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ENVIRONMENTAL MONITORING REPORT
1980, 1981, 1982
FOR THE
FORMER MIDDLESEX SAMPLING PLANT
AND MIDDLESEX MUNICIPAL LANDFILL SITES

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ABSTRACT

During periods of remedial action activities conducted in 1980 and 1981 at designated sites in the Borough of Middlesex, New Jersey, air, water, and sediments were sampled and analyzed to verify the adequacy of contamination control and compliance with applicable standards. Analytical results show that remedial action activities at the Middlesex Sampling Plant (MSP) and vicinity properties were conducted, with few exceptions, within applicable standards.

During 1982, a surveillance monitoring program was initiated at the MSP and at the former Middlesex Municipal Landfill (MML) site. Radioactivity was measured in air and water to allow calculation of radiation doses to the public. The resulting dose from external gamma radiation at the MSP site boundary in 1982 was approximately twice natural background and less than 40 percent (background included) of the Department of Energy (DOE) standard. The highest continuous occupancy dose to the bronchial epithelium (lungs) from radon exposure at the MML boundary was approximately twice the background value or about 60 percent (background included) of the DOE standard.

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ABBREVIATIONS

cm	centimeter
ft	foot
ha	hectare
in.	inch
km	kilometer
km/h	kilometers per hour
m	meter
$\mu\text{g}/\text{m}^3$	micrograms per cubic meter
$\mu\text{R}/\text{h}$	microrentgens per hour
mi	mile
mi/h	miles per hour
mg/l	milligrams per liter
mrem	millirem
mrem/wk	millirem per week
mrem/yr	millirem per year
pCi/g	picocuries per gram
pCi/l	picocuries per liter
pCi/m^3	picocuries per cubic meter
$\text{pCi}/\text{m}^2/\text{s}$	picocuries per square meter per second
yd	yard
yd^3	cubic yards
yr	year

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1.0 INTRODUCTION

This report presents the results of environmental monitoring conducted in the area of the former Middlesex Sampling Plant (MSP) during calendar years 1980, 1981, and 1982 and the former Middlesex Municipal Landfill (MML) during 1982. Both sites, designated for remedial action under the Department of Energy's (DOE) Formerly Utilized Sites Remedial Action Program (FUSRAP), are located in the Borough of Middlesex, Middlesex County, New Jersey as shown in Figure 1-1.

The MSP site is a DOE-owned facility that was used for sampling, storage, and/or shipment of uranium, thorium, and beryllium ores from 1943 until 1967. It is currently utilized for interim storage of low-level radioactive soils and rubble resulting from the cleanup of surrounding properties that had become contaminated as a result of MSP operations. The MML site, owned by the Borough of Middlesex, contains soil contaminated with uranium residues that were deposited during 1948. The landfill ceased operation in 1974.

DOE initiated remedial action at the MSP and vicinity properties in 1980, with cleanup work continuing in 1981. The remedial action was performed to consolidate contaminated materials on the MSP site in order to control migration of contaminants until a final disposition for the site is determined. Environmental monitoring was conducted during 1980 and 1981 in association with remedial action activities, and a routine surveillance program was initiated in 1982.

1.1 MIDDLESEX SAMPLING PLANT

The former Sampling Plant site occupies 3.8 ha (9.6 acres) located at 239 Mountain Avenue in the Borough of Middlesex, as shown in Figure 1-2. There are four buildings currently located on the site which is surrounded by a 2.1-m (7-ft)-high chain link fence. A major portion of the site is paved with asphalt. The topography in the area is gently sloping, with elevations ranging from about

FIGURE 1-1 AREA MAP OF THE MIDDLESEX SAMPLING PLANT (MSP) AND MIDDLESEX MUNICIPAL LANDFILL (MML) SITES

FIGURE 1-2 VICINITY MAP OF MSP SITE

18.3 m (60 ft) above mean sea level (m.s.l.) on the north to 15.2 m (50 ft) above m.s.l. on the south. Soils at the MSP are silty to sandy loams with the thickness over bedrock ranging from 0.5 to 2.4 m (1.5 to 8 ft). All on-site surface water is conveyed via an underground drainage system to the easement ditch south of the site which discharges into a small brook known as "Main Stream."

The Manhattan Engineer District (MED) established the MSP in 1943. The facility was used for sampling, storage, and/or shipment of uranium, thorium, and beryllium ores. All ores received at the facility were handled in a similar manner, including thawing (if necessary), drying, crushing, and screening. Samples were taken for assay from collection hoppers beneath the screens. The ores were subsequently packaged, weighed, and shipped to processing facilities.

Operation of the MSP facilities was terminated in 1955 by the Atomic Energy Commission (AEC), successor to the MED. Later, the AEC used the site for storage and limited sampling of thorium residues. All AEC activities at the MSP ended in 1967. On-site structures were decontaminated, and the site was certified for unrestricted use under criteria in effect at that time.

In 1968, the AEC returned the MSP site to the General Services Administration which transferred the property to the Department of the Navy. The site served as a reserve training center for the U.S. Marine Corps from 1969 to 1979. The MSP was returned to DOE custody in 1980. That same year the DOE initiated remedial action to clean up properties in the vicinity of the former Sampling Plant. A storage pad was constructed at the site to temporarily store contaminated material (primarily soil) from the cleanup activities. The volume of contaminated material stored at the MSP as a result of remedial action conducted to date is presented in Table 1-1.

TABLE 1-1
VOLUMES OF CONTAMINATED SOIL ON THE MSP STORAGE PAD

Source	Quantity (yd ³)
1980 Total (Phase I)	9,421
1981 Total (Phase II)	25,742
Total on Storage Pad	35,163

Source: BNI (Ref. 1)

1.2 MIDDLESEX MUNICIPAL LANDFILL

The former MML site is located 0.8 km (0.5 mi) north-northwest of the MSP within the corporate limits of the Borough of Middlesex, as shown in Figure 1-3. The MML site is situated east of Mountain Avenue, south of Monroe Street, and west of Bound Brook. The landfill has not been used for solid waste disposal since 1974, but a part of the site is currently being used for can, bottle, and paper recycling operations.

The current landfill surface rises from 11 m (36 ft) above m.s.l. near Bound Brook to approximately 16.2 m (53 ft) above m.s.l. near Mountain Avenue. Immediately east of the site, Bound Brook runs northwest along the MML site. Because of the site topography, surface water flows off the site directly into Bound Brook as well as into a storm drain south of the site that discharges into Bound Brook. Shallow unconfined groundwater is present at the site in the landfill materials and in the sands and weathered shales and bedrock beneath the landfill.

The radioactively contaminated portion of the MML site encompasses only about 1.2 ha (3 acres) of the overall 6.1-ha (15-acre) former landfill (Figure 1-3). Approximately two-thirds of the contaminated portion of the site is owned by the Borough of Middlesex, and the remainder is owned by the Middlesex Presbyterian Church. For this report, only this 1.2-ha (3-acre) contaminated area is referred to as the MML.

Landfill operations began in the mid-1940s. In 1948, dirt contaminated with pitchblende (high grade uranium ore) was removed from the MSP and placed on top of the existing fill at the MML. Subsequent landfill operations resulted in varying depths of cover material being placed over the contaminated material.

FIGURE 1-3 VICINITY MAP OF THE MML SITE

1.3 AREA ENVIRONMENTAL CONDITIONS

The average annual daily maximum temperature for the Middlesex area is 62.5°F (16.9°C), and the average daily minimum is 45.2°F (7.3°C). Average monthly highs occur in July [85.6°F (29.8°C)], and average monthly lows occur in January [24.3°F (-4.3°C)]. Average annual snowfall is 69.8 cm (27.5 in.). Average annual total precipitation is 106 cm (42 in.). Winds in the area are predominantly from the southwest at a mean speed of 16 km/h (10 mi/h) (Ref. 2).

Land use in the vicinity of both sites is a mixture of industrial, commercial, residential, and public land. The MML is surrounded by primarily public and some privately owned lands, while the MSP is bounded primarily by industrial and residential properties. The populations of area communities are listed in Table 1-2. The residential population within 1.6 km (1 mi) of the MSP site boundary is estimated to be 10,400 people, living in approximately 2900 dwellings (Ref. 2).

TABLE 1-2
POPULATION IN THE MIDDLESEX AREA

Community	1980	1970	% Change
Middlesex (Borough)	13,480	15,038	-10.36
Middlesex (County)	595,893	583,813	+ 2.03
Piscataway	42,223	36,418	+13.75

Source: Ford, Bacon & Davis Utah, Inc. (Ref. 2)

2.0 SUMMARY OF MONITORING RESULTS

Environmental monitoring was conducted during remedial action work at the MSP and vicinity properties (1980 and 1981), and routine surveillance monitoring was begun at the MSP and MML sites in 1982. Air, water, and sediment samples were collected and analyzed for radionuclides of interest to determine compliance with Concentration Guides (CGs) provided in DOE Order 5480.1A, Chapter XI (Ref. 3).

The purpose of the remedial action was to reduce contamination in the vicinity of the MSP site to levels below currently established limits. Fluctuations in radionuclide concentrations in water and air occurred as work progressed. However, because of contamination control procedures applied to the work, limits were seldom exceeded.

The radiological monitoring at the MSP and vicinity during 1980-1981 remedial action work is summarized as follows:

- o Total uranium and radium-226 concentrations in surface water and sediments at the MSP area decreased.
- o Surface water samples obtained during 1980 and 1981 showed a decreasing trend in uranium and radium-226 concentrations that were less than 8 and 9 percent, respectively, of the CG in 1981.
- o Sediment samples collected at the end of 1981 remedial action contained maximum uranium and radium-226 concentrations less than 63 and 32 percent, respectively, of the criteria.
- o Radon concentrations were below the CG of 3 pCi/l for release to uncontrolled areas during both 1980 and 1981.
- o Air particulate sampling generally indicated a positive correlation between excavation activities and airborne radionuclide concentrations.
- o The maximum average gross alpha concentration at the MSP was less than 1 percent of the CG for thorium-230, the most limiting radionuclide in the uranium decay series.

After the completion of 1981 remedial action work, a routine monitoring program was initiated during 1982.

