national accelerator laboratory
P. O. Box 500, Batavia, Illinois 60510

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I. PREOPERATIONAL ENVIRONMENTAL MONITORING REPORT

S. Baker and F. Schamber

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II. Introduction

The National Accelerator Laboratory (NAL) facility is a 200 GeV proton synchrotron. The primary purpose of the installation is fundamental research in high-energy physics. The 1.2 mile diameter main accelerator (Fig. 1) receives 8 GeV protons from a booster accelerator which is fed by a 200 MeV linear accelerator (Linac). The 200 GeV beam extracted from the accelerator will be taken to three different experimental areas (Fig. 2). Radioactivity will be produced as a result of the interaction of the accelerated protons with matter. Most of this radioactivity will be contained in insoluble shields and beam dumps. Operation of the accelerator at full design energy and intensity will produce some radiation which penetrates the shielding as well as some air-borne activity. Also, some radioactivation of soil will occur. Thus, a broad program of environmental monitoring has been initiated and will be maintained.

III. Summary

The three types of accelerator produced radiation which should be considered for environmental monitoring are penetrating radiation, air-borne radioactivity, and water-borne radioactivity. Of the three, water-borne radioactivity is expected to be the most difficult to control, hence a broad program of water sampling has been established. Shielding has been designed to be adequate for stopping penetrating radiation under foreseeable circumstances, but monitoring for verification both on and off the site is necessary. A central environmental monitoring station has been placed in operation and a mobile environmental radiation laboratory will be set up. The off-site doses will be estimated from surveys made with the mobile laboratory and from monitors placed on the site and near the boundary.

A program for monitoring air-borne radioactivity will be established at a later date since the expected activities for environmental purposes are so low. Under no circumstances is the off-site concentration of air-borne radioactivity expected to approach the limits set forth in the applicable standards.

Water samples were collected from wells on the site, from water supplies in surrounding communities, and from local ponds, creeks and the Fox River. Also, samples were taken from sumps around the accelerator and along the beam lines to establish normal background levels. The samples were analyzed by U. S. Testing Company, Inc. of Richland, Washington for five radionuclides known to be produced in soil, water and shielding materials such as concrete and steel as a result of accelerator operation. None of these radioisotopes was detected. Also, ground water was analyzed for radium and thorium which occur naturally and relatively high concentrations were found. In

order to determine that the samples were being analyzed properly, a program of spiking samples with radioactivity in known concerntrations was begun. Excellent agreement has been obtained in practically every case.

Continuous monitoring of penetrating radiation levels was maintained at the central environmental monitoring station throughout the calendar year 1971 during which time there was no accelerated beam in the main accelerator. Gamma-ray, charged particle, and neutron detectors described in Section IV gave no evidence of any accelerator produced radiation. The levels were consistent with natural background exposures. Occasionally, increases of short duration were detected in the radiation level, but no correlation with any accelerator operation was found.

IV. Monitoring, Data Collection, Analysis and Evaluation

A central monitoring station is maintained in the NAL "village" for detecting penetration radiation. The monitoring equipment consists of five major components.

1. Aluminum-Argon ionization chamber. This chamber is mostly sensitive to muons and gammas, and much less sensitive to neutrons. The data is recorded as daily integrals of the ionization current. A continuous strip-chart record of ionization current is also made.

2. Tissue-equivalent ionization chamber. This chamber is sensitive to neutrons as well as gammas and directly ionizing radiations. The data is recorded as daily integrals of the ionization current and as a strip-chart record of ionization current.

3. A 3 in x 3 in NaI(Tl) radiation ratemeter. This device is sensitive primarily to gamma radiation above 100 keV. The data is recorded as daily integrals of the counts and as a strip-chart record of count rate.

4. Bonner spectrometer. This device is an array of moderating hydrogenous spheres with thermal-neutron sensitive $Li^6I(Eu)$ scintillators located at the center of each sphere. The data is recorded as the daily integral of counts in each detector. It may be unfolded by a computer program to obtain the neutron flux and dose.

5. Precision reproducible (DePangher) long counter. This device is a BF_3 proportional counter moderated by polyethylene to obtain an essentially flat energy response to neutrons. The count rate from this device is thus

a measure of neutron flux. The data is recorded as daily integrals of neutron counts.

