RADIATION SURVEY REPORT

OF THE

MIDDLESEX LANDFILL SITE

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MARCH 25 - APRIL 4, 1974

JUNE 27, 1974

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Introduction and Summary

At the request of Division of Operational Safety, HQ, a radiological survey of certain adjoining properties belonging to the Borough of Middlesex, New Jersey, and the Middlesex Presbyterian Church was made during the period March 25 to April 4, 1974. The historical background leading to the requested survey is discussed in a later section of the report. An area of approximately three acres was found to contain subsurface deposits of radioactivity ranging from about 3 to 60 times naturally occurring gamma background levels. This area is approximately half on Borough property and half on church property. The deposits were found to exist at depths ranging from less than 1 foot to 18 feet. Over 100 soil samples from 39 core holes were taken and analyzed for radium, uranium, and thorium at the New Brunswick Laboratory. An average radium concentration over the three-acre area was found to be about 11 pCi/gm with localized maximum levels up to 140 pCi/gm.

Surface gamma measurements were found to be within the range of normal background variations except in a small area (<1000 ft^2) where the contaminated residual is located near the surface. This area is on Borough property presently used as a sanitary landfill.

Radon samples were taken over the suspect area and inside the church building and compared to background radon levels from offsite areas. Only those samples taken in the area having elevated surface gamma readings were significantly above background levels (i.e., about an order of magnitude higher).. No evidence of elevated radon was found inside the church building.

Preliminary survey findings were discussed in a general way with the Borough Mayor at the time of the onsite survey. No such discussion has been held with church representatives. Representatives of the Middlesex Chronicle and Radio-TV Station WCTC, New Brunswick, made inquiry during the initial phases of the onsite survey. In response, it was indicated that survey findings would be made public when analytical work was completed.

Conclusions

Findings of this survey appear to support the following conclusions:

1. The contaminated area in its present configuration and use presents no significant radiation exposure potential to the public. This should be the case as long as the area is undisturbed by excavation or the construction of habitable enclosures.
2. The exposure of individuals at or exceeding AEC guide levels cannot be convincingly dismissed as a credible possibility under circumstances which could exist if the area were developed in the future with residences or other habitable structures.

Historical Background

In 1948, dirt contaminated with pitchblende was removed from the Middlesex Sampling Plant site to the Borough Dump by a contractor during construction of an asphalt pad.

In May 1960, during a local civil defense (CD) exercise, CD monitors detected elevated radiation levels in the dump and questioned the source of the radioactive material. The matter became a political issue and received newspaper coverage. The AEC noted the issue and upon reviewing its past local activities concluded that AEC operations were the likely source. Upon analytical confirmation of the presence of pitchblende, a further survey of the area was made. Readings taken at that time confirmed gamma radiation levels 20 to 50 times background over a fairly consolidated area of less than a half-acre.

Meetings were held with local officials in November 1960 to discuss the significance of survey findings and to offer remedial assistance. AEC subsequently removed the part of the material nearest the surface (about 650 cubic yards) and covered the area with about two feet of clean dirt sufficient to shield surface radiation levels to about 50 μR/hr. Upon assurance by the AEC that no health hazard existed, Borough officials agreed the situation was satisfactory. No official record of the residual contamination exists in available Borough records.

On January 30, 1974, a meeting was again held with Borough officials to request permission to resurvey the involved area to permit reevaluation of current conditions. It was learned that about five acres previously a part of the dump had been sold to the Middlesex Presbyterian Church and a church building erected thereon. Location of the suspect area, as recollected by "old timers" at the Borough, was near the boundary between church and dump properties. The accuracy of this information has been subsequently confirmed by survey data. At this meeting, the press was informed of AEC survey plans and briefed on the history surrounding the suspected contamination.

Description of Area Surveyed

The area bounded by Mountain Avenue, Pershing Avenue, Westminister Street, and Bound Brook is shown in Attachment I. In 1948, the time of the suspected contaminated soil disposal, essentially all of this area was designated as a landfill site for the Borough of Middlesex. Subsequent to the 1961 AEC cleanup action, a five-acre plot was sold to the Middlesex Presbyterian Church and a building constructed as shown. It was understood from discussions with local people familiar with the history of the site that the church and municipal building were constructed on "non-fill" or solid ground.

