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FEED MATERIALS PRODUCTION CENTER ENVIRONMENTAL MONITORING ANNUAL REPORT FOR 1984

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FEED MATERIALS PRODUCTION CENTER

ENVIRONMENTAL MONITORING ANNUAL REPORT FOR 1984

by

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ABSTRACT

During the year 1984, various environmental data were collected by Feed Production Materials Center (FMPC) personnel. The collection and analysis of these data are part of an on-going FMPC program designed to insure that plant operations fall within the scope of governmental guidelines and to assure the continued integrity of the environment. This report presents these data and associated analytical results. Plant discharges during the year were much less than established DOE/EPA guidelines. Consequently, off-site radiation exposures were only a small fraction of 1984 DOE/EPA guidelines for uncontrolled areas. However, these exposures, when compared to EPA NESHAP standards which were promulgated on February 6, 1985, were higher than recommended for the off-site maximally exposed individual, but significantly lower for all other cases considered. Recent organizational and mechanical changes should preclude any further accidental losses of uranium and other radionuclides back into the environment similar to those which occurred during the fall of 1984. It is expected that these changes will also allow full compliance with the NESHAP standards referenced above.

Non-radioactive contaminants which are released during the normal operation of the facility were also monitored. The data and analyses shown in this report indicate that environmental concentrations of these contaminants were below established standards.

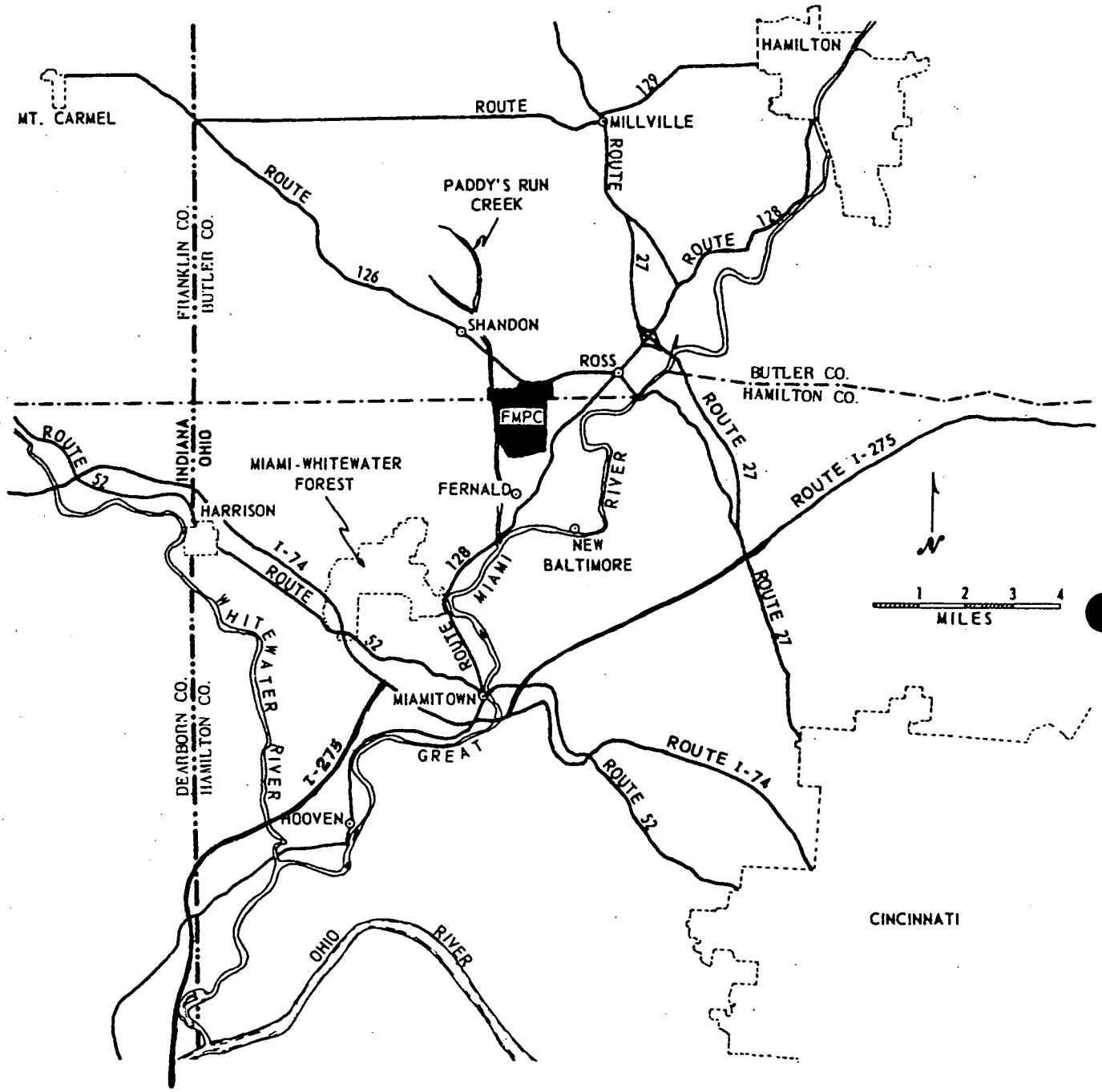

FIGURE 1 Area Map

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INTRODUCTION

The Feed Materials Production Center (FMPC) is an industrial facility owned by the United States Department of Energy (DOE) and managed by NLO, Inc., a private contractor. Located approximately 32 km (20 mi) northwest of downtown Cincinnati, Ohio, production operations cover approximately 55 hectares (136 acres) in the center of a 425 hectare (1050 acres) site. Several rural communities lie within a 1-5 km radius of the plant (Figure 1).

The primary function of the FMPC is the production of metallic uranium fuel cores and other uranium compounds for use at other DOE sites. The ^{235}U content of the purified end product may be depleted, normal, or slightly enriched, however the average content is close to normal. Normal uranium, as found in nature, is 0.71 percent ^{235}U.

The uranium production cycle may begin with ore concentrates, recycled uranium, or with a variety of other uranium compounds. Regardless of the type of material fed into the cycle, it is first dissolved in nitric acid and then extracted into a solution of tributyl phosphate and kerosene to separate the uranium from most of the impurities. A back-extraction process utilizing dilute nitric acid yeilds a solution of uranyl nitrate ($UO_2(NO_3)_2$ $6H_2O$).

Evaporation and heating convert the nitrate solution to uranium trioxide (UO_3) powder. Reduction to uranium dioxide (UO_2) and subsequent reaction with anhydrous hydrogen fluoride (AHF) results in the production of uranium tetrafluoride (UF_4). Uranium tetrafluoride reacted with magnesium (Mg) metal in a refractory-lined reduction vessel produces metallic uranium. This primary metallic uranium is then combined with scrap uranium metal and remelted yielding a purified uranium ingot which may then extruded to form

8

rods or tubes. Sections cut from these extrusions are machined to final dimensions and shipped to other DOE sites for canning and final assembly into reactor fuel elements. The end products may also be primary metallic uranium as well as castings of various shapes.

In the past, small amounts of thorium have been processed but none was produced in 1984. Thorium production processes are similar to those described for uranium. The final product may be in the form of thorium nitrate ($Th(NO_3)_4\ 4H_2O$) solution, solid thorium compounds or metallic thorium.

AREA GEOLOGICAL FEATURES

Glacial action during the time of the Illinoian and Wisconsin ice sheets left the area in much the same geological form as it is today. In the immediate area, outwash from retreating glaciers filled the remains of an ancient river valley. The Great Miami River, which runs in a southerly direction about 1 km east of the FMPC, cut its present course through this fill. The present river bed lies approximately 18 m below the original surface level of the glacial deposit. Nearly 15 m of clay-rich till underlies the FMPC. This is probably the remnant of a large glacial moraine. Beneath this is a wide (approximately 5 km) and deep (about 46 m) bed of sand and gravel.

The FMPC site topography is relatively level; an elevated plain some 177 m (580 ft) above sea level. The land rises slightly to the north (213 m elevation at the northern boundary) and, on the west, slopes downward to Paddy's Run (168 m elevation). Soils at the FMPC are generally characterized as Fincastle-Xenia silt loams grading into Fox-Gennessee and Russell-Xenia-Wynn loams at the western edge and northeast corner of the

site, respectively.

On-site vegetation is typical of that occurring elsewhere in the region under similar land-use practices. The on-site areas north and west of the plant are moderately wooded with a variety of deciduous hardwoods. Along the west side of the site and to some extent on the south, these wooded portions are found mainly along the natural watersheds. Several hectares immediately north of the production area were planted with white pine (Pinus strobus) and Austrian Pine (Pinus nigra). The major planting was done in 1973 as part of an environmental improvement project. The remainder of the site is covered with a variety of pasture grasses typical of the area and most of this is leased to local dairy producers for grazing purposes.

Although there are several small industries nearby, the major economic activities in the area are farming, dairying, and the raising of beef cattle. Major farm crops include sweet corn, field corn, soybeans, and wheat. Several nearby farms are also involved in the production of garden produce which is sold either at local roadside stands or trucked to nearby urban markets.

Due to the nature of the geology underlying the area, groundwater and gravel are also important area products which are sold commercially. A nearby water company (approximately 2 km upstream) which began operations just prior to construction of the FMPC pumps nearly 20 million gallons of water per day. This is sold chiefly to industries in and near Cincinnati. This aquifer, from which the FMPC also obtains its water supply, is recharged in part by the Great Miami River. Many gravel pit operations exist in the Great Miami Valley. These may be found both along the River and in the flood plain some distance inland.

Substantial amounts of industrial and municipal wastes from the upstream communities of Dayton, Middletown, Hamilton, and Fairfield are discharged into the Great Miami, and thus little recreational use is made of the river. Downstream areas of the river are sparsely settled and industries are small and scattered. The confluence of the Great Miami with the Ohio River is located approximately 29 km (18 mi) to the south of the FMPC.

Precipitation for the area averages 958 mm (37.7 inches) annually. 1984 was slightly above average with 969 mm (38.1 inches) total precipitation (measured as water) recorded. Monthly maximum and minimum values were 140.7 mm (5.5 inches) during the month of June and 20.3 mm (0.8 inches) during January, respectively.

ENVIRONMENTAL STANDARDS

Several sets of guidelines and standards are applicable to environmental sampling performed in connection with FMPC operations. These have been established by the DOE, the United States Environmental Protection Agency (EPA), and the State of Ohio Environmental Protection Agency (OEPA).

Contract operators, including NLO, Inc., were required, during 1984, to meet DOE guidelines for radiation protection[1,2]. Regulations in effect during 1984 provided separate guidelines for radionuclide concentrations in air and water in work areas as opposed to offsite areas which are not directly controlled by the DOE. For environmental monitoring purposes, DOE criteria for air and water in offsite areas were generally used as the standard of comparison, however the National Emission Standards for Hazardous Air Pollutants (NESHAP)[3], which became effective on February 6, 1985, were used in this report for comparison. Stream and river water samples are subjected to

the criteria established for offsite waters within the state even though we know of no use of water from either the Great Miami River or Paddy's Run for human consumption.

Criteria used for nonradioactive contaminants in ambient air and water from the Great Miami River and Paddy's Run are taken from standards adopted by the OEPA[4,5]. In the State of Ohio, water quality standards for rivers and streams apply only beyond a specified zone permitted for mixing and dilution of industrial and municipal effluents[5].

QUALITY ASSURANCE

Quality assurance must be an integral part of the overall environmental monitoring effort if our objectives are to be met. Included among the various interlaboratory quality assurance practices are daily calibrations of instrumentation and routine analyses of blanks, standard solutions, and spiked sample aliquots. The values obtained from these analyses are indicative of a well controlled analytical system. Similar results are obtained from the daily analysis of uranium control samples provided by another on-site analytical laboratory. NLO, Inc. also participates in the DOE Quality Assurance Program which is conducted by the DOE Environmental Measurements Laboratory (EML). As a part of this program, EML prepared samples are submitted to participating analytical laboratories for analysis. Results thus obtained are then compared with EML established values. During 1984 water, soil, and air filter samples were analyzed for uranium content. The average ratio between NLO, Inc. results and EML values established for these analyses was 1.14 (Range 0.91-1.32) which indicates good agreement.

Quality control samples provided by the United States Environmental Protection Agency's (USEPA) Environmental Monitoring and Support Laboratory in Cincinnati are also analyzed as part of the quality assurance program at NLO, Inc. Samples analyzed for pH, non-filterable residue, nitrate nitrogen, chloride, fluoride, and sulfate have all given results well within the guidelines recommended by the USEPA.

Overall quality control of the procedures used by the FMPC bio-assay laboratory has recently been assumed by the FMPC Analytical Laboratories Quality Assurance Section.

DATA ANALYSIS

Whereas the reader may be most familiar with data which are normally distributed (e.g., the typical bell-shaped curve), virtually all environmental and radiological data are log-normally distributed[6,7]. A log-normal distribution is one which is characterized by most of the data points lying at the low end of the scale. Thus, such a distribution would be graphically represented by a steep slope beginning at the left and then rising rapidly to the asymptote or apex followed by a gradual decline on the right. Such data, in order to be analyzed using standard statistical procedures, must first be transformed by some means to values which will tend to yield a normal (bell-shaped) distribution. This may be easily accomplished by using the logarithm of each data point rather than the actual data point itself.

The analysis of all data presented herein utilized standard statistical procedures after log-transformation of the raw data. In those cases where the distributional properties of the data were in doubt, D'Agostino's test for normality[8] was applied to both the raw and transformed data. In all

such cases, the dataset in question was found to be more nearly log-normal than otherwise.

The reader, if unfamiliar with log-normal statistics, should note that when referring to measures of dispersion about the mean, such limits are not applied as 'plus or minus' values, but rather as the mean multiplied or divided by (i.e., */, when appearing within the text of this report) the value listed in the table. This is an artifact of log-transformation of the original data prior to analysis. The 95% confidence limits were derived in accordance with Zar[8].

Where applied, the formulae for Student's t test for differences between sample means was as in Zar[8], as were the applicable formulae for ANOVA. All non-parametric tests used were as outlined in Conover[9]. Scatter diagrams on log-probability paper were constructed as described in Speer and Waite[10].

SAMPLE COLLECTION AND ANALYSIS

Air

Conversion of impure uranium and thorium compounds to reactor-grade feed materials involves operations which generate radioactive particulates and reaction products in an air stream. Ventilation and air cleaning systems are used to reduce the exposure of the employees to these particles and to reduce the emission of the particles to the atmosphere. As part of the normal reclamation program at the FMPC, the more valuable of these materials are returned to the production process.

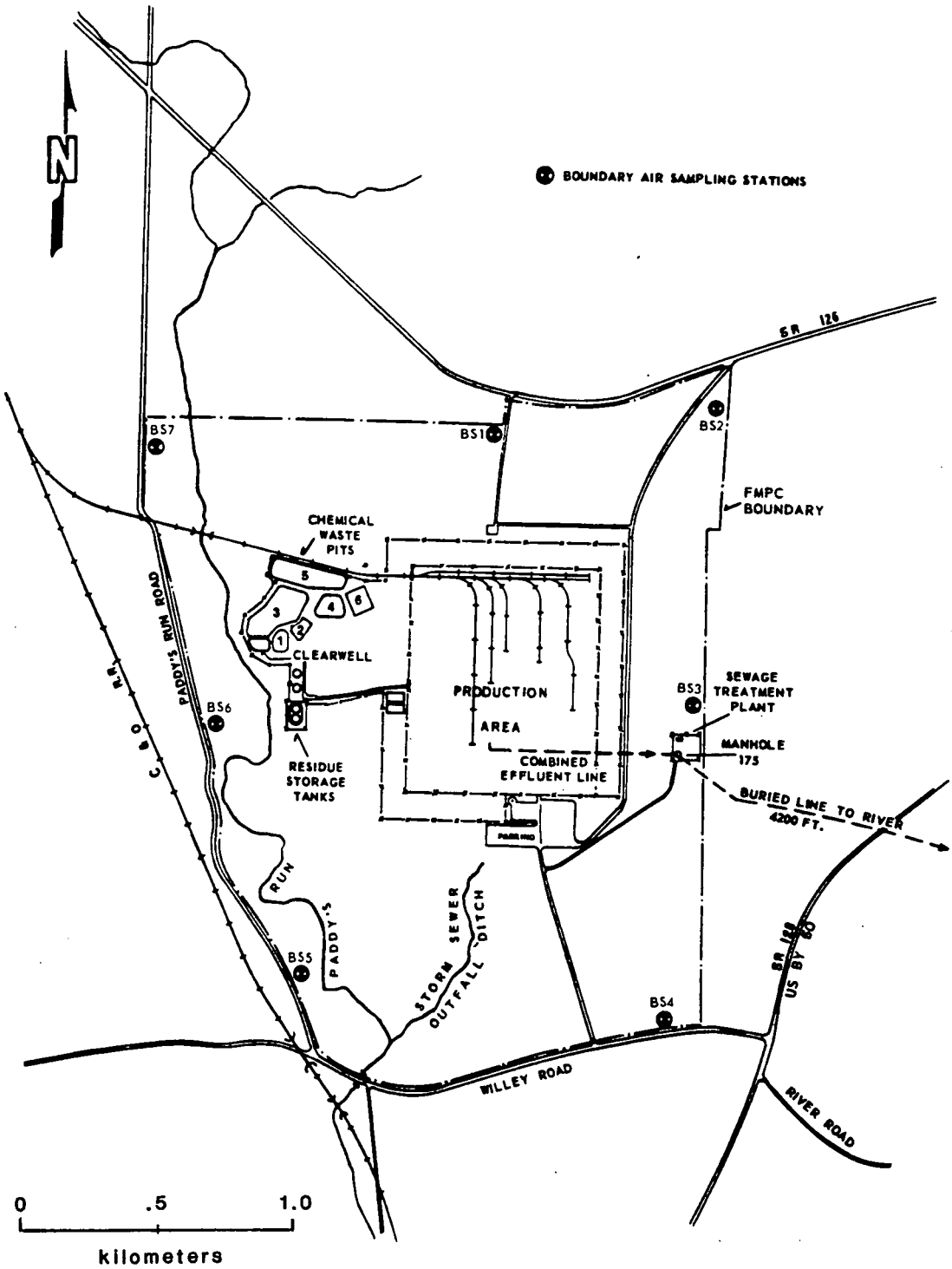


FIGURE 2 FMPC Site Map and Boundary Air Station Locations

Before release to the atmosphere, the air is filtered or scrubbed. A total of 2.65×10^{-1} Ci of uranium were emitted into the atmosphere during 1984. This is more than twice the 1.17×10^{-1} Ci emitted in 1983.

High volume air samplers located along the FMPC boundary collect continuous samples of airborne particulate matter (samples are collected and analyzed at weekly intervals). Seven such stations (see Figure 2) were in operation during 1984. At least three off-site stations will be installed during 1985. At each sampler, air was drawn through a 20 cm by 25 cm filter at a rate of approximately 1 m^3 $minute^{-1}$. Filters were accurately weighed before installation and after collection to obtain the weight of the particulate matter collected. Both filter and particulates were then dissolved in acids and the solutions were analyzed for uranium content and beta activity. Counting was done nine days after collection. A portion of each of these solutions were retained to provide a long-term composite which was used to detect the presence of trace radionuclides. More frequent analyses for these other radionuclides (e.g., ^{237}Np, ^{239}Pu, and ^{232}Th) were not considered necessary due to the extremely small amounts of these elements present on site and as evidenced by analysis of the sample solution.

Average uranium concentrations and beta activity from the various radionuclides present in the air samples are shown in Table 1. A comparison was made between 1983 data and that obtained in 1984. No significant differences were noted in uranium levels between the two years, however beta activity at BS2 and BS3 was significantly higher ($0.02<p<0.05$) in 1984 than in 1983. This difference was probably due to elevated levels of ^{234}Pa and ^{234}Th in connection with the accidental stack losses of November and December, 1984, as there was close temporal correlation between elevated beta levels and actual stack losses.

