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1977 ENVIRONMENTAL MONITORING REPORT

J.R. Naidu, Editor

April 1978

SAFETY AND ENVIRONMENTAL PROTECTION DIVISION

BROOKHAVEN NATIONAL LABORATORY

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SAFETY AND ENVIRONMENTAL PROTECTION DIVISION

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NOTICE

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BROOKHAVEN NATIONAL LABORATORY
ENVIRONMENTAL MONITORING REPORT

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INTRODUCTION

Site Characteristics:

Brookhaven National Laboratory is a multidisciplinary scientific research center situated in the geographical center of Suffolk County on Long Island, about 113 km east of New York City. Its location with regard to surrounding communities is shown in Figure 1. The principal nearby population centers are located in shoreline communities. Much of the land area within a 16 km radius is either forested or under cultivation. However, it is in transition and considerable recent and projected development of suburban housing is located in proximity to the Laboratory.

The Laboratory site is shown in Figure 2. It consists of some 2130 ha most of which is wooded, except for a central developed area of about 405 ha. The site terrain is gently rolling, with elevations varying between 36.6 and 13.3 meters, above sea level. The land lies on the western rim of the shallow Peconic River watershed, with the river itself rising in marshy areas in the north and east sections of the site.

In terms of meteorology, the Laboratory can be characterized as a well ventilated site. In common with most of the eastern seaboard, its prevailing ground level winds are from the southwest during the summer of the year, from the northwest during the winter, and about equally from these two directions during the spring and fall. This is reflected in the annual wind distribution at an elevation of 108 m, as observed by the BNL Meteorology Group, which is shown in Figure 3.

Studies of the hydrology and geology [1-3] of Long Island in the vicinity of the Laboratory indicate that the uppermost Pleistocene deposits, which are locally between 31-61 m thick, are generally sandy and highly permeable. Water penetrates them readily and there is little direct run-off into surface streams except during periods of intense precipitation. The average annual precipitation is 122 cm a^{-1}. About half is lost to the atmosphere through evapotranspiration and half percolates to recharge ground water. As indicated in Figure 4 (from Ref. 1), the ground water in Laboratory vicinity moves predominantly in a horizontal direction to the Great South Bay. This is modified toward a more easterly direction in the Peconic River watershed portions of the site. The estimated rate of movement at the ground water surface is about 16.2 cm d^{-1} [1].

Site Use:

A wide variety of scientific programs are conducted at Brookhaven, including research and development in the following areas:

1) fundamental structure and properties of matter,
2) the interactions of radiation, particles and atoms with other atoms and molecules,

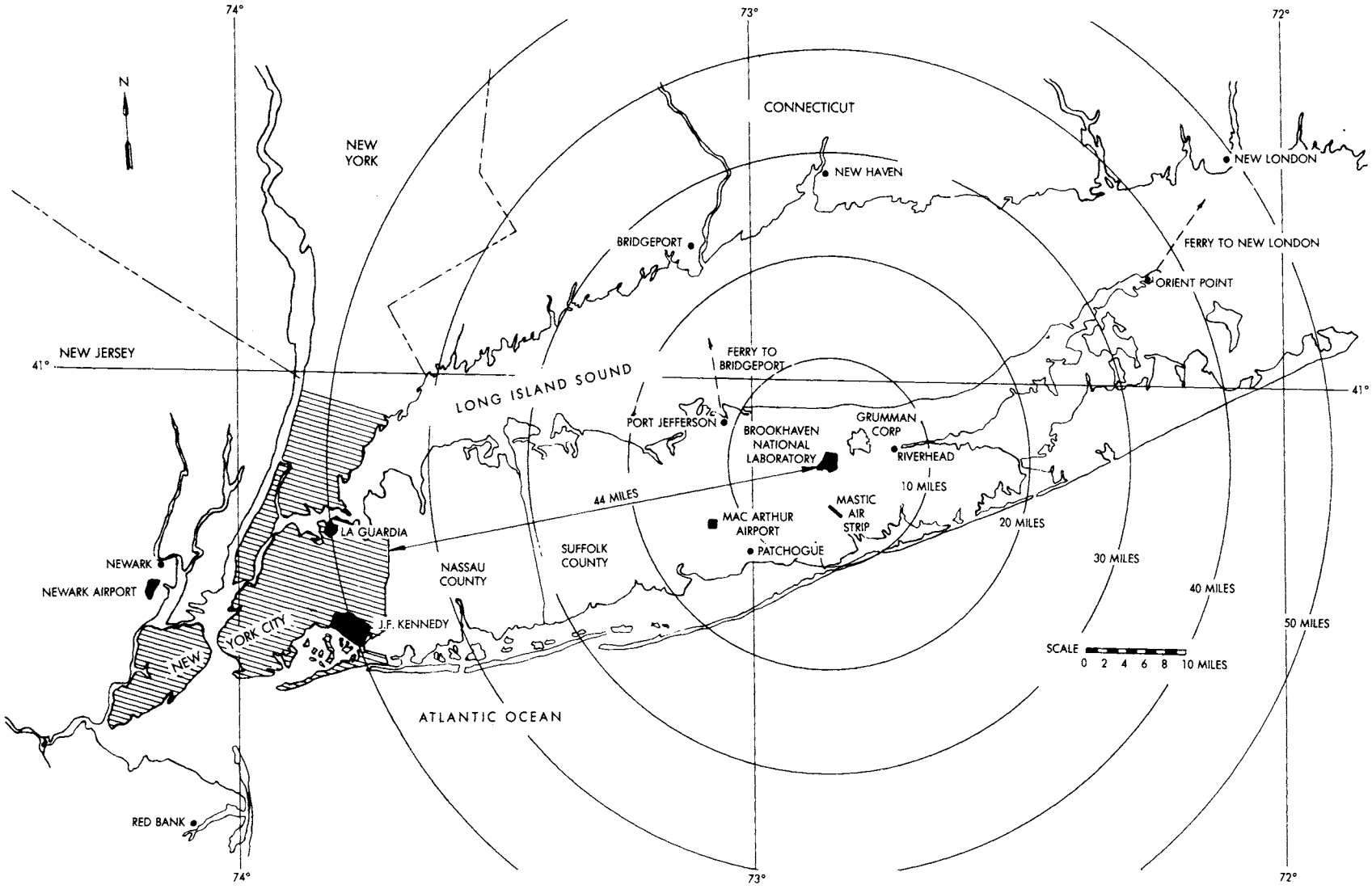
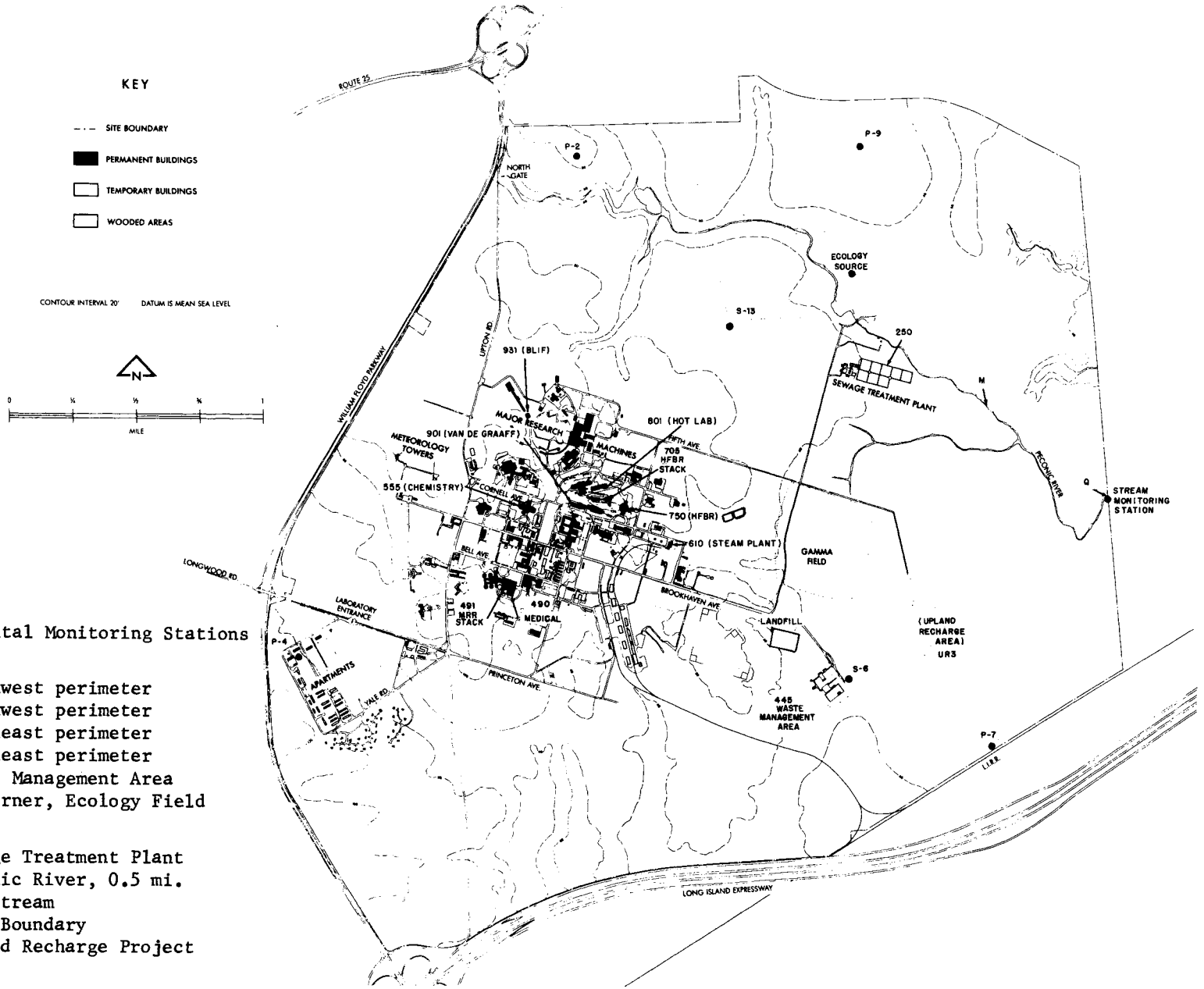


Figure 1. Map of the general Long Island area showing the location of Brookhaven National Laboratory.



Environmental Monitoring Stations

Air

P-2	Northwest perimeter
P-4	Southwest perimeter
P-7	Southeast perimeter
P-9	Northeast perimeter
S-6	Waste Management Area
S-13	SW Corner, Ecology Field

Water

250	Sewage Treatment Plant
M	Peconic River, 0.5 mi. downstream
Q	Site Boundary
UR-3	Upland Recharge Project

Figure 2. Brookhaven National Laboratory Site, including principal sources of external radiation and radioactive effluents and monitoring locations.

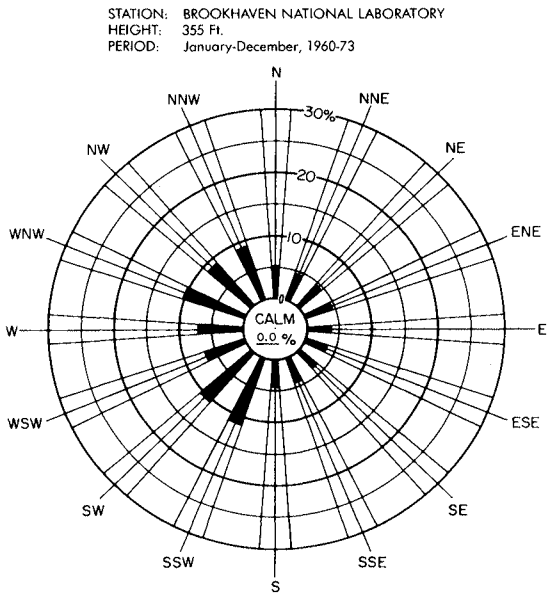


Figure 3. Annual Wind Rose, 1960-1976.

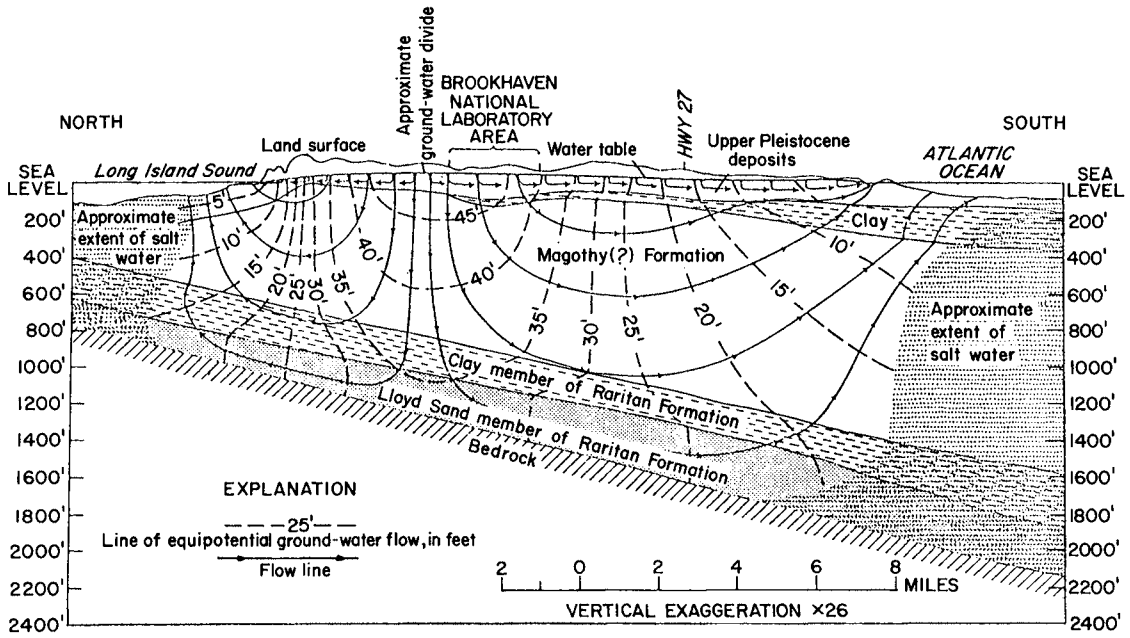


Figure 4. Schematic Ground Water Flow Lines, Brookhaven National Laboratory Area.

3) physical, chemical and biological effects of radiation, and of other energy-related environmental pollutants,

4) radionuclides and medical applications,

5) nuclear and energy-related technology,

6) energy sources, transmission and use including their environmental effects.

Among the major scientific facilities operated at the Laboratory to carry out the above programs are:

1) the High Flux Beam Reactor (HFBR) which is fueled with enriched uranium, heavy water moderated and cooled, and has a routine power level of 40 MW (th),

2) the Medical Research Reactor (MRR), which is an integral part of the Medical Research Center (MRC). It is fueled with enriched uranium, moderated and cooled by natural water, and is operated intermittently at power levels up to 3 MW (th),

3) the Alternating Gradient Synchrotron (AGS), a proton accelerator which operates at energies up to 33 GeV,

4) the 200 MeV Proton Linac, which serves as an injector for the AGS, but also supplies continuous currents of protons for radionuclide production by spallation reactions, in the Brookhaven Linac Isotopes Production Facility (BLIP),

5) the Tandem Van de Graaff, 60-inch Cyclotron, Research Van de Graaff, Vertical Accelerator and Chemistry Van de Graaff, which are used in medium energy physics investigations, as well as for special nuclide production.

Additional programs involving irradiations and/or the use of radionuclides for scientific investigations are carried on at other Laboratory facilities including the Medical Research Center, the Biology Department (including a high activity gamma irradiation source), the Chemistry Department, and the Department of Energy and Environment. The latter includes the Hot Laboratory, where special purpose radionuclides are developed and processed for on- and off-site use. This facility also contains a radioactive waste treatment center, which includes an evaporator for volume reduction of liquid wastes.

Most of the airborne radioactive effluents at Brookhaven originate from the HFBR, BLIP and the research Van de Graaff, with lesser contributions from the Chemistry and Medical Research Centers. The first two produce significant fractions of the Laboratory's liquid radioactive effluents, but additional significant contributions originate from the Medical Research Center, the Hot Laboratory complex, as well as from decontamination and laundry operations.

The Department of Energy and Environment conducts the Meadow-Marsh Project, wherein natural ecosystems are used to treat sewage and return clean water to the ground water aquifer. This experiment is conducted adjacent to a cultivated agricultural area previously established by the Biology Department in the southeast zone of the Laboratory site. It utilizes a portion of the flow from the sanitary waste treatment plant, and therefore, constitutes a potential route for the release of small amounts of radioactivity to ground water.

SUMMARY

The environmental levels of radioactivity and other pollutants found in the vicinity of Brookhaven National Laboratory (BNL) during 1977 are summarized in this report. As an aid in the interpretation of the data, the amounts of radioactivity and other pollutants released in airborne and liquid effluents from Laboratory facilities to the environment are also indicated. The environmental data includes external radiation levels; radioactive air particulates; tritium and iodine concentrations; the amounts and concentrations of radioactivity in and the quality of the stream into which liquid effluents are released; the concentrations of radioactivity in sediments and biota from the stream; the concentrations of radioactivity in and the quality of ground waters underlying the Laboratory; and concentrations of radioactivity in milk samples obtained in the vicinity of the Laboratory.

The external radiation dose for 1977 at the north boundary of the Laboratory attributable to an ecology forest irradiation source was 5.2 mRem a^{-1} (5.2×10^{-5} Sv a^{-1}) or 1% of the applicable Radiation Protection Standard [4]*.

At the boundary of the Laboratory, about 1.0 km northwest of the Alternating Gradient Synchrotron (AGS), the calculated dose due to skyshine (reflected radiation) was about 1.61 mRem a^{-1} (1.61×10^{-5} Sv a^{-1}), or 0.31% of the Standard. This was too small to be measured. Due to their limited range, the external radiation from the AGS and those from the gamma forest source did not produce a measurable additive effect at off-site locations.

Other than tritium, there was no indication of BNL radioactive effluents in environmental air and precipitation samples. The largest concentration of tritium in air at the site boundary, 65 pCi m^{-3} (6.5×10^{-12} μCi ml^{-1} or 2.4×10^{-5} Bq ml^{-1}) was 0.03% of the Radiation Concentration Guide (RCG). The largest average concentration of tritium in precipitation, <203 pCi l^{-1} (2.03×10^{-7} μCi ml^{-1} or 7.5×10^{-3} Bq ml^{-1}) was 0.01% of the RCG for drinking water.

At the Central Steam Plant, the most recent (1977) measurement of the stack emission of air particulates indicated that the average rate was 0.078 lb/10^6 Btu. A calculation based on meteorological parameters indicates that at the site boundary, the concentration of air particulates was 0.35 μg m^{-3}, 0.48% of the yearly average ambient Air Quality Standard [5]. The calculated site boundary concentrations of SO_2 and NO_x emitted from the plant were 0.0015 and 0.0009 ppm, respectively, which were 4.7 and 1.6% of their respective ambient air quality standards.

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* The applicable Radiation Protection Standards and Radiation Concentration Guides for persons in uncontrolled areas are shown with the relevant tabulated data.

About 86% of the sewage effluent released onto the sand filter beds of the Laboratory sewage treatment plant flowed directly into the Peconic River. The balance was assumed to have percolated into the ground water underlying the beds. The gross beta concentration of the bed output was 25.26 pCi l^{-1} (2.52×10^{-8} μCi ml^{-1} or 9.34×10^{-4} Bq ml^{-1}), or 0.9% of the RCG. The tritium concentration was 11.6 nCi l^{-1} (11.6×10^{-6} μCi ml^{-1} or 4.3×10^{-1} Bq ml^{-1}), or 0.6% of the RCG.

About 50% of the combined flow from the sand filter beds and from upstream of the Peconic River permeated into the goundwater. This percolation has occurred between the sewage treatment plant outfall and the Laboratory perimeter and seemed to take place mostly during the latter half of the year. As established at a midway stream sampling location, the gross beta concentration was 26.9 pCi l^{-1} (2.69×10^{-8} μCi ml^{-1} or 10×10^{-4} Bq ml^{-1}), or 1% of the RCG, and the tritium concentration was 12.2 nCi l^{-1} (12.2×10^{-6} μCi ml^{-1}), or 0.4% of the RCG. At the site boundary the gross beta concentration was 29.7 pCi l^{-1} (2.97×10^{-8} μCi ml^{-1} or 1.1×10^{-3} Bq ml^{-1}), or 1% of the RCG, and the tritium concentration was 9.3 nCi l^{-1} (9.3×10^{-6} μCi ml^{-1} or 3.4×10^{-1} Bq ml^{-1}), or 0.3% of the RCG.

About 2% of the total flow from the clarifier at the BNL sewage treatment plant was utilized by the Meadow-Marsh Project. The average gross beta concentration was 59.3 pCi l^{-1} (5.93×10^{-8} μCi ml^{-1} or 2.2×10^{-3} Bq ml^{-1}), or 1.5% of the RCG, and its tritium concentration 5.5 nCi l^{-1} (5.5×10^{-6} μCi ml^{-1} or 2.0×10^{-1} Bq ml^{-1}), or 0.1% of the RCG.

The sewage utilized by the Meadow-Marsh Project contained Cd in a concentration of 100 ppm or 1000 times the water quality standard, Cu in a concentration of 1.9 ppm, which is about five times the standard, Fe in a concentration of 10.7 ppm, which is eighteen times the standard, and Zn in a concentration of 3.5 ppm, which is fifty-one times the applicable water quality standard [6]. However, there is no direct runoff of these effluents and the project is designed to assess the retention of agents commonly present in sewage by various plant systems.

Except for 85 daily pH and 2 %BOD_5 removal levels were "out of limit", all reportable parameters of the Laboratory sewage effluent were within the limits set forth in the Laboratory's permit, issued by EPA under the National Pollution Discharge Elimination System. The average water quality of the sewage treatment plant effluent at the point of discharge was at or within water quality standards for the receiving body of water [5].

Bimonthly sampling of the Peconic River water has indicated a decrease of concentrations of radioactivity as one proceeds downstream of the sewage treatment plant outfall. At a location 4.8 km downstream, the average gross beta concentration as established by bimonthly "grab" sampling was 6.9 pCi l^{-1} (6.9×10^{-9} μCi ml^{-1} or 2.6×10^{-4} Bq ml^{-1}), or 0.20% of the RCG and the tritium concentration less than 1.9 pCi l^{-1} (1.9×10^{-6} μCi ml^{-1} or 7.0×10^{-2} Bq ml^{-1}), or 0.04% of the RCG. About 24 km downstream, at the river's mouth, there the flow was about 25 times that at the Laboratory's site boundary, the average concentration of gross beta activity was 8.1 pCi l^{-1} (8.1×10^{-9} μCi ml^{-1} or 3.0×10^{-1} Bq ml^{-1}) and that of tritium was 0.9 nCi l^{-1} (9×10^{-7} μCi ml^{-1} or 3.3×10^{-2} Bq ml^{-1}). Thus, it was apparent that the total gross beta activity in the river at that location greatly exceeded that at the Laboratory's site boundary. This difference is attributed to the fact that the total flow at the river's mouth is increased due to tributary additions which in turn have added fallout radionuclides that were present in the drainage area of the tributaries.

Seasonal sampling of Peconic River bottom sediments, stream vegetation and of miscellaneous aquatic fauna was conducted. The data indicated that concentration of ^{51}Cr, ^{60}Co and ^{65}Zn, which can be attributed to the Laboratory's effluents, as well as ^{22}Na, ^{137}Cs and ^{144}Ce, which represent fallout contributions were below the Minimum Detection Limits (MDL) of the system used and as such were not reported. The data from a few fish obtained from the river at the former site boundary, suggested the presence of small amounts of the Laboratory's effluent activity. The concentration of ^{137}Cs range from 1900 to 8500 pCi kg^{-1} (7×10^{1} to 3×10^{2} Bq kg^{-1}). This concentration was 0.2 to 0.9% of the RCG based on an assumed ingestion of 50 g d^{-1}.

About 19 million liters of water per day were used for "once through" cooling and returned to groundwater in on-site recharge basins. The concentration of gross beta activity was about four times greater than that of the supply wells and was less than 0.1% of the RCG. Tritium concentrations were less than the MDL which is about 0.2% of the RCG.