In 1948, the landfill area was essentially a gully from the brook to within 100-200 feet of Mountain Avenue. The area is now for the most part level to within about 100 feet or so of the brook indicating the filling which has occurred. Bound Brook flood plain elevation is about fifteen feet below Mountain Avenue. The surface of the landfill has reportedly risen 8-10 feet since 1961. Findings from the gamma scanning of core holes confirm the presence of contaminated material at successively greater depths as one goes away from Mountain Avenue toward the brook.

The current landfill site lies to the south and southeast of church property and is expected to reach final elevations and terminate operation this year. Borough plans for the site are reportedly contingent on the availability of Federal funds. If funds become available, a park-recreation area may be developed in the present landfill area.

Survey Findings

Surface Gamma Survey

The transparent overlay in Attachment I describes the area covered by systematic traverses of areas presently or formerly used for landfill disposal. Other areas around the buildings and parking lots which were not amenable to such systematic traverses were surveyed and found to be generally in the background range of 9 to 11 μR/hr. Asphalt parking areas tended to measure somewhat lower, i.e., 7-9 μR/hr.

Core holes 1, 2, and 6 were drilled to explore areas with elevated gamma readings, i.e., 80 μR/hr, 17 μR/hr, and 30 μR/hr, respectively. Drillings confirmed the presence of contaminated material near the surface. Core hole 34 was drilled at the other location of elevated reading, i.e., 20 μR.hr and no significant subsurface contamination was found. Core holes 7 and 20, with normal background readings at the surface, revealed substantial deposits of radioactive materials at depths from 2 to 4 feet. Hence, it is apparent that surface readings are not a conclusive measurement unless the deposit is very near the surface.

Radon Survey

Radon surveys were conducted by the AEC Health and Safety Laboratory. The intended purpose of the radon survey was to assist in identifying the location of contaminated material in the dump site. As with the surface gamma survey, the radon data are not conclusively indicative for deeper deposits. Extension of the interpretation of radon survey data for other purposes such as the estimation of potential radon sources affecting future construction in the area is not attempted.

Background radon emanation within a few miles of the dump site as measured by HASL revealed fluctuations up to a factor of six. These measurements are made by sealing a "flux can" to the ground and, after a sampling period of 30 minutes, transferring the trapped air from the can to a radon scintillation chamber. Radon emanation rate may then be calculated in curies per unit area per unit time. Comparison with similar type measurements made in the suspect area showed some samples to be above the reference offsite background range. All but one of the elevated samples are in the small area with surface radiation levels of 20-80 μR/hr and are about 10-20 times concurrent offsite radon levels. The other elevated sample, which showed an emanation rate about twice the maximum background levels, was from an area with surface gamma readings of 14-15 μR/hr.

Radon and radon daughter measurements made in the church building were indistinguishable from naturally occurring levels.

Subsurface Survey

Thirty-nine core holes were drilled as shown in Attachment II. Each hole was scanned with a shielded GM probe and gamma radiation readings are tabulated in Attachment III. The maximum radiation level detected was about 0.6 mr/hr. Contaminated material was detected over an area of about three acres as shown by the shaded area on Attachment I. Contamination was found to exist over this area in a layer generally 3-5 feet in thickness and at depths from less than 1 foot to about 18 feet. A couple of typical cross-sections through the contaminated area are illustrated in Attachment IV. It is roughly estimated that between 15-20,000 cubic yards of contaminated material may exist in this area. If so, an obvious dilution of the remaining 6,000 cubic yards hauled here in 1948 has occurred. It should be pointed out that in this report "contaminated" refers to areas where gamma radiation readings in core holes exceed 50 cpm. This represents about 3 times observed background levels in the core holes, i.e., 20 μR/hr. Selection of this criterion is based solely on the fact that the level is sufficiently above field instrument sensitivity and beyond the range of background fluctuations to allow some degree of confidence that the suspect radioactive material is present. The criterion is not selected to suggest that higher levels represent a health hazard.

Soil samples were analyzed by the New Brunswick Laboratory for uranium, thorium, and radium concentrations.

Attachment V is a compilation by core hole of the analytical results. It is noted that radium concentrations over the three-acre area average about 11 pCi/gm with the maximum observed to be 140 pCi/gm. Naturally occurring radium in area soil is about 1 pCi/gm (NYO-1521). Uranium levels up to 280 ppm were found. This compares with the 10 CFR 40 de minimus concentration of 500 ppm. U-concentrations appear to track consistently with radium concentrations as one would expect. Thorium concentrations are not appreciably different from general background levels reported by EPA (ORP/SID 72-1.).