During 1982 no activities were conducted that disturbed contaminated soils on the storage pile at the MSP or affected the contaminated area at the MML site. Air and water samples were collected on a routine basis in 1982 at both sites and analyzed for radionuclides of interest to determine compliance with the CG. Radiation doses were calculated to determine exposure levels to the general public and compared with DOE Radiation Protection Standards (Ref. 3). The following summarize the radiological conditions at the MSP and MML as determined during the 1982 environmental monitoring:

- o In surface waters, average uranium concentrations were less than 7 percent of the CG for uranium released to uncontrolled areas, and average radium-226 concentrations were less than 13 percent of the CG for radium-226 released to uncontrolled areas.
- o In groundwater, the maximum uranium concentration occurred at the MSP and was less than 11 percent of the CG. The maximum radium-226 concentration was recorded at the MML (Location 6) and was 64 percent of the CG.
- o Radon concentrations in the area of the two sites were below the CG of 3 pCi/l for release to uncontrolled areas during 1982. The highest average concentrations of radon in air at the MSP and MML sites were 30 and 48 percent, respectively, of the CG.
- o External gamma radiation levels at the MML site were all within the normal background range of 3.4 to 13 μ R/h. At the MSP, the highest outdoor level at the site boundary (Location 5) averaged 22.1 μ R/h, which is less than twice the upper value of the range for background (13 μ R/h).

Radiation dose calculations represent hypothetical worst-case situations based upon maximum radiological concentrations and assume non-realistic exposure times inhalation, or ingestion. Radiation doses for air and external gamma radiation were calculated for persons at the boundaries of the MSP and MML sites assuming

continuous occupancy at the point of highest outdoor exposure during 1982 and were as follows:

- o At the point of maximum radon concentration at the MSP boundary (Location 4), the continuous-occupancy dose to the bronchial epithelium (lungs) of an individual would have been 300 mrem/yr, which is 20 percent of the DOE Radiation Protection Standard for the general public of 1500 mrem/yr.
- o For the MML area, the maximum measured radon concentrations, assuming continuous-occupancy, would have resulted in a dose to bronchial epithelium of 890 mrem/yr, or about 60 percent of the DOE standard.
- o At the MSP boundary, the continuous-occupancy whole body dose from external gamma radiation would have been 185 mrem/yr which is approximately twice the average background dose of 100 mrem/yr for the state of New Jersey.
- o At the MML site, the maximum external gamma radiation level would have resulted in a whole body dose of 104 mrem/yr. This is about the same as the external radiation dose resulting from naturally occurring radiation in the state of New Jersey.

For drinking water, radiation dose calculations assume that a member of the public drank water throughout all of 1982 from only the source of highest uranium and radium concentrations. This hypothetical worst case situation resulted in the following:

- o From groundwater at the MSP (Wells 11 and 3A), a person would receive an annual bone dose in the first year of 40 mrem, or 3 percent of the DOE Radiation Protection Standard.
- o From surface water at the MSP, the corresponding annual dose in the first year would be 40 mrem, or 3 percent of the DOE standard.
- o The annual bone dose in the first year from groundwater obtained at the MML would be 66 mrem, or 4 percent of the DOE standard.
- o For surface water at the MML site, the annual bone dose would be less than 54 mrem, or 4 percent of the DOE standard.

3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION

This section provides the results of environmental monitoring for the MSP and MML sites, including the sampling, monitoring, and analytical procedures and the extent of conformance with applicable standards. The average values listed in the individual tables are the arithmetic average of the sum of individual results. Individual sources of error (e.g., analytical or sampling error) were not estimated. In computing the averages, where values are less than the limit of sensitivity of the analytical method, values are considered as being equal to the limit of sensitivity and the "average" value is reported without the notation "less than."

During 1980, 1981, and 1982 supplemental radon monitoring was conducted at the MSP by Mound Laboratory, operated for the DOE by Monsanto Research Corporation, Miamisburg, Ohio. Mound's initial monitoring was directed toward activities associated with Phase I remedial action activities at the MSP site, especially around the MSP storage pad, which was being prepared to receive the radioactively contaminated material from off-site properties. Throughout the remainder of 1980, 1981, and 1982, monitoring was undertaken at additional on-site and off-site stations. Mound Laboratory results are incorporated into this report.

DOE standards for radionuclides are provided in the CGs contained in Reference 3. The CGs for radionuclides of concern at the Middlesex Site are included in Appendix A of this report.

3.1 1980 ENVIRONMENTAL MONITORING

The 1980 environmental monitoring was conducted in association with remedial action work (Phase I) that began in June 1980 and was completed in November 1980. Remedial action at the MSP included the construction of a 1.2-ha (3-acre), asphalt-paved storage pad (on-site), and the decontamination and restoration of five adjacent and nearby properties. The contaminated soils from the properties were placed on the storage pad and covered with a reinforced EPDM (ethylene propylene diene monomer) fabric.

Environmental monitoring was conducted during remedial action activities to verify the adequacy of contamination control and document conditions after the remedial action. Monitoring locations and sampling frequency were established to provide coverage of potential pathways for contamination, particularly during removal of contaminated soils. A detailed account of the 1980 remedial action activities is contained in References 4 and 5.

3.1.1 Water Sampling

During 1980, surface water sampling was performed in the vicinity of the MSP to determine the effect of remedial action activities on contamination levels. Sample locations are shown in Figure 3-1. Samples were collected using the grab technique, with the frequency (daily or biweekly) dependent on site activities. Water samples were analyzed for total uranium and dissolved radium, with results presented by location in Tables 3-1 and 3-2.

While uranium concentrations fluctuated during remedial action, all values remained below the CG of 2 mg/l for release to uncontrolled areas. The radium-226 CG of 30 pCi/l for release to uncontrolled areas was seldom exceeded during 1980 remedial action, and the annual averages for all four locations were well below the CG. For soluble radium-226 as listed in Table 3-2, only 2 of the 42 samples

FIGURE 3-1 SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS FOR THE MSP SITE DURING 1980-1982

TABLE 3-1
TOTAL URANIUM CONCENTRATIONS IN SURFACE WATER AT THE MSP - 1980

Sample Location ^a	Number of Samples	Concentration (mg/l)			Percent of Standard ^b (Average)
		Minimum	Maximum	Average	
1 Plant Outfall	41	0.030	0.980	0.448	22
2 Confluence	5	0.005	0.035	0.015	1
3 Main Stream ^c	19	0.005	0.120	0.047	2
4 Upstream	2	0.005	0.005	0.005	1

^aSample locations are shown in Figure 3-1.

^bDOE Order 5480.1A, Chapter XI guide for uranium in water released to uncontrolled areas is 600 pCi/l or 2 mg/l.

^cMain Stream location used in 1980 is the same as the "Downstream" sample location used in 1982.

TABLE 3-2
DISSOLVED RADIUM-226 CONCENTRATIONS IN SURFACE
WATER AT THE MSP - 1980

Sample Location ^a	No. of Samples	Concentration (pCi/l)			Percent of Standard ^b (Average)
		Minimum	Maximum	Average	
1 Plant Outfall	42	1.4	100	17.6	58
2 Confluence	5	1.9	14	6.1	20
3 Main Stream ^c	17	0.53	21	2.7	9
4 Upstream	3	1.3	4.6	3.2	11

^aSample locations are shown in Figure 3-1.

^bDOE Order 5480.1A, Chapter XI guide for radium-226 in water released to uncontrolled areas is 30 pCi/l.

^cMain Stream location used in 1980 is the same as the "Downstream" sample location used in 1982.

obtained at the plant outfall exceeded the CG for release to uncontrolled areas. All other sample locations are off-site and had radium-226 concentrations below the CG for release to uncontrolled areas (30 pCi/l).

Groundwater monitoring wells were drilled during 1980 at 20 locations at the MSP site, as shown in Figure 3-2. The 20 wells were originally drilled for geotechnical purposes; not all wells were sampled, nor was the sampling conducted on a regular basis. Groundwater samples were collected using the bailing technique and analyzed for radium-226 (Refs. 5 and 6). Analyses results for samples collected during 1980 are reported in Table 3-3. Analyses for single samples from a well in 1980 should be compared with Table 3-12, which provides the results of routine sampling conducted in 1982.

Because of the limited size of the site and the proximity of wells to the site boundary, the results were compared to the CG for radium-226 in water released to uncontrolled areas (30 pCi/l). With the exception of Wells 6 and 6A, the radium-226 concentration in groundwater in all wells was within this limit. Using the controlled area CG of 400 pCi/l, the radium-226 concentrations in Wells 6 and 6A were 70 and 32 percent, respectively, of the CG.

3.1.2 Air Sampling

Environmental air monitoring programs were conducted during remedial action at the MSP site and adjacent properties. From July 1 to November 22, 1980, the air monitoring program included analyses for airborne particulates (gross alpha) and radon concentrations (Ref. 6). In addition, radon monitoring was conducted by Mound Laboratory from April 30 to December 30, 1980.

Particulates were monitored using continuous air sample pumps placed approximately at the four cardinal compass points relative to remedial action work areas at the MSP, as shown in Figure 3-3. The

FIGURE 3-2 GROUNDWATER MONITORING WELL LOCATIONS AT THE MSP SITE DURING 1980-1982

TABLE 3-3
RADIUM-226 CONCENTRATIONS IN GROUNDWATER AT THE MSP^a - 1980

Well Number ^b	Dissolved Radium-226 (pCi/l)					Suspended Radium-226 (pCi/l)				
	Number of Samples	Minimum	Maximum	Average	Percent of Standard ^c (Average)	Number of Samples	Minimum	Maximum	Average	Percent of Standard ^d (Average)
1	e	-	-	-	-	-	e	-	-	-
1A	2	1.1+0.6	1.8+1.1	1.45	5	-	-	-	-	-
3	3	1.6	1.7+0.7	1.63	5	2	2.0+0.8	2.3	2.15	1
3A	3	0.65	3.8+0.9	2.55	9	2	2.2+1.2	20.0+2.0	11.1	1
4	3	2.8+0.8	5.3+1.9	4.30	14	1	6.2+1.4	6.2+1.4	6.2+1.4	1
4A	f	-	-	-	-	f	-	-	-	-
5	2	1.4	2.0+1.2	1.7	6	1	2.3	2.3	2.3	1
5A	1	1.4	1.4	1.4	5	1	5.3+2.2	5.3+2.2	5.3	1
68	3	10.0+1.0	790.0+20.2	278.3	927	2	10.0+3.0	1200.0+100	605	2
6A8	2	86.0+4.0	170.0+10	128.0	426	1	1800	1800	1800	6
108	1	1.3	1.3	1.3	5	e	-	-	-	-
11	4	1.4	3.0+1.3	1.89	6	2	7.0+1.3	11.0+3.0	9.0	1
12	3	2.4+1.4	33.0+4.0	12.6	42	1	2.4+10.0	2.4+10.0	2.4	1
13	2	1.7+0.9	24.0+3.0	12.85	43	1	0.9+0.67	0.9+0.67	0.9	1
14	1	20.0+4.0	20.0+4.0	20.0	67	e	-	-	-	-

^aWell locations are shown in Figure 3-2. Wells were drilled and sampled initially as part of a geohydrology study (Ref. 7). Sampling and analyses varied in both the number of wells sampled and the parameters analyzed during this time as compared with 1981 and 1982. Results of a single sample should be compared with Table 3-12, which has the results of routine sampling during 1982.

