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OHIO DEPARTMENT OF HEALTH STUDY OF RADIOACTIVITY IN DRINKING WATER AND OTHER ENVIRONMENTAL MEDIA IN THE VICINITY OF THE UNITED STATES DEPARTMENT OF ENERGY'S

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REPORT

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OHIO DEPARTMENT OF HEALTH STUDY OF RADIOACTIVITY IN DRINKING WATER AND OTHER ENVIRONMENTAL MEDIA IN THE VICINITY OF THE U.S. DEPARTMENT OF ENERGY'S FEED MATERIALS PRODUCTION CENTER AND PORTSMOUTH GASEOUS DIFFUSION PLANT

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Ohio Department of Health Study of Radioactivity In Drinking Water and Other Environmental Media In The Vicinity Of The U.S. Department of Energy's Feed Materials Production Center And Portsmouth Gaseous Diffusion Plant

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ACRONYMS AND UNITS

FMPC	Feed Materials Production Center
GAT	Goodyear Atomic Corporation
LLD	Lower Limit of Detection
mg/l	Milligrams per liter
MMES	Martin Marietta Energy Systems
NCRP	National Council on Radiation Protection and Measurements
NLO	National Lead of Ohio
ODH	Ohio Department of Health
pCi/kg	Picocuries per kilogram
pCi/l	Picocuries per liter
PERMs	Passive Environmental Radon Monitors
PGDP	Portsmouth Gaseous Diffusion Plant
TLD	Thermoluminescent Dosimeter
ug/g	Micrograms per gram
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
USNRC	United States Nuclear Regulatory Commission
WMCO	Westinghouse Materials Company of Ohio

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EXECUTIVE SUMMARY

From September to December 1984, a series of excessive and unanticipated releases of slightly enriched uranium oxide from the Feed Materials Production Center (FMPC) occurred. These releases were reported to the U.S. Department of Energy (USDOE) by the FMPC contractor, National Lead Company of Ohio (NLO). In addition, as a result of an offsite ground water monitoring program initiated by the FMPC and ground water sampling performed by the Ohio Environmental Protection Agency (OEPA) in 1981, above background concentrations of uranium were detected in several offsite wells.

As part of an effort to respond to the surrounding communitys' concerns over these occurrences and the possible impacts of FMPC operations on the local environment, the USDOE requested that the Ohio Department of Health (ODH) establish a sampling program in the vicinity of the FMPC located in Fernald, Ohio. This program encompassed the collection and analysis of water samples and other environmental media in the vicinity of the FMPC as well as interpretation of the data collected through this sampling program.

The USDOE owns an additional facility in Ohio which handles uranium. This facility is known as the Portsmouth Gaseous Diffusion Plant (PGDP) located near Piketon, Ohio, and is presently operated for the USDOE by Martin Marietta Energy Systems (MMES). The USDOE requested that ODH establish a sampling program in the vicinity of this facility as well.

To facilitate these requests, the Ohio Department of Health entered into a cooperative agreement with the USDOE in March 1985 to perform environmental sampling in the vicinity of the FMPC. A separate cooperative agreement for sampling in the vicinity of the PGDP was entered into in April 1985. The sampling program which ODH conducted consisted largely of the collection and analysis of drinking water samples on a request basis from concerned homeowners in the vicinty of the FMPC and PGDP.

In addition to water sampling in the vicinity of the FMPC, ODH collected soil samples, performed environmental radiation exposure measurements, outdoor radon measurements and radon measurements in a number of homes and their water supplies.

In the vicinity of the FMPC, approximately 309 water sources were sampled and analyzed for radioactivity content. These water sources were comprised of private and public wells, cisterns and surface waters such as ponds. Soil samples were collected at 34 locations and analyzed for uranium content. Dosimeters were

installed at 40 locations in the vicinity of the FMPC to measure environmental radiation levels. Environmental radon levels were monitored at 16 locations in the vicinity of the FMPC. Radon levels were also monitored in 25 residences and 1 school. Water samples were collected and analyzed for radon content at 9 of these homes.

The number of water sampling requests from the area surrounding the PGDP was very small. The Ohio Department of Health collected and analyzed water from 7 locations in the vicinity of the PGDP. The cooperative agreement for this sampling program expired in April 1987. Water was the only environmental media sampled in the vicinity of the PGDP.

Although the majority of drinking water samples were collected in 1985 and 1986, the FMPC cooperative agreement project period was extended several times in an effort to respond to citizens' continued requests for sampling in the vicinity of the FMPC. In January 1988, the FMPC agreement expired. Although the agreement has expired, the ODH maintains a continuing involvement at the FMPC. ODH continues to monitor the ambient radon levels along the boundary of the FMPC.

In May 1987, a routine environmental split sampling program with the current site operator, Westinghouse Materials Company of Ohio (WMCO), was established. A split sampling program was also established at the PGDP.

The Ohio Department of Health's primary objective in these cooperative agreements was to sample the drinking water supplies used by residents living in close proximity to the DOE facilities. These sampling programs were conducted in order to determine the extent of any offsite contamination of water supplies and to assess the exposure which might result from ingestion of any significantly contaminated water.

Above background concentrations of uranium were detected in 3 wells in a fairly well delineated area immediately south of the FMPC site. As can be determined from data presented in this report, ODH could find no evidence of contamination in groundwater beyond this area. The ODH did detect above background concentrations of uranium in 1 cistern located immediately north of the site. When in operation, water was supplied to this cistern via a roof gutter collection system. This finding indicates that airborne uranium has been deposited offsite and assessment of the long-term impact upon cistern owners (who use rainwater collection systems) in close proximity to the plant is needed.

Results of the soil sampling did not indicate the existence of areas offsite that were grossly contaminated with uranium. Slightly elevated concentrations of uranium were detected in a number of soil samples collected northeast of the FMPC.

Radiation exposure measurements at the site perimeter did not detect the presence of radiation levels above background except at a location directly west of the K-65 silos. The radiation levels at this location, however, were only slightly above background and doses which might be received at this location would be well below regulatory exposure limits.

Measurements of radon concentrations in homes in the Fernald area revealed that 40% of the homes tested exceeded the current USEPA guideline value. However, measurement of the environmental radon levels at the FMPC site boundary did not reveal the presence of comparable concentrations of radon in the environment. This indicates that the source of radon in the homes is due to the uranium contained in the geology beneath the homes.

Additionally, measurements of radon in water indicated that the ground water was not the source of radon in these homes.

The following report provides a summary and discussion of results of the analyses performed on the environmental samples and other information collected during the cooperative agreement project period.

1.0 INTRODUCTION

The Feed Materials Production Center (FMPC) is a uranium production facility owned by the U.S. Department of Energy (USDOE). It is a large scale integrated facility which produces uranium metal used in the fabrication of fuel cores and target fuel elements for defense programs of the USDOE. The FMPC is located on a 1050 acre site in northwest Hamilton County, with some areas extending north into Butler County (See Fig.1). The production facilities occupy approximately 136 acres in the center of the site.

The site began operation in October 1951 under contract with the National Lead Company of Ohio (NLO). National Lead continued operation of the facility until January 1986 at which time the Westinghouse Materials Company (WMCO) took over operations.

Most of the uranium received at the FMPC has already been through one or more chemical separations at other sites. Uranium isotopes, therefore, have been the principal isotopes discharged to the air and water from the facility.

Historically there have been three possible pathways for uranium movement from this site to the offsite environment. The first pathway involves airborne releases of particulates from the production facilities in the form of a "black oxide" powder. Black oxide is a uranium oxide mixed with graphite. These emissions from the production facilities have always been filtered in what are called "baghouses", primarily to recover uranium which would have otherwise been lost. However, because of frequent filter failures in the baghouses, these wastes were, at times, released directly to the air.

The second release pathway has been storm water runoff from the site which had been contaminated with uranium which was deposited on the ground as a consequence of airborne releases or accidental spills. Some of this runoff discharged into Paddys Run, which is a small creek running north and south just west of the production facilities. It is believed that uranium washed into Paddys Run may contaminate the ground water aquifer south of the FMPC (REF. 1).

The third release pathway may be leakage or runoff from any of six waste pits at the site. These waste pits vary in size and construction. The USDOE and WMCO are currently working with contractors to characterize these pits and determine what potential for release of uranium and other hazardous materials from these pits exists. Potential pathways for release include leakage directly to the ground water aquifer and seepage and surface runoff into Paddys Run.

The FMPC also routinely discharges effluents containing uranium to the Miami River.

In November and December of 1984, accidental airborne releases of uranium oxide from the FMPC production facilities occurred. As a result of public concern over these releases and the elevated concentrations of uranium found in three private wells south of the FMPC prior to these releases, the Ohio Department of Health became involved in the investigations of operations at the FMPC.

In January 1985, the USDOE, in the form of a cooperative agreement, requested that the ODH collect samples of drinking water from persons living in the vicinity of the FMPC. A large number of people in the immediate vicinity of the facility rely on well, and cistern water as their primary source of drinking water.

Population estimates for this area indicate that approximately 1300 people live within a 2-mile radius of the FMPC and approximately 5000 people live within a 3-mile radius of the site (REF. 2). The 3-mile radius encompasses most of the town of Ross, the largest population center lying within the scope of the study.

Under the terms of the Cooperative Agreement with the USDOE, the ODH was asked to perform the following:

1. Collect and analyze potable water samples from wells and cisterns for residents in the vicinity of the FMPC. From available records establish the depth of these wells. Perform a survey of the private water supplies per the Ohio Department of Health Water Supply Inspection Protocol.

2. Split every fifth water sample collected with the FMPC operator. The operator's analytical results would then be compared with the ODH's analytical results.

3. Establish which areas are on community water supply and sample each such system.

4. Analyze water samples for total uranium, gross alpha and gross beta activity. Sample and analyze other environmental media as requested by the USDOE.

5. Interpret the analytical results of the water samples. Provide written reports of the results to well and cistern owners/residents.

6. Establish a toll-free 1-800 telephone number which area residents could use for the purpose of requesting sample collection or to get information regarding analytical results reported to them.

7. Provide a final report to the DOE summarizing ODH's assessment of the data collected.

The sampling project would be implemented in phases. In the first phase, the ODH would take samples within a 2.5 mile radius of the center of the plant. Subsequent phases would be implemented in 2.5 mile increments.

In addition to water sampling requests, ODH received a limited number of requests from area residents for soil sampling. These requests came primarily from people who gardened in relatively close proximity to the facility. The USDOE agreed that these concerns were valid and that soil sampling fell within the scope of work outlined in our cooperative agreement. For comparison purposes, ODH collected soil samples from a number of control locations in addition to those collected on a request basis. Control locations are locations which should not be affected by operations at the FMPC.

In addition to water and soil sampling, the ODH conducted two other types of monitoring in the vicinity of the FMPC. Direct radiation exposure measurement and radon monitoring programs were also conducted. Both of these programs were conducted primarily due to the presence of two K-65 silos located in the northwest section of the FMPC site. These silos contain significant inventories of the radionuclide radium-226.

Other sources of direct radiation exposure at the FMPC site include the uranium feed materials and metal inventories, thorium storage areas and various scrap and rubble piles. In order to perform direct radiation measurements at the facility, thermoluminescent dosimeters (TLD's) packaged for environmental use were obtained and installed at 32 locations on the facility boundary fence and at 8 control locations. These dosimeters remained in place for approximately six months. At the end of six months the dosimeters were replaced with new dosimeters which were also exposed over a period of six months. The TLD's measured the integrated gamma radiation exposure at their respective locations for a total time period of one year.

As mentioned earlier, a significant inventory of radium-226 is contained in the K-65 silos. Radium decays to radon, an inert radioactive gas. This gas was escaping from the silos and residents living in the vicinity of the FMPC were concerned about possible exposure to the radon being released from the silos. Consequently, the USDOE requested that ODH install radon detectors around the facility to monitor environmental levels of radon. In June 1985, ODH installed 16 alpha-track type radon detectors in the vicinity of the facility. Twelve of the detectors were placed on the boundary fence and 4 were placed at control locations.

Radon monitoring was also performed by ODH in 15 homes and one school in the area surrounding the facility. Approximately half of these homes were monitored as a follow-up to the whole body counting the DOE provided to a number of residents. The other half were monitored as control homes for comparison purposes. In addition, a number of residents contacted ODH requesting that their homes be monitored for radon. ODH provided these homeowners with radon detectors.

The results of the radon monitoring performed in these homes is discussed in Appendix D of this report.

During the same time period that samples were being collected in the vicinity of the FMPC, a similar sample collection program was being conducted at another USDOE facility, the Portsmouth Gaseous Diffusion Plant (PGDP). This program was also conducted at the request of the DOE. The PGDP is located in rural Pike County on a 6.3 square mile site approximately 0.6 miles east of the Scioto River Valley (See Fig. 2). The principal site process is the separation of uranium isotopes through gaseous diffusion. The Portsmouth Gaseous Diffusion Plant is owned by DOE and currently operated by Martin Marietta Energy Systems (MMES). At the time the sampling program in the vicinity of the PGDP was begun, however, the facility was operated by Goodyear Atomic Corporation (GAT).

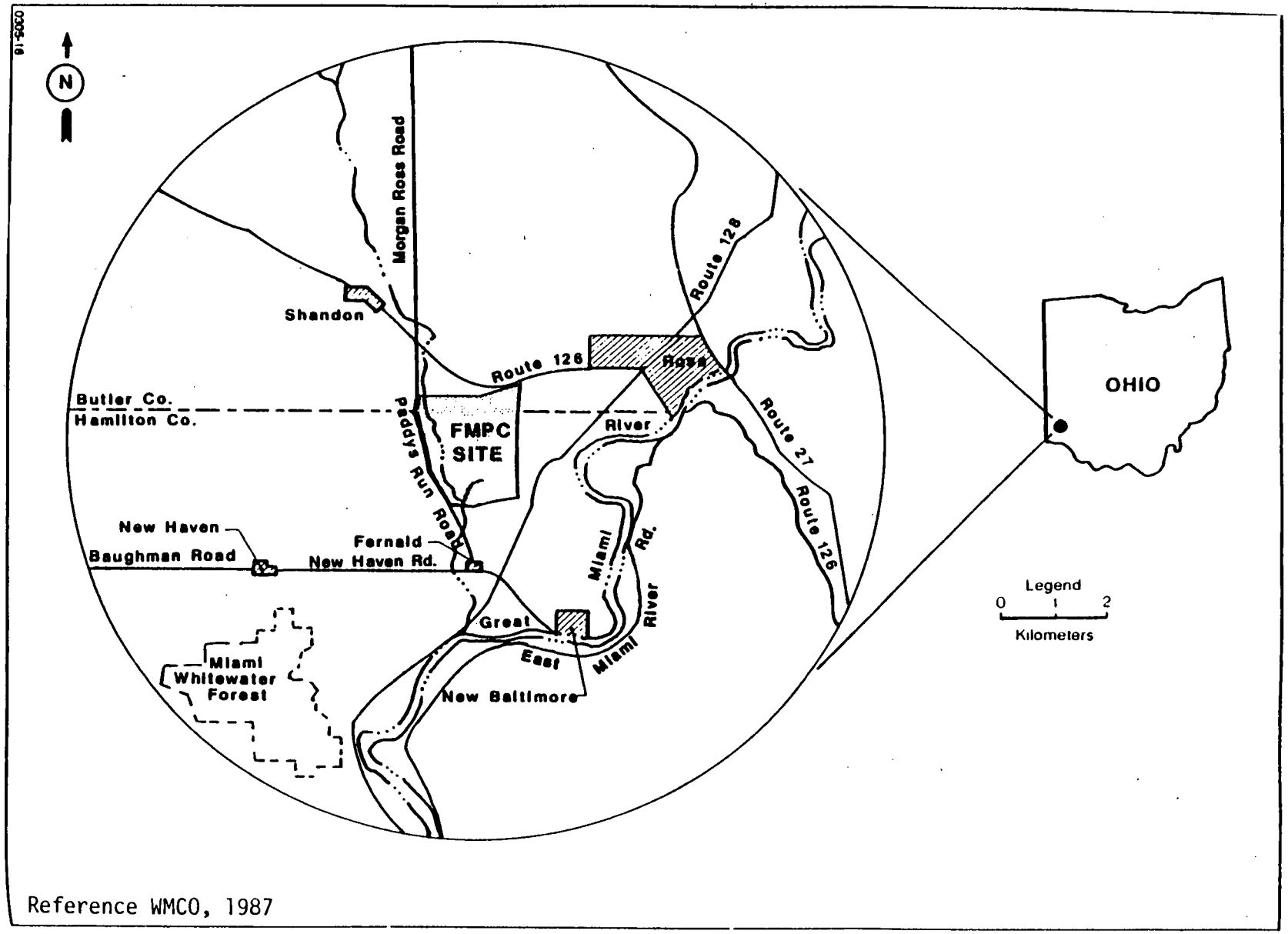
The area surrounding the facility is sparsely populated. The population within a 2 mile radius is approximately 500. No evidence of offsite contamination of ground water with uranium has ever been found in this area by the site operator. The sampling requests received by ODH from this area were very limited.

The cooperative agreement with the USDOE for sampling in the vicinity of the FMPC expired in January 1988. Subsequent to this agreement the ODH has established an ongoing program of routine split sample collection with WMCO. ODH is currently collecting split samples of ground water and surface water at a number of pre-determinded locations on a monthly basis. Split samples of bottom sediments are collected semiannually and milk samples are collected quarterly.

The cooperative agreement with the USDOE for sampling in the vicinity of the PGDP expired in April 1987. The ODH has also established a routine split sampling program at the PGDP. This program consists of monthly collection of surface water at 3 locations and collection of sediment samples semi-annually from these same locations.

FIGURE 1

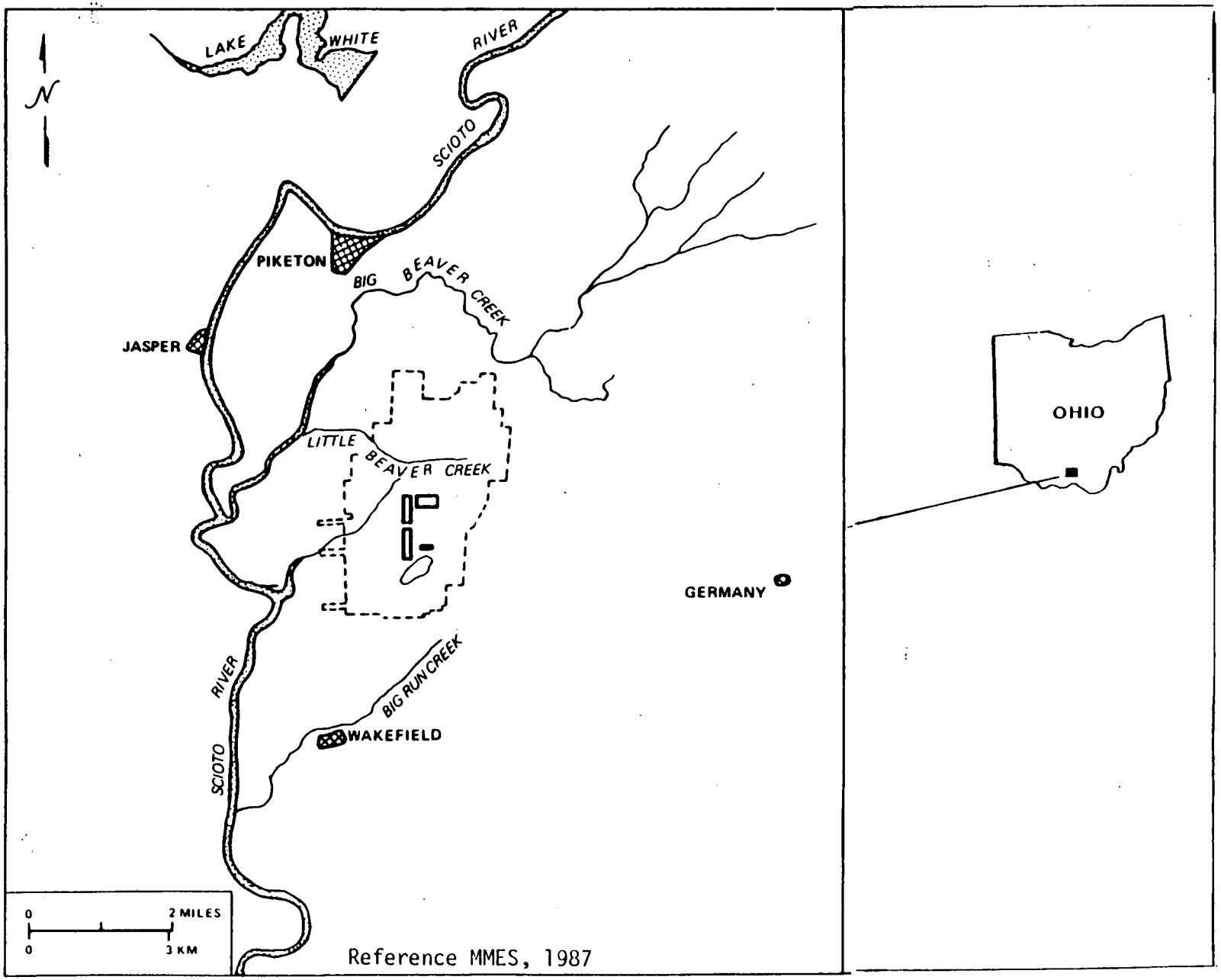
Feed Materials Production Center Site



Reference WMCO, 1987

FIGURE 2

Portsmouth Gaseous Diffusion Plant Site



Reference MMES, 1987

2.0 METHOD OF INVESTIGATION

In February 1985, ODH established a toll-free telphone number as specified in the DOE agreement and began taking requests from residents living in the vicinity of the FMPC and PGDP. A water sample request form was developed and completed for each request (See Figure 3). In preparation for the project, ODH also performed a literature search to develop a library of reference materials pertaining to the facilities of interest.

2.1 WATER SAMPLES

The Ohio Department of Health established a sampling protocol to insure that all water samples were collected in a uniform manner. As specified in the cooperative agreement with the USDOE, sample collection and analysis was performed in accordance with approved U.S. Environmental Protection Agency (USEPA) methods as identified in 40 CFR Part 136; the October 26, 1984, Federal Register, Part VIII, Volume 9, No.209, Pages 43234 through 43441; and related quality assurance requirements.

To facilitate an accurate assessment of any radiation dose a person may have received due to ingestion of significant quantities of uranium in water, ODH primarily sampled water from the faucet in the resident's home most used to acquire drinking water. The rationale was to acquire a sample which was representative of the water the resident was actually drinking. The type of well, pumps and other support equipment used by the resident, e.g. water softener, iron remover, sediment filter, activated charcoal filter, varied greatly in the homes ODH collected water samples from. In order to assess what impact these variables might have on the quality of the water being tested, a water supply inspection form and homeowner survey was completed at each residence sampled (See Figs. 4 & 5). The homeowner survey included an estimate of the daily water consumption by each member of the household.

The water collection procedure basically consisted of filling a one-gallon cubitainer with the resident's tap water after allowing the water to run 5-10 minutes. The sample was then preserved with five milliliters of nitric acid. Every fifth sample collected by ODH was split with WMCO, i.e. two samples were taken at the residence, with subsequent analysis of one sample by the ODH Laboratory and the other by WMCO. This policy allowed comparison of the analysis results reported by each laboratory.

All samples collected were labeled with a unique log number and alpha numerical identification. For sample location identification purposes, the area surrounding the FMPC was divided into sixteen 22.5 degree sectors. The unique alphanumeric identification given to each sample consisted of the sector the sampling site was located in and the distance of the site from the center of the FMPC (See Fig. 6). This identification was recorded on a Sample and Laboratory Data Sheet along with other pertinent sample collection information (See Fig. 7).

The ODH received a large volume of requests for water sampling from the community surrounding the FMPC. ODH staff spent an average of 1-2 days per week collecting samples from residents from February 1985 to July 1986. In order to assure complete coverage of the area in which contamination was known to exist, the ODH determined which wells in that area had not been sampled by the ODH. A letter was mailed to the owner/resident offering to collect and analyze a sample of their drinking water free of charge.

For the remainder of 1986 and through 1987, the ODH extended the cooperative agreemeent and continued to sample a smaller volume of requests up until the expiration of the USDOE agreement in January 1988.

All drinking water samples collected by the ODH were analyzed by the ODH Laboratory in Columbus, Ohio, for gross alpha, gross beta and total uranium alpha activity. Gross alpha and gross beta analyses are very general tests for radioactivity which may be present in water. The analysis for total uranium alpha activity is a test to detect the presence of uranium specifically.

Gross alpha and gross beta counting was performed on a Tennelec apha-beta proportional counter. The ODH Laboratory's lower limit of detection for gross alpha and gross beta is 3.0 pCi/l (picocuries per liter) and 4.0 pCi/l respectively.

The uranium analysis consisted of chemically separating the uranium from other radionuclides in the water, evaporating the eluate and measuring the total uranium alpha activity using an alpha-beta proportional counter. No alpha spectroscopy was performed on the samples, consequently it was not determined whether the uranium detected was depleted or enriched. The percent enrichment of the uranium processed at the FMPC has ranged from 0.2% to 10%.

In addition to gross alpha, gross beta and uranium analyses, ODH performed follow-up analyses on a number of the water samples collected. In instances where the gross beta results exceeded 15 pCi/l, potassium-40 analysis and gamma spectroscopy were performed in an attempt to identify the radionuclide responsible for the elevated gross beta levels. Potassium-40 is a naturally occurring radionuclide normally found in varying amounts in ground and surface waters.

As previously stated, in addition to sample collection and analysis, ODH was responsible for interpreting the results of these analyses and reporting the results to individual home-owners/residents in writing.

There are no regulatory standards for gross alpha, gross beta or uranium in private drinking water systems. Although drinking water standards for gross alpha and gross beta activity exist for public drinking water supplies, no public drinking water standard exists yet for uraninum. Consequently, for purposes of interpreting and reporting results, the ODH established "investigational action levels" for radioactivity in these samples. The investigational action levels ODH established were based on:

1. Data available to ODH and collected by ODH regarding typical background levels of radioactivity in water in the Fernald area.

2. Existing public drinking water standards.

3. Minimum detection capabilities of the ODH Laboratory for the radionuclides of interest in this project.

For purposes of this project, the investigational action levels established by ODH were as follows:

Gross Alpha	> 5 pCi/l
Gross Beta	> 15 pCi/l
Uranium	> 3 pCi/l

When action levels were exceeded, further investigation was carried out. This entailed resampling and/or further analyses.

Although there are no drinking water standards for uranium, there are other published standards regarding limits for release of uranium in effluents to unrestricted areas, e.g. rivers, lakes, etc. These are:

U.S. Nuclear Regulatory Commission (NRC) Maximum Permissible Concentration for natural uranium and U-238 in water	30,000 pCi/l
U.S. Department of Energy (DOE) Standard for natural uranium discharged to uncontrolled areas	1,200 pCi/l

In addition to these existing standards there are two references pertaining to proposed standards for uranium in water which ODH consulted. The USEPA published an advance notice of proposed rulemaking in the Tuesday, September 30, 1986 Federal Register, Vol. 51, No.189, p.34836 (REF. 3). Although this proposed rule-making did not propose a standard for uranium in drinking water,

it did provide estimates of risks associated with different concentrations of uranium in drinking water. Table 10 - Summary of Risk Levels and Occurrence For Radionuclides In Drinking Water has been excerpted from the above mentioned Federal Register and is shown in Figure 8.

The NRC published a proposed rule in the Thursday, January 9, 1986 Federal Register, Vol. 51, No.6, p.1112, which contains a limit of 300 pCi/l of uranium U-238 or U-235 in water effluents. This limit corresponds to a calculated dose of 100 mrem/year to the maximally exposed individual (REF. 4).

When uranium analysis results exceeded the ODH investigational action level, this information was provided to the homeowner/ resident for guidance.

Reports to homeowners/residents consisted of a statement which informed them of whether the results of the sample analysis were or were not within the normal range of background, i.e. did or did not exceed the ODH investigational action levels, and if necessary, provided the homeowner with the above-mentioned information regarding available standards and guidelines. Members of the Ohio Department of Health's staff were also available if the homeowner desired further discussion of the results. Results of the water sampling program are discussed in Section 3.0 of this report.

2.2 SOIL SAMPLES

The ODH received 25 requests for soil sampling. Soil samples were collected from a variety of locations in the vicinity of the FMPC. Homeowners requested that soil samples be collected from areas on their property such as lawns and gardens. For comparison purposes, ODH also sampled 9 additional locations in various directions and at various distances from the facility. When not specifically requested, garden areas were avoided as sampling locations due to the possible contribution of uranium and other naturally occurring radionuclides contained in applied fertilizers.

The soil sample collection procedure consisted of clearing an approximate 12 inch by 12 inch ground area of grass, vegetation, etc., and collecting soil in this area to an approximate depth of 4 inches. Approximately 1 kilogram of soil was collected. All samples were labeled with a unique log number and alpha-numeric identification.

Sample and lab data sheets were completed and the samples were delivered to the ODH Laboratory for analysis of uranium content. At the laboratory, soil samples were prepared for analysis by ashing, decomposing and digesting the samples. This was followed by anion exchange and elution of the uranium. The eluate was evaporated to dryness and counted on an alpha-beta proportional

counter to determine the total uranium alpha activity in the sample. The ODH Laboratory's lower limit of detection for uranium using this method is 1.0 pCi/g (picocuries per gram).

The results of the soil analyses and a discussion of these results is contained in Appendix A of this report.

