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Energy Measurements Group

Aerial Measuring Systems

AN AERIAL RADIOLOGICAL SURVEY OF THE AREA SURROUNDING THE

DRESDEN NUCLEAR POWER PLANT

MORRIS, ILLINOIS

DATE OF SURVEY: SEPTEMBER 1972

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ABSTRACT

The Aerial Measuring Systems (AMS)* was used to survey the area surrounding the Dresden Nuclear Power Plant during September 1972. The survey measured terrestrial gamma-ray exposure rate and spectral data.

A high-sensitivity detection system collected gamma-ray spectral and gross count data. The data were then processed to construct a map of a 625 square mile area showing the spatial distribution of gamma-ray exposure rates 1 m above the ground. Exposure rates and isotopes identified are consistent with that related to normal terrestrial background radiation.

The Dresden area was surveyed in 1968 and 1970. Comparison of the 1968 and 1970 surveys shows no measurable change in the terrestrial gamma exposure rates. Comparison of the 1968 and 1970 surveys indicates a slight decrease in the average terrestrial exposure rate.

*Formerly the Aerial Radiological Measuring System (ARMS).

ACKNOWLEDGMENTS

Special appreciation is given to L. J. Deal, Assistant Director for Field Operations, Division of Operational and Environmental Safety, United States Department of Energy, and B. H. Weiss, Office of Inspection and Enforcement, United States Nuclear Regulatory Commission, for their support and encouragement in this program.

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1.0 INTRODUCTION

1.1 IDENTIFICATION OF SURVEYED PLANT AND AREA

The Aerial Measuring Systems (AMS)[1] operated by EG&G for the United States Department of Energy (DOE)* was used to survey an extensive area surrounding the Dresden Nuclear Power Station in September 1972. The Dresden site is located near Morris, Illinois. The size of the survey area was approximately 1600 km^2.

1.2 AMS PROGRAM

The present survey was made as part of a continuing nationwide AMS program started in 1958 to monitor radiation levels surrounding facilities producing or utilizing radioactive materials. This was the third survey of the Dresden area. The first survey was conducted in September 1968,[2] and the second survey in July 1970.[3]

The detection system on board the aircraft collected gamma-ray gross count and energy spectral data on each flight line of the survey. The gamma radiation and aircraft position information were processed by a computer to construct a map which shows the spatial distribution of gamma-ray exposure rates 1 m above the ground.

1.3 AMS EQUIPMENT AND PROCEDURES

The AMS aircraft and its on-board radiation detection equipment were used in the survey. Since the AMS equipment and procedures have been discussed in detail elsewhere,[1] they will only be described briefly here.

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*Formerly the United States Energy Research and Development Administration (ERDA).

This AMS survey was flown in a Beechcraft Twin Bonanza aircraft at an altitude of 150 m above terrain at a ground speed of about 140 knots (70 m/sec). The ground position of the aircraft, and its altitude above terrain, were measured and recorded every other second by a radar navigation computer system. The position and altitude measurements are accurate to ±100 m and ±1.5 m, respectively. The flight pattern consisted of a series of parallel lines spaced one nautical mile (1.8 km) apart, covering all of the land area within a 12-1/2 nautical mile radius of the facility. At an altitude of 150 m, the field-of-view of the detectors was approximately 400 m wide for a mean gamma energy of naturally occurring isotopes.

The aerial radiation measurements were of two distinct types, made simultaneously: (1) gross gamma count (intensity) measurements, and (2) gamma spectral measurements. The detector system consisted of an array of fourteen 4-in. x 4-in. NaI(Tℓ) scintillation crystals, each coupled to its own photomultiplier assembly. The detector system output was directed both to the gross gamma count computing system and to the multichannel spectrum analyzer. The data collecting system is shown in Fig. 1.

The gross gamma count system consisted of an amplifier-discriminator-computer unit that counted and recorded the total number of gamma rays of energy greater than 50 keV that were detected during a one second time interval. The gross gamma count rate (number of gamma rays detected per second) was digitally recorded, along with aircraft position and altitude, every other second. Aircraft position data were supplied by a track navigational computer and doppler radar. Altitude above terrain was measured with a radar altimeter. As a backup and complement to the digital recording of the gross count data, a record was made on a continuous strip chart of both gross gamma count rate and radar altitude as a function of distance. Typical gross count rates for natural background were several thousand per second.