^bWell locations are shown in Figure 3-2.

^cDOE Order 5480.1A, Chapter XI (Ref. 3). The more restrictive Concentration Guide for soluble radium-226 of 30 pCi/l for release to uncontrolled areas was used because of the limited size of the site and lack of control over groundwater movement off-site.

^dDOE Order 5480.1A, Chapter XI (Ref. 3). The more restrictive Concentration Guide for insoluble radium-226 of 30,000 pCi/l for release to uncontrolled areas was used because of the limited size of the site and the lack of control over groundwater movement off-site.

^eNo analyses.

^fNo water in well.

Although samples were taken from Wells 6, 6A, and 10, these wells were plugged in 1981 during the expansion of the storage pad. Because there will be no future samples for comparative purposes, the results listed in this table preclude meaningful evaluation and are included merely for completeness.

FIGURE 3-3 AIR AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS AT THE MSP SITE DURING 1980-1981 CONSTRUCTION ACTIVITIES

background alpha count rate was established by 2 weeks of monitoring prior to the start of remedial action work. Particulate samples were collected on glass fiber filters, and a 1-week decay period was allowed for short-lived radionuclides to decay (Ref. 6).

Monthly composites of all filters by locations were analyzed for thorium-230, radium-226, lead-210, and total uranium to determine average air concentrations. Analyses indicated that airborne thorium-230 (the radionuclide with the most restrictive limit) concentrations were within the CG of 0.08 pCi/m^3 , with the highest concentration being 0.0009 pCi/m^3 (Ref. 5).

Radon samples were taken at the same locations at the MSP as the air particulate samples (Figure 3-3) (Ref. 6). Forty-eight-hour samples were collected weekly with pulse pumps and bag techniques prior to remedial action work. Samples were taken biweekly during and after the remedial action. The background outdoor radon concentration in the area is about 0.4 pCi/l . During remedial action, outdoor radon concentrations at the MSP ranged from 0.2 to 1.0 pCi/l , as shown in Figure 3-4 (Ref. 4). The fluctuations in radon levels corresponded with excavation and construction activities at the site. Radon levels during remedial action in 1980 did not exceed the radon CG of 3.0 pCi/l for uncontrolled areas.

Mound Laboratory began radon monitoring at the MSP on April 30, 1980 with the installation of five monitors around the MPS storage pad. Variations of radon concentration in the environs of the MSP and determination of the background radon concentration range were not included in Mound's initial monitoring effort. The monitoring network was expanded June 26, 1980, to include two indoor monitoring locations at properties that were being decontaminated. During the first week of July, outdoor monitors were also installed at these locations. The route along which the contaminated material would travel to the MSP was included in the monitoring network. On July 17, two monitors were placed along the route from the first off-site property to the MSP and on July 31 two monitors were placed along

FIGURE 3-4 AVERAGE RADON CONCENTRATIONS AT THE MSP SITE DURING 1980

the route from the second off-site property. A sixth monitor was also installed July 31 at the MSP downwind of where material was being disturbed from construction activities on the storage pad. This monitoring network, as shown in Figures 3-5 and 3-6, was maintained through September 25, 1980.

Mound used Passive Environmental Radon Monitors (PERMs) of the type developed by the DOE Environmental Measurements Laboratory to determine radon concentrations. The instruments were manufactured by EDA Instruments, Inc., Toronto, Canada. The samplers in each monitoring location were run continuously with a typical sample being an integrated measurement over a 1-week period, as the lithium fluoride thermoluminescent dosimeter chips were changed weekly. During the fourth quarter of calendar year 1980, Mound expanded the radon monitoring network to include seven off-site outdoor and one off-site indoor additional locations.

Results for all monitoring performed by Mound during 1980 are presented in Tables 3-4 and 3-5. During the fourth quarter of 1980, average ambient background in the Middlesex area appears to have been in the range of 0.2 to 0.3 pCi/l. All results from on-site and off-site indoor and outdoor locations were below the CG of 3.0 pCi/l. Values recorded in Tables 3-4 and 3-5 are averages reported either during or after completion of remedial action activities. Two indoor monitoring locations at properties being decontaminated approached the 3.0 pCi/l limit with readings of 2.6 and 2.9 pCi/l.

3.1.3 External Gamma Radiation

The external gamma radiation monitoring program utilized thermoluminescent dosimeters (TLDs), which were changed quarterly. The 11 TLD locations are shown in Figure 3-3. TLDs were placed at the air monitoring stations and other on-site locations, including inside the MSP Process Building and the Administration Building. Exposure rates during remedial action operations averaged 2 mrem/wk (Ref. 5). This is equivalent to approximately 12 μ R/h, which is

FIGURE 3-5 MOUND MSP ON-SITE RADON MONITORING LOCATIONS (PERMS)

NOTE: DESIGNATORS A,B, AND C
INDICATE SEVERAL MONITORS AT
THE SAME LOCATION.

*INDICATES INDOOR LOCATION

FIGURE 3-6 MOUND MSP OFF-SITE RADON MONITORING LOCATIONS (PERMS)

TABLE 3-4
MOUND RADON DATA FOR THE MSP - 1980

Sample Location*	Dates Monitoring Started	Number of Samples	Monitoring Period 04/30/80- 09/25/80 (pCi/l)		Monitoring Period 09/25/80- 12/30/80 (pCi/l)	
			Number of Samples			
1	04/30/80	20	1.3	11	1.2	
2	04/30/80	18	0.50	11	0.41	
3	04/30/80	20	0.53	11	0.34	
4	04/30/80	21	0.45	11	0.42	
5	04/30/80	20	0.43	9	0.28	
6	07/31/80	5	0.42	12	0.41	

*Sample locations are shown in Figure 3-5.

TABLE 3-5
MOUND RADON DATA FOR THE MIDDLESEX AREA - 1980

Sample Location ^{a, b}	Dates Monitoring Started	Number of Samples	Monitoring Period	Number of Samples	Monitoring Period
			04/30/80-06/25/80 (pCi/l)		09/25/80-12/30/80 (pCi/l)
M101	09/25/80	-	-	4	0.18
M102	09/25/80	-	-	5	0.16
M103A ^c	06/26/80	3	0.26 ^d	12	0.26
M103B ^c	06/26/80	3	0.14 ^d	10	0.17
M103C ^{c, f}	06/26/80	3	1.9 ^d	11	2.6
M104	12/30/80	-	-	-	-
M105	07/17/80	7	0.27	11	0.27
M106	07/17/80	9	0.20	9	0.19
M107	09/25/80	-	-	7	0.26
M108	09/25/80	-	-	6	0.30
M109 ^f	10/13/80	-	-	5	2.9
M110	09/25/80	-	-	8	0.35
M111	07/17/80	8	0.21	10	0.28
M112	07/17/80	5	0.24	8	0.19
M113A ^c	06/26/80	2	0.18 ^e	10 ^d	0.27
M113B ^{c, f}	06/26/80	2	0.86 ^e	9 ^d	1.1
M113C ^{c, f}	06/26/80	2	0.98 ^e	8 ^d	0.61
M114	09/25/80	-	-	5	0.19
M115	04/02/81	-	-	-	-
M116	12/30/80	-	-	-	-
M117	12/30/80	-	-	-	-
M118	12/30/80	-	-	-	-
M119	04/16/81	-	-	-	-
M120	12/30/80	-	-	-	-
M121	08/05/81	-	-	-	-
M122	08/19/81	-	-	-	-
M123	12/30/80	-	-	-	-
M124A ^c	12/30/80	-	-	-	-
M124B ^{c, f}	12/30/80	-	-	-	-
M125	08/06/81	-	-	-	-
M126	09/25/80	-	-	4	0.27

^aFor consistency, all sample locations are listed in consecutive order. Locations M115 through M125 were not in operation during this period.

^bSample locations are shown in Figure 3-6.

^cDesignators A, B, and C indicate several monitors at the same location.

^dAverage after remedial action.

^eDuring remedial action.

^fIndoor locations.

within the normal background range of 3.4 to 13 μ R/h for the Middlesex area (Ref. 8).

3.2 1981 ENVIRONMENTAL MONITORING

Environmental monitoring during 1981 was conducted in association with remedial action work from May 1981 through mid-January 1982. Remedial action activities included cleanup of 29 parcels of land surrounding the MSP and expansion of the storage pad on the MSP site. Improvements included the erection of a new security fence, construction of a system for contaminated sediment control, and modifications to the south drainage ditch.

Environmental monitoring was conducted during remedial activities to verify the adequacy of contamination control during remedial action and document conditions after remedial action. Monitoring locations and sampling frequency were established to provide coverage of potential pathways for contamination, particularly during removal of contaminated soil. A detailed account of 1981 remedial activities is contained in Reference 1.

Site characterization was also initiated at the MML site during this period. A geotechnical investigation was started in November 1981 and included the installation of 15 monitoring wells at the MML site.

3.2.1 Water Sampling

Surface water sample locations established during 1980 were also monitored during 1981 (see Figure 3-1). Samples were collected weekly and were analyzed for total uranium and dissolved radium-226 (Ref. 1). Results of analyses are reported in Tables 3-6 and 3-7. All surface water samples obtained during 1981 showed uranium and radium-226 concentrations well below the CGs of 2 mg/l and 30 pCi/l, respectively.

TABLE 3-6
TOTAL URANIUM CONCENTRATIONS IN SURFACE WATER AT THE MSP - 1981

Sample Location ^a	Number of Samples	Concentration (mg/l)			Percent of Standard ^b (Average)
		Minimum	Maximum	Average	
Settling Basin ^c	12	0.005	0.400	0.07	1
1 Plant Outfall	20	0.005	0.780	0.15	8
2 Confluence ^d	-	-	-	-	-
3 Main Stream ^e	16	0.005	0.070	0.01	1
4 Upstream	13	0.005	0.012	0.007	1

^aSample locations reflect the remedial actions during 1981 and are shown in Figure 3-1.

^bDOE Order 5480.1A, Chapter XI Concentration Guide for uranium in water released to uncontrolled areas is 600 pCi/l or 2 mg/l.

^cThe settling basin was installed in 1981.

^dModifications to the South Drainage Ditch prevented sampling at the confluence.

^eMain Stream is the same location as the "Downstream" sample location used in 1982.

TABLE 3-7
DISSOLVED RADIUM-226 CONCENTRATIONS IN SURFACE WATER
AT THE MSP - 1981

Sample Location ^a	Number of Samples	Concentration (pCi/l)			Percent of Standard ^b (Average)
		Minimum	Maximum	Average	
Settling Basin ^c	6	0.3	2.9	1.4	5
1 Plant Outfall	9	0.1	12.0	2.6	9
2 Confluence ^d	-	-	-	-	-
3 Main Stream ^e	6	0.1	1.2	0.4	1
4 Upstream	5	0.10	0.69	0.4	1

^aSample locations reflect remedial actions during 1981 and are shown in Figure 3-1.