2.3 DIRECT RADIATION MEASUREMENTS

In order to perform direct radiation measurements in the vicinity of the FMPC, the ODH purchased thermoluminescent dosimeters (TLDs) packaged for environmental use from R.S. Landauer Jr. & Co. Landauer is a commercial laboratory located in Glenwood, Illinois, and is accredited by the National Bureau of Standards through the National Voluntary Laboratory Accreditation Program (NVLAP).

A TLD typically consists of 1 or more small chips of thermoluminescent phosphors (crystalline material) enclosed in some type of plastic holder. When the TLD (thermoluminescent phoshor) is exposed to radiation, ionization and excitation processes cause the trapping of electrons at sites of lattice imperfections in the crystal. After the TLD's used by the ODH had been exposed and were removed from the environment, they were returned to Landauer to be "read". In order to be "read", the TLD is first heated to a specified temperature. When TLD's are heated, the trapped electrons are released. As they are released, energy is released in the form of light. The amount of light emitted is proportional to the dose of radiation received by the TLD, so the intensity of the light is measured using special equipment and the dose is reported in millirems (mrems).

TLDs were installed in pairs on the site boundary fence at 31 locations. In order to obtain a uniform distribution around the site, the area was divided into 22.5 degree sectors and 2 dosimeter locations per sector were established. Dosimeters were also installed in similar fashion at 9 control locations. All dosimeters were installed at a height of approximately 4-5 feet above the ground.

Dosimeters were first installed in September 1985. After six months of exposure, these dosimeters were retrieved and replaced with new dosimeters. The second sets of dosimeters remained in place for a period of six months and were then retrieved for reading. This provided the ODH with a full year of exposure data. Upon retrieval, dosimeters were sent to Landauer to be read and a report of the integrated gamma exposure received by each TLD was provide to the ODH. This data and a discussion of the data is contained in Appendix B of this report.

2.4 ENVIRONMENTAL RADON

In late 1985, an investigation into the structural integrity of the K-65 silos located in the northwest region of the FMPC was performed for the USDOE by Camargo Associates, Ltd. This investigation revealed that the silo domes had deteriorated, allowing leakage of radon gas to the atmosphere. In order to determine the significance of this leakage to residents living nearby, radon concentrations in the air in the vicinity of these silos and elsewhere were monitored using "Track Etch" Type F detectors purchased from Terradex Corporation located in Walnut Creek, California. Terradex is a commercial laboratory which has successfully participated in the USEPA's radon proficiency testing program.

Using a dissemination method similar to the one used for TLDs, radon detectors were installed in 12 of the 16 sectors covering the FMPC. The detectors were placed in environmental housings and installed on the boundary fence surrounding the facility. "Track-Etch" Type F detectors were also deployed at 4 control locations. All detectors were placed at a height of approximately 4 - 7 feet above the ground.

At each location detectors were collected and replaced approximately every six months beginning in June 1985 when they were first installed. An exception to this schedule occurred in April 1986. The detectors were collected after only three months in the field in order to determine if environmental radon levels were substantially elevated above background following an accidental release of a significant quantity of radon during maintenance activities on one of the K-65 silos that month. The ODH continues to monitor radon in the vicinity of the FMPC. Results of this monitoring program and a discussion of the results is contained in Appendix C of this report.

2.5 RADON IN HOMES

Subsequent to the accidental release of uranium from the FMPC in December 1984, the Department of Energy provided a whole body counting service to a number of individuals who had expressed concern over the possibility of internal contamination from living near the facility.

Elevated levels of radon (Rn-222) and thoron (Rn-220) daughter products were detected in a number of individuals' whole body counts. As follow-up to these findings, the ODH initiated a study of the radon levels in the homes of these individuals. "Track Etch" Type F radon detectors were purchased from Terradex for this monitoring program. This study was conducted from July 1985 to July 1986.

In addition to the above-mentioned homes, the ODH selected 7 additional homes to serve as control homes to monitor radon levels in during approximately the same time period.

Detectors were installed in pairs for quality assurance purposes. Radon levels were monitored both on a quarterly basis and an annual basis. On a quarterly basis (every 3 months), detectors were retrieved and replaced. This was performed over a total time period of 4 quarters. The quarterly changeout of detectors allowed the ODH to monitor the presence of any seasonal or short-term fluctuations of radon concentrations occuring in the house. The annual detectors (those that remained in the home for an entire year) were placed in the home along with the first quarterly detectors and retrieved at the end of the fourth quarter (i.e. after a year's time). The data from these detectors provided the ODH with an estimate of the occupant's annual average exposure to radon in the home.

In addition to the alpha track detectors, Passive Environmental Radon Monitors (PERMs) were placed in 2 of the homes from February 1985 to January 1986. PERMs were also installed in pairs for quality assurance purposes. The TLD detectors inside the PERMs were changed and read on a monthly basis. In response to a request from the principal of Crosby Elementary School, PERMs were also placed at several locations in the school building.

Typically, all detectors were placed on the first floor level of the house and in the area most occupied by the residents. USEPA protocols for placement of detectors were followed in this study (REF. 5).

A survey form detailing the house design features was completed for each house monitored. The ODH planned to use this information to identify those features which might affect the build-up of radon concentrations in the home.

During the time frame that ODH was performing radon monitoring in the vicinity of the FMPC, studies of radon levels were also being conducted in other regions of the state. The release of radon gas is not solely a man-made problem. Radon is also a naturally occurring radioactive gas which is generated in the earth as a result of the decay of naturally occurring uranium and radium present in rock and soil. Consequently, the presence of elevated levels of radon in homes is a national problem which various federal and state agencies have recently begun to address.

Due to a combination of increased public awareness of radon and the publicity regarding activities at the FMPC, a number of residents in the vicinity of FMPC contacted our office to request radon detectors for their home. The DOE agreed to fund the purchase of detectors by the ODH to comply with these requests. The ODH provided detectors to 13 residents whorequested them.

Data gathered from these homes provides additional information on radon levels both in and outside the Fernald area. The results of the radon monitoring performed by the ODH area contained in Appendix D of this report.

2.6 RADON IN WATER

In general, elevated radon concentrations in a home result primarily from the release of naturally occurring radon from the earth beneath the home (REF. 6). Under certain conditions, ground water from wells used by homeowners can also be a significant source of radon in the home. If the ground water contains high concentrations of radon (> 10,000 pCi/l), use of this water for showering, washing, etc., can release significant quantities of radon from the water to the air in the home.

In a number of the homes the ODH found to have elevated radon levels, a water sample was collected to determine if this was a possible source of radon. Water sampling kits were obtained by the ODH from the USEPA. All samples were taken in accordance with the USEPA sampling protocol (REF. 7). Water samples were sent to a USEPA Laboratory for analysis. Results of these analyses are also contained in Appendix D of this report.

FIGURE 3

WATER SAMPLE REQUEST

DATE OF REQUEST: / / /

NAME OF CALLER: _____

MAILING ADDRESS: _____

CITY: _____ STATE: _____ ZIP: _____

STREET ADDRESS IF DIFFERENT FROM ABOVE: _____

_____

TOWNSHIP: _____ COUNTY: _____

PHONE NUMBER (WORK) _____ (HOME) _____

WATER SOURCE:

- ☐ INDIVIDUALLY USE
- ☐ JOINTLY USED WELL
- ☐ CISTERN
- ☐ PUBLIC WATER SUPPLY/IDENTIFY _____
- ☐ OTHER/IDENTIFY _____

IF NOT PRIVATE WELL WHO IS PROPERTY OWNER?

NAME: _____

ADDRESS: _____

CITY: _____ STATE: _____ ZIP: _____

PHONE: _____

APPROXIMATE DISTANCE AND DIRECTION FROM NLO/FEED MATERIALS PRODUCTION PLANT

_____

_____

_____

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FIGURE 4

WATER SUPPLY INSPECTION AND SANITARY SURVEY FORM

Health District |__|__|__|__|__|

Inspection Date |__|__|__|__|__|__|
M M D D Y Y

Name _____ Address _____ |__|__|__|__|
Insp. No.

|__| Usage
1. Community
2. Other Public supply
3. Private

|__| Type Supply
1. New Water Supply
2. Alteration
3. Repair

|__| Type Construction
1. Drilled-Cable Tool
2. Drilled-Rotary
3. Driven
4. Dug
5. Spring
6. Cistern
7. Pond
8. Hauled, storage
9. Other

|__| Casing or Walls
1. Iron
2. Galvanized
3. Plastic
4. Concrete
5. Stone
6. Brick
7. Tile
8. Other

|__| Type of Instalation
1. Pitless Adapter
2. Well House
3. Well Pit
4. Buried Seal
5. Basement/offset
6. Other

|__| Pump
1. Submersible
2. Jet
3. Hand
4. Other

|__| Sewage System
1. Private
2. Semi Public
3. Municipal

|__| Bact. Analysis

|__| Chem. Analysis
(Results attached)

Location
|__| Topography
|__| Sewers and/or Sewage Systems
|__| Bodies of Water
|__| Roadway/Right-of-Way
|__| Fuel Oil/Gasoline Storage Tank
|__| Buildings
|__| Animal Enclosures and Manure Piles
|__| Other Sources of Contamination

Development
|__| Casing/ Wall Condition
|__| Casing Extended Above Grade
|__| Well Pit-Cover and/or Drainage
|__| Protection from Contamination
Cistern/Pond/Spring
|__| Continuous Disinfection
|__| Filtration (as required)
|__| Other

Pump
|__| Proper Maintenance
|__| Leakage
|__| Other

Distribution System
|__| Maintenance
|__| Cross Contamination
|__| Submerged Inlets
|__| Treatment and/or Disinfection

|__| Type of Investigation
1. Inspection
2. Survey
3. Complaint

Compliance Date |__|__|__|__|__|__|
M M D D Y Y

|__|__|__|

RECOMMENDATIONS AND COMMENTS

_____

_____

_____

_____

_____

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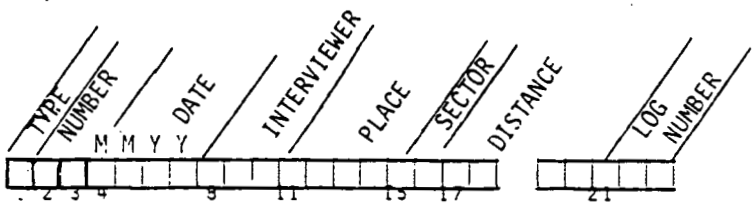
FIGURE 5

HOMEOWNER SURVEY



NAME 24

STREET 64

CITY 94 ZIP 114

HOME PHONE (119) -

OFFICE PHONE (129) -

DATE (MMDDYY)	TIME (2400)	INTERVIEWER
139		
152		
165		
178		

HELLO, I AM _____ WITH THE OHIO DEPARTMENT OF HEALTH. I AM HERE TO SAMPLE YOUR WATER. ARE YOU _____ WHO PHONED OUR TOLL FREE NUMBER TO HAVE YOUR WATER SAMPLED? I NEED SOME INFORMATION TO GO WITH THE SAMPLE. I ALSO NEED TO SEE YOUR WELL.

Refusal

1. Who refused _____
2. Sex of refusal _____
3. Reason Given _____

_____

FIGURE 5

[ ] 191 SEX: MALE _____ FEMALE _____

1. DO YOU HAVE ANY REASON TO BELIEVE THAT YOUR PROPERTY, SOIL OR WATER

[ ] 192 MIGHT BE CONTAMINATED? YES _____ NO _____ DON'T KNOW _____

[ ] 193 2. IF YES, WHY, WHAT, WHEN, WHERE?

[ ] 195 3. DO YOU HAVE A CISTERN OR A WATER TANK? YES _____ NO _____

DON'T KNOW _____ IF NO, GO TO 4.

[ ] 196 IS IT USED FOR DRINKING? YES _____ NO _____ IF NO, GO TO 4.

[ ] 197 IS IT FOR RAINWATER COLLECTION? YES _____ NO _____

[ ] 198 DO YOU HAVE WATER HAULED IN? YES _____ NO _____ IF NO, GO TO 4.

[ ] 199 HOW OFTEN DO YOU GET DELIVERY? ONCE A MONTH _____ EVERY OTHER WEEK _____

EVERY THREE WEEKS _____ ONCE A WEEK _____

[ ][ ][ ][ ] 200 HOW MUCH WATER IS DELIVERED EACH TIME? _____ GALLONS

[ ][ ][ ][ ] 204 4. HOW DEEP IS YOUR WELL? _____ FEET

[ ] 208 5. DO YOU DRINK WATER FROM YOUR WELL? YES _____ NO _____ IF NO, GO TO 8.

6. TO ESTIMATE THE POSSIBLE EFFECTS FROM YOUR DRINKING WATER, WE NEED THE FOLLOWING INFORMATION ON MEMBERS OF YOUR HOUSEHOLD:

	AGE		SEX	ML/DAY INTAKE		
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

WATER, COFFEE, RECONSTITUTED MILK, JUICE

FIGURE 5

[ ] 249 7. WHICH ONE IS YOU? _____ AGE GO TO 9.

[ ] 251 8. DID YOU USED TO DRINK FROM YOUR WELL? YES _____ NO _____ IF YES,

[ ] 252 HOW LONG AGO WAS IT? _____ YEARS IF YES, RETURN TO 6. IF NO,

[ ] 254 WHERE DO YOU GET YOUR DRINKING WATER? _____

9. DO YOU HAVE:

[ ] 256 WATER SOFTENER YES _____ NO _____

[ ] 257 IRON REMOVER YES _____ NO _____

[ ] 258 CHLORINATOR YES _____ NO _____

[ ] 259 CARBON FILTER YES _____ NO _____

[ ] 260 DISTILLER YES _____ NO _____

[ ] 261 10. HAS ANY MEMBER OF YOUR HOUSEHOLD EVER WORKED AT THE FERNALD PLANT?

YES _____ NO _____ DON'T KNOW _____

[ ] 262 11. IF YES, WHICH ONE? _____ AGE

[ ] 264 HOW LONG DID HE WORK THERE? _____ YEARS

[ ] 266 12. WHAT DO YOU CONSIDER TO BE THE BIGGEST HEALTH PROBLEM IN THIS COUNTY?

_____

_____

[ ] 268 13. HOW DO YOU FIND OUT ABOUT VARIOUS COMMUNITY EVENTS AND LOCAL SERVICES?

_____

[ ] 270 14. WHICH NEWSPAPER DO YOU READ ON A REGULAR BASIS?

_____

[ ] 272 15. TO WHICH RADIO STATIONS DO YOU MOST OFTEN LISTEN?

_____

[ ] 274 16. HOW MANY YEARS OF SCHOOLING HAVE YOU COMPLETED? _____ YEARS

[ ] 276 17. HOW LONG HAVE YOU LIVED AT THIS ADDRESS? _____ YEARS

[ ] 278 18. WAS YOUR PREVIOUS ADDRESS WITHIN FIVE MILES OF HERE? _____ YES _____ NO

IF NO GO TO 19. IF YES, WHAT WAS YOUR PREVIOUS ADDRESS?

_____

FIGURE 5

279 HOW LONG DID YOU LIVE THERE? _____ YEARS

281 19. DO YOU OWN OR RENT THIS HOME? OWN _____ RENT _____ OTHER _____

THANK YOU FOR YOUR TIME.

FIGURE 6 SECTOR/DISTANCE MAP

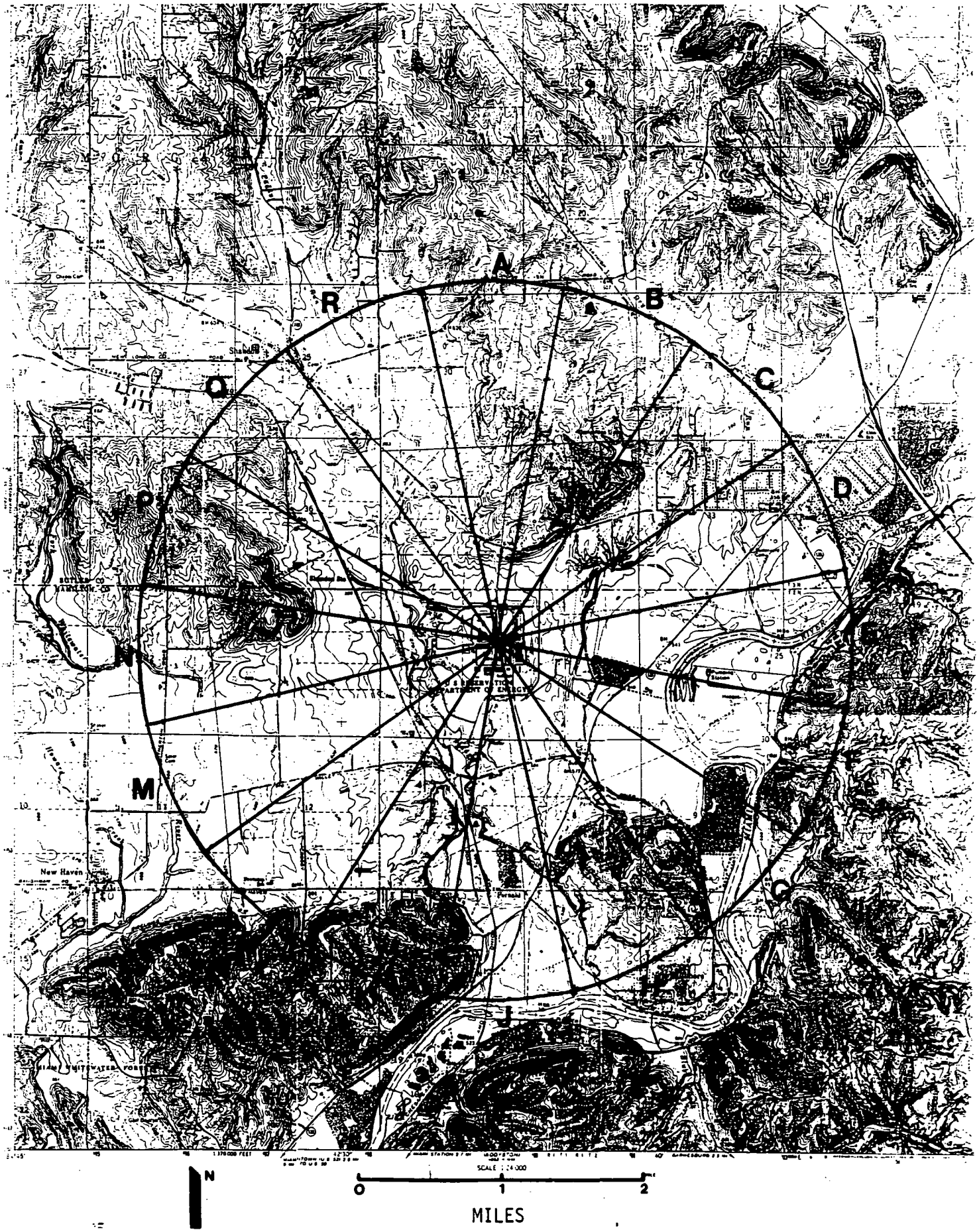


FIGURE 7

OHIO DEPARTMENT OF HEALTH
RADIOLOGICAL HEALTH UNIT

Sample and Laboratory Data Sheet

Sample-ID

Plant	Sector	Distance	Date Collected / / 19	Mil. Time	Code *	No.

*Sample Codes: AF Animal Feed, CC Charcoal Cartridge, FI Fish, FP Filter Paper, MI Milk, PR Produce, SE Sediment, WA Water, VE Vegetation, OT Other

Sample Location

Street	City	State	Zip

Collected By

Last Name	First Name	Agency Name

Sample Description

Air Sample		Other Sample
Running Time	Hours	Substance
Air Flow: Stop	Cubic Feet	Size
Start	Cubic Feet	Additional Information
Total Volume	Cubic Feet (To Be Filled In By Lab)	
	Cubic Meters (To Be Filled In By Lab)	

Analysis Requested/Special Instructions: _____

Shipped to:	Via	Date / /19

To Be Filled Out By Laboratory Personnel

Laboratory Name

Received By: Last Name	First Name	Date	Lab ID

Results of Analysis

Nuclide	Activity	Unit	2 Sigma Error	LLD
1. -	. E		. E	. E
2. -	. E		. E	. E
3. -	. E		. E	. E
4. -	. E		. E	. E
5. -	. E		. E	. E
6. -	. E		. E	. E
7. -	. E		. E	. E

Analyzed By _____ Date ____/ ____/19 Sample Disposition _____

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FIGURE 8

TABLE 10 - Summary of Risk Levels and Occurrence for Radionuclides in Drinking Water*

	Annual effective dose equivalent[1] (mrem/yr)	pCi/l			
		Ra-226	Ra-228	Natural uranium[2]	Ra-222
Risk levels:					
10^{-3}	100	100	200	700	10,000
10^{-4}	10	10	20	70	1,000
10^{-5}	1	1	2	7	100
10^{-6}	0.1	0.1	0.2	0.7	10
Occurrence: Population weighted concentration averages:					
All supplies		0.3-0.8	0.4-1.0	0.3-2.0	50-300
Ground water supplies		1.6	1.8	3	approx. 400
Surface water supplies		.....	.....	1	.....
Actual concentration		0-200	0-50	0-600	0-500,000

* The calculations in this table involve uncertainties of the order of 4 to 5.

[1] Rounded off to one significant figure. Note that the dose limit for man-made radioactivity in drinking water under the Interim Regulations is 4 mrem/year, at the end of 70 years.

[2] Using $f_1 = 0.05$.

3.0 RESULTS OF INVESTIGATION

The Ohio Department of Health collected and analyzed water from approximately 309 locations in the vicinity of the FMPC during the duration of the DOE/ODH cooperative agreement. The following is a breakdown of the types of water sources sampled at these locations:

Drinking water from private wells - 246
Drinking water from cisterns - 54
Drinking water from public water supplies - 1
Water from industrial supplies - 2
Miscellaneous surface water, e.g. ponds - 6

3.1 PRIVATE WELLS

Results of the analyses for gross alpha, gross beta and uranium activity in these water supplies were as follows:

gross alpha activity	< = 3 pCi/l	-	229
	> 3 and < = 15 pCi/l	-	12
	> 15 pCi/l	-	5
gross beta activity	< = 4 pCi/l	-	164
	> 4 and < = 15 pCi/l	-	63 *
	> 15 pCi/l	-	23
uranium activity	< = 3 pCi/l	-	241
	> 3 and < = 15 pCi/l	-	1
	> 15 pCi/l	-	3

Figure 9 displays the locations of all wells sampled by the ODH in the vicinity of the FMPC. All analytical results for the samples collected from these wells are presented in Table 1. The analysis results were also plotted on maps to allow the ODH to define any areas of contamination. Symbols and color coding

* Some of the wells have been included in more than one activity category as a result of variations in the gross beta analysis results obtained upon resample.

Note: < means "less than"
< = means "less than or equal to"
> means "greater than"

have been employed on these maps to identify water sample sources, locations and analysis results. The symbol of a circle denotes a well location and the gross alpha results for all wells sampled have been plotted in Figure 12. The gross beta and uranium activity results for all wells sampled have been been plotted in Figures 13 and 14 respectively. In addition to analysis results, the ODH felt it would be useful to map the locations of drilled versus dug wells and wells where water was treated or untreated. The use of auxilliary equipment (e.g. filters, ion exchangers etc.) to treat the water might affect the concentration of radioactivity detected in the samples collected by the ODH (See Figures 15,16 & 17).

Results of the analyses performed on the samples collected from wells in the vicinity of the FMPC indicated that the average background radioactivity content in this area is as follows:

gross alpha activity	< 3.0
gross beta activity	< 4.0
uranium activity	< 1.0

As can be seen from Figure 14 and Table 1, above background concentrations of uranium were detected by the ODH in 3 wells. All of these wells had previously been identified by NLO as having elevated concentrations of uranium. Two of these wells were used only for industrial purposes and did not serve as a source of drinking water. Only Log #107 was used as a drinking water source by the homeowner/resident(s). A new well was drilled to a greater depth at this location and sampled for radioactivity. No evidence of contamination was detected in the new well.

Based on these results, the uranium contamination in the ground water appears to be limited to a fairly well delineated area immediately south of the plant. No evidence of contamination was found at a distance greater than 1.6 miles from the FMPC. Log #049, located at a distance of 1.6 miles from the center of the facility, was the most distant well location found to have an elevated concentration of uranium.

At location 092 two wells were in use. One of the wells provided water to the resident's home and the other to the resident's business. Analysis results for the well serving the resident's home indicated the presence of normal background levels of alpha, beta and uranium. Analysis of the business well revealed levels of gross alpha and gross beta significantly elevated above background. The uranium analysis determined that uranium was not responsible for the elevated alpha activity.

In an attempt to identify the source of the alpha activity in this well, the ODH performed further analyses such as K-40 and gamma spectral analyses. In addition, the ODH split a sample with the USEPA. This sample was sent to the Eastern Environmental Radiation Facility (EERF) for analysis. Analyses for

the alpha emitters radium, thorium and plutonium were performed. The presence of 20.4 pCi/l of radium-226 (Ra-226) was detected by the EERF. Radium-226 is a naturally occurring radionuclide. The USEPA's public drinking water standard for Ra-226 + Ra-228 is 5 pCi/l. It was recommended to the owner that this well not be used as a source of drinking water. Although both wells were drilled to a depth of 80 feet on the same property, a significant distance and difference in elevation separated them. It is presumed that the difference in analysis results is a consequence of the wells tapping different aquifers.

At location 307 the residents utilized a spring rather than a well for obtaining drinking water. Water collected in the springhouse was piped to the house. Although only background concentrations of gross alpha and uranium were detected in water collected at this spring, the gross beta activity was above the ODH action level. In an attempt to determine the source of beta, the water was resampled. Analysis of this sample yielded gross beta results below the ODH action levels. This type of variation in gross beta analysis results was observed quite frequently. It is theorized that flucuations in the height of the ground water table influence the water's concentration of naturally occuring beta emitters such as K-40.

According to the ODH/DOE cooperative agreement, every fifth water sample collected was split with the FMPC operator. Analytical results obtained by the operator were then compared with results obtained by the ODH (See Table 2). Comparison of the results indicated no significant difference between the analytical results at the 99% confidence level. The agreement of results was independently verified by a professor at the University of Cincinnati (See Fig. 20). Locations at which split samples were collected are displayed in Figure 18.

As mentioned previously, in addition to water sample collection, the ODH completed a well inspection form for each well sampled. Results of the well inspections performed at each location revealed that a wide variety of well types and conditions exist in the Fernald area. The well types varied from 150 year old dug wells to new drilled wells with pitless type adaptors. The conditions of these wells varied from excellent to unsanitary. A number of wells were not covered adequately and were susceptible to contamination.

3.2 CISTERNS

Results of the analyses for gross alpha, gross beta and uranium in these water supplies were as follows:

gross alpha activity	< = 3 pCi/l	-	36
	> 3 and < = 15 pCi/l	-	1
	> 15 pCi/l	-	1
gross beta activity	< = 4 pCi/l	-	34
	> 4 and < = 15 pCi/l	-	4 *
	> 15 pCi/l	-	2
uranium activity	< = 3 pCi/l	-	53
	> 3 and < = 15 pCi/	-	0
	> 15 pCi/l	-	1

Figure 10 displays the locations of all cisterns sampled by the ODH. All analytical results for cistern samples are presented in Table 3. The symbol of a square denotes a cistern location and the gross alpha results for all cisterns sampled have been plotted in Figure 12. The gross beta results for all cisterns sampled have been been plotted in Figure 13 and the uranium results in Figure 14.

Only one cistern water sample was found to contain a concentration of uranium significantly above background. This cistern's source of water was rainwater collected via the roof gutters. According to the owner, the cistern had been disconnected from this collection system approximately 2 years prior to sample collection and had not been used for drinking since that time. The water which was present in the cistern at the time of sampling, therefore, had not been disturbed for approximately two years. Prior to sampling, the owner agitated the water in the cistern. A dipper was used to collect water from the cistern.

At many of the homes surveyed the resident utilized hauled water (water hauled in by truck and transferred from the truck to the cistern) in addition to rainwater as a cistern water source. The frequency of delivery varied widely from every other week to once in a several year period.

A number of residents also had a well which was used as a drinking water source in addition to the cistern. Some of the residents had discontinued using their cistern or well water for drinking purposes and were now using a community water supply or buying bottled water.

* Some of the cisterns have been included in more than one activity category due to variations in the gross beta results obtained upon resample.

3.3 PUBLIC WATER SUPPLIES

As defined by the EPA, a public water system means "a system for the provision to the public of piped water for human consumption, if such system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year." (REF. 8)

The Ohio Department of Health identified one public drinking water supply and one large industrial use water supply (served by 2 wells) in the vicinity of the FMPC. These supplies are identified as Log #246 and Log #306 respectively. Both supply water from large wells and are, therefore, identified in Figures 9, 12, 13, & 14.

Results of the analyses for gross alpha, gross beta and uranium in these water supplies are as follows:

Log#	Location	Alpha	Beta	Uranium
246	FC 3.9	< 3.0	< 4.0	3.0E-1 ± 4.0E-1
306	FE 1.5	< 3.0	< 4.0	6.0E-1 ± 3.5E-1
306	FE 1.5	1.0E0 ± 2.0E0	5.0E0 ± 3.0E0	not performed
306	FE 1.4	6.6E1 ± 8.0E0	1.15E2 ± 7.0E0	not performed

The water supplier identified as Log #306 owned two wells which were approximately 0.4 miles apart. According to a representative for this supplier, these wells do not provide drinking water to the public but are used strictly to supply water to major Cincinnati industries.