Groundwater surveillance was conducted in a network of some 87 sampling wells installed adjacent to and downstream from identified areas where there is a potential for the percolation to and migration of radioactivity and other contaminants in groundwater. Immediately adjacent to the sand filter beds and to the Peconic River on-site and at the site boundary, gross beta, tritium and ^{90}Sr concentrations approached those observed during the current or recent years in the Laboratory's liquid effluent. These were up to a few percent of the RCG's. The largest gross alpha concentration, 3.3 pCi l^{-1} (3.3×10^{-9} μCi ml^{-1} or 1.2×10^{-4} Bq ml^{-1}) was 1.5% of the RCG for unidentified mixtures containing alpha activity other than ^{226}Ra. It was not directly relatable to any known Laboratory effluent releases. The largest average gross beta concentration, 30.2 pCi l^{-1} (3.02×10^{-8} μCi ml^{-1} or 1.1×10^{-3} Bq ml^{-1}) was accompanied by a ^{90}Sr concentration of 0.2 pCi l^{-1} (0.2×10^{-9} μCi ml^{-1} or 7.4×10^{-6} Bq ml 1^{-1}), which was 0.3% of the controlling RCG. The largest average tritium concentration, 15.3 nCi l^{-1} (15.3×10^{-6} μCi ml^{-1} or 5.7×10^{-1} Bq ml^{-1}) was 0.5% of the RCG.

Concentrations of gross alpha and gross beta and ^{90}Sr radioactivity were found to be slightly higher in a sampling well about 305 m east of the site boundary, then those at the boundary itself. The gross alpha concentration, 2.0 pCi l^{-1} (2.0×10^{-9} μCi ml^{-1} or 7.4×10^{-6} Bq ml^{-1}) was 2.0% of the RCG. However, this was not directly relatable to any known recently discharged Laboratory effluent. The gross beta concentration was 9.9 pCi l^{-1} (9.9×10^{-9} μCi ml^{-1} or 3.7×10^{-4} Bq ml^{-1}), and the ^{90}Sr concentration was 3.0 pCi l^{-1} (3.0×10^{-9} μCi ml^{-1} or 1.1×10^{-4} Bq ml^{-1}). The latter was 3.5% of the RCG.

Except for pH levels slightly lower than the Water Quality Standard, but within the local natural variation, most other indices of water quality in these surveillance wells were within the standards. In a limited sampling of a few on-site wells immediately adjacent to the sand filter beds and to the Peconic River on-site, Fe and Zn were found up to ten times their respective water quality standards. These levels exceeded those found in recent Laboratory liquid effluents, and might be an artifact produced by the sampling well casing rather than being present in groundwater itself.

On-site, adjacent to the Solid Waste Management area, the landfill, the former open dump, the decontamination facility storm sewer sump, and at the Meadow-Marsh Project area, above ambient background concentrations of gross beta activity, ^{90}Sr, and tritium were found in a number of nearby groundwater surveillance wells. Much of the gross beta activity appeared to be related to ^{90}Sr.

At the Waste Management area, the largest ^{90}Sr concentration, 97.1 pCi l^{-1} (9.7×10^{-8} μCi ml^{-1} or 3.6×10^{-3} Bq ml^{-1}), or 36% of the RCG, was found in a well 152 m south of the site. This level reflects the effects of a known inadvertent injection into groundwater which occurred in 1960.

At the landfill, a gross alpha concentration of 18.0 pCi l^{-1} (1.8×10^{-8} μCi ml^{-1} or 6.7×10^{-6} Bq ml^{-1}), or 20% of the RCG, a gross beta concentration of 130.0 pCi l^{-1} (1.3×10^{-7} μCi ml^{-1} or 4.8×10^{-3} Bq ml^{-1}), or 5% of the RCG, and a tritium concentration 735 nCi l^{-1} (7.35×10^{-6} μCi ml^{-1} or 2.7×10^{1} Bq ml^{-1}), or 20% of the RCG were the largest found. They occurred in wells between the landfill and a location 61 m south of the boundary of the working area.

At the decontamination facility storm sewer sump, a ^{90}Sr concentration of 29.5 pCi l^{-1} (2.95×10^{-8} μCi ml^{-1} or 1.1×10^{-3} Bq ml^{-1}), or 10% of the RCG was found in a surveillance well about 46 m southeast of the sewer outfall into the sump.

With the exception of the presence of Fe and Zn in wells adjacent to the landfill area, all on-site water quality and purity parameters were within the established standards. Immediately adjacent to the landfill, the concentration of Fe was 136 ppm, or 230 times the standard and that of Zn was 0.8 ppm, or 1.3 times the standard.

All of the above on-site levels of radioactivity or other agents above ambient background in ground water appeared to be confined to within a few hundred feet of their origin, and would require decades of travel before reaching the site boundary. Concentrations of radioactivity, and water quality parameters, in ground water from perimeter surveillance wells (other than those adjacent to the Peconic River) were at or near background and only a few percent of RCG's.

Milk samples were obtained by the New York State Department of Environmental Conservation from two Suffolk County dairy farms, one 10 km southeast and one 40 km east of the Laboratory site, following the Chinese nuclear test in September 1977. The peak activity concentration of ^{131}I in milk from the closer farm was 16 pCi l^{-1} (16.0×10^{-9} μCi ml^{-1} or 6×10^{-4} Bq ml^{-1}). The data was within the variations of ^{131}I concentrations in milk samples for that period within New York State. This activity concentration was considerably lower than those of the previous year (1976) of about 200 pCi l^{-1} (7.4 Bq l^{-1}) of milk.

The collective average dose equivalent rate (total population dose), for the population up to a distance of 80 km, attributable to Laboratory sources was calculated to be 19.92 rem a^{-1} (person-rem a^{-1}), as compared to a natural background dose equivalent rate to the same population of about 269,377 rem a^{-1} (person-rem a^{-1}).

MONITORING DATA COLLECTION, ANALYSIS AND EVALUATION

Radiation Monitoring

Dose equivalent rates at the site boundary, including natural background (as influenced by fallout) and increments attributable to Laboratory activity, were measured by the use of CaF thermoluminescent dosimeters exposed for monthly periods at each of the four perimeter monitoring stations P-2, P-4, P-7, and P-9, as shown in Figure 2.

The observed monthly average dose equivalent rates are given in Table 1. There was no measurable addition to the natural background attributable to Laboratory activities, except at the northeast perimeter. At this location, the Ecology Forest irradiation source, which contained about 6161 curies (2.28×10^{14} Bq) of ^{137}Cs (as of 1/1/77), produced a dose equivalent rate of $5.2 \pm .2$ mRem a^{-1} ($5.2 \times 10^{-5} \pm 2 \times 10^{-6}$ Sv a^{-1}) or 1.0% of the Radiation Protection Standard for a hypothetical individual member of the general public at this location on the Laboratory perimeter. Background was 56.2 mRem a^{-1} (5.62×10^{-4} Sv a^{-1}).

Airborne Effluents and Ground-Level Air Particulates, Tritium and Radioiodine Monitoring

Facilities and Effluents

The principal Laboratory facilities that currently discharge radioactive effluents to the atmosphere are listed in Table 2. The installed on-line effluent monitoring and sampling devices are also indicated. The location of these facilities on the Laboratory site is shown in Figure 2. The types and amounts of these effluents released during 1977 are shown in Table 3.

Oxygen-15 and argon-41 are radioactive gases and are environmentally significant as sources of increased external radiation at or near the point of generation. Calculations indicate that oxygen-15, which has a half-life of two minutes, is evolved from the BLIP facility at a rate of 0.21 Ci μamp^{-1} h^{-1} (7.8×10^{9} Bq μamp^{-1} h^{-1}) when the facility is operated at the full beam current of 180 μamps. Thus, the equilibrium activity at the point of generation would be 1.8 Ci (6.6×10^{10} Bq). Argon-41, which has a half-life of 110 minutes, is released from the Medical Reactor Stack at a rate of 1 Ci MW $(th)^{-1}$ h^{-1} (3.7×10^{10} Bq MW $(th)^{-1}$ h^{-1}) when it is operated at full power of 3 MW (th). Assuming equilibrium is attained, a conservative assumption, the equilibrium activity is .8 Ci (2.95×10^{11} Bq) at the reactor stack. Considerable dilution with the ambient air occurs between the point of generation of both these sources of radioactivity and the site boundary. Additionally, radioactive decay decreases the air activity concentrations of both these radionuclides during the transit time between the source and the site boundary. Both these factors, dilution and decay, reduce the air activity concentrations to a level at which no detectable increase in the dose equivalent rate at the site boundary occurs.

Tritium (^3H) has a half-life of 12.3 years, and is a very low energy beta emitter ($\overline{T\beta}$ = 5.7 KeV). Its principal environmental significance is as tritiated water vapor, which is taken up and utilized by living systems as water. Of the 1236 Ci (4.6 x 10^{13} Bq) of tritium released from the Laboratory facilities during 1977, 1041 Ci (3.9 x 10^{13} Bq) (84%) was in the gaseous form, and 195 Ci (7.2 x 10^{12} Bq) (16%) was released as tritiated water vapor.

The amounts of conventional pollutants released from the Central Steam Plant are shown in Table 4. Those for sulfur dioxide (SO_2) and nitrogen oxide (NO_x) are derived from reported emission factors for comparable plants [7], supplemented by analysis for sulfur content of the fuel oil utilized at the plant. The amount of particulates was based on the average concentration found in stack sampling of the steam boiler units in a series of tests conducted during 1977. The Laboratory, in February 1977, conducted extensive tests on stack emission rate of particulates. This was done by an outside laboratory as approved by EPA. Their results indicate the average emission rate of particulates, 0.078 lb/MBTU, was below the emission limit of 0.1 lb/MBTU as set forth by the New York State Department of Environmental Conservation (Part 227, Stationary Combustion Installations).

Sampling and Analysis

The Brookhaven environmental monitoring air sampling program is designed to distinguish concentrations of airborne radioactivity attributable to natural sources and activities remote from the Laboratory, e.g., above ground nuclear weapons tests from Laboratory activities. All of that detected during 1977 was attributable to the first two sources. In addition, recent fallout from the Chinese nuclear test of September 1977 was also monitored.

High volume (500 l m^{-1}) positive displacement air pumps (Gast 3040) were operated at a monitoring station east of the Solid Waste Management areas (Fig. 2, S-6), and at the northeast and southwest perimeter stations (P-9 and P-4). The air sampling media consisted of a 7.6 cm diameter air particulate filter (Gelman type G) followed by a 7.6 cm x 2.5 cm bed of petroleum-based charcoal (Columbia Grade LC 12/28 x mesh) for collection of radiohalogens. Short term fluctuations in airborne radioactive particulate concentrations are indicative of the presence of recent weapons tests debris. To distinguish between nuclear weapon test debris and that resulting from activities of the Waste Management operations, the air particulate filters at station S-6 were changed and counted on a daily basis during the work week. The air particulate filters at the other stations were changed and counted on a biweekly basis.

After allowing several days for the decay of short lived natural radioactivity, gross alpha counts of air particulate samples from the Solid Waste Management area station were made, using a 12.7 cm diameter Zn-S coated detector with a photomultiplier tube. After allowing for decay, gross beta counts of air particulate samples from all locations were made using a 12.7 cm beta scintillator. These data are shown in Table 5. The seasonal trend of an early spring maximum, as observed for both gross α and gross β activity in 1975, shifted toward late spring in 1976 and early summer in 1977. An increase in gross beta and alpha over the years was also observed. Additional radioactivity, which was introduced into the environment during September through November 1976 by the Chinese Nuclear Tests, has resulted in an increase in the gross α activity during September 1976.

The gross α activity remained at this level during the early part of 1977 and gradually dropped to 1975 levels towards the end of the year. Gross β activity declined following the September 1976 peak and continued to decline in 1977. However, the gross β activity relative to previous years increased during early summer following increased precipitation, due to scavenging of β, γ emitting fallout radionuclides created during the previous weapon tests. A slight increase in gross β activity was noted in October 1977 following the latest Chinese nuclear test of September 1977. Throughout the year no significant differences between sampling locations were noted, indicating the absence of Laboratory produced radionuclides in air particulate samples.

In addition to the gross beta counts indicated above, shortly after the end of each month, analyses for gamma emitting nuclides were performed on a monthly composite of all individual air particulate samples. Additional gamma analyses were also scheduled at six month and one year post-collection to facilitate the resolution of short and long lived nuclides with full energy peaks too close to be resolved by the NaI detection system employed. The charcoal samples were reanalyzed at one month post-collection to determine ^{131}I by decay in its full energy peak region during this time. Data are reported in Table 6. The increase in gross β activity noted in late 1976, following the Chinese nuclear test, was evident in early 1977 but at a lower concentration. The values further decreased towards the later months but increased slightly in October-November following the latest Chinese nuclear test (September 1977). Fission product nuclides did not exhibit a similar trend, however, statistically significant levels of ^{131}I and ^{140}Ba-La were noted immediately following the Chinese nuclear test. Other nuclides, such as ^{7}Be and ^{95}Zr-Nb, were at low levels but were uniform in activity throughout the year. Nuclides such as ^{103}Ru, ^{106}Ru, ^{137}Cs, ^{141}Ce and ^{144}Ce were at or below the Minimum Detection Limit (MDL) for the counting system used. These data indicate the absence of Laboratory effluent contributions.

Sampling for tritium vapor was performed at the same air sampling stations by drawing a small side stream of air (~100 cm^3/min) through silica gel cartridges. These were changed on a monthly basis. During colder months when the capacity of silica gel to absorb unsaturated water vapor was decreased, the sampling cycle was lengthened. The collected vapor was subsequently removed from the gel by heating. It was then condensed and assayed by liquid scintillation counting. The tritium air concentration data obtained during 1977 is indicated in Table 7. The background concentration was inferred from that found in precipitation collected off site. The yearly average concentration at the site boundary, about 65 pCi m^{-3} (0.65×10^{-10} $\mu Ci\ cm^{-3}$ or 2.41×10^{-6} Bq cm^{-3}) was 0.03% of the applicable Radiation Concentration Guide (RCG).

The current Laboratory environmental monitoring program does not include air sampling for non-radioactive substances. The calculated annual average concentrations at the site boundary of the conventional pollutants released from the Central Steam Plant are indicated in Table 4. All were less than 2% of the EPA Primary Air Quality Standard for these constituents. The use of waste oil, a possible source of trace element contamination in the atmosphere, has been discontinued since 1975.

About 200 kg of various pesticides, chiefly organo-phosphates, Thiodan, Diazinon, Carbaryl and Parathion, were applied [8] on site during 1977, principally to protect crops which were grown for biological research purposes. All of these pesticides were considered biodegradable, with persistence times in the order of a week. Furthermore, they were applied with a "sticker" additive to minimize becoming airborne subsequently.

Precipitation

Two pot-type rain collectors each with a surface area of 0.33 m^2, are situated adjacent to the Sewage Treatment Plant (see Fig. 2). Two routine collections were made from these, one whenever precipitation was observed during a previous 24 hour (or weekend) period, and the other once a week whether or not precipitation occurred. Part of each collection was evaporated for gross beta counting, a small fraction composited for monthly tritium analysis, and the balance put through ion exchange columns for subsequent quarterly ^{89}Sr-^{90}Sr and gamma analyses. The data for 1977 (with the exception of tritium) are reported in Table 8. There was no detectable indication of Laboratory released airborne radioactivity precipitation collected on site. The amounts of naturally produced gamma emitters, such as ^{7}Be and ^{22}Na were slightly higher than in 1975 and 1976. Those of shorter lived fission and activation products, such as ^{54}Mn, ^{65}Zn, ^{95}Zr-Nb, and ^{131}I were below their MDL despite the Chinese nuclear test in September 1977.

To obtain an indication of tritium washout, small precipitation collectors, in addition to the pot-type collectors, were established at the perimeter stations (P-2, P-4, P-7, P-9) and at Blue Point, some 20 km southwest of the Laboratory site. As indicated in Table 9, the average tritium concentration in the collectors located at station P-9 and at the sewage treatment plant (in the predominant downwind direction form Laboratory release locations) and at other collectors, were all reduced significantly when compared to 1975 and 1976. The levels detected were at or below the MDL. The average concentration (on site) was less than 0.01% of the RCG for drinking water. The estimated total deposition of tritium on the Laboratory site during 1977 was 4.1 curies (1.5×10^{11} Bq) (using the yearly totals of on-site and perimeter concentrations). The washout of Laboratory effluent appears to have been about 3.3 curies (1.2×10^{11} Bq) or about 1.7% of the reported stack release of tritium vapor.

Liquid Effluent Monitoring

To minimize the volumes of liquids that would have to be handled prior to on site release or processing into solid form for off site burial, the basic principle of liquid waste management at the Laboratory is confinement and containment. Accordingly, liquid wastes are segregated on the basis of their anticipated concentrations of radioactivity or other potentially harmful agents.

The primary water cooling systems of such facilities as the Alternating Gradient Synchrotron, the High Flux Beam Reactor, and the Medical Research Reactor, each of which contain multicurie (terabecquerel) amounts of radioactivity, are closed systems with no direct connection to any Laboratory waste system.

Small volumes (up to a few liters) of concentrated liquid wastes containing radioactivity or other hazardous agents are withheld from the Laboratory waste systems. They are stored at their sources of generation in small containers for pickup by the Laboratory's Waste Management Group and subsequent packaging for off site disposal (in the case of hazardous agents, by an EPA licensed contractor).

Facilities which may produce larger volumes (up to several hundred liters/batch) of radioactive or otherwise contaminated waste liquids are provided with dual waste handling systems, one for "active" (D-probably contaminated) and one for "inactive" (F-probably uncontaminated) wastes. As shown in Figure 5, wastes placed into the "active" or D system are collected in holdup tanks. After sampling and analysis, they are either transferred by installed pipelines or by tank truck to storage tanks adjacent to the Laboratory liquid waste evaporator. At this facility liquids are concentrated about a hundred fold and ultimately disposed of as solid wastes. If found to be of sufficiently low concentration, D wastes may be routed directly from holdup tanks to the Laboratory sanitary waste system.

As shown in Figure 5, "inactive" or F wastes, depending on the results of analysis, are routed directly to the Laboratory sanitary waste system, where they are diluted by large quantities (approaching 4,000,000 l d^{-1}) of cooling and other uncontaminated water routinely produced by diverse Laboratory operations. Sampling and analysis of facility holdup tanks are done to facilitate waste management; while effluent sampling is done at the sewage treatment plant to establish the concentration and amounts of environmental releases.

The small amounts of low level radioactive waste effluents that may be routinely disposed of by release into the Laboratory's sanitary waste system are established by administrative limits [9], which correspond to those applicable to sewage systems. Within these limits, individual releases are kept as low as practicable.

Primary treatment to remove suspended solids from the liquid stream collected by the sanitary waste system is provided by a 950,000 liter clarifier. Its liquid effluent then flows onto sand filter beds, from which about 86% of the water is recovered by an underlying tile field. This water is chlorinated and released into a small stream that forms one of the headwaters of the Peconic River.

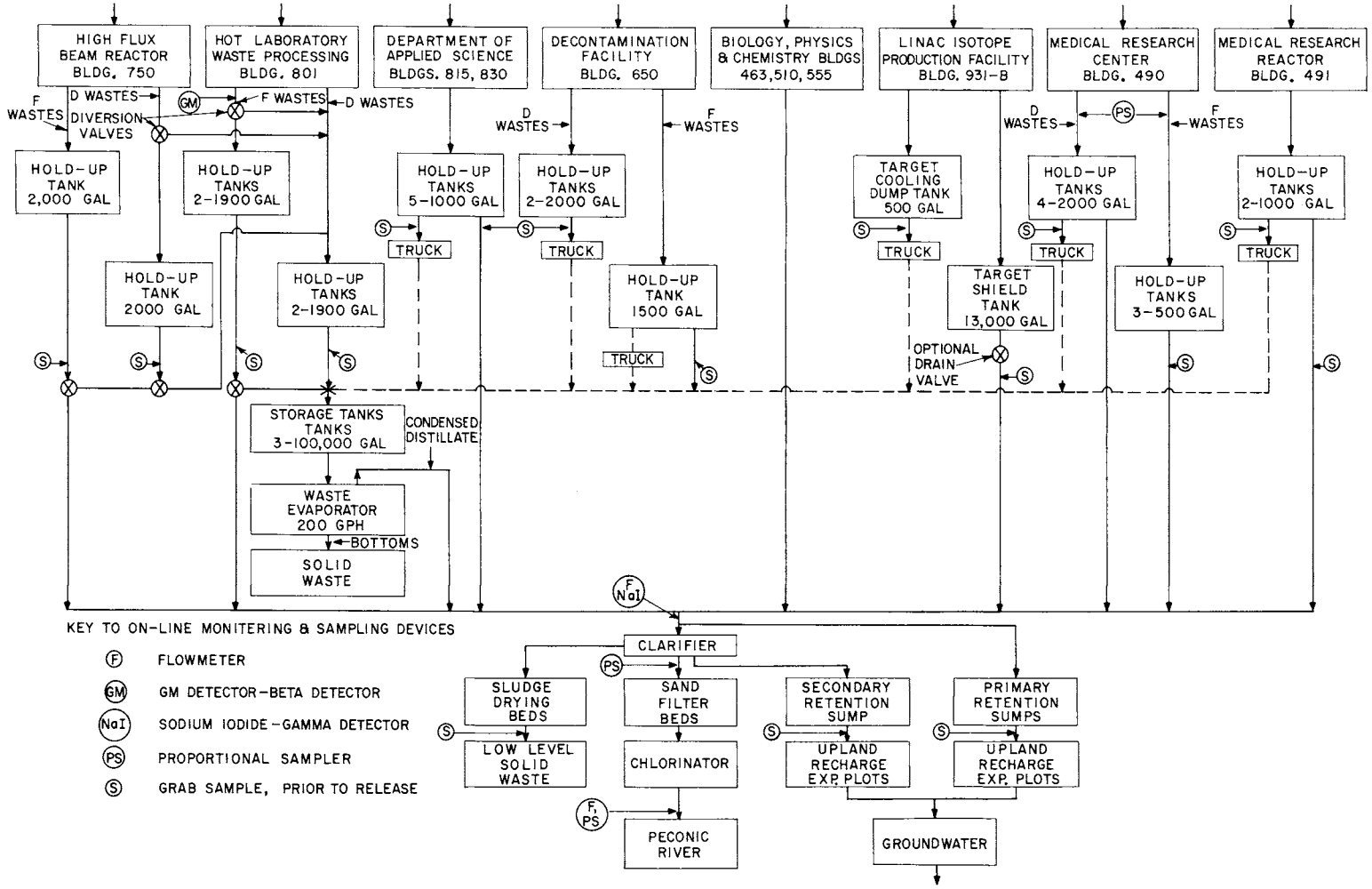

Figure 5. BNL Liquid Effluent Systems.

A schematic of the sewage treatment plant and its related sampling arrangements are shown in Figure 6. In addition to the inplant flow measurement and sampling instrumentation, totalizing flowmeters (Leopold and Stevens TP 61-2), with provision for taking a sample for each 7576 liters of flow in combination with positive action battery operated samplers (Brailsford DU-1) are located at the chlorine house, at the former site boundary which is 0.8 km downstream on the Peconic River, and at the site boundary, 2.6 km downstream.

An aliquot of each daily (or weekend) sample of the input to the sand filter beds and of their output to the chlorine house outfall was evaporated for gross alpha and gross beta analysis, and another was counted directly for tritium analysis. Samples from the two downstream locations were obtained three times a week. Aliquots of each sample were analyzed for gross beta, alpha, and for tritium. Another aliquot, proportional to the measured flow during the sampling period, was passed through ion exchange columns for subsequent analysis as an integrated sample. Unless the gross beta count indicated immediate identification for each location was necessary, one set of these columns was analyzed directly on a monthly or quarterly basis for gamma emitting nuclides and another was eluted for radiochemical processing for ^{90}Sr analysis.