^bDOE Order 5480.1A, Chapter XI Concentration Guide for radium-226 in water released to uncontrolled areas is 30 pCi/l.

^cThe settling basin was installed in 1981.

^dModifications to the South Drainage Ditch prevented sampling at the confluence.

^eMain Stream is the same location as the "Downstream" sample location used in 1982.

In addition to the wells drilled and monitored during 1980, eight new on-site wells were drilled at the MSP during 1981. Three existing wells (6, 6A, and 10) were plugged to accommodate storage pad expansion. Locations of all wells are included in Figure 3-2. In 1981 wells were sampled monthly during remedial action activities and analyzed for uranium and radium-226 and the results of analyses are provided in Table 3-8. Analyses for single samples from wells should be compared with the results of routine sampling for 1982 contained in Tables 3-15 and 3-16. The CGs for uncontrolled areas of 2 mg/l uranium and 30 pCi/l radium-226 were used because of the limited size of the site, proximity of wells to the boundary, and lack of control over groundwater movement. All wells at the MSP showed uranium concentrations below the CG for uranium in water for uncontrolled areas. With the exception of the three wells (6, 6A, and 10) that were plugged to accommodate on-site expansion, all wells were within the uncontrolled area limits for radium-226.

3.2.2 Sediment Sampling

Stream sediment samples were collected monthly at the Main Stream (Location 3) and plant outfall (Location 1) water sample locations during 1981 (Figure 3-1). Samples were composites of sediment collected from both banks and the center of the stream at each location. Results of sample analyses for total uranium and radium-226 are reported in Table 3-9. The DOE limit for uranium in soil during the 1981 remedial action was 40 pCi/g and the DOE limit for radium-226 was 5 pCi/g above background (Ref. 9). Final samples taken at the completion of 1981 remedial action work show uranium and radium concentrations well below the limits at both the plant outfall (25 pCi/g uranium and 0.5 pCi/g radium-226) and Main Stream (7 pCi/g uranium and 1.9 pCi/g radium-226) locations.

TABLE 3-8

RADIUM-226 AND URANIUM CONCENTRATIONS IN GROUNDWATER AT THE MSP^a - 1981

Well Number ^b	Number of Samples	Dissolved Radium-226 (pCi/l)				Number of Samples	Uranium (mg/l)			
		Minimum	Maximum	Average	Percent of Standard ^c (Average)		Minimum	Maximum	Average	Percent of Standard ^d (Average)
1	2	0.1	0.1	0.1	0	2	0.005	0.009	0.007	1
3	2	1.1+0.3	1.2+0.4	1.15	4	3	0.005	0.017	0.009	1
3A	1	1.8+0.5	1.8+0.5	1.8	6	3	0.005	0.051	0.02	1
4	1	3.1+0.9	3.1+0.9	3.1	10	1	0.006	0.006	0.006	1
4A	2	0.2+0.1	0.6+0.2	0.4	1	3	0.005	0.043	0.017	1
5	1	5.4+1.6	5.4+1.6	5.4	18	1	0.008	0.008	0.008	1
6 ^e	1	5600+1700	5600+1700	5600	18700	1	0.99	0.99	0.99	50
6A ^e	1	110.0+30	110.0+30	110	366	1	0.2	0.2	0.2	10
10 ^e	2	0.3+0.1	330.0+100	165	550	3	0.005	0.4	0.14	7
11	0	-	-	-	-	1	0.05	0.05	0.05	3
12	0	-	-	-	-	1	0.005	0.005	0.005	1
13	0	-	-	-	-	1	0.015	0.015	0.015	1
14	1	0.1	0.1	0.1	0	2	0.005	0.015	0.10	1
15	1	0.7+0.2	0.7+0.2	0.7	2	1	0.007	0.007	0.007	1
20S	1	0.1	0.1	0.1	0	4	0.005	0.005	0.005	1
20D	0	-	-	-	-	4	0.005	0.006	0.005	1
21S	0	-	-	-	-	4	0.005	0.005	0.005	1
21D	0	-	-	-	-	4	0.005	0.005	0.005	1
22D	0	-	-	-	-	4	0.005	0.005	0.005	1
23D	0	-	-	-	-	4	0.005	0.005	0.005	1

^aSampling was not routine but reflected site characterization or remedial action work conducted during 1981. Results of single samples should be compared with Tables 3-11 and 3-12, which provide the results of the routine sampling during 1982.

^bWell locations are shown in Figure 3-2.

^cDOE Order 5480.1A, Chapter XI, Concentration Guide for radium-226 in water released to uncontrolled areas is 30 pCi/l. This more restrictive guide was used for comparison because of the limited size of the site, proximity of wells to the boundary, and lack of control over groundwater movement.

^dDOE Order 5480.1A, Chapter XI, Concentration Guide for uranium in water released to uncontrolled areas is 600 pCi/l or 2 mg/l. This more restrictive guide was used for comparison because of the limited size of the site, proximity of wells to the boundary, and lack of control over groundwater movement.

^eAlthough samples were taken from Wells 6, 6A, and 10, these wells were plugged in 1981 during the expansion of the storage pad. Because there will be no future samples for comparative purposes, the results listed in this table preclude meaningful evaluation and are included merely for completeness.

TABLE 3-9
RADIUM-226 AND URANIUM CONCENTRATIONS IN SEDIMENT
AT THE MSP - 1981

Sample Location ^a	Number of Samples	Concentration (pCi /g)			Percent of Standard ^c (Average)
		Minimum	Maximum	Average ^b	
<u>Total Uranium</u>					
Plant Outfall	3	2.4	400+20	142.4	356
Main Stream	4	5.7	11.5	8.4	1.0
<u>Total Radium-226</u>					
Plant Outfall	3	0.5+0.2	39+12	13.9	278
Main Stream	4	1.9+0.6	2.8+0.8	2.2	44

^aSample locations are shown in Figure 3-1.

^bSamples obtained during time work was being done on the South Drainage Ditch. Average does not reflect the trend to decreasing concentrations that occurred during remedial action.

^cDOE limit for uranium in soil was 40 pCi/g and the limit for radium-226 in soil was 5 pCi/g above background during 1981 remedial action (Ref. 9). Background for radium-226 in soil in the Middlesex area is 1 pCi/g.

3.2.3 Air Sampling

Air monitoring stations were operated during 1981 to sample particulates and radon concentrations during remedial action activities. Continuous air samplers were placed as near as possible to the four cardinal compass points on the perimeter of areas scheduled for remedial action (Figure 3-3). Results of analyses for gross alpha are summarized in Figures 3-7 and 3-8 (Ref. 1). Analyses indicate that average gross alpha air concentrations at the MSP from July to November 1981 ranged from less than 0.002 pCi/m^3 to 0.011 pCi/m^3 . In the drainage area south of the MSP site, gross alpha concentrations were much lower than at the MSP. The maximum average gross alpha concentration at the MSP was less than 15 percent of the CG for thorium-230 (0.08 pCi/m^3), the most limiting radionuclide of the uranium decay series.

Monthly composites of all air filters collected during 1981 were analyzed for airborne particulate concentrations. The results of analyses for radium-226, thorium-230, lead-210, and uranium are shown in Table 3-10. The radionuclide concentrations were well below guidelines (Ref. 6).

Radon-222 concentrations obtained with pulse pump and bag techniques during 1981 at the MSP show that radon levels were less than the CG of 3.0 pCi/l as shown in Figure 3-9 (Ref. 1). At the completion of work on the storage pile in 1981, radon flux measurements were made at six locations as shown in Figure 3-10. The measurements showed radon emanation rates ranging from 0.1 to $1.3 \text{ pCi/m}^2/\text{s}$ with an average rate of $0.4 \text{ pCi/m}^2/\text{s}$ (Ref. 1).

Mound continued the radon monitoring network established in 1980 and added several new monitoring locations during calendar year 1981. During the first quarter, an additional eight off-site outdoor locations and one off-site indoor location were added to the monitoring network, for a total of 21 outdoor locations and 5 indoor locations. During the second quarter two additional off-site

FIGURE 3-7 AVERAGE GROSS ALPHA AIR CONCENTRATIONS AT THE MSP SITE DURING 1981

FIGURE 3-8 AVERAGE GROSS ALPHA AIR CONCENTRATIONS IN THE SOUTH DRAINAGE AREA AT THE MSP SITE DURING 1981

TABLE 3-10
MEAN CONCENTRATIONS IN AIRBORNE PARTICULATES IN SAMPLE COMPOSITES
AT THE MSP AND SOUTH DRAINAGE AREA^a - 1981

Radionuclide ^b	June	July	August	September	October
<u>Sampling Plant</u>					
Total Uranium	0.4	0.3	0.3	0.3	0.2
Thorium-230	0.3	0.2	0.1	0.2	0.1
Radium-226	0.3±0.1	0.3±0.2	0.4±0.2	1.0±0.3	0.3±0.1
Lead-210	10.9±2.0	10.0±1.3	13.2±1.8	13.0±2.0	12.7±2.3
<u>South Drainage Area^c</u>					
Total Uranium				1.2	10.8
Thorium-230				0.8	7.7
Radium-226				1.3±0.7	58.6
Lead-210				18.7±7.3	132.5

^aAll concentrations in 10^{-3} pCi/m³ except for total uranium concentrations, which are reported in units of 10^{-3} µg/m³. All concentrations reported at a 95 percent confidence level.

^bDOE Order 5480.1A, Chapter XI, Concentration Guides for listed radionuclide concentrations in air in uncontrolled areas are: total uranium, 3 µg/m³; thorium-230, 3×10^{-1} pCi/m³; radium-226, 2 pCi/m³; and lead-210, 8 pCi/m³.

^cSouth Drainage Area is the general area along the South Drainage Ditch and Main Stream that was monitored during remedial action work.

FIGURE 3-9 AVERAGE RADON CONCENTRATIONS AT THE MSP SITE DURING 1981

FIGURE 3-10 SHORT-TERM RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS ON THE MSP STORAGE PILE AT THE END OF 1981

outdoor locations were added, and during the third quarter, three more indoor locations and five outdoor locations were added to the network. The on-site monitors at the MSP were repositioned during the beginning of the third quarter as shown in Figure 3-5. In the fourth quarter the monitoring network was decreased to 22 outdoor off-site locations and 4 indoor off-site locations.

