep plowing, as a result of continued cultivation and weathering processes.

A copy of the Hall-Otero agreement is attached (Appendix 1).

5. DOE CONTRACTOR REPORTS AND RECOMMENDATIONS

Many technical and scientific interchanges took place between staff of the JEN and the Los Alamos Scientific Laboratory (LASL) following the accident. Technical expertise from LASL was instrumental in negotiating cleanup levels, formulating the Hall-Otero Agreement, and installing equipment in Madrid and Palomares to be used subsequently by JEN personnel. Some JEN personnel visited LASL to learn certain technical procedures for sampling and meaureing materials for plutonium.

Dr. Wright Langham of LASL visited Palomares in the fall of 1971, some five and a half years after the accident. His trip report (March 1972) contained the following major recommendations:

1. encourage the JEN to publish their observations and data related to the accident;
2. increase operational support to the JEN and provide more technical staff;
3. update the equipment used by the JEN and provide at least one additional alpha spectrometer;
4. reevaluate their approaches to the four points of the agreement and modify them as indicated by the experience and information accumulated since the time of the accident;
5. consider the advisability of providing the JEN with a lung counter to recount some of the Palomares residents who were examined during the first year following the accident; and
6. manifest more interest in the work of the JEN through more review of their efforts.

Dr. Langham's recommendations resulted in a renewed interest on the part of the AEC in obtaining more information on the Palomares accident. Unfortunately, Dr. Langham was killed in an aircraft accident in May 1972, less than three months after his report was written. In early June, Dr. Ramos (then in charge of Project Indalo for the JEN), in a letter to Dr. H.D. Bruner of the AEC, outlined some of the more pressing equipment needs of the JEN for use in Project Indalo. This ultimately led to the involvement of others at LASL in assisting the JEN via AEC Headquarters in updating equipment used at Palomares and Madrid to increase interest in the research and development program associated with Project Indalo. During FY

1974, the AEC Division of Biomedical and Environmental Research (DBER) made available $27,000 in capital equipment funds for Project Indalo. It was LASL's responsibility to obtain the necessary equipment and, if necessary, to assemble and test the equipment prior to sending it to the JEN in Madrid.

In February 1974, Dr. C.R. Richmond (then at LASL) visited Palomares and Madrid. The following six items from his trip report (August 6, 1974) represent his assessment of the six major actions recommended by Langham in 1972:

1. Encourage the Spanish to Publish Their Observations to Date

I feel that it is extremely important to have a major publication on the "Palomares story" that will reach large segments of the scientific community and, in time, the general public. The temptation is to preserve the status quo and not stir the water, but the story of Palomares should be told in these days of almost paralyzing fear of plutonium on the part of some members of the public. A considerable amount of information on the Palomares subject has appeared in print since 1966, but very often the reports are difficult to obtain. During my visit, I obtained several papers in Spanish and French which had been prepared by the JEN technical staff. The references attached to this report represent the bulk of the reports available on the subject.

The Hall-Otero Agreement states that any publications should be jointly approved by the United States and Spain, and this constraint has been interpreted by some as one reason that a major publication has not been prepared. I do not believe this to be true. Drs. Ramos and Iranzo discussed this topic with me in some detail, and I believe we all agree on the need for a report in a widely read scientific journal. There are several possibilities which could be explored, and I have informally offered any assistance I could provide to Drs. Ramos and Iranzo should a decision be made to prepare a report.

2. Increase Operational Support to Provide More Technical Staff

I believe the AEC support of about $25,000 per year was temporarily interrupted but is now in force once again. Technical support of Project Indalo is important and should be continued actively by both the AEC and the JEN. The information that will accrue in time from Project Indalo will certainly be well worth the relatively small investment.

3. Update Their Equipment and Provide at Leasat One Additional Alpha Spectrometer

This has been done, as indicated earlier, with FY 1974 funds made available by AEC/DBER. It is important, however, that we do not allow the equipment to fail as was the case of the two air samplers in Palomares. I suggest that additional funds be made available, as needed, by the AEC or the JEN to prevent such reoccurrences. We have developed an equipment list (approximately $15,000) of items which could be used in Project Indalo. The

JEN personnel are willing to spend some of their money for new equipment if we recommend their doing so. However, I would do so only if the items could be purchased in Spain, as there are many difficulties involved in getting materials into Spain through normal channels. I also suggest that any future shipments be made through either the United States Embassy in Spain or via Torrejon Air Force Base. This would also be a great help to the JEN personnel.

The equipment includes a programmable calculator; standard radioactive sources of uranium-234, uranium-235, plutonium-238, plutonium-239, and americium-241 for energy calibration (absolute activity not required); four additional channels for alpha spectrometry; 50-volt power supply for alpha spectrometer, equipment rack, and grounding bus; modern portable oscilloscope; HV adaptor box; coupling fluid for the echo encephalograph, etc. Perhaps as important is the need for technical liaison, which will be discussed below.

4. Reevaluate Their Approaches to the Four Points of the Agreement and Modify Them as Indicated by the Past Six Years of Experience and Accumulated Data

The four points of the agreement are still basically sound and need not be altered. Unfortunately many of the measurements needed have not been made because of the lack of certain pieces of equipment (alpha spectrometers) or the failure and non-replacement of others (air samplers). I discussed this with JEN personnel, and they are enthusiastic and would like to "renew" the effort. It is time to begin selective sampling of domesticated animals at Palomares (we observed goats grazing throughout the contaminated area near Impact Point 2 west of the village) which are consumed by people. I also believe more work should be initiated on plutonium-239 measurements in snails, rodents, and lizards at selected locations in Palomares. I have sent information to JEN personnel on techniques for plutonium-239 analysis of tissues and methods for using plutonium-242 as an analytical tracer (better than the plutonium-236 that is currently used).

As indicated earlier, additional measurements of urine samples are needed, as are chest measurements of some Palomares residents. I believe Drs. Ramos and Iranzo have established the necessary rapport with the Palomares residents and can probably convince the residents to participate in such an effort with little fanfare.

5. Consider the Advisability of Providing Them with a New Lung Counter to Recount a Number of the 100 Palomares Residents Examined the First Year after the Accident

The dual crystal (NaI-CsI) phoswich detectors have been installed in Madrid, and calibration measurements are in progress. Dr. Langham suggested that the minimum detectable activity (MDA) might be 4 $\pm$ 4 nanocuries plutonium-239, but a value of 7 to 8 nanocuries is more likely. The MDA for americium-241 will be about 0.3 nanocurie. Since the United States is

committed to an assistance program, I believe we should offer the best available equipment, technology, and expertise as we are, in a sense, "on display" to many European scientists who visit the JEN.

6. Manifest More Interest in Their Work Through More Review of Their Efforts

I strongly concur with this suggestion. The ultimate success or failure of Project Indalo (in terms of accruing valuable information on plutonium in the environment or merely accumulating numbers) may depend on this point. The Spanish investigators are competent and proud, but it is necessary for them to maintain strong links with investigators in the United States. There has been correspondence between several U.S. contacts and JEN personnel, but there is a need for better liaison and information exchange.