Soil samples were collected along the brook to assess any run off from the contaminated residual. Grass was also collected in the vicinity of core hole 20 for analysis. These analytical data are included in Attachment V.

Evaluation of Data

Two conditions require evaluation to permit an understanding of the health and safety implications of radioactive material remaining in the landfill site.

Case 1. What is the potential for radiation exposure to individuals assuming the area remains undeveloped or otherwise undisturbed by excavation below the existing surface?

Case 2. What is the potential radiation exposure to individuals if the area is developed and subsurface deposits are disturbed and/or exposed?

Case 1 suggests a situation which may exist at the site for at most a few years. The present landfill site is expected to terminate operation in the immediate future. The part of the church property which contains radioactive material will likely have a development potential independent of that of the Borough Landfill but equally as unpredictable at this time.

It is clear, however, that for as long as Case 1 conditions exist the credible potential for gamma radiation or radon exposure approaching a fraction of the AEC population guides is negligible. Certainly no health hazard attributable to the radioactive deposit can be imagined for Case 1.

Case 2. For the conditions anticipated in this case one must consider the additive exposure effect of gamma radiation levels existing at the site and the radon concentrations which emanate from residual radium deposits.

Projected external gamma exposure from maximum residual radiation levels (0.6 mr/hr) could be on the order of 5 Rem/yr if one assumed continuous occupancy and ignored the practicalities of geometry, attenuation, and radiation field averaging. One may allow at least a factor of 0.1 reduction to account for these parameters and retain some margin of conservatism. Thus, exposure at the 0.5 Rem/yr level may be considered possible under very limited circumstances. Further reduction of this projected exposure rate is probably possible; however, since no radiological control exists over the use of the site, it is considered inadvisable to rule out those circumstances which are, in fact, theoretically possible.

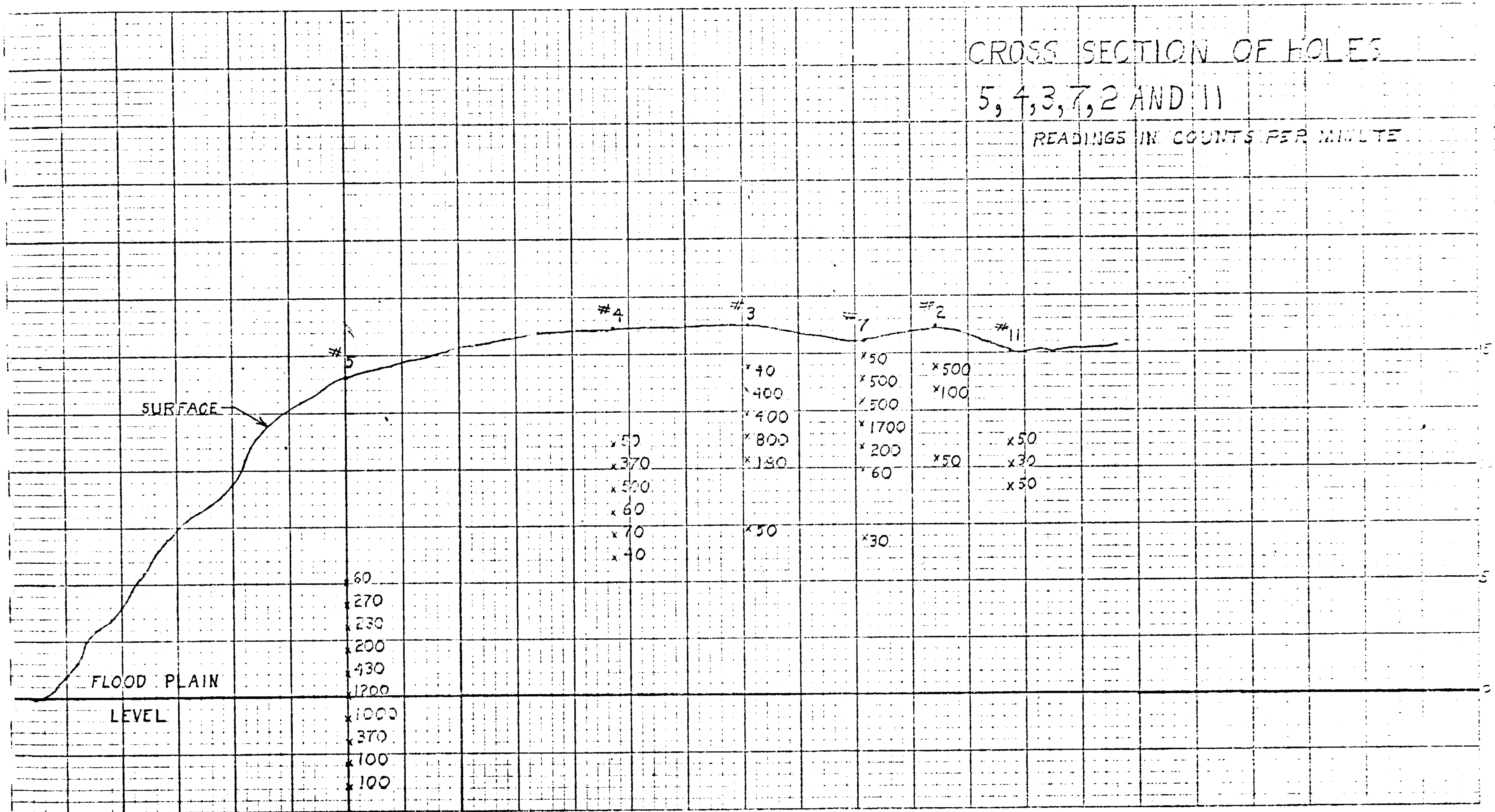
Projected radon exposure becomes significant only if buildings are constructed in the contaminated area causing a concentration or buildup inside the structures. Appendix VI provides a computation of radon buildup in a house assuming soil concentrations on the order of 100 pCi/gm. Based on soil analyses, this level must be considered credible.