It should be noted that at location #210 two wells existed which supplied water for a local water hauling service. Although these wells are not considered a public water supply by definition, they did supply water to a number of residents. The analysis results for these wells are, therefore, provided here.

Log#	Location	Alpha	Beta	Uranium
210(1)	FD 02.2	< 3.0	< 4.0	6.0 E-1 ± 4.0 E-1
210(2)	FD 02.2	< 3.0	< 4.0	5.0 E-1 ± 4.0 E-1

Note: The symbol " ± " means "plus or minus" and reflects the statistical uncertainty (2 sigma error) associated with the analytical result. The symbol "E" means "exponent". All analytical results reported by the ODH are presented in scientific notation form.

Examples: 115 = 1.15 E2 0.6 = 6.0 E-1

3.4 SURFACE WATER

The Ohio Department of Health received a number of requests to sample a variety of surface waters, e.g. ponds on residential property. Although drinking water was not obtained from these sources, homeowners wished to have this water tested because they were concerned about exposure to radioactivity resulting from contact with this water, e.g. swimming, fishing, etc.

The ODH sampled surface waters at six locations in the vicinity of the FMPC. All analytical results for these samples are presented in Table 4. Figure 11 displays the locations at which the surface water samples were collected. The symbol of a triangle denotes a surface water sampling location. The gross alpha activity results for all surface water samples have been plotted in Figure 12. The gross beta and uranium activity results have been plotted in Figures 13 and 14 respectively.

All analytical results for the surface water samples were below ODH investigational action levels except at location #073. Analyses of the water collected from the pond at this location yielded an elevated gross alpha result. The pond water was resampled to corroborate the initial results. The subsequent analysis detected gross alpha activity slightly above the ODH action level. The uranium activity detected in both samples was below the ODH action level. The elevated gross alpha results were most likely due to naturally occurring alpha emitters such as radium. This water was not used for human consumption and should not represent a health concern.

3.5 HOMEOWNER SURVEY

Part of the Ohio Department of Health's contribution to the cooperative agreement with DOE was the development and administration of a public awareness or homeowner survey. All residents from whom the ODH collected a water sample were surveyed. A survey interview was conducted when ODH personnel visited the residence to collect a water sample. The survey consisted of a series of questions pertaining to the resident's water supply, water consumption, attitude regarding contamination of the water supply, health problems, sources of information or news, etc. (See Fig. 5). The following is a summarization of the responses provided to ODH personnel conducting interviews in the vicinity of the FMPC.

At each residence one household member was interviewed. A female member of the household was interviewed at 61% of the residences and at 39% of the residences a male member was interviewed.

Attitudes: When asked if they had any reason to believe that their property, soil or water might be contaminated, 33% of the residents interviewed responded YES, 36% responded NO, and 31% responded that THEY DID NOT KNOW. Although only 33% responded with a definite yes, a greater percentage (52%) volunteered to the ODH reasons why they thought their property, soil or water could possibly be contaminated. This inconsistency may exist because residents who answered they did not know to the above question believed there was a possibility that their property might be contaminated but did not feel strongly enough about it to answer yes to that question.

Of the 52% who gave reasons for believing that their property, soil or water might be contaminated, 53% believed that this possible contamination was due to their closeness to the FMPC. Other responses included:

6% based their assessment on information obtained from the newspaper.

6% held this belief due to the taste or smell of their water.

4% believed it was due to the FMPC and other chemical plants in the area.

4% had heard that a neighbor's water was contaminated.

The remaining 27% of residents interviewed gave a variety of answers; e.g. their belief was based on environmental observations such as trees dying or black debris on the roof, etc. Others gave reasons such as a personal illness, e.g. cancer.

When residents were asked what they considered to be the biggest health problem in the county, the followg responses were obtained.

28% the FMPC
19% did not know
14% cancer
9% pollution of water supply
4% air and water pollution
4% air pollution

The remaining 22% of the responses were varied. Examples of other responses given were: exhaust from semi tractor trailers traveling through the area, farming chemicals, chemical plants in the area, poverty, pollen, etc.

Water Supply and Support Equipment: The following information was obtained regarding the water supply and support equipment used by the residents:

Residents using a water softener - 32%
an iron remover - 68%
a chlorinator - 2.6%
distillation - 1.5%

Of the residents using a cistern as a source of drinking water, 76% utilized rainwater collection and 45% had water hauled in. This indicates that 19% used a combination of these two supplies.

Personal Information: Of the households surveyed, 8% had a member who had worked at the FMPC. Of this group 57% had worked at the FMPC for 1-5 years, 10% had worked 6-10 years and 33% had worked 11-32 years at the FMPC.

The educational background of the residents surveyed was as follows:

11% had completed 0-8 years of schooling.
58% had 9-12 years of schooling (43% completed 12 years of schooling).
31% had 13-20 years of schooling.

Residents who were interviewed were also asked how long they had lived at their present address. Responses were as follows:

33% 0-5 years
25% 6-10 years
23% 11-20 years
11% 21-30 years
7% 31-50 years
1% < 50 years

Of the residents interviewed 36% had lived at a previous address which was within 5 miles of their present address.

Sources of Information: Residents were asked how they found out about various community events and local services, which newspaper they read on a regular basis and which radio station they most often listened to. It was felt that this information could be useful to the ODH in the event that the ODH wanted to get information to residents living in the vicinity of the FMPC.

Of the residents surveyed, 62% found out about community events and services through the newspaper. The newspaper most widely read was the CINCINNATI ENQUIRER. The HAMILTON JOURNAL was also a popular newspaper. Other sources of information for residents were personal contacts; e.g neighbor, word of mouth, school, etc. (15%) and television (15%). A smaller percentage of residents

stated that they received information from such sources as community meetings and radio.

Responses to the question regarding which radio station was most often listened to were as follows:

18%	did not listen to any one station most often
16%	WLW
11%	WKRC 55
9%	WUBE
7%	WWEZ 92
6%	95 FM

A variety of stations were listened to by the remaining 33% of the residents interviewed.

3.6 WATER SAMPLES COLLECTED IN THE VICINITY OF THE PGDP

The Ohio Department of Health collected and analyzed water from seven locations in the vicinity of the PGDP. Five of the locations were within 2 miles of the center of the facility. Log #4 was located approximately 9 miles northeast of the facility and Log #5 was located approximately 60 miles northeast of the faciltiy in Amesville, Ohio. Two wells and a cistern were sampled at location #5. Although considered outside the influence of the PGDP, the resident did request that the ODH sample his water due to concerns regarding the faciltiy. The ODH agreed to perform the sampling and felt it could serve as a control location.

The locations of the wells sampled in the vicinity of the PGDP are plotted in Figure 19. All analytical results for these water samples are shown in Table 5.

All analytical results for the samples collected were below the the ODH investigational action levels except at Loc. #6. The gross alpha, beta and uranium concentrations in the water collected at this location exceeded the ODH investigational action levels. According to the owner, the property was used by the resident for recreational purposes only and this well was not used as a source of drinking water. Consequently, no further analyses were performed on this water except a K-40 analysis. Results of this analysis detected the presence of 15.4 mg/l of K-40.

TABLE 1

FMPC WELL WATER SAMPLE RESULTS

(pCi/l +/- 2 sigma error)

LOG#	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
*002	FD 04.5	1.3 E0 +/- 9.6 E-2	0.0 E0 +/- 6.1 E-1	2.6 E-1 +/- 2.9 E-1
*002	FD 02.0	1.0 E0 +/- 9.0 E-2	1.92 E1 +/- 8.3 E-1	2.6 E-1 +/- 2.9 E-1
003	FG 02.1	3.4 E0 +/- 1.7 E0	7.4 E0 +/- 4.0 E0	1.0 E0 +/- 5.0 E-1
004	FJ 02.2	< 3.0	< 4.0	2.0 E-1 +/- 4.0 E-1
005	FP 00.8	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
006	FG 01.5	< 3.0	1.3 E1 +/- 4.1 E0	0.0 E0 +/- 3.0 E-1
*007	FK 01.9	< 3.0	8.0 E0 +/- 3.4 E0	0.0 E0 +/- 2.8 E-1
*007	FK 01.9	< 3.0	9.0 E0 +/- 3.0 E0	2.0 E-1 +/- 3.0 E-1
009	FD 02.8	< 3.0	4.0 E0 +/- 2.9 E0	2.0 E-1 +/- 3.0 E-1
010	FD 02.8	< 3.0	< 4.0	7.0 E-1 +/- 5.0 E-1
011	FD 03.0	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1
012	FD 01.7	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
*013	FQ 01.2	< 3.0	1.95 E1 +/- 4.2 E0	1.0 E-1 +/- 3.0 E-1
*013	FQ 01.2	(K-40)6.5 E1 +/- 3.6 E1	1.8 E1 +/- 3.7 E0	3.0 E-1 +/- 3.0 E-1
014	FD 02.2	< 3.0	< 4.0	3.0 E-1 +/- 3.0 E-1
015	FD 02.8	< 3.0	4.0 E0 +/- 3.0 E0	2.0 E-1 +/- 4.0 E-1
016	FD 02.0	< 3.0	< 4.0	3.0 E-1 +/- 3.0 E-1
*017	FJ 01.7	< 3.0	5.3 E1 +/- 4.6 E0	8.0 E-1 +/- 5.0 E-1
*017	FJ 01.7	(K-40)3.4 E1 +/- 2.9 E1	7.3 E0 +/- 4.3 E0	
*017	FJ 01.7		5.4 E0 +/- 3.0 E0	
*017	FJ 01.7	< 3.0	9.29 E0 +/- 3.8 E0	6.5 E-1 +/- 3.9 E-1
*018	FA 01.1	< 3.0	6.0 E0 +/- 3.5 E0	2.0 E0 +/- 7.0 E-1
#018	FA 01.1	6.0 E0 +/- 9.0 E0	4.7 E1 +/- 1.0 E1	0.0 E0 +/- 3.0 E-1
*018	FA 01.1	(K-40)8.6 E1 +/- 6.5 E1	< 4.0	
019	FP 01.0	< 3.0	< 4.0	5.0 E-1 +/- 4.0 E-1
020	FQ 01.2	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
021	FL 02.1	< 3.0	6.0 E0 +/- 6.6 E0	3.0 E-1 +/- 3.0 E-1
022	FL 01.8	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
023	FD 02.3	3.0 E0 +/- 2.0 E0	< 4.0	6.0 E-1 +/- 5.0 E-1
024	FP 01.3	< 3.0	8.3 E0 +/- 3.9 E0	0.0 E0 +/- 3.0 E-1
026	FL 02.1	3.0 E0 +/- 6.0 E-2	< 4.0	0.0 E0 +/- 3.4 E-1
027	FD 02.0	< 3.0	5.0 E0 +/- 3.1 E0	5.0 E-1 +/- 5.0 E-1
028	FK 05.0	< 3.0	4.0 E0 +/- 2.8 E0	3.0 E-1 +/- 1.0 E-1
030	FD 02.8	< 3.0	< 4.0	9.0 E-1 +/- 5.0 E-1
031	FQ 02.5	< 3.0	< 4.0	4.0 E-1 +/- 4.0 E-1
032	FQ 02.5	< 3.0	< 4.0	3.0 E-1 +/- 3.0 E-1
033	FK 01.0	< 3.0	4.2 E0 +/- 3.6 E0	9.0 E-1 +/- 3.0 E-1
034	FD 02.2	< 3.0	< 4.0	8.0 E-1 +/- 5.0 E-1
035	FQ 01.3	< 3.0	4.0 E0 +/- 3.6 E0	5.0 E-1 +/- 4.0 E-1
*036	FG 02.1	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
*036	FG 02.2	< 3.0	5.0 E0 +/- 3.0 E0	3.0 E-1 +/- 3.0 E-1

Laboratory LLD for this analysis was 8.0 pCi/l.
* Log #002 - Resident owned 2 separate wells at different locations.
* Log #007 - One well existed at this location and was resampled.
* Log #013 - One well existed at this location and was resampled.
* Log #017 - One well existed at this location and was sampled 3 times.
* Log #018 - Two separate wells existed at this location.
* Log #036 - Two separate wells existed at this location.

TABLE 1 continued

(pCi/l +/- 2 sigma error)

LOG#	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
037	FN 01.9	< 3.0	< 4.0	3.0 E-1 +/- 3.0 E-1
038	FA 02.3	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1
039	FQ 02.5	5.0 E0 +/- 2.5 E0	< 4.0	9.0 E-1 +/- 5.0 E-1
040	FR 05.0	< 3.0	1.3 E1 +/- 1.8 E0	3.0 E-1 +/- 4.0 E-1
041	FC 01.8	< 3.0	< 4.0	9.0 E-1 +/- 5.0 E-1
042	FC 01.8	< 3.0	< 4.0	4.0 E-1 +/- 4.0 E-1
043	FD 02.1	< 3.0	2.2 E1 +/- 3.9 E0	7.0 E-1 +/- 5.0 E-1
044	FC 01.8	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
*045	FL 02.4	< 3.0	< 4.0	3.1 E-1 +/- 4.2 E-1
*045	FL 02.4	< 3.0	3.0 E1 +/- 4.7 E0	3.1 E-1 +/- 4.2 E-1
*045	FL 02.4	< 3.0	5.1 E0 +/- 22.6 E0	0.0 E0 +/- 3.0 E-1
*046	FC 02.0	< 3.0	6.0 E0 +/- 2.7 E0	1.0 E-1 +/- 2.0 E-1
*046	FD 02.6	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
047	FD 02.7	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
048	FX 00.0	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
*049	FJ 01.6	1.89 E1 +/- 5.9 E0	1.91 E1 +/- 4.9 E0	3.0 E1 +/- 2.5 E0
*049	FJ 01.6	1.77 E1 +/- 5.4 E0	1.14 E1 +/- 4.1 E0	2.47 E1 +/- 2.2 E0
*049	FJ 01.6	(K-40)3.9 E1 +/- 2.9 E1	1.0 E1 +/- 3.9 E0	
050	FG 03.3	< 3.0	< 4.0	2.0 E-1 +/- 2.0 E-1
053	FK 05.5	< 3.0	6.0 E0 +/- 3.0 E0	2.0 E-1 +/- 4.0 E-1
054	FR 03.8	< 3.0	< 4.0	2.0 E-1 +/- 4.0 E-1
055	FC 01.8	< 3.0	5.0 E0 +/- 3.1 E0	4.0 E-1 +/- 4.0 E-1
056	FD 02.4	< 3.0	6.0 E0 +/- 3.0 E0	4.0 E-1 +/- 4.0 E-1
057	FD 02.4	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
060	FL 02.0	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
062	FD 02.9	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
063	FK 03.9	3.0 E0 +/- 3.4 E0	< 4.0	7.0 E-1 +/- 5.0 E-1
064	FC 01.9	< 3.0	< 4.0	5.0 E-1 +/- 5.0 E-1
065	FG 01.7	< 3.0	< 4.0	1.0 E-1 +/- 4.0 E-1
*066	FH 02.5	< 3.0	1.7 E1 +/- 5.2 E0	0.0 E 0 +/- 3.0 E-1
*066	FH 02.5		4.0 E1 +/- 8.0 E0	
068	FH 02.5	< 3.0	4.7 E0 +/- 3.1 E0	1.0 E-1 +/- 3.0 E-1
069	FF 02.6	1.2 E1 +/- 1.2 E1	3.0 E1 +/- 4.8 E1	0.0 E0 +/- 3.0 E-1
070	FD 02.4	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
072	FM 04.4	3.0 E0 +/- 2.3 E0	< 4.0	9.7 E-1 +/- 4.5 E-1
073	FC 01.2	< 3.0	4.0 E0 +/- 3.2 E0	8.0 E-1 +/- 5.0 E-1
075	FL 01.4	< 3.0	4.3 E0 +/- 9.7 E0	4.0 E-1 +/- 4.0 E-1
076	FL 01.4	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
077	FL 02.8	< 3.0	5.0 E0 +/- 3.0 E0	2.0 E-1 +/- 3.0 E-1
078	FK 01.9	< 3.0	4.8 E0 +/- 3.3 E0	3.0 E-1 +/- 3.0 E-1
079	FF 08.0	< 3.0	< 4.0	1.2 E0 +/- 5.0 E-1
080	FQ 01.2	< 3.0	< 4.0	5.0 E-1 +/- 4.0 E-1
082	FH 02.3	< 3.0	5.9 E0 +/- 3.2 E0	3.0 E-1 +/- 3.0 E-1
085	FK 01.0	< 3.0	4.0 E0 +/- 3.2 E0	2.0 E-1 +/- 3.9 E-1

* Log #045 - Two wells existed at this location. One of the wells was sampled twice.
* Log #046 - Resident owned 2 separate wells at different locations.
* Log #049 - One well existed at this location and was sampled 3 times.
* Log #066 - One well existed at this location and was sampled twice.

TABLE 1 continued

(pCi/l +/- 2 sigma error)

LOG#	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
087	FD 02.4	4.0 E0 +/- 3.0 E0	4.0 E0 +/- 2.2 E0	1.0 E0 +/- 5.0 E-1
089	FH 02.5	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1
091	FM 02.3	< 3.0	< 4.0	2.0 E-1 +/- 4.0 E-1
*092	FK 02.9	7.2 E1 +/- 3.3 E1	1.07 E2 +/- 2.8 E1	0.0 E0 +/- 2.0 E-1
*092	FK 02.9	< 3.0	8.0 E0 +/- 2.8 E0	1.0 E-1 +/- 3.0 E-1
*092	FK 02.9	2.74 E1 +/- 8.75 E0	1.12 E2 +/- 1.28 E1	9.0 E-2 +/- 2.2 E-1
*092	FK 02.9	(K-40)1.4 E2 +/- 6.5 E1		
*094	FE 01.5	< 3.0	< 4.0	5.0 E-1 +/- 4.0 E-1
*094	FE 01.5	< 3.0	< 4.0	4.0 E-1 +/- 3.0 E-1
095	FD 03.4	< 3.0	4.8 E0 +/- 3.2 E0	6.0 E-1 +/- 4.0 E-1
096	FL 01.4	< 3.0	< 4.0	3.0 E-1 +/- 3.0 E-1
097	FG 02.5	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
098	FR 00.9	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
099	FD 02.5	< 3.0	< 4.0	4.0 E-1 +/- 5.0 E-1
100	FM 05.1	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
101	FD 01.7	< 3.0	< 4.0	7.0 E-1 +/- 5.0 E-1
102	FD 02.4	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
104	FL 06.0	< 3.0	< 4.0	5.0 E-1 +/- 4.0 E-1
106	FM 04.5	< 3.0	< 4.0	3.4 E0 +/- 1.4 E0
*107	FJ 00.9	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1
*107	FJ 00.9	1.01 E2 +/- 9.2 E0	4.3 E1 +/- 6.0 E-1	1.55 E2 +/- 5.5 E0
*107	FJ 00.9	1.06 E2 +/- 1.2 E1	1.12 E2 +/- 9.0 E0	1.46 E2 +/- 5.4 E0
109	FK 02.0	< 3.0	< 4.0	9.8 E-1 +/- 4.7 E-1
*112	FB 02.2	< 3.0	< 4.0	0.0 E0 +/- 4.0 E-1
*113	FB 00.9	< 3.0	1.8 E1 +/- 3.5 E0	1.0 E0 +/- 5.0 E-1
*113	FB 00.9		2.0 E1 +/- 4.0 E0	
114	FH 01.4	< 3.0	< 4.0	4.0 E-1 +/- 3.0 E-1
115	FF 00.7	6.0 E0 +/- 3.2 E0	< 4.0	8.0 E-1 +/- 5.0 E0
117	FC 02.8	< 3.0	< 4.0	2.0 E-1 +/- 4.0 E-1
118	FH 02.4	< 3.0	< 4.0	1.0 E-1 +/- 4.0 E-1
119	FD 02.9	< 3.0	6.0 E0 +/- 3.0 E0	5.0 E-1 +/- 4.0 E-1
*120	FJ 01.6	< 3.0	4.8 E2 +/- 1.1 E1	1.0 E-1 +/- 3.0 E-1
*120	FJ 01.6	(K-40)1.0 E2 +/- 5.4 E1	5.5 E1 +/- 5.4 E0	0.0 E0 +/- 2.0 E-1
*121	FJ 01.7	< 3.0	2.6 E1 +/- 4.3 E0	0.0 E0 +/- 3.0 E-1
*121	FJ 01.7		1.1 E1 +/- 4.8 E0	
124	FA 04.5	3.0 E0 +/- 1.9 E0	1.1 E1 +/- 3.0 E0	6.0 E-1 +/- 4.0 E-1
126	FC 02.0	< 3.0	4.5 E0 +/- 3.7 E0	6.0 E-1 +/- 5.0 E-1
127	FD 02.1	< 3.0	< 4.0	2.0 E-1 +/- 4.0 E-1
128	FM 03.1	< 3.0	1.9 E1 +/- 3.6 E0	8.0 E-1 +/- 4.0 E-1
128	FM 03.1	(K-40) 6.8 E1 +/- 3.8 E1		
129	FM 03.1	< 3.0	< 4.0	3.0 E-1 +/- 4.0 E-1
130	FK 00.9	< 3.0	< 4.0	5.4 E-1 +/- 3.7 E-1
131	FD 02.4	< 3.0	< 4.0	0.0 E0 +/- 4.0 E-1
134	FG 01.9	< 3.0	< 4.0	8.0 E-1 +/- 5.0 E-1

* Log #092 - Two wells existed at this location. One of the wells was resampled to determine the source of elevated alpha counts. (See p. 25, Results of Investigation).
* Log #094 - Two wells existed at this location.
* Log #107 - Two wells existed at this location. One of the wells was sampled twice.
* Log #112 - A spring was sampled at this location.
* Log #113 - One well existed at this location and was sampled twice.
* Log #120 - One well existed at this location and was sampled twice.
* Log #121 - One well existed at this location and was sampled twice.

TABLE 1 continued

(pCi/l +/- 2 sigma error)

LOG#	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
135	FH 02.6	< 3.0	< 4.0	3.0 E-1 +/- 5.0 E-1
136	FM 04.0	< 3.0	< 4.0	6.0 E-1 +/- 4.0 E-1
*139	FK 02.8	3.0 E0 +/- 3.1 E0	< 4.0	1.0 E0 +/- 5.0 E-1
*139	FK 02.8	< 3.0	5.0 E0 +/- 1.0 E-1	9.0 E-1 +/- 6.0 E-1
142	FA 00.6	< 3.0	< 4.0	1.0 E0 +/- 6.0 E-1
143	FD 02.7	< 3.0	5.0 E0 +/- 2.9 E0	5.0 E-1 +/- 4.0 E-1
144	FK 02.8	< 3.0	4.5 E0 +/- 3.6 E0	5.0 E-1 +/- 5.0 E-1
145	FD 03.2	< 3.0	5.0 E0 +/- 2.0 E0	0.0 E0 +/- 4.0 E-1
146	FM 03.2	< 3.0	1.0 E1 +/- 3.2 E0	3.0 E-1 +/- 4.0 E-1
148	FK 01.1	< 3.0	< 4.0	3.0 E-1 +/- 4.0 E-1
151	FL 03.4	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
152	FM 03.2	< 3.0	< 4.0	0.0 E0 +/- 4.0 E-1
*153	FJ 02.0	< 3.0	1.0 E1 +/- 3.3 E0	3.0 E-1 +/- 4.1 E-1
*153	FJ 02.0	(K-40)4.2 E1 +/- 3.0 E1	< 4.0	
*153	FJ 02.0		< 4.0	
154	FK 01.9	< 3.0	< 4.0	5.0 E-1 +/- 5.0 E0
155	FQ 02.4	< 3.0	9.0 E0 +/- 3.3 E0	4.0 E-1 +/- 4.0 E-1
156	FH 01.4	< 3.0	< 4.0	3.0 E-1 +/- 8.0 E-1
*157	FK 04.0	< 3.0	5.1 E0 +/- 2.7 E0	8.0 E-1 +/- 5.0 E-1
*157	FK 04.0	< 3.0	4.0 E0 +/- 3.5 E0	1.1 E0 +/- 5.0 E-1
*158	FM 03.3	< 3.0	2.6 E1 +/- 4.5 E0	0.0 E0 +/- 3.4 E-1
*158	FM 03.3	(K-40)1.6 E1 +/- 2.6 E1	2.3 E1 +/- 4.8 E0	
159	FD 02.5	< 3.0	9.0 E0 +/- 2.8 E0	2.0 E-1 +/- 3.0 E-1
162	FE 01.2	< 3.0	< 4.0	4.0 E-1 +/- 4.0 E-1
164	FL 03.4	< 3.0	< 4.0	2.0 E-1 +/- 4.0 E-1
165	FL 01.9	< 3.0	< 4.0	3.0 E-1 +/- 3.0 E-1
166	FL 01.9	< 3.0	< 4.0	3.0 E-1 +/- 3.0 E-1
167	FH 02.6	< 3.0	< 4.0	1.0 E-1 +/- 4.0 E-1
169	FK 03.8	4.7 E0 +/- 2.8 E0	< 4.0	1.0 E0 +/- 5.0 E-1
171	FH 02.4	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
172	FH 02.6	4.0 E0 +/- 2.09 E0	< 4.0	5.0 E-1 +/- 4.0 E-1
174	FH 02.5	3.1 E0 +/- 2.8 E0	< 4.0	4.0 E-1 +/- 4.0 E-1
177	FD 02.7	< 3.0	4.3 E0 +/- 2.9 E0	4.0 E-1 +/- 4.0 E-1
178	FM 03.3	< 3.0	9.0 E0 +/- 3.0 E0	2.0 E-1 +/- 3.0 E-1
*179	FH 02.0	< 3.0	< 4.0	5.0 E-2 +/- 3.5 E-1
*179	FH 02.1	3.9 E0 +/- 2.4 E0	< 4.0	8.0 E-1 +/- 4.0 E-1
181	FB 00.7	< 3.0	< 4.0	9.0 E-1 +/- 5.0 E-1
182	FM 03.5	< 3.0	7.3 E0 +/- 3.0 E0	1.0 E-1 +/- 3.0 E 0
184	FG 01.8	3.0 E0 +/- 2.01 E0	< 4.0	1.0 E0 +/- 6.0 E-1
185	FM 03.8	< 3.0	< 4.0	3.0 E-1 +/- 4.0 E-1
187	FC 02.0	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
188	FM 04.0	< 3.0	4.0 E0 +/- 2.5 E0	0.0 E0 +/- 3.0 E-1
189	FL 00.9	3.0 E0 +/- 6.0 E-2	4.0 E0 +/- 2.0 E-2	4.0 E-1 +/- 4.0 E-1
191	FG 02.0	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1

* Log #139 - One well existed at this location and was sampled twice.
* Log #153 - One well existed at this location and was sampled twice.
* Log #157 - Two wells existed at this location.
* Log #158 - One well existed at this location and was sampled twice.
* Log #179 - Two wells existed at this location.

TABLE 1 continued

(pCi/l +/- 2 sigma error)

LOG #	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
192	FB 01.0	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
193	FM 05.5	< 3.0	< 4.0	3.0 E-1 +/- 3.0 E-1
194	FG 01.6	< 3.0	< 4.0	4.0 E-1 +/- 4.0 E-1
195	FG 01.3	< 3.0	5.0 E0 +/- 3.6 E0	3.9 E-1 +/- 3.3 E-1
196	FK 01.7	< 3.0	4.0 E0 +/- 3.0 E0	0.0 E0 +/- 3.0 E-1
198	FM 03.6	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
199	FM 03.1	< 3.0	< 4.0	0.0 E0 +/- 4.0 E-1
201	FG 02.3	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
202	FD 02.5	< 3.0	< 4.0	8.0 E-1 +/- 5.0 E-1
203	FC 05.0	< 3.0	7.0 E0 +/- 4.0 E0	3.0 E-1 +/- 3.0 E-1
204	FD 01.8	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
205	FD 02.6	< 3.0	< 4.0	4.0 E-1 +/- 4.0 E-1
207	FQ 02.1	< 3.0	5.4 E0 +/- 3.8 E0	3.0 E-1 +/- 4.0 E-1
208	FM 04.5	< 3.0	< 4.0	4.0 E-1 +/- 4.0 E-1
209	FR 02.4	< 3.0	< 4.0	7.0 E-1 +/- 5.0 E-1
*210	FD 02.2	< 3.0	< 4.0	6.0 E-1 +/- 4.0 E-1
*210	FD 02.2	< 3.0	< 4.0	5.0 E-1 +/- 4.0 E-1
211	FD 02.1	< 3.0	< 4.0	3.0 E-1 +/- 4.0 E-1
212	FL 00.8	< 3.0	6.0 E0 +/- 3.3 E0	2.0 E-1 +/- 3.0 E-1
213	FD 02.2	< 3.0	< 4.0	3.0 E-1 +/- 3.0 E-1
214	FB 01.7	< 3.0	< 4.0	1.0 E-1 +/- 4.0 E-1
215	FD 02.1	< 3.0	< 4.0	0.0 E0 +/- 0.4 E0
216	FD 02.9	< 3.0	3.0 E0 +/- 3.0 E0	8.0 E-1 +/- 5.0 E-1
217	FL 04.1	< 3.0	4.0 E0 +/- 3.1 E0	5.0 E-1 +/- 4.0 E-1
218	FD 02.4	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
219	FK 01.3	< 3.0	< 4.0	0.0 E0 +/- 4.0 E-1
220	FD 02.4	< 3.0	5.0 E0 +/- 2.9 E0	5.0 E-1 +/- 4.0 E-1
222	FR 02.7	< 3.0	5.0 E0 +/- 2.9 E0	2.0 E-1 +/- 3.0 E-1
223	FC 01.9	< 3.0	< 4.0	6.0 E-1 +/- 6.0 E-1
224	FD 03.5	< 3.0	4.7 E0 +/- 3.1 E0	3.0 E-1 +/- 4.0 E-1
225	FL 06.0	< 3.0	< 4.0	6.0 E-1 +/- 4.0 E-1
226	FM 10.0	< 3.0	< 4.0	4.0 E-1 +/- 3.0 E-1
229	FD 02.9	< 3.0	< 4.0	3.0 E-1 +/- 4.0 E-1
230	FD 02.5	< 3.0	6.0 E0 +/- 2.8 E0	4.0 E-1 +/- 4.0 E-1
231	FH 03.1	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
232	FR 02.4	8.0 E0 +/- 3.0 E0	1.58 E1 +/- 4.2 E0	1.0 E-1 +/- 3.0 E-1
234	FD 02.1	< 3.0	< 4.0	9.0 E-1 +/- 5.0 E-1
235	FK 06.5	< 3.0	6.0 E0 +/- 3.0 E0	7.0 E-1 +/- 4.0 E-1
236	FH 02.6	< 3.0	8.0 E0 +/- 4.0 E0	0.0 E0 +/- 2.0 E-1
237	FR 02.9	< 3.0	1.48 E1 +/- 3.7 E0	1.2 E0 +/- 6.0 E-1
238	FD 02.1	< 3.0	4.0 E0 +/- 3.0 E0	3.0 E-1 +/- 3.0 E-1
239	FE 10.0	< 3.0	7.0 E0 +/- 3.5 E0	5.0 E-1 +/- 4.0 E-1
240	FM 04.5	< 3.0	< 4.0	1.0 E0 +/- 5.0 E-1
241	FD 02.4	< 3.0	< 4.0	5.0 E-1 +/- 4.0 E-1
244	FD 02.3	< 3.0	< 4.0	4.0 E-1 +/- 5.0 E-1
246	FC 03.9	< 3.0	< 4.0	3.0 E-1 +/- 4.0 E-1
247	FH 01.5	< 3.0	< 4.0	3.2 E-1 +/- 3.0 E-1
249	FN 05.9	< 3.0	5.0 E0 +/- 3.5 E0	2.0 E-1 +/- 3.0 E-1

* Log# 210 - Two separate wells existed at this location.