I believe the AEC needs a primary technical contact in the United States who can assist the JEN personnel in technical matters and who can make the needs of the JEN known in Washington. Further, I recommend that this person, or someone familiar with Project Indalo, visit the JEN on an annual basis. Because of communications problems, there is no substitute for an actual visit.

Also in 1974, P. Dean and others of LASL significantly upgraded the Spanish counting program with the installation of new alpha spectrometers, chest counters, and weather monitoring stations; this equipment was the best state-of-the-art available in the United States at that time.

P. Dean made two trips to Spain in 1975 to investigate problems related to analysis of whole-body counting data which were traced to equipment malfunctioning. This situation emphasized the need for closer liaison between the Spanish JEN and DOE. In a meeting with General Olivares, head of the JEN, and other JEN personnel, Dean proposed the formation of two three-man committees, Spanish and U.S., to review the Project Indalo program. This proposal was agreed upon, and Drs. Ramos, Iranzo, and de los Santos currently represent the JEN and Spain, and the authors of this proposal represent the Department of Energy and the United States. In addition, the DOE now provides for a continuing technical liaison with the JEN through Mr. Dean's annual visits.

In 1977, Dean found additional equipment difficulties which reduced the effectiveness of the JEN to carry out the radioanalysis of samples. Funds were requested from DOE to alleviate this situation. These funds were received early in 1978. The equipment was installed in Madrid by Dean in September during his annual visit and represented a four-fold increase in counting capability.

6. RECOMMENDATIONS FOR AN EXPANDED PROGRAM INDALO

6.1 Ongoing Programs Related to the Four Major Points of the Hall-Otero Agreement

6.1.1 People

Soon after the accident in 1966, 100 of the most likely exposed residents of Palomares were taken to Madrid and counted over the chest region by means of a proportional counter. The lower limit of detection was approximately 40 nanocuries (nCi), and no positive activities were determined in any of the measured individuals. The detector was later modified to give a minimum detectable limit of about 25 nCi, and several of the individuals who might have received higher exposures than others were counted. No positive measurements were observed even with the improved detector sensitivity. Forty-nine of the subjects were males over 14 years of age, 32 were females over 14 years of age, 10 were males under 14 years of age, and 9 were females under 14 years of age. Measurements were made at the laboratories of the Division of Protection and Medicine of the JEN in Madrid. Prior to counting, the subjects underwent a complete medical examination in order to determine their state of health.

Attempts were made to search for plutonium contamination in human subjects in 1975 using NaI-CsI phoswich detectors installed by Dean in 1974. These detectors are considered to be the best currently available and have a minimum detectable limit of about 20 nCi of ^{239}Pu. However, the 1975 data are considered to be unreliable because of problems associated with the counting equipment (principally high and variable background measurements). Additional measurements were made in April 1978 on some Palomares residents, but no results are available at this time. Only rarely have any of the subjects been measured more than once. It is not possible to unequivocally state, based on data obtained to date, the presence or amount of plutonium in the residents of Palomares. Neither can we state unequivocally that no internal contamination has occurred. It is of considerable importance that this question be resolved as soon as possible. Regardless, it is somewhat reassuring that this severe contamination event apparently has not resulted in heavy internal contamination (for example,

relative to the occupation reference value of 16 nCi for plutonium-239 in lung tissue). High activity levels would have been detected, even with the less sensitive counting equipment.

Twenty-four-hour urine samples were collected from the 100 individuals originally studied during their 1966-67 visit to Madrid. Three complete 24-hour urine samples were taken from each subject on three consecutive days. Alpha spectrometry was used to determine the plutonium-239 content of the urine. Seventy-one percent of the subjects showed no indication of urinary plutonium. Eighteen percent showed, in some of the analyses, plutonium contents of less than 0.1 disintegration per minute per 24-hour sample, 9% showed activity levels between 0.1 and 0.2 disintegration per minute per 24-hr sample, and 2% showed levels between 0.2 and 1.0 disintegration per minute in the 24-hour urine samples.

Additional samples were obtained from subjects who visited Madrid in 1975 and 1976. All the 1975 measurements were negative. Several of the 1976 measurements may have been positive and perhaps in the range of 0.1 disintegration per minute per 24-hour sample. Data for one subject suggest a value possibly 4 times higher than this.

Although urine assay can be a sensitive measure of systemic body burdens of plutonium it cannot yield quantitative data on inhalation exposures and lung burdens.

Drs. Iranzo and Richmond recently devised a follow-up study protocol which would involve annual measurements (chest counting, urine radiochemistry, medical examination, radiology, blood and urine chemistry, and chromosome analysis) on several subgroups. Others could be included should they express an interest. The subgroups would include the following:

ten children born in Palomares since 1966;

ten people present in Palomares during the accident and living nearest the areas of highest contamination;

ten people working in areas in Palomares currently associated with the highest levels of residual contamination;
ten adults now in Palomares who were not present in 1966;
ten JEN staff in Madrid who worked at Palomares after the accident; and
ten JEN staff in Madrid who are not involved with Project Indalo and who are not exposed occupationally to plutonium.

Thus, about 60 people would be studied each year. Of these, 40 would be selected from the 2000 or so residents of Palomares. Ten of the 60 would have no connection with Palomares and would represent a control group. Ten of the 60 would be JEN employees who were at Palomares during the initial cleanup. In addition to the control groups described above, the current effort to count all Palomares residents will be continued. Any person found to be positive will be recounted.

All new JEN employees provide blood samples for karyotyping, and samples from uranium miners are routinely examined. Other organizations concerned with radiation protection often scan a few cells to check for obvious genetically related syndromes and save the samples for reference and analysis at a later date should some question arise about exposure. This procedure should be adopted for the present until other provisions can be made for all the human study groups including those from Palomares. Controls for measurements of Palomares residents come primarily from the JEN staff. It would be much better to use a control group from a nearby village and we feel that this should be done if at all possible. This applies to all of the human measurements programs.

For the planned study mentioned above, it is expected that a two-day urine sample (PM-AM/PM-AM) will be collected from each of the 60 subjects at three-month intervals. Replicates from each sample would be measured by alpha spectrometry for plutonium-239. Thus, up to 480 samples per year would need to be analyzed. Additional analytical support and additional alpha spectrometers will be needed for this task. Urine samples from these subjects should be assayed also for americium-241 and other radionuclides using solid-state Ge(Li) systems.

The proposed subgroups would receive full medical and radiological examinations (including chest couting and urine assay) during each of the five years of this plan. The information obtained should allow conclusions to be drawn concerning the extent of internal plutonium contamination. These data would be reviewed each year by the six members of the technical groups from the United States (Richmond, Dean, and Wachholz) and Spain (Iranzo, de los Santos, and Ramos) and by other consultants if necessary and program alterations would be made as required.

Although it is recognized that there may be considerable difficulty involved, it is suggested that the feasability of studying long term health consequences of the Palomares population be explored. Currently medical histories are being taken from those people brought to Madrid for examination.