Results for all monitoring performed by Mound during 1981 are reported in Tables 3-11 and 3-12. All results from on-site and off-site, indoor and outdoor locations were below the CG of 3.0 pCi/l. Values recorded in Tables 3-11 and 3-12 are averages reported either during or after completion of remedial action activities.

The average ambient background ranged from 0.14 to 0.19 pCi/l with the lower value being recorded during the colder months. A small radon concentration gradient toward the south and east is evidenced by above ambient background concentrations of radon at three off-site monitoring locations (MI08, MI10, and MI22). Above background concentrations of radon were not observed beyond 200 to 500 m (219 to 547 yd) from the site perimeter in these directions. Toward the north and west no concentrations exceeded the background range during any quarter in 1981.

3.2.4 External Gamma Radiation

The external gamma radiation monitoring program for 1981 was an extension of the 1980 program. Average dose rates around the MSP during 1981 were approximately 3 mrem/wk (Ref. 1). This is equivalent to about 20 μ R/h which is approximately 150 percent above the upper value of the range for background (13 μ R/h) for the Middlesex area (Ref. 8).

After sealing the storage pile on the Sampling Plant site at the conclusion of the 1981 remedial action, a portable ion chamber was used to measure external radiation exposure rates at 14 locations on the pile (Figure 3-10). The exposure rates ranged from 11 to

TABLE 3-11
MOUND RADON DATA FOR THE MSP - 1981

Sample Location*	Dates Monitoring Started	Number of Samples	Monitoring Period 12/30/80- 04/02/81 (pCi/l)	Number of Samples	Monitoring Period 04/02/81- 07/02/81 (pCi/l)	Number of Samples	Monitoring Period 07/02/81- 10/01/81 (pCi/l)	Number of Samples	Monitoring Period 10/01/81- 12/30/81 (pCi/l)
1	04/30/80	11	0.66	12	0.56	12	0.38	9	0.19
2	04/30/80	9	0.34	11	0.25	11	0.45	9	0.25
3	04/30/80	10	0.22	10	0.21	12	0.24	11	0.36
4	04/30/80	11	0.31	12	0.27	10	0.22	11	0.24
5	04/30/80	11	0.22	13	0.23	12	0.27	9	0.12
6	07/31/80	8	0.18	12	0.25	11	0.23	7	0.14
Background		-	0.14	-	0.15	-	0.19	-	0.14

*Sample locations are shown in Figure 3-5.

TABLE 3-12
MOUND RADON DATA FOR THE MIDDLESEX AREA - 1981

Sample Location ^a	Dates Monitoring Started	Number of Samples	Monitoring Period 12/30/80 04/02/81 (pCi/l)	Number of Samples	Monitoring Period 04/02/81 07/01/81 (pCi/l)	Number of Samples	Monitoring Period 07/01/83 10/01/81 (pCi/l)	Number of Samples	Monitoring Period 10/01/81 12/30/81 (pCi/l)
M101	09/25/80	9	0.13	12	0.12	12	0.17	10	0.12
M102	09/25/80	11	0.16	11	0.19	12	0.19	11	0.10
M103A ^b	06/26/80	10	0.17	12	0.13	11	0.14	8	0.09
M103B ^b	06/26/80	11	0.14	11	0.15	5	0.19	-	-
M103C ^{b,c}	06/26/80	9	2.3	13	1.2	12	1.2	11	1.4
M104	12/30/80	2	0.13	12	0.19	11	0.25	9	0.16
M105	07/17/80	9	0.18	6	0.14	5	0.24	-	-
M106	07/17/80	8	0.19	7	0.15	7	0.19	10	0.15
M107	09/25/80	11	0.21	12	0.15	10	0.15	10	0.14
M108	09/25/80	11	0.26	12	0.23	12	0.36	9	0.21
M109 ^c	11/13/80	8	1.7	10	1.9	12	1.2	11	1.4
M110	09/25/80	9	0.27	13	0.30	9	0.39	8	0.30
M111	07/17/80	10	0.10	10	0.13	4	0.18	-	-
M112	07/17/80	9	0.15	7	0.14	11	0.19	10	0.14
M113A ^b	06/26/80	7	0.14	10	0.14	9	0.21	8	0.19
M113B ^{b,c}	06/26/80	6	0.96	6	1.2	5	1.6	-	-
M113C ^{b,c}	06/26/80	5	0.59	5	0.35	5	0.18	-	-
M114	09/25/80	11	0.15	10	0.15	11	0.21	9	0.15
M115	04/02/81	-	-	13	0.24	11	0.21	9	0.15
M116	12/30/80	1	0.33	11	0.19	12	0.18	7	0.21
M117	12/30/80	1	0.43	10	0.17	11	0.17	8	0.21
M118	12/30/80	1	0.21	11	0.19	11	0.20	10	0.15
M119	04/16/80	-	-	10	0.14	12	0.17	8	0.11
M120	12/30/80	7	0.12	10	0.11	11	0.17	-	-
M121	08/05/81	-	-	-	-	6	0.23	9	0.15
M122	08/19/81	-	-	-	-	2	0.25	4	0.26
M123	12/30/80	4	0.34	7	0.18	12	0.18	9	0.19
M124A ^b	12/30/80	7	0.14	11	0.14	12	0.23	6	0.19
M124B ^b	12/30/80	4	0.97	11	0.68	10	0.40	6	0.51
M125	08/06/80	-	-	-	-	7	0.82	11	0.49
M126	09/25/80	5	0.23	10	0.15	11	0.20	8	0.11
Background		-	0.14	-	0.15	-	0.19	-	0.14

^aSample locations are shown in Figure 3-6.

^bDesignators A, B, and C indicate several monitors at same location.

^cIndoor locations.

26 μ R/h or 103 to 228 mrem/yr (Ref. 1). These external radiation exposure rates are, at a maximum, only about 50 percent of the DOE Radiation Protection Standard for radiation dose to the general population of 500 mrem/yr.

3.3 1982 ENVIRONMENTAL MONITORING

The MSP and MML sites are not producers of radioactive material. As discussed in a preceding section, the MSP site is used for the storage of radioactive contaminated soil and rubble from the cleanup of surrounding properties while the MML site contains soil contaminated with small amounts of uranium ore. The 1982 environmental monitoring program was conducted to ensure that past remedial action and existing conditions are not detrimental to the public or environment.

3.3.1 Water Sampling

Using the grab sampling technique, surface water samples were collected quarterly at the four MSP locations shown in Figure 3-1 and two locations at the MML site shown in Figure 3-11. In addition, the settling basin was sampled on a non-routine basis after periods of rainfall. A 4-liter sample was obtained, with the temperature and pH determined at the time of collection. The sample was divided into two aliquots. One aliquot was filtered and then preserved by adjusting the pH to 1 or lower by the addition of nitric acid. Samples were analyzed by Eberline Instrument Corporation (EIC) for total uranium and dissolved radium-226. The untreated aliquot of the sample was stored on-site until sample analyses were completed and the results were reviewed. It was then discarded in the on-site settling basin.

The results of analyses for uranium and radium-226 in surface water during calendar year 1982 are presented in Tables 3-13 and 3-14, respectively. Uranium concentrations ranged from less than 0.005 to 0.22 mg/l and radium-226 levels ranged from less than 0.08 to

FIGURE 3-11 ENVIRONMENTAL MONITORING LOCATIONS AT THE MML SITE DURING 1982

TABLE 3-13
TOTAL URANIUM CONCENTRATIONS IN SURFACE WATERS AT THE MSP AND MML - 1982

Sample Location	Total Uranium Quarterly Results (mg/l)				Number of Samples	Total Uranium (mg/l)			Percent of Standard ^a (Average)
	1st	2nd	3rd	4th		Minimum	Maximum	Average	
<u>Sampling Plant^b</u>									
Settling Basin	c	c	c	c	16	0.005	0.018	0.006	1
1 Plant Outfall	d	0.012	0.220	0.190	3	0.012	0.220	0.14	7
2 Confluence	d	0.012	0.041	0.008	3	0.008	0.041	0.02	1
3 Downstream	d	0.005	0.009	0.024	3	0.005	0.024	0.013	1
4 Upstream	d	-	0.005	0.008	2	0.005	0.008	0.007	1
<u>Landfill^e</u>									
1 Upstream	d	0.005	0.005	0.014	3	0.005	0.014	0.008	1
2 Downstream	d	0.005	0.005	0.009	3	0.005	0.009	0.006	1

^aDOE Order 5480.1A, Chapter XI, Concentration Guide for uranium in water released to uncontrolled areas is 600 pCi/l or 2 mg/l.

^bSample locations for the MSP are shown in Figure 3-1.

^cSettling basin sampled only after periods of rainfall.

^dSamples not obtained 1st quarter because of ice conditions.

^eSample locations for the MML are shown in Figure 3-11.

TABLE 3-14

DISSOLVED RADIUM-226 CONCENTRATIONS IN SURFACE WATERS AT THE MSP AND MML - 1982

Sample Location	Dissolved Radium Quarterly Results (pCi/l)				Number of Samples	Dissolved Radium (pCi/l)			Percent of Standard ^a (Average)
	1st	2nd	3rd	4th		Minimum	Maximum	Average	
<u>Sampling Plant^b</u>									
Settling Basin	c	c	c	c	16	0.01	1.4	0.3	1
1 Plant Outfall	d	0.36+0.11	6+2	5.1+1.5	3	0.36	6.0	3.8	13
2 Confluence	d	0.10+0.06	0.37+0.11	1.0+0.3	3	0.10	1.0	0.49	2
3 Downstream	d	0.32+0.10	0.13+0.08	0.9+0.3	3	0.13	0.9	0.45	2
4 Upstream	d	2.6+0.8	0.18+0.06	0.7+0.2	3	0.18	2.6	1.16	4
<u>Landfill^e</u>									
1 Upstream	d	0.08	0.35	0.1	3	0.08	0.35	0.18	1
2 Downstream	d	0.18	0.08	0.1	3	0.08	0.18	0.12	1

^aDOE Order 5480.1A, Chapter XI, Concentration Guide for radium-226 in water in uncontrolled areas is 30 pCi/l.^bSample locations for the MSP are shown in Figure 3-1.^cSettling basin sampled only after periods of rainfall.^dSamples not obtained first quarter because of ice conditions.^eSample locations for the MML are shown in Figure 3-11.

6.0 pCi/l with the highest concentrations of both uranium and radium-226 occurring at the MSP outfall (Location 1). All uranium concentrations in surface waters were less than 11 percent of the CG for uranium in uncontrolled areas (2 mg/l). All radium-226 levels were less than 20 percent of the CG for radium-226 in uncontrolled areas (30 pCi/l).