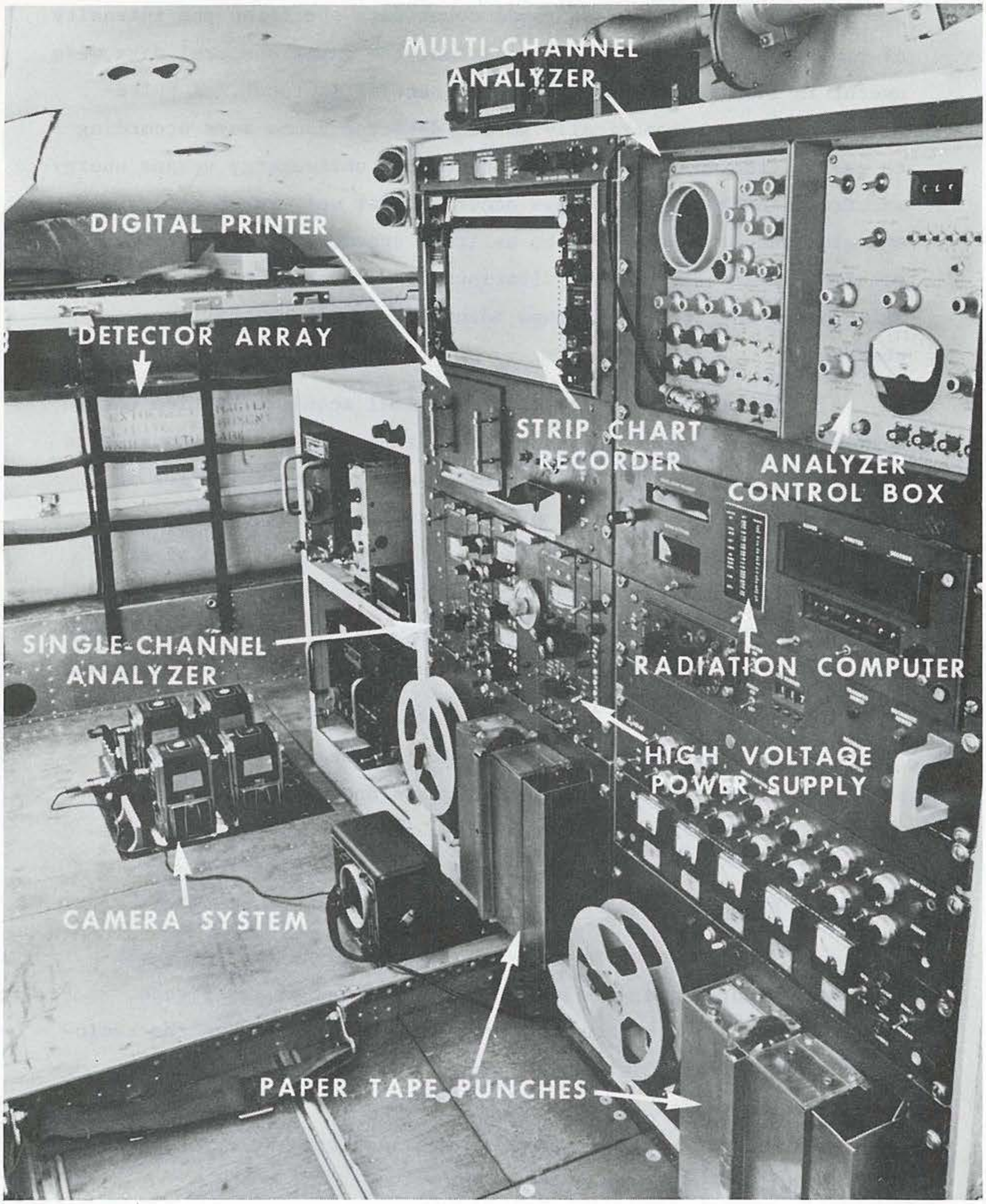


Figure 1. View of the interior of the Aerial Measuring Systems (AMS) aircraft showing detector package and electronic data collection system.

Whereas the gross gamma count data specified the intensity of radiation as a function of position, the gamma spectral data were useful in identifying particular radioactive isotopes. A pulse-height analyzer automatically sorted detected gamma rays according to energy, thereby generating a number per unit-energy versus energy spectrum. Although gamma rays occur only at well known discrete energies characteristic of the emitting species, air scattering tends to smear the detected distribution. Nevertheless, characteristic peaks that permit isotope identification were readily observable.

In wide area surveys, the typical acquisition time for a gamma-ray spectrum is several minutes; thus the spectrum represents the average radiological properties of a tract several miles in length. However, if an area of interest is indicated by an increase in the gross gamma count rate, spectral data acquisition times of only a few seconds can be used to isolate the area spatially. If further investigation is warranted, a ground mobile unit with equipment similar to that in the aircraft is available to provide greater spatial and energy resolution.

In addition to the equipment just described, the AMS aircraft also carried an air sampling and analysis system for the measurement of airborne radioactivity.

1.4 REDUCTION AND PRESENTATION OF DATA

The raw data from the gross gamma count and the gamma spectral measurements were permanently recorded on paper tape, which is computer processed and analyzed to characterize the radiological properties of the area surveyed. Using an altitude-dependent conversion factor obtained from prior calibration measurements, the corrected count rate was converted to exposure rate (μR/hr) at 1 m above ground.

The exposure rate conversion factor was obtained from repeated flights 60 m to 300 m above terrain containing known distributions of natural isotopes. Such conversion factors have proven valid over distributed fission product fields, with a variation of less than 25%. In practice, average exposure rate differences over large areas of 1 μR/hr can be reliably observed in repeated flights over the same area.

2.0 REACTOR AND SITE CHARACTERISTICS

2.1 REACTOR CHARACTERISTICS

The Dresden Nuclear Power Station is located in northeast Illinois, approximately ten miles east of Morris, Illinois.

The principal nuclear contractor is General Electric Company. The facility is operated by Commonwealth Edison Company.

Table 1 gives the specifications of the reactor facility at the time of the survey.

Table 1. Reactor Facility Specifications.

Reactor Unit	Reactor Type	Start-Up Date	Power Levels (Megawatts)		Status
			Electrical	Thermal	
1	Boiling Water	1959	200	700	Operational
2	Boiling Water	1970	809	2,527	Operational
3	Boiling Water	1971	809	2,527	Operational

2.2 SITE AREA CHARACTERISTICS

The terrain within the survey area is comprised mainly of flat farmland areas interrupted occasionally by the strip mines and their associated gravel pits. Major water bodies lying within the survey boundaries are the Illinois, Des Plaines, and Kankakee Rivers. Numerous smaller streams are also in evidence. A geological isopleth map of the Dresden area is shown in Fig. 2.

The known hazards to low-level survey flights are transmission towers in the Joliet area and next to the reactor site itself. Small airfields are at a minimum within the area and Joliet is the only airfield within the survey region with significant activity.