6.1.2 Air

The point of the Hall-Otero Agreement concerned with air monitoring resulted in the installation of four continuously operating air monitoring stations and two meteorological stations which were strategically located with respect to the contaminated areas. One of the air monitoring and meteorological stations was located in the center of Palomares in Area 5 (Appendix 6). Continuous air monitoring at all four stations was continued for several years following their installation. Daily samples were counted for gross alpha activity, and ten-day samples were pooled and analyzed for plutonium using alpha spectrometric techniques. Uranium-234 and uranium-235 were determined in the 1967 air samples. These data were reported by Iranzo and Salvador at the Second International Congress on Radiation Protection held at Brighton, England in May 1970. A preprint of this information has been available to the scientific community, but the data have not yet been published. The complete reference to this work is contained in the bibliography (Appendix 8) attached to this report (taken from C. R. Richmond, Foreign Travel Report, dated August 6, 1974). A cursory examination of the data given in the Iranzo and Salvador report suggests a resuspension factor of the order of 10^{-6} for the worst (windy) conditions reported. This is an example of the kind of information that could be deduced from a careful and thorough workup of data obtained to date on the Palomares incident.

Positive measurements were obtained occasionally for air samples collected at all stations, with the highest values coinciding with periods of high wind velocity (above 35 kilometers per hour). For 1966 and 1967, the mean plutonium-239 values in Palomares were 0.38 x 10^{-15} and 0.09 x 10^{-15} Ci/cm^3, respectively (0.38 and 0.09 fCi/m^3). The currently proposed EPA screening level for plutonium in the environment, overaged over one year, is 1 fCi/m^3; some individual values during 1966 and 1967 at Palomares exceeded the EPA value. The patterns of contamination on the filters suggested that the plutonium was in particulate form.

Unfortunately, in 1969 one of the original four air sampling stations (nearest Impact Point 2) was discontinued and since then only three have been available for use. Dr. Langham, in his 1972 report, indicated that only the air sampling station in the center of the village (Area 5) and the one in the irrigated fields east of the village (Area 3) were in operation in late 1971. The air sampler in Area 2-2 (Appendix 7) was temporarily inoperative at that time. All three stations were renovated in 1974.

It is quite interesting that the air samples (10 day averages) measured during the past few years are all at the lower limit of detection, which is around 10^{-17} Ci/cm^3 (10^{-2} fCi/m^3). Studies are currently under way and will be continued to correlate individual 24 hr. samples with wind speed and direction. Iranzo and colleagues are trying to establish possible trends in the change in air concentrations versus time since 1966. No particle-size measurements have been obtained to date.

It is unfortunate that air sampling Station 2-1 was removed in 1969, since it was located in a position to sample possible movement of material from the untreated hillsides near Impact Point 2. Since this area is now undergoing intensive cultivation, including the terracing of these hillsides, it is imperative that Station 2-1 be reestablished. In September 1978, during a visit to Palomares, Iranzo and Dean selected a new site for the station and obtained an estimate of the cost of setting it up. This cost is included in the operating budget. Minor funds will also be required to recondition the existing stations.

6.1.3 Vegetation

Six sites were originally selected as study plots within the areas known to be contaminated. These plots are shown in Appendix 9. Areas 2 and 3 each have two study plots, and a control plot designated 2-3b was established about 5 kilometers north of Palomares. One study plot was established in Area 5. Each was a 50 x 50 meter square with nine sampling points on the diagonals for the five plots in Palomares. Cores were removed in duplicate at each sampling point at depths of 0 to 5, 5 to 15, 15 to 25, 25 to 35, and 35 to 40 cm, for a total of 90 samples per plot each year.

Vegetation samples, both wild and cultivated, were collected once each year at the same time the soil samples were obtained. There has been good correspondence between the location of plant and soil samples at each site within a given study plot.

Ashes from the samples collected from 1968 onward have been retained and are available for analysis. However, ash samples are not available for samples collected in 1966 and 1967. Plutonium-239 measurements have been made from 1968 on. The main problem with sample analysis is related to the occasional presence of plutonium particulates on the vegetation, which can give occasional very high results. This effect is almost always noted in the wild vegetation and not in the cultivated crops. Many species of plants, both cultivated and wild, are measured; for the cultivated plants both foliage and fruit are measured for plutonium contamination. In virtually every instance, the fruit of the cultivated crops shows no plutonium contamination. Iranzo continues to obtain vegetation samples from outside the originally established study plots in an attempt to monitor for redistribution of the residual contamination. This effort requires more resources, increases the number of samples to be measured and contributes to the backlog. It would be useful at some future data to analyze some of the stored ash samples obtained from vegetation for americium-241. This requires the acquisition of solid-state measuring systems which would also be useful for soil analysis. Sampling Station 3-2, which was washed out in the 1973 flood, has been reestablished.

6.1.4 Soil

Because of the possibility of plutonium redistribution in Area 2 during recent years, the Spanish began measuring plutonium in the upper soil surfaces (about a millimeter or so in depth) in a newly established sampling area. Thus they are falling behind in their routine measurements associated with samples obtained from the five original sampling stations (study plots). It should be noted that for each of the sampling stations measured per year, there are replicate measurements done for separate soil samples collected at nine points on a grid for five depths resulting in 90 measurements per year (9 x 5 x 2 per site).

Plutonium-239 soil measurements were not started until 1969. Samples from which replicates are taken for measurement are stored for future analysis. It will be possible to go back and measure these accumulated samples for americium-241 and other radionuclides. There is currently a backlog of samples awaiting analysis. Currently those samples taken from the soil surfaces are being processed. Next the depth profiles will be obtained for samples collected in 1975, 1976, and 1977.

To help reduce the backlog of uncounted samples and to accelerate the couting program, the DOE provided funds for an additional 16 alpha spectrometers. This equipment was purchased and installed in Madrid by Dean in September of 1978. Although this produced a considerable improvement in JEN capabilities, (increasing the number of operating detectors from 4 to 20) there is still no capability for the assay of americium-241 and other nuclides. To correct this deficiency and to provide additional support to the plutonium counting program we feel that a solid state detector system (4 detectors) should be added to the JEN counting facility.

6.2 New Activities

6.2.1. Ground Area Survey

A survey of surface activity throughout Area 2 and spot checks in and around Palomares should be undertaken as soon as feasible. Dr. Iranzo and appropriate U.S. experts from ORNL, LLL and LASL have discussed the various methods of making such a survey. The technique selected is described in Section 7.2.

Because of recent cultivation of previously uncultivated but contaminated land (in Area 2) by farmers in Palomares, it is anticipated that additional soil sampling may be required. Estimates of the extent and cost of such sampling and analysis cannot be made until a ground survey of Area 2 is completed.

6.2.2. Animal sampling program

Although animals are not grown commercially in Palomares, goats, chickens, and sheep are raised for local consumption. Both the goats and sheep graze freely over the uncultivated land, particularly in Area 2, including Areas 2-0 and 2-1. The possibility exists, therefore, of transport of plutonium to the Palomares residents. We propose that in a modest program be initiated to sample appropriate tissues of animals whenever possible. It must be modest due to the small numbers of animals involved and the lack of a commercial market.