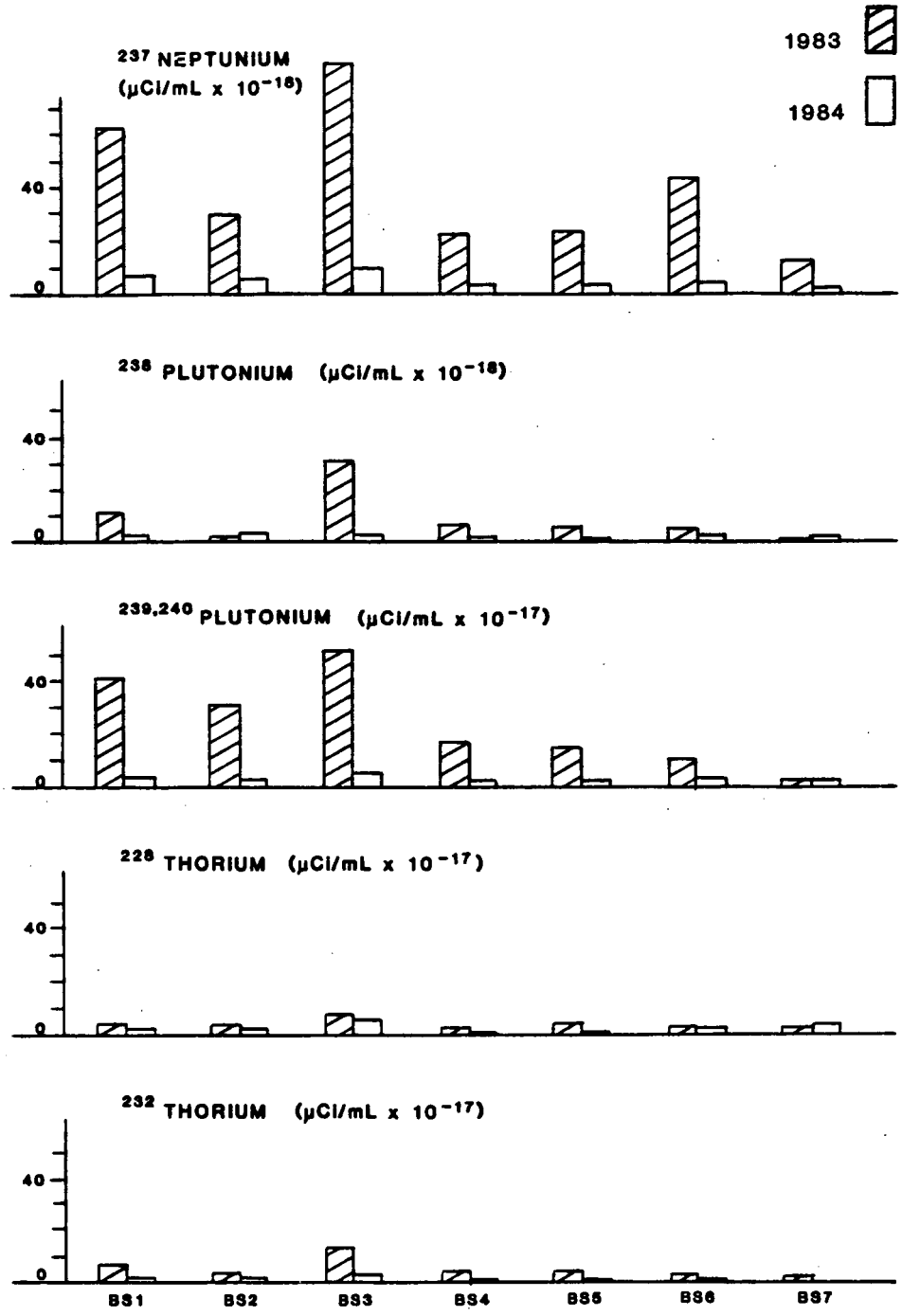


FIGURE 3 A Comparison of Non-uranic Radionuclide Concentrations in Air: 1983 vs. 1984

Trend analyses (Daniel's test for trend)[9] of average uranium levels for each quarter of 1982 through 1984 showed a significant upward trend ($0.025<p<0.05$) at BS2. This could be attributable to a shift in prevailing wind direction during this period of time. Similar analyses regarding beta activity, however, indicated a downward trend, over time, at BS5 ($0.025<p<0.05$).

Data regarding the airborne trace radionuclides encountered on site are also presented in Table 1. 1984 levels were generally much lower than those measured in 1983 (see Figure 3). ^{230}Th was included in this year's analysis in addition to those radionuclides presented in previous years. Concentration levels of additional nuclides will be quantified in 1985 as part of a continuing effort to further enhance the environmental program at the FMPC.

Radon (^{222}Rn) is a naturally occurring element which is produced from the decay of radium (^{226}Ra), also a natural element which is found in soils and rock. As in 1983, concentrations of ^{222}Rn, were monitored at 7 on-site and 2 off-site monitoring stations using commercially available track-etch devices. Results are shown in Table 2. Statistical analysis of the data indicated that there was no difference between on- and off-site levels. Typical background levels of ^{222}Rn range between 0.2 and 0.35 pCi per liter of air and background levels are included in the data presented in Table 2. Thus, these data indicate that any contaminant levels attributable to FMPC operations are well below those established by regulatory agencies.

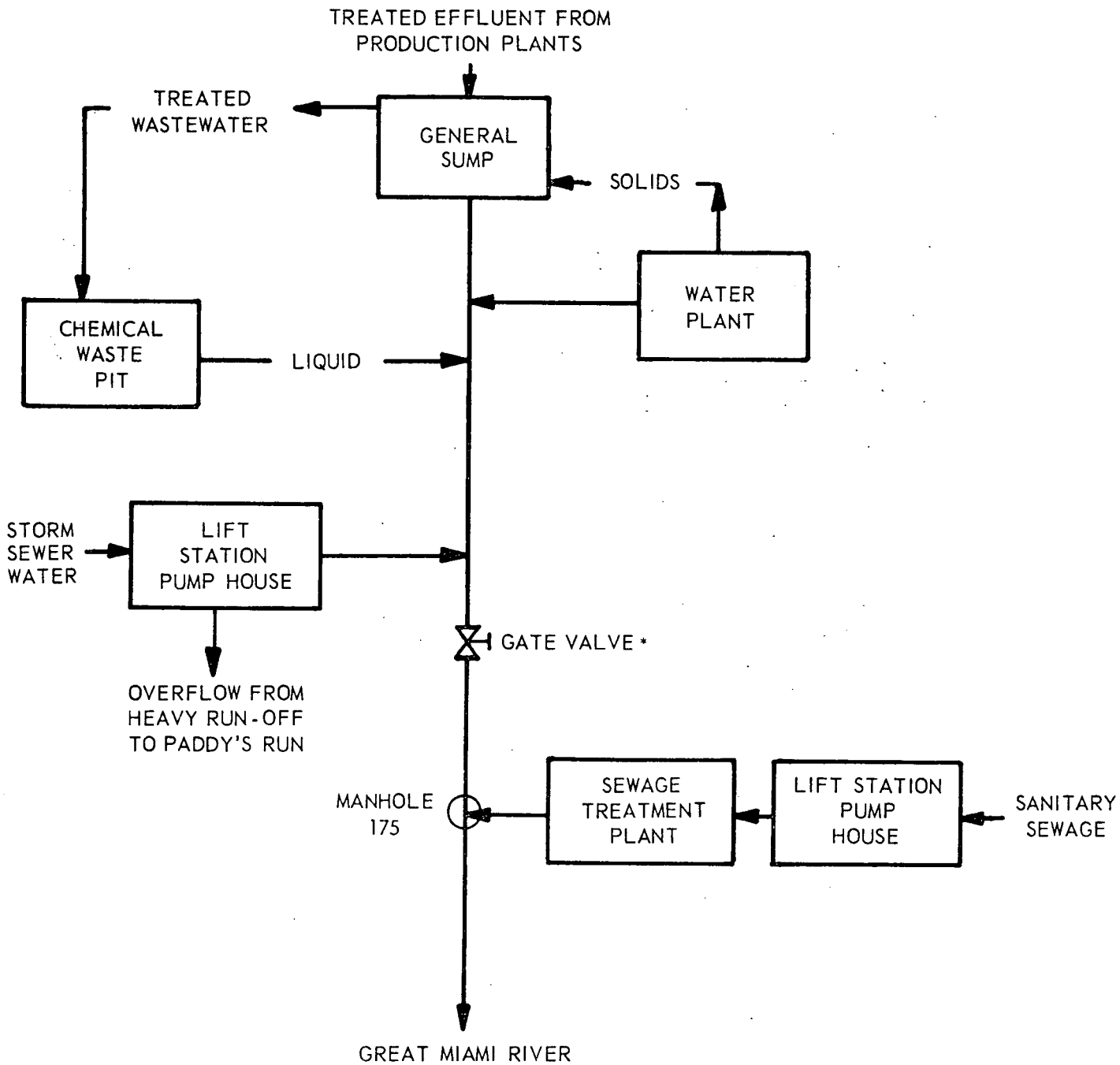
In addition to those data collected by the FMPC, data were collected by the Monsanto Research Corporation (MRC), Miamisburg, Ohio during the period from 20 September 1984 to 5 February 1985 using a device which employed a charged thermoluminescent dosimeter. These data show radon levels during this time

period to be lower than averages shown in Table 2. At BS2, BS3, and BS4, MRC data indicated average readings which were within the range of normal background.

Surface Water

Each of the major production plants on the project has sumps and equipment for the collection and initial treatment of process waste water. Uranium is collected for recycling as part of this treatment. Effluents from each plant are collected at a centralized facility, the General Sump, for additional treatment. Treated wastes are allowed to settle and clear before final disposition. Clear supernatant from the settling tank and clear effluent from the pit are combined with other water streams and discharged into the Great Miami River in accordance with permits issued under the National Pollutant Discharge Elimination System (NPDES). Analyses are performed on the effluent stream to assure complaince. Analytical procedures are outlined in the next paragraph. A diagram of the waste water treatment process is shown in Figure 4.

Water sampling locations are shown in Figure 5. At the final access point on the effluent line, W2, a Parshall Flume type water sampler continuously collects a sample which is proportional to the total flow. Samples (24 hr composites) were collected daily and analyzed for uranium, alpha and beta activity, and pH. Analyses for chlorides, fluorides, and nitrates were conducted on one sample each week. One-month composites of the daily samples were analyzed for ^{226}Ra, ^{228}Ra, ^{106}Ru, and thorium. Annual composites were analyzed for other radionuclides of interest. From sampling point W2 the plant effluent is discharged into the river through a buried pipeline.



**Storm sewer water can be diverted to the Chemical Waste Pit or the General Sump by first halting the pumping from both locations and then closing the gate valve.*

FIGURE 4 Liquid Waste Stream Flow Diagram

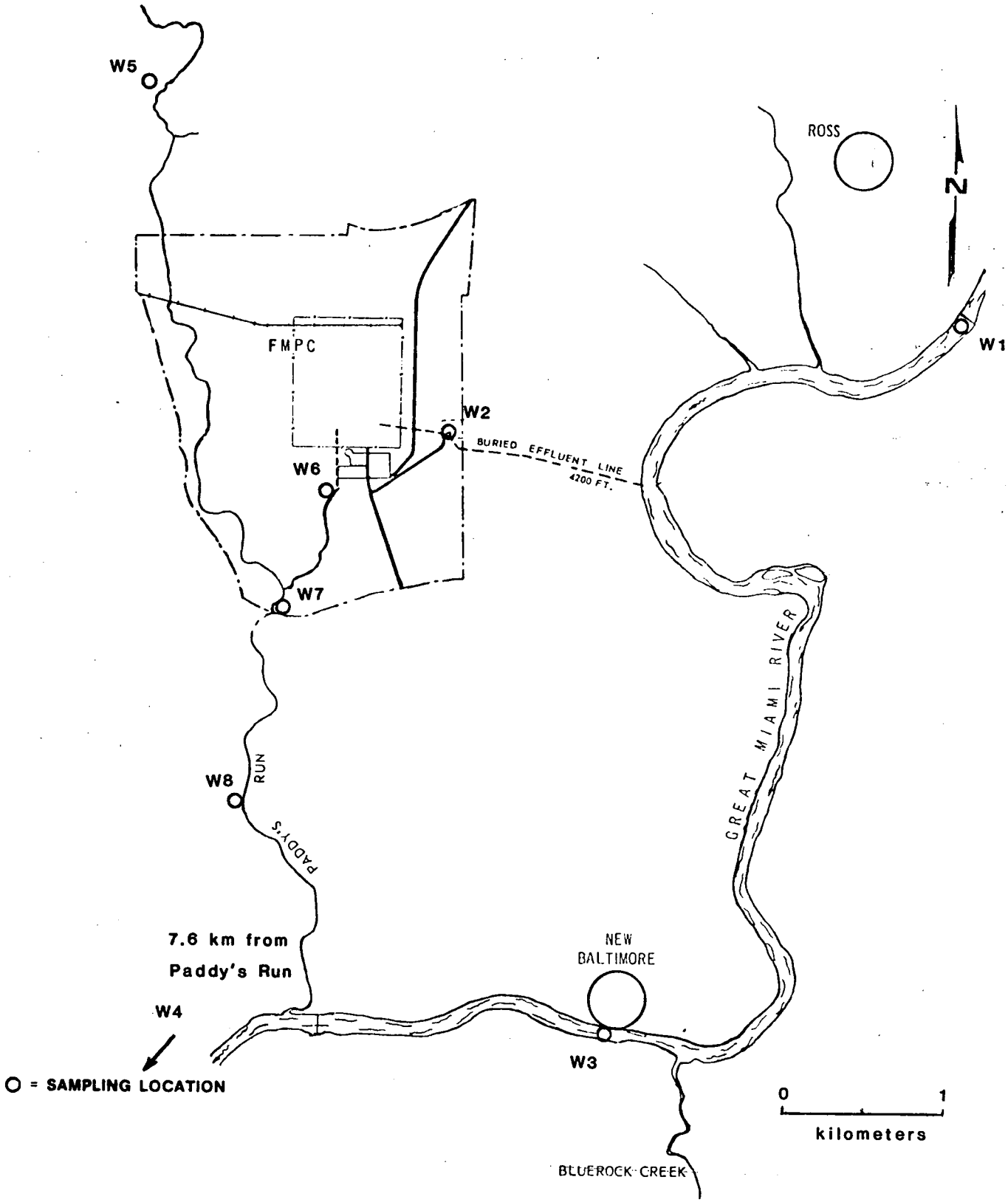


FIGURE 5 Surface Water Sampling Locations

Daily grab samples were collected at river sampling points W1 (upstream) and W3 (downstream, see Figure 5). These were combined monthly for radium analyses. A weekly grab sample was collected at point W4 (Miamitown) 7.5 km downstream from the confluence of Paddy's Run with the Great Miami River. At least one sample per week from each of the three river sampling points was analyzed for uranium, alpha and beta activity, chloride, fluoride, nitrate, non-filterable solids, and pH.

Paddy's Run is a small ephemeral stream lying along the west site boundary which joins the Great Miami River a little more than 3 km south of the FMPC. During periods of heavy runoff, excess water in the storm sewer system overflows at point W6 to a natural drainage ditch which discharges into Paddy's Run at a point just above W7.

Grab samples were collected weekly from each Paddy's Run sampling location (W5 and W7, or W8 if no water was available at W7, as shown on Figure 5). These samples were analyzed for uranium, alpha and beta activity, and pH. Chloride, fluoride, and nitrate analyses were performed on one sample each month. ^{226}Ra and ^{228}Ra analyses were performed on bimonthly composites of water collected at W5, and, when available, on monthly composites collected at W7.

Radionuclide concentrations in Paddy's Run and the Great Miami River are shown in Table 3. Although average concentrations appear lower than in 1983, most were similar for the two year period. The lower values noted in 1984 are, in most cases, merely an artifact of using log-normal statistics. Arithmetic means were reported in and prior to 1983. As in previous years, all average levels were lower than established DOE guidelines with only a few greater than 2% of the applicable limit. As noted in Table 4, radionuclide

concentrations in the FMPC plant efluent stream were also well within established DOE guidelines, ranging from a high of 3.62 percent to a low of <0.0001 percent of the guidelines.

Non-radioactive contaminant levels in Great Miami River and Paddy's Run waters (Table 5) were generally similar to or lower than in 1983. Only fluoride at Sampling Points W5 and W8, nitrate nitrogen at W8, and chloride at W7 were higher, but not significantly so. Samples were not collected at Sampling Point W6 during the year. This station was temporarily dismantled due to construction of a new stormwater retention pond.

Soil

As part of the normal monitoring program, soil samples were collected from each of 15 on- and off-site locations (Figure 6) twice during the year. Each sample was made up of a composite of 9 cores 2 cm in diameter and 5 cm deep, but exclusive of plant matter insofar as this was possible. The cores were taken from the top layer of the soil profile with one core being obtained from each coordinate of a 4 m^2 grid.

Soil samples from each of the 15 regular sites were analyzed only for uranium in order to observe the possible contribution fallout from stack effluents may make to uranium concentrations in the soil. Results are shown in Table 6.

During the summer of 1984, 105 additional samples were taken at points located outside the FMPC boundary. This was done in order to construct a surface map showing the uranium concentration profile in the top 5 cm of soil. The results of this study are shown on Figure 7. The above-background uranium concentrations shown immediately to the east of the FMPC

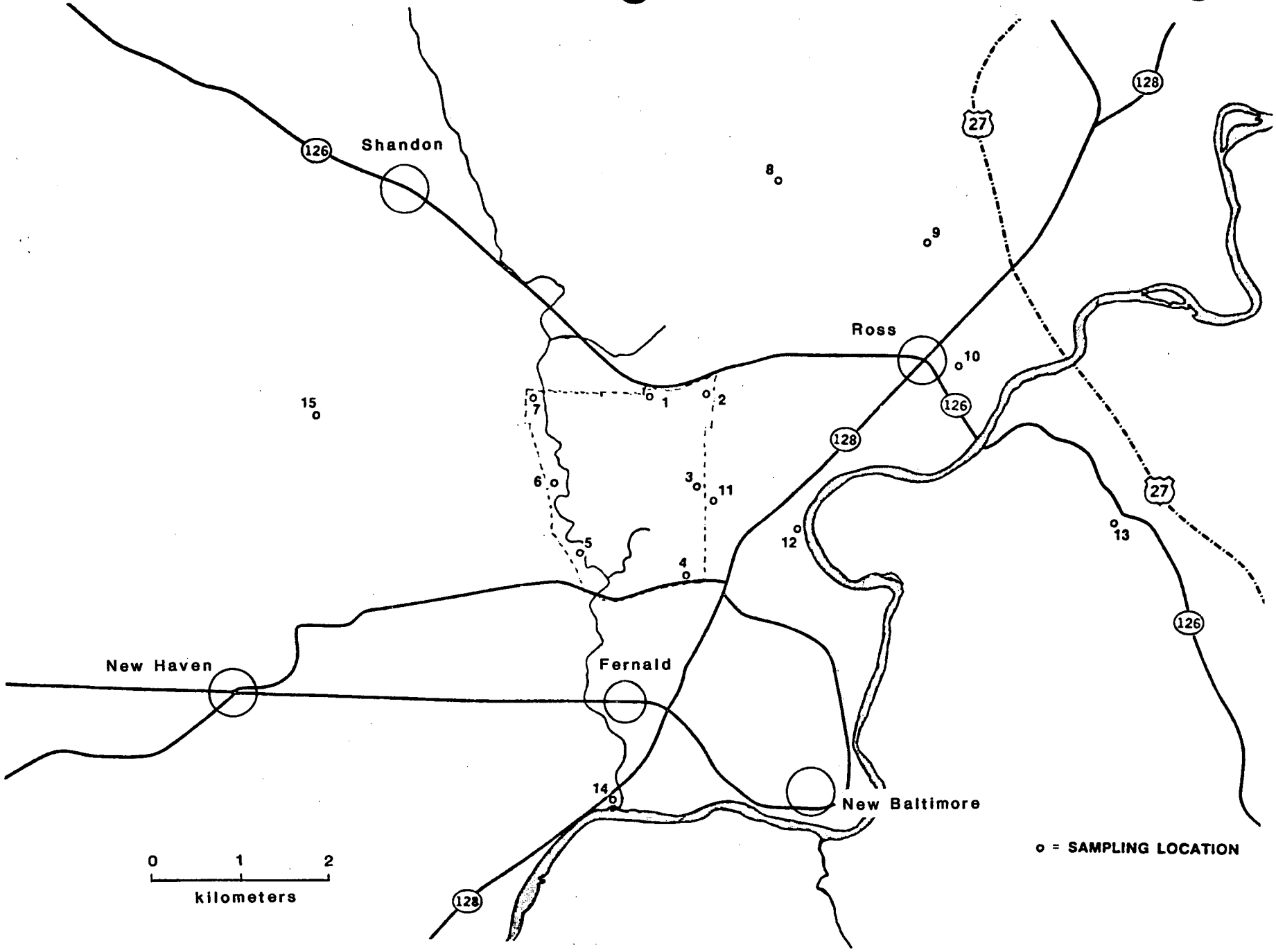
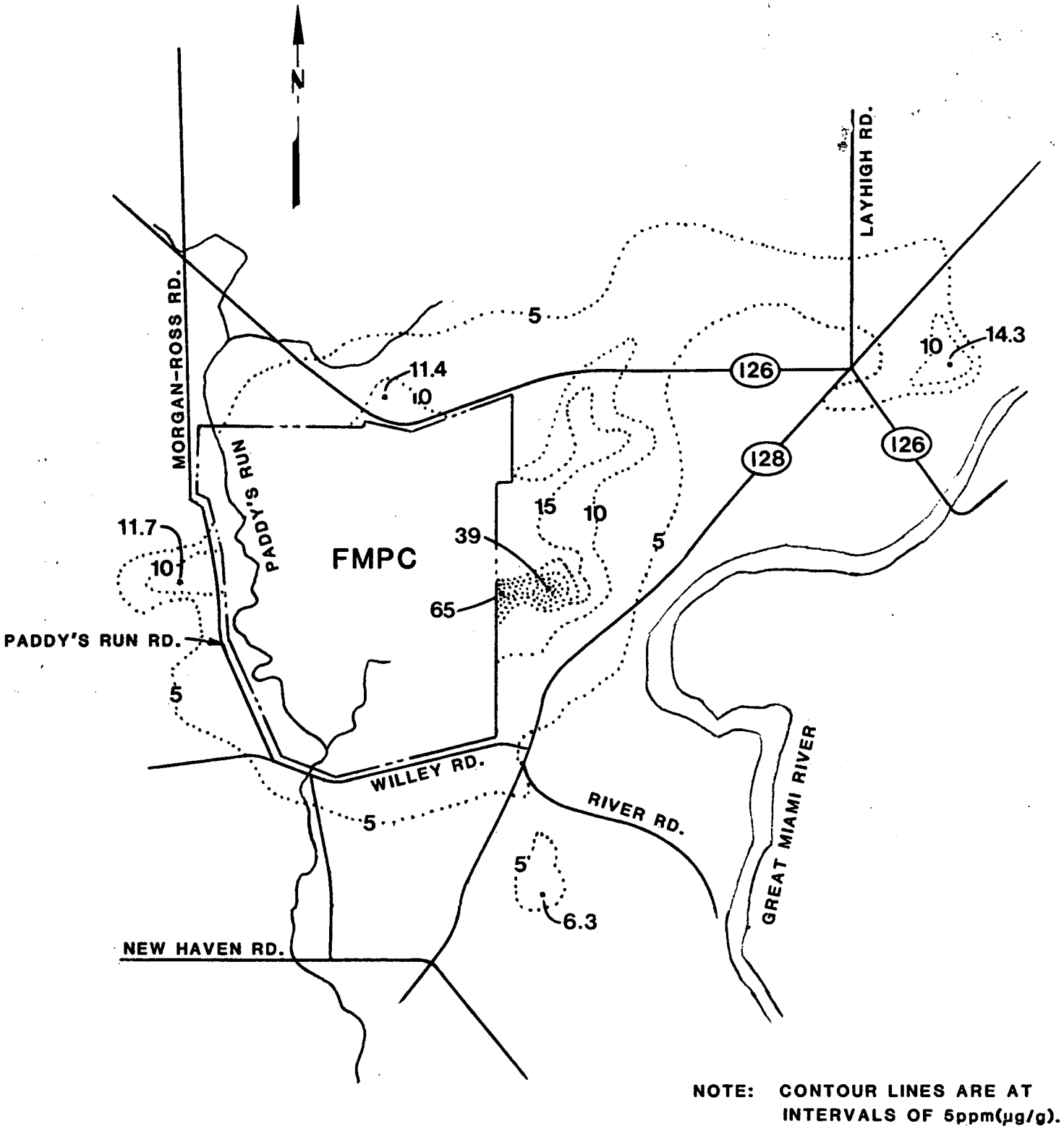


FIGURE 6 Routine Soil Sampling Locations



NOTE: CONTOUR LINES ARE AT INTERVALS OF 5ppm(μg/g).