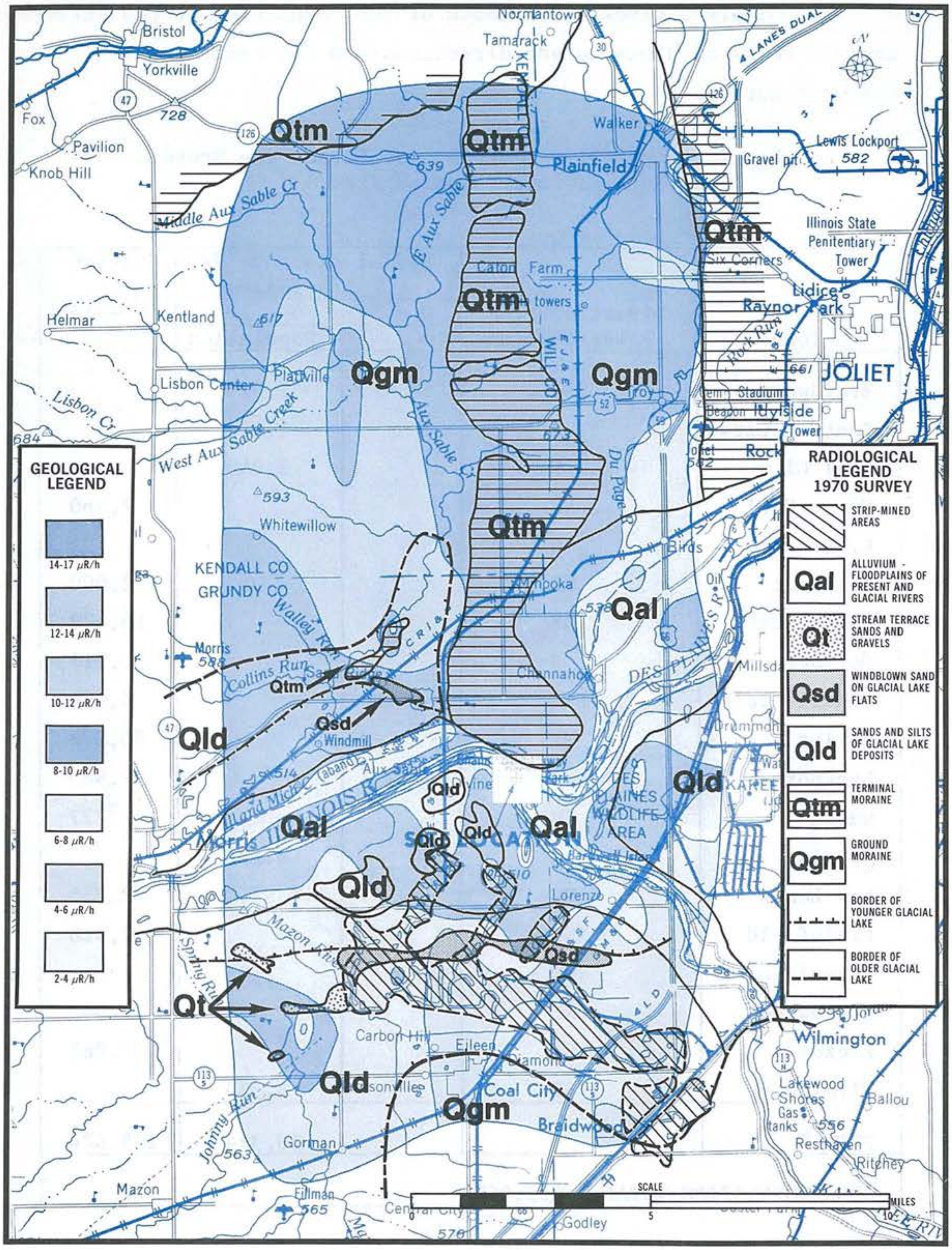


Figure 2. A geological isopleth map of the area surrounding the Dresden Nuclear Power Station.

Table 2 gives a breakdown of the population of the survey area in terms of distance and direction from the reactor site (1970 census figures).[4]

Table 2. Population Distribution Within the Dresden Nuclear Power Station Area.[4]

Town	Direction From Power Station	Radial Distance From Station (Miles) 0 - 5	5 - 10	10 - 15
			Population	
Braidwood	SSE		2,323	
Central City	S		1,377	
Coal City	S		3,040	
Crest Hill	NE			7,460
E. Brooklyn	S			72
Fairmont	NE			2,000
Forest Park	NE			15,472
Gardner	S			1,212
Ingalls Park	ENE			5,000
Joliet	NE			80,378
Lockport	NE			9,985
Mazon	SW			727
Morris	W		8,194	
New Lenox	NE			2,855
Plainfield	NNE			2,928
Platville	NNW		125	
Ridgewood	NE			5,500
Rockdale	NE			2,085
Wilmington	SE		4,335	
TOTALS			19,394	135,674
AREA POPULATION TOTAL: 155,068				

3.0 SURVEY PLAN

3.1 SPECIFICATION OF FLIGHT LINES

The flight pattern for the Dresden survey consisted of twenty-five flight lines approximately 46 km long and spaced one nautical mile (1.8 km) apart (Fig. 3). The flight lines were oriented in a north-south direction. Radiation data, together with aircraft position and meteorological information, were collected along each flight line.

3.2 COORDINATION WITH LOCAL AUTHORITIES

AMS survey missions are conducted under special waiver from the Federal Aviation Administration. The survey plan was discussed with the General Aviation District Office at Chicago, and public announcements were published in the local newspapers prior to the survey operation, in accordance with the FAA waiver for low-level flights.

The base of operations for the survey mission was Rockford, Illinois.