6.2.3. Particle-size determination

It is clear that much of the plutonium detected on air filters and in soil samples is in the form of particles. We propose that we now learn more about the distribution of particle sizes in both Areas 2 and 3 since we have no useful knowledge of this parameter at present. Assessment of potential dose to man from plutonium contaminated soil requires some knowledge of the particle-size distribution. The current state-of-the-art in this field will be reviewed in detail and U.S. experts consulted as to the best procedures and equipment to use. Various techniques such as fission fragment analysis, autoradiography, and electron microscopy might be employed either in Spain or in collaboration with DOE laboratories.

7. RESOURCES REQUIRED

The following resources will be required for a five-year segment of the expanded Project Indalo studies. Presumably Year 1 would coincide with the DOE FY 1979. Recent years (1976 and 1977) indicate a large increase in the cost of living in Spain (20% per year). Thus we have incorporated a 20% annual escalation value into our planning estimates for this factor. We cannot at this time, despite recent (May 1978) discussions between Drs. Iranzo and Richmond, break down operating costs according to the major sections of the Hall-Otero Agreement. We have estimated, however, that the total operating funds would probably be divided somewhat as follows:

People 35%

Air 10%

Crops and soil 35%

Animal tissues 20%

The area survey would hopefully represent a one-time cost during the five-year period and is included in the first year cost estimates.

Execution of several recommendations made in Section 6 requires the purchase of equipment in the first year. The total cost of equipment would be $175,000. Maintenance of this equipment would be covered by operational funds.

7.1 Operating Costs

The following table lists the operating funds (in thousands of dollars) to be supplied to the project over the five-year segment by the U.S. DOE:

Fiscal year	79	80	81	82	83	Total
Year	1	2	3	4	5	
Cost, in thousands	150	200	240	290	350	1,230

It should be notd that the above assumes a 20% per year increase for the cost of living; therefore, there is little real continued growth except for a $20,000 increase between Year 1 and Year 2.

7.2 Equipment Funds

The ground survey proposed in Section 6 will require the purchase of two field survey instruments. Since the original survey of 1966, field survey technology has changed considerably. We recommend the use of a FIDLER type instrument that uses phoswich detectors. This instrument is believed to be the best currently available and is especially well suited for the very rough terrain in Area 2 at Palomares.

Estimated cost - $20,000

To expedite all sampling programs described in Section 6, particularly with regard to assays for americium-241 and other nuclides, we propose the purchase of four intrinsic germanium solid-state detectors. These instruments would also be used in the soil survey program to correlate surface measurements with actual soil content (10 mm-deep layers). To take maximum advantage of the resolution of the detectors necessitates the use of a computer-based pulse height analyzer, similar to the one the JEN currently uses in the alpha spectrometry system. This analyzer will permit rapid, on-line analysis of the data, including isotope identification and quantitation. These calculations are complicated and tedious and if done manually could result in an accumulation of unanalyzed data. The analyzer is also very flexible and can be used with other counting systems within the JEN.

Estimated total cost - $107,000

($20,000 for each detector + electronics).

The proposed air sampling program will require the addition of one complete air sampling station, to be placed in Area 2-1. In addition, the three current stations need to be reconditioned. The establishment of Station 2-1 will also require providing electrical power at the site. The cost will be about $5000 and will be covered in the operating expenses.

Estimated total cost - $1000

The particle size distribution measurements will require the use of cascade impactor devices. We propose that two be purchased. Portable power generators will also be required since the instruments will be used at

various locations throughout Palomares at various times of the year; power lines will not be available.

Estimated total cost - $4000

We also recommend the purchase of a computer-based pulse height analyzer to be used in the whole-body and chest counting program. As with the solid-state detector, this analyzer will expedite data analysis. It is especially important that data on people be analyzed immediately. The people being counted for plutonium are available in Madrid only for a short time and the counting results must be obtained before they leave. Only in this way can repeat counts be made if the results are invalid due to equipment failure or for some other reason. This analyzer would also be available to aid in the soil and vegetation counting programs.

Estimated total cost - $33,000

Cost Summary:

1.	Field survey instruments (FIDDLER, modified by LASL), 2 each	$ 20,000
2.	Intrinsic germanium detector, 4 each	107,000
3.	Air samplers for Palomares	1,000
4.	Particle sizing instruments (cascade impactor), 2 each	4,000
5.	Pulse height analyzer, for human counters	33,000
6.	General updating of current electronics to accommodate new equipment	10,000
	Total	$175,000

Wherever possible, shipments of materials should be arranged with the assistance of the U.S. Embassy in Madrid.

7.3 Program Liaison

It is important to maintain close relations with Dr. Iranzo and the technical staff at the JEN's Division of Protection and Medicine. Periodic visits are important, as data should be analyzed at least annually, perhaps just after the human data are obtained and analyzed. The U.S. advisory group (Richmond, Dean, and Wachholz) should also meet periodically to review the progress and needs of Project Indalo. Dr. Iranzo visited the United States in July 1978. He should be encouraged to visit whenever practicable.

7.4 Agency

The DOE inherited its responsibility for Project Indalo from its predecessor agencies. It is particularly important, because of the current climate in the United States and abroad concerning the effects of radiation on man, to devote the required resources and attention to this important situation. We are indeed fortunate that excellent rapport has been maintained among the individuals involved on the project in the United States and Spain since 1966.