RADIATION PROFILE OF CORE HOLES
READINGS IN COUNTS PER MINUTE (CPM)
2.6 CPM $\approx$ 1 μR/hr

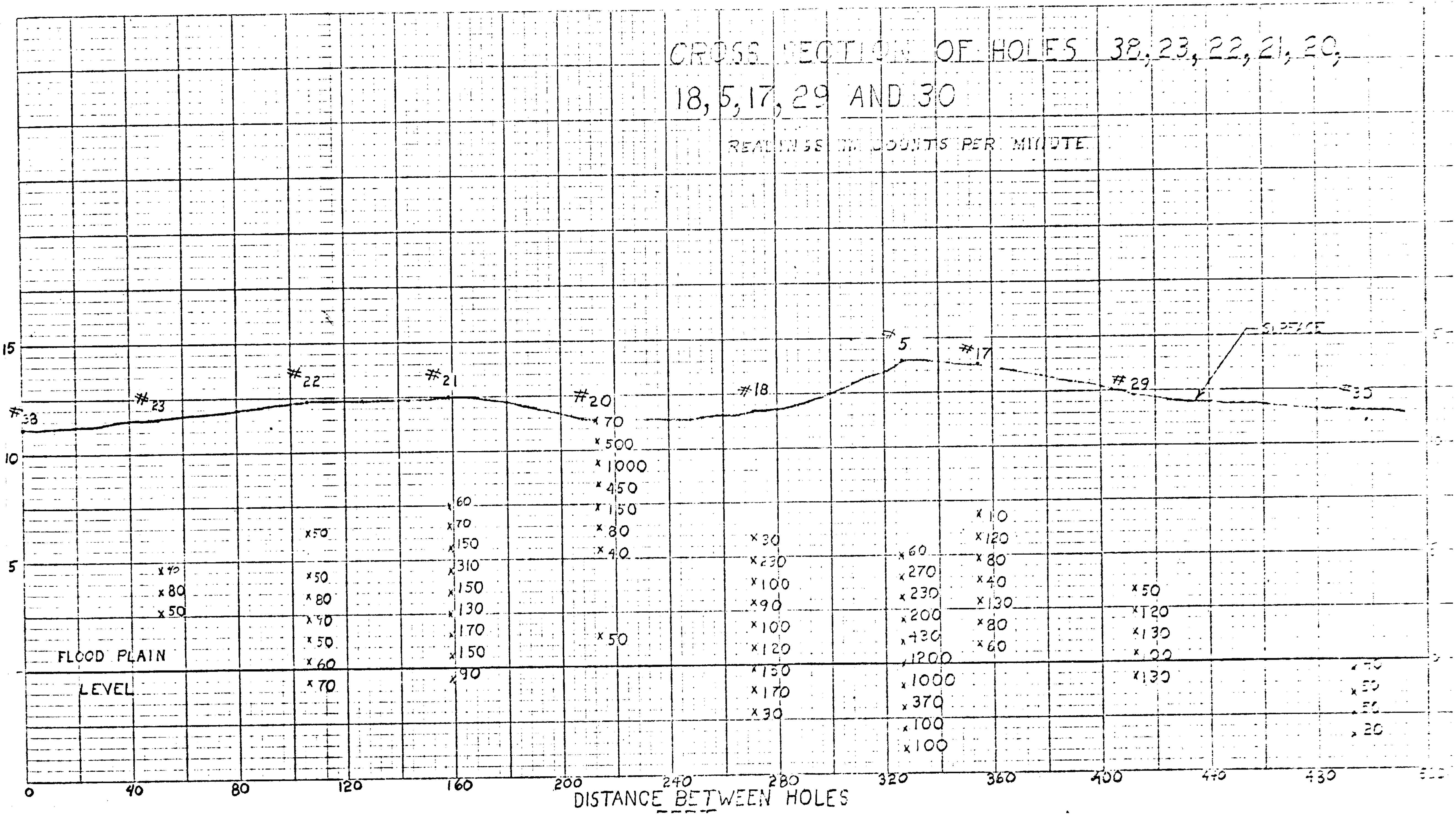
Hole No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Surface elevation above the flood plain in Ft.	14.50	15.24	16.26	16.19	14.06	16.25	15.65	15.16	14.17	14.98	15.08	15.00	15.23	14.35	13.44	14.44	13.[illegible]
gamma level, μR/hr, at 3' above hole	80	17	13	8	11	30	11	15	10	11	10	12	9	9	9	9	11
Hole - Depth in Ft.																	
0'	700			20	30	60	50	20	20	30	20	20	20	20	20	20	20
1'				30	20	170	50			20	20	40	30	10	40	20	20
2'	270	500	40	10	20		500	150	90	20	40	40	80	70	30	40	10
3'	70	100	400	10	10	70	500	110	100	20	20	20	100	60	50	240	10
4'			400	10	10		1700		100	50	50	10	220	150	50	800	10
5'			800	50	10		200	110	40	20	30	30	120	170	370	480	20
6'	40	50	180	370	10	40	60		40	20	50	40	60	70	130	120	20
7'				500	10				50	30	30	50	20	30	60	110	10
8'				60	10			30	70	10	30	30	10	20	40	120	120
9'	25	50	50	70	60	30	30		50	20	30	40	30	20	50	110	60
10'			50	40	270				30	10	20	20	20	10	40	90	40
11'	40	30		40	230			30	40	10	20	20	30	10	30	100	130
12'				50	200	30	30		30		20		30	20	40	70	60
13'				50	430			30			20				40	20	60
14'					1200		30				30					10	