Groundwater was monitored during 1982 using 19 of the 20 wells (Well 5A is damaged) at the MSP and 15 wells at the MML site. All wells were sampled quarterly using an airlift sampling method. Well locations are shown in Figure 3-2 for the MSP and Figure 3-11 for the MML. Twenty-four hours prior to sampling, the wells were pumped to a predetermined level (or dry). A 4-liter sample was obtained, and the temperature and pH were determined immediately. The sample was divided into two parts with an untreated aliquot being stored until the analysis results for the submitted sample were reviewed. The sample for analysis was filtered, and nitric acid was added until the pH was adjusted to 1 or lower. Samples were analyzed for total uranium and radium-226 by EIC.

Concentrations of uranium and radium-226 in groundwater samples taken during 1982 are provided in Tables 3-15 through 3-18. In wells at the MSP site, maximum uranium concentrations ranged from less than 0.005 to 0.34 mg/l (Table 3-15) and maximum radium-226 levels ranged from less than 0.2 to 2.3 pCi/l (Table 3-16). The annual average concentrations were less than 11 percent of the CG for uranium released to uncontrolled areas (2 mg/l) and less than 6 percent of the CG for radium-226 released to uncontrolled areas (30 pCi/l). At the MML site, maximum uranium concentrations ranged from less than 0.005 to 0.023 mg/l (Table 3-17), with all annual average values being less than 1 percent of the CG for uncontrolled areas (2 mg/l). Maximum radium-226 concentrations at the MML site ranged from 0.6 to 24 pCi/l (Table 3-18). The highest average value was at sample Location 6, near the center of the contaminated zone, and was 64 percent of the CG for radium-226 released to uncontrolled areas (30 pCi/l). The remaining average radium-226 values were less than 3 percent of the CG.

TABLE 3-15

URANIUM CONCENTRATIONS IN GROUNDWATER AT THE MSP - 1982

Sample Location ^a	Total Uranium Quarterly Results (mg/l)				Number of Samples	Total Uranium Concentration (mg/l)			Percent of Standard ^b (Average)
	1st	2nd	3rd	4th		Minimum	Maximum	Average	
1	0.011	0.015	0.013	0.005	4	0.005	0.015	0.011	1
1A	0.011	0.014	0.034	0.012	4	0.011	0.034	0.018	1
3	0.010	0.008	0.017	0.018	4	0.008	0.018	0.016	1
3A	0.170	0.160	0.120	0.041	4	0.041	0.170	0.080	4
4	0.005	0.005	0.021	c	3	0.005	0.021	0.010	1
4A	0.093	0.066	0.060	0.022	4	0.022	0.093	0.060	3
5	0.220	0.064	0.015	0.026	4	0.015	0.220	0.081	4
9	0.024	0.030	0.007	0.006	4	0.006	0.030	0.017	1
11	0.061	0.170	0.270	0.340	4	0.061	0.340	0.210	11
12	0.005	0.011	0.014	0.005	4	0.005	0.014	0.009	1
13	0.015	0.007	0.005	0.005	4	0.005	0.015	0.008	1
14 ^c	c	c	c	c	c	c	c	c	c
15	0.016	0.013	0.011	0.005	4	0.005	0.016	0.011	1
20D	0.005	0.005	0.005	0.005	4	0.005	0.005	0.005	1
20S	0.005	0.005	0.013	0.005	4	0.005	0.013	0.007	1
21D	0.006	0.006	0.005	0.005	4	0.005	0.006	0.006	1
21S	0.006	0.005	0.007	0.005	4	0.005	0.007	0.006	1
22D	0.011	0.005	0.005	0.005	4	0.005	0.011	0.007	1
23D	0.005	0.005	0.005	0.006	4	0.005	0.006	0.005	1

^aSample locations are shown in Figure 3-2; well 5A damaged.

^bDOE Order 5480.1A, Chapter XI, Concentration Guide for uranium in water released to uncontrolled areas is 2 mg/l or 600 pCi/l.

^cSample location dry.

TABLE 3-16

DISSOLVED RADIUM-226 CONCENTRATIONS IN GROUNDWATER AT THE MSP - 1982

Sample Location ^a	Dissolved Radium-226 Quarterly Results (pCi/l)				Number of Samples	Dissolved Radium-226 Concentration (pCi/l)			Percent of Standard ^b (Average)
	1st	2nd	3rd	4th		Minimum	Maximum	Average	
1	0.5+0.2	0.4+0.1	0.56+0.17	0.1	4	0.1	0.56	0.39	1
1A	0.5+0.2	0.1+0.1	0.20+0.06	0.3+0.1	4	0.1	0.5	0.28	1
3	0.7+0.2	0.3+0.1	0.43+0.13	0.3+0.1	4	0.3	0.7	0.43	1
3A	1.6+0.5	1.5+0.5	1.2+0.4	2.3+0.7	4	1.2	2.3	1.7	6
4	0.7+0.20	0.5+0.2	0.20+0.07	c	3	0.2	0.7	0.47	2
4A	0.7+0.2	0.2+0.1	0.63+0.19	0.6+0.2	4	0.2	0.7	0.53	2
5	0.6+0.2	0.1+0.1	0.29+0.09	0.1	4	0.1	0.6	0.27	1
9	0.6+0.2	0.8+0.2	1.3+0.4	0.6+0.2	4	0.6	1.3	0.83	3
11	0.6+0.2	0.9+0.3	0.67+0.20	0.7+0.2	4	0.6	0.9	0.72	2
12	0.4+0.1	0.4+0.1	0.27+0.08	0.1	4	0.1	0.4	0.19	1
13	0.2+0.1	0.1+0.1	0.10+0.06	0.2+0.1	4	0.1	0.2	0.15	1
14	c	c	c	c	c	c	c	c	c
15	0.3+0.1	0.3+0.1	0.29+0.09	0.1+0.1	4	0.1	0.3	0.25	1
20D	0.5+0.2	0.1+0.1	0.27+0.08	0.2+0.1	4	0.1	0.5	0.37	1
20S	0.3+0.1	0.4+0.1	0.20+0.06	0.9+0.3	4	0.2	0.9	0.45	2
21D	0.3+0.1	0.2+0.1	0.22+0.07	0.6+0.2	4	0.2	0.6	0.33	1
21S	0.2+0.1	0.2+0.1	0.55+0.17	0.5+0.2	4	0.2	0.55	0.36	1
22D	0.3+0.1	0.4+0.1	0.38+0.11	0.2+0.1	4	0.2	0.4	0.32	1
23D	0.4+0.1	0.5+0.2	0.67+0.20	1.1+0.3	4	0.4	1.1	0.67	2

^aSample locations are shown in Figure 3-2; well 5A damaged.

^bDOE Order 5480.1A, Chapter XI, Concentration Guide for radium-226 in water released to uncontrolled areas is 30 pCi/l.

^cSample location dry.

TABLE 3-17

TOTAL URANIUM CONCENTRATIONS IN GROUNDWATER AT THE MML - 1982

Sample Location ^a	Total Uranium Quarterly Results (mg/l)				Number of Samples	Total Uranium Concentration (mg/l)			Percent of Standard ^b (Average)
	1st	2nd	3rd	4th		Minimum	Maximum	Average	
1	0.005	0.005	0.005	0.005	4	0.005	0.005	0.005	1
2	0.003	0.005	0.005	0.005	4	0.003	0.005	0.004	1
3	0.007	0.005	0.005	0.005	4	0.005	0.007	0.006	1
4	0.003	0.005	0.005	0.005	4	0.003	0.005	0.005	1
5	0.005	0.008	0.005	0.005	4	0.005	0.008	0.006	1
6	0.003	0.007	0.005	0.008	4	0.003	0.008	0.006	1
8A	0.003	0.005	0.005	0.010	4	0.003	0.010	0.006	1
9	0.003	0.005	0.005	0.005	4	0.003	0.006	0.005	1
10	0.003	0.005	0.006	0.005	4	0.003	0.006	0.005	1
11	0.003	0.007	0.012	0.005	4	0.003	0.012	0.007	1
13	0.003	0.005	0.016	0.005	4	0.003	0.016	0.007	1
14	0.010	0.006	0.023	0.016	4	0.006	0.023	0.014	-
15	0.003	0.005	0.005	0.005	4	0.003	0.005	0.005	1
16	0.010	0.005	0.005	0.005	4	0.005	0.010	0.006	1
17	0.003	0.005	0.014	0.014	4	0.003	0.014	0.009	1

^aSample locations are shown in Figure 3-11.

^bDOE Order 5480.1A, Chapter XI, Concentration Guide for uranium in water released to uncontrolled areas is 2 mg/l or 600 pCi/l.

TABLE 3-18

DISSOLVED RADIUM-226 CONCENTRATIONS IN GROUNDWATER AT THE MML - 1982

Sample Location ^a	Dissolved Radium-226 Quarterly Results (pCi/l)				Number of Samples	Dissolved Radium-226 Concentration (pCi/l)			Percent of Standard ^b (Average)
	1st	2nd	3rd	4th		Minimum	Maximum	Average	
1	2+1	0.3+0.1	0.1	0.9+0.3	4	0.1	2.0	0.83	3
2	0.4+0.1	0.8+0.2	0.5+0.2	0.8+0.2	4	0.4	0.8	0.63	2
3	0.3+0.1	0.1	0.6+0.2	1.1+0.3	4	0.1	1.1	0.53	2
4	0.5+0.2	0.3+0.1	2.1+0.6	0.8+0.2	4	0.3	2.1	0.93	3
5	0.9+0.3	0.7+0.2	0.6+0.2	0.8+0.2	4	0.6	0.9	0.75	3
6	20+6	24+1	17+5	16+5	4	16.0	24.0	19.3	64
8A	0.7+0.2	0.6+0.2	1.1+0.3	0.7+0.2	4	0.2	0.8	0.53	2
9	0.7+0.2	0.6+0.2	1.1+0.3	0.7+0.2	4	0.6	1.1	0.78	3
10	0.1	0.1+0.1	0.1	0.6+0.2	4	0.1	0.6	0.23	1
11	0.7+0.2	0.7+0.2	1.2+0.4	1.3+0.4	4	0.7	1.3	0.98	3
13	0.4+0.1	0.3+0.1	0.5+0.2	0.9+0.3	4	0.3	0.9	0.53	2
14	0.6+0.2	0.6+0.1	0.8+0.2	1.0+0.3	4	0.6	1.0	0.75	3
15	0.1+0.1	0.1	0.2+0.1	0.8+0.2	4	0.1	0.8	0.30	1
16	0.4+0.1	0.5+0.2	0.9+0.3	0.6+0.2	4	0.4	0.9	0.60	2
17	0.1	0.1	0.7+0.2	0.4+0.1	4	0.1	0.7	0.33	1

^aSample locations are shown in Figure 3-11.^bDOE Order 5480.1A, Chapter XI, Concentration Guide for radium-226 in water released to uncontrolled areas is 30 pCi/l.