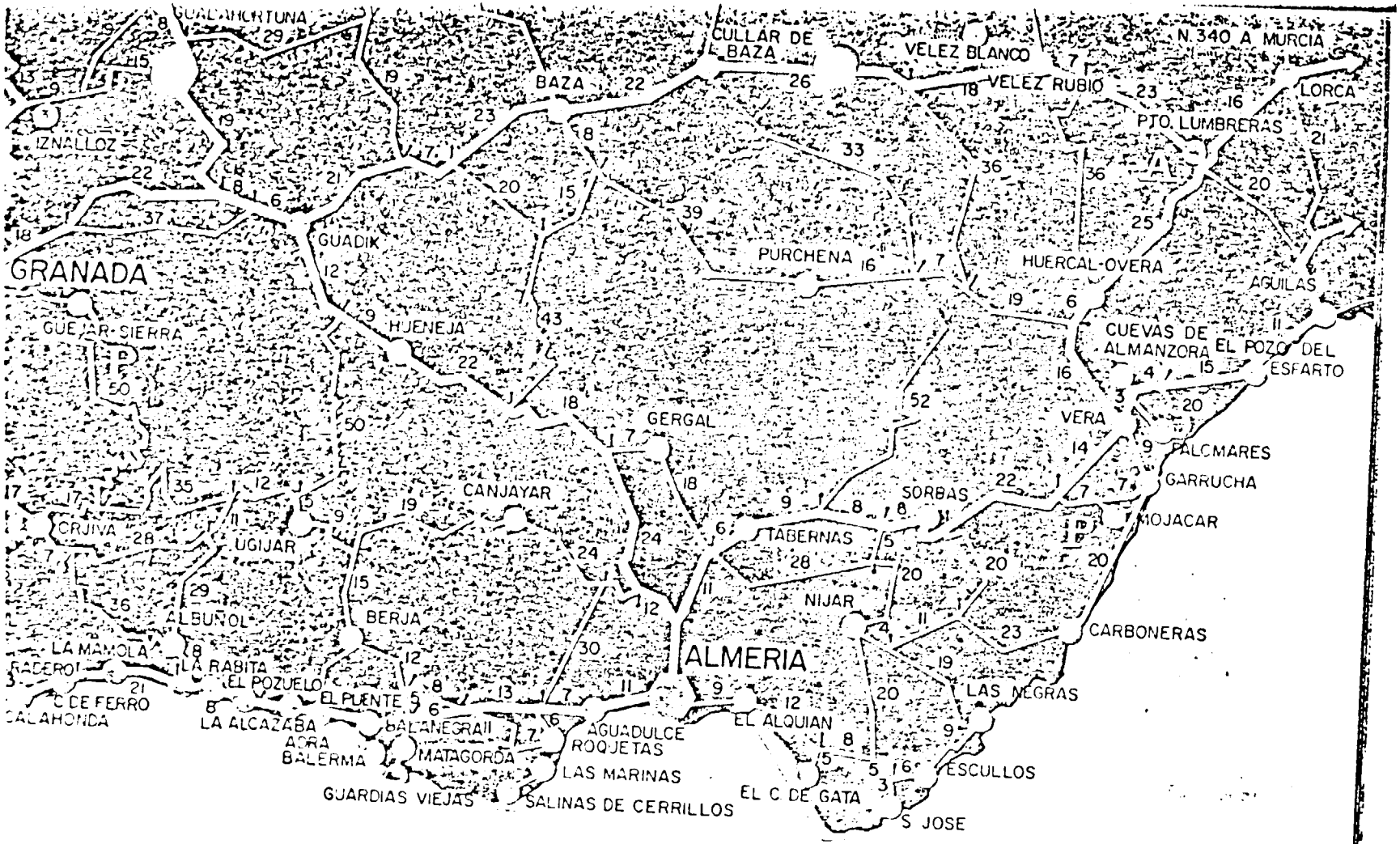
It is also clear that we must do all that is necessary together with the JEN to learn about any potential health effects that may develop among the people of Palomares.

7.5 Government

The U.S. Goverment has an obligation via the Hall-Otero Agreement to Project Indalo. In particular, the U.S. Goverment agreed to "continued provision, beyond the first year, of specialized equipment, technical assistance and advice for as long as both parties mutually agree to be desirable on the basis of observations as they are obtained." The initial remedial action costs at Palomares were large. However, the investment of U.S. Goverment operating funds for Project Indalo since 1966 have been minimal ($356,000 through FY 1978), as has been that for capital equipment. These costs are negligible as compared with the original cleanup costs following the accident.

8. LONG-TERM CONSIDERATIONS