15'					1000	20					30					20	
16'					370	30					20						
17'					100						20						
18'					100						20						

Hole No.	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Surface elevation above the flood plain in Ft.	11.70	12.55	11.40	12.56	12.34	11.67	10.34	9.91	7.39	16.38	16.99	12.39	12.10	15.96	14.06	14.77	5.55
gamma level, μR/hr, at 3' above hole	10	10	10	9	8	9	10	11	10	8	9	8	9	9	12	12	20
Hole - Depth in Ft.																	
0'	20	20	70	10	10	20	20	30	20	20	30	20	20	10	20	20	20
1'	30	40	500	10	20	10	30	20	10	20	20	20	20	10	20	20	40
2'	20	40	1000	20	20	30	20	20	20	10	20	20	10	10	40	30	30
3'	10	20	450	30	10	30	30	20	20	20	30	20	10	10	40	50	30
4'	30	30	150	20	10	20	20	20	10	10	20	10	10	20	50	20	20
5'	20	120	80	60	10	20	20	20	10	10	20	10	20	10	50	30	20
6'	30	270	40	70	50	20	30	20	30	10	20	20	20	60	30	40	30
7'	230	70		150	20	40	70	60	40	50	10	20	10	50	30	30	10
8'	100	70		310	50	80	70	90	30	120	10	20	10	40	30	30	20
9'	90	50		150	80	50	50	90	30	60	60	50	10	20	30	30	
10'	100	50	50	130	90	20	50	80	10	40	50	120	20	30	20	20	
11'	120	30		170	50	20		80	20	40	40	130	10	30	20	20	
12'	150	20		150	60	20				50	40	100	40		30	20	
13'	170			90	70	30				50		130	50				
14'	30												50				
15'													20				