3.3.2 Air Sampling

Radon gas detectors were maintained at four locations at the MML site and 17 locations at the MSP Plant site, as shown in Figures 3-11 and 3-12, respectively (Ref. 1). Detectors were exchanged and analyzed quarterly. The radon gas monitoring program uses Terradex Type-F Track-Etch detectors with a reported sensitivity level of 1.0 pCi/l per month at the minimum detection level of 0.27 pCi/l. Detectors were obtained from the Terradex Corporation, placed and exchanged at the sample locations by site personnel, then returned to Terradex for analytical services.

The results of analyses for radon at the MSP and MML for 1982 are provided in Table 3-19 (Ref. 1). The applicable CG value for radon in controlled areas is 100 pCi/l and 3.0 pCi/l in uncontrolled areas. The highest annual average concentrations of radon in air at the MSP and MML sites were 30 percent and 48 percent, respectively, of the CGs for release to uncontrolled areas.

Mound continued the radon monitoring program in calendar year 1982. However, the monitoring network was significantly reduced due to the completion of the off-site decontamination activities. The reduced program consisted of three outdoor off-site locations and six outdoor on-site locations. All contaminated materials were stored and sealed on the MSP storage pad, thus effectively reducing radon emissions. Monitoring continued on-site at the MSP to observe the effectiveness of the EPDM sealer. Results for all monitoring performed by Mound during 1982 are reported in Tables 3-20 and 3-21. All results from on-site and off-site, outdoor locations were below 3.0 pCi/l. All results except for on-site PERM Station 3 (1.4 pCi/l second quarter) were below 1.0 pCi/l. PERM Station 3 is located at the southeast corner of the Process Building and is recording variations in radon as influenced by the direction of the wind and the proximity of the Process Building. The average ambient background ranged from 0.11 to 0.18 pCi/l with the higher value being in the third quarter during the warmer months.

FIGURE 3-12 LONG-TERM RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS PLACED BY BNI AT THE MSP SITE DURING 1982

TABLE 3-19

RADON-222 CONCENTRATIONS AT THE MSP AND MML - 1982

Sample Location	Radon-222 Quarterly Results (pCi/l) ^a				Number of Samples	Radon-222 Concentration (pCi/l) ^a			Percent of Standard ^d (Average)
	1st ^b	2nd	3rd	4th		Minimum	Maximum	Annual Average ^c	
<u>Sampling Plant^{e, f}</u>									
2	b	0.69	0.83	0.45	3	0.45	0.83	0.66	22
4	b	0.44	0.92	0.48	3	0.44	0.92	0.61	20
5	b	0.44	0.71	0.27	3	0.27	0.71	0.47	16
7	b	0.55	0.44	0.17	3	0.17	0.55	0.39	13
8	b	0.13	0.35	0.45	3	0.13	0.45	0.31	10
9	b	0.16	0.23	0.36	3	0.16	0.36	0.25	8
10	b	0.30	0.53	0.17	3	0.17	0.53	0.33	11
11	b	0.23	0.89	0.36	3	0.23	0.89	0.49	16
12	b	0.27	0.83	0.21	3	0.21	0.83	0.44	15
13	b	0.06	0.14	0.30	3	0.06	0.30	0.17	6
14	b	0.16	0.62	0.21	3	0.16	0.62	0.33	11
15	b	0.16	0.83	0.21	3	0.16	0.83	0.40	13
16	b	0.09	0.44	0.36	3	0.09	0.44	0.30	10
17	b	0.30	0.59	0.30	3	0.30	0.59	0.40	13
18	b	0.41	0.62	0.17	3	0.17	0.62	0.40	13
19	b	0.34	0.38	0.39	3	0.34	0.39	0.37	12
20	b	0.30	0.74	0.21	3	0.21	0.74	0.42	14
<u>Landfill^g</u>									
1	b	0.23	0.50	2.02	3	0.23	2.02	0.92	31
2	b	0.23	0.59	1.31	3	0.23	1.31	0.71	24
3	b	0.62	0.23	1.75	3	0.23	1.75	0.87	29
4	b	0.55	0.29	3.44	3	0.29	3.44	1.43	48

^aThese measurement are total radon concentrations; background has not been subtracted.

^bDetectors not installed until end of first quarter, 1982.

^cAverage is calculated on the number of measurements corresponding to an identical number of quarters.

^dDOE Order 5480.1A, Chapter XI, Concentration Guide limit for radon in air released to uncontrolled areas is 3.0 pCi/l.

^eSample locations for the MSP are shown in Figure 3-12.

^fSample locations 1, 3, and 21 are inside buildings and not included in this table.

^gSample locations for the MML are shown in Figure 3-11.

TABLE 3-20
MOUND RADON DATA FOR THE MSP - 1982

Sample Location*	Dates Monitoring Started	Number of Samples	Monitoring Period 12/30/80 04/02/81 (pCi/l)	Number of Samples	Monitoring Period 04/02/81 07/02/81 (pCi/l)	Number of Samples	Monitoring Period 07/02/81 10/01/81 (pCi/l)	Number of Samples	Monitoring Period 10/01/81 12/30/81 (pCi/l)
1	04/30/80	6	0.18	8	0.11	8	0.24	10	0.13
2	04/30/80	9	0.12	12	0.43	8	0.24	10	0.25
3	04/30/80	11	0.66	13	1.4	11	0.85	11	0.96
4	04/30/80	8	0.13	11	0.25	10	0.21	10	0.12
5	04/30/80	7	0.19	11	0.20	11	0.32	10	0.25
6	07/31/80	3	0.11	10	0.11	8	0.18	5	0.15
Background		-	0.11	-	0.11	-	0.18	-	0.15

*Sample locations are shown in Figure 3-12.

TABLE 3-21
MOUND RADON DATA FOR THE MIDDLESEX AREA - 1982

Sample Location ^a	Dates Monitoring Started	Number of Samples	Monitoring Period 12/30/81 03/03/82 (pCi/l)	Number of Samples	Monitoring Period 03/31/82 06/30/82 (pCi/l)	Number of Samples	Monitoring Period 06/30/82 09/29/82 (pCi/l)	Number of Samples	Monitoring Period 09/29/82 12/29/82 (pCi/l)
M101	09/25/80	3	0.06						
M102	09/25/80	2	0.12						
M103A ^b	06/26/80	1	0.22						
M103B ^b	06/26/80								
M103C ^{b,c}	06/26/80	3	0.75						
M104	12/30/80	6	0.13	8	0.11	10	0.21	10	0.19
M105	07/17/80								
M106	07/17/80	1	0.15						
M107	09/25/80	1	0.05						
M108	09/25/80	2	0.12						
M109 ^c	11/13/80	4	0.76						
M110	09/25/80	2	0.18						
M111	07/17/80								
M112	07/17/80	8	0.10	9	0.14	10	0.19	8	0.13
M113A ^b	06/26/80	2	0.12						
M113B ^{b,c}	06/26/80								
M113C ^{b,c}	06/26/80								
M114	09/25/80	2	0.07						
M115	04/02/81	3	0.12						
M116	12/30/80	3	0.14						
M117	12/30/80	3	0.14						
M118	12/30/80	2	0.05						
M119	04/16/80								
M120	12/30/80								
M121	09/05/81								
M122	09/19/81								
M123	12/30/80	2	0.10						
M124A ^b	12/30/80	2	0.13						
M124B ^b	12/30/80	3	0.28						
M125	09/06/80	4	0.33						
M126	09/25/80	4	0.10	5	0.08	6	0.13	9	0.12
Background		-	0.11	-	0.11	-	0.18	-	0.15

^aSample locations are shown in Figure 3-6.

^bDesignators A, B, and C indicate several monitors in same location.

^cIndoor locations.

3.3.3 External Gamma Radiation

External gamma radiation exposure levels were measured using lithium fluoride (LiF) TLDS at four locations at the MML site and 17 locations at the MSP, as shown in Figures 3-9 and 3-10, respectively. The results of analyses are provided in Table 3-22. The highest average gamma radiation level (39.8 $\mu\text{R/h}$) was measured inside the MSP Process Building (Location 21). The highest outdoor levels at the MSP boundary (Locations 5, 13, 14, and 20) averaged 18.6 $\mu\text{R/h}$, which is approximately 135 percent above the upper value of the range for background (13 $\mu\text{R/h}$). The highest average exposure level (22.1 $\mu\text{R/h}$ at Location 5) along the MSP site boundary was less than 50 percent of the DOE Radiation Protection Standard for the population of 500 mrem/yr (Ref. 3). At the MML site, all of the monitored locations were within the normal background range of 3.4 to 13 $\mu\text{R/h}$ (Ref. 8).

3.3.4 Quality Control

Established procedures were followed in the collection and analysis of environmental samples during 1982. Bechtel personnel working at the two sites collected and prepared samples in accordance with specific procedures. Sample analyses conducted by EIC were governed by an internal quality control program consisting of duplicate, spike, and blank samples. EIC's internal quality control results are compared monthly with EPA crosscheck program results. Sample analyses conducted by the Terradex Corporation were also governed by an internal quality control program.

3.3.5 Calculation of Potential Radiological Exposure to the Public

Radiation doses may result from exposure to a radiation field (external) or ingestion or inhalation of radioactive materials (internal). The DOE Radiation Protection Standard for total body is 500 mrem/yr and for any specific organ 1500 mrem/yr.

TABLE 3-22
EXTERNAL GAMMA RADIATION LEVELS AT THE MSP AND MML^a - 1982

Sample ^b Location	Number of Measurements ^c	Exposure Rate (μR/h)		
		Minimum	Maximum	Average
<u>Sampling Plant^d</u>				
1	4	5.4	18.3	13.5
2	4	21.6	27.7	24.3
3	4	22.0	33.2	25.1
4	4	13.7	20.7	18.1
5	4	19.0	25.6	22.1
6	4	9.1	34.5	24.1
7	4	14.7	22.9	18.6
8	4	17.9	22.1	19.1
9	4	17.0	29.2	22.4
10	4	20.4	23.8	22.3
11	4	12.6	40.0	29.4
12	4	14.7	32.4	23.6
13	4	15.7	29.2	21.2
14	4	13.7	25.4	19.5
15	4	17.6	22.1	19.2
16	3	15.3	21.5	13.5
17	4	13.2	18.4	16.2
18	4	12.4	16.2	14.9
19	4	12.7	17.6	15.3
20	4	9.7	12.5	10.9
21	4	15.1	49.9	39.8
<u>Landfill^e</u>				
1	3	10.3	11.7	11.0
2	3	10.3	13.0	11.9
3	3	8.8	11.1	10.3
4	3	9.1	10.6	9.9

^aBackground in the Middlesex area ranges from 3.4 to 13 μR/h (Ref. 8).