This document addresses the reassessment of Project Indalo's needs for a five-year period beginning with FY 1979. It is important, however, to realize that because of the time periods involved - both for the human life span and the radiological half-life of plutonium - attention must be paid to Project Indalo for some time to come. It would be tragic and irresponsible not to provide some basis for continuity and institutional memory of Project Indalo. We must also remind overselves that only a dozen years have passed since the accident. What will be learned, including negative results, will be well worth the investment.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GUADIX
PURCHENA
HUERCAL-OVERA
AGUILAS
GRANADA
GUEJAR-SIERRA
HUENEJA
CUEVAS DE ALMANZORA
EL POZO DEL ESPARTO
GERGAL
VERA
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CANJAYAR
SORBAS
MOJACAR
CORJIVA
UGIJAR
TABERNAS
NIJAR
CARBONERAS
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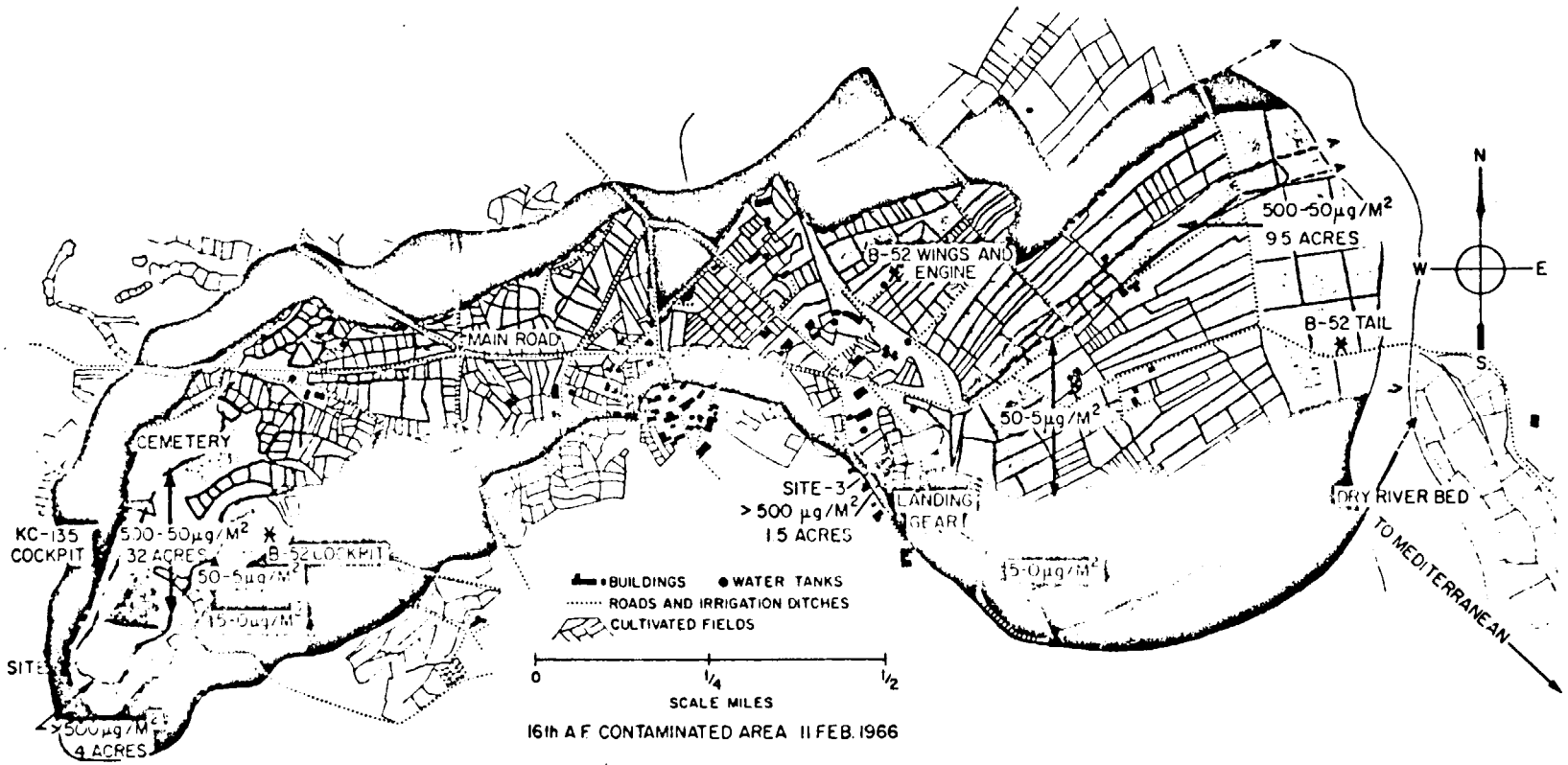
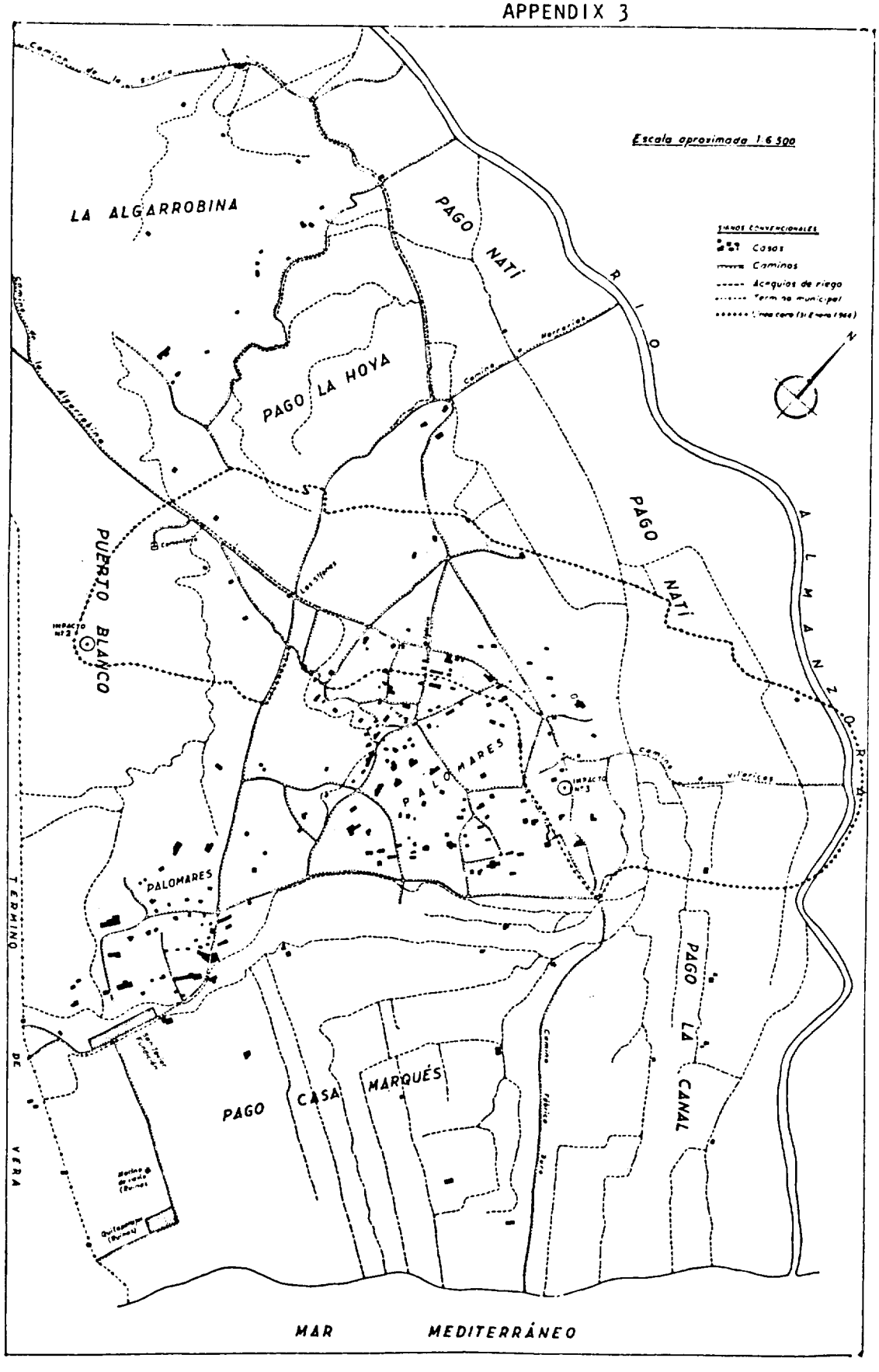
APPENDIX 1