The monthly average flow and the monthly totals of gross beta and principal nuclide activities at the clarifier (input to the filter beds) and at the chlorine house (output from the beds) are shown in Table 10. Yearly totals and average concentrations are indicated. The average monthly flow at the clarifier has decreased over the years resulting in corresponding decreased percent losses to the ground water, however, the output at the chlorine house has been comparable. The loss to the ground water is therefore a function of the input to the sand filter beds. In 1977, 2% of the flow into the clarifier was utilized by the Meadow Marsh Project and 86% of the same flow appeared in the output at the chlorine house after passing through the sand filter beds. The balance was assumed to have percolated to the ground water flow under the beds. Estimates of the amount of radioactivity released to the ground water in this manner during 1977 are shown in Table 10. These were calculated on the additional assumption that the average concentrations of the contained nuclides corresponded to those in the output from the beds, as observed at the chlorine house. Radionuclide concentrations over the past three years, 1975 to 1977, have indicated fluctuations as a function of input into the sand filter beds. The ground water levels are directly related to input levels for all radionuclides except for ^{3}H, ^{7}Be, ^{22}Na, ^{134}Cs and ^{137}Cs. These latter nuclides have low distribution coefficients and as such pass through the filter beds and appear at the chlorine house or in ground water in activity concentrations similar or higher than that of the input levels. The increase in activity concentration is a function of the decreases in the volume of water at the chlorine house, while the total amount of the above radionuclides coming through the sand filter beds is the same. Radionuclides, such as ^{51}Cr, ^{65}Zn, ^{95}Zn-Nb, ^{125}Sb, ^{131}I and ^{144}Ce, which were detected in previous years were all at or below MDL (see Appendix B) and as such were not reported in the table. The conversion in 1974 of the Brookhaven Linear Isotopic Production (BLIP) Facility's cooling system from a single pass to a closed system has prevented the release of ^{51}Cr and ^{65}Zn to the sanitary sewage system. The remaining nuclides, i.e., fission products, are on the decrease in worldwide fallout and is reflected, inspite of recent Chinese nuclear tests, in the reduced concentrations in the effluent sampled at the chlorine house. It must be remembered that rainfall, with its radionuclide burden of fission products, does contribute to the flow at the chlorine house.

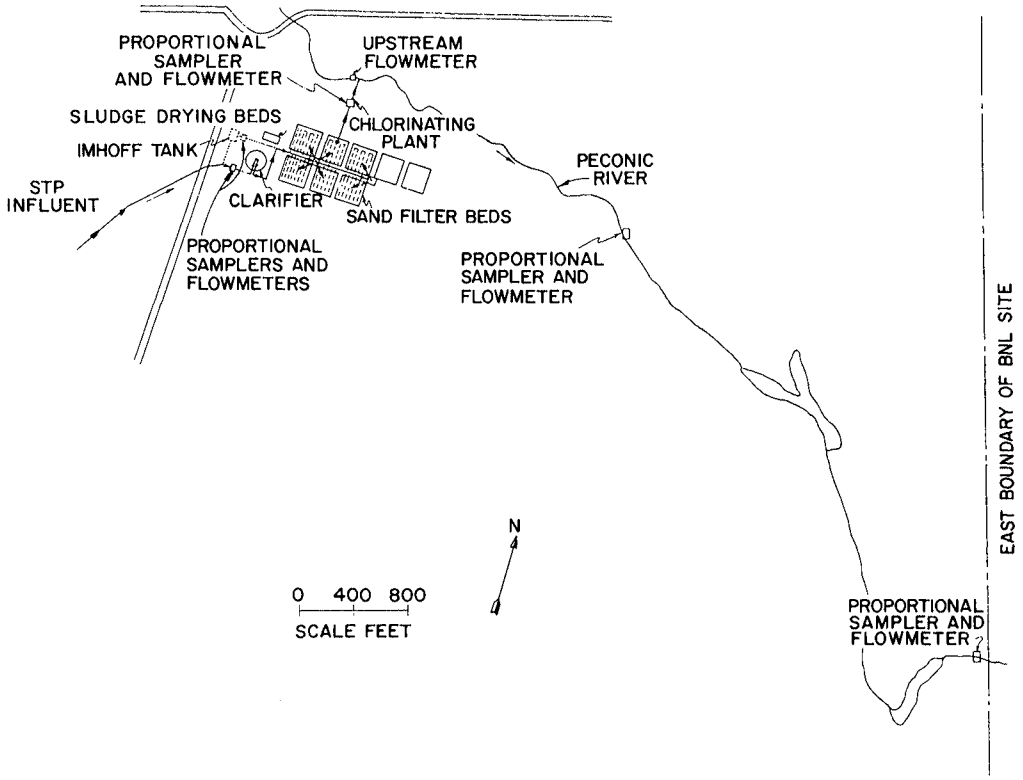

Figure 6. Sewage Treatment Plant, including related monitoring arrangements.

Flow and activity concentration information at the former site boundary sampling location, 0.8 km downstream (see Fig. 6), and at the present site boundary are shown in Table 11. Climatic conditions during the summer of 1977, has resulted in flow conditions totally different from the previous years, in that the flow at the site boundary was less than one third of the flows recorded in 1975 and 1976. Such low flows have permitted a higher percent of water to percolate into the ground water system, 16% in 1975, 30% in 1976, and almost 60% in 1977. This was confirmed by the fact that flows in August and September at the site boundary were negligible. In general the radionuclide activity concentrations have increased over the years 1975 to 1977, but this is related to decreasing flow with the total activity remaining almost constant. This is true for radionuclides, such as ^{7}Be, ^{22}Na, and ^{137}Cs, which as indicated earlier have remained in solution and therefore have not significantly precipitated out of the water body. Upper limit estimates of the total activity that may have percolated to the underlying water is also shown in Table 11. These are based on the decrease in total activity between the former site boundary and the perimeter.

Analysis of monthly composite samples of the Peconic River at the former site boundary (0.8 km downstream from the chlorine house) during this period showed that, on the average, 5% of the total activity consisted of ^{90}Sr and that no appreciable amounts of long lived radioactive iodine or bone-seeking nuclides such as radium were present. Under these circumstances the applicable RCG was 3000 pCi l^{-1} (3.0×10^{-6} μCi ml^{-1} or 1.1×10^{-1} Bq ml^{-1}). The gross beta concentration in the portion which percolated to ground water was 28.9 pCi l^{-1} (2.89×10^{-8} μCi ml^{-1} or 1.1×10^{-3} Bq ml^{-1}) or <1% of the RCG.

At the Laboratory perimeter (2.6 km downstream from the chlorine house), 5% of the yearly activity was ^{90}Sr. The applicable RCG was also 3000 pCi l^{-1} ($1.1 \times 1 \times 10^{-1}$ Bq ml^{-1}). The observed gross beta concentration of the water released downstream was 36.0 pCi l^{-1} (3.60×10^{-8} μCi ml^{-1} or 1.3×10^{-3} Bq ml^{-1}) or 1% of the RCG.

On December 9, 1976, a calculated volume of 70 m^3 of dried sludge containing 120 mCi(3.8×10^{9} Bq) of beta emitters and 0.62 mCi (2.3×10^{9} Bq) of alpha emitters (by gross analysis) was inadvertently removed from the STP and dumped at the landfill. This was in apparent contravention to a DOE recommendation that the use of the sanitary landfill for the disposal of low level radioactive waste (e.g.,sewage sludge)be discontinued. In view of this further disposal of such sludge has been curtailed. This recommendation was based on the fact that radioactivity from the sludge so disposed may slowly leach into the ground water table. This landfill has been used for sludge disposal several times in the past decade. The sludge is spread evenly on the top of the landfill about 15 m above the water table area. Our experience to date has demonstrated that, with the exception of ^{90}Sr, the radioactive elements in the sludge are essentially immobile in the soil. In addition to the time required for any strontium to be leaked to ground water, it would require about 50 years for it to move from the landfill to the site boundary. To date the largest concentration of ^{90}Sr in wells immediately adjacent to 61 m south of the landfill area is about 10 pCi l^{-1} (3.7×10^{-1} Bq l^{-1}). Therefore, the Laboratory does not foresee this inadventent dumping of sludge on the landfill in the above amounts and concentrations to add materially to the long term need for monitoring or restriction of the use of this landfill for other purposes. To substantiate this observation

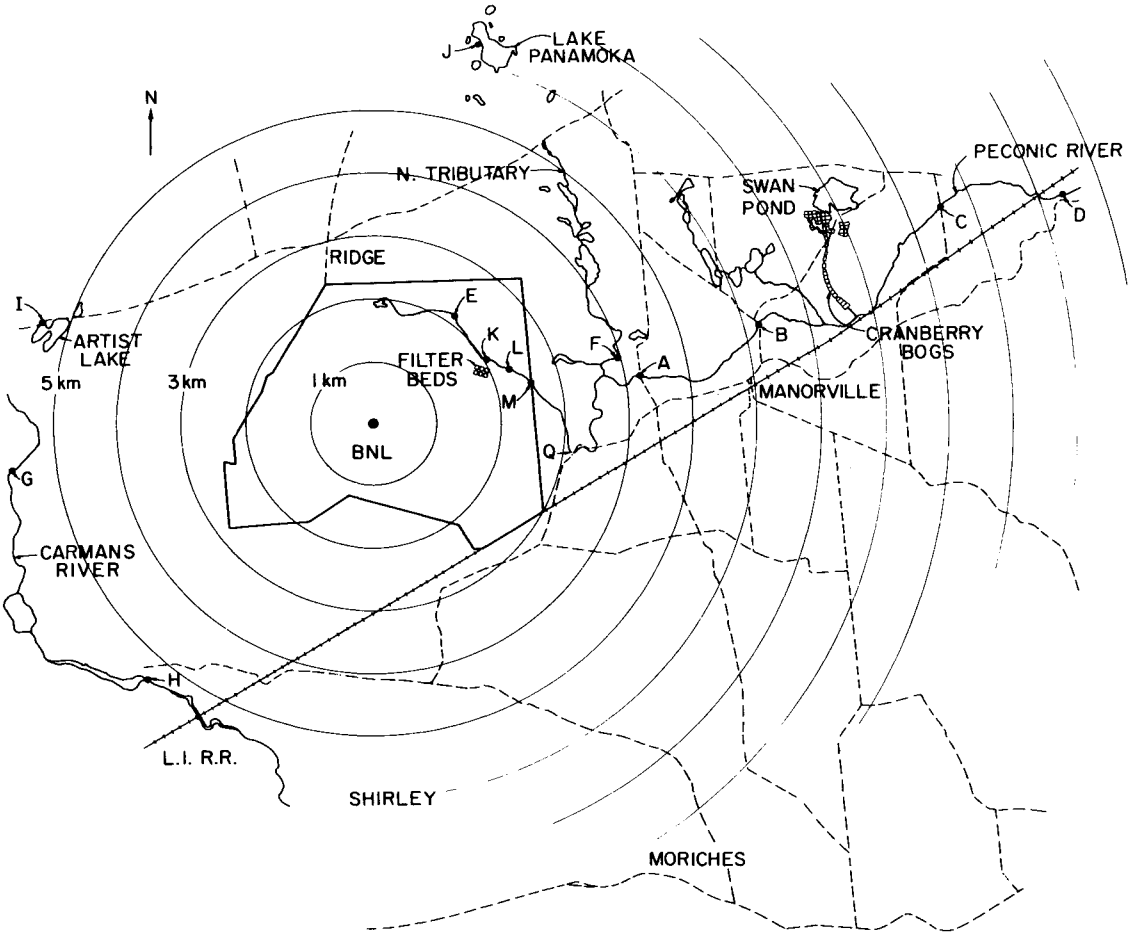

Figure 7. Peconic River, On-Site and Downstream Sampling Locations.

an indepth study has been initiated to determine the limiting concentrations that could be permitted to be disposed of on the landfill and yet result in concentrations, at the point of public use, of radionuclides at levels corresponding to 0.01 MPC or less.

During 1977, the Laboratory experienced two oil spills. The first one occurred between October 22 and 24, 1977. A flair on the return line of the fuel tank in one of the boiler rooms broke. As a result of this, oil flowed from the fuel tank onto the boiler room floor and subsequently under the door and outside. The amount of oil spilled was estimated to be 800 l of which about 400 l entered a storm drain and ultimately reached a pond through a diverted sluiceway. Consultants called in by Plant Engineering (PE) indicated that cleanup was not economically feasible and that the oil which had spread into the underbrush alongside the pond would be biologically degraded. No action was therefore taken by PE. The second spill occurred on November 26, 1977, when approximately 87,000 l of oil (a mixture of 60% #6 oil and 40% mineral spirits) was released from a ruptured pipe west of the steam plant. The cause of the accident was attributed to abnormal concentration of water below an empty 19,000 l tank which forced the tank to rise resulting in subsequent rupture of the pipe. Due to the nature of the terrain the oil was confined to an area of about 0.5 ha, most of which was wooded. PE used sand to contain the spread of oil and by using portable pumps approximately 11,000 l of oil was retrieved. In the area of heaviest oil concentration, trees and shrubs were removed to assist in the spreading of sand. Test borings done by PE at several places within the spill revealed a heavy clay layer approximately 0.25 to 0.30 m below the top soil. Sampling of the soil at different depths done by S&EP indicated, on analysis, that the oil had not reached the clay layer but was confined to the top 0.3 m. This retention of oil was further assisted by the water logged soil. It was observed that no oil had reached (or could reach) any navigable waters. The approaching winter and consequent freezing of the water in the soil would further prevent any downward migration of the oil. Recommendations were made to PE that during spring the top soil should be tilled and fertilized so as to assist the bacterial fauna in rapid degradation of the oil. Wells adjoining the steam plant would be monitored during the spring thaw (1978) and additional monitoring wells would be put in if the initial monitoring data of the wells indicated the need. The U.S. Environmental Protection Agency (EPA) was informed of the spill and a meeting was held with their representatives on December 16, 1977, at which time EPA expressed satisfaction that the steps taken by PE and S&EP were appropriate, and that the BNL Spill Prevention and Control Plan (SPCC) was adequate.

As of January 31, 1975, the effluent from the Laboratory sewage treatment plant was subject to the conditions of The National Pollutant Discharge Elimination System (NPDES) Permit No. NY 000 5835. Quarterly reports were prepared in accordance with this permit using data obtained by the sewage treatment plant operators, A yearly summary of these data, which follows the same format as these quarterly reports, is shown in Table 12. It includes a specification of the permit conditions. The Laboratory effluent was within these conditions, with the exception of some daily pH levels and two instances where the % BOD_5 removals were "out of limit" as set by the permit. The effluent sampling is located in the chlorine house whereas the sampling station used by Safety and Environmental Protection (Table 13) is downstream of the above location.

The daily pH levels were below 5.8 on 85 occasions. However, these were only slightly below the lower level set forth in the permit and within the local natural range of ground water (pH 4.5-5.5). A study initiated to determine the causative factors behind such "out of limit" pH values has indicated that the low pH of rainfall (pH 2.5-4.9) on Long Island is a significant factor in lowering the pH of the Laboratory effluent as it passes through the sand filter beds. The U.S. EPA is considering the possibility of lowering BNL's permit standard on this parameter (pH). The % removal of BOD_5 is determined by subtracting the BOD_5 of the effluent from the BOD_5 of the influent and then determining the % removal. However, if the influent BOD_5 is itself very low and the effluent BOD_5 is only very slightly lower than that of the influent BOD_5 level, the % removal of BOD_5 can vary significantly by very small changes in the BOD_5 of the effluent. The two exceptions to the stipulated 85% removal of the BOD_5 was therefore in reality the difference between two very small numbers.

In addition to the above measurements, the Safety and Environmental Protection Division conducts routine measurements of water quality and purity of the filter beds effluent, upstream of the Peconic River, at the former perimeter of the Laboratory (0.8 km downstream) and at the present Laboratory perimeter (2.6 km downstream). A summary of these data for 1977 is shown in Table 13. The outflow from the sand filter beds into the Peconic River was considerably above water quality standards for minimum dissolved oxygen (DO) [6, 10], except during summer when flow at the site perimeter was nil and the water bed stagnated. Although occasionally below the standard, the pH was within the range of local ambient levels. After mixing with the upstream flow, the temperature increment was within the standard [11] at the Laboratory perimeter. Monthly analyses for selected metals in sump, downstream and control sampling stations were also performed. The data are shown in Table 14. Yearly average concentrations were, before dilution, at or within the standard for the receiving body of water [6, 10]. It was observed that the Zn value was in excess of the limit in the filterbed effluent. This is further discussed in the section dealing with metal data from surveillance wells.

A small portion of the liquid effluent flow from the clarifier was diverted from the sand filter beds for application to the Meadow-Marsh experimental plots. A summary of the total flows and of the gross beta, tritium and ^{90}Sr total activities and activity concentrations is shown in Table 15.

Water quality parameters of the Laboratory's effluent used in the Meadow-March Project were evaluated by the Department of Energy and Environment (BNL) [12]. These data are shown in Table 16. The effluents met the standards for ground surface discharge with the exception of the metals Cd and Fe, BOD_5, coliform, and suspended solids [6]. It should be noted that the purpose of this experiment is to determine the efficiency of natural ecosystems for the removal of pollutants in the applied effluents and was based on the premise that the "effluent" percolating to the saturated zone (3-4.5 m below the ground surface in the area) would be within ground water quality standards.

Because of the permeable nature of the local soils, there was no surface runoff from the experimental area, and hence no direct route by which these effluents might reach a service stream.

Monthly "grab" water samples were obtained at on- and off-site locations along the upper tributary of the Peconic River, into which the Laboratory routinely discharges low level radioactive wastes. Reference "grab" samples were obtained from other nearby streams and bodies of water outside the Laboratory's drainage area. The sampling locations, as shown in Figure 7, were as follows:

Off-Site (Peconic River, proceeding downstream)

A - Peconic River at Schultz Road, 4.85 km downstream,
B - Peconic River at Wading River-Manorville Road, 7.04 km downstream,
C - Peconic River at Manorville, 10.67 km downstream,
D - Peconic River at Calverton, 14.23 km downstream,
R - Peconic River at Riverhead, 19.35 km downstream.

Controls (Not in the Laboratory drainage)

E - Peconic River, upstream from the Laboratory effluent outfall,
F - Peconic River, north tributary (independent of the Laboratory drainage),
H - Carman River, outfall of Yaphank Lake,
I - Northeast corner of Artist Lake on Route 25.

Individual monthly and yearly average gross beta, tritium and ^{90}Sr concentrations at downstream and control locations are shown in Table 17. A comparison with the on-site and perimeter concentrations shown in Table 11 suggests that the concentrations of Laboratory effluents in the Peconic River, downstream of the outfall, diminish rapidly to near background levels at the more distant sampling locations. Considering the concentrations of radioactivity near the mouth of the Peconic River at Riverhead, where the flow over the years has been about 25 times that at the Laboratory perimeter, it was evident that the total amounts of radioactivity at this location was much greater than those released into the Peconic River at the Laboratory perimeter. This probably represents tributary additions from rainfall and subsequent washout from drainage areas other than that of the Laboratory. During 1977 measurements of selected water quality and purity parameters at downstream locations on the Peconic River and at control locations were initiated in order to provide some perspective on the same parameters in the Laboratory effluent (as reported in Table 13). These limited "grab" sample data are shown in Table 18. The effect of somewhat elevated levels of some parameters in the Laboratory effluent such as dissolved solids, nitrate, and phosphorus, was not apparent downstream.

During the summer of 1977 an intensive program aimed at understanding the effect of the Laboratory's effluent on the Peconic River system over the years was initiated. This study, which is expected to take three to four years, will be phased in gradually. In 1977, the program was exploratory, where in sampling stations, sampling techniques and analytical procedure and limitations were tried out. The results so obtained will be used to develop an adequate program to be implemented in 1978 and in 1979 it is hoped that the data so obtained would be amenable to modelling for predictive purposes. Additional data from previous years will also be used.

Figure 7 indicates some of the sampling locations. These are:

E - Reference point-headwaters of the Peconic River-Control Station,
K - 0.045 km, no vegetation, significant influence of chlorine,
L - 0.106 km,
M - 0.798 km, referred to as the former site boundary,
Q - 2.11 km, the present site boundary, fishes collected from here,
A - 4.85 km,
S - 7.05 km,
T -10.82 km, significant mussel bed,
U -14.23 km,
W -18.18 km, mussel bed,
Y -22.21 km, salt water meets fresh water.

These locations were sampled for sediment and vegetation common to most of the sites. A significant departure from previous sediment sampling techniques was the use of coring to collect river bottom sediments. This procedure will enable determination of both vertical and horizontal migration of radionuclides in the bottom sediments. Fish samples were restricted to Station Q because of time constraints. Mussel samples were available only from Stations T and W. Intensive sampling of the above parameters will be done in 1978.

The data in Table 19 is restricted to ^{137}Cs and ^{40}K. These isotopes are from the same periodic group and occur in significant quantities above the MDL and ^{137}Cs is a principal contributor to body burden estimates in man. Other nuclides such as ^{60}Co, which is attributable to Laboratory effluents, did occur but were either less than or equal to the MDL for the counting system used (see Appendix B). Samples are being analyzed for ^{90}Sr and will form part of the comprehensive report in 1978.

The concentration of ^{137}Cs and ^{40}K in sediment exhibit a direct relationship to the organic content and inversely to the rate of movement of the river at the sampling sites. Stations K, M, Q, and S are regions where the rate of flow decreases resulting in increased settling and buildup of the sediment from the water column. These are the regions showing an increased concentration of these radionuclides. In addition, these were also the areas high in vegetation. Figure 8 represents a graphical interpretation of ^{137}Cs concentration in the top 2.5 cm of the bottom sediment as a function of location along the Peconic River for the years 1972-1977. It indicates a decline in ^{137}Cs concentrations as one progresses downstream.

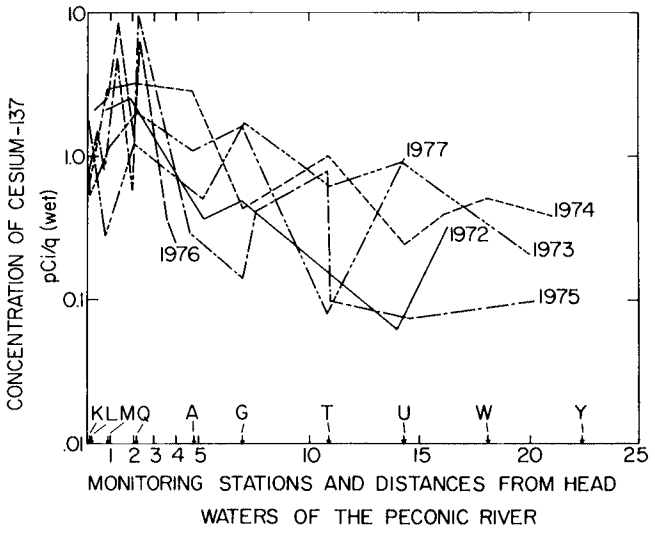

Figure 8. Plot of Cesium-137 Activity in the Top 2.5 cm of the River Bottom Sediment as a Function of Distance Downstream from the Peconic River for the Years 1972-1977.

^{137}Cs and ^{40}K levels in vegetation have indicated species specificity, in that, Potamogeton sp concentrates these nuclides to a greater extent than Vallisneria americana or Ceratophyllum deomersum. This is probably related to the former having an extensive root system in the sediment.

Fishes have exhibited a distinct correlation between habits and concentration of ^{137}Cs and ^{40}K. The surface feeders such as Ameriurus nebulosus do not concentrate these radionuclides to the same extent as the bottom feeders, such as Esox americanus, Helioperca macrochira, Micropterus salmoides, Notropis bifrenatus, Enneacanthus obesus. The mussel (species unidentified) has not shown any significant concentrations above sediment levels, which may be attributed to the fact that during summer tissue buildup is negligible thereby reducing the concentration of ^{137}Cs and ^{40}K.

Looking at the concentration factors for ^{137}Cs at Station Q, it is noted that there is indeed biological magnification across the food chain: water vegetation-fish. The vegetation to water ratio is 630, and fish to water ratio ranges from 640 to 2830. These studies similar observations in aquatic environments [13]. Using the range of concentrations of ^{137}Cs in fish flesh (edible portion) one can compute, on an assumed intake of 50 grams per day, body burdens in man to be ranging from 0.2 to 0.5% of the Radiation Concentration Guides.

Potable Water and Process Supply Wells

The Laboratory's potable water wells and cooling water supply wells are screened at a depth of about 30 m, or about 15 m below the water table, in the Long Island surface layer of glacial outwash, sand and gravel. As apparent from Figure 9, these wells are located generally west to northwest of the Laboratory's principal facilities in the local ground water flow pattern. An average of about 2.94×10^4 m^3 d^{-1} was pumped from them.

Bimonthly grab samples were obtained from these wells. These were analyzed for gross alpha, gross beta and tritium. All gross alpha concentrations were <1 pCi/liter ($<1 \times 10^{-9}$ μCi ml^{-1} or 3.7×10^{-5} Bq ml^{-1}), and almost all tritium concentrations were <1.0 nCi/liter ($<10^{-6}$ μCi/ml or 3.7×10^{-2} Bq ml^{-1}). The gross beta and tritium results are set forth in Table 20. There were no significant differences in the gross beta concentrations among these wells which might be attributed to Laboratory effluents. These values have been consistent over many years. However, well #3 has been showing an increase in gross beta values indicating possible leakage in the well casing which could bring in radioactivity from sumps which receive water from the cooling systems of the facilities.