A number of short periods of increased radiation levels have been observed since the monitoring station was put into operation, but no correlation with accelerator production of penetrating radiation has been found. The three gamma sensitive monitors (aluminum-argon ion chamber, tissue-equivalent ion chamber, and NaI(Tl) crystal) have consistently indicated natural-background-level exposures of approximately 0.006 milliRoentgens/hour except for the brief periods discussed above. The neutron monitors have indicated an average flux of approximately 17 n/(cm^2-hr), which is consistent with the expected cosmic-ray neutron background. This corresponds to a neutron dose of approximately 0.0005 mrem/hr.

For monitoring of air-borne radioactivity commercially available air sampling equipment has been purchased. Filters can be examined in the NAL Nuclear Counting Laboratory which has a large variety of detection equipment including a high resolution lithium drifted germanium semiconductor detector with 10 percent efficiency relative to a 3 in x 3 in NaI(Tl) crystal. High resolution will be necessary for identifying unknown radioactive nuclides.

Having a nuclear counting laboratory on the site will also permit prompt examination of water samples which might contain radioactivity. The laboratory is well equipped to detect the 0.477 MeV gamma ray from the decay of Beryllium-7, a radioisotope which is produced in water by the interaction of high-energy protons. Its relatively short half-life (53 days) results in a high specific activity which rapidly disappears compared with 12 year half-life tritium (H-3) which is also produced in water. Thus, the detection of Be^7 can serve as

an early warning for the appearance of tritium.

Water samples were taken in the locations shown in Figures 1 and 2 on site and the descriptions of the water systems sampled are given in Table 1. The sumps located around the accelerators and along the beam lines sample shallow ground water collected from the footings and underdrains. When design intensity is reached, the Neutrino Laboratory meson decay pipe is expected to receive intense radiation. Consequently, preoperational sampling in that area has been thorough and monthly samples will continue.

A number of farm wells less than 100 feet deep on the site obtain water from the Silurian aquifer which provides drinking water for many farm families off the site. Thus, it is important to repeatedly verify that no radioactivity has been added to this supply. Also, a deep well on the site is sampled monthly as is surface water from the cooling ponds. Water from the three creeks leaving the site is sampled annually. As part of the preoperational program to establish normal background radioactivity concentrations in the water, water supplies in the surrounding Illinois communities of Aurora, Batavia, Geneva, North Aurora, Warrenville, West Chicago and Wheaton, as well as the NAL village (formerly Weston), were sampled. Appreciable quantities of radium were found (Table 2), but none of the radioisotopes which could be produced by the accelerator was present. The maximum permissible concentrations are not applied to naturally occurring radionuclides, hence the table is provided for comparison purposes only.

Although the water used to cool the magnets in the accelerator is recirculated, some radioactivity is expected to be collected in the ion exchange column resins used for

deionizing the water to maintain low conductivity. Samples will be collected during regeneration to monitor any release of activity.

The water sampling program was initiated in September of 1970. U. S. Testing Company, Inc. (Richland Laboratory, Richland, Washington) was contracted to perform the analyses. The specifications for the analyses are given in Section V. An unmarked sample spiked with known amounts of five accelerator produced radionuclides plus perhaps radium and thorium was included in most shipments to test the techniques used in the analyses. The five accelerator produced radioisotopes are as follows:

Radionuclide	Half-life	Emission	Energy
Be^{7}	53 days	Gamma	0.477 MeV
Mn^{54}	313 days	Gamma	0.835 MeV
Na^{22}	2.6 years	Gamma	0.511 and 1.28 MeV
Ca^{45}	163 days	Beta	0.25 MeV end point
H^{3}	12.3 years	Beta	0.019 MeV end point

Not one of these isotopes was found in any of the samples analyzed. The concentration guides are found in Section V and details on sampling frequency at a given location can be found in the Environmental Monitoring Report for Calendar Year 1971. A number of preoperational samples were taken in 1972 before the external beam lines had received any protons. See Figure 2. These results will appear in later reports, along with other preoperational samples farther from the accelerator along the Meson and Proton Laboratory beam lines.