Hole No.	35	36	37	38	39
Surface elevation above the flood plain in Ft.	13.23	13.20	12.83	11.18	13.61
gamma level, µR/hr, at 3' above hole	10	10	10	10	10
Hole - Depth in Ft.					
0'	20	10	10	10	10
1'	30	10	10	10	40
2'	20	10	20	10	30
3'	30	20	30	10	60
4'	60	100	20	10	40
5'	50	230	20	20	70
6'	60	110	10	20	40
7'	180	60	20	30	30
8'	180	50	40	30	20
9'	120	40	40	10	20
10'	50			30	20
11'	30			20	20
12'				20	30
13'				20	



DISTANCE BETWEEN HOLES (SCALE 20 FT. PER 5 DIVISIONS)



CROSS SECTION OF HOLES 38, 23, 22, 21, 20,
18, 5, 17, 29 AND 30
READINGS IN COUNTS PER MINUTE
SURFACE
#38
#23
#22
#21
#20
#18
#5
#17
#29
#30
15
10
5
FLOOD PLAIN
LEVEL
x 40
x 80
x 50
x 50
x 50
x 80
x 40
x 50
x 60
x 70
60
70
150
310
150
130
170
150
90
x 70
x 500
x 1000
x 450
x 150
x 80
x 40
x 50
x 30
x 230
x 100
x 90
x 100
x 120
x 130
x 170
x 30
x 60
x 270
x 230
x 200
x 430
x 1200
x 1000
x 370
x 100
x 100
x 10
x 120
x 80
x 40
x 130
x 80
x 60
x 50
x 120
x 130
x 130
x 20
0
40
80
120
160
200
240
280
320
360
400
DISTANCE BETWEEN HOLES

CORE HOLE SOIL SAMPLES

Sample Location	Ra Pci/g	µg U/g*	µg Th/g*
Hole 1			
0-1 ft.	23	40	5
6-8 ft.	7	6	7
10-12 ft.	3.9	3	8
Hole 2			
3-5 ft.	5.4	5	11
6-8 ft.	1.2	2	8
9-11 ft.	0.5	3	7
11-12 ft.	0.1	19	9
Hole 3			
6-8 ft.	140	280	9
9-11 ft.	28	40	9
11-13 ft.	6	11	11
13-18 ft.	3	7	11
Hole 4			
6-8 ft.	97	130	10
12 ft.	13	15	10
Hole 5			
13-20 ft.	26	90	6
Hole 6			
0-2 ft.	13	40	8
2-5 ft.	15	70	6
8-13 ft.	5	6	7
13-18 ft.	7.1	4	9
18-20 ft.	2.5	3	7
Hole 7			
0-2 ft.	0.3	3	9
2-5 ft.	60	60	8
13-20 ft.	13	4	8
Hole 8			
0-2 ft**	33	80	11
1-5 ft.	23	40	18
5-8 ft.	9.5	12	10
8-13 ft.	4.8	8	19
Hole 9			
0-2 ft.	24	14	7
2-5 ft.	19	30	12
5-8 ft.	3.6	6	14
8-13 ft.	4.7	10	25
Hole 10			
0-2 ft.	<0.1	4	11
2-5 ft.	5.8	3	6
5-8 ft.	5.7	3	5
8-13 ft.	1.5	1	5
Hole 11			
0-2 ft.	2.4	3	7
5-13 ft.	8.0	3	8
Hole 12			
0-2 ft.	7.6	3	8
2-8 ft.	1.8	3	7
8-13 ft.	2	4	11
Hole 13			
0-2 ft.	1	3	7
2-5 ft.	6	40	14
5-8 ft.	10	17	20
Hole 14			
0-2 ft.	4.1	3	7
2-5 ft.	9.9	17	25
5-10 ft.	3.7	6	20
10-12 ft.	3.6	3	6
Hole 15			
0-2 ft.	6.2	8	13
2-5 ft.	9.0	12	10
5-8 ft.	25	30	15
Hole 16			
0-2 ft.	6	3	10
8-12 ft.	12	22	9
18-20 ft.	8.7	9	8
Hole 17			
0-1 ft**	<1.0	4	12
0-8 ft.	2.8	3	10
8-20 ft.	7.3	14	5
Hole 18			
0-2 ft.	3.7	3	12
10-15 ft.	4	8	7
15-20 ft.	9.3	12	5
Hole 19			
0-3 ft.	7.7	3	13
3-8 ft.	4.2	20	7
8-13 ft.	6.1	7	15
13-18 ft.	1.2	5	8
Hole 20			
0-3 ft.	4	6	9
3-8 ft.	112	200	8
8-13 ft.	5.8	8	9
Hole 21			
0-5 ft.	2.9	4	7
5-8 ft.	5	3	4
8-13 ft.	10	15	7
13-18 ft.	3.3	7	6
Hole 22			
0-3 ft.	3.5	1.5	3
3-7 ft.	3.4	1.5	5