FIGURE 7 Uranium Levels in Soils Adjacent to the FMPC

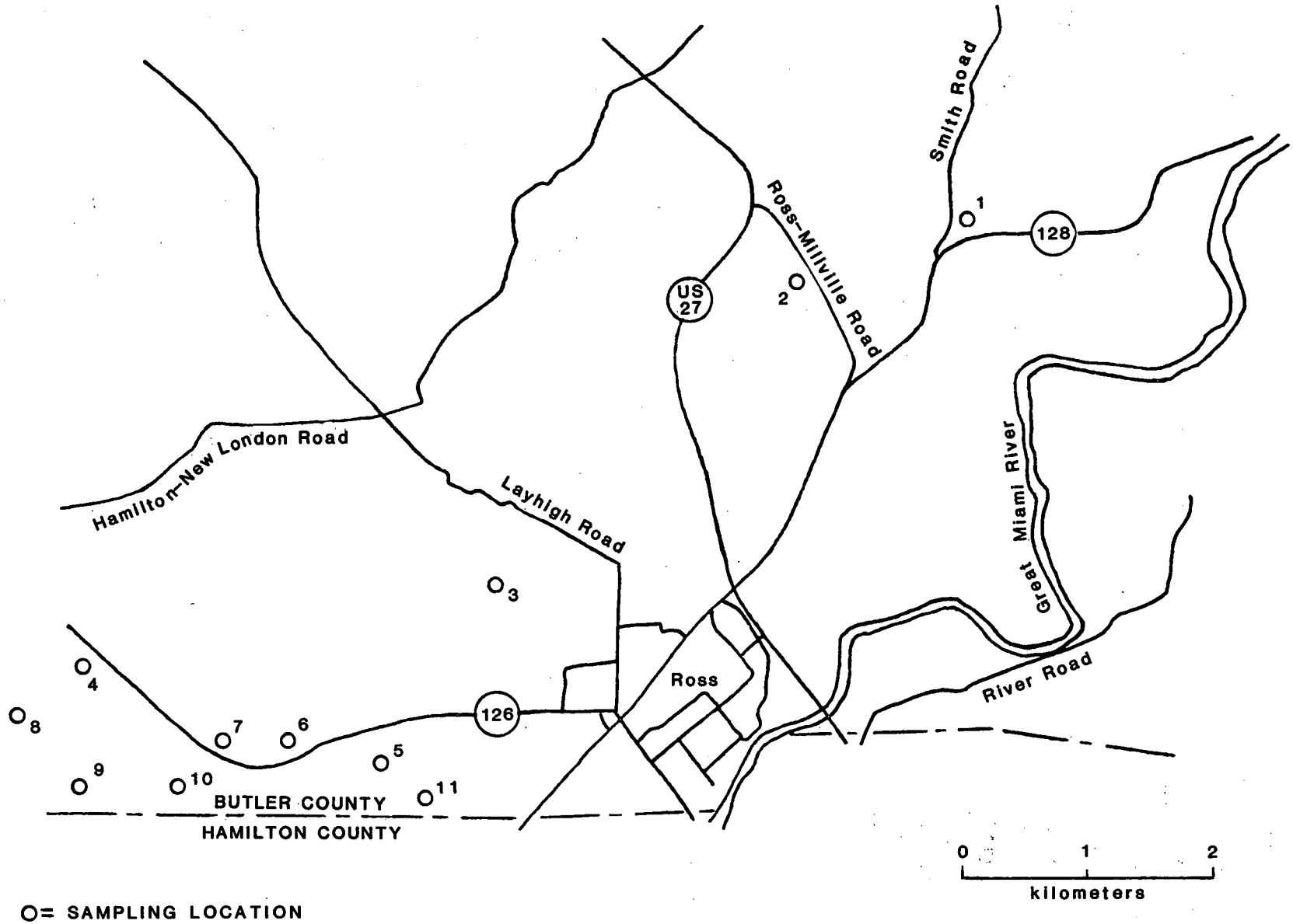


FIGURE 8 Non-routine Soil Sampling Locations: Butler County, Ohio

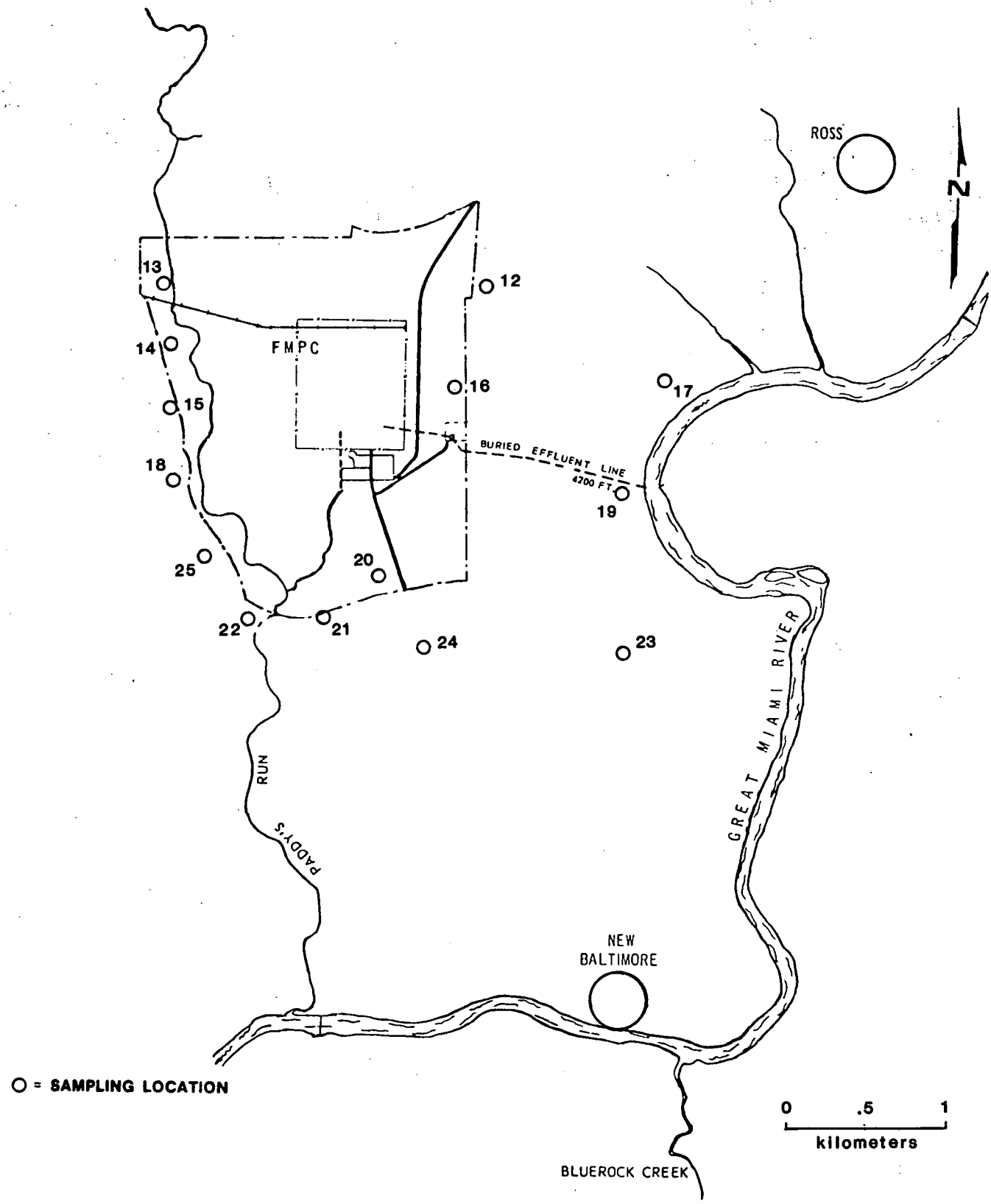


FIGURE 9 Non-routine Soil Sampling Locations: Hamilton County, Ohio

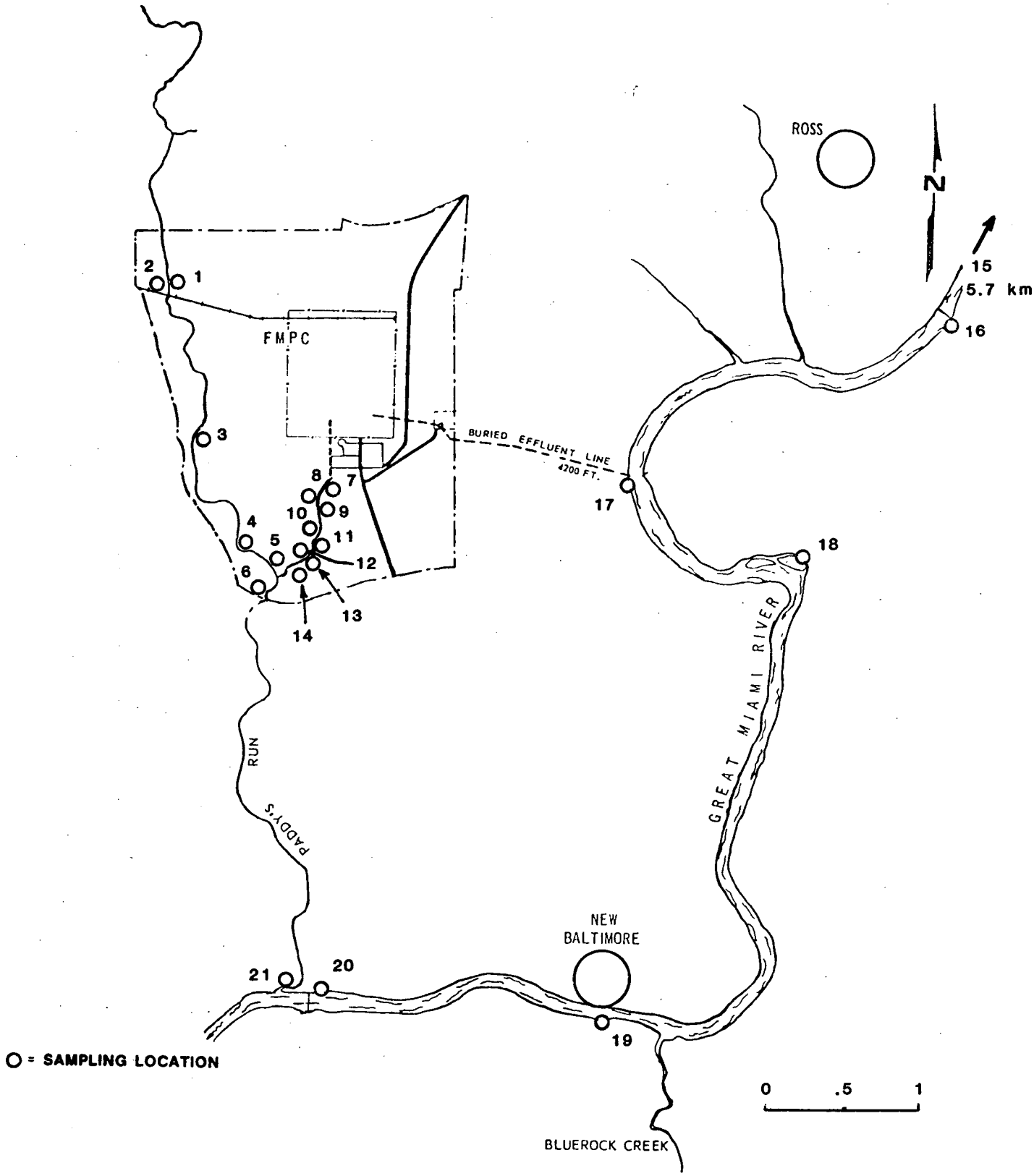


FIGURE 10 Sediment Sampling Locations

boundary are probably artifacts of the former operation of an incinerator adjacent to the sewage treatment plant, and while above recommended levels, have been declining each year. This decline is probably due to the transmigration and concomitant dilution of the uranium present in the soil profile.

The high point located on the east side of Ross, Ohio (14.3 ppm) is a reflection of the fact that a major portion of this particular sample was made up of cinders (residue from burning coal) which typically contain higher concentrations of uranium than does soil and would not be related to FMPC operations.

Concentrations less than 5 ppm were not shown as uranium concentrations of from 1 to 4 or 5 ppm are typical in southwestern Ohio soils depending on the location sampled.

No standards have been established for soil radionuclide levels other than guidelines relative to burial of radioactive contaminants. The FMPC uses 35 pCi(U) g^{-1} (52 ppm) of soil as a reference point, this being the level generally used in the DOE's remedial action programs for acceptance of decontaminated areas.

Although FMPC operations do not produce any of the plutonium isotopes as a by-product, some of the scrap material processed may include trace quantities of plutonium, thus, in addition to the above analyses, 25 of the 105 additional samples (see Figures 8 and 9) collected were analyzed for ^{238}Pu and $^{239,240}Pu$ as well as for ^{237}Np, ^{99}Tc, ^{228}Th, ^{230}Th, and ^{232}Th. The results of these analyses are shown in Table 7.

Sediment

Sediment samples were collected semi-annually from selected locations along the Great Miami River, Paddy's Run, and the Storm Sewer Outfall Ditch. As technetium had previously (1983) been found to be present in trace quantities in some of the materials sent to the FMPC for uranium recovery, some sediment samples have been analyzed for ^{99}Tc as well as uranium since that point in time to determine the affect FMPC operations may be having on this segment of the environment. Sediment sampling locations were as shown on Figure 10.

As can be seen in Table 8, the uranium concentrations in on-site sediments vary greatly both in space and time. The temporal variation is likely due to the flushing action of seasonal rainfall. The variation between sampling points is a little more difficult to explain. In those cases relating to the variation observed in the storm sewer outfall ditch sediments (Sampling Points 7-14), much is probably due to variation in distance of flow before the water percolates downward into the sand and gravel. This is a function of precipitation quantity and duration.

The following actions are to be taken prior to the collection of samples during the first half of 1985: (1) permanent steel posts will be erected at all Paddy's Run and storm sewer outfall ditch sampling points, (2) an improved method will be used for sample collection, and, (3) each particle size class within a sample will be analyzed separately.

Uranium concentrations in sediment samples collected from off-site locations (Table 9) are indicative of background levels commonly found in the area and there were no significant differences between sediments from upstream and downstream locations. While there is some indication of elevated levels of

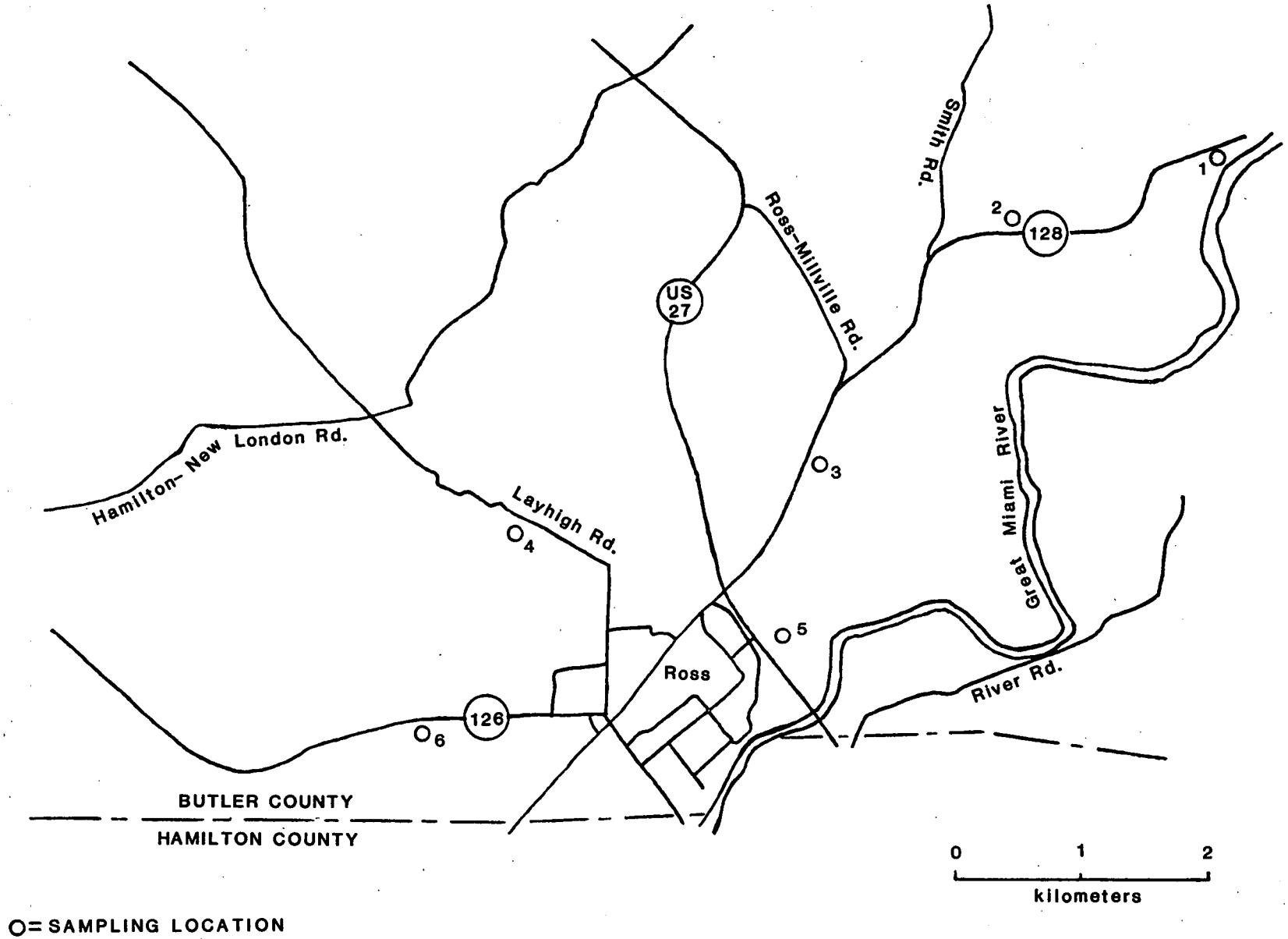


FIGURE 11 Grass and Forage Sampling Locations:
Butler County, Ohio

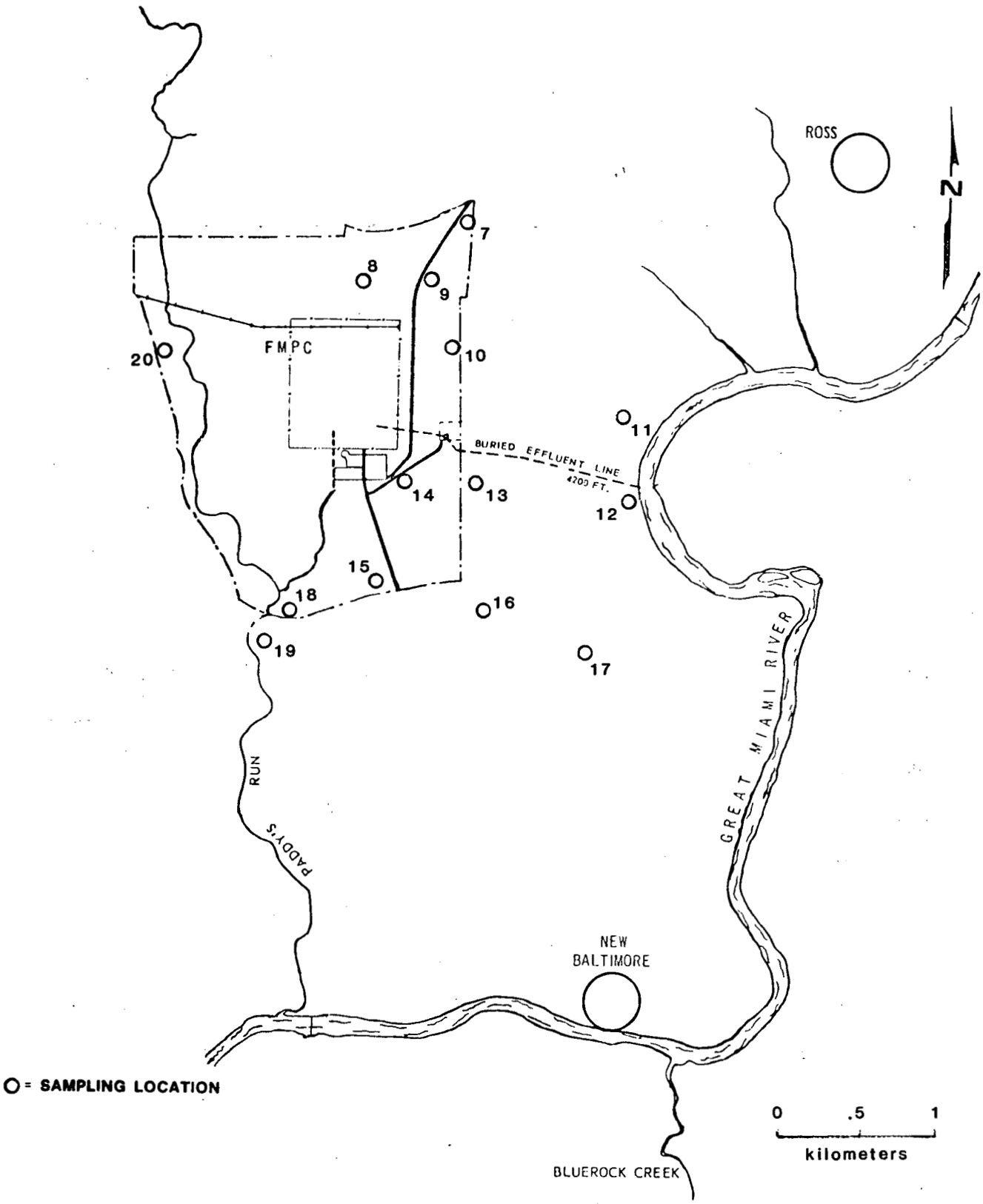


FIGURE 12 Grass and Forage Sampling Locations: Hamilton County, Ohio

^{99}Tc in the storm sewer outfall ditch (Table 8), samples from other areas are similar to one another and, like uranium concentrations, probably are representative of background concentrations for area sediments.