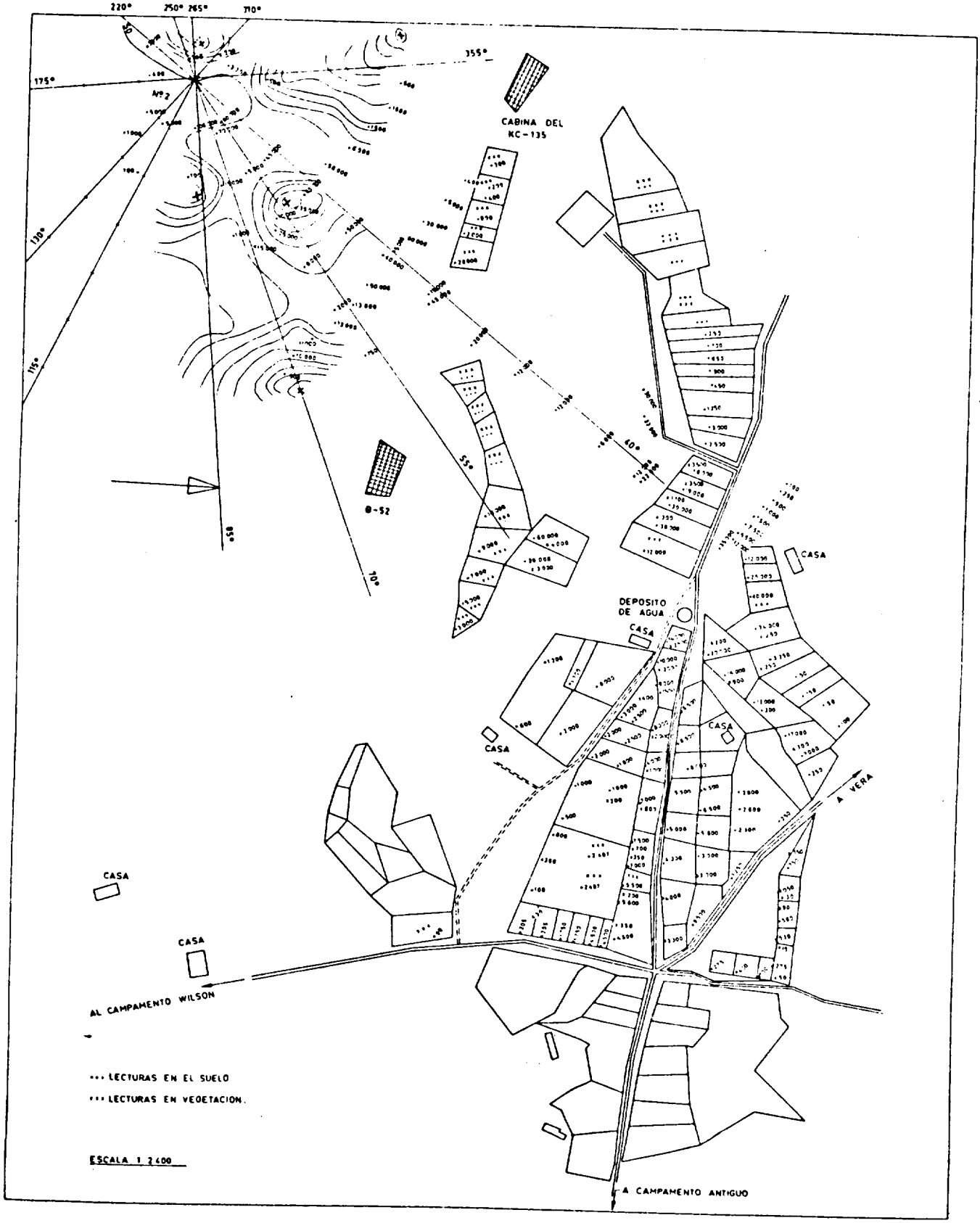
16th A F CONTAMINATED AREA 11 FEB. 1966

APPENDIX 2

APPENDIX 3


Escala aproximada 1:6.500
SIGNOS CONVENCIONALES
Casas
Caminos
Acequias de riego
LA ALGARROBINA
PAGO NATÍ
PAGO LA HOYA
PUERTO BLANCO
PAGO NATÍ
ALMANZORA
PALOMARES
PALOMARES
TERMINO DE VERA
PAGO CASA MARQUÉS
PAGO LA CANAL
MAR MEDITERRÁNEO

APPENDIX 4



Appendix 5

APPENDIX 5

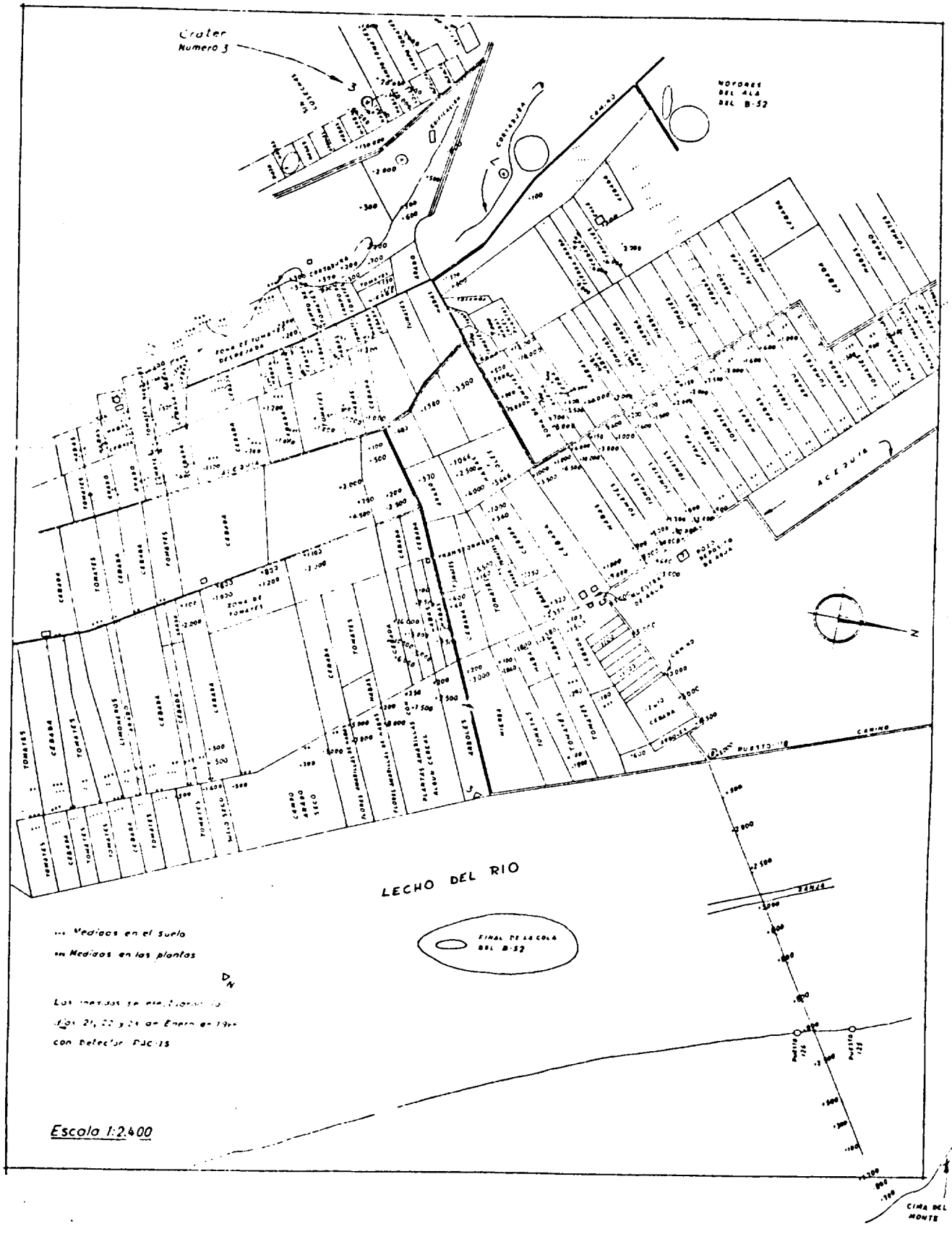
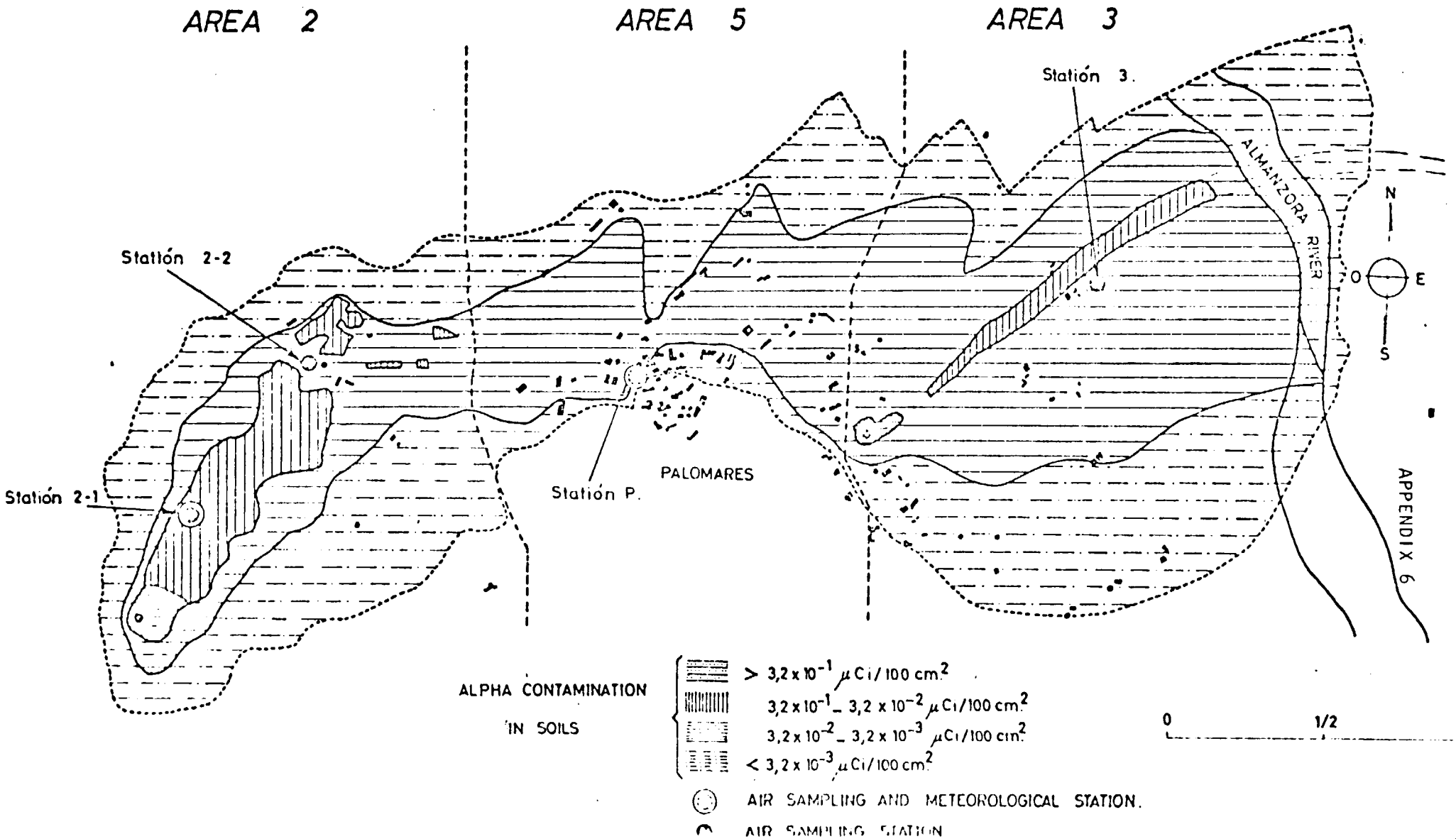