TABLE 1 continued

(pCi/l +/- 2 sigma error)

LOG #	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
250	FK 02.0	< 3.0	6.0 E0 +/- 3.0 E0	1.2 E0 +/- 5.0 E-1
251	FM 03.2	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1
252	FM 03.4	< 3.0	< 4.0	0.0 E0 +/- 4.0 E-1
253	FD 02.4	< 3.0	< 4.0	4.0 E-1 +/- 4.0 E-1
254	FG 00.9	< 3.0	5.0 E0 +/- 2.9 E0	3.0 E-1 +/- 3.0 E-1
255	FH 02.4	< 3.0	4.0 E0 +/- 2.6 E0	1.0 E-1 +/- 3.0 E-1
257	FD 02.1	< 3.0	< 4.0	1.1 E0 +/- 6.0 E-1
258	FM 03.4	< 3.0	5.0 E0 +/- 3.2 E0	3.0 E-1 +/- 4.0 E-1
262	FM 05.0	< 3.0	9.0 E0 +/- 3.0 E0	1.0 E-1 +/- 3.0 E-1
263	FM 03.3	< 3.0	1.0 E1 +/- 3.0 E0	1.0 E-1 +/- 3.0 E-1
266	FQ 02.5	< 3.0	< 4.0	5.0 E-2 +/- 3.0 E-1
268	FQ 02.5	< 3.0	2.4 E1 +/- 4.2 E0	1.3 E0 +/- 5.0 E-1
271	FJ 02.0	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
273	FL 02.0	< 3.0	< 4.0	0.0 E0 +/- 2.5 E-1
274	FL 02.0	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
275	FJ 01.5	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
276	FK 01.2	< 3.0	< 4.0	1.6 E0 +/- 6.0 E-1
277	FP 08.0	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
279	FL 02.4	< 3.0	1.2 E1 +/- 3.8 E0	1.0 E-1 +/- 3.0 E-1
284	FL 02.4	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
285	FJ 01.6	< 3.0	< 4.0	1.9 E-1 +/- 2.6 E-1
286	FL 02.4	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
287	FM 02.5	< 3.0	< 4.0	2.8 E-1 +/- 2.9 E-1
288	FN 01.5	< 3.0	< 4.0	4.2 E-1 +/- 3.3 E-1
289	FJ 01.2	1.72 E2 +/- 1.56 E1	9.50 E1 +/- 8.4E0	2.5 E2 +/- 6.77E0
290	FL 02.4	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1
296	FQ 02.1	< 3.0	< 4.0	5.2 E-1 +/- 4.2 E-1
297	FQ 02.1	< 3.0	< 4.0	7.3 E-1 +/- 2.3 E-1
299	FD 02.5	3.0 E0 +/- 2.33 E0	< 4.0	6.0 E-1 +/- 3.7 E-1
300	FL 02.4	< 3.0	< 4.0	3.3 E-1 +/- 3.1 E-1
302	FD 02.4	< 3.0	4.75 E0 +/- 3.46 E0	5.6 E-1 +/- 3.6 E-1
303	FA 02.5	< 3.0	6.96 E0 +/- 2.71 E0	1.11 E0 +/- 4.6 E-1
304	FQ 02.0	< 3.0	9.86 E0 +/- 3.08 E0	1.9 E-1 +/- 2.2 E-1
305	FQ 02.0	< 3.0	< 4.0	5.1 E-1 +/- 3.3 E -
*306	FE 01.5	< 3.0	< 4.0	6.0 E-1 +/- 3.5 E-1
*306	FE 01.5	1.0 E0 +/- 2.0 E0	5.0 E0 +/- 3.0 E0	
*306	FE 01.4	6.6 E1 +/- 8.0 E0	1.15 E2 +/- 7.0 E0	
*307	FK 06.7	< 3.0	3.57 E1 +/- 4.61 E0	8.3 E-1 +/- 4.1 E-1
*307	FK 06.7	(K-40)1.2 E1 +/- 7.6 E1		
*307	FK 06.7		1.06 E1 +/- 3.37 E0	
310	FG 02.5	< 3.0	1.23 E1 +/- 3.59 E0	1.4 E-1 +/- 2.9 E-1
*311	FK 01.5	< 3.0	3.25 E1 +/- 5.72 E0	3.7 E-1 +/- 1.2 E-1
*311	FK 01.5	(K-40)7.1 E1 +/- 5.9 E1		
312	FC 04.0	< 3.0	< 4.0	4.2 E-1 +/- 3.3 E-1
*313	FA 05.0	4.58 E0 +/- 3.21 E0	< 4.0	2.8 E-1 +/- 2.9 E-1
315	FJ 02.5	< 3.0	4.64 E0 +/- 4.31 E0	2.36 E0 +/- 7.2 E-1

* Log #306 - Two wells existed at separate location. One of the wells was sampled twice. (See p. 28, Results of Investigation).

* Log #307 - This sample was taken from a spring and was sampled three times to determine the source of beta counts. (See p. 26, Results of Investigation).

* Log #311 - One well existed at this location and was sampled twice.

* Log #313 - This sample was not groundwater. It was a sample of a local bottled water which was purchased in Ross, Ohio.

TABLE 1 continued

(pCi/l +/- 2 sigma error)

LOG #	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
316	FJ 02.5	< 3.0	< 4.0	6.5 E-1 +/- 4.5 E-1
*317	FM 02.3	< 3.0	1.81 E1 +/- 5.31 E0	0.0 E0 +/- 2.9 E-1
*317	FM 02.3	(K-40)8.9 E1 +/- 6.2 E1		
318	FM 05.3	< 3.0	< 4.0	0.0 E0 +/- 2.4 E-1
320	FQ 03.0	< 3.0	6.0 E0 +/- 2.5 E0	0.0 E0 +/- 2.0 E-1

* Log #317 - One well existed at this location.

TABLE 2

FMPC/ODH SPLIT SAMPLE RESULTS

LOG #	LOCATION	FMPC RESULTS TOTAL URANIUM (mg/l)	FMPC RESULTS TOTAL URANIUM (pCi/l)*	ODH RESULTS TOTAL URANIUM ALPHA (pCi/l)	RATIO FMPC/ODH
007	FK 01.9	0.0002	0.134	0.0 +/- 0.29	-
013	FQ 01.2	0.0004	0.268	0.1 +/- 0.3	2.7
017	FJ 01.7	0.0013	0.871	no data (1)	
C029	FR 0.9	0.042	28.14	20.3 +/- 2.1	1.4
032	FQ 02.5	0.0008	0.536	0.3 +/- 0.3	1.8
033	FK 01.0	0.0005	0.335	0.9 +/- 0.3	0.4
034	FD 02.2	0.0011	0.737	0.8 +/- 0.5	0.9
053	FK 05.5	0.0005	0.335	0.2 +/- 0.4	1.7
055	FC 01.8	0.0005	0.335	0.4 +/- 0.4	0.8
066	FH 02.5	0.0004	0.268	0.0 +/- 0.3	-
082	FH 02.3	0.0004	0.268	0.3 +/- 0.3	0.9
089	FH 02.5	0.0005	0.335	0.2 +/- 0.3	1.7
096	FL 01.4	0.0005	0.335	0.3 +/- 0.3	1.1
107	FJ 00.9	0.0004	0.268	0.2 +/- 0.3	1.3
114	FH 01.4	0.0008	0.536	0.4 +/- 0.3	1.3
126	FC 02.0	0.0009	0.603	0.6 +/- 0.5	1.0
136	FM 04.0	0.0005	0.335	0.6 +/- 0.4	0.56
142	FA 00.6	0.0015	1.005	1.0 +/- 0.6	1.0
144	FK 02.8	0.0008	0.536	0.5 +/- 0.5	1.1
151	FL 03.4	0.0003	0.201	0.0 +/- 0.3	-
152	FM 03.2	0.0004	0.268	0.0 +/- 0.4	-
155	FQ 02.4	0.0006	0.402	0.4 +/- 0.4	1.0
C160	FR 02.9	0.0003	0.201	0.1 +/- 0.4	2.0
162	FE 01.2	0.0009	0.603	0.4 +/- 0.4	1.5
C163	FK 01.7	0.0004	0.268	0.15 +/- 0.25	1.8
165	FL 01.9	0.0003	0.201	0.3 +/- 0.3	0.7
171	FH 02.4	0.0006	0.402	0.0 +/- 0.3	-
172	FH 02.6	0.0014	0.938	0.5 +/- 0.4	1.9
C176	FJ 02.5	0.0005	0.335	0.1 +/- 0.2	3.4
184	FG 01.8	0.0011	0.737	1.0 +/- 0.6	0.7
187	FC 02.0	0.0002	0.134	0.0 +/- 0.3	-
192	FB 01.0	0.0006	0.402	0.1 +/- 0.3	4.0
193	FM 05.5	0.0002	0.134	0.3 +/- 0.3	0.45
194	FG 01.6	0.0003	0.201	0.4 +/- 0.4	0.5
195	FG 01.3	0.0004	0.268	0.39 +/- 0.33	0.7
203	FC 05.0	0.0013	0.871	0.3 +/- 0.3	2.9
205	FD 02.6	0.0006	0.402	0.4 +/- 0.4	1.0
211	FD 02.1	0.0005	0.335	0.3 +/- 0.4	1.1
218	FD 02.4	0.0003	0.201	0.0 +/- 0.3	-
220	FD 02.4	0.0010	0.670	0.5 +/- 0.4	1.3
224	FD 03.5	0.0005	0.335	0.3 +/- 0.4	1.1
227	FF 04.5	0.0004	0.268	0.2 +/- 0.3	1.3
233	FR 04.0	0.0003	0.201	0.0 +/- 0.2	-

(1) Gross beta analysis only was performed by ODH on this sample. Previous analyses of water from this well yielded uranium results of 0.8 +/- 0.5 pCi/l and 0.65 +/- 0.39 pCi/l.

C - Identifies water source as a cistern

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TABLE 2 continued

LOG #	LOCATION	FMPC RESULTS TOTAL URANIUM (mg/l)	FMPC RESULTS TOTAL URANIUM (pCi/l)*	ODH RESULTS TOTAL URANIUM ALPHA (pCi/l)	RATIO FMPC/ODH
241	FD 02.4	0.0010	0.670	0.5 +/- 0.4	1.3
C243	FA 02.5	0.0010	0.670	0.2 +/- 0.2	3.35
C248	FJ 02.6	0.0006	0.402	0.3 +/- 0.5	1.3
250	FK 02.0	0.0006	0.402	1.2 +/- 0.5	0.3
257	FD 02.1	0.0007	0.469	1.1 +/- 0.6	0.4
269	FE 03.3	0.000075	0.050	0.0 +/- 0.2	-
271	FJ 02.0	0.000093	0.062	0.0 +/- 0.2	-
273	FL 02.0	0.0005	0.335	0.0 +/- 0.25	-
275	FJ 01.5	0.000078	0.052	0.0 +/- 0.2	-
277	FP 00.8	0.0001	0.067	0.0 +/- 0.2	-
C291	FK 01.1	0.0003	0.201	0.31 +/- 0.37	0.65
294	FH 02.5	0.0006	0.402	0.67 +/- 0.4	0.6
310	FG 02.5	< 0.0001	< 0.067	0.14 +/- 0.29	-

* In converting FMPC results from mg/l to pCi/l, the assumption was made that the uranium detected had a specific activity close to that of natural uranium in secular equilibrium. The conversion factor used was 670 pCi/mg (REF. 9).

NOTE: FMPC results were provided to the ODH by the FMPC contractor.

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TABLE 3

CISTERN WATER SAMPLE RESULTS (FMPC)

(pCi/l +/- 2 sigma error)

LOG #	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
025	FH 03.3	< 3.0	4.8 E0 +/- 4.0 E0	1.0 E-1 +/- 3.0 E-1
*029	FR 00.9	1.96 E1 +/- 5.5 E0	6.47 E1 +/- 8.0 E0	2.93 E1 +/- 2.29 E0
*029	FR 00.9	(K-40) 1.97 E2 +/- 6.8 E1		
*029	FB 00.9	2.9 E+1 +/- 4.2 E0	5.8 E1 +/- 5.2 E0	2.03 E1 +/- 2.1 E0
035	FQ 01.3	< 3.0	< 4.0	8.0 E-1 +/- 5.0 E-1
038	FA 02.3	4.0 E0 +/- 2.9 E0	< 4.0	1.1 E0 +/- 5.0 E-1
040	FR 05.0	< 3.0	< 4.0	1.0 E-1 +/- 4.0 E-1
050	FG 03.3	< 3.0	< 4.0	2.0 E-1 +/- 2.0 E-1
*061	FL 01.0	< 3.0	2.74 E1 +/- 4.7 E0	1.0 E0 +/- 5.0 E-1
*061	FL 01.0	< 3.0	< 4.0	Analysis not performed
*061	FL 01.0	(K-40) none detected	5.0 E0 +/- 3.6 E0	0.0 E0 +/- 3.0 E-1
066	FH 02.5	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
071	FH 03.2	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
074	FH 04.3	< 3.0	< 4.0	6.0 E-1 +/- 5.0 E-1
079	FF 08.0	< 3.0	< 4.0	1.0 E-1 +/- 2.0 E-1
086	FL 01.9	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1
088	FB 00.7	< 3.0	< 4.0	4.0 E-1 +/- 4.0 E-1
090	FK 02.8	< 3.0	< 4.0	4.0 E-1 +/- 4.0 E-1
093	FF 02.5	< 3.0	< 4.0	2.0 E-1 +/- 4.0 E-1
108	FA 00.7	< 3.0	< 4.0	7.0 E-1 +/- 5.0 E-1
110	FH 02.6	< 3.0	< 4.0	7.0 E-1 +/- 5.0 E-1
111	FH 02.6	< 3.0	< 4.0	0.0 E0 +/- 4.0 E-1
115	FF 00.7	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
122	FL 01.9	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1
125	FC 04.5	< 3.0	< 4.0	1.2 E0 +/- 4.0 E-1
132	FR 03.4	< 3.0	4.3 E0 +/- 3.1 E0	1.1 E0 +/- 5.0 E-1
133	FH 01.5	< 3.0	< 4.0	8.0 E-1 +/- 4.0 E-1
138	FA 02.4	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
140	FJ 01.7	< 3.0	< 4.0	0.0 E0 +/- 2.9 E-1
141	FK 02.6	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-3
160	FR 02.9	< 3.0	< 4.0	1.0 E-1 +/- 4.0 E-1
163	FK 01.7	< 3.0	< 4.0	1.5 E-1 +/- 2.5 E-1
169	FK 03.8	< 3.0	< 4.0	1.0 E-1 +/- 2.0 E-1
175	FK 02.8	< 3.0	< 4.0	5.0 E-1 +/- 4.0 E-1
*176	FJ 02.5	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
*176	FJ 02.5	< 3.0	< 4.0	1.0 E-1 +/- 2.0 E-1
190	FR 02.9	< 3.0	< 4.0	5.0 E-1 +/- 4.0 E-1
200	FH 04.0	< 3.0	< 4.0	0.0 E0 +/- 4.0 E-1
227	FF 04.5	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1
233	FR 04.0	< 3.0	3.0 E0 +/- 3.0 E0	0.0 E0 +/- 2.0 E-1
236	FH 02.6	< 3.0	< 4.0	5.0 E-2 +/- 2.0 E-1
242	FK 03.1	< 3.0	9.0 E0 +/- 5.0 E0	1.0 E-1 +/- 2.0 E-1

* Log# 029 - One cistern existed at this location and was sampled twice.
Log# 061 - One cistern existed at this location and was sampled three times.
Log# 176 - Two cisterns existed at this location.

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TABLE 3 continued

(pCi (pCi/l +/- 2 sigma error)

LOG#	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
243	FA 02.5	< 3.0	< 4.0	2.0 E-1 +/- 2.0 E-1
248	FJ 02.6	< 3.0	< 4.0	3.0 E-1 +/- 5.0 E-1
*256	FH 01.2	< 3.0	< 4.0	0.0 E0 +/- 4.0 E-1
269	FE 03.3	< 3.0	< 4.0	0.0 E0 +/- 2.0 E-1
270	FG 03.0	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
278	FK 01.8	< 3.0	< 4.0	5.3 E-2 +/- 2.9 E-1
280	FK 01.2	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
281	FK 02.7	< 3.0	< 4.0	0.0 E0 +/- 2.2 E-1
282	FK 02.8	< 3.0	< 4.0	3.0 E-1 +/- 4.0 E-1
283	FJ 02.3	< 3.0	< 4.0	5.0 E-2 +/- 2.0 E-1
291	FK 01.1	< 3.0	< 4.0	3.1 E-1 +/- 3.7 E-1
292	FK 01.0	< 3.0	< 4.0	8.3 E-1 +/- 4.3 E-1
293	FK 02.1	< 3.0	< 4.0	6.2 E-1 +/- 3.9 E-1
294	FH 02.5	< 3.0	< 4.0	6.7 E-1 +/- 4.0 E-1
301	FK 02.0	< 3.0	< 4.0	1.4 E-1 +/- 2.4 E-1
314	FF 04.0	< 3.0	< 4.0	4.6 E-1 +/- 3.4 E-1

* Log# 256 - A spring feeds this cistern.

TABLE 4

SURFACE WATER SAMPLE RESULTS (FMPC)

(pCi/l +/- 2 sigma error)

LOG#	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
*073	FC 01.2	1.3 E1 +/- 4.0 E0	2.4 E1 +/- 8.0 E0	2.5 E0 +/- 7.0 E-1
*073	FC 01.2	6.26 E0 +/- 2.92 E0	< 4.0	2.04 E0 +/- 6.3 E-1
075	FL 01.4	< 3.0	< 4.0	1.0 E-1 +/- 3.0 E-1
081	FR 05.0	< 3.0	4.0 E0 +/- 4.0 E0	3.0 E-1 +/- 4.0 E-1
093	FF 02.5	< 3.0	< 4.0	1.0 E-1 +/- 2.0 E-1
*151	FL 03.4	< 3.0	6.0 E0 +/- 5.0 E-1	6.0 E-1 +/- 4.0 E-1
186	FF 01.0	< 3.0	< 4.0	1.2 E0 +/- 5.0 E-1

* NOTE: All surface water samples were from ponds except at Location #151 which was from a branch of Dry Run Creek.

* Log# 073 - One pond existed at this location and was sampled twice.

TABLE 5

WATER SAMPLE RESULTS (PGDP)

(pCi/l +/- 2 sigma error)

LOG #	LOCATION	GROSS ALPHA	GROSS BETA	URANIUM
* 1	GJ 1.3	< 3.0	< 4.0	1.0 E-1 +/- 2.0 E-1
1	GJ 1.3	< 3.0	4.0 E0 +/- 3.0 E0	0.0 E0 +/- 3.0 E-1
2	GE 1.8	< 3.0	< 40	0.0 E0 +/- 2.0 E-1
3	GE 1.8	< 3.0	< 4.0	1.0 E-1 +/- 2.0 E-1
4	GC 9.0	< 3.0	< 4.0	2.0 E-1 +/- 3.0 E-1
* 5A	-	< 3.0	< 4.0	0.0 E0 +/- 3.0 E-1
* 5B	-	< 3.0	< 4.0	5.0 E-1 +/- 3.0 E-1
* 5C	-	< 3.0	9.0 E0 +/- 4.0 E0	0.0 E0 +/- 3.0 E-1
6	GL 4.5	5.0 E0 +/- 2.5 E0	2.1 E1 +/- 4.0 E0	5.0 E0 +/- 1.0 E0
6	GL 4.5	(K-40) 15.4 mg/l		
7	GE 1.0	< 3.0	< 4.0	0.0 E0 +/- 9.0 E-3

* Log #1 - Two separate wells existed at this location.
Log #5 - Two separate wells and 1 cistern existed at this location. This residence was located in Amesville, Ohio, approximately 60 miles from the PGDP. The cistern is identified as 5C.

SPLIT SAMPLE RESULTS

LOG #	LOCATION	PGDP RESULTS Total Uranium (mg/l)	PGDP RESULTS Total Uranium (pCi/l)*	ODH RESULTS Total Uranium Alpha (pCi/l)
2	GF 2.0	< 0.001	< 0.67	0.0 E0 ± 2.0 E-1

* In the conversion of PGDP results from mg/l to pCi/l, the assumption was made that the uranium detected had a specific activity close to that of natural uranium in secular equilibrium. The conversion factor used was 670 pCi/mg. (REF. 9).

Note: PGDP results were provided to the ODH by the PGDP contractor.

Information Regarding the Use of the Following Maps (Fig. 9-17)

In Figures 9, 10, 11, 15, 16, 17 and 18, the Symbol Color Table is not applicable. These maps indicate locations only and do not contain analytical information.

In a number of the figures, primarily Figures 12, 13 and 14, corrections to the plotted information have been made by hand. These corrections were necessary due to incorrect color coding, illegible log numbers or plotting errors made by the consultant who prepared the maps for the Ohio Department of Health.

In the figures where the Symbol Color Table is applicable, it was intended that a location color coded green was to denote the following:

uranium activity > 3 pCi/l
alpha activity > 3 pCi/l
beta activity > 4 pCi/l

After review by the ODH, it was discovered that the consultant also color coded green the following:

uranium activity = 3 pCi/l
alpha activity = 3 pCi/l
beta activtiy = 4 pCi/l

Consequently a location color coded green denotes the following:

uranium activity $\geq$ and $\leq$ 15
alpha activity $\geq$ and $\leq$ 15
beta activity $\geq$ and $\leq$ 15

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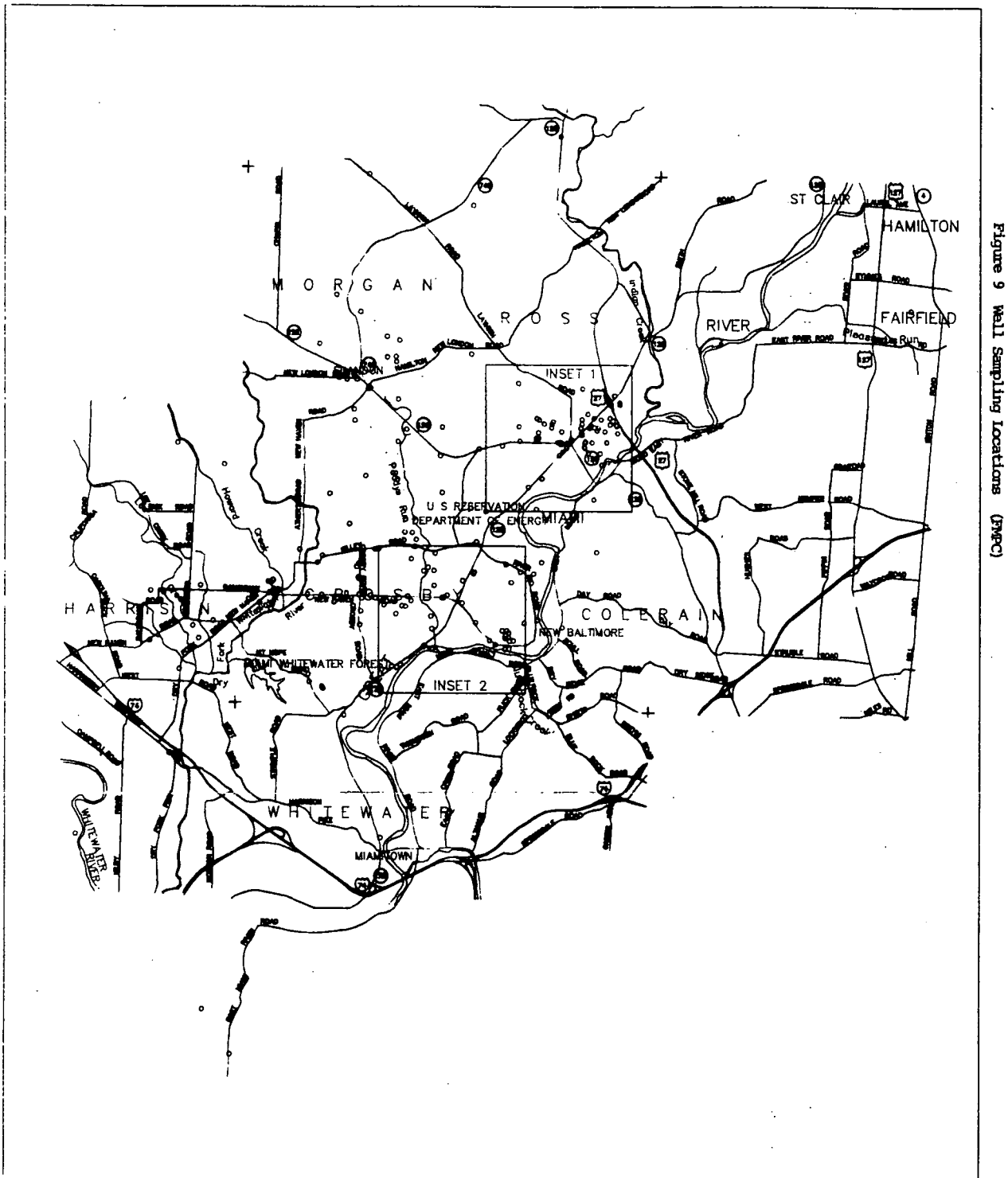
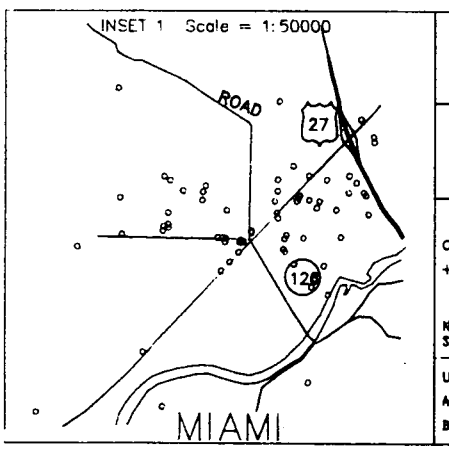




Ohio Department of Health
Water Sampling Project
in the Vicinity of
Feed Materials Production Center

Well Sampling Locations
24 November, 1986
Scale 1:100000
Consultant: WEGA, Inc. Milford, OH

Symbol Key

O - Well □ - Cistern Δ - Surface Water
+ - Split Sample - Log Number of Sample

Symbol Color Table

NUCLIDE SAMPLE	pC/l BLACK	GREEN	RED
Uranium	<= 3	> 3 and <= 15	> 15
Alpha	<= 3	> 3 and <= 15	> 15
Beta	<= 4	> 4 and <= 15	> 15

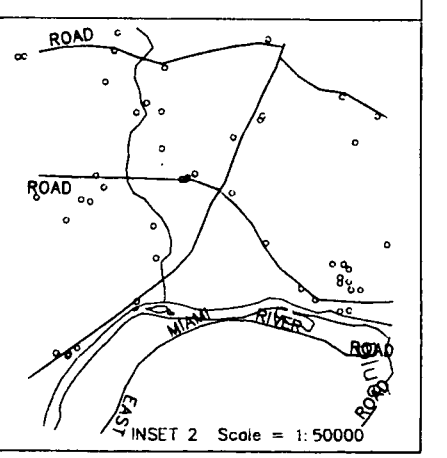


Figure 9 Well Sampling Locations (FMPC)