Trend analyses of uranium concentrations noted during the past ten years in sediments from the storm sewer outfall ditch, Paddy's Run, and the Great Miami River (where sufficient data were available for analysis) generally indicated no change. Whereas upward trends were indicated at Sampling Points 5, 6, 19, and 20, such trends were only significant at Sampling Points 5 ($0.01<p<0.02$) and 19 ($0.002<p<0.01$). A general downward trend was detected at Sampling Point 1.

Grass and Other Forage

During the fall of 1984, samples of grass and other available forage were collected from randomly selected sites (see Figures 11 and 12). Each sample was a composite of a number of sub-samples sufficient to provide approximately 500 g (wet weight) total. Each sub-sample consisted of all above ground plant material (material was clipped at ground level +2 cm using battery charged grass shears) from a 0.5 m diameter circular quadrat (5 such sub-samples = 1 m^2 of ground cover). After collection, the samples were air dried and subsequently shipped to independent laboratories for analysis. Each sample was analyzed for fluoride and uranium content. This routine will be performed at least three times during the 1985 growing season to assess the impact FMPC operations may have on the pasture-cow-milk foodchain.

Results for 1984 are shown in Table 10. Although no standards for either uranium or fluoride levels in grass and other forage have been established

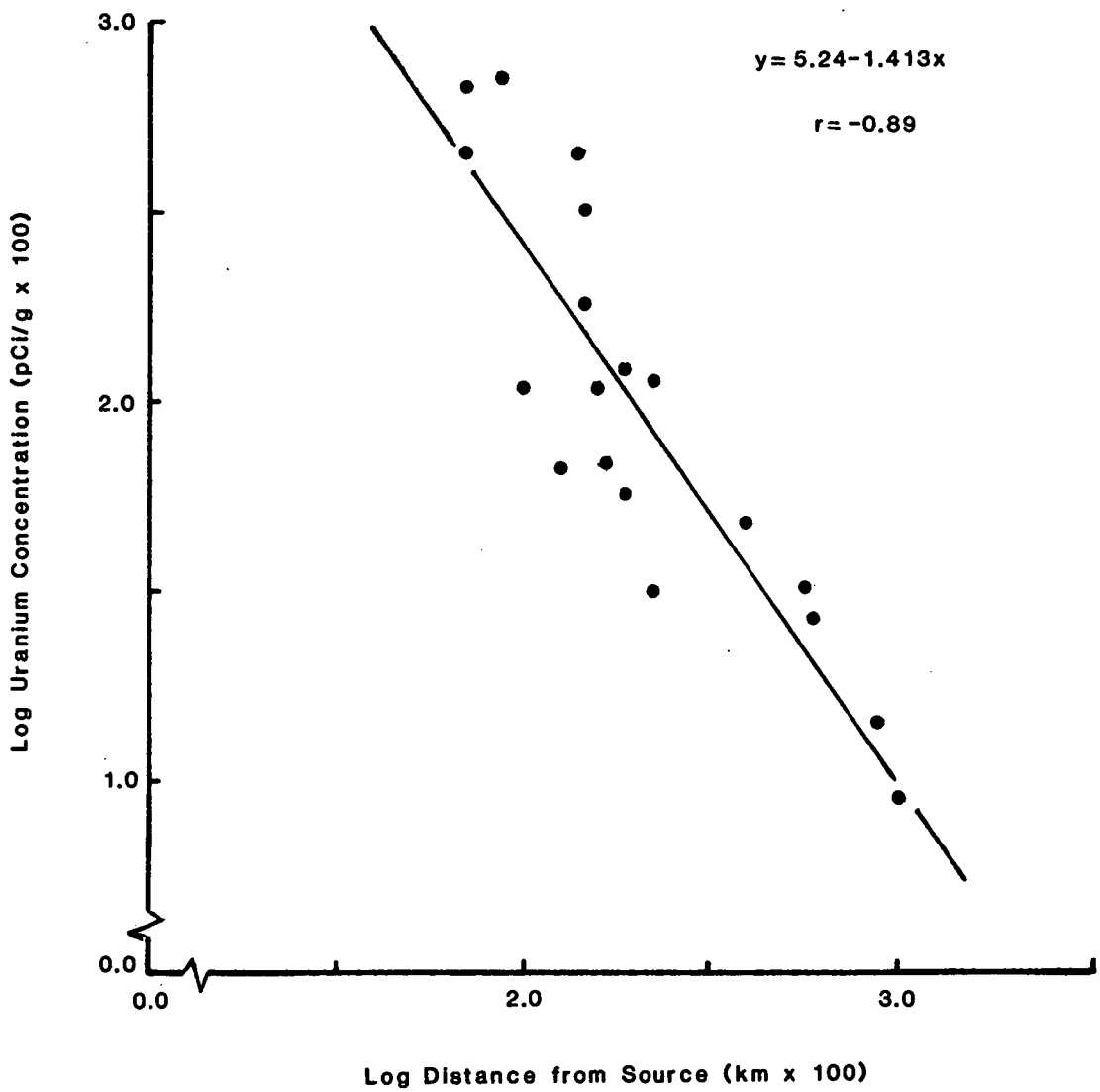


FIGURE 13 Uranium Concentration in Forage vs. Distance from Source

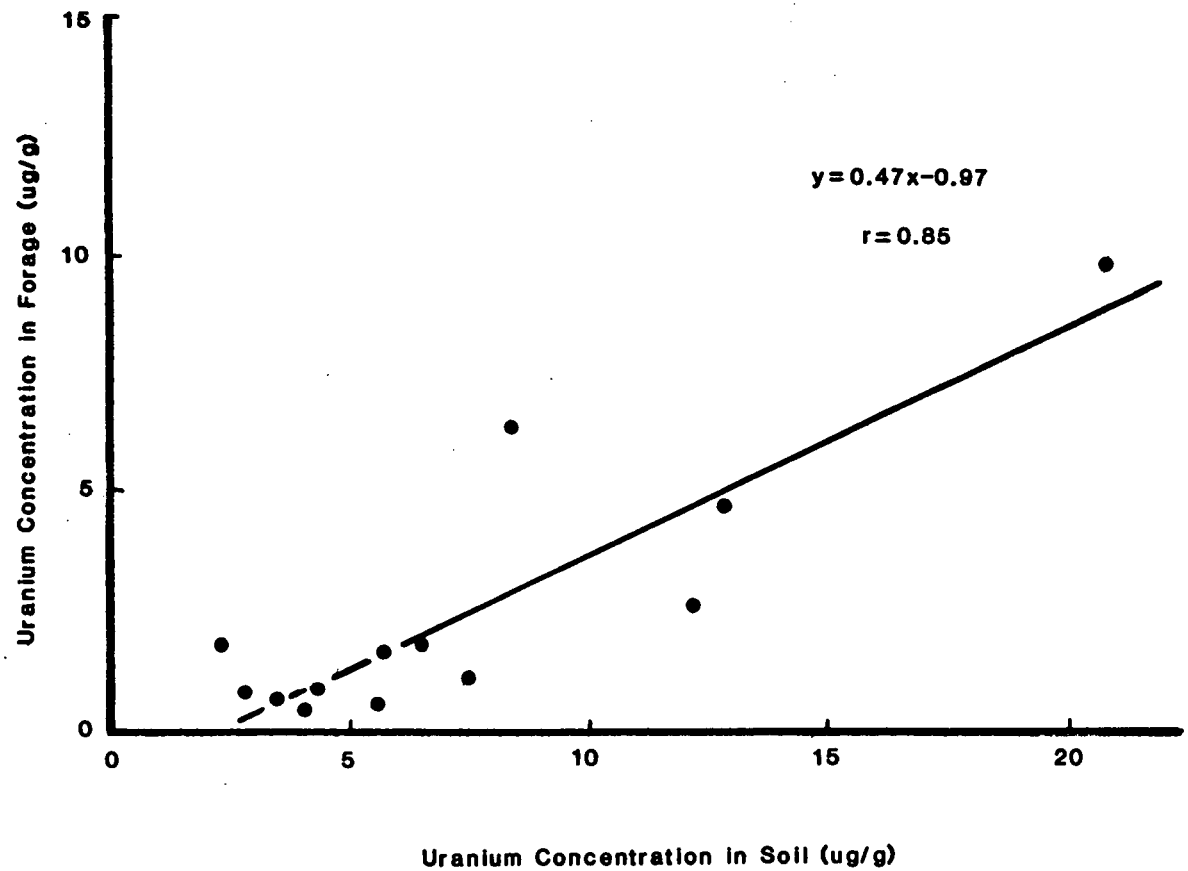


FIGURE 14 Correlation Between Uranium Concentration in Soil and Forage

by the Ohio Environmental Protection Agency, Kentucky has established levels for both gaseous and non-gaseous fluorides. The DOE plant at Paducah, Kentucky thus falls under this regulation. Kentucky Air Pollution Regulations allow up to 80 ppm (one-month average) fluoride (as fluoride ion) in and on forage for consumption by grazing ruminants. When measured over the 6-month growing period, 40 ppm are allowed.

The mean fluoride level detected in the FMPC samples was 9.3 (*/ 1.14) ug g^{-1} which is well below both values. The average uranium concentration was 1.49 ug g^{-1} (1.0×10^{-6} */ 1.80 uCi g^{-1}) dry weight. There was no correlation between the observed fluoride concentration at each sampling point and the distance of that point from the source. The opposite was true for uranium concentrations as data showed decreased levels of uranium in plant material with increased distance from the plant site (Figure 13). This relationship was not linear, however. There was also good positive correlation between uranium levels in grass and soil as would be expected (Figure 14).

Garden Produce

Methodology for collection and sampling of locally grown produce was changed during 1984. Potatoes were determined to be the best locally available source for measuring the possible introduction of uranium into the food chain via vegetable matter[11]. Consequently, 5 replicate samples were collected from area farms and gardens (Figure 15). Six replicates collected from Indiana, Kentucky, and Michigan locations were used as a control (background) sample. Peels were analyzed separately from the meat, but both were analyzed for uranium content. Results of these analyses are displayed in Table 11.

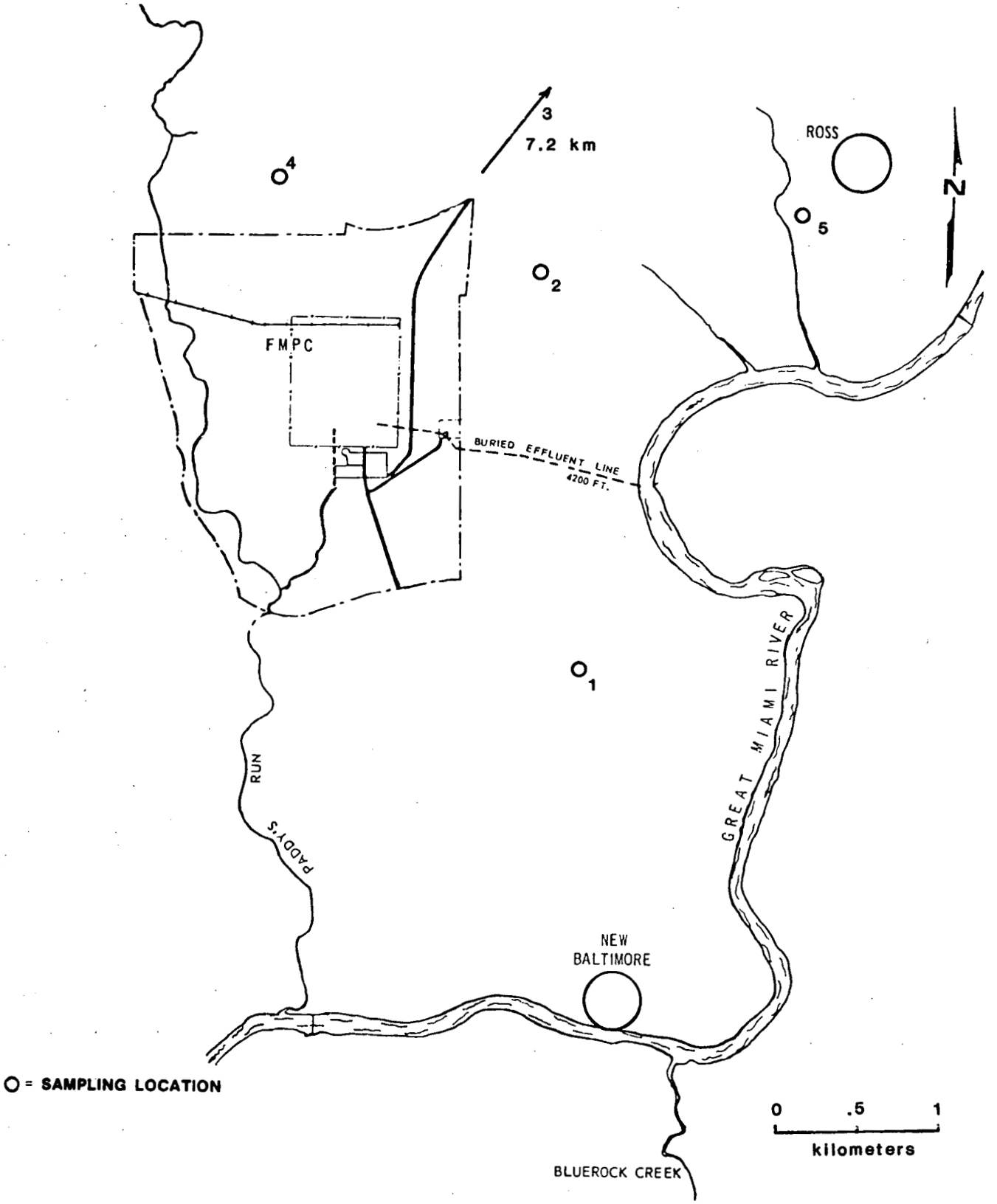


FIGURE 15 Sampling Locations for Garden Produce

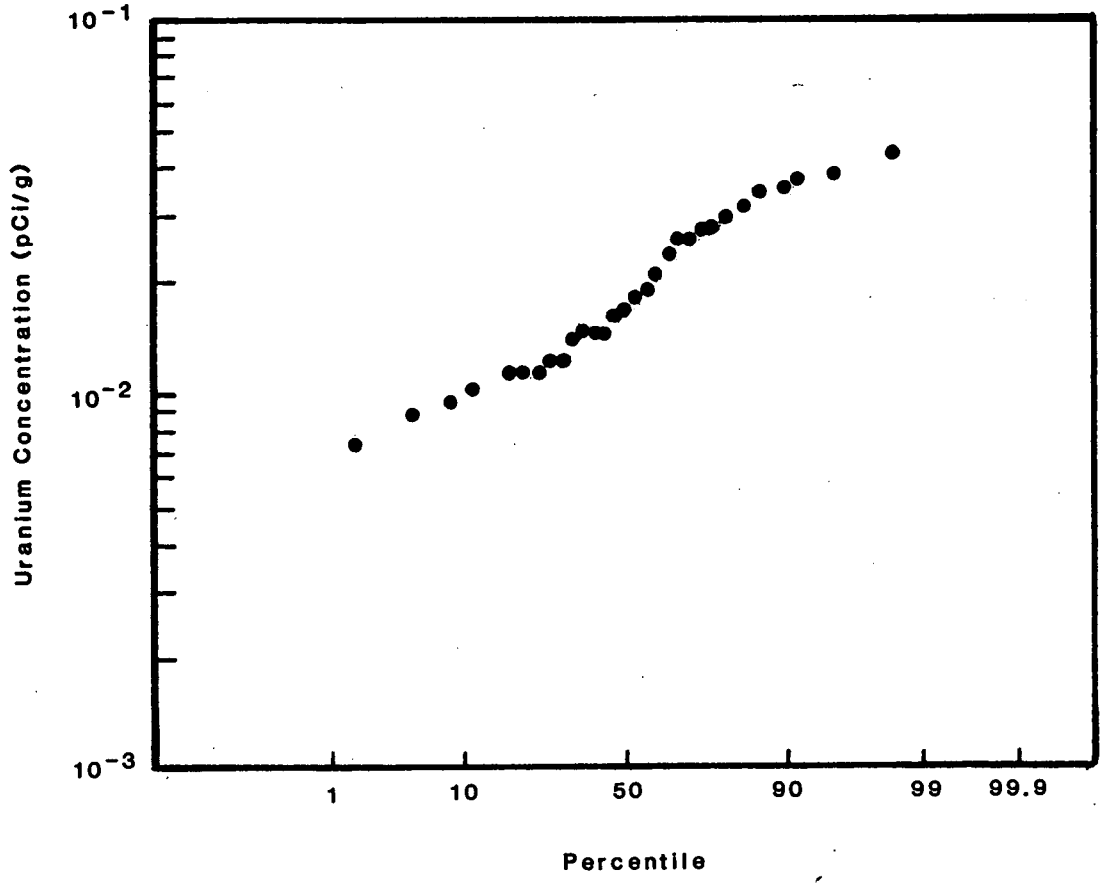


FIGURE 16 Uranium in Potatoes: Skins Only

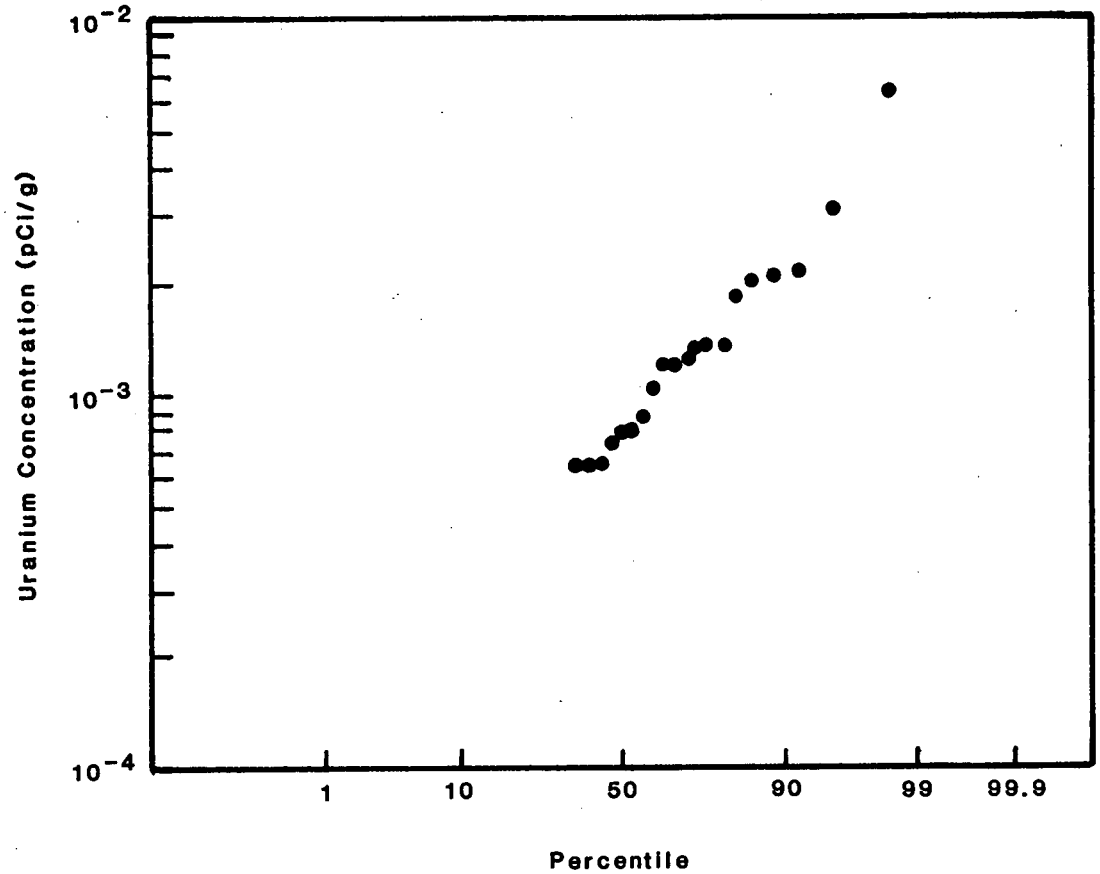


FIGURE 17 Uranium in Potatoes: Less Skins

Whereas analysis of variance revealed a significant difference between the peels from sample 4 and those of samples 2 and 5, none of these were significantly different from the control (background) sample. There were no significant differences between mean uranium concentrations in the flesh of any of the six samples of potatoes. Both analyses indicate that FMPC operations had no apparent affect on uranium concentrations in garden produce. Figures 16 and 17 indicate that all samples in each category were from a single distribution.