V. References

The concentration guides used in the analyses of the water samples were taken from the Atomic Energy Commission Manual, Chapter 0524, Annex A, Table II, Column 2 (Water in Uncontrolled Areas) and reduced by a factor of three as appropriate for a suitable sample of exposed population. The smaller of the values given for soluble and insoluble forms has been used in each case. The specifications are given in Table 3. The concentration guides for air-borne activity were taken from the same source, Table II, Column 1 (Concentrations in Air in Uncontrolled Areas), and divided by a factor of three for application to populations. The appropriate standard for penetrating radiation applied to populations was taken from the AEC Manual, Chapter 0524, Paragraph II.A: 0.17 rem/year (exposure to whole body, gonads, or bone marrow).

Figure 1 - Map of Sampling Locations

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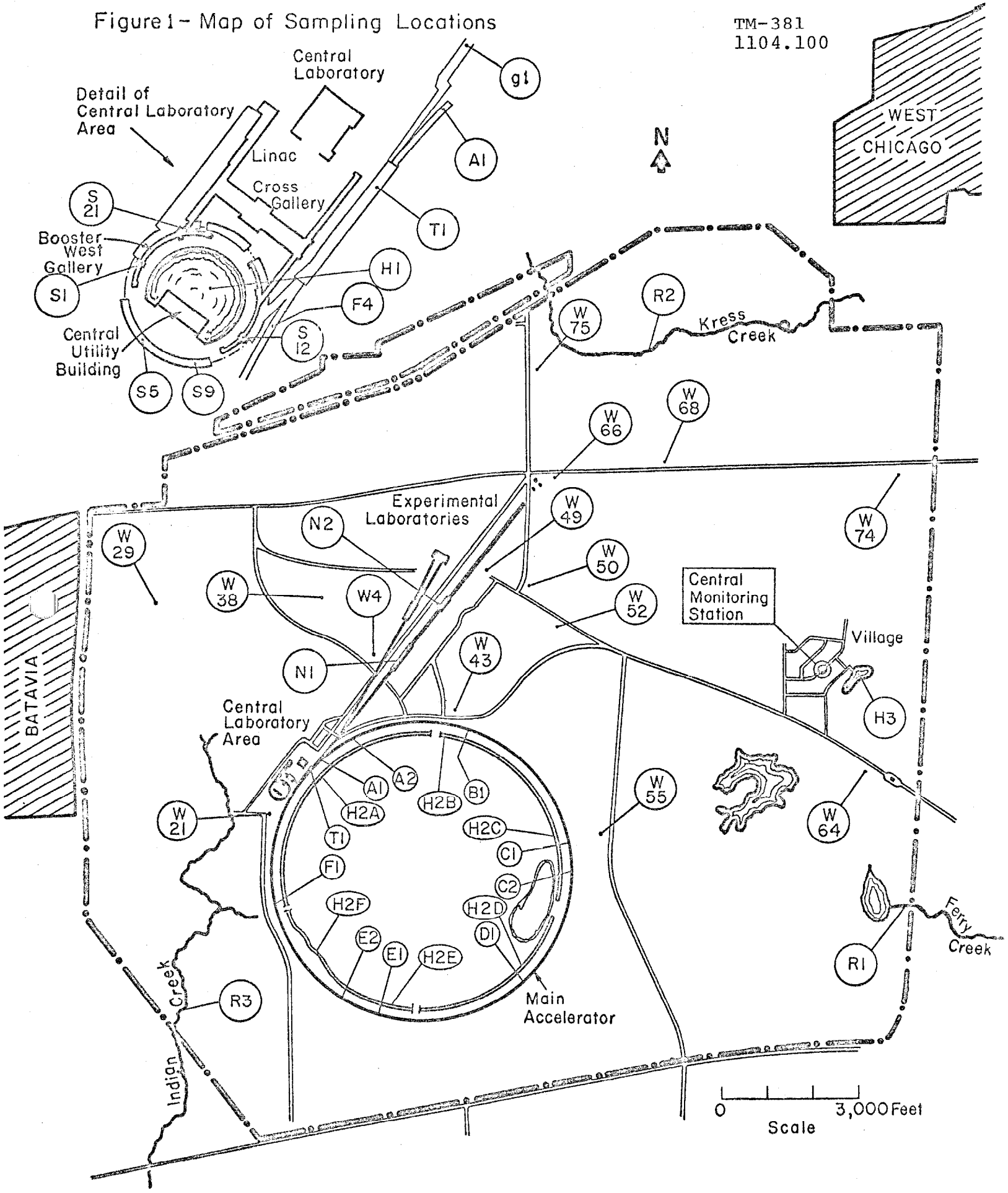