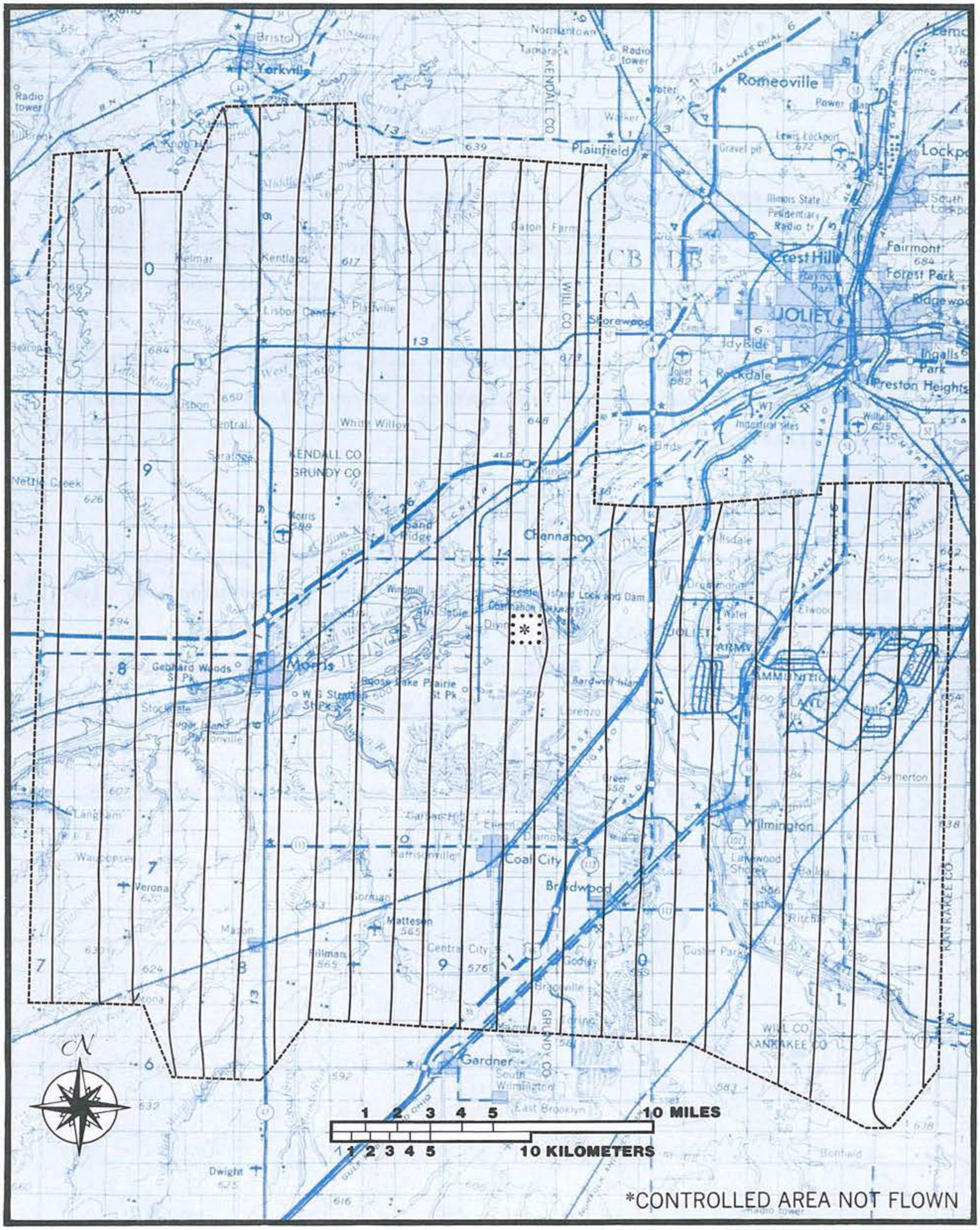


Figure 3. Survey flight lines superimposed on a USGS topographic map of the area surrounding the Dresden Nuclear Power Station.

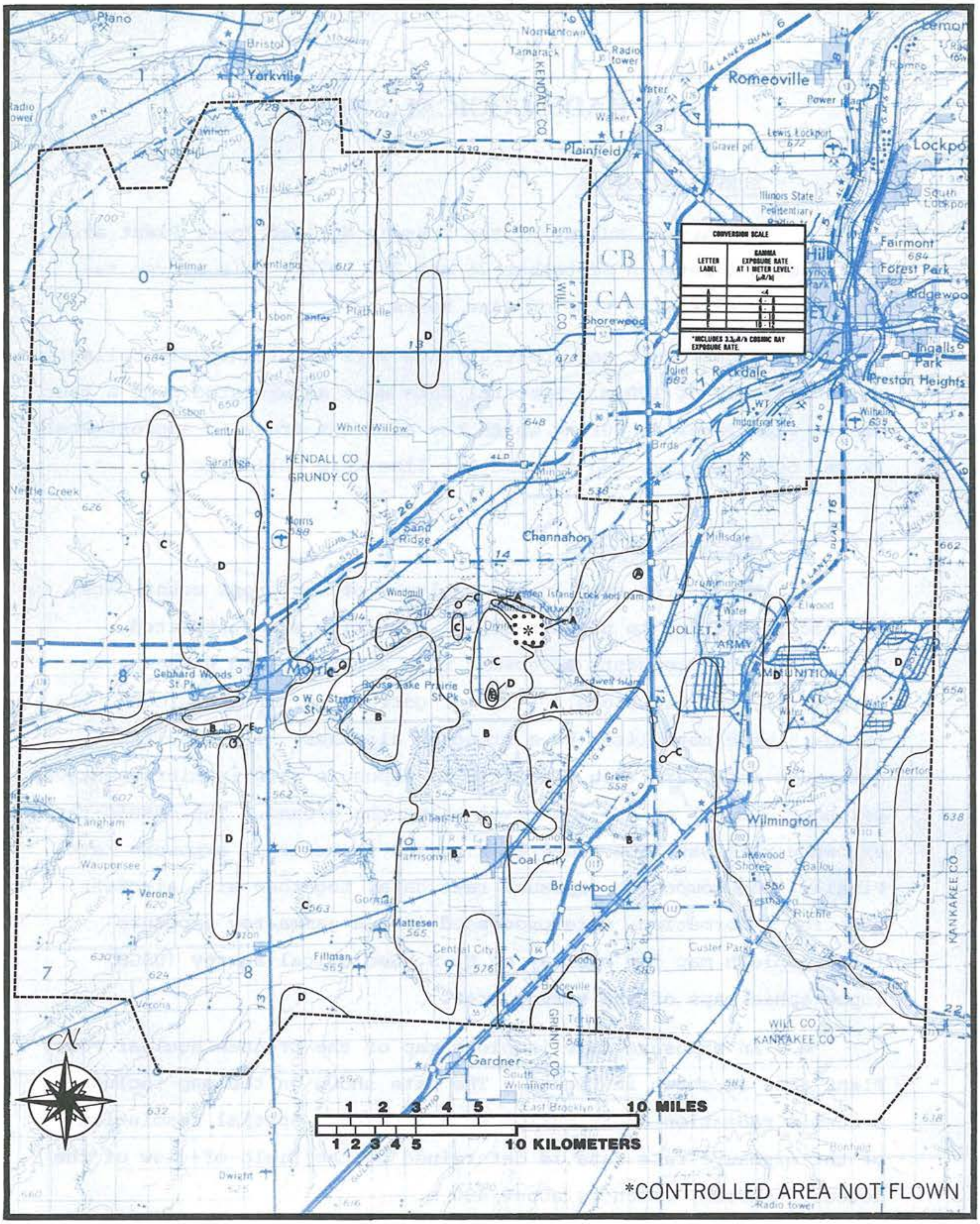


Figure 4. Exposure rate isopleths superimposed on a USGS topographic map of the area surrounding the Dresden Nuclear Power Station.

4.0 RADIOLOGICAL SURVEY

4.1 SURVEY MISSIONS

The aerial survey of the Dresden Nuclear Power Plant area was conducted between September 26 and 29, 1972. This survey required a total flying time of nine hours.

Gross count and spectral data were simultaneously collected at an altitude of 150 m. Spectral data were accumulated over a four minute time interval during which the aircraft traveled approximately 22 km; consequently, two spectra per line were collected.

4.2 GROSS COUNT DATA

As a first step in the analysis of the gross count data, the background due to nonterrestrial radiation was subtracted. This background consists of cosmic ray, aircraft, and airborne radioactivity contributions.[5] After correction for background, the data were normalized to a standard air mass. The resultant net count data were then converted to exposure rate in microroentgens per hour (μR/hr) at the 1 m level above the ground. The cosmic-ray exposure rate was then added back to the terrestrial exposure rate. Finally, the composite exposure rate data, together with aircraft position information, were processed into a gamma-ray exposure rate isopleth map for overlay on U. S. Geological Survey (USGS) topographic maps of the survey area.

An exposure rate isopleth map of the Dresden Nuclear Power Plant area is shown in Fig. 4. The data shown on the map include a cosmic radiation contribution of 3.3 μR/hr. Spatial resolution of the exposure rate data is determined by the field-of-view of the detector system, which is about 400 m.