Milk

Milk produced by cows grazing on FMPC and adjacent pasture land was collected and analyzed on a quarterly basis. A similar sample was collected concurrently from a remote site 29-30 km southeast of the FMPC for comparison purposes. No detectable quantity of uranium was present in the samples from the two locations during 1984 (Table 12).

Fish

With the aid of a fisheries research team and electroshocking equipment from the University of Cincinnati, fish were collected from three areas of the Great Miami River (Figure 18) in early October, 1984. A total of 481 fish representing 18 species were taken: 105 from sampling location 1, 113 from location 2, and 263 from location 3. The fish from each location were placed in plastic bags, packed in ice, and subsequently scaled and prepared as for human consumption (heads and entrails removed, filleted if total weight was above 800-900 grams). They were then frozen, packed in dry ice, and shipped to an independent testing lab for analysis. Only uranium concentrations were analyzed in 1984. Results of the analyses are listed in

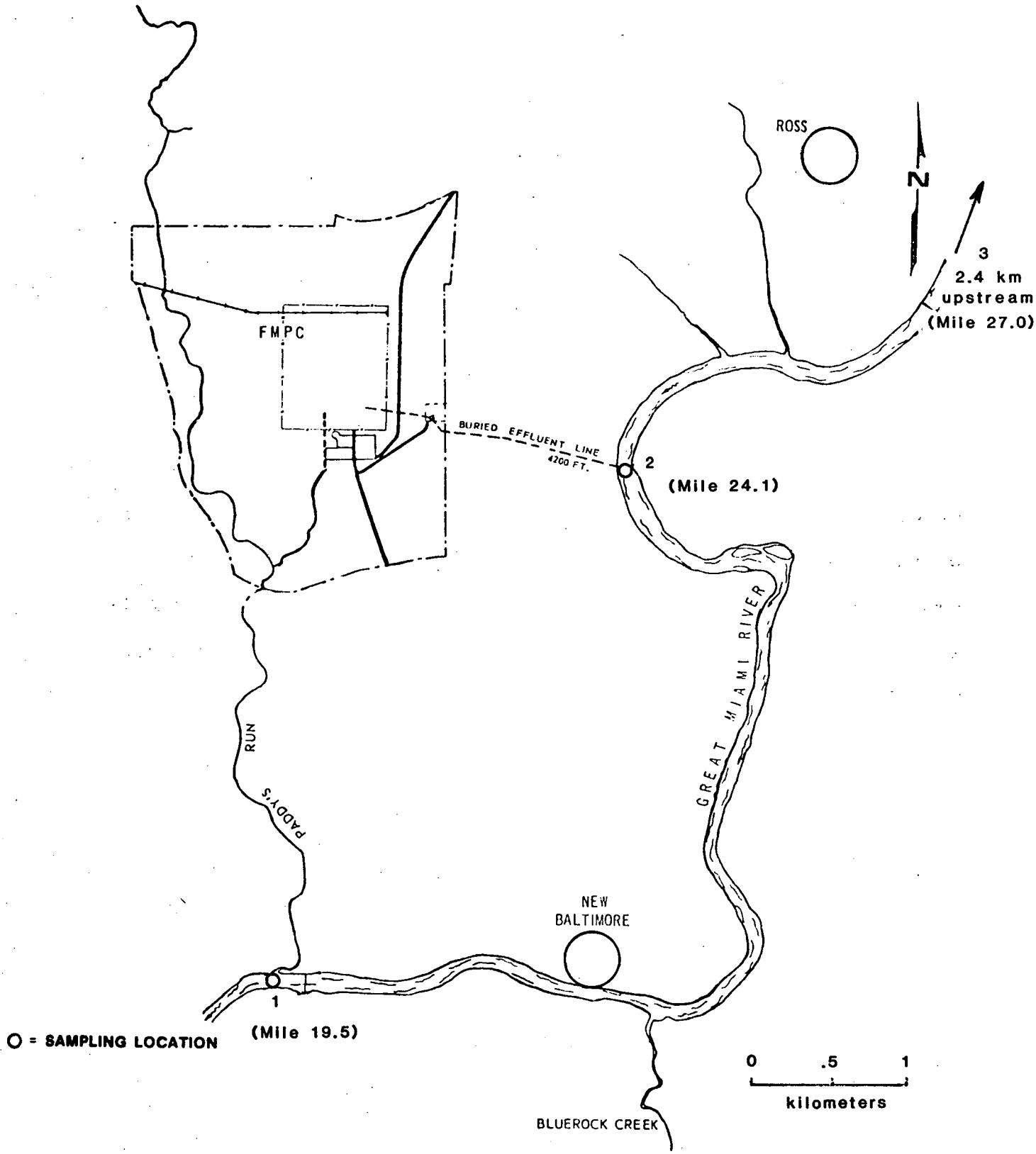


FIGURE 18 Fish Sampling Locations

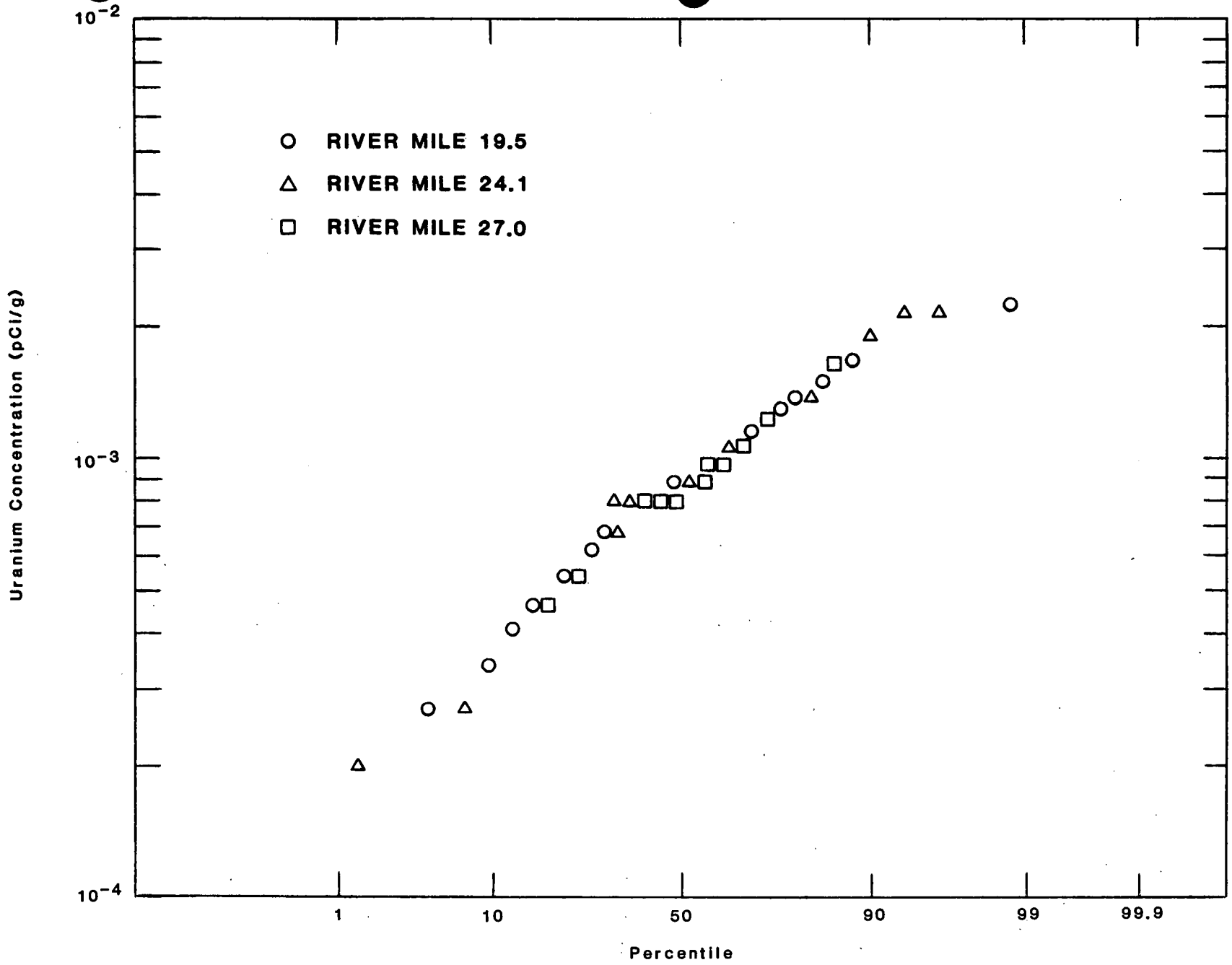


FIGURE 19 Uranium Concentration in Fish from the Great Miami River

Table 13. Due to the physiological differences between species and concomitant relative differences in bone content, the amount of uranium per gram of ash in each sample was used for statistical analysis purposes. It is worth noting that the average uranium concentration was greatest upstream of the FMPC effluent outfall and lowest downstream. There were no significant differences between sites or species, and all fish, relative to uranium concentration, appeared to be from a single population (Figure 19).

Well Water

Water samples were collected quarterly from each of 13 on-site and monthly from 21 off-site wells during the year. The locations of these wells are shown in Figures 20 and 21. Water from on-site wells was analyzed for pH, alpha and beta activity, uranium, chloride, sulfate, and nitrate. Off-site well water was analyzed for uranium and nitrate only with the exception of Wells 8 and 9 (owned and operated by the Southwestern Ohio Water Company), both of which were also analyzed for ^{226}Ra and ^{228}Ra.

Whereas there are no standards for radionuclide levels in drinking water (only wells P1, P2, and P3 are used for drinking and culinary purposes on site), analyses for radionuclides in on-site wells (Tables 14A, B, and C) give results that are generally similar to those of past years. Trend analyses (Table 16) for samples collected during 1982, 1983, and 1984 (n=10 to 14) indicate significant downward trends in uranium concentrations in wells P3, T3, T5, and T9. Gross alpha contamination, on the other hand, had increased over time in 5 of the 15 wells, but only significantly so in T8S and T8D. A significant increase in beta activity also was noted in P1 and T8S.

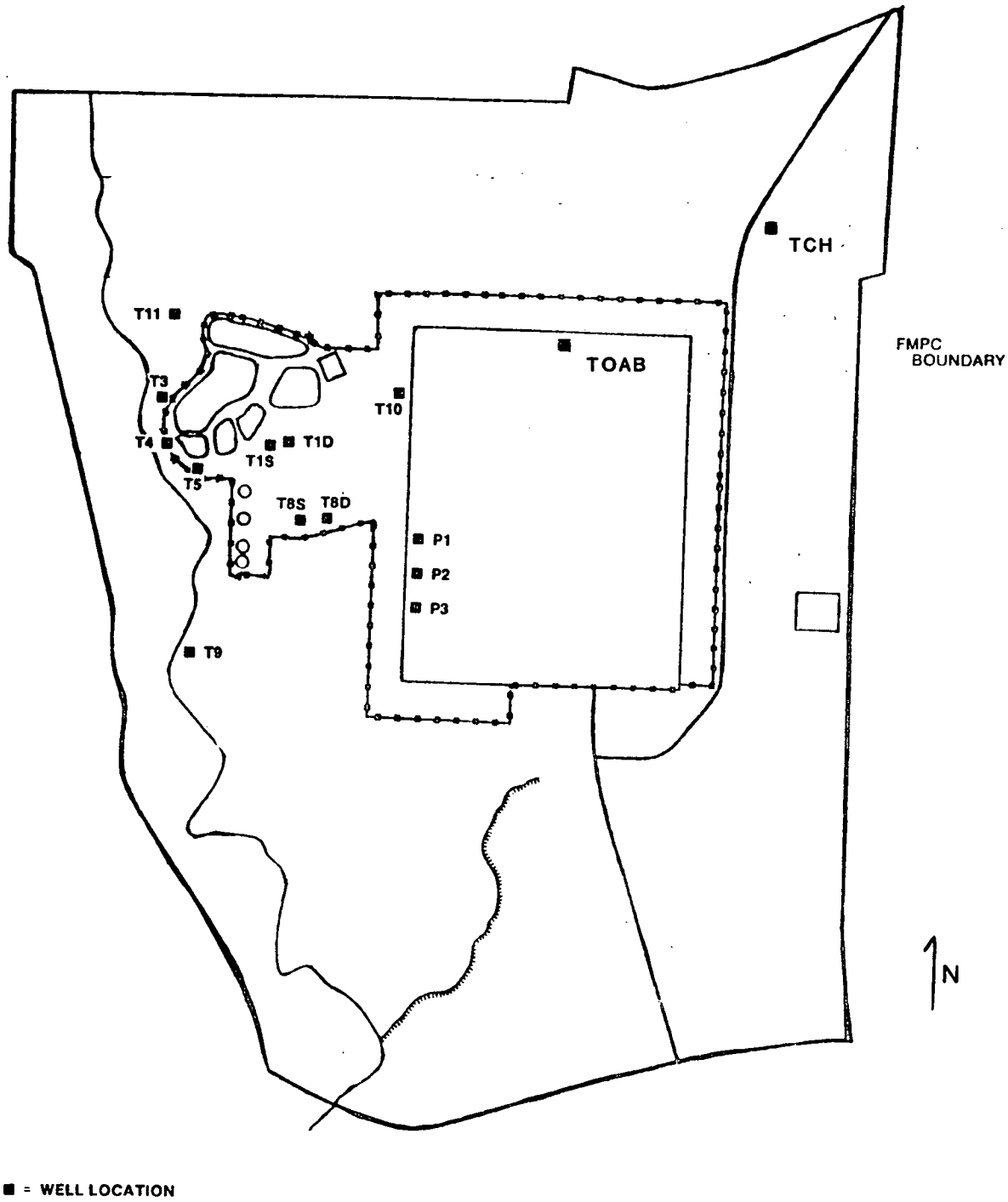


FIGURE 20 FMPC On-site Production and Test Well Locations

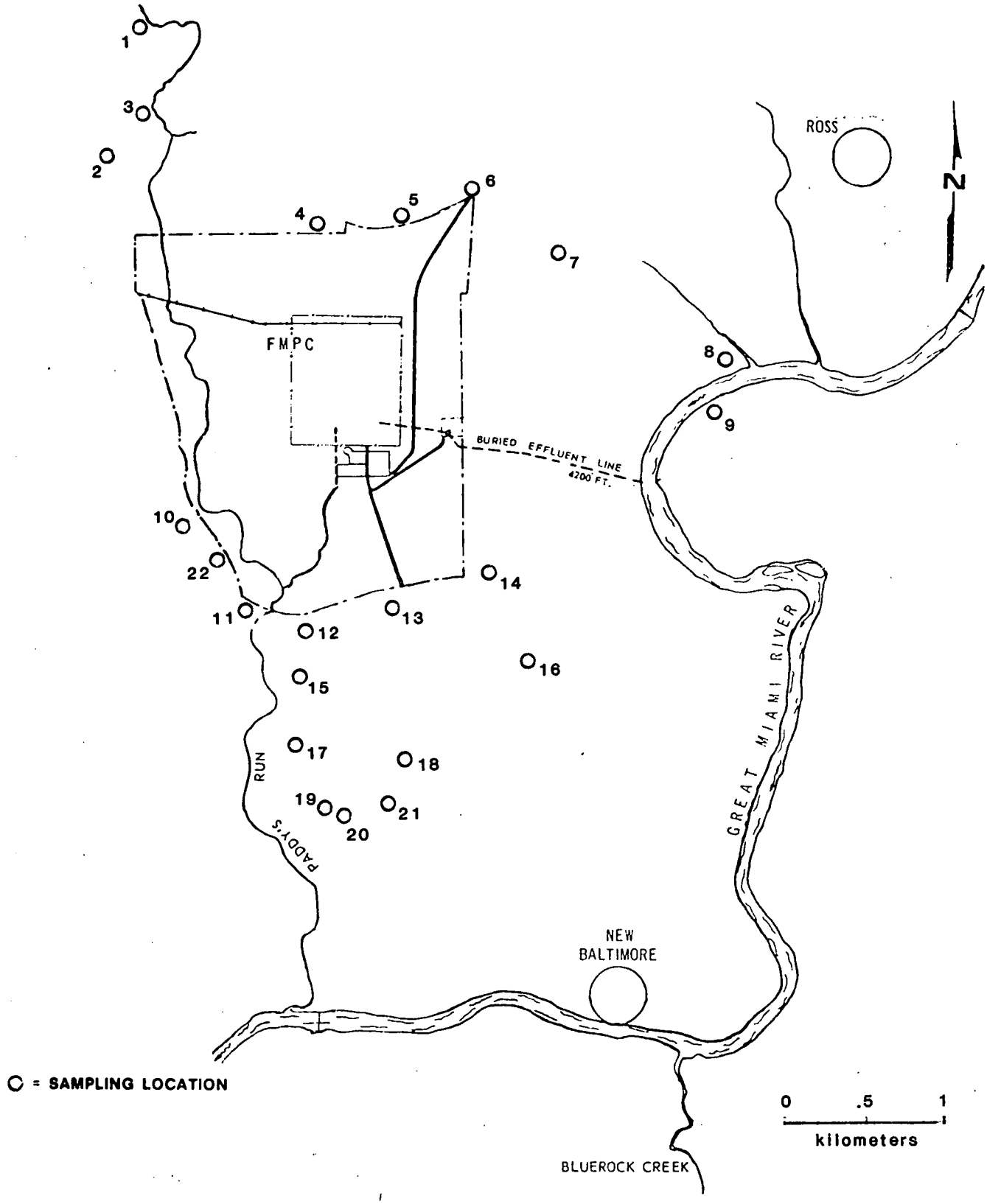


FIGURE 21 Off-site Monitoring Well Locations

Tables 15A and B present the results of analyses for non-radioactive contaminants in on-site wellwater. While pH levels were essentially unchanged from previous periods, chloride and nitrate nitrogen contamination exhibited highly significant downward trends in the majority of wells (Table 16). Sulfate ion contamination, where trends were significant, had increased over time.

Results of analyses for uranium and nitrate nitrogen contamination in off-site wellwater are shown in Tables 17 and 18, respectively. Trend analyses (Table 19) for uranium indicated downward trends in most cases, however significant upward trends were noted in wells 19 and 20. Nitrate nitrogen levels, where any trend was evident, had decreased over the two year period. Regarding radium concentrations in Wells 8 and 9, the water from each well contained less than 0.0005 pCi ml^{-1} of either isotope.

A groundwater study was initiated by NLO and conducted during 1984 by Dames and Moore to determine the source(s) of above background concentrations of uranium in three of the offsite wells. The field work consisted of the installation and development of 23 groundwater monitoring wells. Sampling of each of these wells and a radionuclide migration modeling study were subsequently performed. The Dames and Moore report to be released in July 1984 will present the results of these studies. The 23 additional test wells will be included in the sampling program for on-site and off-site wells in 1985.

NPDES PERMIT

In 1984, the FMPC discharged an average of 0.58 million gallons of water per day to the Great Miami River (as measured at Sampling Point W2). An additional 0.16 million gallons of water was discharged, on the average, to Paddy's Run via the Storm Sewer Outfall per each storm event in 1984. Both of these discharge points, as well as four other on-site locations, are defined and regulated by a National Pollutant Discharge Elimination System (NPDES) permit. This permit, issued by Region V of the USEPA, is administered by the Ohio EPA and requires the FMPC to characterize their effluent stream by analyzing samples collected at the aforementioned locations. Schedules for sampling are specified in the permit and results are reported to the USEPA on a quarterly basis and to the Ohio EPA on a monthly basis.