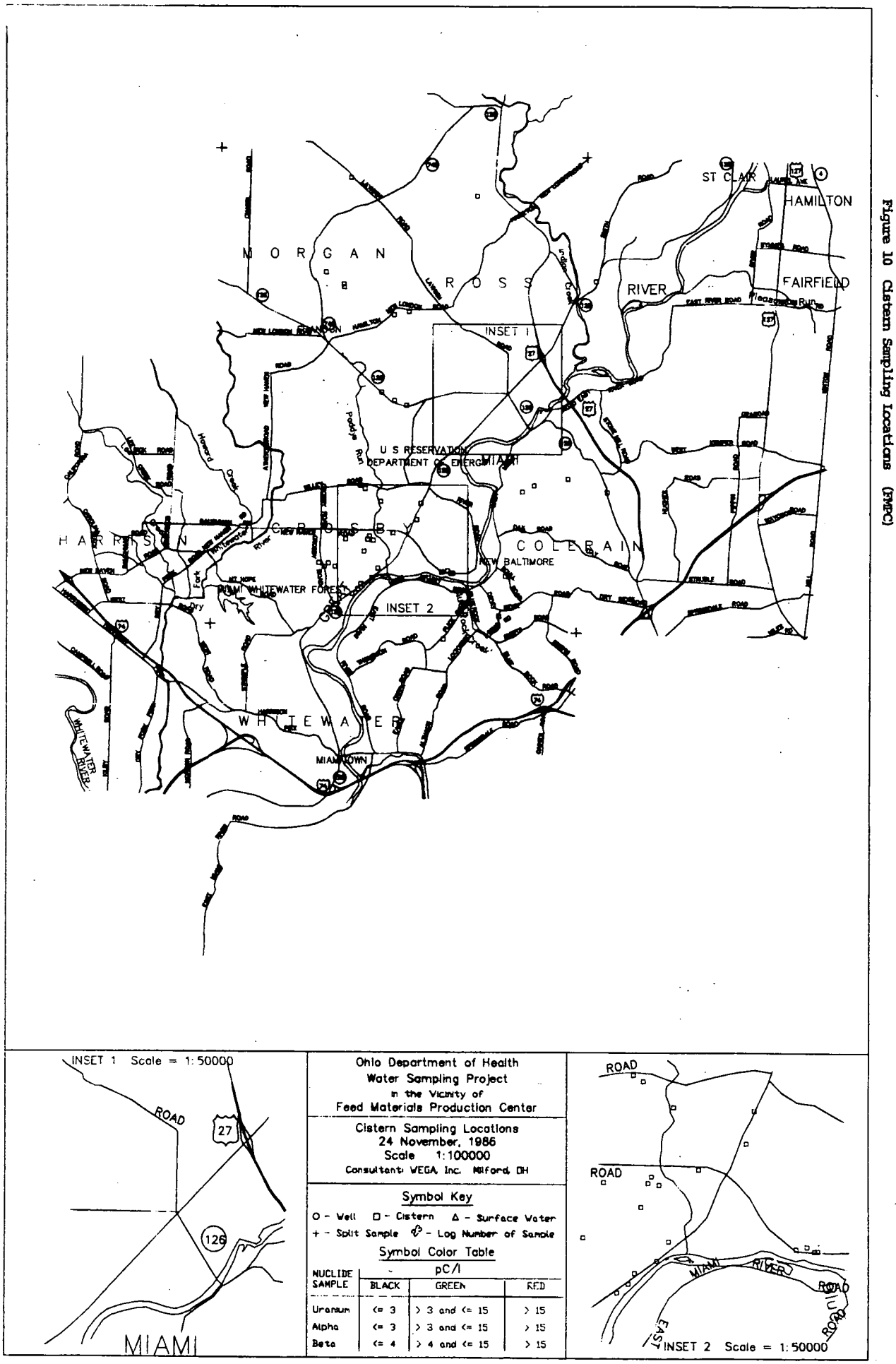
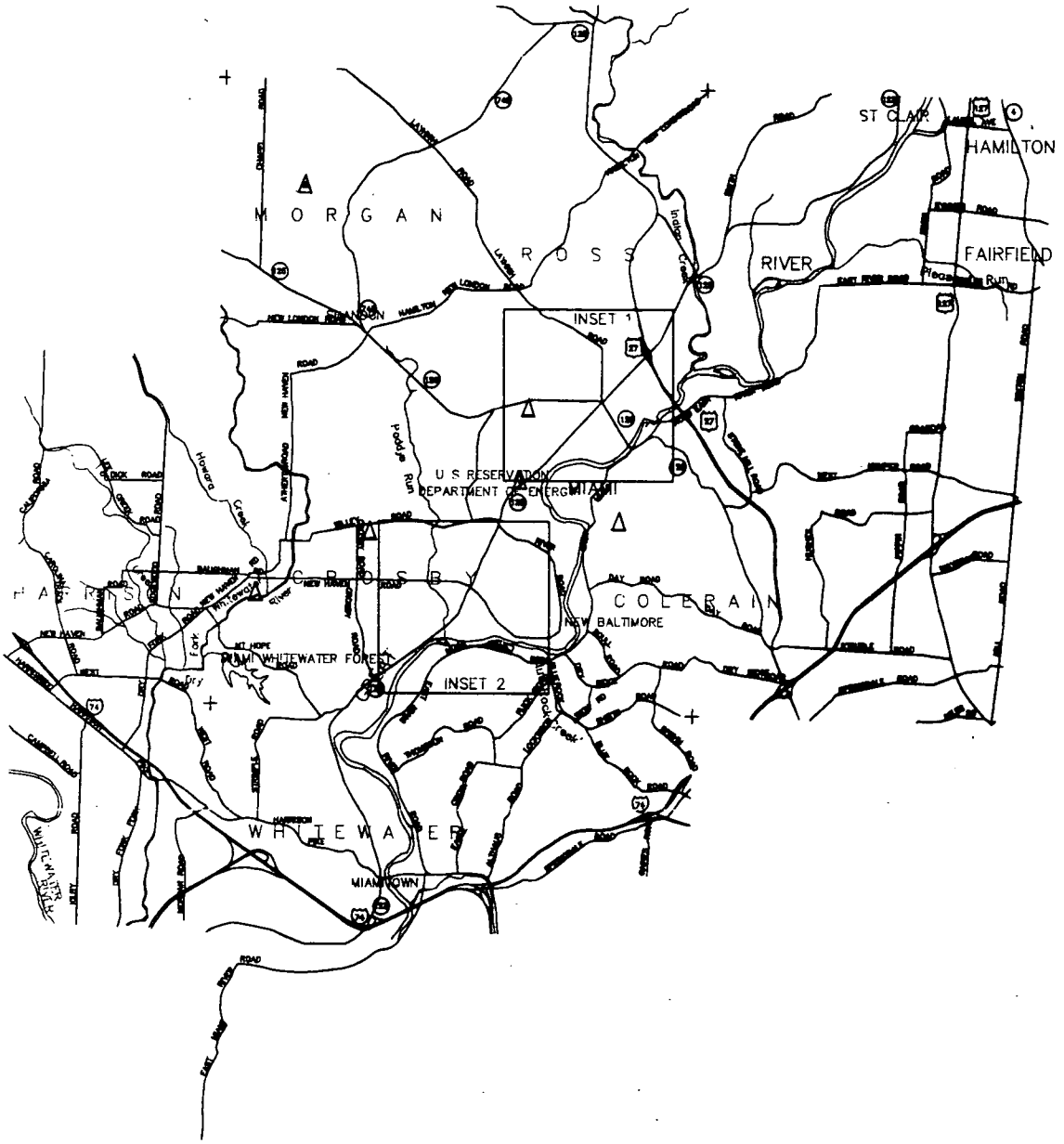
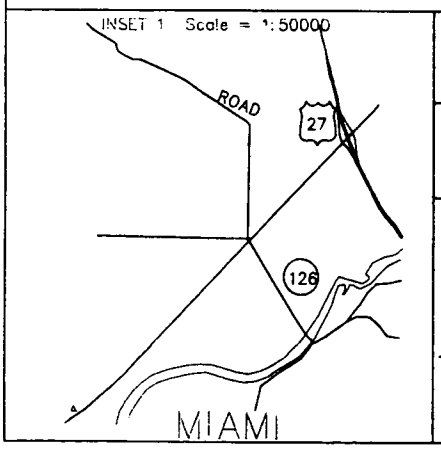


Figure 10 Cistern Sampling Locations (FMPC)





Ohio Department of Health
Water Sampling Project
in the Vicinity of
Feed Materials Production Center

Surface Water Sampling Locations
24 November, 1986
Scale 1:100000
Consultant: WEGA Inc. Milford OH

Symbol Key

O - Well □ - Cistern Δ - Surface Water
+ - Split Sample - Log Number of Sample

Symbol Color Table

NUCLIDE SAMPLE	pC/l BLACK	GREEN	RED
Uranium	<= 3	> 3 and <= 15	> 15
Alpha	<= 3	> 3 and <= 15	> 15
Beta	<= 4	> 4 and <= 15	> 15

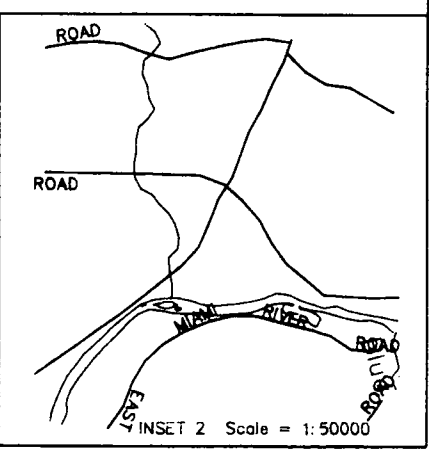


Figure 11 Surface Water Sampling Locations (FMPC)

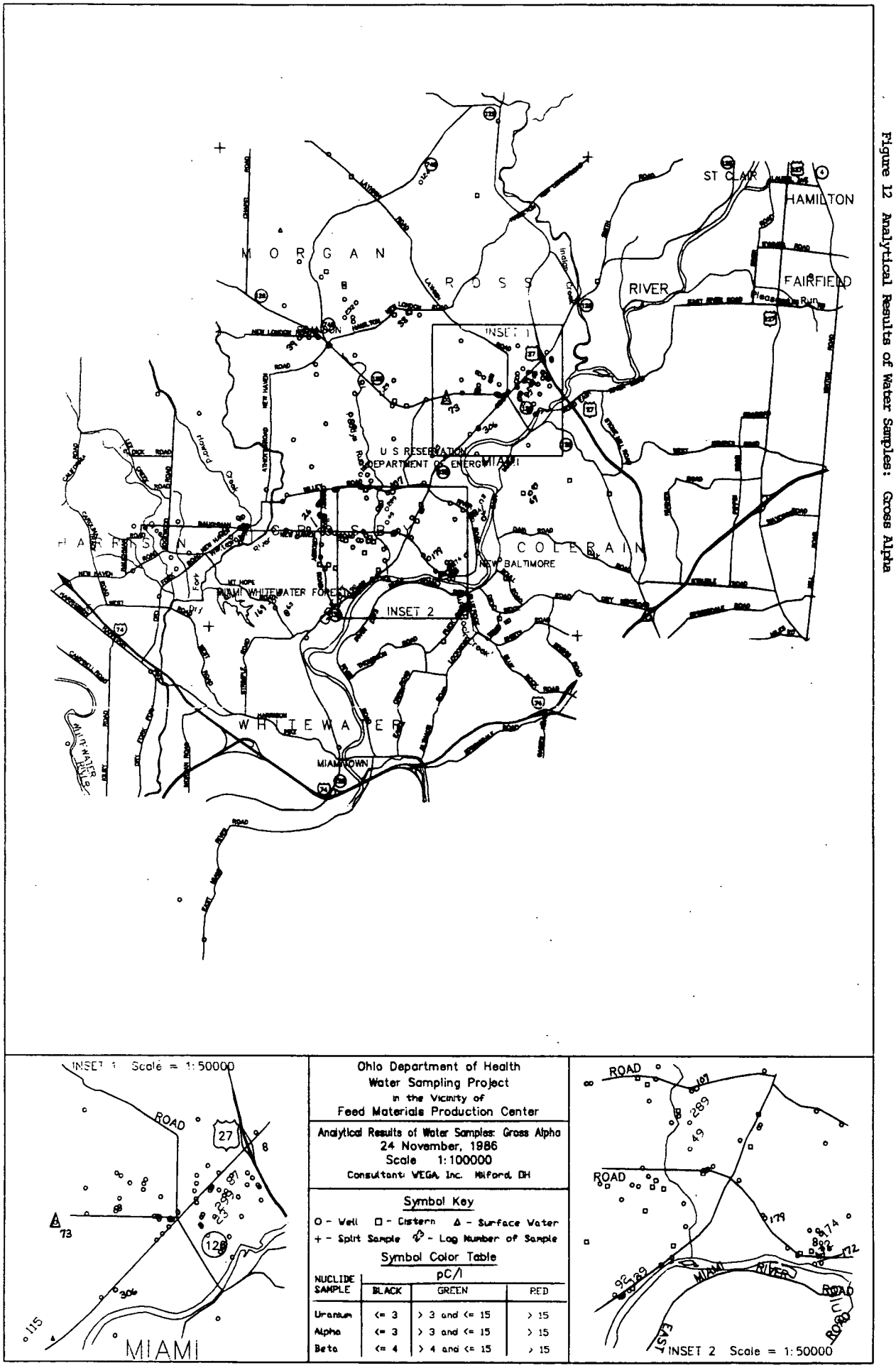
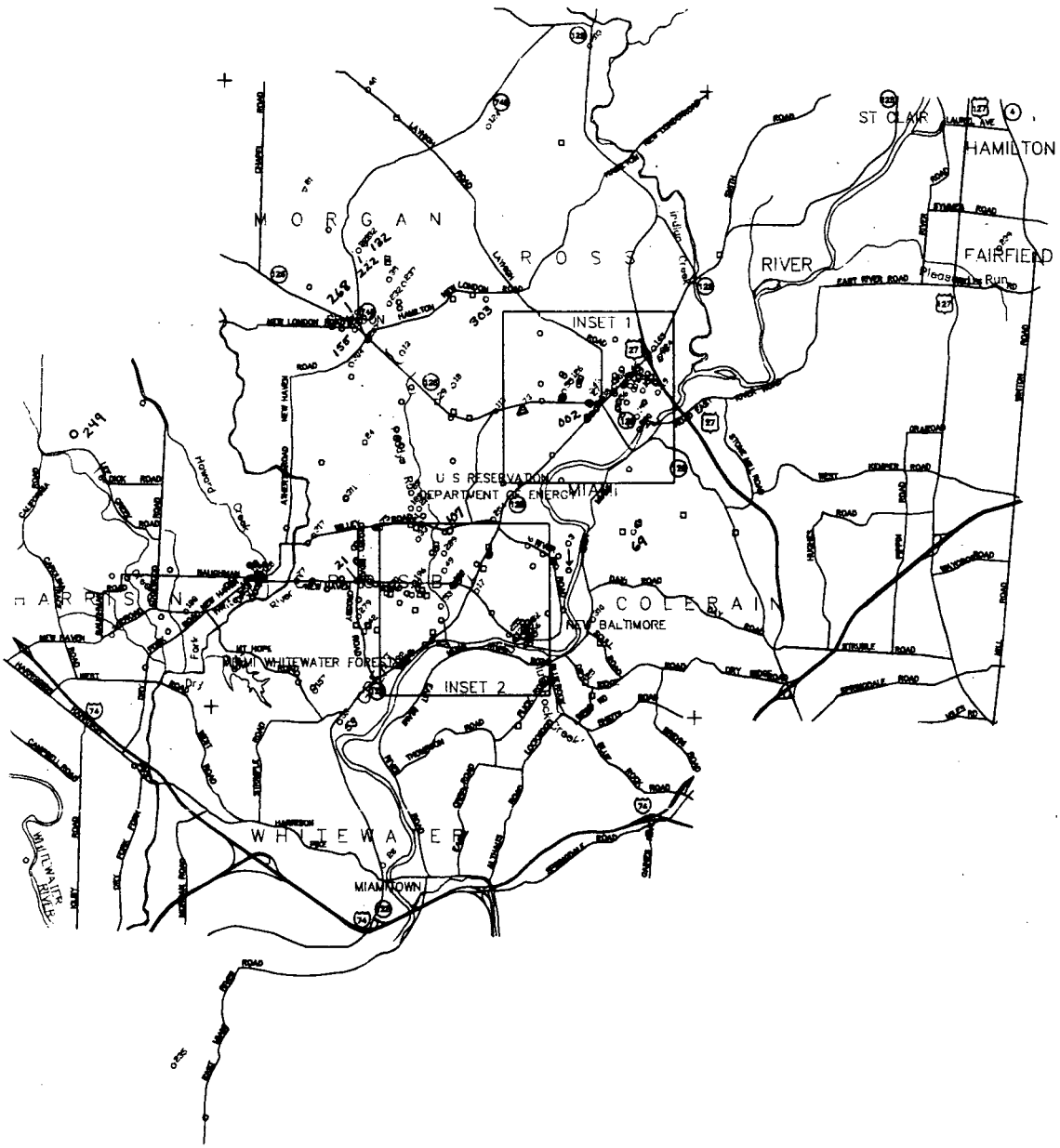
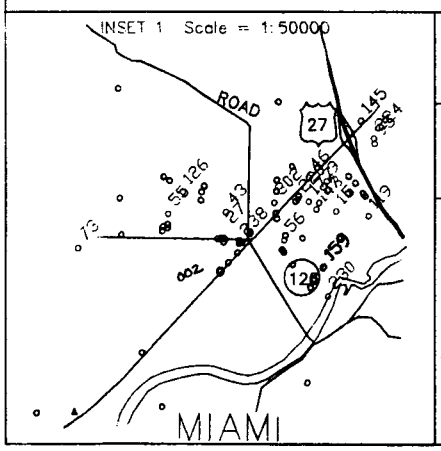


Figure 12 Analytical Results of Water Samples: Gross Alpha

Figure 13 Analytical Results of Water Samples: Gross Beta





Ohio Department of Health
Water Sampling Project
in the Vicinity of
Feed Materials Production Center

Analytical Results of Water Samples: Gross Beta
24 November, 1986
Scale 1:100000
Consultant: WEGA, Inc. Milford, OH

Symbol Key

O - Well □ - Cistern Δ - Surface Water
+ - Split Sample 23 - Log Number of Sample

Symbol Color Table

NUCLIDE SAMPLE	pC/l BLACK	GREEN	RED
Uranium	<= 3	> 3 and <= 15	> 15
Alpha	<= 3	> 3 and <= 15	> 15
Beta	<= 4	> 4 and <= 15	> 15

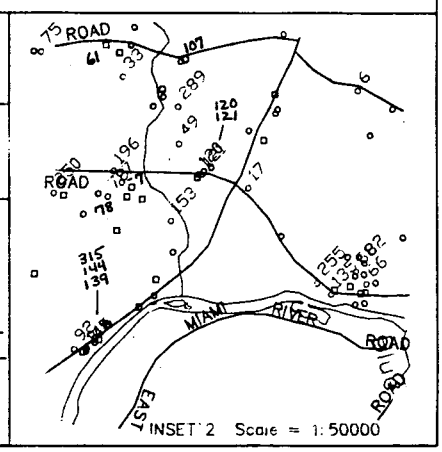
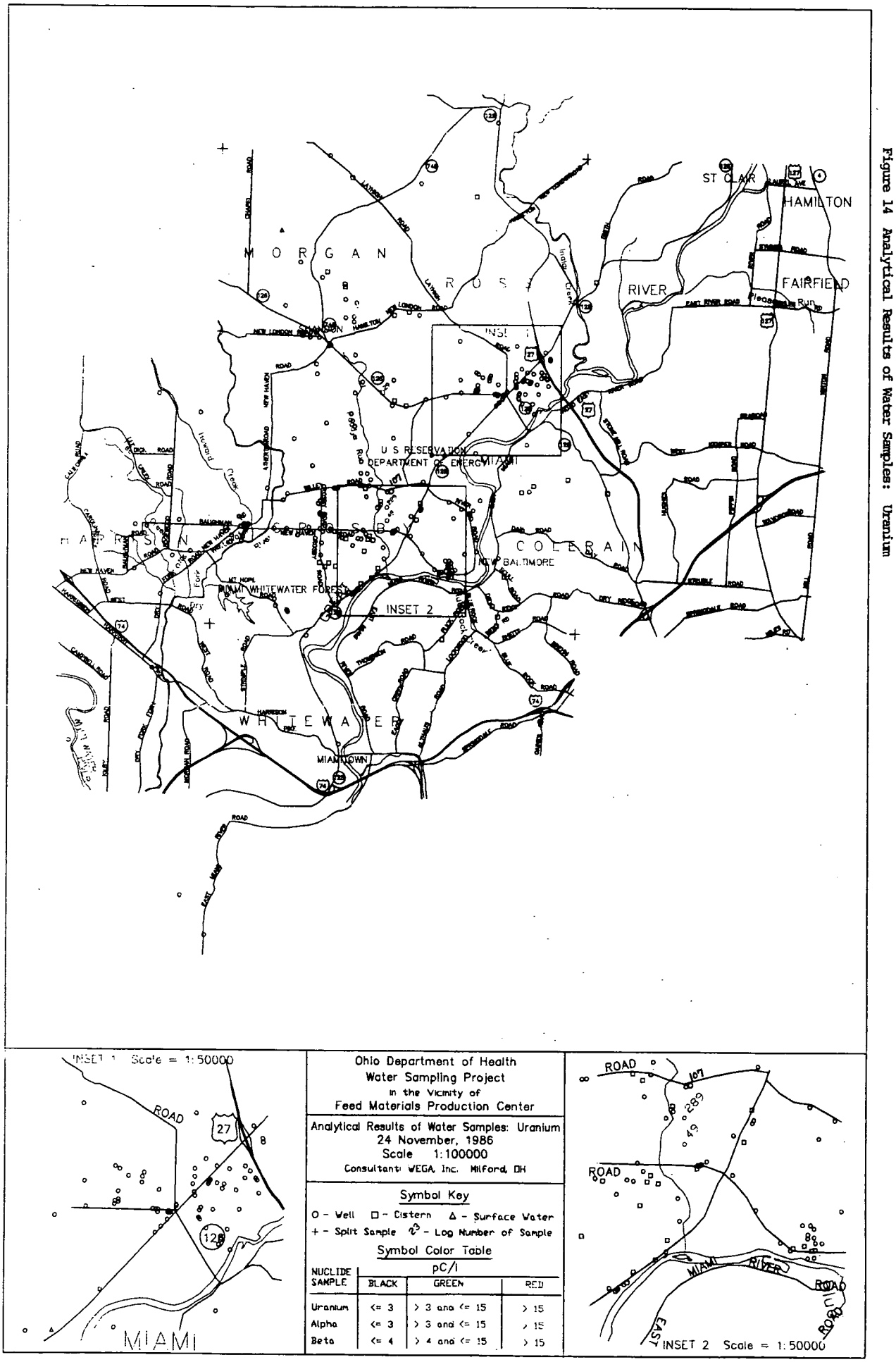


Figure 14 Analytical Results of Water Samples: Uranium



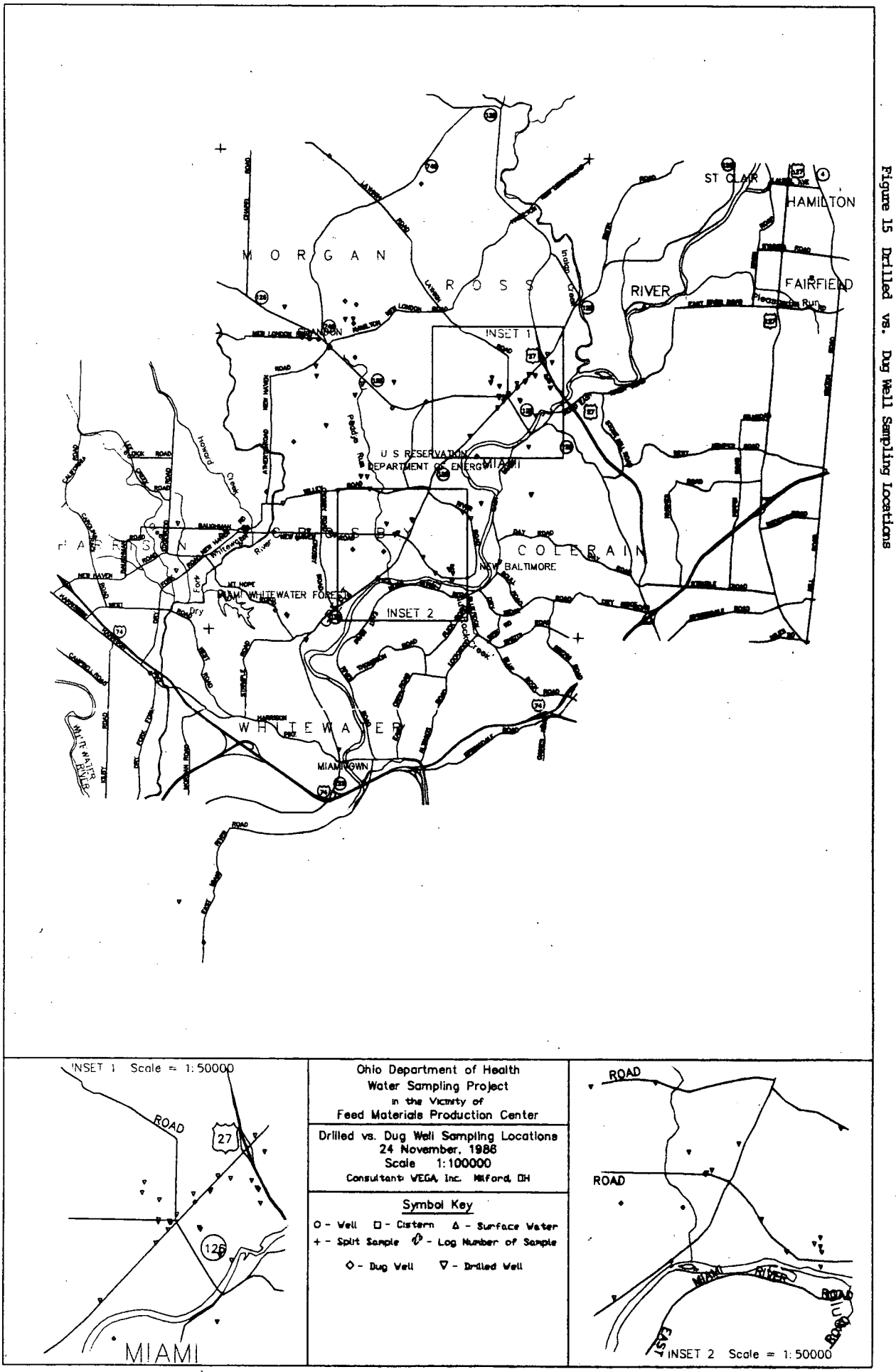
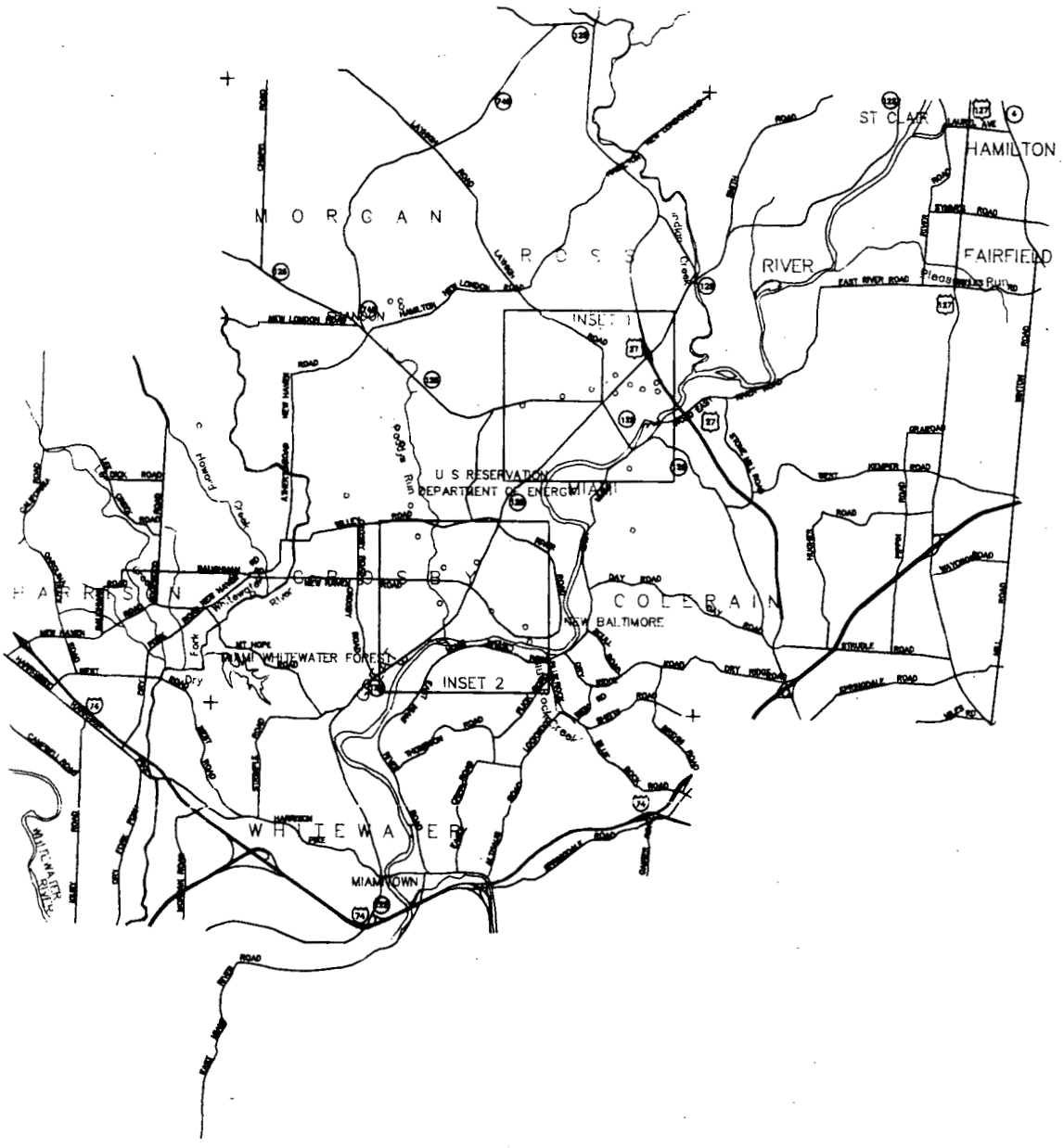
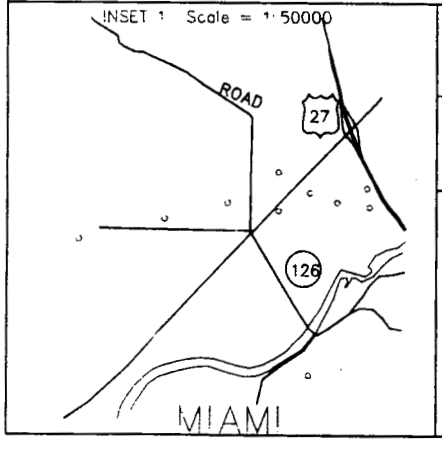