^bSample locations 1, 3, and 21 are inside buildings.

^cTLD detectors at the MSP, October 1, 1981 - December 30, 1982, and the MML, April 19 - December 30, 1982.

^dSample locations for the MSP are shown in Figure 3-12.

^eSample locations for the MML are shown in Figure 3-11.

The potential radiation dose to members of the general public living in the Middlesex area was calculated using measured environmental data obtained during 1982 and dose assessment models recommended in Appendix B of Reference 10.

The dose from radon exposure was calculated for persons at the MSP and MML site boundaries assuming continuous-occupancy throughout 1982. For the MSP the highest annual average outdoor radon-222 concentration (0.47 pCi/l) was at sample Location 5 (Figure 3-12). The calculated continuous-occupancy dose to the bronchial epithelium (lungs) for an individual at this location would be 300 mrem/yr. This dose from radon inhalation is 20 percent of the DOE Standard and is equivalent to 70 percent of the average exposure due to naturally occurring sources of radon (Ref. 11). For the MML site, the highest annual average radon-222 concentration (1.43 pCi/l) was measured at sample Location 4 (Figure 3-11). The calculated continuous-occupancy dose to the bronchial epithelium for an individual at this location would be 890 mrem/yr, or about 200 percent of the average exposure due to naturally occurring sources of radon (Ref. 11). This dose from radon inhalation corresponds to about 60 percent of the DOE standard.

The dose from external gamma radiation to a person continuously residing at the maximum average point of 22.1 μ R/h (Location 5 in Figure 3-12) on the MSP site boundary would have been 185 mrem. This value is approximately 200 percent the average background dose of 100 mrem per year for the state of New Jersey (Ref. 12). At the MML site, the dose from external gamma radiation to a person continuously residing at the point of the highest average exposure of 11.9 μ R/h (Location 2 in Figure 3-12) would have been 104 mrem. This value is not significantly different from the estimated 100 mrem/yr average background dose for the state of New Jersey (Ref. 11).

The radiation doses that a member of the public would receive in the unlikely event that water from the site was used as the only source of drinking water have also been calculated. These dose values

should be compared to the DOE Radiation Protection Standard of 1500 mrem/yr to the bone of an individual. The hypothetical doses from water consumption assume that the individual consumes the water at the point of maximum concentration. For the MML site, well water from sample Location 6 (Figure 3-11) had the maximum concentration of radium-226 (24 pCi/l) and sample Location 14 had the maximum concentration of uranium (0.023 mg/l). Total hypothetical bone dose to an individual from consuming this water for 1 year would be about 66 mrem. Calculated bone doses from both uranium (0.014 mg/l) and radium-226 (0.35 pCi/l) for water from Bound Brook (Location 1) at the MML site would be 2 mrem/yr. Dose to bone from either scenario is less than 100 mrem/yr average background.

Analyses of well water from the former MSP site indicate that Well 11 (Figure 3-2) had the maximum concentration of uranium (0.340 mg/l) and Well 3A had the maximum radium-226 concentration (2.3 pCi/l). The total hypothetical dose to the bone of an individual resulting from drinking water from these wells for 1 year would be 40 mrem.

For surface water, if water from the plant outfall (Figure 3-1) at the MSP site were used, the total hypothetical bone dose from both uranium (0.22 mg/l) and radium-226 (6.0 pCi/l) would be 40 mrem.

The above calculations and comparison of hypothetical doses to the standards give a theoretically worst-case comparison. A much more realistic, while still conservative, calculation can be made assuming a 1 hr/wk exposure at the points of maximum external radiation and radon concentrations along the site boundary. This calculation gives a maximum dose of about 6 mrem or only about 1.3 percent of the lung dose from natural background.

3.4 ENVIRONMENTAL TRENDS

Environmental monitoring for 1980 (Refs. 4 and 5) and 1981 (Ref. 1) was conducted in conjunction with remedial action activities being

carried out at the MSP and vicinity properties. The average values listed in the individual tables for each of these 2 years do not necessarily reflect the actual trend during these years since:

- o There is no continuity in sampling times with regard to construction activities; i.e., it would be difficult to determine whether sampling was conducted prior to, during, or after remedial action construction activities.
- o For many samples, the validity of comparison between 1980 and 1981 data would be questionable due to the minimal number of samples collected per year; i.e., the determination of radium-226 and uranium concentrations in groundwater.
- o Sample collection, analysis, and interpretation were performed by different contractors during 1980 (Refs. 4 and 5) and 1981 (Ref. 1); this data collection was not designed for trend analysis.

Remedial action was conducted because contamination exceeded limits. Thus, radionuclide concentrations at a sample location (especially in water) fluctuated and, on occasion, exceeded applicable limits. In most cases, this was limited to a single location because contamination control methods effectively contained any subsequent movement. The overall effect of the remedial actions during 1980 and 1981 was the lowering of radionuclide concentrations to within guideline limits.

Environmental trends for radon concentrations using Mound Laboratory data can be estimated for 1980-1982. Multiple samples were collected and analyzed during a similar time sequence each year. The percent of the DOE Concentration Guide for radon-222 average values is presented for the MSP (Table 3-23) and the Middlesex area (Table 3-24). The trend at the MSP shows a decrease in radon concentrations from 1980 through 1982. The high concentrations at Station 3 in 1982 is due to the proximity of the Process Building as discussed in Section 3.3.2. The overall trend for the Middlesex area also exhibits a decrease in radon-222 concentrations. Maximum values were 25 percent of the DOE Concentration Guide for uncontrolled areas.

TABLE 3-23
TREND IN MOUND RADON-222 DATA FOR THE MSP, 1980-1982^a

Station ^b	<u>1980</u> Percent of Standard	<u>1981</u> Percent of Standard	<u>1982</u> Percent of Standard
1	42	15	6
2	15	11	9
3	14	9	32
4	15	9	6
5	12	7	8
6	14	7	5
BG	-	5	5

^aBased on average concentrations compared with the DOE limit of 3 pCi/l.

^bLocations shown in Figure 3-5.

TABLE 3-24
TREND IN MOUND RADON-222 DATA FOR THE
MIDDLESEX AREA, 1980-1982^a

Station ^b	<u>1980</u> Percent of Standard	<u>1981</u> Percent of Standard	<u>1982</u> Percent of Standard
M101	6	5	2
M102	5	5	4
M103A ^d	9	4	7
M103B ^d	5	5	C
M103C ^d	75	51	25
M104	-	6	5
105	9	6	-
106	7	6	5
107	9	5	2
108	10	9	4
109	97	52	25
110	12	11	6
111	8	5	-
112	7	5	5
113A ^d	8	6	4
113B ^d	33	42	-
113C ^d	27	12	2
114	6	6	4
115	-	7	5
116	-	8	5
117	-	8	2
118	-	6	-
119	-	5	-
120	-	4	-
121	-	6	-
122	-	9	-
123	-	7	3
124A ^d	-	6	4
124B ^d	-	21	9
125	-	22	11
126	-	6	4
BG	-	5	5

^aBased on average concentration compared with the DOE limit of 3 pCi/l.

^bLocations shown in Figure 3-6. Dates on which monitoring started at a station varied.

^cWhere no value is provided, the station was not in operation.

^dDesignators A, B, C indicate several monitors at same location.

A routine monitoring program was initiated at the MSP and the MML in 1982 (Ref. 1). This program will assess the effectiveness of the 1980 and 1981 remedial actions at the MSP and vicinity properties.

Radiation doses for 1982, to an individual at the boundaries of the MSP and the MML are summarized in Table 3-25. These doses represent a hypothetical worst-case situation based on maximum radiological concentrations. As discussed in Subsection 3.3, in no case were the calculated doses greater than the DOE Concentration Guide Standards. External gamma radiation approached 200 percent of background at the MSP and radon levels were about 200 percent of background at the MML. Trend information for environmental monitoring locations will be provided as annual Middlesex Environmental Monitoring Reports become available for analysis.

TABLE 3-25
COMPARISON OF RADIATION DOSES AT MIDDLESEX WITH BACKGROUND AND
RADIATION PROTECTION STANDARDS* - 1982

STDS		MSP			MML		
Background (mrem)	Standard (mrem)	Dose (mrem)	Percent of Background	Percent of Standard	Dose (mrem)	Percent of Background	Percent of Standard
430	1500	300	70	20	890	200	59
100	500	185	200	50	104	100	20
100	1500	40	40	3	66	66	4
100	1500	40	40	3	54	54	4

doses are based on hypothetical worst-case situations for maximum radiological concentrations.

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3. U.S. Department of Energy. Order 5480.1A, Chapter XI, "Radiation Concentration Guides," (Formerly ERDA 0524).
4. NLO, Inc. Project Report of Phase I Remedial Action of Properties Associated with the Former Middlesex Sampling Plant Site, Cincinnati, OH, September 1981.
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9. Los Alamos Scientific Laboratory. Interim Soil Limits for D&D Projects, LA-L-R-79-1865-Rev., Los Alamos, NM, September 1979.
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11. National Council on Radiation Protection Measurements. Natural Background Radiation in the United States, NCRP Report 45, NCRP Scientific Committee 43 on Natural Background Radiation, Washington, DC, 1975.
12. U.S. Environmental Protection Agency. Estimates of Ionizing Radiation Doses in the United States 1960-2000, Office of Radiation Programs, Division of Criteria and Standards, ORP/CSD 72-1, Rockville, MD, August 1972.

APPENDIX A
ENVIRONMENTAL STANDARDS

DOE Order 5480.1A, Chapter XI (Ref. 3), Attachment XI-1 contains the applicable Concentration Guides (CGs) which provide limits for maximum permissible radioactivity both on-site (controlled area, Table I) and beyond the external perimeter of the site (uncontrolled area, Table II). The CGs for the common radionuclides at the MSP and MML sites are presented in Table A-1.

TABLE A-1
RADIOACTIVITY CONCENTRATION GUIDES
FOR THE MSP AND MML SITES

Radionuclide	Transport Media	Controlled Area	Uncontrolled Area
Uranium-Natural	Water (soluble)	60 mg/l (20,000 pCi/l)	2 mg/l (600 pCi/l)
	Water (insoluble)	1500 mg/l (500,000 pCi/l)	60 mg/l (20,000 pCi/l)
	Soil*		40 pCi/g
Radium-226	Water (soluble)	400 pCi/l	30 pCi/l
	Water (insoluble)	900,000 pCi/l	30,000 pCi/l
	Soil*		5 pCi/g above background
Radon-222	Air	100 pCi/l	3 pCi/l

*DOE remedial action criteria for soil cleanup for release for unrestricted use during 1980 and 1981.