A total of 1820 NPDES analyses were performed in 1984. From this total, an effluent parameter exceeded either its daily maximum or monthly average discharge limit only 31 times. Overall compliance with the NPDES permit limits was greater than 98 percent for the year. The combined general sump and clearwell sampling location was the site for 29 of the 31 exceedances, due mainly to more frequent pumping of the clearwell because of excessive rainfall and increased process operations at the FMPC. Only two exceedances were recorded at a final discharge point (Sampling Point W2). Table 20 summarizes these data for 1984.

OTHER ENVIRONMENTAL CONTROLS

Sewage Plant Effluent

Effluent from the FMPC Sewage Treatment Plant is combined with other effluents at Manhole-175 (=W2, see Figure 4). Prior to discharge from the Sewage Treatment Plant, however, the effluent is carefully monitored and sampled to determine the efficiency of operation. As Table 20 indicates, the treatment plant was in 100 percent compliance with its NPDES limits in 1984.

The current treatment system incorporates the use of a two-stage trickling filter process as the primary means for biological treatment, however, the trickling filters could be operated in parallel if an increase in flow ever demanded such a modification. In addition, an ultraviolet disinfection system was installed during 1984 to replace the use of chlorine as the bacterial disinfectant. This modification was done in accordance with stipulations set forth in the NPDES permit. Other wastewater pollution control projects outlined in the permit are presently under construction. These include a biodenitrification treatment system, a diversion system for coal-pile runoff, and a stormwater runoff retention basin. Completion of these projects is expected in 1986.

Steam Plant Emissions

The steam generation plant at the FMPC utilizes two boilers with a total design capacity of 150,000 pounds of steam per hour. Electrostatic precipitators keep the particulate discharge below the Ohio EPA particulate limit of 0.19 pounds per million BTU input. Compliance testing, as required by the OEPA, will be performed on the steam plant in the early part of 1985. Discharge from the steam generation plant is in full compliance with OEPA

standards.

Sulfur dioxide (SO_2) emission limits for stationary facilities have been adopted by the OEPA. Under these rules, the limit for the FMPC steamplant is less than 1 kg (2.2 pounds) of SO_2 per million BTU input from each boiler. This limit is equivalent to the use of coal containing 1.3 percent sulfur. Coal containing only one percent or less sulfur is purchased in order to meet the states SO_2 emission requirement.

Particulates from Industrial Processes

Maximum rates of emmission of particulates from industrial processes are described in OEPA Rule 3745-17-11, Restrictions on Particulate Emissions from Industrial Processes. Through the use of numerous dust collectors, scrubbers, electrostacic precipitators, and various other types of air cleaning equipment, non-radioactive particulate emissions from FMPC process operations are well below the established OEPA limits. All air emission points are being permitted in 1985 as required by the OEPA.

Incinerator Operations

The FMPC solid waste incinerator is used for the destruction of non-radioactive combustible material such as wood, discarded paper, and plastic. The incinerator was specified to meet state emission standards of one gram particulate matter per kilogram of liquid, semi-solid, or solid refuse and salvageable material charged. An incinerator operating permit has been issued by the State of Ohio for the solid waste incinerator and compliance testing will be performed on this facility in 1985 as required. A liquid waste incinerator has been constructed for the disposal of non-hazardous

waste oils. A permit to operate this device was filed with the Ohio EPA in June, 1982. Stack emissions from this incinerator are minimized by a baghouse collector.

ESTIMATION OF RADIATION DOSE EQUIVALENT

The AIRDOS-EPA and DARTAB computer programs were used by the Oak Ridge National Laboratory (ORNL) to calculate committed dose equivalent to the maximally exposed individual and the 80 km population dose equivalent due to FMPC operations. The results of these computer runs are based on a total airborne uranium emission during 1984 of 0.265 Ci (376 kg). Of this amount, 0.084 Ci (124.4 kg as natural uranium) were emitted in accidental stack losses from September through December 1984, and would account for approximately 32% of the committed dose equivalent calculated by the computer model. However, evaluation of boundary station air sampling data for the period showed no significant increase in uranium concentration and thus no evidence exists that this additional uranium reached the FMPC site boundary. The following parameters and their respective values were used for the computer runs: (1) eighty percent of the airborne uranium particles were assumed to be of the Y solubility class and twenty percent were assumed to be of the W solubility class, (2) a default value of .1 micron was assumed for particle size, (3) the average stack height was assumed to be 13.4 m (43.6 feet), (4) stack velocity was zero due to the presence of raincaps, and (5) the most current meteorological data which typified FMPC conditions, measured at Dayton, Ohio from 1970 to 1974, were used in the calculations .

These programs compute dose equivalent commitments due to airborne releases

of uranium through all inhalation, ingestion, and direct radiation pathways. and calculations follow the methodology of the International Commission on Radiological Protection (ICRP) 26/30[12], with EPA modifications. An EPA organ dose weighting factor was used instead of the ICRP weighting factor. These programs calculate committed dose equivalent to members of the general public, therefore the 70-year dose equivalent factors recommended by the EPA were used instead of the ICRP 26/30 50-year dose equivalent for committed dose to an adult worker. Furthermore, the program considers pulmonary tissue as the critical target organ, whereas the ICRP uses the lung as the target organ. The pulmonary tissue incorporates some of the lymph system and results in a slightly higher 'lung' dose conversion factor.

In 1984 emissions from DOE facilities were subject to the guidelines on radionuclide concentrations and committed dose equivalents set forth in DOE Order 5480.1A[1]. Specifically, guidelines for committed dose equivalent to the individual at the point of maximum probable exposure are 500 mrem for whole body exposure and 1500 mrem for exposure to other organs. For the general population the guidelines for annual exposure are 170 mrem whole body and 500 mrem to other organs. More conservative limits for exposure from airborne emissions (25 mrem whole body dose, 75 mrem to a critical organ) set forth by the EPA NESHAP[3] were promulgated in February 1985. Direct and ingested radiation dose is discussed in terms of the DOE guidelines and the dose from inhalation of airborne emissions is discussed in terms of the new NESHAP guidelines. Where appropriate, the committed dose equivalent is discussed in terms of the effective dose equivalent instead of the whole body dose equivalent. The term 'whole body' refers to all human organs or tissue exclusive of the skin and the cornea. The effective dose equivalent represents a weighted average of committed dose equivalents to

specific organs defined by ICRP 26[12]. Effective dose equivalent is equal to a whole body dose equivalent which would result in an equal risk of stochastic health effects for a given radionuclide exposure.

Maximum Individual Dose Equivalent

The AIRDOS/DARTAB results indicate a 70-year dose equivalent commitment of 100 mrem to pulmonary tissue due to airborne emissions. The 50-year committed whole body dose equivalent was estimated at 1.8 mrem. This was based on the concentration at the point of maximum exposure to an off-site individual. The concentration value used was supplied by the ORNL meteorological model. Both these dose commitments are well within the 1984 DOE guidelines. Thus, whereas the pulmonary tissue dose does exceed the NESHAP guideline, the whole body dose is well within NESHAP guidelines. As previously noted, changes in organization and mechanization designed to more closely control stack and other emmissions should assure full compliance with NESHAP during 1985.

80 km Population Dose Equivalent

Using AIRDOS/DARTAB and the most current available meteorological data collected at Dayton, Ohio from 1970 to 1974, and an estimate of the human population within 80 km of the FMPC of 2.5 million (Table 21), the population 70 year dose equivalent commitment due to uranium emissions was estimated at 370 person-rem. The whole body dose equivalent due to natural radiation for the same population group is about 275,000 person-rem.

Maximum Dose Equivalent to Nearest Resident from Direct Radiation

Exposure from direct gamma radiation was measured with thermoluminescent detectors placed in seven air monitoring stations on the FMPC boundary. These TLD's were changed and processed every three months. The data are shown in Table 22. The maximum annual average dose equivalent was measured at BS-6. Subtracting the natural background dose of 0.01 mrem/hr from this yields a maximum potential dose equivalent due to FMPC operations of 0.006 mrem/hr. This would result in an annual dose equivalent of 53 mrem at the boundary station. However, application of the inverse square law to obtain the dose at the residence nearest to BS-6 yields a committed dose equivalent of only 9.8 mrem.

Maximum Potential Dose Equivalent to a Population Group

The community of Ross, Ohio (pop. approximately 3000) is located 4 km from the center of the FMPC. Because of the prevailing wind direction, any possible airborne contaminants moving toward Ross would be measured at boundary stations BS-2 or BS-3. In addition, because of wind frequency, the average airborne concentrations are generally higher at BS-3. Therefore, these calculations are based on the BS-3 averages because the object was to calculate a worst case scenario using current emission levels. The methodology of the calculations and the dose conversion factors used in all calculations except those done by the AIRDOS/DARTAB model were as described in DOE/TIC-11468[13]. The average annual concentrations of radionuclides were used to calculate the average FMPC site emission rates and thence the average concentration of uranium and other radionuclides in the center of Ross. Based on calculations using atmospheric transport and dispersion

equations, the average concentraton of uranium at Ross was estimated to be 1.72×10^{-3} pCi per cubic meter.

Assuming a conservative 100 percent occupancy, the 50 year committed dose equivalent for an individual in Ross due to 1984 FMPC operations was calculated to be 4.5 mrem to the bone endosteum, 10.5 mrem to the lungs, and 1.4 mrem effective dose equivalent.

Maximum Individual Ingested Dose Equivalent

The Great Miami River is not used as a source of drinking water; however, calculations were performed to compute the 50 year committed dose equivalent for the worst case scenario of a person obtaining drinking water from the river immediately downstream from the FMPC effluent discharge. An daily intake of 1.2 liters[13] would result in a 50 year dose equivalent commitment of 0.073 mrem annually to the bone surface and an annual committed effective dose equivalent of 0.01 mrem. The maximum dose equivalent due to drinking river water would thus be less than 0.006 percent of the DOE limit on intake.

Twenty two offsite wells were sampled monthly to determine the average concentration of uranium in well water. Above backgrkound concentrations were measured in well numbers 12, 15, and 17 (Table 17). Although only well number 12 has been documented as being used as a source of drinking water in 1984, the 50-year committed dose equivalents due to ingestion of well water were calculated for all three wells. This was done to determine the actual maximum committed dose equivalent to an individual and the maximum potential dose equivalent commitment due to drinking water from an offsite well. The maximum committed dose equivalents of 66.4 mrem effective dose and 908.0

mrem to the bone endosteum due to ingestion of water from well number 12 are 13.3% and 60.5% of the DOE dose guidelines for those organs. The maximum potential dose equivalents from drinking from well number 15 are 89.0 mrem effective dose and 1203.8 mrem to the bone endosteum, 17.8% and 80.3% of the dose guidelines for those organs. The maximum potential dose equivalents from drinking from well number 17 are 14.6 mrem effective dose and 199.5 mrem to the bone endosteum, 2.9% and 13.3% of the dose guidelines for those organs. It should be noted that well number 12 was replaced by NLO in April of 1985 and is no longer used as a source of drinking water, and that the other wells were not used as a source of drinking water in 1984.

In order to investigate the potential health hazard that might be associated with eating locally grown produce and/or fish from local streams, potatoes from farms and gardens near the FMPC and fish taken from the Great Miami River were analyzed for uranium content. As discussed in the section on Sample Collection and Analysis, there was no significant difference between mean uranium concentrations in the local samples and the control (background) samples for either produce or fish. Therefore, it would appear that FMPC operations do not contribute to a radiation dose due to consumption of either of these food items.

A summary of the data regarding potential radiation exposure due to FMPC operations is presented in Table 23.

n6

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(5) Ohio Environmental Protection Agency, "Water Quality Standards," Regulation No. 3745-1, Laws and Regulations, February, 1978.

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(11) Tracy, B. L., F. A. Prantl, and J. M. Quinn, "Transfer of ^{226}Ra, ^{210}Pb and uranium from soil to garden produce: assessment of risk," Health Physics 44:469-477, 1983.

(12) International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection, ICRP Publication No. 26, Oxford; Pergamon Press, 1977.

(13) Miller, C. W. (ed.), Models and Parameters for Environmental Radiological Assessments, U. S. Department of Energy, DOE/TIC-11468, 1984.

APPENDIX

TABLE 1 Radionuclides in Air

Routinely Monitored Radionuclides

Sampling Point (1)	Number of Samples	Uranium ($pCi/L \times 10^{-5}$)					Gross β Activity (4) ($pCi/L \times 10^{-5}$)				
		Maximum	Minimum	Average	95% (2) C. L.	% of Guideline	Maximum	Minimum	Average	95% (2) C. L.	% of Guideline
BS1	53	12.52	0.03	1.03	1.35		34.52	0.96	4.91	1.24	
BS2	53	4.57	0.04	0.92	1.29		29.68	1.17	4.56	1.22	
BS3	53	18.79	0.23	1.36	1.30		104.16	1.42	6.38	1.28	
BS4	53	1.45	0.05	0.35	1.25	(3)	10.54	0.92	2.60	1.16	(3)
BS5	53	3.73	0.03	0.40	1.32		27.28	1.15	2.88	1.18	
BS6	53	4.31	0.04	0.63	1.32		68.28	1.14	3.39	1.21	
BS7	53	1.78	0.05	0.30	1.29		14.29	0.51	2.46	1.18	

Other Radionuclides
($pCi/L \times 10^{-9} \pm 2\sigma$)

Sampling Point (1)	Number of Samples	^{237} Neptunium		^{238} Plutonium		^{239,240} Plutonium		^{228} Thorium		^{230} Thorium		^{232} Thorium	
		Level	% of Guideline	Level	% of Guideline	Level	% of Guideline	Level	% of Guideline	Level	% of Guideline	Level	% of Guideline
BS1		8.31 ± 0.5		2.21 ± 0.4		42.09 ± 3.2		24.20 ± 2.1		494.51 ± 10.5		14.73 ± 2.1	
BS2		6.80 ± 0.4		3.95 ± 0.8		35.11 ± 3.3		30.72 ± 2.2		559.57 ± 11.0		17.56 ± 1.1	
BS3		10.71 ± 0.6		2.65 ± 0.7		55.38 ± 6.0		50.56 ± 2.4		746.44 ± 12.0		27.69 ± 2.4	
BS4	(5)	2.27 ± 0.2	(3)	0.97 ± 0.2	(3)	16.54 ± 1.0	(3)	13.44 ± 1.0	(3)	155.08 ± 10.3	(3)	9.41 ± 1.0	(3)
BS5		2.79 ± 0.3		1.07 ± 0.4		20.39 ± 2.1		17.17 ± 1.1		321.91 ± 10.7		10.73 ± 1.1	
BS6		4.83 ± 0.4		2.30 ± 0.4		28.53 ± 2.2		24.14 ± 2.2		406.07 ± 11.0		15.36 ± 1.1	
BS7		1.81 ± 0.2		1.70 ± 0.5		20.37 ± 2.3		26.03 ± 2.3		531.83 ± 11.3		15.84 ± 2.3	

Footnotes:

(1) See Figure 2.

(2) C. L. = Average Concentration ×÷ the value shown. Derived from log-transformed data; $= t_{(0.05,\ df)} S_{\bar{x}}$.

(3) The following guidelines were established by DOE Order 5480.1A, Attachment XI-1, Table II (Note 3c for gross β), insoluble particles in air, and were in effect during 1984:

Uranium	2.0×10^{-3} pCi/L	^{239,240} Plutonium	1.0×10^{-3} pCi/L
Gross β	1.0×10^{-1} pCi/L	^{228} Thorium	2.0×10^{-4} pCi/L
^{237} Neptunium	4.0×10^{-3} pCi/L	^{230} Thorium	3.0×10^{-4} pCi/L
^{238} Plutonium	1.0×10^{-3} pCi/L	^{232} Thorium	1.0×10^{-3} pCi/L

The NESHAP Limits promulgated in 1985 relate to body and organ dose, however, and are addressed elsewhere in the text of this report as well as in Table 23.

(4) Includes Uranium activity, thus highly conservative.

(5) A composite of 53 weekly samples.

TABLE 2 ^{222}Radon In Ambient Air

Location	Number of Samples	Concentration (*p*Ci/L)					Normal Background Level
		Maximum	Minimum	Average	95% (2) C. L.	% of Guideline	
Onsite (1)							
BS1	4	1.03	0.81	0.917	1.20	(3)	0.20 - 0.35 *p*Ci/L
BS2	4	1.08	0.41	0.801	1.86		
BS3	4	1.11	0.61	0.843	1.41		
BS4	4	0.73	0.48	0.591	1.37		
BS5	4	1.34	0.71	0.970	1.64		
BS6	8	1.55	0.28	0.584	1.35		
BS7	4	1.34	0.42	0.717	2.11		
Offsite							
8 mi. ENE	4	2.19	0.29	0.836	3.72	(3)	
5 mi. WSW	4	0.59	0.19	0.357	1.91		

Footnotes:

(1) See Figure 2.

(2) C. L. = Average Concentration ×÷ the value shown. Derived from log-transformed data; $= t_{(0.05,\, df)} S_{\bar{x}}$.

(3) DOE Order 5480.1A, Attachment XI - 1, Table II, established a guideline level of 3 *p*Ci/L above background, but see Footnote (3), Table 1.

TABLE 3 Radionuclides in Surface Water

Radionuclide	Sampling Point (1)	Number of Samples (2)	Concentration (pCi/L) Maximum	Minimum	Average	95% (3) C. L.	% of Guideline	Guideline pCi/L (4)
Gross α (5)	W1	52	8.11	0.90	2.25	1.11	7.5	30
	W3	52	9.91	0.90	2.66	1.12	8.9	
	W4	52	11.71	1.35	2.79	1.11	9.3	
	W5	52	5.41	0.45	1.80	1.17	6.0	
	W7	26	127.93	6.31	13.96	1.37	46.5	
	W8	26	65.77	4.95	9.28	1.25	30.9	
Gross β (5)	W1	52	8.56	2.25	4.86	1.08	16.2	30
	W3	52	54.50	3.15	10.23	1.18	34.1	
	W4	52	46.40	2.70	9.73	1.20	32.4	
	W5	52	10.81	0.90	4.64	1.13	15.5	
	W7	26	46.85	<6.31	<10.86	1.25	<36.2	
	W8	26	50.45	<7.21	<16.94	1.23	<56.5	
^{137}Cesium	W1	1			<1.89		<0.01	20,000
	W3	1			<1.62		<0.01	
	W4	1			<1.62		<0.01	
^{226}Radium	W1	12	0.45	<0.45	<0.45	1.00	<1.5	30
	W3	12	0.45	<0.45	<0.45	1.00	<1.5	
	W4	12	0.45	<0.45	<0.45	1.00	<1.5	
	W5	6	0.45	<0.45	<0.45	1.00	<1.5	
	W7	9	0.45	<0.45	<0.45	1.00	<1.5	
^{228}Radium	W1	12	0.45	<0.45	<0.45	1.00	<1.5	30
	W3	12	0.45	<0.45	<0.45	1.00	<1.5	
	W4	12	0.45	<0.45	<0.45	1.00	<1.5	
	W5	6	0.90	<0.45	<0.57	1.46	<1.9	
	W7	9	0.90	<0.45	<0.49	1.19	<1.6	
^{90}Strontium	W1	1			0.43	±1.27 (6)	0.14	300
	W3	1			1.57	±1.89	0.52	
	W4	1			1.51	±2.14	0.50	
^{99}Technetium	W1	1			1351.35	±27.03	0.45	300,000
	W3	1			14.32	±3.24	<0.01	
	W4	1			12.43	±3.24	<0.01	
^{234}Uranium	W1	1			2.16	±0.24	0.05	4,000
	W3	1			1.22	±0.16	0.03	
	W4	1			1.32	±0.16	0.03	
^{235}Uranium	W1	1			0.30	±0.14	0.008	4,000
	W3	1			<0.27		<0.007	
	W4	1			<0.27		<0.007	
^{236}Uranium	W1	1			0.30	±0.14	0.006	5,000
	W3	1			<0.27		<0.005	
	W4	1			<0.27		<0.005	
^{238}Uranium	W1	1			2.51	±0.24	0.42	600
	W3	1			2.14	±0.24	0.36	
	W4	1			1.68	±0.16	0.28	
Uranium (7)	W1	52	25.73	0.68	1.62	1.19	0.14	1,200
	W3	52	16.25	0.68	1.62	1.14	0.14	
	W4	52	18.97	0.68	1.62	1.14	0.14	
	W5	52	6.77	0.68	1.35	1.15	0.11	
	W7	26	168.57	5.42	15.44	1.41	1.29	
	W8	26	65.67	3.39	9.48	1.28	0.79	

Footnotes:

(1) See Figure 5.

(2) Samples are composited for radium analyses as follows: one-month composites of daily samples from W1 and W3; one-month composites of weekly samples from W4, two-month composites of weekly samples from W5, and one-month composites of all available weekly samples from W7. An annual composite was used for those isotopes where only a single sample is noted.

(3) C. L. = Average ×÷ the value shown. Derived from log-transformed data; $= t_{(0.05,\ df)} S_{\bar{x}}$.

(4) DOE Order 5480.1A, Attachment XI-1, Table II (Note 2 for Gross α and Gross β). Guidelines listed are for soluble isotopes.

(5) Gross α and Gross β activity values contain activity of uranium and radium in the samples, thus are highly conservative.

(6) Counting uncertainties at 95% C. L. (^{137}Cesium includes an additional 6% intrinsic uncertainty). This applies to all values preceded by ±.

(7) Normal background levels of uranium in local surface waters range between 1.4 and 2.8 pCi/L.