4.3 SPECTRAL DATA

Gamma energy spectral data were recorded from about 0.05 to 3.0 MeV. The recording system was calibrated prior to airplane takeoff with an yttrium-88 source, which emits two prominent gamma rays of 0.898 and 1.836 MeV. The gain for each crystal in the 14 crystal detector array was set independently.

A pulse-height spectrum typical of those taken during the survey is shown in Fig. 5. Table 3 lists the prominent gamma-ray energies and associated source isotopes identified in the spectrum. Differences in shape between spectra taken over different portions of the survey area are minor, and the isotopes identified in all spectra are the same. Only isotopes consistent with normal background radiation are apparent.

Table 3. Gamma-Ray Energies and Isotopes Consistent with Spectral Data of Figure 5.

Observed Energy (MeV)	Radionuclides Consistent with Spectral Photopeaks		
	Fission Products	Activation Products	Terrestrial Radiation
0.51	. . . .	. . . .	Annihilation radiation
0.61	. . . .	. . . .	^{214}Bi
0.76	. . . .	. . . .	^{214}Bi
0.93	. . . .	. . . .	^{214}Bi
1.12	. . . .	. . . .	^{214}Bi
1.46	. . . .	. . . .	^{40}K
1.76	. . . .	. . . .	^{214}Bi
2.62	. . . .	. . . .	^{208}Tl

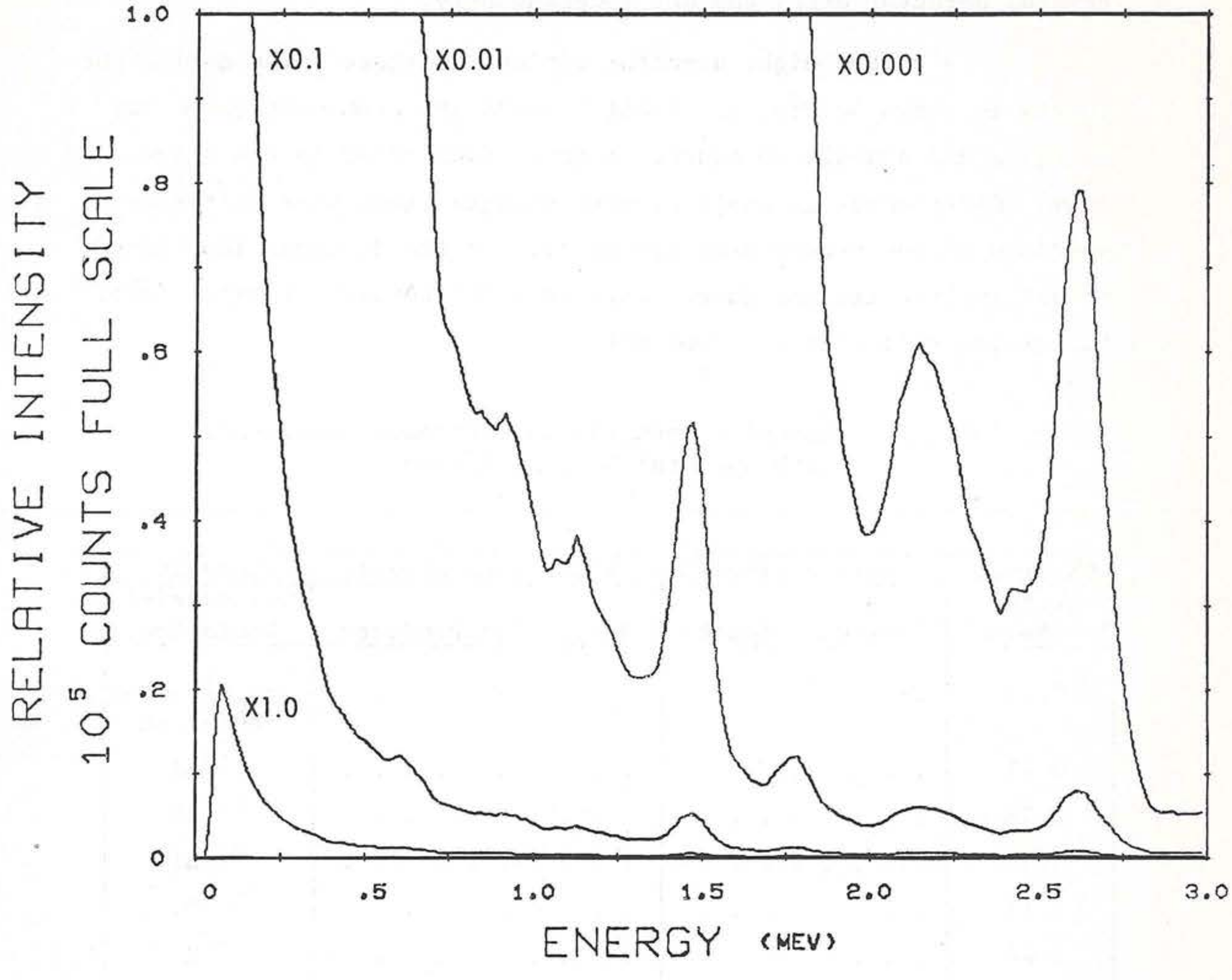


Figure 5. Typical gamma pulse-height spectrum for survey area.

5.0 SURVEY COMPARISON

5.1 PREVIOUS SURVEYS

The September 1972 survey was flown using the same programmed flight lines as the September 1968 survey. The navigator visually directed the pilot, from USGS topographic maps, along the programmed flight line. The 1970 survey consisted of ten flight lines approximately 37 km long. These flight lines were in the general area of the 1968 survey. A detailed point-by-point comparison of the survey data can be made for data points collected in the same geographical area in each survey.

5.2 COMPARISON PROGRAM

Computer software has been developed to compare the data from two surveys of the same area.(6) During these two surveys, the AMS system accumulated and recorded gross count data in one second intervals. Since latitude and longitude were simultaneously recorded, each data point uniquely characterized the exposure rate directly below the aircraft. All data points were converted to the exposure rate at a level 1 m above the ground.

Whenever the survey patterns for these two surveys overlap, data points may be individually compared if they are within the field-of-view of the detector system. The field-of-view, also called the circle of investigation, is the gamma field measured by the detector, and its size is determined by using calibration sources distributed over the area below the aircraft. The size of this area depends on the altitude of the aircraft, the gamma radiation energy, and the source distribution over the terrestrial surface and with depth. The AMS system is normally flown at an altitude of 150 m. If one assumes that the gamma isotopes are uniformly distributed on the surface, one can calculate the radius of the circle measured by the detector.[7,8,9] For the range of gamma energies of interest in the present surveys, the AMS field-of-view was approximately 400 m in diamter.