Crater
Numero 3
MOTORES
DEL ALA
DEL B-52
ACEQUIA
LECHO DEL RIO
FINAL DE LA COLA
DEL B-52
... Medidas en el suelo
... Medidas en las plantas
Escala 1:2.400
CIMA DEL
MONTE

Figura 1.


AREA 2
AREA 5
AREA 3
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Station P.
PALOMARES
APPENDIX 6
ALPHA CONTAMINATION
IN SOILS
> 3,2 x 10⁻¹ μCi/100 cm²
3,2 x 10⁻¹ _ 3,2 x 10⁻² μCi/100 cm²
3,2 x 10⁻² _ 3,2 x 10⁻³ μCi/100 cm²
< 3,2 x 10⁻³ μCi/100 cm²
AIR SAMPLING AND METEOROLOGICAL STATION.
AIR SAMPLING STATION
0
1/2

APPENDIX 7

COPY

Madrid, Spain,
February 25, 1966.

Dear Professor Otero:

Pursuant to our Agreement for Cooperation for Civil Uses of Atomic Energy between Spain and the United States I wish to propose that we expand our collaboration in the fields of health and safety. Accordingly, on behalf of the United States Atomic Energy Commission and in accordance with the relevant articles in our Agreement for Cooperation of August 16, 1957, as amended, I suggest we investigate various health and safety aspects of fissionable materials when released into a rural agricultural environment.

Collaborative investigations shall be initiated as soon as possible of the physiological and ecological behavior of plutonium oxide in a previously contaminated rural area that has been decontaminated in accordance with mutually agreed upon decontamination limits and procedures. More specifically the investigations shall consist of the points I have set forth in the attached annex to this letter.

It is understood that information considered essential to our collaboration shall be shared freely by the two agencies as well as all information derived from these investigations. It is further understood that the results derived shall not be released to the public without the concurrence of the two agencies.

If these ....

Excmo. Sr. D. José María Otero Navascues,
Marques de Hermosilla,
Presidente de la Junta de
Energía Nuclear,
Avenida Complutense 22,
Ciudad Universitaria.

COPY

If these proposals are acceptable to you, I suggest that this letter and your letter of acceptance shall constitute an understanding on these subjects between our two agencies.

Sincerely,

John A. Hall
Assistant General Manager for
International Activities
ATOMIC ENERGY COMMISSION

Enclosure: Annex

ANNEX

1. Collection of information on uptake and retention of plutonium and uranium by representative numbers of a population group potentially exposed to inhalation of a plutonium oxide aerosol,
2. measurement of temporal and seasonal fluctuations in plutonium air concentrations above a plutonium oxide contamination agricultural area that has been subjected to the agreed upon decontamination procedures,
3. serial measurements of contamination levels (both by plant uptake from the soil and wind dispersal) of agricultural products produced in a contaminated area subsequent to decontamination and,
4. studies of the temporal migration and redistribution of plutonium oxide in soil, decontaminated by deep plowing, as a result of continued cultivation and weathering.

COPY

Annex

The Junta will assume the position of principal investigator with the U.S.A.E.C. providing support in the form of technical assistance and advice and specialized equipment and materials not readily available to the Junta.

In the role of principal investigator the Junta will assume responsibility for the following:

1. Provision of building and laboratory space required to initiate and carry on the program.
2. Establishment, with the help of U.S. specialists, of sampling methods, routines and schedules for population, air, produce and soil measurements.
3. Provision of logistic support required by sampling and measuring schedules.
4. Performance of all scientific measurements and tests.
5. Compilation and documentation of all scientific data.
6. Provision of travel for its own specialists sent to the United States for consultation, planning or training purposes.

Annex

In the role of secondary investigator, the U.S.A.E.C. will assume responsibility for the following:

1. Provision, either through funding or by transfer, of specialized equipment and material required by the program. During the first year this will consist of:
   a. A whole body counter, complete with crystal spectrometer and plutonium X-ray detector.
   b. One (8 place) scintillation alpha counter of the type currently in use at the Los Alamos Scientific Laboratory or the New York Health and Safety Laboratory.
   c. One alpha spectrometer complete with multi-channel analyzer and data read-out equipment.
   d. Additional, less specialized equipment, such as analytical balances, centrifuges, special chemicals, etc., in the amount of approximately $15,000.
   e. Plutonium and uranium analytical standards.

f. Four generator-powered hi-Vol air samplers of the latest design for continuous field operation.

2. Provision of a visiting specialist to install and calibrate the whole body counter and to train Junta personnel in its use.

3. Provision of visiting specialists in methods of plutonium and uranium analysis, to install specialized analytical equipment and train Junta personnel in techniques of plutonium and uranium measurement which are used in the United States, published and unpublished.

4. Provision of a visiting specialist in soil and plant sciences to help develop the studies of plutonium translocation in the soil and its uptake by cultivated crops.

5. Continued provision, beyond the first year, of specialized equipment, technical assistance and advice for as long as both parties mutually agree to be desirable on the basis of the observations as they are obtained.

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