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TABLE 4 Radionuclides Discharged at Sampling Point W2 During 1984

Radionuclide (1)	Total Curies	Concentration (pCi/L)					Guideline pCi/L (4)
		Maximum	Minimum	Average	95% (2) C. L.	% of Guideline	
^{137} Cesium	0.017	21.89	20.00	20.92	±3.77	0.005	4×10^5
^{237} Neptunium	0.0002	0.25	0.10	0.16	±0.04	<0.001	9×10^4
^{238} Plutonium	0.00003	0.035	0.030	0.032	±0.02	<0.0001	1×10^5
$^{239, 240}$ Plutonium	0.00005	0.089	0.018	0.040	±0.01	<0.0001	1×10^5
^{226} Radium	<0.017	81.08	<0.45	<14.48	1.75 (3)	<3.62	4×10^2
^{228} Radium	<0.014	68.02	<0.45	<9.23	1.87 (3)	<1.15	8×10^2
^{106} Ruthenium	0.0005	1.53	0.23	0.50	1.48 (3)	<0.001	4×10^5
^{90} Strontium	0.012	19.19	10.27	14.04	±4.01	0.14	1×10^4
^{99} Technetium	18.96	29729.73	16756.76	22319.81	±854.67	2.23	1×10^6
^{232} Thorium	0.0005	1.08	0.32	0.56	1.28 (3)	0.001	5×10^4
^{234} Uranium	0.34	432.43	405.41	418.70	±81.08	0.42	1×10^5
^{235} Uranium	0.018	23.51	20.54	21.98	±6.76	0.02	1×10^5
^{236} Uranium	0.021	32.43	20.00	25.47	±11.47	0.03	1×10^5
^{238} Uranium	0.39	540.54	432.43	483.47	±81.08	2.42	2×10^4
Uranium (5)	0.68	1333.69	352.04	663.31	1.35 (3)	1.66	4×10^4

Footnotes:

(1) Radionuclides in the plant effluent which is discharged to the Great Miami River through a buried pipeline, (with the exception of the two radium isotopes, ruthenium, and uranium) from two 6-month composites. An additional 3.8×10^{-2} Curies of uranium was contained in storm sewer overflow discharged into Paddy's Run above sampling point W7.

(2) Counting uncertainties at 95% C. L. (^{137}Cesium includes an additional 6% intrinsic uncertainty) unless otherwise specified.

(3) C. L. = Average Concentration ×÷ value shown. Derived from log-transformed data and = $t_{(0.05,df)} S_{\bar{x}}$.

(4) DOE Order 5480.1A, Attachment XI-1, Table II, Concentration Guides for Water in Controlled Areas. Guidelines for soluble isotopes are listed.

(5) From average monthly concentration data.

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TABLE 5 Ion and pH Levels in Surface Water

Parameter	Sampling Point (1)	Number Of Samples	Concentration (mg/L)					Guideline (3)
			Maximum	Minimum	Average	95% C. L. (2)	% of Guideline	
Fluoride	W1	52	1.0	0.2	0.44	1.11	22	2.0 mg/L
	W3	52	1.0	0.3	0.45	1.10	23	
	W4	52	1.1	0.2	0.45	1.12	23	
	W5	12	0.5	0.1	0.23	1.26	12	
	W7	12	0.6	0.2	0.26	1.24	13	
	W8	12	0.4	0.1	0.17	1.32	9	
Nitrogen (in nitrate ions)	W1	52	8.8	2.3	4.27	1.09	19	22 mg/L
	W3	52	9.0	2.2	4.36	1.10	20	
	W4	52	8.9	2.1	4.39	1.10	20	
	W5	12	4.3	0.9	2.64	1.34	12	
	W7	11	4.9	0.6	2.13	1.49	10	
	W8	12	4.0	0.1	0.39	2.47	11	
Chloride	W1	52	145	17	54.6	1.12	22	250 mg/L
	W3	52	97	17	54.3	1.12	22	
	W4	52	99	17	55.1	1.12	22	
	W5	12	46	14	29.9	1.25	12	
	W7	12	135	14	25.1	1.41	10	
	W8	12	168	21	38.4	1.43	15	
pH (4)	W1	52	9.0	7.9	(5)	(5)	(5)	6.5 - 9.0
	W3	52	9.1	7.9				
	W4	52	9.2	7.3				
	W5	52	8.2	7.5				
	W7	26	8.4	7.6				
	W8	26	8.3	7.5				

Footnotes:

(1) See Figure 5.

(2) C. L. = Average Concentration ×÷ value shown. Derived from log-transformed data and = $t_{(0.05,df)} S_{\bar{x}}$.

(3) Ohio EPA Water Quality Standards, Administrative Code Chapter 3745-1.

(4) pH is reported in standard units.

(5) Not applicable.

TABLE 6 Uranium in Routine Soil Samples

Sampling Point (1)	Concentration (pCi/g dry wt.)					
	August	95% (2) C. L.	% of Guideline	December	95% (2) C. L.	% of (3) Guideline
1	8.32	±0.41	23.8	10.22	±0.55	29.2
2	10.64	±0.54	30.4	7.31	±0.33	20.9
3	68.50	±3.46	195.7 (4)	39.94	±1.70	114.1 (4)
4	8.32	±0.34	23.8	6.57	±0.34	18.8
5	5.37	±0.54	15.3	12.80	±0.62	36.6
6	7.36	±0.41	21.0	1.56	±0.23	4.5
7	3.29	±0.34	9.4	3.52	±0.26	10.1
8	3.06	±0.14	8.7	1.90	±0.26	5.4
9	3.74	±0.20	10.7	4.13	±0.26	11.8
10	2.01	±0.14	5.7	3.86	±0.24	11.0
11	13.78	±0.68	39.4	19.29	±0.80	55.1
12	1.80	±0.14	5.1	2.44	±0.24	7.0
13	6.54	±0.34	18.7	1.08	±0.16	3.1
14	2.07	±0.14	5.9	2.30	±0.18	6.6
15	13.22	±1.39	37.8	2.23	±0.16	6.4

Footnotes:

(1) See Figure 6.

(2) C. L. = 2σ.

(3) Value of 35 pCi/g used as guideline for these calculations.

(4) This location is on site near an out of service incinerator.

TABLE 7 Radionuclides in Soil

Sampling Location (1)	Radionuclide (pCi/g ± 2σ)							
	^{237}Neptunium	^{238}Plutonium	^{239,240}Plutonium	^{99}Technetium	^{228}Thorium	^{230}Thorium	^{232}Thorium	Uranium
1	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.3	0.7 ± 0.1	1.1 ± 0.1	0.8 ± 0.1	1.4 ± 0.1
2	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.6	0.9 ± 0.2	1.0 ± 0.2	1.0 ± 0.2	2.6 ± 0.1
3	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.5	1.2 ± 0.1	1.4 ± 0.1	1.2 ± 0.1	2.8 ± 0.1
4	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.06	0.0 ± 0.6	0.9 ± 0.1	1.0 ± 0.1	0.9 ± 0.1	1.9 ± 0.1
5	0.0 ± 0.4	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.5	1.1 ± 0.1	1.5 ± 0.1	1.2 ± 0.1	10.5 ± 0.5
6	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.4	1.3 ± 0.2	1.8 ± 0.2	1.7 ± 0.2	5.9 ± 0.3
7	0.0 ± 0.2	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.5	0.8 ± 0.1	1.2 ± 0.1	1.1 ± 0.1	7.7 ± 0.4
8	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.4	0.6 ± 0.2	1.5 ± 0.2	0.9 ± 0.2	3.2 ± 0.3
9	0.0 ± 0.2	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.6	0.8 ± 0.1	1.1 ± 0.1	0.8 ± 0.1	7.3 ± 0.3
10	0.0 ± 0.3	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.6	1.0 ± 0.1	1.4 ± 0.1	1.0 ± 0.1	8.9 ± 0.5
11	0.0 ± 0.3	0.0 ± 0.05	0.0 ± 0.06	0.0 ± 0.6	0.9 ± 0.1	1.3 ± 0.1	0.8 ± 0.1	10.8 ± 0.5
12	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.8	1.1 ± 0.1	1.4 ± 0.1	1.2 ± 0.1	5.7 ± 0.3
13	0.0 ± 0.2	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.4	1.1 ± 0.1	1.2 ± 0.1	1.0 ± 0.1	2.8 ± 0.1
14	0.0 ± 0.3	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.6	1.0 ± 0.1	1.3 ± 0.1	1.0 ± 0.1	7.1 ± 0.3
15	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.4	1.0 ± 0.1	1.3 ± 0.1	1.0 ± 0.1	3.4 ± 0.2
16	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.4	1.1 ± 0.1	1.2 ± 0.1	1.1 ± 0.1	11.8 ± 0.6
17	0.0 ± 0.2	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 1.0	0.8 ± 0.1	1.0 ± 0.1	0.7 ± 0.1	2.4 ± 0.1
18	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.8 ± 0.7	1.6 ± 0.2	2.0 ± 0.3	1.5 ± 0.2	3.3 ± 0.1
19	0.0 ± 0.4	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.4	0.6 ± 0.1	1.1 ± 0.1	0.7 ± 0.1	3.7 ± 0.2
20	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	4.0 ± 0.6	1.1 ± 0.1	1.4 ± 0.1	1.1 ± 0.1	2.5 ± 0.1
21	0.0 ± 0.2	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.4	0.8 ± 0.1	1.2 ± 0.1	0.9 ± 0.1	4.8 ± 0.3
22	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.5	0.3 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	3.5 ± 0.2
23	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.05	0.0 ± 0.5	0.8 ± 0.1	1.5 ± 0.1	0.8 ± 0.1	2.3 ± 0.1
24	0.0 ± 0.4	0.0 ± 0.06	0.0 ± 0.05	3.8 ± 0.5	1.2 ± 0.1	1.3 ± 0.1	1.1 ± 0.1	1.4 ± 0.1
25	0.0 ± 0.1	0.0 ± 0.05	0.0 ± 0.07	1.8 ± 0.8	1.6 ± 0.1	1.0 ± 0.1	1.7 ± 0.1	3.7 ± 0.2

Footnotes:

(1) See Figures 8 and 9.

TABLE 8 Uranium and Technetium in On-Site Sediments

Radionuclide	Sampling Point (1)	Concentration (pCi/g dry wt.)			
		May (2)	95% C. L.	August (3)	95% (4) C. L.
Uranium	1	2.30	±0.35 (5)	0.89	±0.07
	2	2.71	±0.41	1.09	±0.07
	3	5.96	±0.89	14.41	±0.68
	4	4.54	±0.68	1.30	±0.14
	5	42.31	±6.35	15.71	±0.68
	6	296.53	±44.48	9.00	±0.68
	7	42.85	±6.43	4.66	±0.21
	8	123.21	±18.48	22.78	±1.38
	9	168.57	±25.29	19.11	±0.68
	10	185.50	±27.83	125.81	±6.15
	11	214.61	±32.19	2.82	±0.14
	12	141.49	±21.22	32.81	±1.37
	13	18.69	±2.80	69.41	±3.44
	14	20.11	±3.02	45.15	±2.05
^{99}Technetium (6)	1	0.70	±0.2 (4)		
	6	30.0	±2.0		
	7	4.3	±0.2		
	11	16.0	±0.6		

Footnotes:

(1) See Figure 10.

(2) Analysis by FMPC Bioassay Lab.

(3) Analysis by commercial laboratory.

(4) C. L. = $\pm 2\sigma$.

(5) C. L. = ±15% (equipment specification).

(6) ^{99}Tc samples consisted of a composite of May and August material.

TABLE 9 Radionuclides in Great Miami River Sediments

Sampling Point (1)	Distance From FMPC Effluent Outfall	Uranium Concentration		^{99}Technetium Concentration	
		pCi/g (2)	95% C. L. (3)	pCi/g (2)	95% C. L. (3)
	Upstream				
15	5.9 km	2.62	±0.28		
16	2.4 km	0.00	±0.42	0.00	±0.4
	Downstream				
17	0.015 km	2.64	±0.34	1.30	±0.2
18	1.3 km	0.00	±0.42		
19	5.3 km	1.86	±0.22	0.80	±0.2
20	7.2 km	2.96	±0.34		
21	7.5 km	1.36	±0.20	0.00	±0.2

Footnotes:

(1) See Figure 10.

(2) Dry weight.

(3) C. L. = $\pm 2\sigma$.

TABLE 10 Uranium and Fluoride in Grass and Other Forage (1)

Sampling Point (2)	Distance (km) From FMPC (3)	Uranium Concentration		Fluoride Concentration	
		pCi/g (4)	95% C. L. (5)	ppm (4)	% of Standard (6)
1	10.5	0.09	±0.01	6.7	8.4
2	8.7	0.14	±0.01	9.8	12.3
3	6.2	0.27	±0.02	9.2	11.5
4	4.1	0.48	±0.03	7.5	9.4
5	5.3	0.33	±0.01	10.2	12.8
6	2.3	1.12	±0.06	8.7	10.9
7	1.4	4.33	±0.22	7.8	9.8
8	0.7	4.59	±0.21	10.5	13.1
9	0.9	5.06	±0.22	9.8	12.3
10	0.8	7.09	±0.30	13.1	16.4
11	1.9	0.56	±0.03	8.1	10.1
12	1.9	1.24	±0.06	6.3	7.9
13	1.0	1.09	±0.06	9.1	11.4
14	0.7	6.67	±0.36	19.5	24.4
15	1.3	0.66	±0.03	11.9	14.9
16	1.7	0.44	±0.03	9.7	12.1
17	2.2	0.32	±0.02	6.6	8.3
18	1.5	1.78	±0.14	10.4	13.0
19	1.6	1.06	±0.05	6.4	8.0
20	1.2	3.20	±0.15	12.8	16.0

Footnotes:

(1) The plant material analyzed was primarily brome grass (*Bromus* spp.), but some samples contained species from the following genera: *Allium, Daucus, Hordeum, Medicago, Melilotus, Poa, Secale,* and *Triticum.*

(2) See Figures 11 and 12.

(3) For the purposes of this table only, the center of the production area (Figure 2) was used for distance measurements.

(4) Dry weight.

(5) C. L. = $\pm 2\sigma$.

(6) No Ohio standard established; Kentucky standard of 80 ppm was used (see text).

TABLE 11 Uranium Concentration in Garden Produce: Potatoes

Sampling Point (1)	Number of Samples	Concentration in Peels (pCi/g dry wt.)				Concentration in Flesh (pCi/g dry wt.)			
		Maximum	Minimum	Average	95% (2) C. L.	Maximum	Minimum	Average	95% (2) C. L.
1	5	0.186	0.087	0.127	1.08	0.028	0.005	0.010	1.33
2	5	0.267	0.133	0.194	1.03	0.013	<0.002	<0.004	1.41
3	5	0.288	0.089	0.156	1.13	0.014	<0.003	<0.004	1.34
4	5	0.091	0.068	0.079	1.01	0.012	<0.002	<0.003	1.28
5	5	0.366	0.090	0.182	1.18	0.007	<0.003	<0.005	1.15
Control (3)	6	0.267	0.052	0.109	1.16	0.009	<0.003	<0.005	1.10

Footnotes:

(1) See Figure 15.

(2) C. L. = Average Concentration ×÷ value shown. Derived from log-transformed data; $= t_{(0.05,\ df)} S_{\bar{x}}$.

(3) Control samples were collected from a number of remote sites in Indiana, Ohio, and Michigan.

TABLE 12 Uranium In Milk

Sampling Location (1)	Number of Samples	Average Concentration (2)		Standard
		μg/L	pCi/L	
1	5	<1.0	<0.68	(3)
2	5	<1.0	<0.68	(3)

Footnotes:

(1) Sampling locations: 1 = dairy farm adjacent to the FMPC.
2 = dairy farm in Kentucky approximately 29 km southeast of the FMPC.

(2) All analyses for both sites yielded the same results; i.e., <1 μg/L.

(3) No standards have been established.

TABLE 13 Uranium Concentration in Fish

Sampling Point (1)	Species (2)	Number of Samples	Concentration (pCi/g) (3)			
			Maximum	Minimum	Average	95% (4) C. L.
1	1	2	0.181	0.132	0.155	7.54
	2	4	0.344	0.184	0.263	1.65
	3	5	0.777	0.172	0.368	2.25
	4	1			0.152	
	5	1			0.270	
	6	1			0.075	
	Total	14	0.777	0.132	0.242	1.47
2	1	1			0.067	
	2	3	0.538	0.195	0.305	3.64
	3	5	0.747	0.221	0.458	1.80
	4	1			0.247	
	6	1			0.185	
	Total	11	0.747	0.067	0.299	1.60
3	1	1			0.284	
	2	2	0.339	0.338	0.338	1.01
	3	5	0.550	0.253	0.357	1.50
	4	1			0.486	
	5	1			0.221	
	6	1			0.257	
	Total	11	0.550	0.221	0.331	1.22

Footnotes:

(1) See Figure 18.

(2) Species: 1 = Freshwater drum (*Aplodinotus grunniens*), smallmouth bass (*Micropterus dolomeiu*), and largemouth bass (*M. salmoides*).
2 = Carp (*Cyprinus carpio*) and golden redhorse (*Moxostoma erythrurum*).
3 = Gizzard shad (*Dorosoma cepedianum*).
4 = River carpsucker (*Carpiodes carpio*).
5 = Sunfish (*Lepomis* spp.).
6 = White bass (*Morone chrysops*).

(3) All concentrations in pCi(U)/g ash; wet weight: ash weight ratio ≅31:1.

(4) C. L. = Average Concentration ×÷ the value shown. Derived from log-transformed data; $= t_{(0.05, df)} S_{\bar{x}}$.

TABLE 14A Uranium in FMPC On-Site Well Water

Sampling Point (1)	Number of Samples	Concentration (pCi/L)				
		Maximum	Minimum	Average	95% (2) C. L.	% of (3) Standard
P1	4	0.54	0.20	0.34	1.93	0.03
P2	4	0.74	0.20	0.34	2.43	0.03
P3	4	0.27	0.14	0.14	1.74	0.01
T1S	2	6.09	5.28	5.69	1.90	0.47
T1D	4	1.22	0.20	0.34	3.84	0.03
T3	4	2.17	1.76	1.90	1.15	0.16
T4	3	5.15	4.60	4.87	1.15	0.41
T5	3	2.50	2.44	2.44	1.03	0.20
T8S	4	0.95	0.54	0.61	1.53	0.05
T8D	3	30.47 (4)	0.14	1.15	1.3×10^3	0.10
T9	4	0.95	0.54	0.81	1.51	0.07
T10	2	15.16	1.29	4.40	6.4×10^6	0.37
T11	4	1.35	0.20	0.54	3.80	0.05
TOAB	4	5.42	0.47	1.83	5.43	0.15
TCH	4	8.19	5.48	6.43	1.34	0.54

Footnotes:

(1) See Figure 20.

(2) C. L. = Average Concentration ×÷ the value shown. Derived from log-transformed data; $= t_{(0.05, df)} S_{\bar{x}}$.

(3) 1200 pCi/L per DOE Order 5480.1A, Attachment XI-1, Table II is the standard for uncontrolled waters and does not apply to on-site well water. Used for reference purposes only.

(4) Dip sample; bucket may have been contaminated.

TABLE 14B Gross α Activity in On-Site Well Water

Sampling Point (1)	Number of Samples	Concentration (pCi/L) (2)				
		Maximum	Minimum	Average	95% (3) C. L.	% of (4) Standard
P1	4	2.70	2.25	2.36	1.16	7.9
P2	4	1.35	0.45	0.93	2.28	3.1
P3	4	0.90	0.45	0.76	1.74	2.5
T1S	2	7.66	7.66	7.66	1.00	25.5
T1D	4	2.25	0.45	1.05	2.95	3.5
T3	4	4.96	2.70	3.38	1.58	11.3
T4	3	4.96	4.05	4.49	1.28	15.0
T5	3	4.05	3.15	3.58	1.37	11.9
T8S	4	2.70	1.35	1.96	1.60	6.5
T8D	3	23.42 (5)	<3.15	<7.15	13.60	<23.8
T9	4	2.70	2.25	2.58	1.15	8.6
T10	2	24.32	21.17	22.69	2.42	75.6
T11	4	2.25	<0.90	<1.49	1.88	<5.0
TOAB	4	<4.05	<2.25	<2.73	1.55	<9.1
TCH	4	8.56	1.04	4.84	5.75	16.1

Footnotes:

(1) See Figure 20.

(2) Includes activity due to Uranium (see Table 20A), thus results are conservative.

(3) C. L. = Average Concentration ×÷ the value shown. Derived from log-transformed data; $= t_{(0.05,\,df)} S_{\bar{x}}$.

(4) 30 pCi/L per DOE Order 5480.1A, Attachment XI-1, Table II is the standard for uncontrolled waters and does not apply to on-site wells. Used for reference purposes only.

(5) Dip sample; bucket may have been contaminated.

TABLE 14C Gross β Activity in On-Site Well Water

Sampling Point (1)	Number of Samples	Concentration (pCi/L) (2)				
		Maximum	Minimum	Average	95% (3) C. L.	% of (4) Standard
P1	4	4.95	4.05	4.49	1.14	15.0
P2	4	3.15	1.35	1.99	2.04	6.6
P3	4	3.15	1.80	2.32	1.44	7.7
T1S	2	22.97	11.26	16.24	92.70	54.1
T1D	4	2.25	0.90	1.42	3.66	4.7
T3	4	5.86	4.50	5.27	1.19	17.6
T4	3	6.76	5.86	6.30	1.19	21.0
T5	3	7.21	4.95	5.78	1.63	19.3
T8S	4	4.05	2.70	3.34	1.32	11.1
T8D	3	29.73 (5)	0.90	3.31	1.2×10^2	11.0
T9	4	4.95	3.60	4.02	1.27	13.4
T10	2	38.74	32.43	35.45	3.09	118.2
T11	4	3.60	2.25	2.65	1.53	8.8
TOAB	4	32.43	19.37	26.54	1.43	88.5
TCH	4	15.77	4.95	7.19	2.32	24.0

Footnotes:

(1) See Figure 20.