The computer program made a point-by-point comparison of the exposure rates (at a level 1 m above the ground) for all points within the field-of-view. The mean difference in exposure rate, the standard deviation, and a normal distribution for the exposure rate difference frequency versus measured difference, were calculated.

For all sites resurveyed to date, the exposure data averaged over the entire site have been reproducible within ±1.0 μR/hr. The number of matched data point pairs (those within the same 400 m field-of-view) varies for each pair of surveys compared. Even though the same flight line map is flown, the actual number of point pairs depends on navigation accuracy.

The accuracy of the comparison measurement depends on topography, the cosmic ray exposure rates, and the concentration of airborne radionuclides on the days of the separate surveys. AMS equipment has demonstrated the ability to detect changes in the terrestrial and cosmic-ray exposure rate of less than 1.0 μR/hr. Depending on the natural terrestrial and cosmic-ray exposure rates, 1.0 μR/hr represents a 5 to 15 percent change in the terrestrial exposure rates for most areas in the United States.

5.3 COMPARISON RESULTS

Figure 6 shows the comparison results of the 1968 and 1970 Dresden Nuclear Power Plant surveys. A total of 1551 overlapping data points from each survey could be directly compared. Since the mean difference in terrestrial exposure rates was 0.34 μR/hr, and well within one standard deviation (1.09 μR/hr), we may say there has been no measurable change in the terrestrial exposure rate over the Dresden Nuclear Power Plant survey area between 1968 and 1970 (±1.09 μR/hr at the 67% confidence level).

Comparison of the 1968 and 1972 surveys of the Dresden Nuclear Power Plant area (Fig. 7) shows a decrease in the mean terrestrial exposure rate of -1.06 μR/hr. The one standard deviation for the comparison test was ±0.90 μR/hr. Since the mean exposure rate exceeds one standard deviation, we may say there was a decrease in the terrestrial gamma-ray exposure rate between 1968 and 1972 (at the 67% confidence level). Possible explanations for the reduction in the terrestrial exposure rate:

1. Construction of a large cooling pond in the center of the survey area. Infrared photos taken in 1970 (Fig. 8) and in 1972 (Fig. 9) show a definite change in the geography of the survey area.

2. Climatological data from the Peru Sewage Plant (U. S. Department of Commerce, National Oceanic and Atmospheric Administration) shows a very dry period during the 1968 survey, and an increase in the monthly precipitation starting after 1970 (Table 4). Spoil piles from strip mining have high concentrations of natural potassium and uranium-thorium daughters, as reported in the 1968 and 1970 Dresden surveys. The increased moisture content may have reduced the exposure rate levels, which were as high as 10 to 15 μR/hr. Unfortunately, the Illinois Geological Survey has no data on the fluctuation of the level of the saturated water zone in the strip-mined areas.

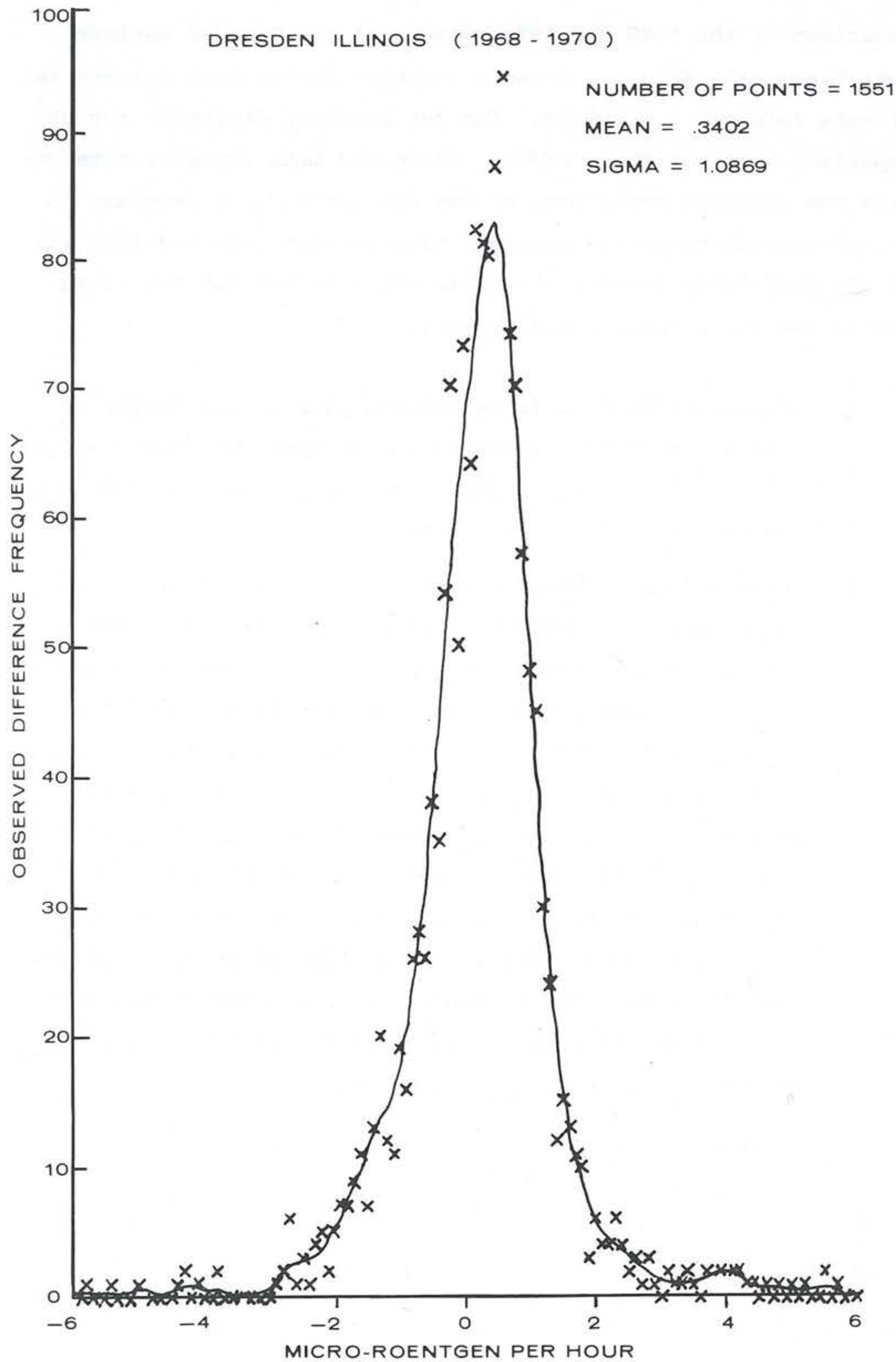


Figure 6. Comparison results of the 1968 and 1970 Dresden surveys.