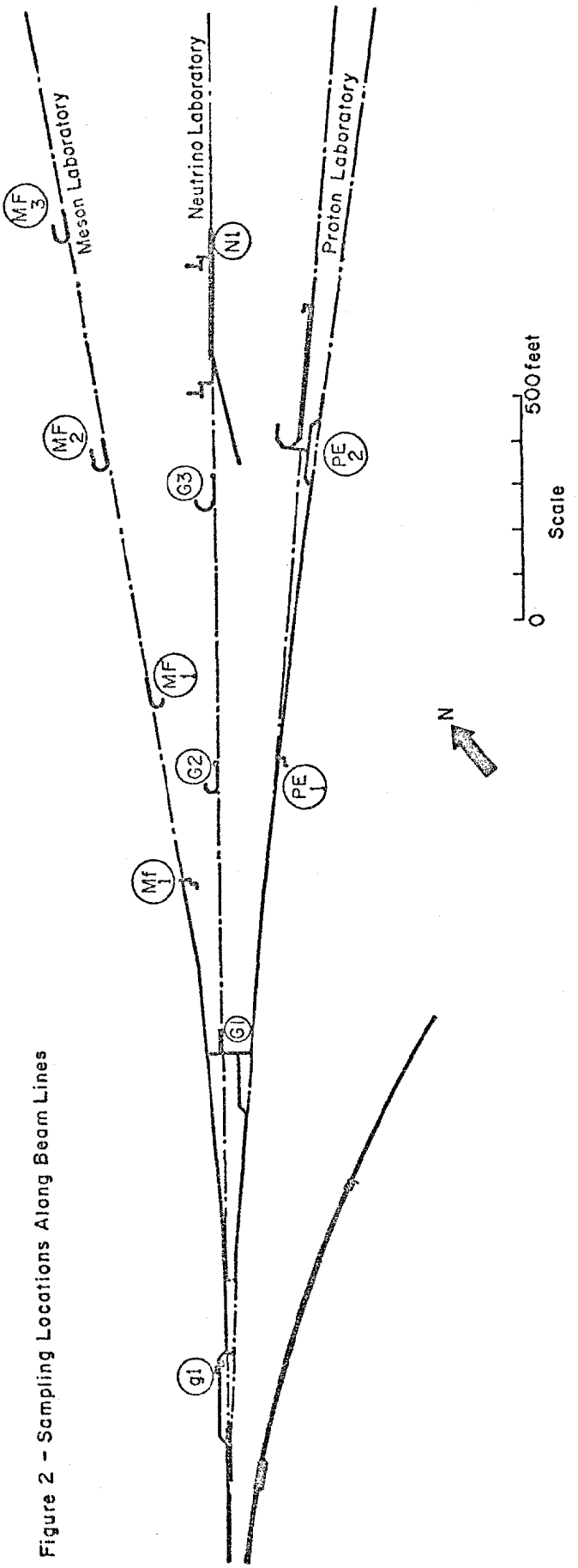

Figure 2 - Sampling Locations Along Beam Lines

Table 1
Description of Sampling Locations

Designation	Description	Water System Sampled
A1,A2,B1,C1, C2,D1,E1,E2, F1	Sumps adjacent to Main Accelerator enclosure	Shallow ground water from footings
g1,G1,G2,G3	Sumps along beam line between Transfer Hall and Neutrino Lab Front-end enclosure	Shallow ground water from footings
H1	Central Utilities Building Cooling Pond	Industrial cooling water
H2A,H2B,H2C, H2D,H2E,H2F	Main Accelerator Cooling Pond	Industrial cooling water
Mf1,MF1,MF2,MF3	Sumps along beam line between Transfer Hall and Meson Lab Front-end enclosure	Shallow ground water from footings
N1	Sump in Neutrino Lab Front-end enclosure	Shallow ground water collected in decay pipe underdrains
N2	Sump in Neutrino Lab Enclosure 100	Shallow ground water collected in decay pipe underdrains
PE1,PE2	Sumps along beam line between Transfer Hall and Proton Lab Front-end enclosure	Shallow ground water from footings
R1	Ferry Creek	Surface water
R2	Kress Creek	Surface water
R3	Indian Creek	Surface water
S1,S5,S12,S21	Sumps adjacent to Booster enclosure	Shallow ground water from footings
T1	Sump adjacent to extraction area in Transfer Hall	Shallow ground water from footings
V	NAL Village water supply	Silurian aquifer
W4,W7,W21,W29,W38, W43,W49,W50,W52, W55,W59,W64,W66, W68,W74,W75	Cased farm wells	Silurian aquifer