(2) Includes activity due to Uranium (see Table 20A), thus results are conservative.

(3) C. L. = Average Concentration $\times \div$ the value shown. Derived from log-transformed data; $= t_{(0.05, df)} S_{\bar{x}}$.

(4) 30 pCi/L per DOE Order 5480.1A, Attachment XI-1, Table II is the standard for uncontrolled waters and does not apply to on-site wells. Used for reference purposes only.

(5) Dip sample; bucket may have been contaminated.

TABLE 15A pH and Chloride in On-Site Well Water

Sampling Point (1)	Number of Samples	pH		Chloride (mg/L)				
		Maximum	Minimum	Maximum	Minimum	Average	95% (3) C. L.	% of (4) Standard
P1	4	7.6	7.5	44	39	41.2	1.09	16.5
P2	4	7.6	7.5	19	17	18.0	1.07	7.2
P3	4	7.6	7.4	13	12	12.7	1.07	5.1
T1S	2	7.5	7.3	23	18	20.3	4.75	8.1
T1D	4	7.8	7.4	22	20	21.2	1.08	8.5
T3	4	7.5	7.4	23	20	21.5	1.10	8.6
T4	3	7.5	7.4	27	20	22.8	1.46	9.1
T5	3	7.4	7.3	21	19	20.0	1.13	8.0
T8S	4	7.6	7.4	21	19	20.2	1.08	8.1
T8D	3	7.7	7.4	12	8	10.5	1.79	4.2
T9	4	7.8	7.5	24	19	21.4	1.19	8.6
T10	2	6.8	6.8	79	74	76.5	1.51	30.6
T11	4	8.6	7.5	21	17	19.2	1.16	7.7
TOAB	4	8.5	7.0	577	540	559.8	1.05	223.9
TCH	4 (5)	7.5	7.1	57	4	22.8	42.4	9.1

Footnotes:
(1) See Figure 20.
(2) C. L. = $\pm 2\sigma$.
(3) C. L. = Average $\times \div$ the value shown. Derived from log-transformed data; = $t_{(0.05,\ df)} S_{\bar{x}}$.
(4) 250 mg/L per Ohio EPA Rule 3745-82-02, Secondary Maximum Contaminant Levels.
(5) Only 3 for Chloride.

TABLE 15B Nitrate Nitrogen and Sulfate in On-Site Well Water

Sampling Point (1)	Number of Samples	Nitrate Nitrogen (mg/L)					Sulfate (mg/L)				
		Maximum	Minimum	Average	95% (2) C. L.	% of (3) Standard	Maximum	Minimum	Average	95% (2) C. L.	% of (4) Standard
P1	4	1.40	<0.11	<0.48	5.31	<4.8	97	64	79.0	1.35	31.6
P2	4	<0.11	<0.11	<0.11	1.00	<1.1	142	9	18.4	8.74	7.4
P3	4	<0.11	<0.11	<0.11	1.00	<1.1	45	40	42.2	1.09	16.9
T1S	2	1.67	<0.11	<0.43	2.7×10^7	<4.3	80	79	79.5	1.08	31.8
T1D	4	<0.11	<0.11	<0.11	1.00	<1.1	17	2	8.1	4.87	3.2
T3	4	<0.11	<0.11	<0.11	1.00	<1.1	101	92	97.7	1.07	39.1
T4	3	4.25	2.71	3.23	1.82	32.3	68	62	65.3	1.12	26.1
T5	3	<0.11	<0.11	<0.11	1.00	<1.1	91	80	83.5	1.20	33.4
T8S	4	<0.11	<0.11	<0.11	1.00	<1.1	75	53	65.5	1.27	26.2
T8D	3	0.68	<0.11	<0.21	13.07	<2.1	12	2	6.0	10.92	2.4
T9	4	1.78	<0.11	<0.49	9.77	<4.9	81	71	74.9	1.10	30.0
T10	2	234.93	26.90	79.50	9.5×10^5	795.0(5)	769	723	745.6	1.48	298.2 (5)
T11	4	1.22	<0.11	<0.36	8.52	<3.6	95	5	43.0	9.82	17.2
TOAB	4	0.11	<0.11	<0.11	1.00	<1.1	663	563	608.0	1.12	243.2 (5)
TCH	4	7.93	0.72	2.28	4.75	22.8	252	28	132.4	5.27	53.0

Footnotes:

(1) See Figure 20.

(2) C. L. = Average ×÷ the value shown. Derived from log-transformed data; $= t_{(0.05,\ df)} S_{\bar{x}}$.

(3) 10 mg/L per Ohio EPA Rule 3745-81-11, Maximum Contaminant Levels for Inorganic Chemicals.

(4) 250 mg/L per Ohio EPA Rule 3745-82-02, Secondary Maximum Contaminant Levels.

(5) Standards apply only to drinking water, and thus only to wells P1, P2 and P3. Used for reference purposes only on others.

TABLE 16 Trend Analysis of Radionuclide, Ion, and pH Levels in On-Site Well Water: 1982 - 1984 (3)

Well	Parameter						
	pH	α	β	U	Cl	NO3	SO4
P1		(2)↑	$.01<p<.02$↑			(2)↓	$p<<.002$↑
P2						$.002<p<.01$↓	(1)↑
P3				$.02<p<.05$↓	(1)↑	$.002<p<.01$↓	$.02<p<.05$↑
T1S		(2)↑			$.002<p<.01$↓	$.002<p<.01$↓	(2)↓
T1D				(2)↓	$.002<p<.01$↓	$.02<p<.05$↓	(1)↓
T3			(2)↑	$.01<p<.02$↓		$.002<p<.01$↓	$p<<.002$↑
T4							
T5	(2)↓			$.01<p<.02$↓	$.002<p<.01$↑	$.02<p<.05$↓	(1)↑
T8S	(2)↓	$.02<p<.05$↑	$p<.002$↑		$p<.002$↓	$.002<p<.01$↓	(2)↓
T8D		$.01<p<.02$↑			$.02<p<.05$↓		(2)↑
T9	(2)↓		(2)↓	$.002<p<.01$↓			(1)↑
T10		(1)↓			$.01<p<.02$↓		(1)↓
T11					(1)↓		
TOAB					$.002<p<.01$↓	$.002<p<.01$↓	
TCH		(1)↑		(2)↑			

Footnotes:
(1) $.05<p<.1$
(2) $.1<p<.2$
(3) The direction of the arrow to the right of the probability estimate indicates the direction of the trend.

TABLE 17 Uranium in Off-Site Well Water

Sampling Point (1)	Number of Samples	Concentration (pCi/L)				
		Maximum	Minimum	Average	95% (2) C. L.	% of (3) Standard
1	12	0.54	0.20	0.34	1.24	0.03
2	9	0.54	0.14	0.27	1.46	0.02
3	10	0.47	0.20	0.34	1.26	0.03
4	10	1.42	1.02	1.29	1.08	0.11
5	11	1.76	1.29	1.42	1.07	0.12
6	12	1.62	0.81	1.29	1.16	0.11
7	11	1.15	0.74	0.95	1.08	0.08
8	12	0.81	0.47	0.54	1.10	0.05
9	12	1.02	0.54	0.81	1.10	0.07
10	12	0.47	0.27	0.34	1.10	0.03
11	7	0.88	0.54	0.68	1.19	0.06
12	11	182.79	128.63	165.19	1.07	13.77
13	12	0.41	0.34	0.41	1.06	0.03
14	12	0.81	0.68	0.74	1.03	0.06
15	12	247.11	193.62	219.35	1.06	18.28
16	11	0.81	0.20	0.41	1.38	0.03
17	11	46.04	30.47	36.29	1.08	3.02
18	11	0.41	0.20	0.34	1.17	0.03
19	12	0.34	0.07	0.20	1.38	0.02
20	10	0.47	0.07	0.20	1.48	0.02
21	12	0.34	0.20	0.27	1.10	0.02
22	9	0.88	0.61	0.74	1.11	0.06

Footnotes:
(1) See Figure 21.
(2) C. L. = Average Concentration ×÷ value shown. Derived from log-transformed data; = $t_{(0.05,\ df)} S_{\bar{x}}$.
(3) 1200 pCi/L per DOE Order 5480.1A, Attachment XI-1, Table II.

TABLE 18 Nitrate Nitrogen in Off-Site Well Water

Sampling Location (1)	Number of Samples	Concentration (mg/L)				
		Maximum	Minimum	Average	95% (2) C. L.	% of (3) Standard
1	12	<0.11	<0.11	<0.11	1.00	<1.1
2	9	0.18	<0.11	<0.12	1.13	<1.2
3	10	<0.11	<0.11	<0.11	1.00	<1.1
4	10	1.67	0.63	1.15	1.21	11.5
5	11	16.47	1.31	7.83	1.87	78.3
6	12	8.18	1.27	3.70	1.51	37.0
7	11	<0.11	<0.11	<0.11	1.00	<1.1
8	11	3.66	1.08	2.04	1.34	20.4
9	11	3.43	1.49	2.53	1.18	25.3
10	12	<0.11	<0.11	<0.11	1.00	<1.1
11	7	4.18	1.17	3.24	1.53	32.4
12	11	2.73	1.22	1.95	1.21	19.5
13	12	2.06	1.27	1.62	1.11	16.2
14	12	4.50	1.36	2.98	1.26	29.8
15	12	3.84	1.87	2.65	1.16	26.5
16	11	0.16	<0.11	<0.12	1.08	<1.2
17	11	0.32	<0.11	<0.13	1.26	<1.3
18	11	<0.11	<0.11	<0.11	1.00	<1.1
19	12	<0.11	<0.11	<0.11	1.00	<1.1
20	10	1.27	<0.11	<0.25	1.86	<2.5
21	12	<0.11	<0.11	<0.11	1.00	<1.1
22	9	1.69	<0.11	<0.68	2.37	<6.8

Footnotes:
(1) See Figure 21.
(2) C. L. = Average Concentration ×÷ value shown. Derived from log-transformed data; = $t_{(0.05,\ df)} S_{\bar{x}}$.
(3) 10 mg/L per Ohio EPA Rule 3745-81-11, Maximum Contaminant Levels for Inorganic Chemicals.

TABLE 19 Trend Analysis of Uranium and Nitrate Concentrations in Off-Site Well Water: 1983 thru 1984 (1, 5)

Sampling Location (2)	Uranium	Nitrate	Sampling Location (2)	Uranium	Nitrate
1	(4)↑		12	$.0386<p<.146$↓	$p<.001$↓
2			13		$.001<p<.0118$↓
3			14	$.0312<p<.2188$↓	$.0062<p<.0386$↓
4	$.02<p<.05$↓		15	$p<.0004$↓	
5		$p<.0624$↓	16		$p<.0312$↓
6		$p<.0312$↓	17		$.0078<p<.0704$↓
7			18		$p<.0516$↓
8	(3)↑		19	$p<.004$↑	$p<.0312$↓
9	(4)↑	(3)↓	20	$p<.0156$↑	$.004<p<.039$↓
10	$p<.0214$↓	$p<.0156$↓	21		$p<.0156$↓
11	$p<.0312$↓		22		$p<.002$↓

Footnotes:

(1) Where necessary due to a lack of data, only 1984 data were used in the analyses.

(2) See Figure 21.

(3) $.05<p<.1$

(4) $.1<p<.2$

(5) The direction of the arrow to the right of the probability estimate indicates the direction of the trend.

TABLE 20 NPDES Data for 1984

Parameter	Units	Number Of Samples	Minimum	Maximum	Annual Average	NPDES Permit Limits		Percent Compliance
						Daily Maximum	Monthly Average	
Discharge 001 (MH175)								
Flow rate	MGD	Continuous	0.072	1.102	0.576	NA	NA	NA
pH	pH Units	Daily Grab	7.3	9.3	NA	Range = 6.5 to 10.0		100
Suspended Solids	mg/L*	53	<2	33	8	60	20	100
Ammonia (as N)	kg/day	53	<1	46	6	43	28	98
Oil & Grease (mg/L)	mg/L	53	<5	9	5	15	NA	100
Residual Chlorine	mg/L	25[b]	0.01	0.08	0.05	0.10	NA	100
Nitrate (as N)	kg/day	53	86	2318	990	3180	1590	98
Discharge 002 (Storm Sewer Outfall)								
Flow rate	MG/Event	Continuous	0.006	1.00[a]	0.161	NA	NA	NA
pH	pH Units	Grab/Event	7.4	8.5	NA	Range = 6.5 to 9.0		100
Suspended Solids	mg/L*	98	<2	64	8	100	30	100
Oil & Grease	mg/L	98	<5	17	5	15	NA	100
Sampling Location 001A (Sewage Treament Plant)								
Flow rate	MGD	Continuous	0.020	0.246	0.119	NA	NA	NA
pH	pH Units	Daily Grab	7.1	8.3	NA	Range = 6.5 to 9.0		100
BOD_5	mg/L* (kg/day)	53	<1(0.1)	18(6.0)	7(2.9)	40(10.0)	20(5.0)	100
Suspended Solids	mg/L* (kg/day)	53	1(0.3)	12(8.7)	4(2.0)	40(10.0)	20(5.0)	100
Fecal Coliform	MPN/100ml*	29[b]	1[c]	2000	356	2000	1000	100
Sampling Locations 001B & C (Combined General Sump & Clearwell)								
Flow rate	MGD	Continuous	0.0	0.312	0.182	NA	NA	NA
Suspended Solids	kg/day	53	0.6	17.8	5.1	12.8	6.2	94
Chromium (+6)	kg/day	53	0.0003	0.013	0.005	0.008	0.004	75
Chromium (total)	kg/day	53	0.003	0.047	0.018	0.102	0.050	100
Iron	kg/day	53	0.06	0.66	0.20	0.85	0.41	98
Nickel	kg/day	53	0.003	0.161	0.049	0.256	0.124	100
Copper	kg/day	53	0.005	0.104	0.025	0.051	0.025	86
Sampling Location 001D (Lift Station)								
Flow rate	MGD	Continuous	0.0	0.632	0.249	NA	NA	NA
Suspended Solids	mg/L	53	<2	73	8	100	30	100
Oil & Grease	mg/L	53	<5	7	<5	15	NA	100

Footnotes:

NA = Not applicable.

* = Flow-weighted averages.

[a] Estimated during an extreme storm event.

[b] Monitoring not required during winter months.

[c] Occurred subsequent to installation of the ultraviolet disinfection system.

TABLE 21 Population Distribution Within 80 - km (50 mi) of the FMPC

Compass Sector	Estimated Population (1)			
	0 - 8 km (0 - 5 mi)	8 - 16 km (5 - 10 mi)	16 - 32 km (10 - 20 mi)	32 - 80 km (20 - 50 mi)
N	445	3,395	6,743	29,597
NNE	221	18,959	12,805	148,079
NE	489	32,001	36,705	557,783
ENE	2,489	25,760	29,830	55,078
E	512	40,770	70,762	85,240
ESE	713	54,533	150,630	107,365
SE	1,606	36,467	247,846	118,490
SSE	985	28,932	207,202	51,946
S	669	19,214	53,673	39,116
SSW	390	4,217	10,614	21,987
SW	185	2,957	13,066	16,574
WSW	440	4,961	3,930	19,199
W	519	1,765	3,292	31,629
WNW	157	1,361	5,211	21,605
NW	511	1,433	1,802	37,945
NNW	519	1,134	21,042	71,493
Totals	10,850	277,859	875,153	1,413,126
Total in all sectors: 2,576,988				

Footnote:

(1) Based on "Report of Findings, Population Studies for DOE Feed Materials Production Center, Near Fernald, Ohio, for NLO, Inc.", May 18, 1981.

TABLE 22 Radiation Dose Rates at Site Boundary

Location (1)	Dose Rate, mR/hr $\times 10^{-3}$	
	Range (2)	Average
BS1	8.7 - 10.0	9.7
BS2	9.4 - 11.3	10.3
BS3	9.0 - 11.4	10.3
BS4	8.0 - 11.0	9.7
BS5	8.1 - 11.6	10.5
BS6	13.8 - 17.1	15.5
BS7	10.7 - 12.3	11.4

Footnotes:

(1) See Figure 2.

(2) Continuous monitoring dosimeters were processed quarterly.

TABLE 23 Summary of 1984 Radiation Exposure

Type of Exposure	Organ	Dose mrem/yr	Guideline (1, 2)	% of Guideline (2)
Ingestion - Drinking Water				
Maximum Individual 50-year Committed Dose Equivalent				
Great Miami River Water	Effective	0.010	-	-
	Bone Endosteum	0.073	500	0.015
Offsite Well Number 12	Effective	66.4	-	-
	Bone Endosteum	908	1500	60.5
Offsite Well Number 15	Effective	89	-	-
	Bone Endosteum	1204	1500	80.3
Offsite Well Number 17	Effective	14.6	-	-
	Bone Endosteum	199	1500	13.3
Inhalation				
Maximum Individual Committed Dose Equivalent	Whole Body	1.8	[25]	[7.2]
	Pulmanary Tissue(3)	100	1500 [75]	6.7 [133.3]
80 Km Population Dose Equivalent	Effective (3)	370 person-rem	-	-
Maximum Potential 50-year Dose in a Population Group (Ross, Ohio)	Effective	1.4	-	-
	Bone Endosteum	4.5	500	0.9
	Lungs	10.5	500	2.1
Direct Radiation				
Maximum Dose Equivalent to Nearest Resident	Whole Body	9.8	500	2.0

Footnotes:

(1) Guidelines - DOE Order 5480.1A in effect for 1984, for individuals at point of maximum exposure, 500 mrem whole body, 1500 mrem to other organs. For sample of exposed population, 170 mrem whole body, 500 mrem to other organs. Currently, there are no regulatory guidelines for effective dose commitments.

(2) NESHAP, promulgated 2-6-85, are shown in [ ].

(3) Calculated with AIRDOS/DARTAB computer model by ORNL.

FEED MATERIALS PRODUCTION CENTER

ENVIRONMENTAL MONITORING ANNUAL REPORT FOR 1984

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NLO, Inc.

A SUBSIDIARY OF NL INDUSTRIES, INC.

P. O. BOX 39158 CINCINNATI, OHIO 45239

PHONE: AREA CODE: 513 - 738 - 6200

AUG [illegible]

J. A. Reafsnyder
Site Manager
Department of Energy
P. O. Box 39158
Cincinnati, Ohio 45239

Dear Mr. Reafsnyder:

CORRECTIONS TO THE FMPC ENVIRONMENTAL MONITORING ANNUAL REPORT FOR 1984 (NLCO-2028)

Enclosed are copies of an Errata Notice for corrections to the Environmental Monitoring Annual Report for 1984 as discussed with V. Fayne of your staff. Corrections to page 50 involved eliminating reference to dose from well water ingestion in terms of a percentage of DOE Guidelines. The change to page 76 involved correction of a typographical error in the heading of the dose column to eliminate confusion regarding the total dose received for a 50-year period.

The corrections were made Wednesday, August 14, and corrected copies of the report were distributed at the public meeting at Crosby Township school on Thursday, August 15, 1985.

These errata notices are being provided for your use and distribution to those to whom the report distribution was made prior to August 15, 1985. In addition to the errata notice, copies of the corrected pages 50 and 76 are available upon request. Please direct any questions or requests for additional corrected pages to R. W. Keys (extension 273) or D. A. Fleming (extension 211) of my staff.

Sincerely yours,

Original Signed By
R. M. SPENCELEY

R. M. Spenceley
Manager

RWK:DAF/vvs

encl. - Errata Notice - 185 copies

cc: W. J. Adams
✓M. W. Boback
D. A. Fleming - R. W. Keys
W. J. Grannen - P. I. Campisi
W. H. Kelley
R. B. Weidner
Central Files

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ERRATA NOTICE

FEED MATERIALS PRODUCTION CENTER ENVIRONMENTAL

MONITORING ANNUAL REPORT, NLCO-2028, JULY 1985

(1) Page 49 - 2nd sentence, change "backgrkound" to "background."

(2) Page 49-50 - The last sentence of page 49 and first paragraph of page 50 should be as follows:

The maximum committed dose equivalents due to ingestion of water from well number 12 are 66.4 mrem effective dose and 908.0 mrem to the bone endosteum. The maximum potential dose equivalents from drinking from well number 15 are 89.0 mrem effective dose and 1203.8 mrem to the bone endosteum. Comparisons of the dose equivalents to applicable dose guidelines are shown in Table 23. The maximum potential dose equivalents from drinking from well number 17 are 14.6 mrem effective dose and 199.5 mrem to the bone endosteum. It should be noted that well number 12 was replaced by NLO in April of 1985 and is no longer used as a source of drinking water, and that the other wells were not used as a source of drinking water in 1984.

(3) Page 76 - Table 23. Column three, heading, units of mrem/yr should be mrem; column one, bottom row, "Maximum Dose Equivalent . . . .," should be "Maximum Annual Dose Equivalent . . . ."

Also col 2, 5th line. Change "pulmonary" to "pulmonary"