Figure 15 Drilled vs. Dug Well Sampling Locations





Ohio Department of Health
Water Sampling Project
in the Vicinity of
Feed Materials Production Center

Treated Ground Water Sampling Locations
24 November, 1986
Scale 1:100000
Consultant: WEGA, Inc. Milford, OH

Symbol Key

O - Well □ - Cistern Δ - Surface Water
+ - Split Sample - Log Number of Sample

Symbol Color Table

NUCLIDE SAMPLE	pC/l BLACK	GREEN	RED
Uranium	<= 3	> 3 and <= 15	> 15
Alpha	<= 3	> 3 and <= 15	> 15
Beta	<= 4	> 4 and <= 15	> 15

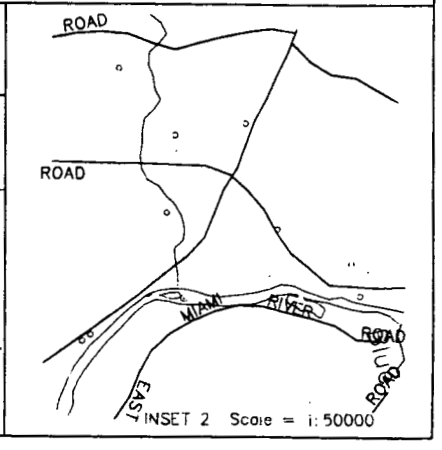
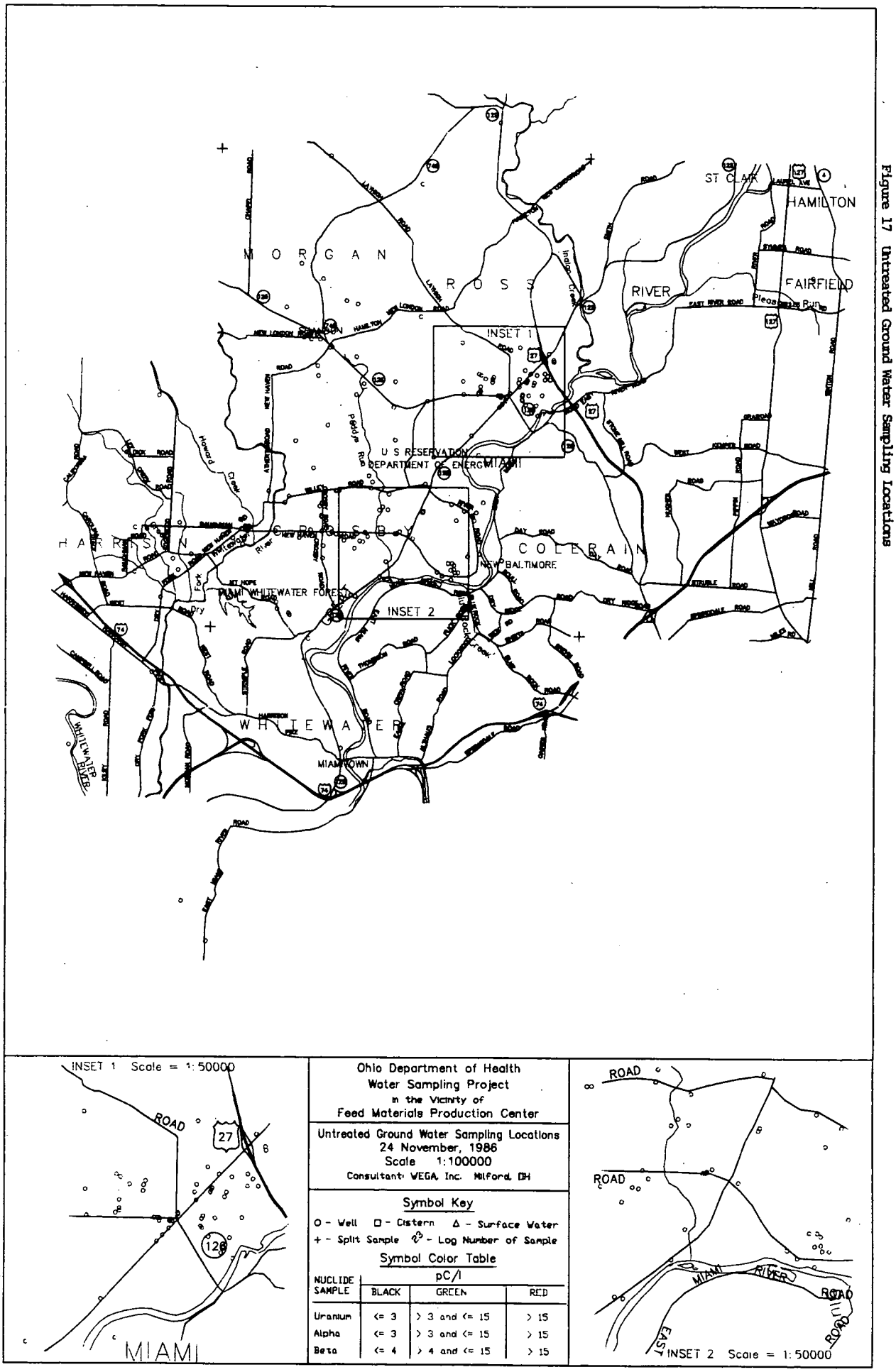


Figure 16 Treated Ground Water Sampling Locations

Figure 17 Untreated Ground Water Sampling Locations



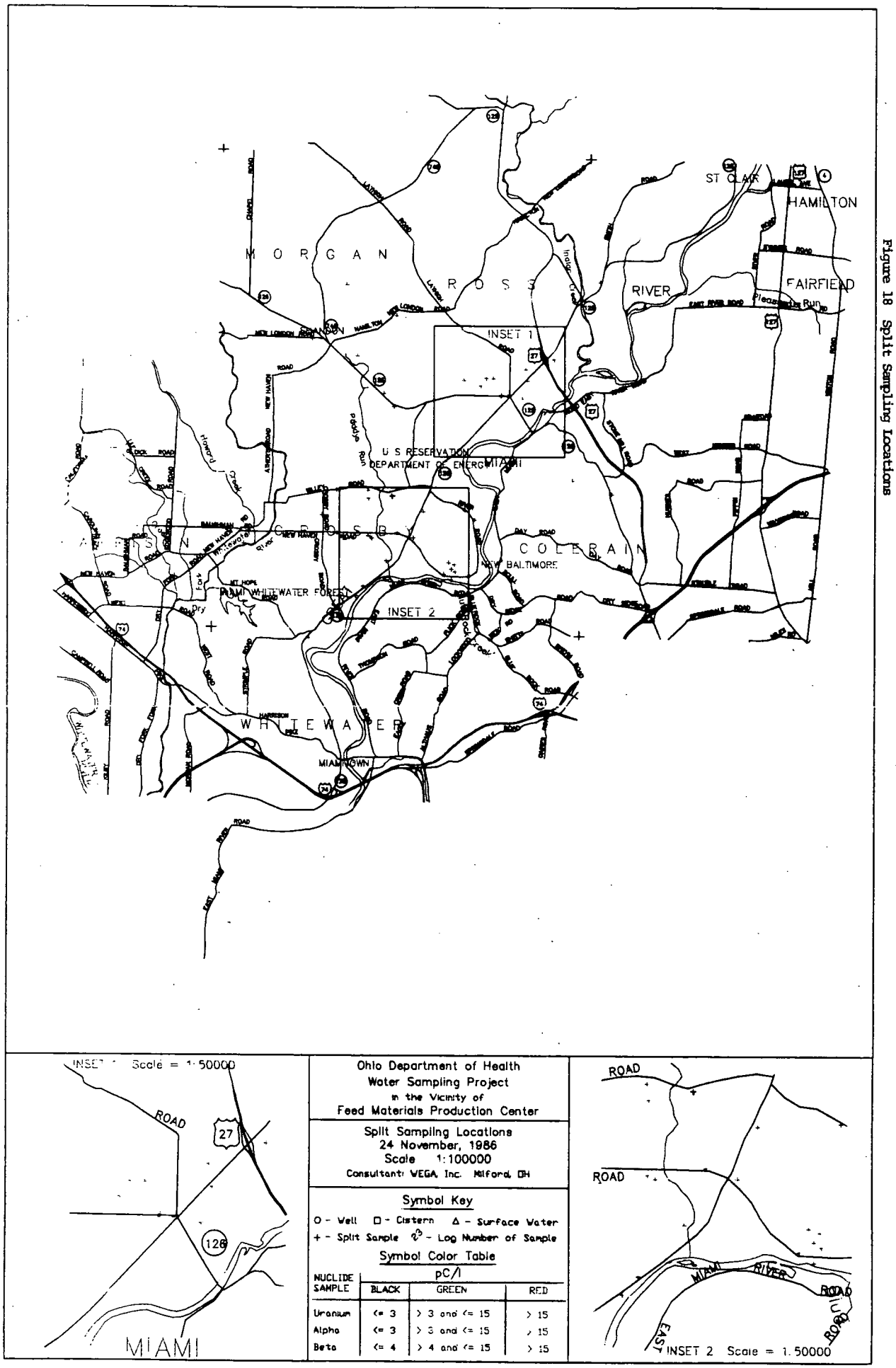


Figure 18 Split Sampling Locations

FIGURE 19

WELL SAMPLING LOCATIONS IN THE VICINITY OF THE PGDP

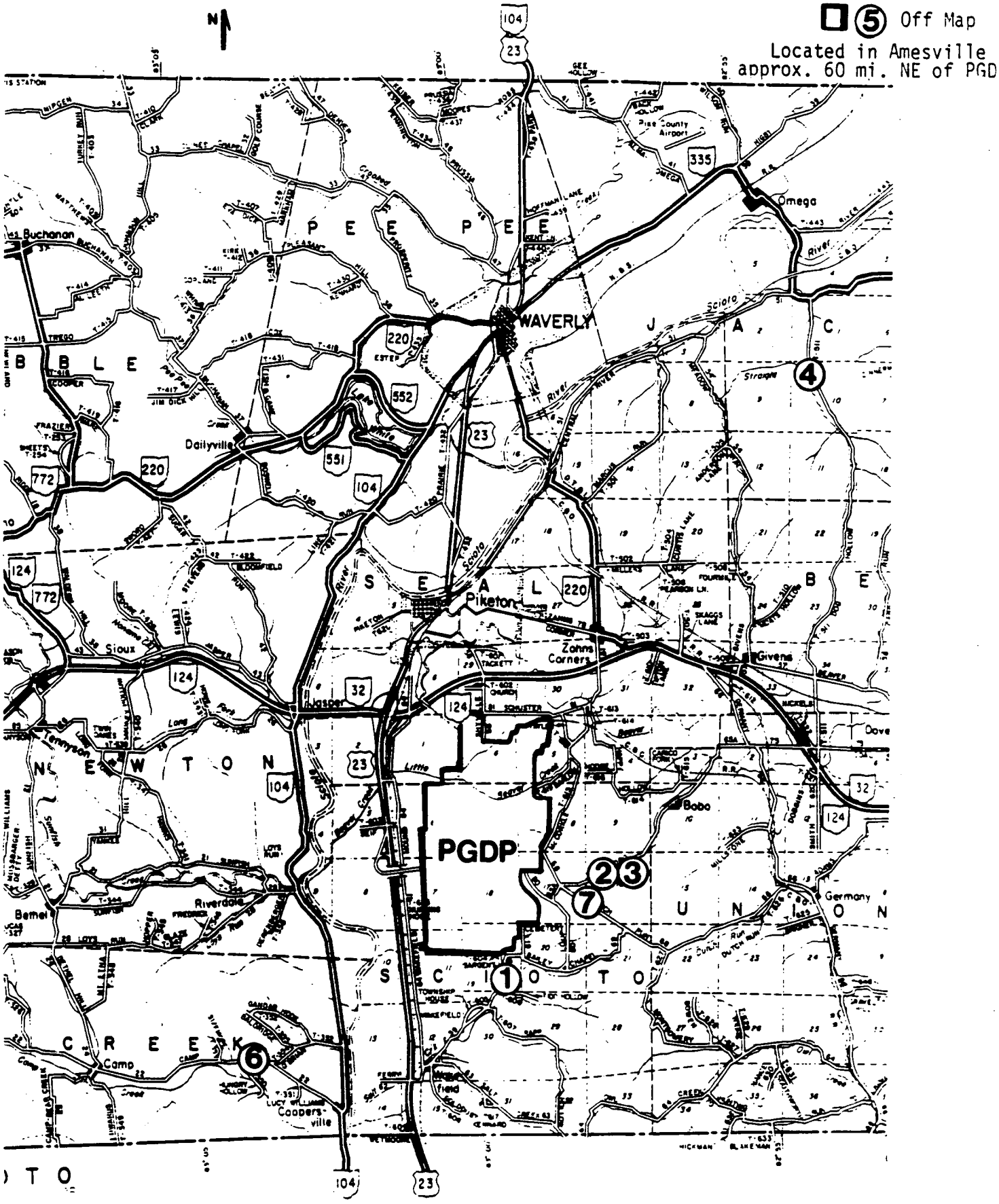


FIGURE 20

University of Cincinnati
Medical Center

University of Cincinnati Hospital
University Hospital

234 Goodman Street
Cincinnati, Ohio 45267-0577

Eugene L. Saenger Radioisotope Laboratory
Mail Location #577
TELEPHONE (513) 872-4282

February 18, 1987

Ms. Deborah Steva
Health Physicist
Ohio Department of Health
246 N. High Street
P.O. Box 118
Columbus, Ohio 43266-0118

Dear Debbie:

Thanks so much for the data which you have sent me. The correlation coefficient between your data and those of WMCO is 0.996. Employing a paired t-test there is no significant difference between your data and that of WMCO of $p > 0.1$.

Sincerely,

Ted

Edward B. Silberstein, M.D.
Professor of Radiology and Medicine

EBS:smm
#11

4.0 INTERPRETATION OF DATA AND RECOMMENDATIONS

4.1 BACKGROUND

Uranium is a heavy, silvery-white metal which has fourteen isotopes, all of which are radioactive. Since uranium is a naturally occurring radionuclide found in varying concentrations in various rock types, it consequently is found in varying concentrations in the various environmental media. Cothern and Lappenbusch estimate that the average uranium concentration in ground water supplies in the U.S. is 3.0 pCi/l. The average concentration of uranium in surface water is estimated to be 1.0 pCi/l (REF. 9).

Naturally occurring uranium is composed of three isotopes with the following abundances by weight: 99.27% U-238, 0.72% U-235, and 0.006% U-234. Although U-234 makes up a small percentage of natural uranium by weight it contributes approximately 50% of the radioactivity present in 1 gram of natural uranium. One gram of natural uranium in equilibrium contains 0.33 uCi of U-238, 0.15 uCi of U-235 and 0.3 uCi of U-234, thus 1 gram of natural uranium has an activity of 0.67 uCi.

Under equilibrium conditions, the U-238 and U-234 activity exists in a 1:1 ratio. This ratio can vary under certain environmental conditions however. In the environment U-234 can become separated from the U-238 by chemical processes involving the intermediate members of the decay chain or by a change in water solubility for the daughter radionuclides following decay of the parent. U-234/U-238 ratios have been found to range from 0.5 - 12.25. Extremes, however, are believed to be rare cases. The ratio seems rarely to exceed 2. It should be noted that because of the uncertainty of this ratio, chemical (e.g. fluorimetric) measurements may be misleading as to the actual radioactivity present. A study done by the USEPA found U-234/U-238 activity ratios of 1.8 $\pm$ 1.6 and 1.7 $\pm$ 1.2 in the Cincinnati area (REF. 9).

When put into solution, uranium forms the uranyl ion and this ion forms soluble salts with all common anions except phosphate. When ingested, the uranyl ion is rapidly absorbed from the gastrointestinal (GI) tract. A review and analysis of the world literature by Wrenn, et al., 1985, indicates that between 1% and 2% of ingested uranium is absorbed from the GI tract (REF. 10). The uranium is carried as a soluble bicarbonate complex and is also bound to plasma protein (REF. 11). The soluble uranium compound (uranyl ion) and those that solubilize in the body by the formation of a bicarbonate complex can produce acute renal damage. This is a chemical toxicity and is independent of the amount of radioactivity. In the body uranium accumulates in the bone and other soft tissues (e.g. kidney, fat, lung).

4.2 WATER

At the National Workshop for Radioactivity in Drinkinng Water held in Easton, Maryland in May 1983, a committee presented a paper entitled "Metabolism of Ingested U and Ra." The committee concluded "that limits for natural uranium in drinking water should be based on chemical toxicity (which has been observed in man and quantified in animal), rather than on a hypothetical radiological toxicity in skeletal tissue (which has not been observed in either man or animals)." The committee recommended a limit of 100 ug/l (67 pCi/l) for natural uranium in drinking water based on chemical toxicity to the kidney. This limit is more conservative than a limit (174 pCi/l) based on a radiation-induced risk (hypothetical risk of bone sarcomas). A safety factor of at least 50 has also been built into this recommendation (REF. 10). A more conservative guidance of 10 pCi/l has been suggested by R. Cothern et al. (REF. 12).

No USEPA standard for natural uranium in drinking water exists as yet although development of a standard is proceeding. At Location 049, a concentration of 30.0 pCi/l of uranium was detected in the well water sample collected by the ODH. At Location 107, a uranium concentration of 107 pCi/l was detected and at Location 289 a uranium concentration of 250 pCi/l was detected. Two and possibly three of these wells contain uranium concentrations which would exceed the above-mentioned suggested limits for public drinking water supplies. Although the concentration of uranium in these wells might exceed the suggested limits, at an ingestion rate of 2 liters per day, chemical toxicity to the kidney of persons who have ingested this water would not be expected due to the conservatism built into the calculations. According to risk estimates of Wrenn et al., these uranium concentrations would represent a lifetime risk of bone sarcoma in the range of 10E-4 to 10E-5. (REF. 10)

Consumption of uranium in the concentrations found in the above mentioned wells results in unnecessary chemical and radiation exposure. In the analysis reports sent to the owners of these wells, it was recommended that such water supplies be treated to reduce the uranium concentration or an alternative drinking water supply be used.

The USEPA (in an advance notice of proposed rulemaking) published a table which contains estimates of the number of public drinking water supplies in the U.S. that exceed various levels of natural uranium. From this table it is estimated that 100 - 2000 public drinking water supplies contain uranium concentrations that exceed 7 pCi/l. It is estimated that 20 - 500 public drinking water supplies have uranium concentrations that exceed 70 pCi/l and 1 - 10 have concentrations that exceed 700 pCi/l (REF. 3). Methods being investigated by the USEPA for uranium removal include anion exchange, lime softening and reverse osmosis (REF. 13).

With regard to the elevated concentration of uranium found in a cistern in the vicinity of the FMPC, it appears that a cistern using rainwater collection may represent a potential collection system for airborne uranium which travels off the FMPC site and is deposited on rooftops. The sample collected from the cistern in question was taken after the water in the cistern had been agitated and was drawn from the cistern via a dipper lowered into the cistern. Under normal circumstances, uranium would tend to settle to the bottom of the cistern and water drawn via a floating intake in a cistern should contain a smaller percentage of this uranium. This may explain why above background concentrations of uranium were not detected in water samples collected from other cisterns in the vicinity of the FMPC. However, any agitation e.g. delivery of water by a water hauler could similarly cause uranium to become suspended in the cistern water and be consumed by the homeowner. A more detailed study of this theory and the possible impact to cistern owners in the vicinity of the FMPC using rainwater collection systems should be investigated.

4.3 SOIL

In addition to the NCRP guidance for uranium in soil used for agricultural purposes, the ODH consulted several other sources of information regarding uranium concentrations in soils. Uranium is known to be found in phosphate deposits and can consequently be found in phosphate fertilizers. Phosphate fertilizer uranium concentrations may range from 25 - 67 pCi/g (2.5 E4 - 6.7 E4 pCi/kg) assuming it is naturally occurring uranium at equilibrium (REF 9).

In 1981, a Branch Technical Position was adopted by the U.S. Nuclear Regulatory Commission (USNRC) regarding disposal or onsite storage of residual thorium or uranium. The position adopted in this document (based upon USEPA cleanup standards) was that a concentration of 35 pCi/g (3.5 E4 pCi/kg) of depleted uranium, 30 pCi/g (3.0 E4 pCi/kg) of enriched uranium or 10 pCi/g natural uranium buried in the soil, would not present a danger to health and safety (REF. 14).

All soil samples collected and analyzed by the ODH contained uranium concentrations which were below the above-mentioned reference concentrations. The ODH did not find any uranium in soil in concentrations which would presently constitute a danger to any offsite resident's health and safety.

4.4 ENVIRONMENTAL RADIATION AND RADON

Through measurement of radiation exposure levels at the site boundary, the ODH has determined that current operations at the facility do not create a direct radiation exposure hazard to offsite residents. Similarly, environmental radon measurements performed at the site boundary did not detect concentrations of radon which would result in any additional radiation dose being received by residents if the K-65 silos remain in their present condition. Radon levels should continue to be monitored to assure that levels do not change as a result of the aging condition of the silos.

4.5 RADON IN HOMES

Radon levels exceeding the current USEPA guideline were found in 40% of the homes monitored by the ODH in the vicinity of the FMPC. Based on information and data collected by the ODH, it was concluded that the source of radon is uranium contained in the geology beneath the home. Radon concentrations found in the vicinity of the FMPC are not considered unusual when compared with the ODH findings in other areas of Ohio. ODH is currently recommending that all Ohio residents monitor their homes for radon. Based on data presented in this report, this recommendation is particularly applicable for Butler and Hamilton County residents.

Based on the limited data obtained from measurement of radon in ground water, the ODH concluded that ground water is not a significant source of radon in homes utilizing this water. In addition, the concentrations of radon in water detected do not represent an ingestion hazard. Since little data regarding radon levels in private water supplies throughout the state exists, it is suggested that, if possible, future water sampling programs in the vicinity include analysis for radon to broaden the data base.

In summary, all of the monitoring performed by the ODH in the vicinity of the FMPC measured radiation and radioactivty at a specific point in time. The data gained as a result of these measurements is useful for determining any present risk to residents residing in the vicinity of the FMPC. It can not be used to determine, to any great extent, past exposures via water, air, etc. With the exception of the 3 wells and one cistern found to contain uranium concentrations elevated above background, the ODH could find no evidence of the existence of radiation sources or radioactivity in soil or water which would currently represent a threat to the health and safety of residents living in the vicinity of the FMPC.

Historically it has been observed that changes in types and quantities of radioactive materials utilized at the FMPC have occurred. As with any facility utilizing radioactive material that can potentially be released to the environment, a comprehensive routine environmental monitoring program is necessary. A monitoring program is necessary not only to detect any changes in radiation levels or concentrations of radioactivity in the environment, but also to alert the facility that containment systems such as air filters, wastewater containment, etc. are not working properly.

The ODH recognizes that WMCO has expanded and upgraded the FMPC environmental monitoring program since taking over operation of the facility in 1985. The maintenance and continuation of a quality environmental monitoring program should continue to be a priority at the FMPC.

In addition, a good forum for communication between the FMPC operator and the surrounding community should be maintained. As a result of conversation and interviews with area residents, the ODH feels that it is beneficial for both parties when information regarding environmental monitoring results and other activities of interest to residents is made available to residents in a simple and timely fashion.

APPENDIX A

SOIL SAMPLES

The Ohio Department of Health collected a total of 34 soil samples in the vicinty of the FMPC. All soil samples collected by the ODH were submitted to the Ohio Department of Health Laboratory to be analyzed for total uranium content. Concentrations of uranium were reported in picocuries of uranium per kilogram of soil (pCi/kg). The concentration of uranium detected in the samples collected by the ODH ranged from 0.469 E3 pCi/kg to 6.859 E3 pCi/kg. Analytical results of all soil samples are presented in Table 6. The locations where soil samples were collected by ODH have been plotted in Figure 21.

In addition to the soil samples collected for the ODH/DOE sampling project, the ODH collected 2 split samples with EG&G, a consultant hired by National Lead of Ohio to perform radiation measurements and collect soil samples at various locations in the vicinity of the FMPC. These samples were collected in April 1985 and are identified as 2A and 6A in Table 6.

From Table 6 and Figure 21, it appears that relatively higher soil uranium concentrations exist in an area northeast of the FMPC. The presence of elevated uranium concentrations in soil in areas northeast of the plant was also detected and documented in an evironmental study performed by IT Corporation (REF. 15).

Currently there are no standards which limit the concentration of uranium in soil. The concentration of natural uranium in rocks varies considerably. Reported concentrations range from 0.45 ug/g (0.30 pCi/g) in sandstones, to 80 ug/g (53.6pCi/g) in bituminous shale and 120 ug/g (80.4 pCi/g) in Florida phosphate rock (REF. 16 & 17).

Soil uranium concentrations may vary due to the following factors: soil type and rock type from which the soil was derived, weathering patterns at the site, introduction of topsoil from an alternate site and application of phosphate fertilizers.

The National Council on Radiation Protection and Measurements Report No.77 (NCRP #77) gives a value of 1.8 ug/g (1.2 E3 pCi/kg) as an average background uranium soil concentration. The NCRP has also published a guide which can be used for agricultural purposes. If uranium concentrations of 3000 ug/g (2.0 E6 pCi/kg) or more exist in the rooting zones of crops to be grown, the NCRP recommends that the land be used for crops that have minimal uptake of radionuclides of the uranium series or for crops that are not directly consumed by humans (REF. 18).

In addition to NCRP Report No. 77, a 1981 USNRC Branch Technical Position regarding disposal or onsite storage of residual thorium or uranium was used as a reference to determine the significance of uranium activity detected in a number of soil samples collected by the ODH. This document adopted the position that a concentration of 35 pCi/g (3.5 E4 pCi/kg) of depleted uranium or 30 pCi/g (3.0 E4 pCi/kg) of enriched uranium buried in the soil, would not present a danger to health and safety (REF. 14).

All soil samples collected and analyzed by the ODH contained uranium concentrations which were below these reference concentrations.