Recharge Basin

After use in "once through" heat exchangers and for process cooling, about 18 million l d^{-1} (MLD) of the water used by the Laboratory was returned to ground water in on-site recharge basins: about 6.4 MLD to basin N located about 610 m northeast of the AGS; about 5.7 MLD to basin O about 670 m east of the HFBR; and about 6.1 MLD to basin P 305 m south of the MRR (see Figure 9). An organic phosphate was added to the AGS cooling and process water supply, which is independent of the Laboratory's potable supply, to establish a PO_4 concentration of about 2 ppm in order to maintain the ambient iron in solution. Of the total AGS pumpage, about 5.3 MLD was discharged to the N basin, and 2.7 MLD to the O

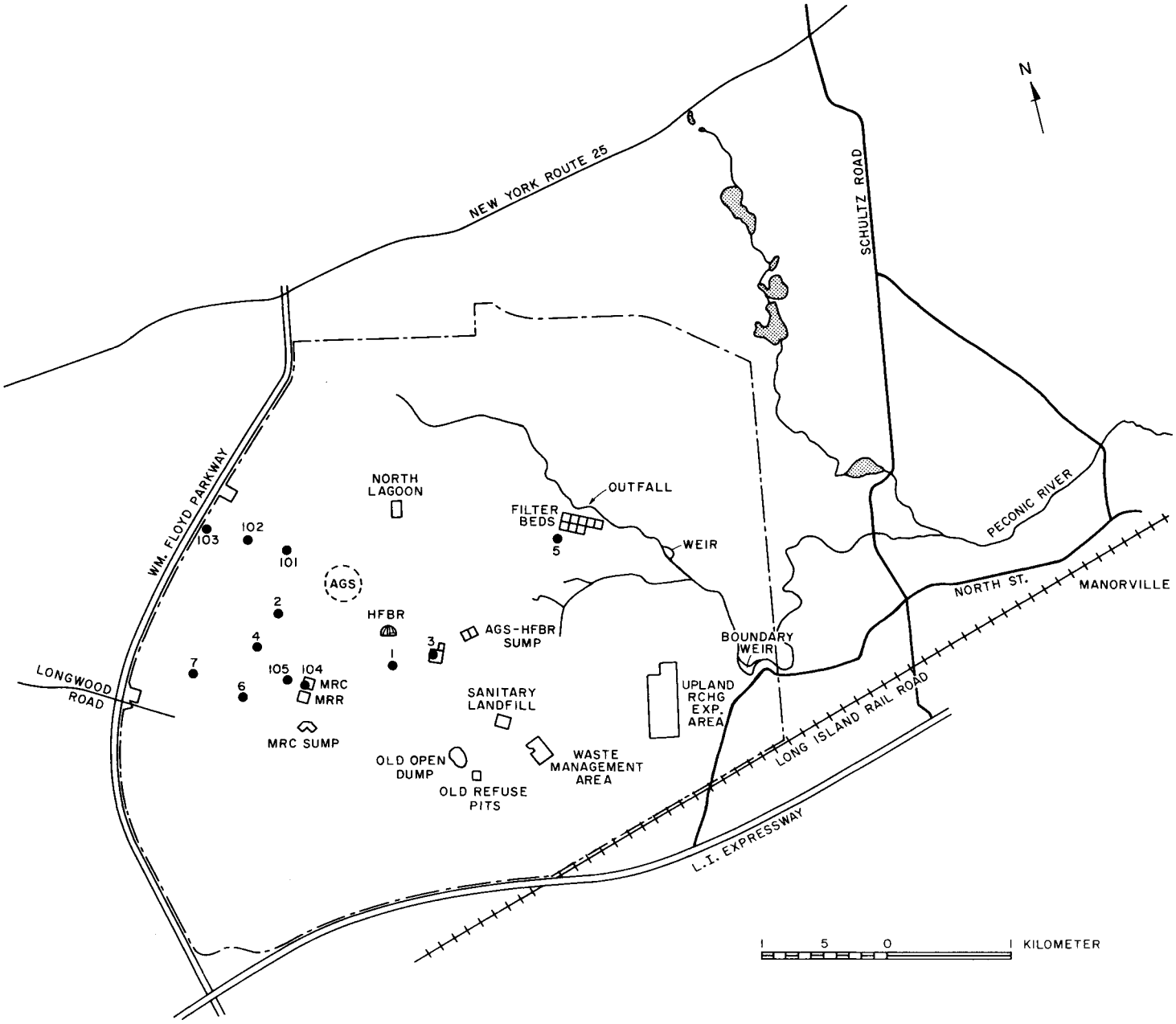

Figure 9. On-Site Potable and Supply Wells, with Respect to Principal Effluent Release Locations.

basin. The HFBR secondary cooling system recirculates through mechanical cooling towers. It is treated to control corrosion and the deposition of solids. Blowdown from this system, about 0.38 MLD contains PO_4 in a concentration of about 10 ppm and benzotriazole in a concentration of 3-4 ppm. It is also discharged to the O sump. The MRR-MRC "once through" coolant is not routinely treated and is discharged to the P basin. Concentrations of radioactivity and other agents in these basins are monitored by routine weekly grab sampling. The average gross beta and tritium activity concentrations are shown in Table 21. The average gross beta activity concentration in the sump north of the AGS, east of Steam Plant, and Linac was slightly above background, due to the occasional release of short lived nuclides contained in AGS beam stops and Linac. It was 0.4% to 0.8% of the applicable RCG. The average gross beta and tritium activity concentrations in the other basins were slightly increased above those in the Laboratory supply wells, and were about 0.1% of the applicable RCG for unidentified gross beta emitters, and less than 0.1% of that for tritium in drinking water.

Water quality data is obtained from periodic (approximately monthly) analyses of "grab" samples from the recharge basins, and from a culvert which conducts some air conditioning tower blowdown and other storm sewer influents from the southeast Laboratory building complex to a natural sump south of the warehouse area (about 1.2 km south of Building 610, see Fig. 2). The data for 1977 are shown in Table 22. All were within established standards for ground water quality except in cases where washout from recharging of ion exchange resins (used in softening water) increased the concentrations of chlorides and dissolved solids.

Ground Water Surveillance

Samples of ground water were obtained from a network of shallow wells previously installed in the vicinity of several areas where there existed a potential for the percolation of radioactivity from the surface downward into the saturated zone of ground water. The included areas which were adjacent to on-site recharge basins, to sand filter beds, to downstream Peconic River, to solid waste management area, to former open dump, to sanitary landfill, to decontamination facility sump, and to the Meadow-Marsh Project area. The locations of most of these ground water surveillance wells are shown in Figure 10. The locations of the several wells installed at the landfill and solid waste management area are shown in Figure 11.

For convenience in assessing the data, the wells have been divided into several groups. Yearly average gross alpha, gross beta, and tritium activity concentrations of the wells adjacent to the sand filter beds, and downstream on the Peconic River are summarized in Table 23. During the year, at least one sample from locations adjacent to the recharge basins and from locations immediately adjacent to the sand filter beds and the Peconic River were analyzed for ^{90}Sr and ^{137}Cs (by gamma analysis) and are included in the table. Corresponding information for wells in proximity to downstream of the solid waste management area, to the landfill and former dump zones, and to the decontamination facility sump (about 1 km east of the HFBR) is summarized in Table 24. Data for wells monitoring the Meadow-Marsh Project was not available as these wells were not sampled due to technical reasons. They will, however, be sampled in 1978.

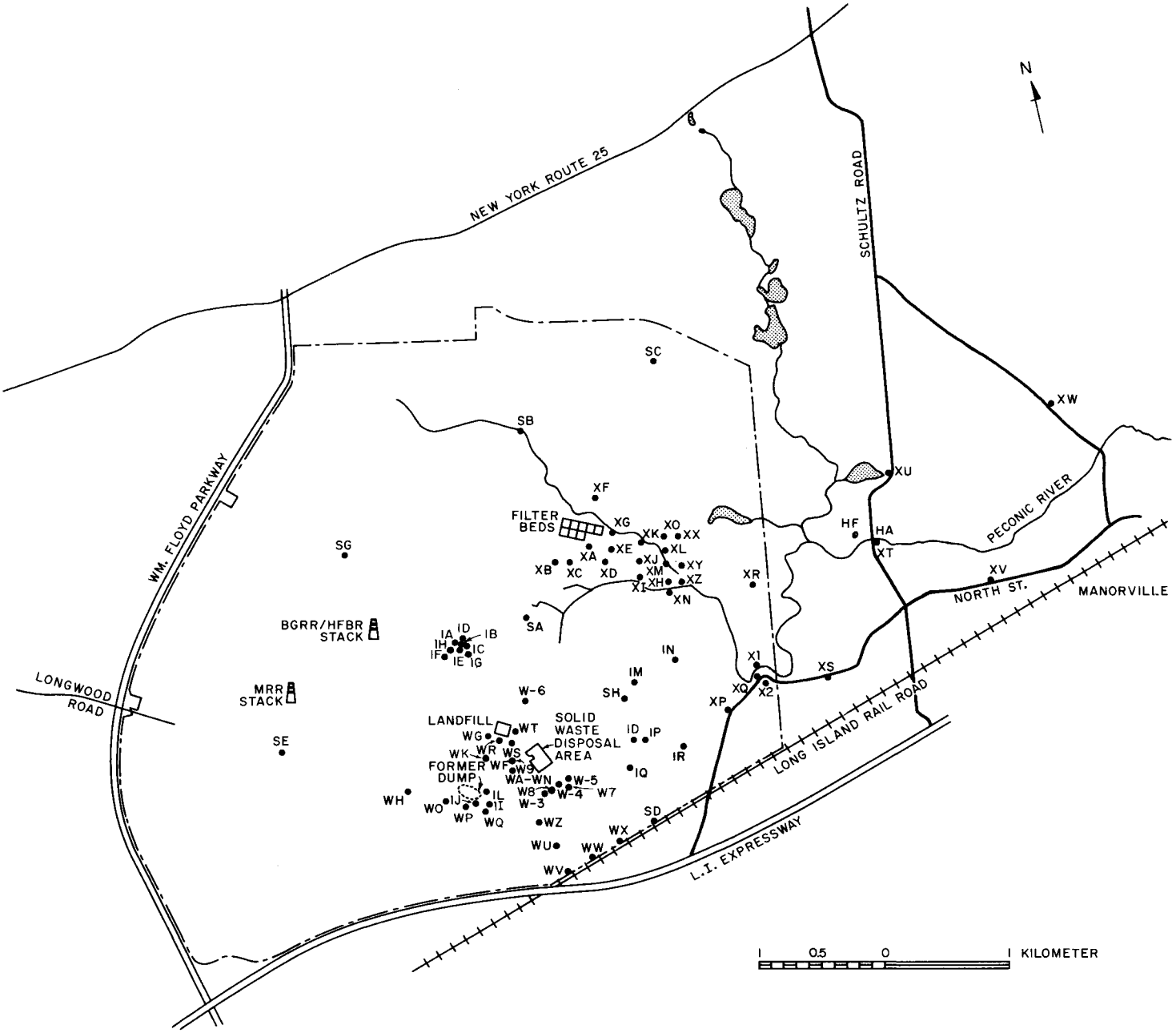

Figure 10. On-Site, Perimeter and Off-Site Ground Water Surveillance Wells.

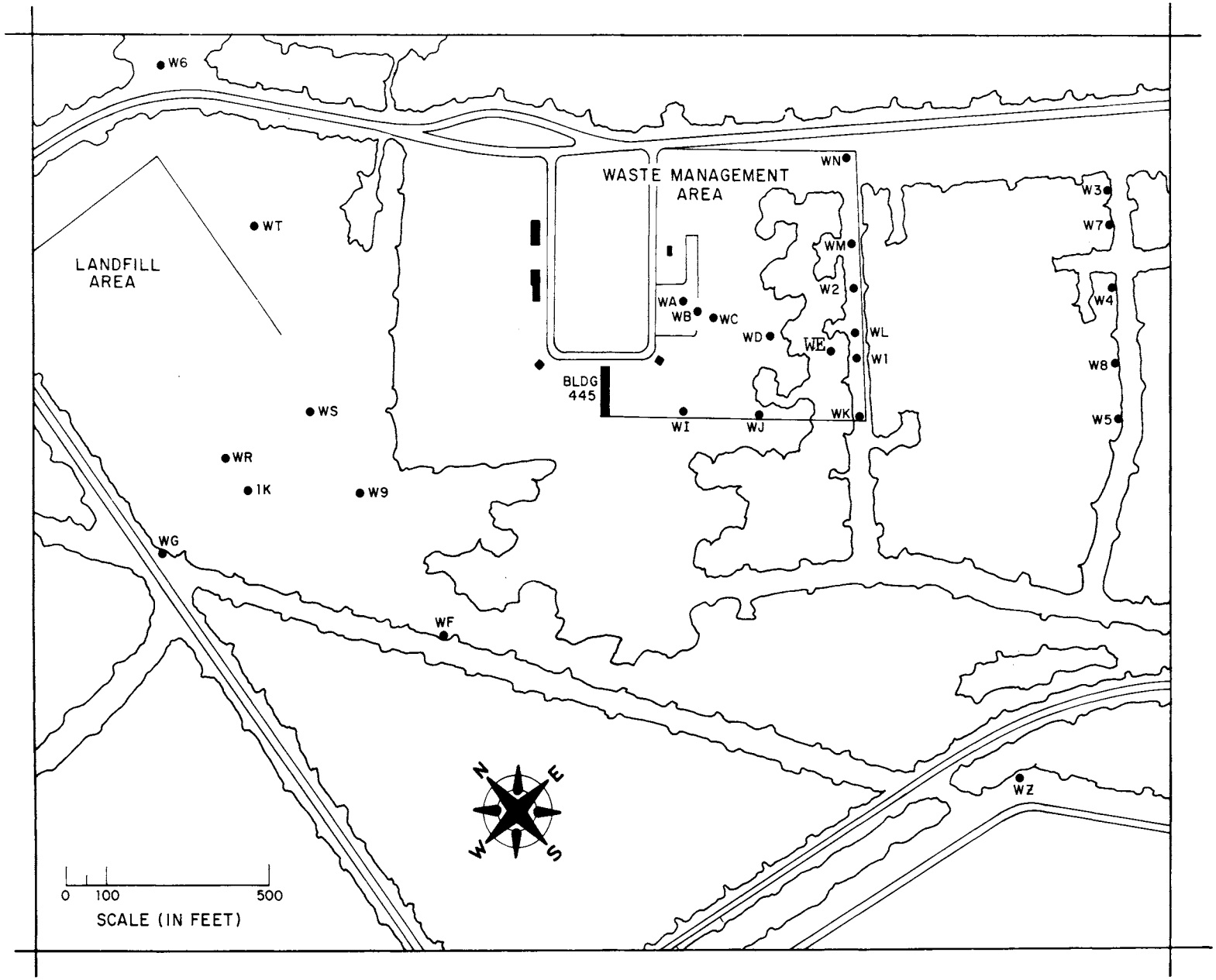

Figure 11. Solid Waste Management and Landfill Area
Ground Water Surveillance Wells.

These data show that the spread of radioactivity in the ground water from Laboratory operations remained limited to within a few hundred meters of the identifiable foci. Above background activity concentrations of gross beta emitters, tritium, and ^{90}Sr were found on-site adjacent to the sand filter beds and to the Peconic River, at small fractions of the RCG's. They were generally less than the activity concentration noted in 1975, but were higher than 1976 values indicating movement of successive wavefronts emanating from source points. Adjacent to the Peconic River at the site boundary, all activity concentrations were equal to or less than 0.1% of Radiation Concentration Guides. Compared with 1975 and 1976, gross beta, ^{90}Sr, and tritium activity concentrations for 1977 were generally similar to the former but higher by an order of magnitude in several wells immediately adjacent to the solid waste management area. Once again, movement of successive wavefronts from the source point are evident. The elevated ^{90}Sr activity concentrations, approaching 20% of the Radiation Concentration Guide, in well WK and W-1 are continuing to reflect the inadvertent release of approximately 1 Ci (3.7×10^{10} Bq) of this nuclide to ground water at well WA in 1960. Increased gross beta and tritium activity concentrations were apparent in several wells immediately adjacent to the landfill area. A 50 to 75% change in activity concentrations was apparent in wells adjacent to the former open dump and the decontamination facility (650) sump and represents a further decrease over 1975 values. The largest activity concentration was 10% of the Radiation Concentration Guide.

Several water quality and purity parameters were evaluated for all ground water surveillance wells. The data for those wells proximate to on-site sumps, the sand filter beds, and downstream of the Peconic River on- and off-site, are shown in Table 25. The solid waste management area, the landfill and dump area and the Building 650 sump, are shown in Table 26. In addition, Table 27 presents similar data on Potable and Cooling Water supply wells. This data is further compared with tap water for a few of the parameters in the same table. In all cases the ground water quality parameters were within standard limits. Analysis for selected metals were conducted for a few wells immediately adjacent to the sand filter beds, to the Peconic River, to the waste management, landfill and former dump areas. These data are shown in Table 28. Results of trace element analyses for potable and cooling water supply wells, and tap water are given in Table 29.

In general, the data were comparable to data of 1975 and 1976. With the exception of pH, all analyzed water quality parameters were within New York State Water Quality Standards. The somewhat lower pH levels appear to reflect natural ambient levels, since higher pH levels were present in the input to and output from the sewage treatment plant (see Table 12). Concentrations of Fe and Zn in excess of water quality standards were found in wells immediately adjacent to the sand filter beds, the Peconic River, and landfill areas and the 650 sump area. It is not clear to what extent they may be an artifact produced by the sampling well casings, or reflect the leaching of accumulations of these metals from past Laboratory releases. Investigations into the Laboratory-wide use of zinc containing chemicals focused our attention on a compound used as a cleaning agent for cooling towers in the past. A recent analysis of this compound made by the Laboratory indicated a concentration of zinc to be about 3 mg/ml of the compound. It was gathered from discussions with Plant Engineering that the washings were discharged into the sewage system. It seems possible that this input may be retained in the sand filter beds and leached into the ground water system, thereby contributing to the increases noted. This phenomena remains under investigation.

Much lower levels of Zn were found in the Laboratory supply wells. Several contain Fe in excess of the standard, but most of this is removed prior to use. Zn and Fe are considered as nuisance elements and not as health hazard.

A depiction of the general direction and rate of ground water movement, originally published in the U. S. Geological Survey Study, is shown in Figure 12. The Upland Recharge Project [14] has determined a ground water velocity of 13.4 cm d^{-1} which is in good agreement with the U. S. Geological Survey Study estimate of 16.2 cm d^{-1}. Thus, it appears that many years of travel time would be required for ground water containing radioactivity or other pollutants to reach an off-site well, during which considerable dilution by infiltration of precipitation would be anticipated.

Chinese Nuclear Test

An atmospheric Chinese nuclear test (20th in their series) on September 17, 1977, led to the initial detection of ^{131}I in air on September 23, 1977. Brookhaven National Laboratory in conjunction with similar state and Federal agencies in this part of the country instituted an accelerated monitoring program upon learning of this test. Peak concentrations of ^{131}I of about 16 pCi l^{-1} (5.9 x 10^{-1} Bq l^{-1}) were found in milk produced at Long Island dairy farms towards the end of September 1977. They were considerably lower than those of the previous year of 1976 (18th of the series) of about 200 pCi l^{-1} (7.4 Bq l^{-1}) of milk. This maybe due to lack of adequate rainfall during the passage of the fallout cloud over BNL. Thus, radioactive material was deposited, in large part, by dry deposition only and not by washout mechanisms which played a major role in the deposition of fallout radioactivity in previous years.

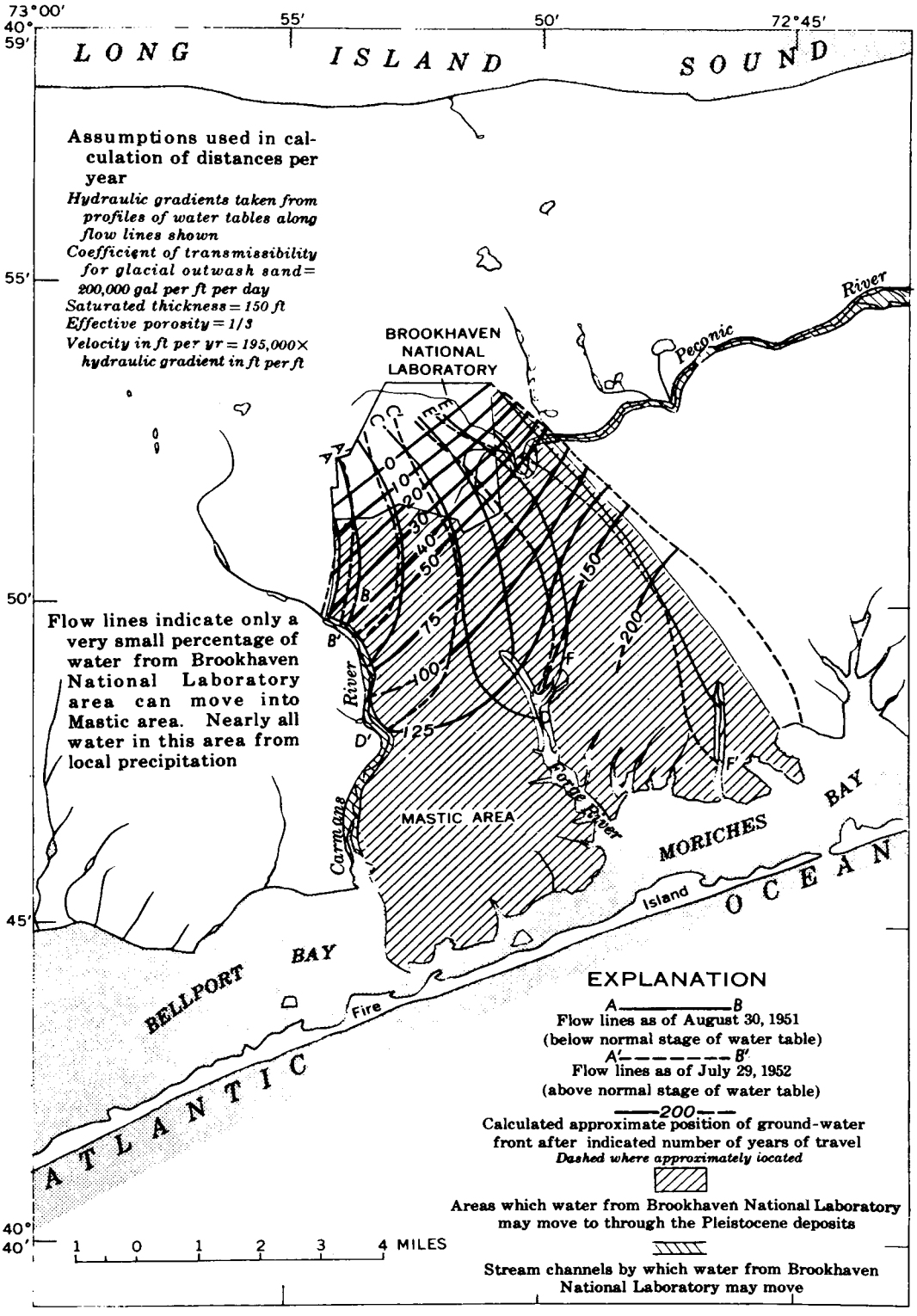

Figure 12. Direction and Time of Travel of Ground Water Laterally in Upper Pleistocene Deposits from BNL Area to Points of Discharge.

OFF SITE DOSE ESTIMATES

Increased levels of radiation and concentrations of radioactivity, in air and water, above ambient background, with resulting increased doses to people, result from the following four Laboratory sources:

Airborne radioactive effluents, primarily tritium,
Radioactive liquid effluents,
The ^{137}Cs source in the Biology Department Ecology Forest,
Skyshine from the Alternating Gradient Synchrotron (AGS)

These are discussed below, and the collective dose equivalent rate due to Laboratory operations during 1977 is calculated.

Annual Average Collective Dose Equivalent Rate Due to Airborne Effluents

As indicated in Table 2, a total of 1236 Ci (4.6×10^{13} Bq) of tritium was released from various Laboratory facilities during 1977, making it a principal source of dose equivalent to persons off-site. In taking this figure, in estimating dose equivalent it was conservatively assumed that all the tritium released was in the form of tritiated water vapor at the site boundary.