Table 2

Radium in Local Water Supplies

Batch	Location	Radium Concentration (pCi/ml)	Fraction of MPC*
12	NAL Deep Well	0.0075	0.75
13	Well #55	0.002	0.2
13	Well #50	0.002	0.2
13	Well #21	0.003	0.3
13	Batavia	0.030	3.0
13	Aurora	0.024	2.4
13	Well #43	0.003	0.3
14	Well #21	0.0005	0.05
14	Well #43	0.001	0.1
14	Well #64	0.0009	0.09
14	Well #50	0.0008	0.08
14	Well #29	0.0008	0.08
14	Well #49	0.0007	0.07
14	NAL Village	0.0008	0.08
15	NAL Deep Well	0.0122	1.22
15	North Aurora	0.00275	0.028
15	NAL Village	0.0004	0.04
16	Well #39	0.001	0.1
16	West Chicago	0.012	1.2
16	NAL Village	0.001	0.1
18	Well #52	0.0001	0.01
18	Well #29	0.00007	0.007
18	Wheaton	0.00004	0.004
19	Well #75	0.0001	0.01
19	Well #74	0.0003	0.03
20	Well #21	0.0002	0.02
20	Well #50	0.0004	0.04
20	Aurora	0.0006	0.06
21	Well #49	0.0004	0.04
21	Well #68	0.0008	0.08
24	Warrenville	0.019	1.9
24	West Chicago	0.028	2.8
24	Geneva	0.022	2.2
24	Batavia	0.024	2.4
24	North Aurora	0.022	2.2
24	Aurora	0.020	2.0
25	NAL Deep Well	0.016	1.6
26	NAL Deep Well	0.005	0.5
26	NAL Deep Well	0.006	0.6

*Maximum Permissible Concentration

Table 3

Specifications for the Analyses
of Radionuclides in Water

Radionuclide	Concentration Guide µCi/ml	Specified[1] Sensitivity µCi/ml	Specified[2] Precision µCi/ml
Na^{22}	1×10^{-5}	3×10^{-7}	3×10^{-7}
Ca^{45}	3×10^{-6}	3×10^{-7}	3×10^{-7}
Mn^{54}	3.3×10^{-5}	5×10^{-8}	5×10^{-8}
H^{3}	1×10^{-3}	3×10^{-6}	3×10^{-6}
Be^{7}	6.7×10^{-4}	5×10^{-7}	5×10^{-7}
Total Radium[3]	1×10^{-8}	1×10^{-9}	1×10^{-9}
Total Thorium[4]	6.6×10^{-7}	3×10^{-8}	2×10^{-8}

1. The concentration guides are taken from the AEC Manual, Chapter 0524, Annex A, Table II, Column 2 (Water in Uncontrolled Areas) and reduced by a factor of three as appropriate for a suitable sample of exposed population. The smaller of the values given for soluble and insoluble forms has been used in each case.

2. The precision and sensitivity are stated for the 68% confidence level (one standard deviation).

3. The concentration guide is the Chapter 0524 guide for Ra^{226}. This is therefore an extremely conservative guide for total radium.

4. Chapter 0524 gives the concentration guide for natural thorium as 0.33 pCi/ml with the definition that 1 Curie of natural thorium is equal to 3.7×10^{10} disintegrations/sec from Th^{228} plus 3.7×10^{10} disintegrations/sec from Th^{232}. The concentration guide for total thorium (assumed to be Th^{228} and Th^{232} only) is thus taken to be twice this value.