Attachment V

Sample Location	Ra Pci/g	µg U/g*	µg Th/g*
Hole 23			
0-3 ft.	<1.0	2	5
3-8 ft.	10	7	5
8-13 ft.	8.3	4	6
Hole 24			
0-3 ft.	5.0	2	4
3-8 ft.	5.6	2	4
Hole 25			
0-3 ft.	4.0	4	7
3-8 ft.	4.2	3	6
8-11 ft.	4.4	2	5
Hole 26			
0-3 ft.	3.3	5	6
Hole 27			
0-3 ft.	2.9	3	7
3-8 ft.	4.4	9	9
Hole 28			
0-3 ft.	3.4	2	5
3-8 ft.	0.5	1	9
8-13 ft.	5	7	6
Hole 29			
0-3 ft.	4.5	1.5	4
3-13 ft.	4	5	3
13-18 ft.	19	25	7
Hole 30			
0-3 ft.	2.8	3	5
3-8 ft.	1.7	2	5
8-13 ft.	7	3	5
13-18 ft.	3.3	2	4
Hole 31			
0-3 ft.	6.7	3	6
3-8 ft.	<0.1	11	11
8-13 ft.	2.8	3	6
Hole 32			
0-3 ft.	3	4	6
3-8 ft.	<0.1	4	15
8-13 ft.	4.7	2	7
Hole 33			
0-3 ft.	8.7	4	8
3-8 ft.	3.7	2	6
8-13 ft.	5.2	2	6
Hole 34			
0-3 ft.	5.1	4	11
3-8 ft.	<1.0	4	7
8-13 ft.	2.4	4	10
Hole 35			
0-3 ft.	3.9	2	7
3-8 ft.	11	16	8
8-3 ft.	5.3	9	5
Hole 36			
0-3 ft.	3.1	4	5
3-8 ft.	7.6	17	7
8-13 ft.	11	16	10 **
Hole 37			
0-3 ft.	3.5	2	4
3-8 ft.	5.8	2	5
8-13 ft.	0.8	2	5
Hole 38			
0-7 ft.	<0.1	2	6
7-13 ft.	4.1	5	5
Hole 39			
0-8 ft.	1.5	3	7
8-13 ft.	9.5	4	7
Creek 1			
On Flood Plane N of Hole 38	3.1	1.5	4
Creek 2			
On Flood Plane N of Hole 38	3.5	1.5	3
Creek 3			
On Flood Plane E of Hole 26	4.0	2	5
Creek 4			
On Flood Plane E of Hole 5	4.6	1.5	4
Grass at Hole 20	3.4	0.4	1.5

* Accuracy of these values is estimated to be ± 20%

** Sample from the original hole which could not be drilled beyond this depth.

STATEMENT OF PROBLEM

What radon concentration would be expected in the basement of a house constructed in the future on the Middlesex Borough Landfill site and subject to the effects of a residual radium concentration such as remains in the three-acre area identified by the 1974 AEC-OR survey?