Air activity concentrations of tritium vapor at the site boundary were so low that measurement was difficult. Data give in Table 7 indicate an average concentration of 63 pCi m^{-3} (2.3 Bq m^{-3}) at the site boundary (~2500 meters from the HFBR stack) in addition to the background value, which equaled about 1.8 pCi m^{-3} (6.7×10^{-2} Bq m^{-3}). Continuous exposure at the Radiation Concentration Guide (2×10^{5} pCi m^{-3} or 7.4×10^{3} Bq m^{-3}) would result in a per caput annual average dose equivalent rate of 500 mRem a^{-1} (5×10^{-3} Sv person^{-1} a^{-1}). Thus, the per caput annual average dose equivalent rate at this distance attributable to Laboratory air effluent tritium vapor was ($63/2 \times 10^{5}$) (500) or 0.16 mRem a^{-1} (1.6×10^{-6} Sv person^{-1} a^{-1}) or 0.03% of the Radiation Protection Standard. Since the background per caput dose equivalent rate (Table 6) in this area was about 56 mRem a^{-1} (5.6×10^{-4} Sv person^{-1} a^{-1}), this tritium contribution amounts to an increase at the site boundary of about 0.1%, which is within the temporal and spatial variations of the background itself.

As was previously stated, the dose equivalent due to ^{41}Ar and ^{15}O were considered insignificant and as such were not included in the final estimates.

Routine analyses for air particulate radioactivity and for radiohalogens were made throughout 1977 on air samples collected at several locations. Although several nuclides attributable to fallout from weapons testing were found, there was no evidence of activity attributable to Laboratory operations.

Beyond the site boundary dose rates due to tritium in air effluents from the Laboratory were very small, compared with background and variations in background. This should be considered in the interpretation of the computation of the total population exposure attributable to this Laboratory effluent, as shown in Table 30. The parameter X/Q, tabulated in the second column, is the ratio of ground level concentration to rate of emission, i.e., concentration per unit emission rate, and is a function of meteorological conditions and distance from the source. The values have been calculated for the 97.5 m release height of the HFBR stack and are averages for a whole year and for all sixteen tabulated directions. While their use produces an underestimate at close-in distances for releases from shorter stacks, overall it results in some overestimation of population exposure, since X/Q values in the direction of major population centers to the west of the Laboratory are lower than the 360° averages. Values of dose rate in the third column are derived from the measured value for the 1.6 to 3.2 km interval (0.225 mR a^{-1}) by multiplying by the appropriate ratios of X/Q values. The collective average dose equivalent rate (total population dose) due to the Laboratory tritium effluent was 19.15 rem a^{-1} (person-rem) and due to natural background (56.2 mR a^{-1}) was 269,377 rem a^{-1} (person-rem).

Doses Due to Liquid Effluents

Since the Peconic River is not utilized as a drinking water supply, nor for irrigation, its waters do not constitute a direct pathway for the ingestion of radioactivity. The upper portions of the river, where a slight increase in radioactivity above background concentraction (principally ^{137}Cs) was found in sediments, vegetation and fish, is utilized for occasional recreationl fishing. Making the assumption that the total catch of fish by 100 fishermen was 1×10^3 kg, and the maximum ^{137}Cs concentration in fish flesh was 8500 pCi kg^{-1} (3×10^2 Bq kg^{-1}), Table 19, ingestion would have been 8.5×10^{-6} Ci (3.1×10^5 Bq). This corresponds to an average individual dose commitment of 2.72 mRems (2.72×10^{-5} Sv) or 0.53% of the Radiation Protection Standard. The estimated collective average dose equivalent rate (total dose) from this indirect pathway is 0.272 rem a^{-1} (person-rem). It may reasonably be assumed that there was also some accumulation of ^{90}Sr from Laboratory effluents in these fish. Since this nuclide is concentrated principally in the inedible bone, the resulting dose appeared to have been small in comparison to ^{137}Cs.

Although not directly relatable to the Laboratory liquid effluents during 1977, a ^{90}Sr concentration of 3.0 pCi l^{-1} (1.1×10^{-1} Bq) was found in an off-site surveillance well, about 305 km east of the Laboratory site boundary at the Peconic River. Using dose commitment factors published by Shleien [15], a potential individual 50 year bone dose commitment of 11 mRem (0.00011 Sv) for infants and 9 mRem (0.00009 Sv) for adults may be calculated for a small number of people living in the adjacent area. This is about 0.2% of the Radiation Protection Standard. This calculation is based on the assumption that during 1977, all of their drinking water was obtained from shallow water supply wells, containing ^{90}Sr in a concentration equal to that of the surveillance well. It is estimated that not more than twenty-five people reside in this locality and thus, the collective average dose equivalent rate (total dose commitment) did not exceed 0.35 rem a^{-1} (person-rem). Their collective average dose equivalent rate (total dose) from natural background (including internal radiation) would have been about 2.5 rem a^{-1} (person-rem) during 1977.

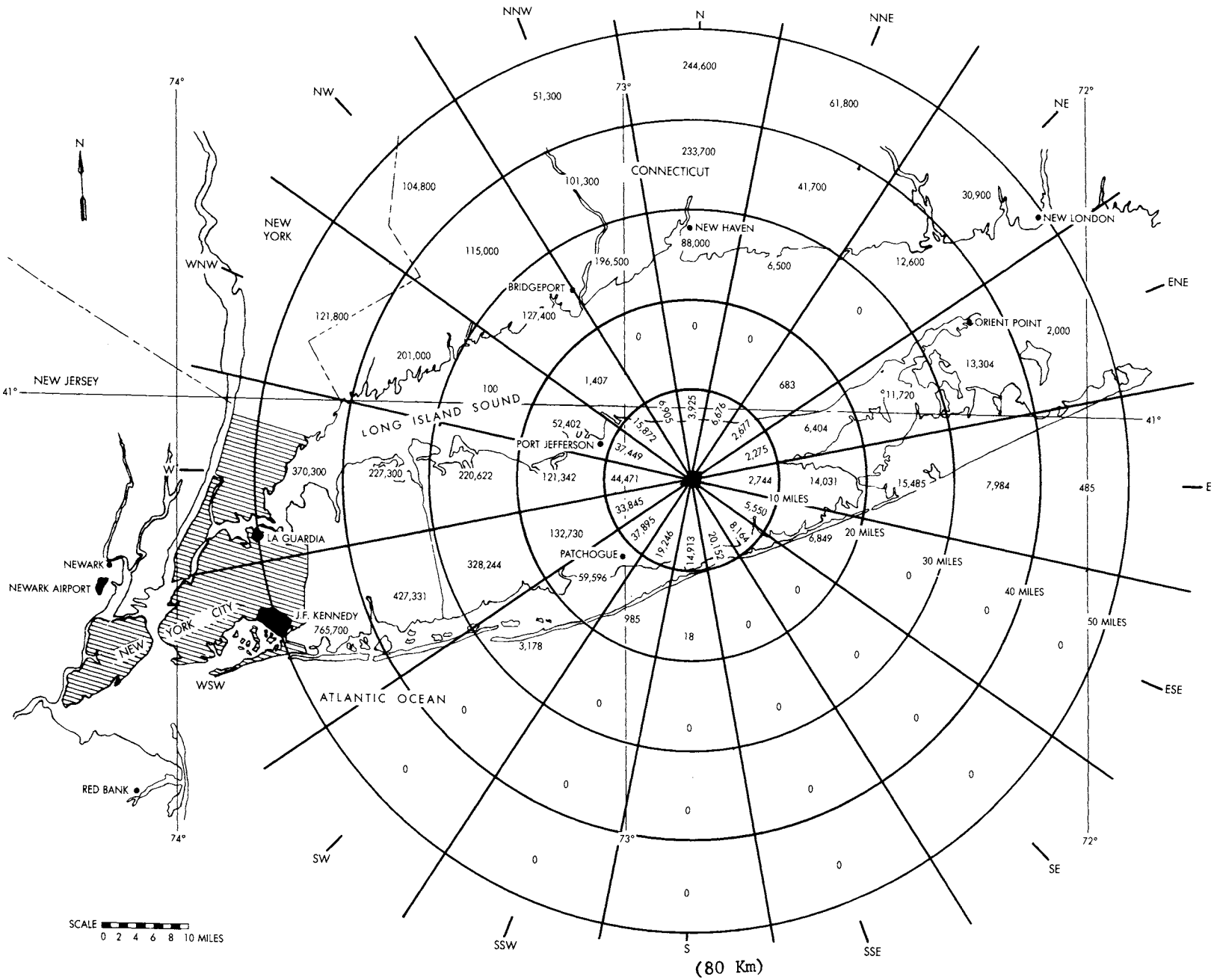

Figure 13. Resident Population (1977) within a 80 Km Radius of BNL.

Doses Due to the Gamma Forest ^{137}Cs Source

A 6161 Ci* ^{137}Cs source is located in the northeast part of the BNL site, 1010 meters from the north boundary. The dose rate at this boundary during 1977, as determined by the Laboratory Environmental Monitoring Group, was 5.2 mRem a^{-1} (.000052 Sv), or 1.0% of the Radiation Protection Standard.

Population doses beyond the site boundary due to this source have been computed using a population count by segements centered on the HFBR stack. Average dose rates for each population segment and for each distance from the source are given in Table 31.

Since the dose rate from this source decreases very rapidly with distance, only population segments located 5 km from the source were considered. The off-site collective average dose equivalent (total dose) is 0.11 rem a^{-1} (person-rem a^{-1}), and appreciable contributions are found only in the NNE and NE sectors.

Doses Due to Alternating Gradient Synchrotron

The Alternating Gradient Synchrotron (AGS) is a 33 GeV proton synchrotron located 1180 meters from the nearest site boundary. Although the machine is heavily shielded, some neutrons do escape through it or from areas where experiments are in progress. Some of these neutrons reach off-site areas either directly or in most cases, by scattering from the air, which is called skyshine.

Dose rates due to AGS skyshine were measured at a distance of 854 meters from the machine. The relationship between these dose rates and values of the AGS circulating beam intensity has previously been established. From this relationship and machine operating records, the dose to AGS operation during 1977 at a distance of 854 meters is estimated to be 1.61 ± 0.6 mRem ($1.61 \times 10^{-5} \pm 0.6 \times 10^{-5}$ Sv).

The decrease in dose rate at distances >854 meters is due to an inverse-square factor and exponential absorption by the air. Measurements of dose rate previously made at various distances out to 900 meters indicate that the dose rate decreases with a relaxation length of 600 meters. Values of dose rate beyond the site boundary can be computed by using the following equation:

$$\text{mRem } a^{-1} = 1.6(854/r)^2 e^{-(r-854)/600}$$

where r = distance in meters from the AGS centroid.

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*As of 1/1/77

Values of dose rate in mRem a^{-1} for a selection of distances from the AGS are shown in the following table:

r, km	$(854/r)^2$	(r-854)/600	e - (r-854)/600	mRem a^{-1}
1	0.73	0.243	0.784	0.921
2	0.182	1.91	0.148	0.043
3	0.0811	3.58	0.0279	0.0036
4	0.0455	5.25	0.00525	0.00038
4.5	0.0360	6.08	0.00229	0.00013
5	0.0291	6.90	0.00101	0.00005

At the site boundary nearest to the AGS, about 1.0 km to the northwest, the estimated dose was 0.92 mRem a^{-1} (0.92×10^{-5} Sv a^{-1}), or 0.18% of the Radiation Protection Standard.

Population doses beyond the site boundary due to this source have been computed, with use of an available population count with relation to distance from the HFBR stack. Collective average dose equivalent (average dose) rates for each population segment and for each distance from the source are also given in Table 31.

Since the dose rate from this source decreases rapidly with distance, only population segments with radii of 1.6 to 3.2 and 3.2 to 4.8 kms were considered. The off-site collective average dose equivalent (total dose) was 0.04 rem a^{-1} (person-rem a^{-1}) and applicable contributions were found only in the NW and NNW sectors.

Collective Average Dose Equivalent Rate (Total Population Dose)

The collective average dose equivalent rate (total population dose) beyond the site boundary, within a radius of 80 km, due to Laboratory operations during 1977 is the sum of the values due to the four components discussed above, as shown below:

	rem a^{-1} (person-rem a^{-1})
Airborne effluents	19.15
Liquid effluents	0.27
	0.35
Gamma-forest source	0.11
AGS skyshine	0.04
Total	19.92

The collective average dose equivalent (total annual dose) due to external radiation from natural background, to the population within a 80 km radius of the Laboratory amounts to about 269,377 rem a^{-1} (person-rem a^{-1}), to which about 83,000 rem a^{-1} (person-rem a^{-1}) should be added for internal radioactivity from natural sources.

APPENDIX A

QUALITY CONTROL

Radioactive Measurements

Certified radioactive standards from the National Bureau of Standards, U.S. Department of Commerce, are used to standardize radiation measurement instruments. These Standards are certified to be at least within 5% of stated values. In some cases, certified standards were also obtained from Amersham/ Searle. Daily checks of performances are made using the Standards as well as backgrounds. In addition, some samples are counted both in NaI system and Ge(Li) system. Ge(Li) system were calibrated using a new multi-gamma NBS Standard obtained in October 1977. The results from NaI and Ge(Li) systems agree within 5%. For tritium measurements a number of Standards and blanks are included with each run of a liquid scintillator counter which has a programmed automatic sample changer.

The Analytical Laboratory of the Safety and Environmental Protection Division is a participant in the inter-lab comparisons of radioactivity in samples of different matrices of water, air filters, and other media. These samples are distributed by the Department of Energy (DOE) through the Environmental Measurements Laboratory (EML), New York, formerly known as the Health and Safety Laboratory (HASL), on a quarterly basis. Our results in general agree within 15% of their values.

Procedures for nonradioactive contaminants are those presented in Standard Methods for the Examination of Water and Wastewater (13th edition, 1971). All Standards are prepared from standard reference grade and analytical grade reagents in accordance with the requirements of Standard Methods. Standards are run with each set of samples analyzed and at least one duplicate and blank is run with each set.

APPENDIX B

Minimum Detectable Limit (MDL)

Some of the values in gamma scans by NaI detector are not indicated in the tables as these values were at or below MDL. The MDL values are a function of Matrix (efficiency), Count Time (background), etc. A typical table is indicated below:

Units: 10^{-6} μCi (Gross)
Detector: Two 4" NaI crystals
Geometry: Planchet and air particulates

Count Time (sec)	7 Be	144 Ce	57 Co	58 Co	60 Co
4,000	65.7	20.0	4.12	11.5	17.8
8,000	46.2	20.4	2.90	8.05	12.5
40,000	20.5	9.10	1.29	3.57	5.51
60,000	16.7	7.43	1.60	2.91	4.49

Count Time (sec)	134 Cs	137 Cs	59 Fe	131 I
4,000	15.9	7.14	3.89	6.01
8,000	11.2	5.02	2.74	4.23
40,000	4.95	2.23	1.22	1.88
60,000	4.04	1.81	0.99	1.53

Count Time (sec)	54 Mn	22 Na	125 Sb	65 Zn
4,000	7.07	22.3	30.7	15.9
8,000	4.97	15.6	21.6	11.2
40,000	2.20	6.92	9.20	4.94
60,000	1.80	5.64	7.83	4.03

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This report was typed by M. Redmond and E. Dahl. Their painstaking effort is commended and recognized.

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TABLE 1

1977 BNL Environmental Monitoring Background
and Dose Equivalent Rates
(mRem/week)

Month	Location			Northeast perimeter	Source*	Average Background**
	P-2	P-4	P-7	P-9A		
January	1.08	1.07	1.09	1.12	0.04	1.08
February/ March	1.14	1.12	1.20	1.17	0.02	1.15
April/May	1.18	1.16	1.25	1.26	0.06	1.20
June	1.18	1.12	1.32	1.44	0.23	1.21
July	1.14	1.08	1.17	1.23	0.10	1.13
August	1.20	1.14	1.21	1.49	0.31	1.18
September	1.15	1.13	1.19	1.31	0.15	1.16
October	NA***	1.28	1.32	1.30	0.00	1.30
November/ December	1.02	1.33	1.38	1.30	0.06	1.24
Total (mRem/year)	51.2	56.8	60.7	63.1	5.2	56.2
Average (mRem/week)	1.14	1.16	1.24	1.29	0.11	1.18
Error $\pm$ 2 S.D.	0.12	0.18	0.18	0.24	0.2	0.12

Locations of monitoring stations indicated on Figure 2

* ^{137}Cs Ecology Forest Irradiation Source radiation level derived by subtracting average background at other stations from total measured level at northeast perimeter.

**Average of P-2, P-4 and P-7, unaffected by BNL on site radiations or effluents.

***Not Available.

Data for this table supplied by J. Gilmartin (S&EP) using $CaF_2(Dy)$ environmental monitoring TLDs which were placed in the above locations by E. Hartmann (S&EP).

mRem = 0.00001 Sv.

TABLE 2

1977 BNL Environmental Monitoring Gaseous Effluent
Release Locations and On-Line Monitoring and Sampling Devices

Building*	Facility and release point radioactive effluents	Release height (m)	Principal nuclide(s)	On-Line monitoring	Sampling devices
490	Medical Research Center Roof Stack	13.7	Tritium (vapor)	None	Desiccant for tritium vapor
491	Medical Research Reactor Stack	45.7	Argon-41	Moving tape for radio-particulates	Charcoal for radioiodines
555	Chemistry Building Roof	16.8	Tritium (vapor)	None	Desiccant for tritium vapor
705	High Flux Beam Reactor/ Hot Laboratory Stack	97.5	Tritium (vapor)	Beta scintillator for radioacitve gases; Kanne chamber for tritium (gas+vapor)	Desiccant for tritium vapor; particulate filter for gross beta; charcoal cartridge for radioiodines
901	Van de Graaff Accelerator	18.3	Tritium (gas+ vapor)	Kanne chamber for tritium (gas+vapor)	Desiccant for tritium vapor**
931	Linac Isotope Facility	18.3	Tritium (vapor) Oxygen-15	G-M detector for radiogases	Desiccant for tritium vapor
Steam Plant Effluents					
610	Central Steam Plant Stack	19.8	Particulates; SO_2; NO_x	None	None

* Locations given in Figure 2.
**Tritium gas evaluated from Kanne chamber indications.

TABLE 3

1977 BNL Environmental Monitoring Airborne Effluent Data
Radioactive Effluents

Building	Facility and release point	Elevation* (m)	Nuclide	Amount (Ci)
491	Medical Research Reactor Stack	45.7	^{41}Ar	363**
490	Medical Research Center Stack	13.7	^{3}H (vapor)	1.35
555	Chemistry Building Stack	16.8	^{3}H (vapor)	71.48
705	High Flux Beam Reactor/ Hot Laboratory Stack	97.5	^{3}H (vapor)	119.22
			Gross beta (particulate)	1.08×10^{-5}
			^{127}Xe	1.55
901	Van de Graaff Accelerator Stack	18.3	^{3}H (gas)	1041.28
			^{3}H (vapor)	2.52
931	Linac Isotope Production Facility	18.3	^{3}H (vapor)	0.084
			^{15}O	67206+

*Above ground level.

**Calculated from reported operating time and "one-time" measured emission rate at 3 MW power level.

+Calculated from reported operating time and estimated production rate at 180 uAmp full beam current.

Curie (Ci) = 3.7×10^{10} Bq.

TABLE 4

1977 BNL Environmental Monitoring Emission of SO_2, NO_x and Particulates from Central Steam Plant (Bldg. 610)

Effluent	Total kg	Calculated stack concentration	Average boundary concentration*	EPA Primary Air Quality Standard[5]
SO_2	4.9×10^{5}**	383 ppm	1.50×10^{-3} ppm	0.03 ppm
NO_x	2.2×10^{5}	222 ppm	9.00×10^{-4} ppm	0.05 ppm
Particulates	3.5×10^{4}+	0.09 gm/m^3	0.35 $\mu g/m^3$	75 $\mu g/m^3$

*Based on average X/Q of 2.4×10^{-7} sec/m^3 calculated by BNL Meteorology Group (1977).

**Based on average 1.0% sulfur content.

+Based on measured average value during February 1977 stack sampling conducted on main steam boiler unit (New York Testing Laboratories, Inc., Westbury, N.Y., 11590).

Table based on data supplied by Plant Engineering (E.E. Shelton).

TABLE 5

1977 BNL Environmental Monitoring Average Gross Alpha and Gross Beta Concentrations in Air Particulate Filters (pCi/m^3 or 1.0×10^{-12} $\mu Ci/ml$)

			Gross Alpha				Gross Beta		
Month	Location	No.	Average	Maximum	Minimum	No.	Average	Maximum	Minimum
January	Waste area	20	.0011	.0020	.0003	21	.0908	.1830	.0259
	S.W. perimeter					4	.0510	.0884	.0152
	N.E. perimeter					5	.0786	.1090	.0468
February	Waste area	19	.0011	.0027	.0002	19	.0853	.1310	.0462
	S.W. perimeter					4	.0615	.0755	.0519
	N.E. perimeter					4	.0608	.0718	.0524
March	Waste area	23	.0007	.0017	.0001	23	.1192	.6540	.0547
	S.W. perimeter					4	.0567	.1100	.0157
	N.E. perimeter					4	.1161	.1790	.0727
April	Waste area	21	.0009	.0022	.0001	21	.1761	.3370	.0207
	S.W. perimeter					4	.2135	.2560	.1510
	N.E. perimeter					4	.1679	.1780	.1500
May	Waste area	18	.0010	.0061	.0000	18	.3806	.7190	.0607
	S.W. perimeter					5	.4789	.6400	.3820
	N.E. perimeter					5	.4376	.5960	.3140
June	Waste area	21	.0007	.0017	.0002	21	.4299	.9630	.0601
	S.W. perimeter					4	.4620	.5940	.3500
	N.E. perimeter					4	.4014	.5180	.3170
July	Waste area	19	.0008	.0022	.0004	19	.3661	.6560	.1220
	S.W. perimeter					4	.3454	.4500	.2450
	N.E. perimeter					4	.3377	.3730	.2750
August	Waste area	23	.0007	.0021	.0000	23	.3244	.5520	.1650
	S.W. perimeter					5	.3724	.5200	.2340
	N.E. perimeter					5	.3449	.5010	.2730
September	Waste area	23	.0007	.0018	.0000	23	.2680	1.3600	.0133
	S.W. perimeter					4	.2107	.4190	.0770
	N.E. perimeter					4	.2157	.4430	.0714
October	Waste area	21	.0007	.0017	.0000	21	.3592	1.1700	.0984
	S.W. perimeter					5	.3896	.9990	.1980
	N.E. perimeter					5	.3252	.8220	.1600
November	Waste area	19	.0005	.0014	.0000	19	.1383	.3330	.0432
	S.W. perimeter					4	.1253	.1520	.0954
	N.E. perimeter					4	.1179	.1520	.0523
December	Waste area	21	.0007	.0016	.0001	21	.0909	.1680	.0372
	S.W. perimeter					4	.0769	.1310	.0000
	N.E. perimeter					4	.0719	.1190	.0482
Yearly	Waste area	248	.0008	.0027	.0000	249	.2350	1.3600	.0133
Summary	S.W. perimeter					51	.2474	0.9900	.0000
	N.E. perimeter					52	.2282	0.8220	.0718
Estimated % error of individual sample				25				10	
Radiation Concentration Guide[4] for unidentified mixtures				0.100				100	

$\mu Ci = 3.7 \times 10^4$ Bq.

$pCi = 3.7 \times 10^{-2}$ Bq.

TABLE 6

1977 BNL Environmental Monitoring Monthly Average Concentrations of Gross Beta Activity and of Gamma Emitting Nuclides in Monthly Composite Air Particulate and Charcoal Filters

(pCi/m^3 or 10^{-12} $\mu Ci/ml$)

Month	Average Gross β	Sample Volume m^3	NUCLIDES 7 Be	95 Zr-Nb	106 Ru	131 I*	137 Cs	140 Ba-La	144 Ce
January	0.076	46410	0.12	--	0.007	--	--	--	--
February	0.071	42730	0.21	0.07	0.005	--	--	--	--
March	0.104	48900	0.18	0.12	--	--	--	0.006	--
April	0.184	49920	0.19	0.05	--	--	0.0002	--	--
May	0.432	53290	0.18	--	--	--	--	--	--
June	0.429	55190	0.14	0.09	0.015	--	--	--	--
July	0.351	50800	0.12	0.17	0.010	--	--	--	--
August	0.345	67370	0.12	0.18	0.008	--	--	--	--
September	0.233	59040	0.10	0.09	--	1.6	--	0.01	--
October	0.357	61410	0.09	0.11	--	0.5	--	0.006	--
November	0.128	57130	0.17	0.08	--	0.009	--	0.002	--
December	0.081	53150	0.19	0.10	--	0.018	--	--	--
Radiation Concentration Guide[4]	100		$4x10^4$	$2x10^3$	200	100	500	1000	200

Error on the counting of samples is estimated to be about 15%.