FIGURE 21
SOIL SAMPLING LOCATIONS IN THE VICINITY OF THE FMPC

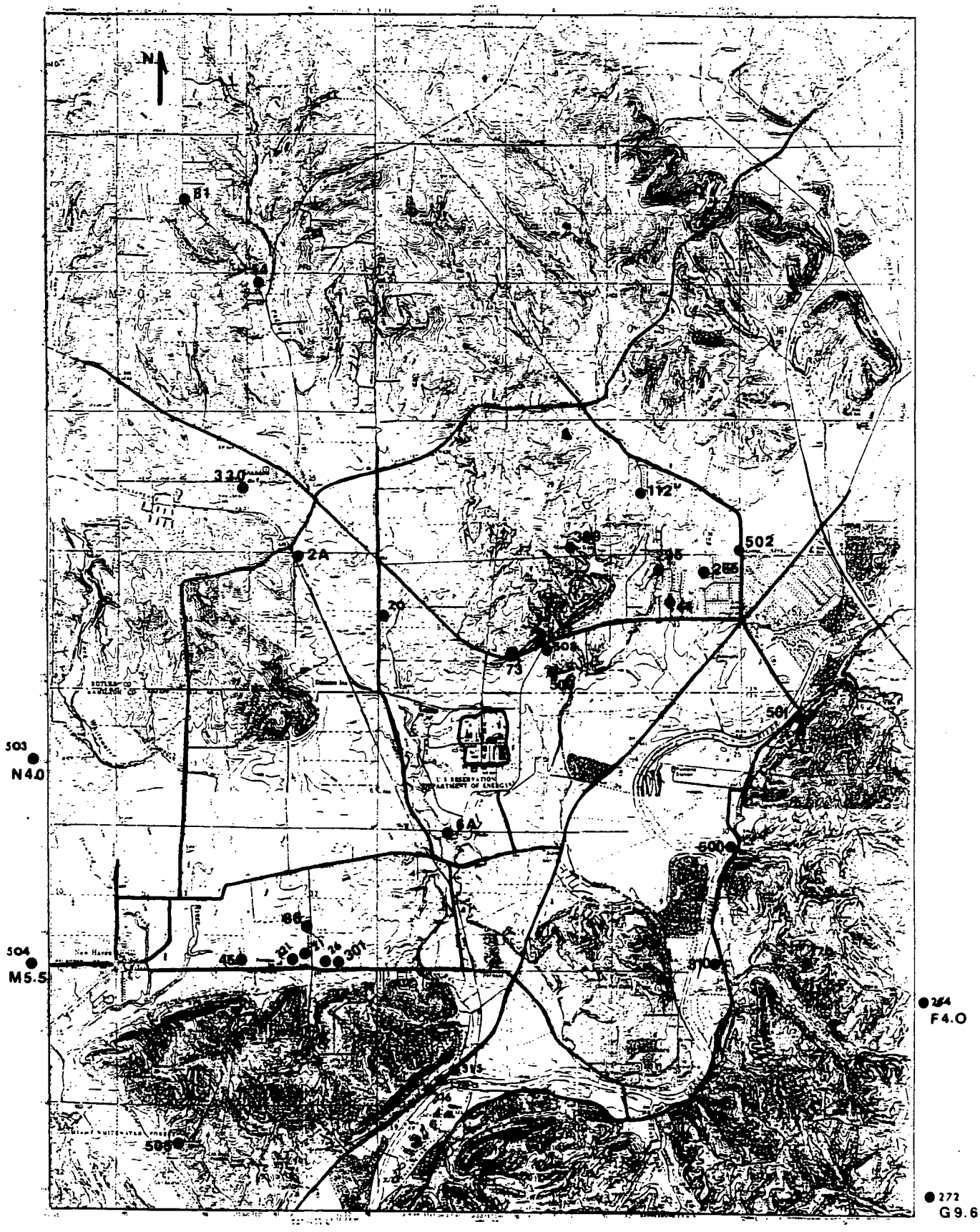


TABLE 6

SOIL SAMPLE RESULTS

(pCi/kg +/- 2 sigma error)

LOG#	LOCATION	URANIUM	NOTES
2A	FQ 02.0	1.6 E3 +/- 6.0 E2	CF, EG&G Split
6A	FK 0.75	2.1 E3 +/- 6.0 E2	Sediment, EG&G Split
020	FQ 01.2	2.253 E3 +/- 7.18 E2	G
021	FL 02.1	3.412 E3 +/- 8.00 E2	Y
026	FL 02.1	1.46 E3 +/- 5.84 E2	Y
044	FC 01.8	2.926 E3 +/- 8.06 E2	Y
045	FL 02.4	2.916 E3 +/- 8.04 E2	G
054	FR 03.8	2.650 E3 +/- 7.50 E2	G
073	FB 01.1	4.987 E3 +/- 9.00 E2	G
081	FR 05.0	1.365 E3 +/- 5.0 E2	G
086	FL 01.9	2.143 E3 +/- 4.84 E2	Y
112	FB 02.2	3.937 E3 +/- 9.20 E2	F
176	FJ 02.5	2.645 E3 +/- 7.60 E2	Y
264	FF 04.0	2.520 E3 +/- 7.4 E2	G
265	FC 02.1	3.675 E3 +/- 8.80 E2	G
270	FF 03.0	2.100 E3 +/- 7.00 E2	G
272	FG 09.6	2.310 E3 +/- 6.00 E2	Y
295	FC 01.8	3.399 E3 +/- 8.64 E2	B
295	FC 01.8	5.434 E3 +/- 1.074 E3	Y
301	FK 02.0	7.79 E2 +/- 4.67 E2	Y
309	FB 01.7	5.279 E3 +/- 1.059 E3	Y
310	FG 02.5	1.886 E3 +/- 6.16 E2	G
310	FG 02.5	2.703 E3 +/- 7.35 E2	G
315	FJ 02.5	2.502 E3 +/- 7.08 E2	Y
316	FJ 02.5	1.954 E3 +/- 6.26 E2	Y
321	FL 02.1	5.581 E3 +/- 1.11 E3	F
330	FQ 02.6	2.222 E3 +/- 4.92 E2	Y
500	FF 01.6	3.998 E3 +/- 8.99 E2	O Very close to CF
501	FE 02.4	2.593 E3 +/- 7.19 E2	O
502	FC 02.5	2.769 E3 +/- 7.28 E2	O
503	FN 04.0	4.69 E2 +/- 3.06 E2	O
504	FM 05.5	2.306 E3 +/- 6.74 E2	O
505	FL 03.8	1.549 E3 +/- 2.83 E2	O
507	FC 01.0	3.012 E3 +/- 8.24 E2	O
508	FC 01.0	6.859 E3 +/- 1.212 E3	O CF
509	FC 0.75	5.098 E3 +/- 1.058 E3	O CF

G - Garden Area Y - Yard Area F - Uncultivated Field
B - Bank of a Creek CF - Cultivated Field
O - Location chosen by ODH, typically undisturbed ground.

APPENDIX B

DIRECT RADIATION MEASUREMENT

Environmental radiation exposure rate measurements were made in the vicinity of the FMPC using Thermoluminescent Dosimeters (TLDs). The TLDs were placed at 31 locations around the FMPC site. (See Fig. 22). The dosimeters were placed on site boundary fenceposts at a height of approximately 4 feet. At locations where fenceposts were not available, the dosimeter was attached to a tree close to the fenceline.

In addition to site boundary dosimeters, dosimeters were installed at 8 control locations. (See Fig. 23). As discussed in Section 2.0, dosimeters were installed in pairs and remained in the field for approximately 6 months. At the end of this time period all dosimeters were replaced with fresh dosimeters which remained in the field for an additional 6 months.

Although the dosimeters were encased in plastic, it was discovered that this did not totally protect them from rain damage. The ODH also experienced loss of detectors as a result of vandalism and curious cows which graze on the site. Indication of detector loss or damage is noted in the column labeled "Field Notes" in Table 7.

The total dose in millirems (mrems) received by each dosimeter is reported in Table 7. Unless otherwise noted, the dose listed was reported as resulting from gamma or X-ray exposure. An "M" value in the exposure column signifies that the dose to the detector was below the laboratory's minimum measurable quantity. The TLD's used in this study have a miniumum reporting value of 10 mrem for gamma and X-rays and 40 mrem for energetic beta particles.

In the dosimetry report received from the laboratory by ODH, a deep dose and shallow dose was reported for each dosimeter. Due to the energy of the gamma or X-rays the dosimeters were exposed to, these values were equal. Consequently, only one value has been reported and represents both doses. The exception to this is noted for TLD #130 at location T-25. The dosimetry report indicated that this dosimeter had received a deep dose exposure of 20 mrem, a shallow dose exposure of 90 mrem and a beta dose of 70 mrem. When this dosimeter was retrieved from the field, it was found detached from the fencepost and lying on the ground. Although other dosimeters were also found on the ground at the time of retrieval, none were reported as having received a beta dose and shallow dose different from the deep dose. Although no soil samples were collected at this location by ODH, other studies have reported elevated uranium concentrations in soil in this area (REF. 15 & 19) which might have contributed to the dose received by this dosimeter.

From Table 7, it appears that radiation levels at points on the western site boundary may be slightly elevated above levels detected at other monitoring locations. At all other locations, the radiation exposure did not vary significantly from that at the control locations (locations T-32 through T-40).

Radiation levels at points on the western boundary (70 mrem/year) and the radiation levels measured at all other fence line locations were less than the NCRP recommended levels for public exposure (REF. 20) and the DOE standard for public exposure (REF. 21).

The NCRP recommended level for annual public exposure is 100 mrem/year (effective dose equivalent) for continuous or frequent exposure and 500 mrem/year (effective dose equivalent) for infrequent exposure. The DOE standard is 170 mrem/year based on a suitable sample of the population and 500 mrem/year for individuals at points of maximum probable exposrue. Both DOE standards are expressed as annual dose equivalent or dose commitment. For comparison, a survey of background radiation in the United States by Levin et al. (1968), reported a background radiation level of 89 mrem/year for Ohio (REF. 22).

It should be noted that TLD #00 is a control dosimeter and was not deployed in the field. This is different from a dosimeter placed at a control location. A control dosimeter is included with each shipment of dosimeters as a means to determine radiation doses received during transit. The control dosimeter reading therefore is always subtracted from the readings of the other dosimeters used in the field.

During the second 6-month exposure period, the exposure reported for one dosimeter at location T-17 and one at T-34 were significantly above background. As mentioned previously, all dosimeters were deployed in pairs and the pair to these dosimeters did not record similar exposures. In addition, the previous 6-month exposures at these locations were below the minimum measurable quantity. The accuracy or validity of these exposures must be questioned.

TABLE 7

ENVIRONMENTAL RADIATION MEASUREMENTS

TLD#	LOC.	(1) EXPOSURE TO DOSIMETER (mrems)	FIELD NOTES	TLD#	(2) EXPOSURE TO DOSIMETER (mrems)	FIELD NOTES
00	Control	M		00	M	
01	T-1	M		81	20	
02	T-1	M		82	20	
03	T-2	M		83	20	
04	T-2	M		84	20	
05	T-3	ND	Dosimeter missing.	85	ND	Dosimeter missing.
06	T-3	ND	Dosimeter missing.	86	ND	Dosimeter missing.
07	T-4	ND	Dosimeter damaged.	87	20	
08	T-4	M		88	10	
09	T-5	M		89	20	
10	T-5	M		90	20	
11	T-6	M		91	20	
12	T-6	M		92	ND	Dosimeter missing.
13	T-7	ND	Dosimeter missing.	93	10	
14	T-7	ND	Dosimeter damaged.	94	20	
15	T-8	M		95	ND	Dosimeter missing.
16	T-8	ND	Dosimeter damaged.	96	ND	Dosimeter Missing
17	T-9	M		97	20	
18	T-9	M		98	20	
19	T-10	30		99	40	
20	T-10	30		100	40	
21	T-11	10		101	20	
22	T-11	20		102	30	
23	T-12	20		119	20	
24	T-12	M		120	ND	Dosimeter Missing
25	T-13	M		103	20	
26	T-13	M		104	20	

(1) Exposure period 9-5-85 to 3-28-86
(2) Exposure period 3-28-86 to 9-26-86
ND No Data
M Below minimum measurable quantity

TABLE 7 continued

TLD#	LOC.	(1) EXPOSURE TO DOSIMETER (mrems)	FIELD NOTES	TLD#	(2) EXPOSURE TO DOSIMETER (mrems)	FIELD NOTES
27	T-14	M		116	20	
28	T-14	M		117	20	
* 63	T-15	ND	Dosimeter damaged.	105	ND	Dosimeter missing,
* 64	T-15	ND	Dosimeter damaged.	106	10	appeared to have been
* 65	T-16	M		107	20	cut away.
* 66	T-16	M		108	20	
* 67	T-17	M		109	370	
* 68	T-17	M		110	20	
* 78	T-18	M		111	10	
* 79	T-18	M		112	20	
29	T-19	ND	Dosimeter damaged.	113	20	
30	T-19	ND	Dosimeter damaged.	114	20	
31	T-20	M		115	20	
32	T-20	ND	Manufacturer's Defect, TLD	118	20	
33	T-21	M	missing from dosimeter.	124	10	
34	T-21	M		125	20	
35	T-22	M		122	10	
36	T-22	ND	Manufacturer's Defect, TLD	123	30	
37	T-23	M	missing from dosimeter.	121	20	
38	T-23	M		126	M	
39	T-24	20	Found on ground.	127	ND	Dosimeter missing.
40	T-24	ND	Manufacturer's Defect, TLD	128	20	Found on ground.
41	T-25	10	missing from dosimeter.	129	20	
42	T-25	M		130	** D-20	S-90 B-70 Found
43	T-26	10		131	40	on ground.
44	T-26	M		132	20	
45	T-27	M		133	20	
46	T-27	M		134	20	
47	T-28	20	Found on ground.	137	20	
48	T-28	M	Found on ground.	138	30	
49	T-29	M	Found on ground.	135	20	
50	T-29	M		136	20	

* Actually installed on 9-17-85
** D - Deep Dose S - Shallow Dose B - Beta Dose

TABLE 7 continued

TLD#	LOC.	(1) EXPOSURE TO DOSIMETER (mrems)	FIELD NOTES	TLD#	(2) EXPOSURE TO DOSIMETER (mrems)	FIELD NOTES
51	T-30	M		139	ND	Dosimeter missing.
52	T-30	M		140	ND	Dosimeter missing.
53	T-31	M		141	20	
54	T-31	M		142	40	
CONTROLS						
55	T-32	30		151	20	
56	T-32	M		152	20	
57	T-33	M		153	20	
58	T-33	M		154	10	
59	T-34	M		155	160	
60	T-34	M		156	20	
61	T-35	M		157	20	
62	T-35	M		158	20	
* 69	T-36	M		149	20	
70	T-36	M		150	10	
* 71	T-37	M		145	10	
* 72	T-37	ND	Dosimeter missing.			
* 73	T-38	M	Found on ground.	147	10	
* 74	T-38	M		148	20	
* 76	T-39	10		143	M	
* 77	T-39	M		144	20	
75	T-40	M		159	20	
80	T-40	M		160	30	

* Actually installed on 9-17-85.

TABLE 7 continued

The following dosimeters were those that had been found on the ground and were damaged to the degree that the identification number of the dosimeter could not be determined. The dosimeters were still submitted to Landauer for possible analysis. Following are the exposures reported for these dosimeters.

TLD #	EXPOSURE (mrems)
?	40
?	50
?	40
?	40
?	50
?	50
?	60
?	70

FIGURE 22

TLD LOCATIONS (INDICATORS)

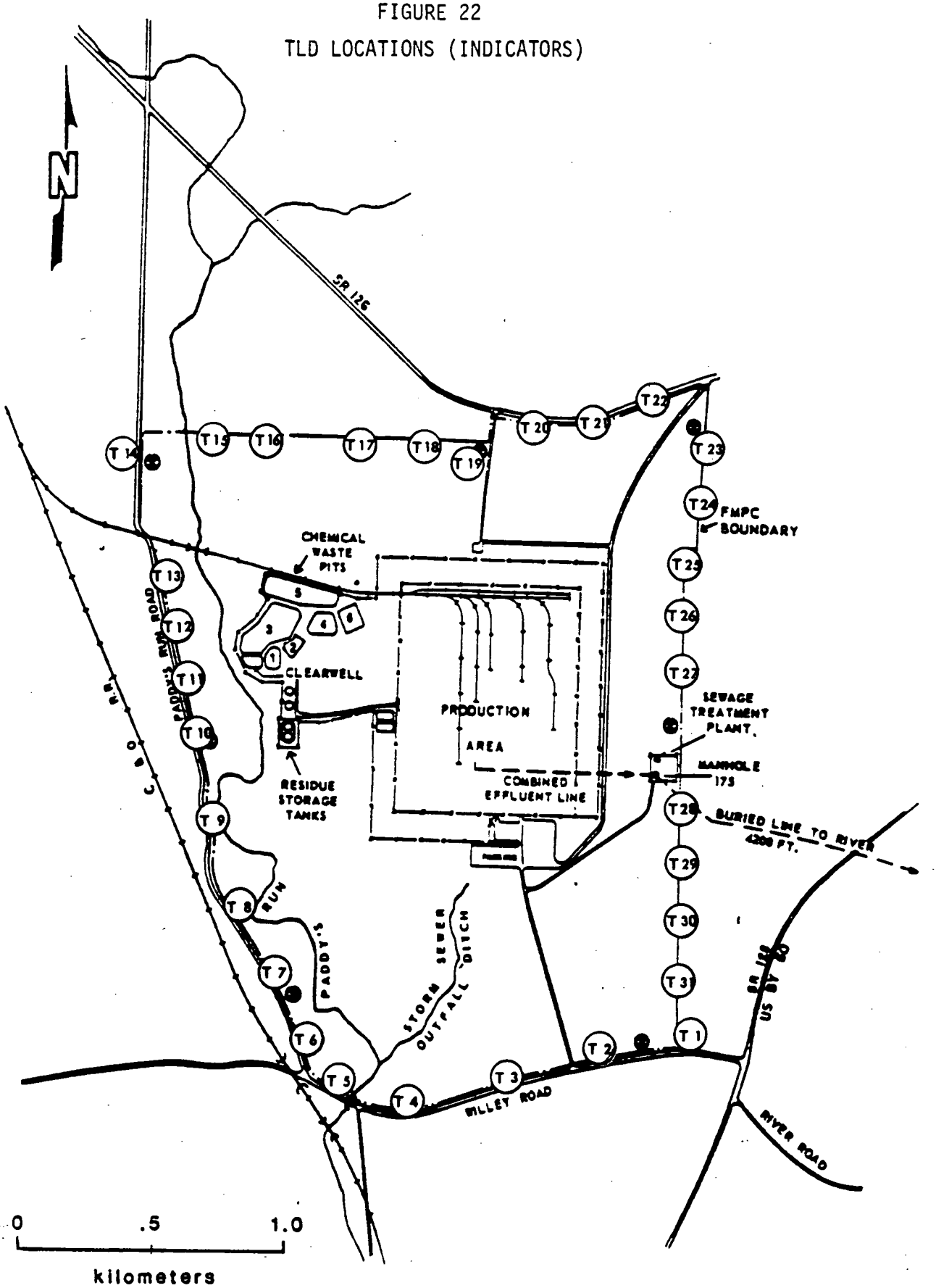


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FIGURE 23
TLD LOCATIONS (CONTROLS)

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APPENDIX C

ENVIRONMENTAL RADON

In June of 1985, the Ohio Department of Health established 16 environmental radon monitoring stations in the vicinity of the FMPC. Twelve stations were located on the FMPC site boundary (See Fig. 24). The remaining 4 stations were established at locations remote from the FMPC and were used as control sites (See Fig. 25).

The primary purpose for establishment of these stations was to determine if radon concentrations beyond the FMPC site boundary were elevated above background as a result of continuous radon gas leakage from the K-65 silos located in the northwest section of the FMPC site.

Terradex Type F Track Etch detectors were used to monitor the radon concentrations at all locations. The Track Etch detector is a passive, integrating type radon device. It consists of a plastic nuclear track recorder attached to the bottom of a small plastic cup. The mouth of the cup is covered with a filter which allows infiltration of radon isotopes but prevents entry of radon decay products and dust. When an alpha particle (emitted by radon) strikes the plastic detector, it leaves a damage track. When returned to the laboratory these damage tracks are enlarged by etching the film in a caustic solution. The tracks are then counted by microscope. Determination of the average exposure rate (pCi/l) is based on the number of tracks counted per unit area and the exposure time.

The Track Etch detectors were placed in protective housings which were secured on fence posts or trees. The detectors were placed at a height of approximately 3-4 feet off the ground. At locations 14 and 15, it was necessary to place the detectors at a height of approximately 8-10 feet to prevent possible vandalism. Detectors were damaged and/or knocked to the ground a number of times at several of the other stations where it was not possible to place them at greater heights. Damage, when it occurred, usually consisted of the detector being dislodged from the fence post and/or a puncture or tear of the filter covering the mouth of the cup holding the detector.

The detectors were changed at intervals of approximately 6 months. In April 1986, the detectors were changed after 3.5 months in the field. This was performed in order to ascertain whether the radon levels in the vicinity of the K-65 silos had been raised significantly following an accidental release of unusually large quantities of radon during the performance of maintenance activities on the silos.

Results of radon measurements through November 1987 are reported in Table 8. From the data for the time period 4/8/87 - 11/6/87, it would appear that the radon concentrations at all locations had decreased. This data does not reflect a true decrease in radon levels, however. The zeros reflect the fact that a lower sensitivity level was used for analysis of the detectors. These detectors were read at the 1.0 (pCi/l)-month sensitivity level instead of the 0.2 (pCi/l)-month level.

From the data shown in Table 8, there does not appear to be a consistent significant difference between the radon concentrations measured in the air at the site boundary closest to the K-65 silos and those measured at the control locations and other locations around the site.

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FIGURE 24

ENVIRONMENTAL RADON MONITORING LOCATIONS

(INDICATORS)

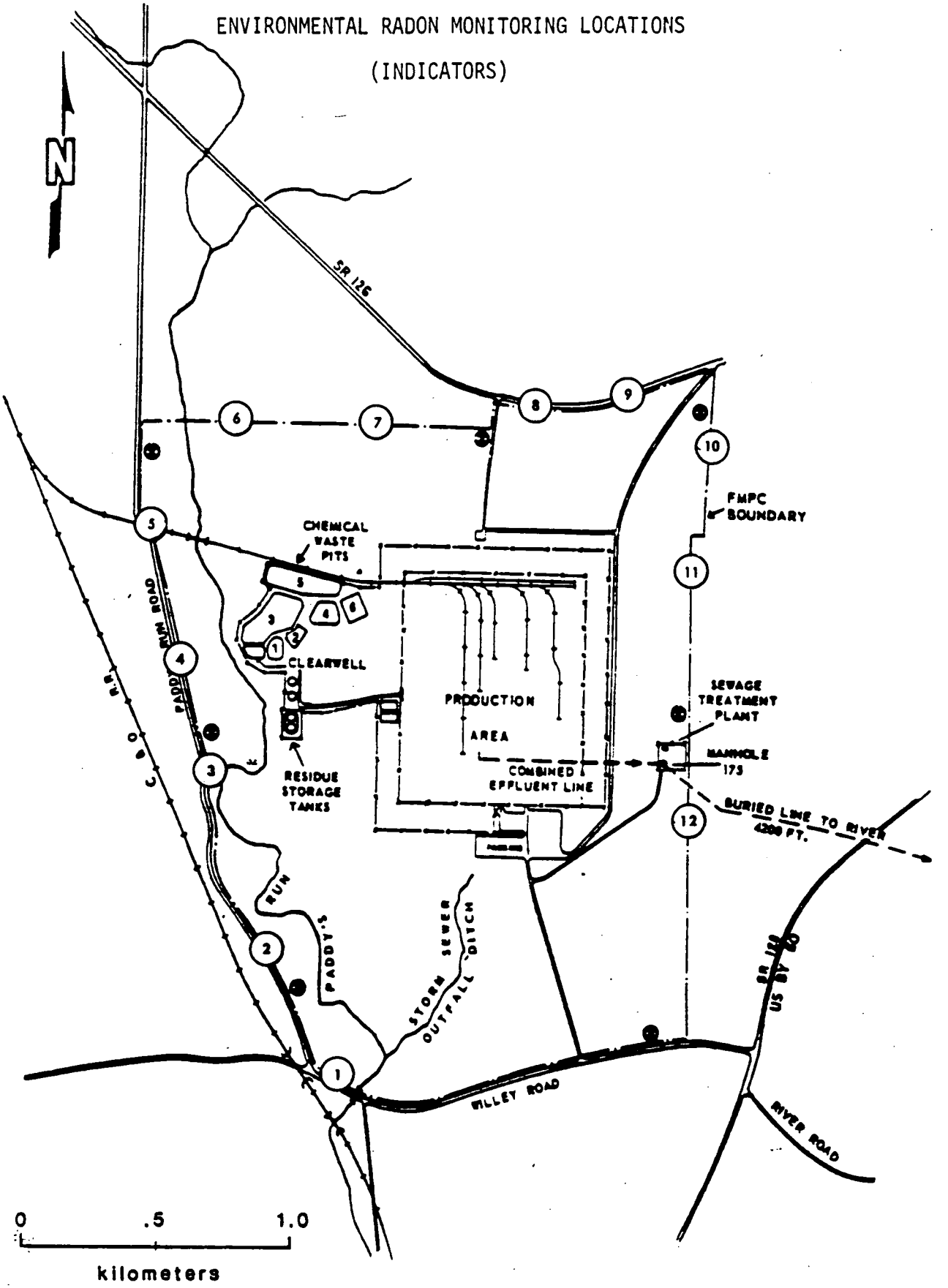

FIGURE 25

ENVIRONMENTAL RADON MONITORING LOCATIONS (CONTROLS)

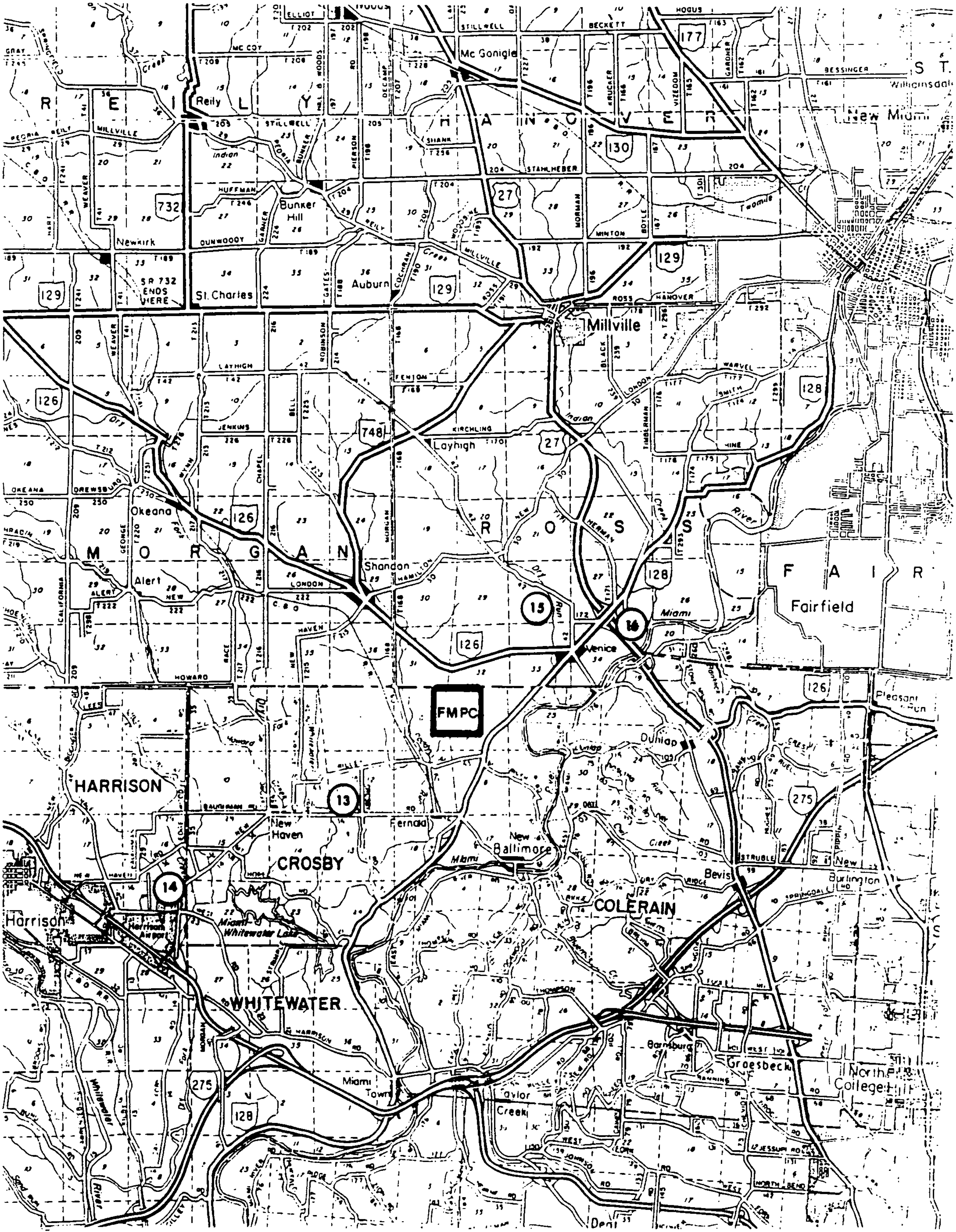

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TABLE 8

ENVIRONMENTAL RADON MEASUREMENTS

LOCATION	RADON CONCENTRATION (pCi/l)							
Indicator	6/6/85-1/14/86	1/14/86-4/29/86	4/29/86-8/12/86		8/12/86-4/8/87		4/8/87-11/6/87	
01	0.69	0.57	0.43		0.2		0.0	
02	0.79	0.59	1.19		1.0		0.0	
03	1.89	0.35	0.47		Missing		0.0	
04	Missing	0.33	4.69	Found on ground.	0.2		0.1	Damaged, found on ground.
05	1.04	0.45	0.89		0.2		0.4	
06	0.55	0.31	0.66		0.3	Found on ground.	0.0	Found on ground.
07	0.47	0.16	0.23		0.3		0.0	
08	0.52	0.45	0.33		0.1		0.0	
09	0.47	0.14	0.40		0.1		0.0	
10	0.17	0.21	0.82		0.2		0.0	
11	0.63	0.28	0.26		0.2		0.0	
12	0.47	0.26	0.55		0.1		0.0	
Control								
13	1.31	0.95	0.28		0.3	Damaged, found on ground.	0.0	Found on ground.
14	0.70	0.38	0.35		0.6		0.0	
15	0.41	0.11	0.09		0.2		0.0	
16	0.37	0.33	0.28		0.5		0.0	

APPENDIX D

RADON IN HOMES

Results of the voluntary whole body counting of FMPC residents performed by the DOE, indicated the presence of a detectable level of radon decay products in nine of the residents counted.

As follow-up to these findings, the ODH offered to monitor the homes of these residents for radon. The ODH was also requested to monitor radon levels in the Crosby Elementary School. The ODH began monitoring radon levels inside two of the above mentioned resident's homes and the school using Passive Environmental Radon Monitors (PERMs). These PERMs were on loan to the ODH from the USEPA and had previously been used to monitor radon elsewhere in Ohio.