STATEMENT OF BASIC ASSUMPTIONS

1. Regarding the prevailing radium concentration:

   Soil analysis over the three-acre area containing residual pitchblende contamination indicates an average radium concentration of about 11 pCi/gm. This compares to a naturally occurring background level of 1 pCi/gm. For this calculation, to assure conservatism, the five highest soil samples have been averaged yielding a radium concentration of about 100 pCi/gm. It is assumed that a house could be exposed to soil containing such a radium level.

2. Regarding the hypothetical future house construction:

   It is assumed that the floor of the basement is 8" below grade and dimensions of the basement are 60'x30'. It is assumed that backfill around the basement wall extends 2' in the perpendicular direction out from the four basement walls. The backfill is assumed contaminated to a level of 100 pCi of radium per gram of soil.

Utilizing these basic assumptions, the following calculation is made to attempt to predict radon levels in future housing which might be constructed on the landfill site.

The source, S, of the radon will be the inventory of radium in the volume, V_b, of backfill:

$$S = V_b \rho \quad (100 \text{ pCi/gm}) \qquad (1)$$

$$V_b \doteq (60'\text{x}8'\text{x}2')\ 2 \text{ walls} + (30'\text{x}8'\text{x}2')\ 2 \text{ walls} = 3\text{x}10^3 \text{ft}^3$$

$$\rho = 100 \text{ lbs/ft}^3 = \text{density of backfill}$$

$$S = 3\text{x}10^3 \text{ ft}^3 \text{ x } 100 \text{ lbs/ft}^3 \text{ x } 450 \text{ gm/lb x } 100 \text{ pCi/gm} = 13.5 \text{ mCi}$$

Assuming the radon to be in equilibrium with the radium, there would be a total of 13.5 mCi of radon produced in the backfill. It is crudely estimated from geometrical considerations that about 1/3 of the radon produced or 4.5 mCi would enter the basement.

Now the question becomes what is the maximum concentration of radon which will occur in the house assuming a minimum ventilation rate of one-half the building volume per hour. This ventilation rate is reported by ORNL to be the lowest observed in their feasibility studies of tritium contaminated natural gas usage in connection with Project Gasbuggy.

Let: N = the number of radon atoms at time, t

C_1 = a constant source of radon atoms

$= 4.5\times10^{-3}$ Ci x 3.7×10^{10} atoms/sec = 1.7×10^{8} atoms/sec

C_2 = a rate at which radon atoms are removed via ventilation

$= .5$/hr = 1.4×10^{-4}/sec

Therefore: $$\frac{dN}{dt} = C_1 - \lambda N - C_2 N \qquad (2)$$

Where λ is the radon decay constant

$$\lambda = \frac{0.693}{3.8 \text{ days} \times 24 \text{ hrs/day} \times 3600 \text{ sec/hr}} = 2.1\times10^{-6}\text{/sec}$$

Since λ is much less than C_2, for purposes of this calculation, the radiological decay of radon will be neglected and the λN term in equation (2) drops out leaving

$$\frac{dN}{dt} = C_1 - C_2 N \qquad (3)$$

Integrating eq. 3 and solving for N gives:

$$N = \frac{C_1}{C_2}(1 - e - C_2 t) \qquad (4)$$

Let $t \to \infty$ to represent an equilibrium condition:

$$N = \frac{C_1}{C_2} \text{ at equilibrium} \qquad (5)$$

$$= \frac{1.7 \times 18^{8} \text{ atoms/sec}}{1.4 \times 10^{-4} \text{ /sec}} = 1.2 \times 10^{12} \text{ atoms of radon}$$

The radon activity at equilibruim in the house will be:

$$N\lambda = \frac{1.2 \times 10^{12} \text{ atoms} \times 2.1 \times 10^{-6}/\text{sec}}{3.7 \times 10^{10} \text{ atomx/sec - Ci}} = 7 \times 10^{-5} \text{ Ci} \qquad (6)$$

The equilibrium radon concentration, X, in the basement due to the radium inventory in the backfill is therefore:

$$X = \frac{70 \ \mu\text{Ci}}{\text{volume of basement}} = 1.4 \times 10^{-7} \ \mu\text{Ci/cc}$$

This equals a working level concentration of 1.3 WL.

It should be pointed out that, if the house were built without basement upon a concrete slab on top of ground contaminated at the 100 pCi/gm concentration, the radon levels in the house may be 2-3 times this level.

In the above calculations, no credit is taken for the attenuation of radon as it diffuses through the walls of the structure.