See Figure 2 for location of sampling stations: P 2, P 4, P 7, P 9, S 6 and S 13.

* ^{131}I collected in charcoal filters, all others in particulate filters.

pCi = 3.7×10^{-2} Bq.

TABLE 7

1977 BNL Environmental Monitoring Average Tritium Vapor Concentration in Air

(pCi/m^3 or 10^{-12} $\mu Ci/ml$)

Period	Waste Management Area	Southwest Perimeter	Northeast Perimeter	Background*
1/4 - 4/7	39	3	9	
4/7 - 7/8	97	27	96	
7/8 - 9/30	164	341	57	1.8
9/30 - 12/30	109	138	133	
Average	71	65	60	
Radiation Concentration Guide[4]	2×10^5			

* Calculated from concentration of tritium in precipitation collected off site. Assuming average temperature of 15°C and 50% relative humidity.

$\mu Ci = 3.7 \times 10^4$ Bq.

$pCi = 3.7 \times 10^{-2}$ Bq.

TABLE 8

1977 Monthly Average Gross Beta Concentration,
Total Gross Beta Activity and Individual Nuclide Activity in Precipitation

Month	Rainfall (cm)	Average Gβ (pCi/liter or 10^{-9} μCi/ml)	(nCi/m^2) Gβ	7 Be	22 Na	65 Zn	90 Sr	131 I	137 Cs	144 Ce
January	1.38	27.0	0.37							
February	3.98	64.3	2.56	13.6	0.09	--	0.038	--	--	0.41
March	11.16	44.3	4.95							
April	9.0	49.5	4.45							
May	3.85	61.8	2.38	12.8	0.66	0.99	0.33	--	0.25	1.36
June	9.03	63.7	5.75							
July	3.20	44.7	1.43							
August	17.95	66.0	11.85	17.8	0.41	0.62	0.18	--	0.33	0.73
September	9.68	25.6	2.48							
October	10.68	202.0	21.58							
November	6.02	45.5	2.74	23.6	0.6	0.9	0.038	--	--	2.2
December	14.20	20.5	2.91							
Total	100.10		63.5	67.8	1.8	2.5	0.59	--	0.58	4.7
Average		63.3								
Average Radiation Concentration Guide[4]		$3x10^3$	$3x10^3$	$8x10^2$	$1x10^4$	$3x10^4$	$8x10^1$	$8x10^1$	$5x10^3$	$3x10^3$

nCi = 3.7×10^1 Bq.

pCi = 3.7×10^{-2} Bq.

TABLE 9

1977 BNL Environmental Monitoring Monthly Average Tritium Concentration in Precipitation (pCi/liter)

Period	P-2	P-4	P-7	P-9	BNL Sewage Treatment Plant	Off-Site (Blue Point)
January-March	<175	<175	<175	<175	<175	NA
April-June	<175	NA	<175	<175	<175	NA
July-September	NA	NA	<198	<198	<198	<373 **
October-December	<198	NA	<198	<198	<198	<198
Yearly Average	<183	<175	<187	<187	<187	<286
Radiation Concentration Guide (4) *	. . . . .		3×10^6		. . . . .	
Yearly Total (pCi/m^2)	<149	< 47	<203	<203	<203	<155

* From tritium in water released to off-site environment.

NA - Not available.

There is an estimated error of up to 50% in the values of tritium.

** Minimum Detection Limit (MDL) for this sample is high due to low sample volume and a short counting time.

MDL for this table is based on 1.64 σ at 90% CL.

pCi = 3.7×10^{-2} Bq.

TABLE 10

1977 BNL Environmental Monitoring Total Activities and Concentrations of Identifiable Nuclides in Liquid Effluents

Month	Flow x 10^{10} ml	GB	GB + γ only[a]	Nuclides ^{3}H	^{7}Be	^{22}Na	^{54}Mn	^{57}Co	^{58}Co	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs
						Clarifier (mCi)							
January	10.30	26.40	30.77	617	3.66	1.18	0.63	0.08	b	0.37	0.15	0.17	0.08
February	9.48	3.81	4.28	2730	b	0.12	0.39	0.08	0.15	0.23	0.17	0.05	0.03
March	10.40	3.69	7.36	2480	0.83	b	2.38	0.46	1.29	0.45	0.13	b	b
April	10.30	6.16	7.99	2480	1.70	0.24	b	0.13	0.15	0.22	0.13	0.07	0.04
May	12.40	2.79	3.53	2530	0.52	b	0.15	0.07	0.45	0.28	0.15	b	b
June	11.80	3.91	4.57	876	0.55	b	0.06	0.05	0.18	0.34	0.15	0.04	b
July	12.00	1.94	2.40	244	0.39	b	0.05	0.02	0.04	0.06	0.13	0.02	0.08
August	11.30	3.55	4.21	582	0.59	0.05	0.05	0.02	b	0.03	0.10	0.17	0.31
September	10.40	3.53	3.78	203	0.20	0.01	0.03	0.02	b	0.08	0.08	0.05	0.05
October	9.65	4.39	4.75	212	0.36	b	b	b	b	1.31	0.11	0.05	b
November	9.04	6.27	8.00	297	1.73	0.25	b	b	b	0.52	0.16	0.07	b
December	9.59	2.44	2.84	643	0.36	0.02	0.02	0.02	b	0.05	0.06	0.02	b
Total	126.66	68.88	84.48	13884	10.89	1.87	5.63	0.95	2.26	3.94	1.52	0.71	0.59
				Average concentration (pCi/liter or 10^{-9} μCi/ml)									
		54.38	66.70	10962	8.60	1.48	4.44	0.75	1.78	3.11	1.20	0.56	0.47
				Groundwater (Sand Filter Beds) (mCi)									
Total	14.24	5.60	6.81	1609	0.83	0.27	0.36	0.06	0.13	0.24	0.19	0.22	0.29
				Average concentration (pCi/liter or 10^{-9} μCi/ml)									
		39.32	47.79	11299	5.82	1.92	2.55	0.40	0.89	1.67	1.31	1.56	2.02
				Chlorine House (mCi)									
January	5.54	3.78	4.84	430	1.06	1.76	b	b		b	0.07	0.34	0.35
February	6.29	1.84	2.45	1910	0.55	0.26	0.04	0.02		0.05	0.03	0.24	0.47
March	7.71	1.94	2.37	1820	0.38	0.11	0.05	b		0.05	0.12	0.31	0.39
April	8.62	2.65	3.19	2240	0.43	0.21	0.11	b		0.06	0.13	0.30	0.44
May	11.00	2.22	2.37	2240	b	0.03	0.15	b		0.03	0.13	0.30	0.29
June	10.10	2.13	2.42	800	0.12	0.04	0.15	0.02	b	0.03	0.21	0.45	0.43
July	11.10	2.00	2.10	228	b	0.02	0.10	b		0.02	0.27	0.30	0.35
August	11.95	2.10	2.14	600	b	b	0.04	b		b	0.14	0.04	0.07
September	9.45	1.77	1.79	172	0.13	0.02	0.02	b		b	0.10	0.17	0.32
October	9.70	1.77	1.92	1370	0.13	0.03	0.02	b		0.02	0.10	0.11	0.24
November	8.57	3.71	4.07	304	0.33	0.30	0.03	b		b	0.14	0.11	0.25
December	9.01	1.63	1.84	575	0.19	0.05	0.02	b		b	0.11	0.13	0.28
Total	109.04	27.54	31.50	12689	3.32	2.56	0.73	0.04	--	0.26	1.55	2.80	3.88
				Average concentration (pCi/liter or 10^{-9} μCi/ml)									
		25.26	28.89	11637	3.04	2.35	0.67	0.04	--	0.24	1.42	2.57	3.56
				Lowland Recharge (mCi)									
Total	4.38	2.47	3.09	193	0.56	0.15	0.06	b	0.34	0.11	0.04	0.04	0.02
				Average concentration (pCi/liter or 10^{-9} μCi/ml)									
		56.41	70.51	4382	12.82	3.42	1.28	b	7.69	2.56	0.89	0.85	0.43
Radiation Concentration Guide[4] (pCi/liter or 10^{-9} μCi/ml)			3×10^{3}[c]	3×10^{6}	2×10^{6}	4×10^{4}	1×10^{5}	5×10^{5}	1×10^{5}	5×10^{4}	3×10^{2}	9×10^{3}	2×10^{4}

a. Includes gamma (only) emitters but excludes tritium.

b. Below the Minimum Detection Limit (MDL) of the system used in estimating the activity. Other radionuclides, such as ^{51}Cr, ^{65}Zn, $^{95}ZrNb$, ^{125}Sb, ^{131}I, $^{140}BaLa$, ^{144}Ce were all below MDL.

c. For mixtures of radionuclides containing <10% ^{90}Sr, $^{125\text{-}133}I$, or long lived alpha emitters. The concentration guides for unknown mixtures depend, within the range given, on whether certain radionuclides are known to be present in concentrations less than 0.1 of their CGs, and the sum of the fractions of the CGs for all such nuclides is less than 0.25.

mCi = 3.7×10^{7} Bq.

μCi = 3.7×10^{4} Bq.

pCi = 3.7×10^{-2} Bq.

TABLE 11

1977 BNL Environmental Monitoring Total Activities and Average Concentrations of Identifiable Nuclides in Liquid Effluents

Month	Flow x 10^{10} ml	Gβ	Gβ + γ only[a]	Nuclides ^{3}H	^{7}Be	^{22}Na	^{54}Mn	^{57}Co	^{58}Co	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs
Former Perimeter (mCi)													
January	7.39	6.54	6.56	1160	b	b	0.02			0.48		0.03	b
February	6.44	1.98	2.36	2420	0.36	0.19	0.02			b	0.65	0.15	0.24
March	7.93	1.73	2.08	1910	0.23	0.11	0.12			b		0.17	0.29
April	10.76	2.65	3.00	2030	0.33	0.14	0.02			0.06		0.15	0.22
May	9.02	1.57	1.58	1650	b	0.03	0.01			b	0.32	0.21	0.24
June	6.63	1.24	1.34	410	0.09	0.02	0.01			b		0.16	0.15
July	7.72	1.72	1.73	172	b	0.02	0.01	b	b	0.05		0.19	0.25
August	8.67	1.53	1.54	521	b	0.01	0.01			0.02	0.34	0.11	0.15
September	9.61	1.96	2.11	182	0.14	0.02	0.01			b		0.19	0.37
October	8.93	*1.67	1.89	1070	0.21	0.04	0.01			b		0.10	0.20
November	7.40	3.36	3.61	254	0.23	0.24	0.02			b	0.32	0.07	0.17
December	12.50	1.81	2.02	763	0.20	0.04	0.01			b		0.12	0.26
Total	103.00	27.76	29.82	12542	1.79	0.86	0.27	b	b	0.61	1.63	1.65	2.71
Average concentration (pCi/liter or 10^{-9} μCi/ml)													
		26.95	28.95	12177	1.74	0.83	0.26	b	b	0.59	1.58	1.60	2.63
Site Boundary (mCi)													
January	1.82	1.27	2.06	81	0.77	0.54	0.02					0.08	0.08
February	3.10	0.79	1.13	490	0.34	0.11	b				0.36	b	0.15
March	5.59	1.08	1.39	798	0.29	0.11	0.02					0.11	0.26
April	11.99	4.83	6.00	1410	1.14	0.36	0.03					0.23	0.51
May	7.81	1.48	1.67	872	0.18	0.05	0.01				0.38	0.14	0.21
June	2.92	0.57	0.67	221	0.09	0.01	0.01	b	b	b		0.05	0.09
July	1.00	0.20	0.21	22	b	b	0.01					b	0.01
August	0.35	0.07	0.07	8	b	b	b				0.02	b	b
September	(0.10)	Insufficient sample for quantitative analysis											
October	2.12	0.50	0.63	268	0.12	0.01	0.01					0.03	0.05
November	4.17	1.03	1.20	175	0.16	0.06	0.01				0.33	0.03	0.07
December	13.60	4.34	4.58	742	0.23	0.06	0.01					0.07	0.07
Total	54.47	16.16	19.61	5087	3.32	1.31	0.21	b	b	b	1.09	0.74	1.60
Average concentration (pCi/liter or 10^{-9} μCi/ml)													
		29.67	36.00	9339	6.10	2.40	0.22	b	b	b	2.00	1.36	2.94
Ground Water (Stream Bed) (mCi)													
Total	50.75	13.73	14.70	6181	0.88	0.42	0.14	b	b	0.30	0.64	0.81	1.39
Average concentration (pCi/liter or 10^{-9} μCi/ml)													
		27.00	28.96	12177	1.73	0.83	0.26	b	b	0.59	1.27	1.60	2.71
Radiation Concentration[4] Guide (pCi/liter or 10^{-9} μCi/ml)			$3x10^{3c}$	$3x10^{6}$	$2x10^{6}$	$4x10^{4}$	$1x10^{5}$	$5x10^{5}$	$1x10^{5}$	$5x10^{4}$	$3x10^{2}$	$9x10^{3}$	$2x10^{4}$

a. Includes gamma (only) emitters but excludes tritium.

b. Below the Minimum Detection Limit (MDL) of the system used in estimating the activity. Other radionuclides, such as ^{51}Cr, ^{65}Zn, $^{95}ZrNb$, ^{125}Sb, ^{131}I, $^{140}BaLa$, ^{144}Ce were all below MDL.

c. For mixtures of radionuclides containing <10% ^{90}Sr, $^{125\text{-}133}I$, or long lived alpha emitters. The concentration guides for unknown mixtures depend, within the range given, on whether certain radionuclides are known to be present in concentrations less than 0.1 of their CGs, and the sum of the fractions of the CGs for all such nuclides is less than 0.25.

mCi = 3.7×10^{7} Bq.

μCi = 3.7×10^{4} Bq.

pCi = 3.7×10^{-2} Bq.

TABLE 12

1977 BNL Environmental Monitoring National Pollution Discharge Elimination System Permit
Summary of Monthly Report Data

Parameter	Status	Quantity					Concentration					Frequency of analysis	Sample type
		Minimum	Average	Maximum	Units	No. ex*	Minimum	Average	Maximum	Units	No. ex*		
Flow	Reported	0.62	0.80	1.04	MGD	0	XX	XX	XX	XX	0	Cont.	NA
	Permit condition	XX	2.3	XX		-	XX	XX	XX	XX	-	Cont.	NA
pH In flow	Reported	6.3	6.8	7.2	Std.	0	XX	XX	XX	XX	0	5/7	Grab
	Permit condition	XX	XX	XX	Units.	-	XX	XX	XX	XX	-	1/1	Grab
pH Effluent	Reported	5.5	5.9	6.2	Std.	85	XX	XX	XX	XX	0	5/7	Grab
	Permit condition	5.8	XX	9.0	Units.	-	XX	XX	XX	XX	-	1/1	Grab
BOD_5 Influent	Reported	101	126	158	kg/	-	20.9	26.0	32.6	mg/l	0	4/30	8 hr.
	Permit condition	XX	XX	XX	day	-	XX	XX	XX		-	1/30	8 hr.
BOD_5 Effluent	Reported	XX	12	17	kg/	0	2.1	3.0	4.2	mg/l	0	4/30	8 hr.
	Permit condition	XX	262	391	day	-	XX	30	45		-	1/30	8 hr.
Percent removal, BOD_5	Reported	XX	90	XX	%	2	XX	XX	XX	XX	0	XX	XX
	Permit condition	XX	85	XX		-	XX	XX	XX	XX	-	1/30	XX
Suspended solids, Influent	Reported	102	144	170	kg/	0	18.7	26.4	31.1	mg/l	0	2/30	8 hr.
	Permit condition	XX	XX	XX	day	-	XX	XX	XX		-	1/30	8 hr.
Suspended solids, Effluent	Reported	XX	4	7	kg/	0	0.3	0.8	1.4	mg/l	0	2/30	8 hr.
	Permit condition	XX	262	391	day	-	XX	30	45	mg/l	-	1/30	8 hr.
Percent removal, Suspended solids	Reported	XX	96	XX	%	0	XX	XX	XX	XX	0	XX	XX
	Permit condition	XX	85	XX		-	XX	XX	XX	XX	-	1/30	XX
Settleable solids Influent	Reported	XX	XX	XX	XX	-	0.5	1.4	2.9	ml/1	0	5/7	Grab
	Permit condition	XX	XX	XX	XX	-	XX	XX	XX		-	1/1	Grab
Settleable solids Effluent	Reported	XX	XX	XX	XX	-	0.0	0.0	0.0	ml/1	0	5/7	Grab
	Permit condition	XX	XX	XX	XX	-	XX	XX	XX		-	1/1	Grab
Residual Chlorine Effluent	Reported	XX	XX	XX	XX	-	0.6	0.9	1.2	mg/l	0	5/7	Grab
	Permit condition	XX	XX	XX	XX	-	XX	XX	XX		-	1/1	Grab
Temperature, Effluent	Reported	12	15	19	°C	-	XX	XX	XX	XX	0	5/7	Grab
	Permit condition	XX	XX	XX		-	XX	XX	XX	XX	-	1/1	Grab
Fecal coliform, Effluent	Reported	XX	XX	XX	n/100	0	0	0	0	n/100	0	4/30	Grab
	Permit condition	XX	XX	XX	ml	-	XX	200	400	ml	-	1/30	Grab

XX Indicate not required.
* Total for the year.
Data collected by R. Richards (Sewage Treatment Plant) and forwarded by H. Haller (Plant Engineering) to Safety and Environmental Protection.

TABLE 13

1977 BNL Environmental Monitoring Liquid Effluent Quality and Purity

Location*	Sample	Temperature °C	pH	Residual chlorine (ppm)	Dissolved oxygen (ppm)	Chlorides (ppm)	Nitrate** nitrogen (ppm)	Total** phosphorous (ppm)	Dissolved solids (ppm)	Conductivity (umhos/cm)	Coliform fecal (#/100 ml)	Coliform total (#/100 ml)
Sand Filter Bed Effluent (A)	Average	15	5.8+	1.5	8.7	27.6	3.3	0.69	112	163	0+	1+
	Minimum	1	4.3	0.0	6.4	21.5	1.6	0.42	90	109	0	0
	Maximum	26	6.8	1.8	12.8	38.5	5.4	0.92	137	235	53	41
	No.	249	249	250	249	53	54	54	13	249	247	245
Upstream of Outfall (E)	Average	11	6.1+	--	6.0	10.7	0.3	0.18	57	69	21+	106+
	Minimum	0	5.0	--	2.0	6.5	0.1	0.05	12	30	0	0
	Maximum	28	7.9	--	9.2	21.0	0.5	1.61	98	160	420	802
	No.	94	94	0	94	12	13	13	11	94	91	80
Former Perimeter (0.8 km) (M)	Average	16	6.0+	0.0	9.2	24.1	2.6	0.55	112	158	47+	147+
	Minimum	2	5.0	0.0	5.4	0.0	0.9	0.28	55	97	0	0
	Maximum	27	6.7	0.0	14.0	38.5	4.3	0.75	160	245	520	2000
	No.	124	124	123	124	44	43	43	9	124	119	111
BNL Perimeter (2.1 km) (Q)	Average	12	6.6+	--	8.4	23.0	1.7	0.51	125	155	67+	181+
	Minimum	0	5.3	--	0.6	15.0	0.2	0.16	90	82	0	0
	Maximum	27	7.8	--	13.4	32.8	3.1	0.93	296	270	1120	2400
	No.	148	148	0	147	52	52	53	12	148	138	100
Water Quality Standard(6, 10)		T_{max}<30 $\Delta T \leq \pm 2.8$	6.5-8.5	--	$\geq$4.0	--	--	--	--	--	--	--

* See Figure 7.
** Weekly composite samples.
\+ Geometric mean.

TABLE 14

1977 BNL Environmental Monitoring: Sump, Downstream and Control Water Samples, Water Quality-Metals

Location*	No. of Samples	Metals (in ppm) Ag	Cd	Cr	Cu	Fe	Hg	Pb	Zn
				Sump					
North of AGS (N)	1	--	0.0007	0.006	0.027	0.863	--	0.015	0.418
East of HFBR (O)	1	--	0.0004	0.006	0.0195	1.082	--	0.006	0.0345
South of MRR (P)	1	--	0.0012	0.006	0.002	0.322	--	0.006	0.03
North of LINAC (T)	1	--	0.0004	0.009	0.013	0.559	--	0.004	0.032
East of Steam Plant (U)	1	--	0.0004	0.017	0.27	2.3	--	0.548	1.10
Water Quality Standard(6)		--	0.3	--	0.4	--	--	--	0.6
				Downstream and Control (average values)					
Filter Bed Effluent (A)	12	0.0046	0.0017	0.0113	0.0905	0.1654	0.0009	0.0063	0.612
Upstream of Outfall (E)	4	0.0025	0.0002	0.0233	0.0045	2.47	--	0.006	0.0223
Former Perimeter (M)	12	0.0042	0.0014	0.0106	0.0691	0.1998	0.0005	0.0078	0.2591
A	4	0.0026	0.0006	0.0058	0.004	0.8813	--	0.0053	0.024
B	4	0.0028	0.0021	0.0095	0.0035	1.205	--	0.006	0.0145
C	4	0.0028	0.0011	0.0088	0.0033	1.237	--	0.006	0.0055
D	4	0.0028	0.0025	0.0085	0.0025	0.6557	--	0.0075	0.008
F (Control)	3	0.003	0.0013	0.0053	0.0027	1.20	--	0.0077	0.0147
H (Control)	4	0.0037	0.0012	0.0048	0.0028	0.334	--	0.0068	0.0053
I (Control)	4	0.0034	0.0011	0.0043	0.0045	0.4548	--	0.0623	0.0088
L	4	0.003	0.0017	0.0053	0.0818	0.153	--	0.007	0.223
R	3	0.003	0.0004	0.007	0.0033	0.2473	--	0.0063	0.006
Water Quality Standard(6)		0.1	0.02	0.1	0.2	0.6	--	0.1	0.3

* Figure 7 and site description on page 25 and 26

TABLE 15

1977 (September 1976-August 1977) BNL Environmental Monitoring Gross Beta, ^{3}H (HTO) and ^{90}Sr in Effluent Applied to Meadow-Marsh Experimental Plots

Month	Flow 10^{10} ml	Gross Beta* Concentration pCi/liter	Gross Beta* Total μCi	^{3}H (HTO) Concentration nCi/liter	^{3}H (HTO) Total mCi	^{90}Sr Concentration pCi/liter	^{90}Sr Total μCi
September-1976	0.38	45.1	171	2.0	8	0.83	3.15
October	0.53	26.4	140	1.3	7		
November	0.43	36.0	155	4.0	17	1.06	14.60
December	0.42	62.4	262	3.2	13		
January-1977	0.53	148.0	784	6.6	35		
February	0.26	48.8	127	19.8	51	0.57	6.90
March	0.42	93.4	392	7.6	32		
April	0.42	60.1	252	6.2	26		
May	0.28	97.0	272	5.2	15	1.10	11.33
June	0.33	34.9	115	4.7	16		
July	0.20	25.9	52	2.4	5		
August	0.18	33.0	59	2.7	5	0.89	3.38
Total	4.38	--	2781	--	230	--	39.36
Average	--	59.3	--	5.5	--	0.89	--
Radiation Concentration Guide(4)		3000**		3000		300	

* Does not include HTO.

** For mixtures of radionuclides containing ≤ 10% ^{90}Sr, $^{125\text{-}131}I$, or long lived alpha emitters.

μCi = 3.7×10^{4} Bq.

nCi = 3.7×10^{1} Bq.

pCi = 3.7×10^{-2} Bq.

TABLE 16

1977 Meadow-Marsh Project Water Quality and Purity - Average Values

Parameter	Units	Station A Sewage Influent	Station C Meadow-Marsh Effluent	Station D Marsh Effluent	Station 6D* Combined Effluent from Stations C & D	Water Quality Standard(6)
Temperature	^{o}C	--	--	--	14.97	Tmax<30**
pH		7.01	7.11	7.31	6.88	6.5-8.5**
Dissolved oxygen	ppm	--	--	--	6.87	>4.0
Chlorides	ppm	27.86	26.59	27.90	24.08	250
BOD	ppm	424.96	21.06	20.39	--	30
Total Coliform	Geometric Mean #/100 ml	210723	391	6576	668	4
Fecal Coliform	Geometric Mean #/100 ml	3181	199	306	215	4
Total Phosphorous	ppm	11.17	3.62	4.70	2.47	--
Total Nitrogen	ppm	3.44	2.19	2.18	1.85	10
MBAS	ppm	0.12	0.12	0.12	--	0.5
Dissolved Solids	ppm	379.39	180.59	192.14	199.75	500
Suspended Solids	ppm	864.33	37.37	57.63	--	30
Conductivity	µmhos/cc	335.45	296.08	319.63	246.82	--
Cadmium (Cd)	ppm	100.00	3.64	3.64	--	0.01
Chromium (Cr)	ppm	0.16	0.02	0.02	--	0.05
Copper (Cu)	ppm	1.94	0.06	0.05	--	0.40
Iron (Fe)	ppm	10.74	1.50	1.43	--	0.6
Manganese (Mn)	ppm	0.34	0.12	0.12	--	0.6
Nickel (Ni)	ppm	76.67	30.00	24.00	--	--
Zinc (Zn)	ppm	3.53	0.19	0.12	--	0.6

* 6D: Sampled and analyzed by S&EP Division.