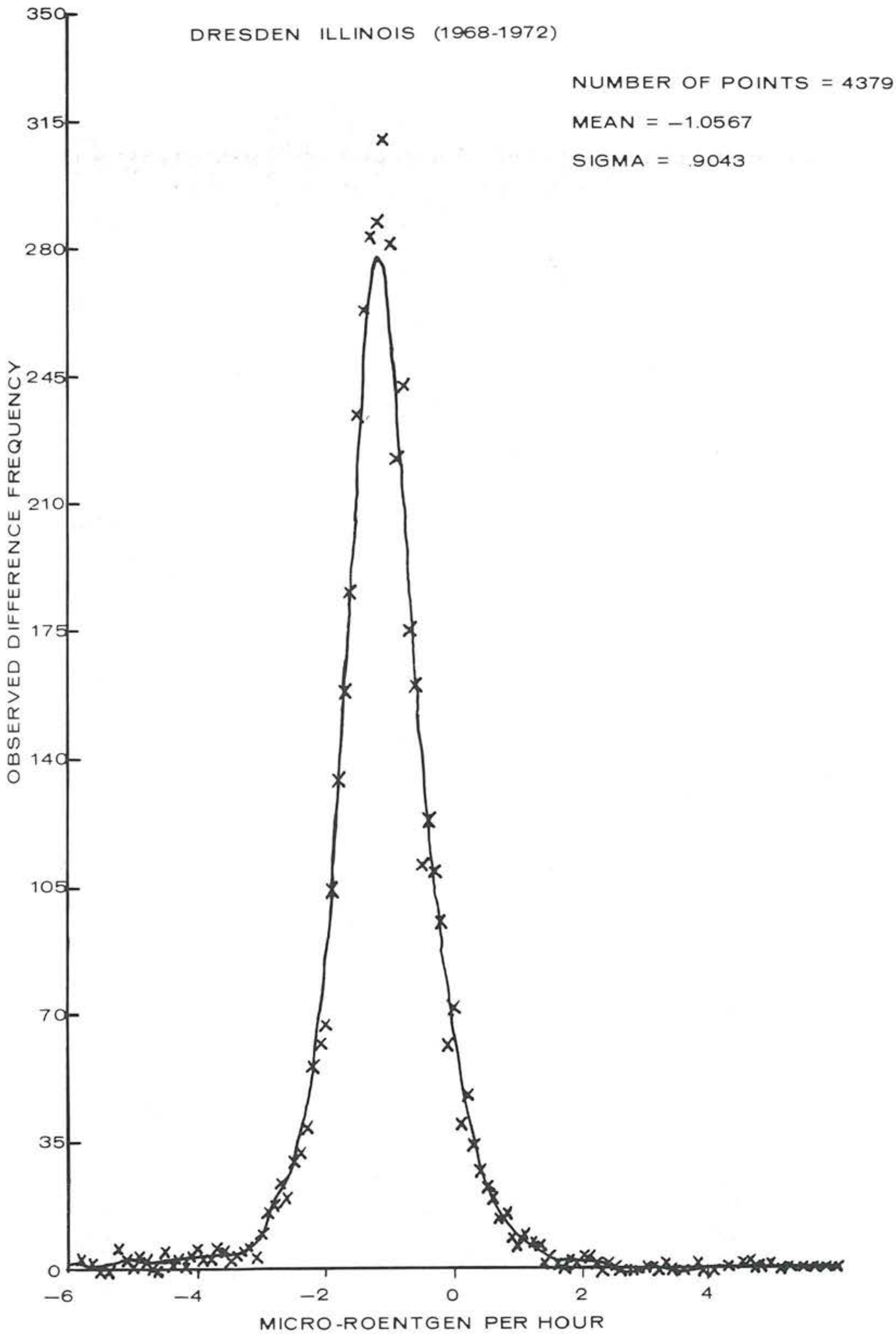


Figure 7. Comparison results of the 1968 and 1972 Dresden surveys.