The PERM is a cylindrical shaped device which has a height of approximately 15 inches and a diameter of approximately 10 inches. It consists of two parts. The lower portion contains the detector, a thermoluminescent (TLD) chip and 3 dry-cell batteries. The batteries are used to provide an electrostatic field which attracts Radium-A (a radon decay product) ions to the TLD chip. This chip absorbs and stores the alpha decay energy from the ions. The upper portion of the PERM is a desiccant which prevents moisture from entering the bottom portion and interfering with the detector. The desiccant required replacement on a monthly basis. At the end of a 1-month time period, the desiccant and TLD chip were removed and replaced. The TLD was then sent to a USEPA laboratory to be read.

For quality assurance purposes the PERMs were installed in pairs. The PERMs were placed on the ground or first-floor level of the home in an area where the residents spent the majority of their time. Results of the measurements made using PERMs are contained in Table 9.

In order to estimate the health risks due to radon exposure in the home, the average annual radon concentration in the home must be determined. Radon levels in a home are known to fluctuate, particularly from season to season. By performing monthly measurements over a period of time with the PERMs, the ODH was able to observe these fluctuations and also determine the average radon concentration by averaging together all of the monthly measurements.

In July 1985, the ODH obtained Track Etch detectors from Terradex Corporation (See Figure 26). Eight of the residents whose whole body counting results indicated the presence of radon decay products accepted ODH's offer to monitor radon levels in their homes. The detectors were placed in pairs in these homes and were replaced on a quaterly basis over a period of 4 quarters.

In addition to quarterly sets of detectors, ODH installed an "annual" set of detectors. These "annual" detectors remained in the home for an entire year. Detectors were typically placed on the ground or first floor in an area of the house where residents spent the majority of their time. Upon removal from the home, detectors were returned to Terradex to be analyzed.

Results of this monitoring program are provided in Table 10. Fluctuations in radon concentrations in the homes were monitored with the quarterly sets of detectors. The resident's average annual radon exposure was measured by the "annual" set of detectors and confirmed by averaging the results of the 4 quarterly sets of detectors.

Table 10 also includes the results of radon monitoring performed in an additional 17 residences (locations 10-30) in the vicinity of the FMPC. At locations 10-17, Track Etch detectors were installed by the ODH in the same fashion as at locations 1-9. These homes were considered contol homes from the standpoint that no whole body counting or a normal whole body counting result existed for the residents. From a list of residents who had contacted the ODH requesting a water sample, the ODH randomly selected these 8 homes (locations 10-17) in various directions and at various distances from the FMPC to serve as a control group.

Locations 18-30 represent residences which were monitored as a result of a request made by the resident. Track Etch detectors with instructions for installation were sent via the postal service to these residents. Residents were instructed to return the detectors after a 3 month monitoring period.

The locations of all of the homes monitored are shown in Figure 27.

In August 1986, the USEPA published a pamphlet entitled "A Citizen's Guide To Radon, What It Is and What To Do About It" (REF. 23). In this pamphlet the USEPA recommended that when the average annual radon concentration in a home exceeds 4 pCi/l actions should be taken to lower the radon levels to about 0.02 WL (4pCi/l) or below. A radon risk evaluation chart was also developed by the USEPA and is contained in the pamphlet (See Fig. 28). In addition, the National Council on Radiation Protection and Measurements (NCRP) recommended in their Report #77 that average annual radon exposures not exceed 2 WLM/year (8 pCi/l) (REF. 18).

Of the 14 homes in which the ODH collected a full year's worth of data, 7 homes had average radon levels which exceeded the 4 pCi/l USEPA guideline. The school's levels were well below this guideline. Of the 10 residences monitored for 3 months on a request basis, 3 had measurement results which indicated the average radon levels might excede the 4 pCi/l guideline and required further monitoring.

All residents were notified of the results of the radon testing performed in their homes. Information was provided as to how their results compared with the USEPA and the NCRP guidelines and whether further measurement or remedial measures should be taken by the resident. The ODH has followed the progress of at least one homeowner in this study who was able to successfully reduce the radon levels in his home to below 4 pCi/l using techniques recommended by the USEPA.

For each home monitored, a survey of the house design features was completed (See Fig. 29). It was hoped that this survey could be used to determine if certain design characteristics increased the probability of occurrence of elevated radon levels in a home (See Table 11). After comparing measurement results with house design features for the homes in this study, the following conclusions were made:

a. No specific design feature appears to standout as a deciding factor in whether a home has elevated radon levels. It appears that elevated radon levels are a result of a combination of factors. Many of the homes with elevated radon levels had a basement or unvented crawlspace, forced air heating, central air conditioning and a relatively energy-efficient home.

b. The survey form was not detailed enough to adequately determine what design or construction features were responsible for the elevated radon levels.

c. The energy efficiency rating of the home was a subjective rating.

d. Each house must be evaluated and inspected individually in order to determine if a house has a radon problem and why.

The ODH had intended to examine the possibility of a correlation between a resident's whole body counting results and the radon concentration in the resident's home, however, only 2 residents were able to provide their whole body counting results to the ODH. In this study 5 of the 7 residents with positive whole body counts had average radon concentrations in their homes that exceeded the USEPA guidleline. In the control group only 2 of 7 residences had average radon concentrations which exceeded the USEPA guideline. If it were practical, whole body counting might possibly be used as an indicator to homeowners that elevated radon levels may exist in their home.

RADON IN WATER

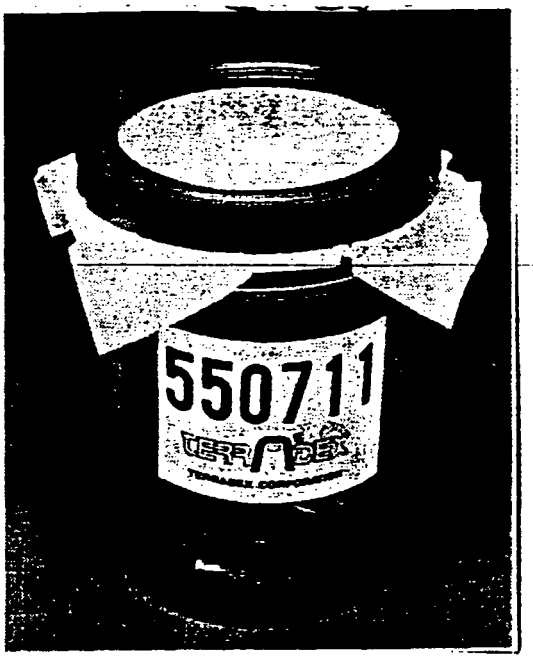
In addition to soil, water can be a source of radon exposure in the home if the home's source of water is ground water. Waterborne radon may be released to the air in a home through such activities as washing and showering. The exposure risks attributed to waterborne radon result from the inhalation of radon released from water to the air in the home and are not a result of ingestion of the waterborne radon.

As a rule of thumb, there will be an increase of about 1 pCi/l in the air inside a home for every 10,000 pCi/l of radon in the water (REF 24). As shown in Table 12, the highest concentration of radon detected in any of the water samples collected was 680 pCi/l. Based on the above information, the ground water being used by these residents is not a significant source of radon exposure and the consumption of this water is not considered a health risk (REF. 24).

In order to provide residents with a reference with which to compare their results, the ODH attached the information shown in Figure 30 to the letter reporting their results.

FIGURE 26

TRACK ETCH TYPE F CUPS



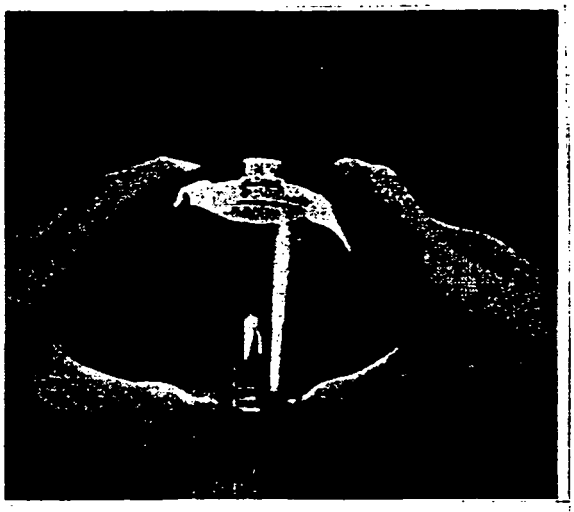


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FIGURE 27

INDOOR RADON MEASUREMENT LOCATIONS

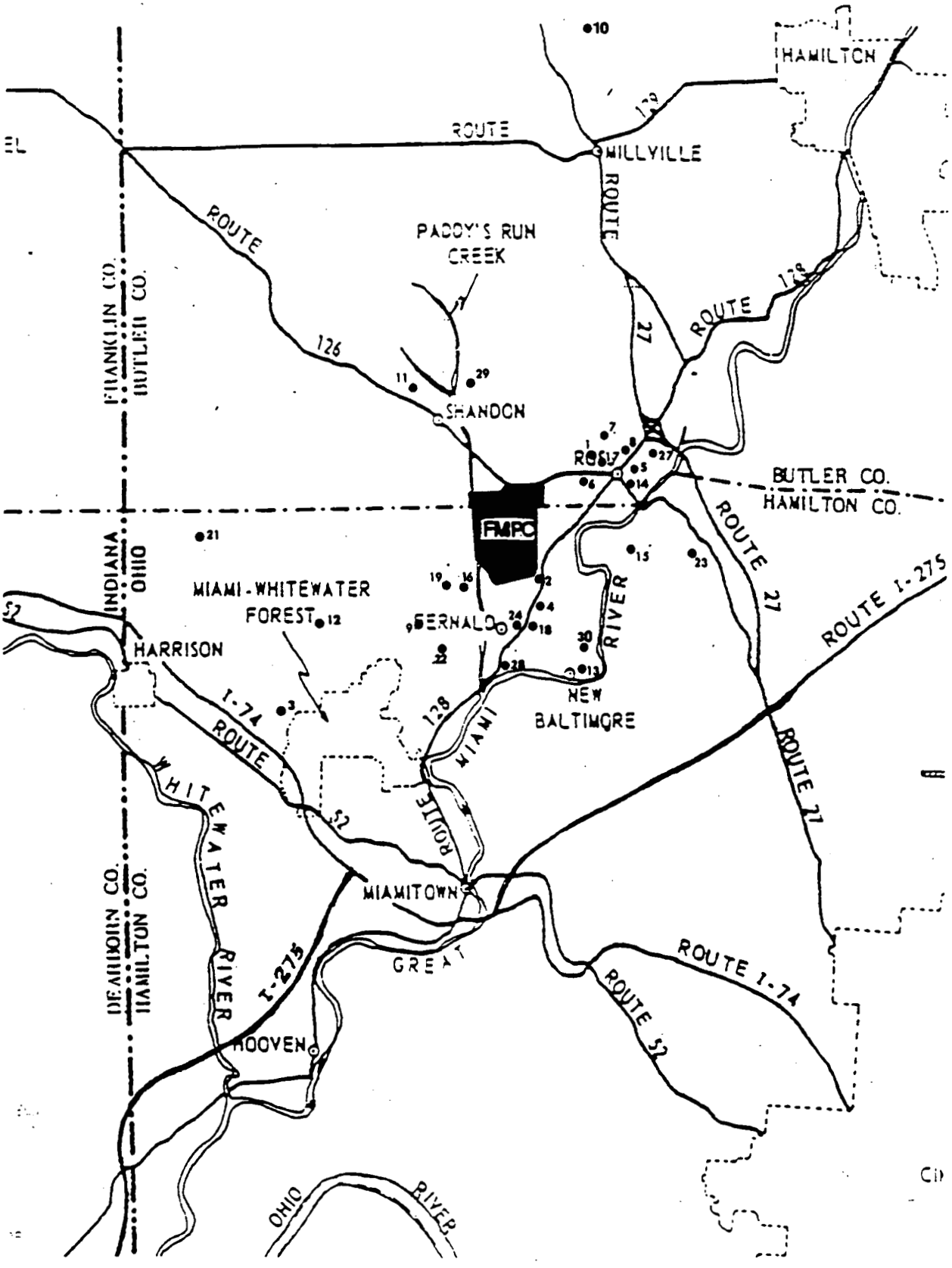

TABLE 9

RESULTS OF RADON MEASUREMENTS MADE USING PERMs

PERM's were placed in pairs in the following 2 homes and 1 public school.

Location	#2	#8	#9
Start Date	07-02-85	02-06-85	02-06-85
Stop Date	08-07-85	03-14-85	03-07-85
PERM 1	1.924 pCi/l	16.162 pCi/l	1.389 pCi/l
PERM 2	1.820 pCi/l	19.745 pCi/l	1.248 pCi/l
Start	08-07-85	03-14-85	03-07-85
Stop	09-05-85	04-10-85	04-10-85
PERM 1	1.290 pCi/l	12.172 pCi/l	1.094 pCi/l
PERM 2	1.280 pCi/l	12.338 pCi/l	1.326 pCi/l
Start	09-05-85	04-10-85	04-10-85
Stop	10-10-85	05-21-85	05-09-85
PERM 1	1.199 pCi/l	3.956 pCi/l	1.737 pCi/l
PERM 2	1.351 pCi/l	4.615 pCi/l	1.495 pCi/l
Start	10-10-85	05-21-85	06-06-85
Stop	11-18-85	06-06-85	07-02-85
PERM 1	0.870 pCi/l	1.797 pCi/l	0.504 pCi/l
PERM 2	1.063 pCi/l	2.018 pCi/l	0.423 pCi/l
Start	11-18-85	06-06-85	07-02-85
Stop	01-15-86	07-02-85	08-07-85
PERM 1	3.513 pCi/l	0.484 pCi/l	0.586 pCi/l
PERM 2	2.142 pCi/l	0.518 pCi/l	0.463 pCi/l
Start	01-15-86	07-02-85	08-07-85
Stop	02-20-86	08-15-85	09-05-85
PERM 1	2.647 pCi/l	0.436 pCi/l	0.574 pCi/l
PERM 2	2.559 pCi/l	0.421 pCi/l	0.733 pCi/l
Start		08-15-85	09-05-85
Stop		09-17-85	10-10-85
PERM 1		0.909 pCi/l	1.547 pCi/l
PERM 2		0.889 pCi/l	1.232 pCi/l
Start		09-17-85	10-10-85
Stop		10-18-85	11-18-85
PERM 1		1.255 pCi/l	0.720 pCi/l
PERM 2		1.248 pCi/l	0.797 pCi/l
Start		10-18-85	11-18-85
Stop		11-27-85	01-15-86
PERM 1		2.367 pCi/l	0.518 pCi/l
PERM 2		2.620 pCi/l	0.497 pCi/l
Start		11-27-85	
Stop		01-30-86	
PERM 1		7.805 pCi/l	
PERM 2		6.963 pCi/l	
AVERAGE	1.8 pCi/l	4.9 pCi/l	0.94 pCi/l

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TABLE 10

RESULTS OF RADON MEASUREMENTS MADE USING ALPHA TRACK DETECTORS

Detectors were placed in each home in sets of two. The result listed for each set represents the average of the results from the 2 detectors in the set. The result listed in the "Avg." column is simply the average of the 4 sets. The annual set of detectors remained in the home during the entire 4 set period and should compare favorably with the "Avg." result.

	1st set	2nd set	3rd set	4th set	Avg.	Annual
LOCATION #1						
start date	07-02-85	10-18-85	01-15-86	04-24-86	-	07-02-85
stop date	10-18-85	01-15-86	04-24-86	07-31-86	-	07-31-86
Radon (pCi/l)	4.1	12.08	16.3	1.8	8.57	10.3
LOCATION #2						
start date	07-02-85	10-18-85	01-15-86	04-24-86	-	07-02-85
stop date	10-18-85	01-15-86	04-24-86	07-14-86	-	07-14-86
Radon (pCi/l)	1.1	0.69	2.8	1.68	1.57	2.35
LOCATION #3						
start date	07-02-85	10-18-85	No further data acquired due to			
stop date	10-18-85	01-15-86	homeowner withdrawing from study.			
Radon (pCi/l)	2.1	3.6				
LOCATION #4						
start date	07-02-85	10-18-85	01-15-86	04-24-86	-	07-02-85
stop date	10-18-85	01-15-86	04-24-86	07-14-86	-	07-14-86
Radon (pCi/l)	0.74	0.38	0.64	0.8	0.64	1.56
LOCATION #5						
start date	07-02-85	10-18-85	01-15-86	04-24-86	-	07-02-85
stop date	10-18-85	01-15-86	04-24-86	07-14-86	-	07-14-86
Radon (pCi/l)	8.1	5.06	13.4	5.3	7.9	8.66
LOCATION #6						
start date	07-02-85	10-18-85	01-30-86	04-24-86	-	07-02-85
stop date	10-18-85	01-30-86	04-24-86	07-14-86	-	07-14-86
Radon (pCi/l)	1.77	7.9	6.1	1.58	4.3	4.38
LOCATION #7						
start date	07-02-85	10-18-85	01-15-86	04-24-86	-	07-02-85
stop date	10-18-85	01-15-86	04-24-86	07-14-86	-	07-14-86
Radon (pCi/l)	11.17	18.39	L 15.5	7.9	13.24	12.78
			* BA 17.13	6.5		
			BS 24.0	21.2		
LOCATION #8						
start date	07-02-85	10-18-85	01-30-86	04-24-86	-	07-02-85
stop date	10-18-85	01-30-86	04-24-86	07-31-86	-	07-31-86
Radon (pCi/l)	0.8	11.9	14.13	0.55	6.8	6.3
LOCATION #9						
start date	07-02-85	10-18-85	01-15-86	04-24-86	-	07-02-85
stop date	10-18-85	01-15-86	04-24-86	07-31-86	-	07-31-86
Radon (pCi/l)	1.33	1.0	0.96	0.52	0.95	1.1

* L - Living Room BA - Bathroom BS - Basement

TABLE 10 continued

RADON MEASUREMENTS PERFORMED USING ALPHA TACK DETECTORS
(Control Locations)

	1st set	2nd set	3rd set	4th set	Avg.	Annual
LOCATION #10						
start date		11-01-85	06-05-86	08-20-86		
stop date		06-10-86	08-20-86	11-13-86		
Radon (pCi/l)		1.31	2.74	1.7	1.9	
LOCATION #11						
start date	11-04-85	02-06-86	05-21-86	08-20-86		
stop date	02-06-86	05-21-86	08-20-86	11-28-86		
Radon (pCi/l)	0.975	0.54	1.37	1.0	0.97	
LOCATION #12						
start date	11-04-85	02-06-86	05-21-86	08-20-86		
stop date	02-06-86	05-21-86	08-20-86	11-13-86		
Radon (pCi/l)	2.35	1.95	1.46	2.4	2.04	
LOCATION #13						
start date	11-04-85	02-06-86	05-21-86	10-02-86		
stop date	02-06-86	05-21-86	10-02-86	11-13-86		
Radon (pCi/l)	12.97	14.17	19.25	10.7	14.27	
LOCATION #14						
start date	NO DATA:	MOVED AND	THREW CUPS	AWAY		
stop date						
Radon (pCi/l)						
LOCATION #15						
start date	11-04-85	02-06-86	05-21-86	08-20-86		
stop date	02-06-86	05-21-86	08-20-86	11-13-86		
Radon (pCi/l)	5.28	2.61	1.49	5.15	3.63	
LOCATION #16						
start date	11-04-85	02-06-86	05-21-86	08-20-86		11-04-85
stop date	02-06-86	05-21-86	08-20-86	11-13-86		11-13-86
Radon (pCi/l)	2.1	3.1	3.25	7.1	3.8	3.35
LOCATION #17						
start date	11-04-85	02-06-86	05-21-86	09-26-86		
stop date	02-06-86	05-21-86	09-26-86	11-13-86		
Radon (pCi/l)	8.25	5.6	2.8	5.45	5.5	

TABLE 10 continued

The following are results of radon measurements made in homes of residents who contacted ODH and requested that their home be monitored for radon. Listed below is the date the detectors were sent to the resident, the date the resident installed the detectors in the home, the date they returned the detectors to ODH and the result of the measurements.

LOCATION #	DATE SENT	DATE INSTALLED	DATE REMOVED	RESULTS (pCi/l)	AVG.
18	04-24-86	05-06-86	08-08-86	4.81 4.06	4.43
19	04-24-86	05-06-86	08-20-86	3.98 2.56	3.27
20	04-24-86	* see note		NO DATA	
21	04-24-86	10-15-86 **	12-17-86	2.7 7.5	5.1
22	04-24-86	05-07-86	08-07-86	0.79 0.70	0.74
23	04-24-86	08-19-86	11-16-86	3.1 2.0	2.55
24	04-24-86	05-07-86	08-08-86	1.18 1.51	1.34
25	04-24-86	MOVED		NO DATA	
26	04-24-86	*** see note		NO DATA	
27	04-24-86	07-21-86	10-26-86	8.7 8.6	8.65
28	04-24-86	05-09-86	08-08-86	1.06 0.77	0.91
29	04-24-86	05-11-86	08-11-86	1.85 0.98	1.41
30 A	**** see note	07-31-86	11-13-86	0.5 3.2	1.85
B				0.4 0.3	0.35
C				0.7 0.8	0.75

TABLE 10 continued

NOTES:

* At location #20, the resident had not installed the detectors as of 8-13-86 but agreed to do so on that date per a telephone conversation. When the resident was again contacted on 8-13-86 concerning the return of the detectors, she was upset and stated that she had not yet installed the detectors and that the ODH no longer needed to be concerned with the results of her test. The detectors were eventually returned unused.

** At location #21 the resident had not installed the detectors as of 8-13-86 and requested that the ODH send a second set of detectors because her children had been playing with the first set. She agreed to install the second set of detectors as soon as she received them. The second set of detectors were mailed on 8-14-86. When the resident was again contacted on 11-12-86 concerning the return of the detectors, she again stated that the detectors had not yet been installed and that she thought the detectors were a gimmick the ODH was using to passify the residents in the Fernald area. Eventually the resident did return the detectors stating that they had been installed on 10-15-86 and removed on 12-17-86.

*** At location #26, the ODH was unable to contact the resident to inquire about the installation of the detectors. The phone at this residence was disconnected.

**** At location #30, the detectors were installed and retrieved by the ODH.

FIGURE 28

Radon Risk Evaluation Chart

pCi/l	WL	Estimated number of lung cancer deaths due to radon exposure (out of 1000)	Comparable exposure levels	Comparable risk
200	1	440—770	1000 times average outdoor level	More than 60 times non-smoker risk
				4 pack-a-day smoker
100	0.5	270—630	100 times average indoor level	
				20,000 chest x-rays per year
40	0.2	120—380		
				2 pack-a-day smoker
20	0.1	60—210	100 times average outdoor level	
				1 pack-a-day smoker
10	0.05	30—120	10 times average indoor level	
				5 times non-smoker risk
4	0.02	13—50		
				200 chest x-rays per year
2	0.01	7—30	10 times average outdoor level	
				Non-smoker risk of dying from lung cancer
1	0.005	3—13	Average indoor level	
0.2	0.001	1—3	Average outdoor level	20 chest x-rays per year

FIGURE 29
HOUSE DESIGN FEATURES SURVEY

State I.D. Number _____ I.D. Number _____

City/Town _____ County _____ State _____

- -

(Circle one)

Type of Dwelling: single family duplex apartment other _____

Number of occupants: _____ Number of smokers: _____

ENERGY EFFICIENT/HOUSE DESIGN FEATURES

Foundation: (Circle one with appropriate modifiers)

-- Slab

-- Crawl Space: vented unvented don't know

-- Basement: concrete floor stone floor dirt floor don't know

-- Don't know

Number of floors, including basement: 1 2 3 4

Floor area: _____Sq ft. Don't know

Storm windows: yes no

Residence is: very drafty drafty normal very tight

General Construction: wood frame masonry other _____

Siding: brick stone wood stucco other _____

Heating fuel: oil wood natural gas bottled gas coal electric

other _____

Heating system: forced air gravity radiator other _____ none

Air conditioner: central room none other _____

Air cleaners used: (i.e., electrostatic precipitators) yes no

- -

LOCATION

How would you describe the area? city town rural farm

Other Comments: _____

_____

TABLE 11

DESIGN FEATURES OF HOMES MONITORED FOR RADON

Location	Foundation	#Floors	Energy Effic.	Construction Siding	Heating Fuel/System	Air Cond.	Air Cleaner
1 *	Basement concrete floor	2	very tight	wood frame wood	heat pump forced air	central	no
2	Basement concrete floor	2	normal	wood frame brick	natural gas forced air	central	no
3	Basement concrete floor	3	drafty	wood frame vinyl	electric heat pump	central	no
4	Unvented crawlspace	1	normal	mobile home	natural gas forced air	none	no
5 *	Basement concrete floor	2	normal	wood frame brick	natural gas forced air	central	yes
6 *	1/2 unvented crawlspace 1/2 bsmt. concrete floor	4	drafty	masonry stone	oil forced air	window unit	no
7 *	Basement concrete floor	2	normal	wood frame brick	electric heat pump forced air	central	yes
8 *	Unvented crawlspace Return air drawn from crawlspace.	1	tight	wood frame aluminum	natural gas forced air	?	no
9	Large public building						

* Homes with measured average annual radon concentration > 4 pCi/l.

TABLE 11 continued

Location	Foundation	#Floors	Energy Effic.	Construction Siding	Heating Fuel/System	Air Cond.	Air Cleaner
10	slab	1	very tight	poured concrete earth berm	wood solar electric	none	no
11	Vented crawlspace	1	normal	mobile home	propane forced air	window unit	no
12	Basement concrete floor	3	very tight	wood frame vinyl	oil hot water baseboard	window unit	no
13 *	Basement concrete floor	3	normal	masonry block	propane forced air	central	no
14	Vented crawlspace	1	very tight	wood frame brick	electric baseboard	window unit	no
15	Basement concrete floor	3	very tight	wood frame cedar	wood firepl. insert electric	central	yes
16	Basement concrete floor	2	normal	wood frame brick	electric heat pump	central	no
17 *	Basement concrete floor	2	drafty	1/2 mobile home w/addition brick	electric forced air	central	no
18 *	Basement concrete floor	2	normal	wood frame brick/wood	propane forced air	central	no

TABLE 11 continued

Location	Foundation	#Floors	Energy Effic.	Construction Siding	Heating Fuel/System	Air Cond.	Air Cleaner
19	mostly slab small bsmt. area w/concrete floor	2	normal	wood frame aluminum	propane forced air	central	no
21 *	Basement concrete floor	3	normal	masonry brick	oil forced air	central	no
22	Vented crawlspace & bsmt. w/concrete floor	2	very tight	wood frame wood	wood/elec. radiator	window unit	no
23	Basement & crawlspace	3	normal	log home	wood/elec. forced air	central	no
24	Basement concrete floor	2	very tight	wood frame wood	wood forced air	central	no
27 *	Basement concrete floor	2	very tight	wood frame brick	natural gas forced air	central	no
28	Basement dirt floor	3	normal	wood frame vinyl	oil forced air	window unit	no
29	Vented crawlspace	1	normal	wood frame & masonry stone & wood	oil forced air	central	no
30	Fort Scott Camp Lodge & Cabins						

TABLE 12

RESULTS OF RADON MEASUREMENTS IN WATER

LOCATION	RADON CONCENTRATION (pCi/l)	% 2 SIGMA ERROR
1	481.1	20.99
	502.1	20.0
2	269.7	37.0
	219.9	45.0
3	DROPPED OUT OF STUDY, NOT SAMPLED	
4	214.5	46.01
	296.7	34.01
5	187.8	51.99
	246.4	40.00
6	115.2	85.03
	206.7	48.0
7	553.9	18.99
	516.2	19.99
8	473.8	21.99
	572.6	18.01
9	382.0	26.99
	335.4	29.99
10 *	230.6	42.99
	376.8	26.99
	285.7	31.0
	417.5	22.0
11	266.2	51.01
	108.5	122.95
12 *	241.8	56.0
	231.4	60.98
	383.6	38.01
	331.2	42.0
13	NOT SAMPLED	
14	MOVED, NOT SAMPLED	

TABLE 12 continued

LOCATION	RADON CONCENTRATION (pCi/l)	% 2 SIGMA ERROR
15 **	- 13.09	999.24
	45.09	292.08
16	462.0	30.0
	484.4	29.0
17	680.8	21.0
	634.2	22.0

* Samples were run twice by laboratory.

** Water sampled was not ground water. Samples were collected from a cistern.

FIGURE 30

EXCERPT from the Federal Register

Tuesday, September 30, 1986
Volume 51, No. 189 Proposed Rules

Environmental Protection Agency, 40 CFR Part 141
Water Pollution Control; National Primary Drinking Water Regulations; Advance Notice of Proposed Rulemaking

TABLE 9. - ESTIMATES OF THE NUMBER OF PUBLIC GROUND DRINKING WATER SOURCES THAT EXCEED VARIOUS LEVELS OF RADON

Lifetime risk level	Radon concentration (pCi/l)	Annual effective dose equivalent	Number of public drinking water supplies that exceed the concentration in Column 2
10E-3	10,000	100	500 - 4,000
10E-4	1,000	10	1,000 - 10,000
10E-5	100	1	5,000 - 30,000
10E-6	10	0.1	10,000 - 40,000

* Rounded off to one significant figure

Definitions:

Lifetime risk level - The excess lung cancer risk due to a lifetime of exposure.

10E-3 - 1 in 1,000 chance

10E-4 - 1 in 10,000 chance

10E-5 - 1 in 100,000 chance

10E-6 - 1 in 1,000,000 chance

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