** or natural range.

TABLE 17

1977 BNL Environmental Monitoring Downstream and Control Water Samples

Month	Downstream locations A	B	C	D	R	Control locations E	F	H
	Gross Beta (pCi/liter)							
January	--	--	--	--	--	--	--	--
February	--	--	--	--	--	--	--	--
March	9.2	9.2	5.5	4.8	3.1	7.1	6.2	5.3
April	--				7.8			
May	3.7	3.7	5.2	1.6	8.6	4.3	<0.6	0.6
June	--				12.1			
July	5.5	2.7	4.5	2.6	10.9	6.4	2.8	2.7
August	--				11.9			
September	9.2	6.1	4.5	4.3	3.1	11.9	5.4	3.8
October	--				6.3			
November	6.7	4.9	4.2	6.2	9.5	6.8	4.4	1.9
December	--				--			
Average	6.9	5.3	4.8	3.9	8.1	7.3	3.9	2.9
	Tritium (HTO) (nCi/liter)							
January	--	--	--	--	--	--	--	--
February								
March	5.2	1.9	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
April					1.2			
May	1.6	1.4	1.2	<0.6	<0.6	<0.2	1.0	0.4
June					<0.6			
July	<0.7	<0.7	<0.7	1.4	<0.2	<0.7	<0.7	<0.7
August					<0.2			
September	<0.7	<0.7	<0.7	0.7	<0.5	<0.6	<0.6	<0.7
October					4.0			
November	1.2	1.3	0.9	0.9	<0.2	0.9	0.9	0.9
December								
Average	1.9	1.2	0.8	0.8	0.9	0.6	0.8	0.6

^{90}Sr (pCi/liter)

Results of 3 samples for ^{90}Sr at location R corresponding to 3 monthly periods from April to December 1977 were 0.6, 0.5, and 0.6 pCi/liter.

Radiation Concentration Guide[4]: Gross β: 3000 pCi/liter for mixtures of radionuclides containing <10% ^{90}Sr, $^{125-133}I$ and long lived alpha emitters.
HTO: 3000 nCi/liter.
^{90}Sr: 300 pCi/liter.

nCi = 3.7×10^{1} Bq.

pCi = 3.7×10^{-2} Bq.

TABLE 18

1977 BNL Environmental Monitoring Downstream and Control Water Quality and Purity

Location*	Sample	Temperature °C	pH	Dissolved oxygen (ppm)	Chlorides (ppm)	Nitrate nitrogen (ppm)	Total phosphorous (ppm)	Dissolved solids (ppm)	Conductivity umhos/cm	Coliform fecal (#/100 ml)	Coliform total (#/100 ml)
A	Average	15	6.2	6.9	7.0	0.3	0.13	59	64	79†	266†
	Minimum	3	5.6	5.0	5.0	0.1	0.05	39	49	4	11
	Maximum	22	6.7	9.6	9.5	0.5	0.24	96	92	200	700
	No.	6	6	6	5	5	5	5	5	5	5
B	Average	16	6.2	6.3	6.8	0.3	0.12	56	60	108†	246†
	Minimum	3	5.8	3.4	6.0	0.1	0.05	36	52	2	2
	Maximum	22	6.7	8.0	9.0	0.4	0.21	88	78	280	800
	No.	6	6	6	5	4	5	5	5	5	5
C	Average	16	6.7	8.7	7.0	0.3	0.08	34	46	74†	251†
	Minimum	3	6.4	6.4	5.5	0.1	0.05	16	5	1	4
	Maximum	25	7.2	11.2	9.0	0.8	0.19	40	60	340	900
	No.	5	5	5	4	5	5	5	5	5	4
D	Average	17	7.0	8.9	8.4	0.2	0.05	40	65	156†	366†
	Minimum	4	6.2	7.4	5.5	0.1	0.05	10	59	8	8
	Maximum	26	8.0	10.6	11.5	0.4	0.07	54	74	362	800
	No.	5	5	5	5	5	5	5	5	5	4
E	See Table 13										
F	Average	15	6.0	7.3	5.6	0.2	0.05	36	42	110†	269†
	Minimum	3	5.3	5.2	3.5	0.1	0.05	9	38	0	0
	Maximum	28	6.7	9.6	8.0	0.4	0.05	48	53	400	1000
	No.	4	4	4	4	4	4	4	4	4	4
H	Average	16	6.9	9.7	8.0	0.5	0.05	48	89	197†	301†
	Minimum	2	6.5	7.2	7.5	0.1	0.05	13	82	22	3
	Maximum	24	7.3	13.0	9.0	1.0	0.05	63	99	380	700
	No.	5	5	5	5	5	5	5	5	4	3
I	Average	17	7.1	9.1	26.5	0.2	0.05	60	115	226†	316†
	Minimum	3	6.8	6.6	25.0	0.1	0.05	15	90	3	17
	Maximum	26	7.3	12.4	30.0	0.3	0.05	83	124	560	900
	No.	5	5	5	5	5	5	5	5	5	4
L	Average	15	5.8	8.8	25.2	5.8	0.50	179	209	0†	0†
	Minimum	9	5.0	7.5	18.0	3.1	0.05	106	156	0	0
	Maximum	21	6.3	10.0	28.5	13.2	0.82	348	320	0	0
	No.	4	4	4	4	4	4	4	4	4	4
R**	Average	18	6.7	9.2	12.5	0.2	0.18	67	90	112†	341†
	Minimum	3	6.2	7.5	10.0	0.1	0.05	49	55	0	0
	Maximum	26	7.6	11.4	17.5	0.5	0.87	96	110	840	2000
	No.	18	18	18	10	10	10	9	18	17	14
Water Quality Standards(6, 10)		Tmax<30	6.5-8.5	≥4.0	--	--	--	--	--	--	--

* See Figure 7 and Site description on page 25 and 26.

** Continuous biweekly sampling.

† Geometric mean.

TABLE 19

Concentrations of Cesium-137 (^{137}Cs) and Potassium-40 (^{40}K) in Water, Sediment, Vegetation and Animals obtained from the Peconic River

Station and distance from head of river	Radio-nuclide	Water (pCi/ml)	Sediment 0.25 cm	Vegetation			Fish						Mussel
				Vallisneria americana (Tape grass)	Potamogeton sp (Pond weed)	Ceratophyllum deomersum (Coontail)	Esox americanus (Pickerel)	Heliopera macrochirn (Sunfish)	Micropterus salmoides (Bass)	Ameriurus nebulosus (Bullhead)	Notropis bifrenatus (Shiner)	Enneacanthus obesus (Pumpkin seed)	
				pCi/g. wet									
J-head	^{137}Cs	--	0.08	--	--	--	--	--	--	--	--	--	--
waters (0km)	^{40}K	--	1.62	--	--	--	--	--	--	--	--	--	--
K	^{137}Cs	.004	0.81	--.	--	--	--	--	--	--	--	--	--
(.045km)	^{40}K	<MDL	3.62	--	--	--	--	--	--	--	--	--	--
L	^{137}Cs	--	0.54	--	--	--	--	--	--	--	--	--	--
(.106km)	^{40}K	--	1.96	--	--	--	--	--	--	--	--	--	--
M	^{137}Cs	.003	1.15	0.22	--	--	--	--	--	--	--	--	--
(.798km)	^{40}K	<MDL	3.64	3.81	--	--	--	--	--	--	--	--	--
Q	^{137}Cs	.003	2.07	--	1.88	--	7.10	8.50	6.20	1.93	5.75	4.42	--
(2.11km)	^{40}K	<MDL	2.00	--	4.34	--	4.10	3.69	5.13	2.45	4.09	6.18	--
A	^{137}Cs	--	1.11	--	1.56	--	--	--	--	--	--	--	--
(4.85km)	^{40}K	--	1.54	--	5.45	--	--	--	--	--	--	--	--
S	^{137}Cs	--	1.65	--	--	--	--	--	--	--	--	--	--
(7.05km)	^{40}K	--	2.62	--	--	--	--	--	--	--	--	--	--
T	^{137}Cs	--	0.08	0.05	0.57	--	--	--	--	--	--	--	0.09
(10.82km)	^{40}K	--	1.76	7.06	2.19	1.93	--	--	--	--	--	--	--
U	^{137}Cs	--	0.95	0.02	--	0.23	--	--	--	--	--	--	--
(14.23km)	^{40}K	--	1.49	1.81	--	1.37	--	--	--	--	--	--	--
W	^{137}Cs	--	<MDL	--	--	--	--	--	--	--	--	--	0.14
(18.18km)	^{40}K	--	1.90	--	--	--	--	--	--	--	--	--	0.54
Y	^{137}Cs	--	<MDL	<MDL		0.05	--	--	--	--	--	--	--
(22.35km)	^{40}K	--	1.48	4.90	--	2.58	--	--	--	--	--	--	--

MDL Minimum Detection Limit (MDL)

-- Not done or sample not present

pCi = 3.7×10^{-2} Bq.

TABLE 20

1977 BNL Environmental Monitoring Gross Beta and Tritium Concentrations
in Potable Water and Cooling Water Supply Wells

Month	Wells									
	1	2	3	4	5	6	7	101	102	104
Gross Beta (pCi/liter)										
January	<1.4	--	6.3	2.4	--	--				
April	<1.4		10.2	<1.5	--	--				4.6
July	4.9	1.6	11.1	2.1	1.1	5.0	1.4	1.9	1.4	2.0
October	1.8	--	8.8	1.9	--	--				
Radiation Concentration Guide[4]:	3000 pCi/liter for unidentified nuclides in the absence of ^{90}Sr, ^{228}Ra, or ^{129}I.									
Tritium Concentration (nCi/liter)										
January	<0.41		<0.42	<0.41		--	--			
April	<0.18		0.38	<0.18		--	--			<0.18
July	--	<0.15	0.2	<0.15	<0.18	<0.18	<0.18	<0.18	<0.18	<0.25
October	0.3		<0.41	<0.16		--	--			
Radiation Concentration Guide[4]:	3000 nCi/liter									

nCi = 3.7×10^{1} Bq.

pCi = 3.7×10^{-2} Bq.

TABLE 21

1977 BNL Environmental Monitoring Monthly Sump Samples
Gross Beta and ^{3}H (HTO) Concentrations

	N			O			P			U			T		
	North of AGS			East of HIRDL			Medical			East of Steam Plant			Linac		
Month	No. Samples	Gross β pCi/liter	HTO nCi/liter	No. Samples	Gross β pCi/liter	HTO nCi/liter	No. Samples	Gross β pCi/liter	HTO nCi/liter	No. Samples	Gross β pCi/liter	HTO nCi/liter	No. Samples	Gross β pCi/liter	HTO nCi/liter
January	4	30.8	<0.5	4	4.4	0.6	--	--	--	4	12.0	0.6	4	137.9	0.5
February	4	7.4	<0.5	4	6.1	<0.5	--	--	--	4	18.4	0.5	5	3.9	0.5
March	4	4.8	0.6	4	5.9	0.6	--	--	--	4	16.5	0.6	4	11.4	0.6
April	5	4.5	0.6	5	3.9	0.6	4	5.6	0.6	5	13.9	0.6	5	3.0	0.7
May	4	5.3	1.1	4	4.0	1.1	4	4.1	1.1	4	13.9	1.1	4	2.0	1.1
June	4	7.5	0.8	4	4.8	1.2	4	1.7	1.4	4	12.5	1.2	4	3.0	1.7
July	5	9.2	1.1	5	4.8	1.0	5	2.8	1.0	5	15.7	0.9	5	2.5	1.0
August	4	1.9	16.1	4	8.3	4.8	4	3.7	5.1	4	31.3	1.3	4	6.6	1.7
September	4	8.3	0.7	4	3.4	0.8	4	2.5	0.7	4	9.1	0.8	4	2.7	0.7
October	4	2.7	0.9	4	4.1	0.8	4	2.9	1.0	4	21.0	1.1	4	109.1	0.8
November	3	6.1	0.9	3	6.5	0.9	3	5.8	1.0	3	74.3	1.0	3	6.8	0.9
December	5	1.4	0.9	5	3.1	0.9	4	2.0	0.8	5	10.4	0.9	5	2.4	0.9
Total	50			50			36			51			51		
Average		11.9	2.0		4.9	1.1		3.4	1.4		19.2	0.9		22.9	0.9

Radiation Concentration Guide[4] Gross β 3000 pCi/liter
HTO 3000 nCi/liter

nCi = 3.7×10^{1} Bq.

pCi = 3.7×10^{-2} Bq.

TABLE 22

1977 BNL Environmental Monitoring Recharge Basin Water Quality and Purity

Location*	Sample	Temperature °C	pH	Dissolved oxygen (ppm)	Chlorides (ppm)	Nitrate nitrogen (ppm)	Total phosphorous (ppm)	Dissolved solids (ppm)	Conductivity μmhos/cm	Coliform fecal (#/100 ml)	Coliform total (#/100 ml)
North of AGS (N)	Average	16	6.7	9.8	16.5	0.3	0.62	81	108	11†	51†
	Minimum	8	6.0	8.0	13.5	0.1	0.05	63	66	0	0
	Maximum	23	7.6	11.4	19.5	0.5	0.99	101	197	62	216
	No.	50	50	50	12	12	12	10	50	12	12
East of HFBR (O)	Average	16	6.8	9.6	20.0	0.5	1.06	83	118	2†	69†
	Minimum	11	5.6	8.4	11.5	0.1	0.05	71	80	0	0
	Maximum	25	8.5	11.6	39.5	0.9	3.22	102	185	18	620
	No.	51	51	51	17	17	17	13	51	13	13
South of MRR (P)	Average	14	7.1	6.2	28.1	1.4	0.06	115	170	0†	3†
	Minimum	12	6.1	5.0	25.5	1.2	0.05	109	160	0	0
	Maximum	20	9.0	11.2	32.0	1.7	0.09	124	190	0	20
	No.	36	36	36	9	8	8	9	36	8	8
South of Warehouse (S)	Average	17	6.8	9.4	21.6	0.6	0.21	92	136	60†	94†
	Minimum	2	5.6	6.6	2.0	0.1	0.05	80	63	0	0
	Maximum	32	8.0	13.0	129.5	2.0	2.59	128	410	548	892
	No.	48	48	48	47	48	48	10	48	45	43
North of LINAC (T)	Average	16	6.9	9.5	16.2	0.3	0.05	86	272	0†	0†
	Minimum	11	6.4	8.2	13.0	0.1	0.03	71	105	0	0
	Maximum	21	8.0	10.6	18.0	0.6	0.05	96	4000	0	0
	No.	25	25	25	6	6	5	5	25	6	6
East of Steam Plant (U)	Average	21	8.4	6.0	774.0	0.8	0.19	1354	1174	0†	2†
	Minimum	16	6.4	3.6	25.5	0.3	0.17	114	114	0	0
	Maximum	26	10.5	8.8	2240**	1.8	0.20	3655**	6190**	0	4
	No.	12	12	12	3	3	2	3	12	1	2
Water Quality Standard(6)		--	6.5-8.5	--	500	20.0	--	1000	--	--	--

* See Figure 9.

** Corresponds to time when ion-exchange resins used in the steam plant for purifying water were being recharged.

† Geometric mean.

TABLE 23

1977 Environmental Monitoring Sand Filter Bed, Peconic River Area, and Miscellaneous On-Site Surveillance Wells Gross Alpha, Gross Beta, Tritium (HTO), ^{90}Sr and ^{137}Cs Average Concentrations

Well	No. Samples	Gross α pCi/liter	Gross β pCi/liter	HTO nCi/liter	^{90}Sr* pCi/liter	^{137}Cs pCi/liter	^{22}Na pCi/liter	^{58}Co pCi/liter	^{60}Co pCi/liter
				Sand Filter Bed and Peconic River Area					
XA	3	0.85±0.36	16.6±1.0	4.3±0.3	4.1±0.2(2)		14.9±0.3	1.2±0.4	1.1±0.3
XB	3	0.39±0.25	2.7±0.7	0.3±0.2	--				
XC	2	0.48±0.33	6.2±0.8	<0.2	--				
XD	2	0.36±0.30	1.2±0.9	0.4±0.3	--				
XE	1	<1.3	1.8±1.0	<0.2	--				
XF	1	<0.3	<1.7	<0.2	--				
XG	5	0.7± 0.3	9.1±0.6	3.2±0.2	1.9±0.2(2)				
XH	1	<0.7	<0.7	<0.8	--				
XJ	1	<0.6	4.2±0.9	<0.6	--				
XK	4	1.2±0.4	11.7±0.8	4.2±0.2	3.1±0.2	0.8±0.4		0.3±0.1	
XL	2	1.5±0.8	22.2±2.0	4.4±0.4	4.7±0.3				
XM	4	1.1±0.4	18.7±0.8	15.3±0.3	2.1±0.2(2)			0.6±0.2	
XN	2	3.3±0.9	9.1±1.6	0.4±0.3	1.2±0.2				
XO	2	0.48±0.4	4.9±0.8	<0.3	1.7±0.2				
XQ	3	0.9±0.6	9.1±0.8	5.7±0.3	1.7±0.2(2)				
XR	2	1.5±1.0	5.6±0.8	0.4±0.3	1.0±0.2				
XS	2	2.0±0.9	9.9±1.0	<0.2	3.0±0.2(2)				
XT	1	<0.6	1.0±0.7	<0.6	--				
XU	1	<0.7	2.2±0.7	<0.8	--				
XV	1	<0.7	30.2±1.9	<0.8	0.2±0.1				
XW	2	0.77±0.47	2.8±0.8	0.6±0.4	0.4±0.1				
XX	2	1.1±0.48	13.1±1.1	3.4±0.5	5.3±0.3		0.5±0.3		0.2±0.1
XY	2	0.58±0.36	7.2±0.9	2.9±0.3	1.9±0.2				
XZ	2	0.34±	1.1±0.7	<0.3	--				
X1	1	<0.6	2.0±0.7	<0.6	--				
X2	2	<0.3	2.2±0.8	4.7±0.2	0.1±0.1				
X3	2	0.5±0.3	3.4±0.7	<0.5	--				
				Miscellaneous On Site					
16	3	0.9±0.6	4.6±0.9	4.3±0.2					
17	1	<0.3	2.2±1.1	<0.2					
2E	2	1.7±1.0	8.5±1.1	<0.2					
2F	2	1.1±0.5	3.5±0.7	0.4±0.3					
2G	2	2.0±0.5	49.0±1.7	0.5±0.4					
SA	2	0.5±0.2	5.2±0.9	0.3±0.2					
SB	1	<1.5	2.1±1.1	<0.2	<0.1				
SC	1	<0.2	<1.4	<0.2	<0.1				
SD	1	<1.5	<1.6	<0.2					
SE	2	0.4±0.2	1.7±0.9	1.4±0.2					
SG	2	1.0±0.8	3.5±0.9	0.9±0.1					
SI	2	2.5±0.7	27.3±1.5	<0.2					
Radiation Concentration Guide(4)		100**	3000+	3000	300	$2x10^4$	$4x10^4$	$1x10^5$	$5x10^4$

*^{90}Sr concentrations established from assay of one sample except in cases where the number is indicated within brackets.

**If ^{226}Ra and ^{220}Ra <10% activity.

+ If $^{125-133}I$ and ^{90}Sr not present.

16, 17, 2E, 2F, 2G, SI not indicated in Figure 10.

nCi = 3.7×10^1 Bq.

pCi = 3.7×10^{-2} Bq.

TABLE 24

1977 Environmental Monitoring Waste Management, Landfill, Former Dump and 650 Area Surveillance Wells Gross Alpha, Gross Beta, Tritium (HTO), ^{90}Sr and ^{137}Cs Average Concentrations

Well	No. Samples	Gross α pCi/liter	Gross β pCi/liter	HTO nCi/liter	^{90}Sr*	^{137}Cs	^{22}Na	^{58}Co	^{60}Co	^{7}Be
					<- - - - - - - pCi/liter - - - - - - - - ->					
				Waste Management Area						
18	2	<1.0	5.3±0.9	0.4±0.3						
19	2	1.2±0.8	2.5±0.8	<0.2						
WB	2	1.1±0.4	32.2±1.4	1.3±0.4	30.6±0.7	2.1±1.3			1.8±0.3	
WC	2	0.4±0.3	14.5±1.0	2.0±0.4	2.5±0.3					
WD	2	0.4±0.3	37.8±1.5	6.4±0.4	13.4±0.5					
WE	2	0.4±0.3	5.8±0.7	0.6±0.3	3.1±0.3					
WI	1	<0.6	7.5±1.0	<0.6						
WJ	1	0.6±0.5	7.3±1.0	<0.6	0.6±0.2					
WK	2	2.0±0.5	210.4±3.4	6.6±0.4	97.1±1.1					
WL	2	1.2±0.4	101.5±2.4	0.7±0.3	62.1±0.9					
WM	2	3.2±0.6	62.9±2.1	1.7±0.4	2.8±0.5					
WN	2	0.4±0.3	3.9±0.8	0.4±0.3	0.3±0.1					
WU	1	<1.7	3.1±1.1	<0.6						
WV	1	<1.6	3.2±1.0	<0.6						
WW	1	<1.6	2.9±1.0	<0.6						
WX	1	<1.6	1.9±1.0	<0.6						
WZ	2	0.8±0.6	4.4±0.9	0.4±0.2	10.9±0.4					
W1	2	1.3±0.9	35.8±1.6	0.6±0.4	16.1±0.5					
W3	1	<0.3	<1.7	<0.4	<0.9					
W4	1	0.4±0.3	6.1±1.3	<0.4	<0.9					
W5	1	0.4±0.3	8.0±1.4	<0.4	<0.9					
W7	1	<0.3	<1.3	<0.4	<0.9					
W8	1	<0.4	7.6±1.4	<0.4						
				Land Fill Area						
2A	1	<1.7	1.3±0.9	<0.6						
2B	2	0.9±0.6	3.6±0.7	0.4±0.3						
2C	2	8.5±3.2	130.8±5.7	117.5±1.1	7.4±0.3		0.5±0.3	0.4±0.2		3.2±8.1
2D	2	7.1±3.8	21.9±1.3	4.6±0.4	1.5±0.2				0.5±0.2	
WF	2	0.4±0.3	2.0±0.9	6.8±0.3	0.3±0.1					
WG	2	0.4±0.3	2.9±0.7	0.3±0.2	<0.1					
WR	4	6.2±2.3	82.7±3.9	18.6±0.4	4.0±0.2(2)		3.0±0.2			11.4±1.5
WS	4	5.4±2.1	76.6±3.6	735.5±2.9	3.7±0.2		3.4±0.4	0.9±0.4		56.2±3.1
WT	1	0.7±0.4	4.4±1.3	<0.2	0.3±0.1					
W6	1	<0.4	3.3±1.4	<0.4	0.2±0.1					
W9	4	18.0±0.8	102.1±4.8	65.9±0.7	8.1±0.3(2)		1.0±0.3	0.6±0.2	0.5±0.3	
1K	2	10.1±2.5	62.2±5.8	34.9±0.4						
				Former Dump Area						
WH	2	1.1±0.9	3.1±1.0	<0.2	0.3±0.1					
WO	2	0.9±0.4	1.4±0.8	0.4±0.3						
WP	2	1.2±0.5	2.4±0.7	2.9±0.3	0.4±0.1					
WQ	2	0.7±0.5	1.2±0.9	0.4±0.3						
1I	2	0.8±0.6	3.0±0.8	<0.2	<0.1					
1J	2	<0.7	1.6±1.1	<0.2	<0.1					
				650 Sump Area						
1A	2	1.2±0.8	27.6±1.5	0.3±0.2	16.9±0.5		0.4±0.2	0.7±0.2	0.4±0.2	
1C	1	0.6±0.4	8.4±1.5	0.4±0.2						
1D	1	<0.3	3.2±1.3	<0.2						
1E	2	1.9±0.8	60.4±1.9	<0.2	18.1±0.5					
1F	1	<0.3	<1.8	<0.2						
1H	2	24.3±0.8	66.5±2.0	0.3±0.2	29.5±0.8					
1T	1	<1.5	2.8±1.1	<0.2	3.2±0.5					
Radiation Concentration Guide(4)		100**	3000+	3000	300	$2x10^4$	$4x10^4$	$1x10^5$	$5x10^4$	$2x10^6$

*^{90}Sr concentration established from assay of one sample except in cases where the number is indicated within brackets.