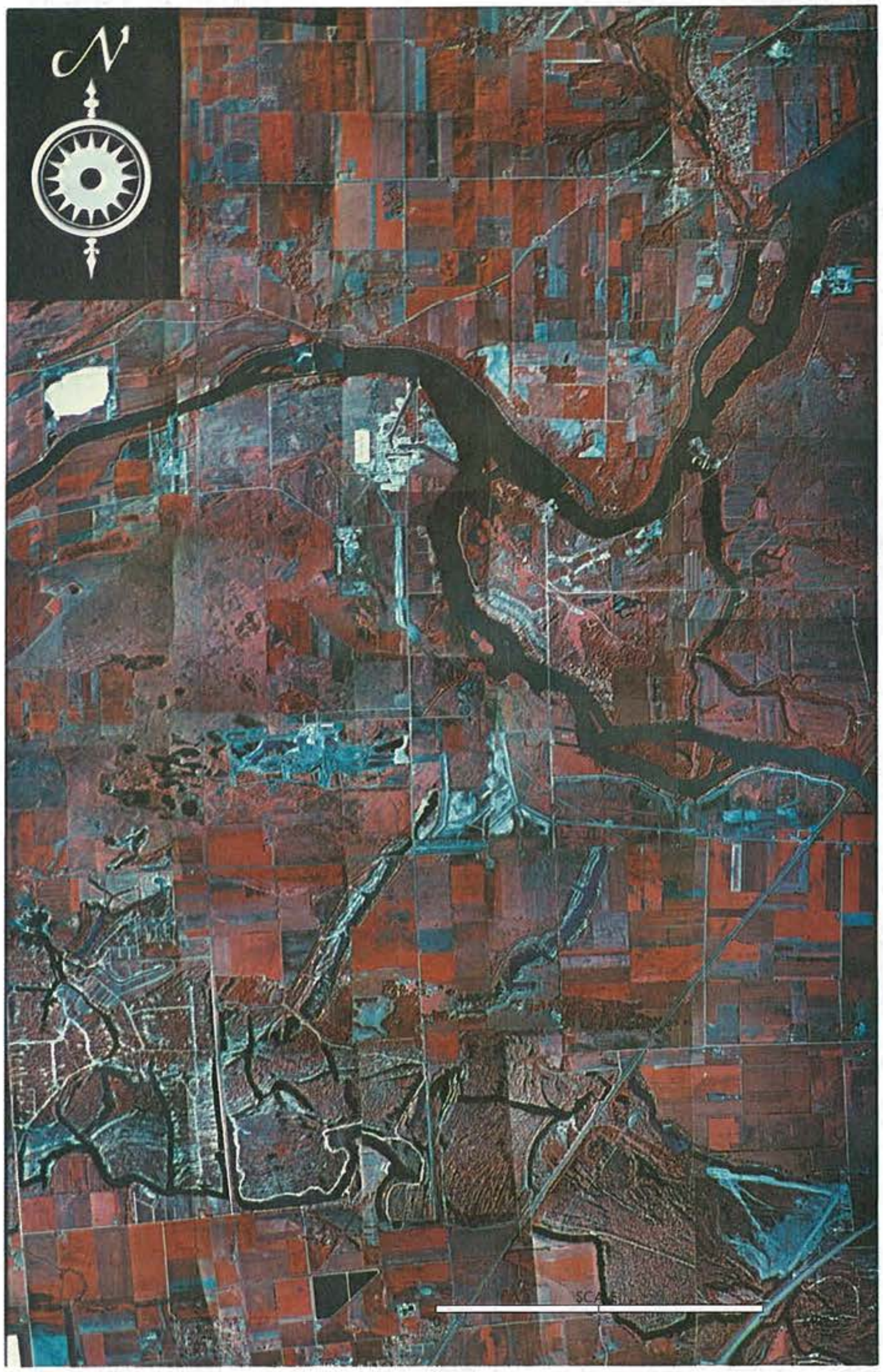
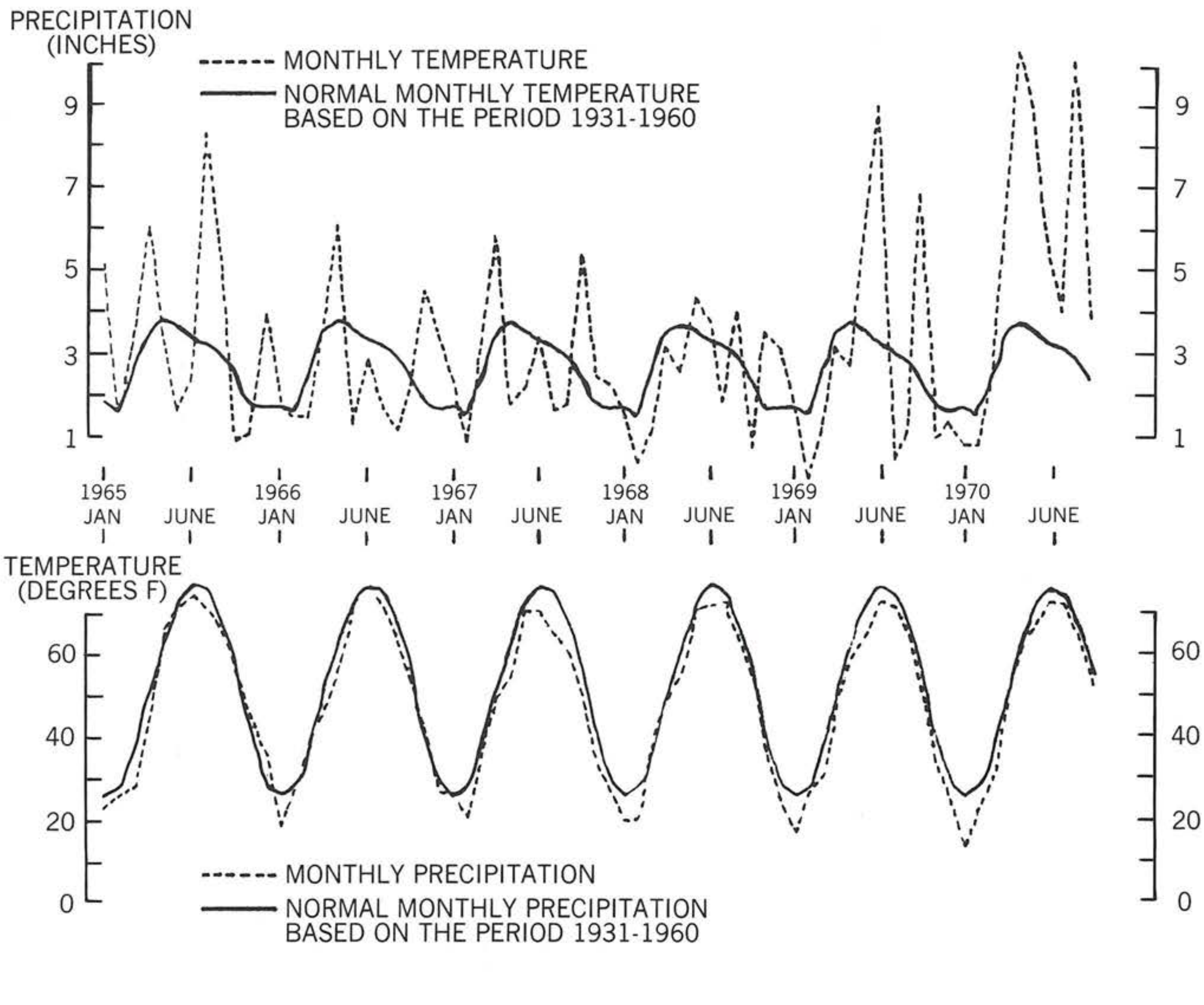


Figure 8. Infrared aerial photograph of the area surrounding the Dresden Nuclear Power Station, August 1970.

Figure 9. Infrared aerial photograph of the area surrounding the Dresden Nuclear Power Station, September 1972.

Table 4. Monthly Precipitation and Temperature Comparison Charts of the Dresden Nuclear Power Station from 1965 through September 1970.



CLIMATOLOGICAL DATA FROM PERU SEWAGE PLANT (U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION)

6.0 SUMMARY AND CONCLUSIONS

The 1 m level exposure rates mapped were mostly in the 8 to 10 μR/hr range. The exposure rates and radioactive isotopes revealed in the survey are consistent with normal terrestrial background. The comparison study between the 1968 and 1970 surveys indicates that there had been no measurable change in the average exposure rate of the Dresden area within an uncertainty of ±1.09 μR/hr. Comparison of the 1968 and 1972 surveys indicates a reduction in the terrestrial exposure rate -1.06 ±0.90 μR/hr. Since the mean exceeds one standard deviation, we can say at the 67% confidence level the terrestrial exposure rate in the Dresden area did decrease. The possible explanations for the decrease in the terrestrial exposure rate are the construction of the large cooling pond, and a definite increase in the monthly precipitation averages between the 1968 and 1972 surveys.

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