**If ^{226}Ra and ^{220}Ra <10% activity.

+ If $^{125\text{-}133}I$ and ^{90}Sr not present.

nCi = 3.7×10^{1} Bq.

pCi = 3.7×10^{-2} Bq.

2A, 2B, 2C, 2D, 18, 19 not indicated in Figure 11.

TABLE 25

1977 BNL Environmental Monitoring Sand Filter Beds, Peconic River and Miscellaneous On-Site Groundwater Surveillance Wells, Water Quality and Purity
(Average Values)

Well Location*	No. of Samples	Temperature °C	pH	Dissolved oxygen (ppm)	Chlorides (ppm)	Nitrate nitrogen (ppm)	Total phosphorous (ppm)	Dissolved solids (ppm)	Conductivity µmho/cm
				Sand Filter Bed and Peconic River Area					
XA	3	19	5.9	6.8	22.2	3.7	0.06	122	162
XB	3	11	6.5	7.8	5.8	0.1	0.05	45	63
XC	2	11	5.5	2.8	3.8	0.1	0.05	38	51
XD	2	12	6.1	4.8	4.3	0.3	0.05	43	39
XE	1	12	5.2	6.4	9.6	0.1	0.05	40	50
XF	1	12	6.4	8.2	6.0	0.1	0.05	64	64
XG	4	12	5.9	6.9	14.3	0.2	0.10	54	103
XH	1	10	5.7	5.4	5.0	0.1	0.05	32	39
XJ	1	9	5.3	2.2	5.0	0.1	0.05	23	37
XK	4	12	6.0	1.9	25.3	0.1	0.12	129	155
XL	2	13	6.4	2.9	26.3	0.1	0.08	113	157
XM	4	13	6.0	8.7	26.4	2.9	0.08	110	161
XN	2	9	4.8	1.6	60.7	0.6	0.05	78	70
XO	2	11	5.7	5.0	6.3	0.1	0.06	42	47
XQ	4	13	6.2	1.8	26.1	0.1	0.07	100	159
XR	2	11	5.8	6.5	4.0	0.2	0.28	30	37
XS	2	12	5.5	8.4	9.5	0.4	0.05	66	94
XT	1	10	6.7	2.2	5.5	0.2	0.36	54	80
XU	1	10	5.3	6.0	6.9	0.1	0.05	22	50
XV	2	11	5.8	5.2	18.6	1.7	0.05	99	156
XW	1	12	5.7	7.8	27.3	0.1	0.05	77	121
XX	2	14	5.6	1.5	21.0	0.2	0.05	72	120
XY	2	13	5.4	1.9	12.2	0.2	0.08	54	79
XZ	2	11	6.5	6.9	3.3	1.2	0.05	37	43
X1	1	10	5.1	4.2	4.0	0.2	0.05	22	36
X2	2	12	5.5	1.4	23.0	0.1	0.06	83	113
X3	2	12	4.9	1.9	6.5	0.1	0.05	34	58
				Miscellaneous On-Site Wells					
SA	2	13	5.7	2.7	27.5	0.6	0.05	87	130
SB	1	10	5.2	7.8	6.5	0.1	0.10	36	48
SC	1	11	5.4	8.0	11.0	0.1	0.05	38	51
SD	1	10	6.4	10.0	6.0	0.1	0.06	32	42
SE	2	15	6.6	8.3	27.0	1.2	0.05	119	173
SG	2	12	6.0	6.9	32.3	0.1	0.08	99	160
SI	2	13	5.7	9.7	30.0	0.5	0.06	100	152
16	2	10	5.4	5.0	23.0	3.6	0.06	114	169
17	2	11	5.8	9.3	3.3	0.6	0.06	22	34
2E	2	12	6.0	6.5	16.0	0.1	0.09	149	230
2F	2	16	6.3	8.3	16.8	0.3	0.05	82	109
2G	2	10	6.2	6.8	23.0	0.4	0.05	62	96
Water Quality Standards[6]		Tmax<30	6.5-8.5**	≥4.0	500	20		1000	

* See Figure 10.

** or natural background range.

NOTE: All samples were analyzed for fecal and total coliforms.
All results were less than 1 colony/100 ml.
16, 17, 2E, 2F, 2G, SI not indicated.

TABLE 26

1977 BNL Environmental Monitoring Solid Waste Management Area, Landfill and Dump Area, and 650 Sump Area Groundwater Wells, Water Quality and Purity (Average Values)

Well Location *	No. of Samples	Temperature °C	pH	Dissolved oxygen (ppm)	Chlorides (ppm)	Nitrate nitrogen (ppm)	Total phosphorous (ppm)	Dissolved solids (ppm)	Conductivity µmho/cm
				Solid Waste Management Area					
WB	2	15	6.0	7.1	5.0	0.3	0.05	43	64
WC	2	13	5.2	6.4	6.5	0.7	0.05	57	68
WD	2	12	5.5	8.9	5.8	1.4	0.05	87	119
WE	2	12	5.5	8.9	4.0	0.1	0.06	33	42
WI	1	12	5.6	6.4	4.5	0.1	0.05	46	58
WJ	1	11	5.2	7.2	7.0	0.3	0.05	52	69
WK	2	12	5.9	8.0	7.0	0.8	0.05	77	90
WL	2	12	5.8	9.0	4.5	0.8	0.05	51	68
WM	2	12	6.1	5.3	6.8	0.6	0.05	82	113
WN	2	12	6.0	6.5	10.5	0.2	0.05	90	111
WV	2	11	5.3	7.6	4.5	0.2	0.08	30	44
WW	1	10	5.2	8.2	11.0	0.1	0.05	56	87
WX	1	8	5.5	7.2	5.5	0.1	0.05	45	71
WZ	2	12	6.4	7.1	9.0	0.2	0.06	53	93
W1	2	12	5.8	8.5	10.7	0.2	0.05	75	88
W3	1	10	6.4	6.6	5.0	0.9	0.05	63	92
W4	1	10	5.9	9.0	2.0	0.4	0.05	34	41
W5	1	10	5.5	9.0	5.0	0.3	0.05	45	53
W6	2	10	6.2	5.6	8.5	0.2	0.05	135	139
W7	1	10	6.1	6.0	6.5	0.6	0.05	58	104
18	2	11	5.2	9.1	3.8	0.1	0.05	56	86
19	2	11	5.4	9.8	5.8	0.1	0.06	49	62
				Landfill Area					
WF	2	12	5.8	8.3	6.8	0.4	0.05	46	59
WG	2	13	5.7	7.7	5.0	0.3	0.05	33	43
WR	3	15	6.6	2.3	2.8	0.3	0.36	492	973
WS	4	12	6.8	1.8	2.2	0.2	0.06	393	805
WT	1	12	6.4	2.0	14.0	0.1	0.05	--	84
W9	4	12	6.5	2.1	4.0	0.3	0.18	612	1140
1K	2	14	6.5	2.0	7.0	0.5	0.05	477	960
2A	1	11	6.7	8.6	6.5	0.1	0.05	34	57
2B	2	11	5.7	9.5	9.0	0.1	0.05	53	68
2C	2	13	6.9	1.3	8.0	0.5	0.06	856	1316
2D	2	13	6.4	1.3	42.0	0.1	0.05	287	566
				Former Dump Area					
WH	2	12	5.9	8.3	17.5	0.7	0.08	80	129
WO	2	12	6.0	10.9	8.7	0.3	0.06	56	61
WP	2	13	5.2	3.0	7.0	2.6	0.11	74	79
WQ	2	12	5.6	9.9	7.2	0.2	0.09	46	57
1I	2	11	5.3	8.0	6.3	0.1	0.06	57	61
1J	2	11	5.7	11.1	4.8	0.1	0.05	40	39
				Building 650 Sump Area					
1A	2	16	6.1	6.2	14.8	0.8	0.14	77	109
1C	1	16	6.5	7.2	6.5	7.9	0.14	65	80
1D	1	17	6.5	6.0	16.0	0.5	0.05	91	113
1E	2	14	6.1	7.3	17.0	0.9	0.06	52	86
1F	1	16	7.6	7.6	20.0	0.4	0.05	82	118
1G	1	17	6.5	6.6	7.5	7.5	0.23	68	80
1H	2	14	6.0	6.5	5.8	1.3	0.05	56	89
Water Quality Standard[6]		Tmax<30	6.5-8.5**	≥4.0	500	20	--	1000	--

* See Figure 10.

** or natural background range.

NOTE: All samples analyzed for fecal and total coliforms.
All results were less than 1 colony/100 ml.
2A, 2B, 2C, 2D, 18, 19 not indicated.

TABLE 27

1977 BNL Environmental Monitoring Potable Water and Cooling Water Supply Wells and Tap Water, Water Quality and Purity

Well Location*	Sample	Temperature °C	pH	Dissolved oxygen (ppm)	Chlorides (ppm)	Nitrate nitrogen (ppm)	Total phosphorous (ppm)	Dissolved Solids (ppm)	Conductivity μmho/cm	Coliform† fecal (#/100 ml)	Coliform† total (#/100 ml)
					Potable Supply Wells						
1	Average	13	6.0	9.8	19.0	0.9	0.07	82	120	0	0
(FA)	Minimum	12	5.6	9.4	18.5	0.8	0.05	73	116	0	0
	Maximum	13	6.2	10.2	20.0	1.0	0.10	90	124	0	0
	No.	4	4	3	4	4	4	4	4	3	4
2	Average	13	6.7	10.0	14.1	0.2	0.06	70	106	0	0
(FB)	Minimum	13	6.7	10.0	14.1	0.2	0.06	70	106	0	0
	Maximum	13	6.7	10.0	14.1	0.2	0.06	70	106	0	0
	No.	1	1	1	1	1	1	1	1	1	1
3	Average	16	6.2	8.3	17.0	0.2	0.15	77	110	0	0
(FC)	Minimum	15	5.8	8.0	16.0	0.1	0.05	70	100	0	0
	Maximum	16	6.6	8.6	19.5	0.5	0.25	97	122	0	0
	No.	4	4	4	4	4	4	4	4	4	4
4	Average	11	6.1	7.6	17.6	0.3	0.12	75	108	0	0
(FD)	Minimum	11	5.7	7.0	14.6	0.1	0.05	63	97	0	0
	Maximum	11	6.4	8.0	20.5	0.4	0.21	86	118	0	0
	No.	3	4	4	4	4	4	4	4	4	4
5	Average	12	6.3	12.0	5.0	0.3	0.05	40	46	0	0
(FE)	Minimum	12	6.3	12.0	5.0	0.3	0.05	40	46	0	0
	Maximum	12	6.3	12.0	5.0	0.3	0.05	40	46	0	0
	No.	1	1	1	1	1	1	1	1	1	1
6	Average	12	6.1	8.4	24.5	0.9	0.05	105	146	0	0
(FF)	Minimum	12	6.1	8.4	24.5	0.9	0.05	105	146	0	0
	Maximum	12	6.1	8.4	24.5	0.9	0.05	105	146	0	0
	No.	1	1	1	1	1	1	1	1	1	1
7	Average	11	6.2	7.8	12.0	0.1	0.05	64	74	0	0
(FG)	Minimum	11	6.2	7.8	12.0	0.1	0.05	64	74	0	0
	Maximum	11	6.2	7.8	12.0	0.1	0.05	64	74	0	0
	No.	1	1	1	1	1	1	1	1	1	1
					Cooling Water Wells						
101	Average	13	5.8	7.0	2.4	0.2	--	74	89	0	20
(FH)	Minimum	13	5.8	7.0	2.4	0.2	--	74	89	0	20
	Maximum	13	5.8	7.0	2.4	0.2	--	74	89	0	20
	No.	1	1	1	1	1	0	1	1	1	1
102	Average	12	6.3	7.2	12.0	0.1	2.01	78	79	0	1
(FI)	Minimum	12	6.3	7.2	12.0	0.1	2.01	78	79	0	1
	Maximum	12	6.3	7.2	12.0	0.1	2.01	78	79	0	1
	No.	1	1	1	1	1	1	1	1	1	1
103	Average	12	6.2	4.2	14.0	0.3	1.97	80	84	0	4
(FJ)	Minimum	12	6.2	4.2	14.0	0.3	1.97	80	84	0	4
	Maximum	12	6.2	4.2	14.0	0.3	1.97	80	84	0	4
	No.	1	1	1	1	1	1	1	1	1	1
104	Average	14	6.3	5.3	23.8	1.1	0.15	110	165	0	0
(FK)	Minimum	13	5.9	5.2	22.1	1.1	0.12	108	157	0	0
	Maximum	14	6.7	5.4	25.5	1.2	0.18	111	172	0	0
	No.	2	2	2	2	2	2	2	2	2	2
105	Average	13	6.0	7.9	30.6	1.5	0.09	112	180	0	0
(FL)	Minimum	13	5.7	7.8	30.2	1.3	0.06	104	174	0	0
	Maximum	13	6.3	8.0	31.0	1.6	0.12	120	185	0	0
	No.	2	2	2	2	2	2	2	2	2	2
					Tap Water						
Tap Water	Average	--	--	--	17.3	0.5	0.08	80	--	--	--
(Bldg. 535)	Minimum	--	--	--	12.5	0.0	0.05	71	--	--	--
	Maximum	--	--	--	21.0	1.0	0.50	93	--	--	--
	No.	0	0	0	52	52	52	12	0	0	0
Water Quality Standards[6]		Tmax<30	6.5-8.5	≥4.0	500	20	--	1000	--	Zero/100ml	--

* See Figure 7.

† Coliform average - Geometric mean.

** or natural background range.

TABLE 28

1977 BNL Environmental Monitoring Groundwater Surveillance Wells
Water Quality-Metals

Location*	No. of Samples	Metals (in ppm) Ag	Cd	Cr	Cu	Fe	Pb	Zn
		Sand Filter Beds and Peconic River Area						
XA	1	0.003	0.003	0.009	0.005	0.21	0.005	0.295
XB	1	0.003	0.003	0.007	0.006	1.13	0.005	4.98
XK	1	0.003	0.003	0.006	0.004	1.96	0.005	1.32
XL	1	0.003	0.003	0.005	0.003	1.63	0.005	0.79
XM	1	0.003	0.003	0.005	0.024	0.49	0.005	0.95
XN	1	0.003	0.003	0.017	0.009	3.41	0.005	0.94
XQ	1	0.003	0.003	0.005	0.003	2.21	0.005	0.300
XS	1	0.001	0.0005	0.002	0.011	3.68	0.005	0.288
XW	1	0.003	0.003	0.040	0.01	1.28	0.022	0.43
XX	1	0.003	0.003	0.018	0.004	6.13	0.005	0.31
X3	1	0.001	0.0005	0.002	0.005	0.158	0.005	0.021
		Miscellaneous on Site						
SA	1	0.001	0.0012	0.008	0.006	0.135	0.005	1.11
SE	1	0.005	0.0008	0.006	0.022	1.141	0.009	0.149
SI	1	0.001	0.0084	0.002	0.017	6.03	0.005	0.032
16	1	0.001	0.0005	0.008	0.005	0.243	0.210	0.044
17	1	0.001	0.0005	0.004	0.004	0.064	0.048	0.043
2E	1	0.001	0.0005	0.007	0.006	2.07	0.04	0.036
2F	1	0.001	0.008	0.002	0.007	1.82	0.005	0.009
2G	1	0.001	0.0005	0.007	0.002	0.09	0.046	0.007
		Solid Waste Management Area						
WB	1	0.003	0.003	0.005	0.005	0.075	0.013	0.774
WE	1	--	0.0009	0.006	0.006	0.133	0.011	0.796
WK	1	0.005	0.0005	0.006	0.006	0.1	0.009	0.359
WN	1	0.005	0.0005	0.006	0.006	0.291	0.018	0.137
W3	1	0.001	0.0006	0.002	0.013	0.070	0.024	0.732
W4	1	0.001	0.0005	0.002	0.006	0.024	0.022	0.636
18	1	0.001	0.0005	0.006	0.005	0.677	0.065	0.03
19	1	0.001	0.001	0.004	0.009	0.128	0.073	0.038
		Lanfilll Area						
WF	1	--	0.0005	0.01	0.009	0.332	0.015	0.445
WG	1	--	0.0013	0.006	0.04	3.3	0.004	0.81
W9	1	0.003	0.003	0.005	0.003	102.0	0.005	0.285
1K	1	0.001	0.0005	0.002	0.005	136.0	0.014	0.293
2B	1	0.001	0.0005	0.002	0.004	0.404	0.024	0.017
2C	1	0.001	0.0005	0.002	0.004	75.8	0.005	0.097
2D	1	0.0001	0.0005	0.002	0.009	28.8	0.005	0.014
		Former Dump Area						
WH	1	0.0013	0.004	0.003	0.011	0.38	0.015	0.272
WP	1	0.003	0.003	0.005	0.014	0.900	0.005	0.037
1I	1	0.009	0.002	0.003	0.014	2.17	0.008	0.033
1J	1	0.0013	0.006	0.003	0.006	1.94	0.018	0.008
Water Quality Standard[6]		0.1	0.02	0.1	0.4	0.6	0.1	0.6

* See Figure 10.
SI, 1G, 1F, 18, 19, 2B, 2C, 2D, 2E, 2F, 2G not indicated.

TABLE 29

1977 BNL Environmental Monitoring Potable Supply Wells, Tap Water and Cooling Water Wells, Water Quality-Metals

Location*	No. of Samples	Metals (in ppm) Ag	Cd	Cr	Cu	Fe	Pb	Zn
			Potable Supply Wells					
1 (FA)	2	0.003	0.0005	0.0135	0.0065	0.0705	0.007	0.009
2 (FB)	1	0.005	0.0005	0.006	0.02	0.966	0.009	0.010
3 (FC)	1	0.005	0.0008	0.006	0.2650	0.4545	0.009	0.015
4 (FD)	2	0.003	0.0006	0.004	0.0325	3.0450	0.007	0.0065
5 (FE)	1	--	0.0009	0.006	0.122	0.3600	0.008	0.1600
6 (FF)	1	--	0.0011	0.006	0.014	2.7000	0.0040	0.0080
7 (FG)	1	--	0.0004	0.0060	0.0050	1.4800	0.0040	0.0310
			Tap Water					
Bldg. 535 (FN)	1	0.005	0.0005	0.01	--	0.174	0.009	0.01
			Cooling Water Wells					
101 (FH)	1	--	0.0005	0.084	0.006	1.1900	0.061	0.014
104 (FK)	1	0.005	0.0005	0.006	0.004	1.0000	0.009	0.016
105 (FL)	1	0.005	0.0005	0.006	0.030	0.800	0.009	0.01
Water Quality Standard[6]		0.1	0.02	0.1	0.4	0.6	0.1	0.6

* See Figure 10.

TABLE 30

1977 BNL Environmental Monitoring Collective Annual Average Dose Equivalent Rate Due to BNL Airborne Effluents in Comparison with Background

Distance from HFBR Stack (km)	$X/Q^{(17)}$	Per Caput Dose Equivalent Rate mRem person^{-1} yr^{-1}	Population* person	Collective Average Dose Equivalent Rate rem yr^{-1}	Background Collective Average Dose Equivalent Rate rem yr^{-1}
1.6- 3.2	2.4×10^{-7}	0.225	1,478	0.33	83
3.2- 4.8	1.0×10^{-7}	0.096	5,331	0.51	300
4.8- 6.4	6.0×10^{-8}	0.055	11,332	0.62	636
6.4- 8.0	3.9×10^{-8}	0.036	19,938	0.72	1,120
8.0-16.1	1.7×10^{-8}	0.016	226,000	3.62	12,700
16.1-24.2	8.0×10^{-9}	0.008	241,437	1.93	13,570
24.2-32.2	5.5×10^{-9}	0.005	155,010	0.78	8,712
32.2-48.4	3.8×10^{-9}	0.003	997,749	2.99	56,073
48.4-64.5	2.7×10^{-9}	0.003	1,381,219	4.14	77,625
64.5-80.6	2.1×10^{-9}	0.002	1,753,685	3.51	98,558
1.2-80.6	--	--	4,793,179	19.15	269,377

* Population data taken from DOE/EIS-0003-D, January 1978 [16]. See Figure 13.

mRem = 0.00001 Sv.

Rem = 0.01 Sv.

TABLE 31

Off-Site Collective Annual Average Dose Equivalent Rate Due to External Radiation Exposure Resulting from the Gamma Forest and AGS

Sector	r (km)	Gamma Forest				AGS			
		Distance (km)	Per Caput Dose Equivalent Rate mRem person^{-1} yr^{-1}	Population*	Collective Average Dose Equivalent Rate rem yr^{-1}	Distance (km)	Per Caput Dose Equivalent Rate mRem person^{-1} yr^{-1}	Population*	Collective Average Dose Equivalent Rate rem yr^{-1}
SSW	1.6-3.2	--	--	0	--	--	--	0	--
	3.2-4.8	>4.8	$<10^{-13}$	244	$<10^{-13}$	4.4	1.8×10^{-4}	244	4.4×10^{-5}
SW	1.6-3.2	--	--	0	--	--	--	0	--
	3.2-4.8	>4.8	$<10^{-13}$	92	$<10^{-14}$	4.3	2.2×10^{-4}	92	2.0×10^{-5}
WSW	1.6-3.2	--	--	0	--	--	--	0	--
	3.2-4.8	>4.8	$<10^{-13}$	338	$<10^{-13}$	4.0	4.1×10^{-4}	338	1.4×10^{-4}
W	1.6-3.2	4.4	3.3×10^{-12}	265	8.7×10^{-13}	2.5	1.3×10^{-2}	265	3.4×10^{-3}
	3.2-4.8	>4.8	$<10^{-13}$	845	$<10^{-13}$	3.9	5.8×10^{-4}	845	4.9×10^{-4}
WNW	1.6-3.2	4.2	2.5×10^{-11}	265	6.5×10^{-12}	2.1	3.2×10^{-2}	265	8.5×10^{-3}
	3.2-4.8	>4.8	$<10^{-13}$	652	$<10^{-13}$	3.6	8.8×10^{-4}	652	5.7×10^{-4}
NW	1.6-3.2	3.4	1.7×10^{-11}	192	3.3×10^{-12}	2.0	5.3×10^{-2}	192	1.1×10^{-2}
	3.2-4.8	>4.8	10^{-13}	240	$<10^{-13}$	3.5	1.3×10^{-3}	240	3.1×10^{-4}
NNW	1.6-3.2	2.8	1.7×10^{-6}	161	2.7×10^{-7}	2.0	5.3×10^{-2}	161	8.5×10^{-3}
	3.2-4.8	>4.8	$<10^{-13}$	72	$<10^{-13}$	3.5	1.3×10^{-3}	72	9.4×10^{-5}
N	1.6-3.2	2.1	3.3×10^{-9}	193	6.4×10^{-10}	2.3	2.0×10^{-2}	193	4.2×10^{-3}
	3.2-4.8	--	--	0	--	--	--	0	--
NNE	1.6-3.2	1.4	5.7×10^{-2}	196	1.2×10^{-2}	2.5	1.3×10^{-2}	196	2.5×10^{-3}
	3.2-4.8	2.4	3.3×10^{-5}	380	1.3×10^{-5}	3.6	8.8×10^{-4}	380	3.3×10^{-4}
NE	1.6-3.2	1.2	9.9×10^{-1}	96	9.5×10^{-2}	2.9	5.5×10^{-3}	96	5.3×10^{-4}
	3.2-4.8	2.0	6.6×10^{-4}	190	1.3×10^{-4}	3.5	8.8×10^{-4}	190	1.7×10^{-4}
ENE	1.6-3.2	--	--	0	--	--	--	0	--
	3.2-4.8	--	--	0	--	--	--	0	--
E	1.6-3.2	--	--	0	--	--	--	0	--
	3.2-4.8	2.8	1.7×10^{-6}	319	5.4×10^{-7}	4.0	4.0×10^{-4}	319	1.3×10^{-4}
ESE	1.6-3.2	--	--	0	--	--	--	0	--
	3.2-4.8	3.5	2.5×10^{-9}	319	8.0×10^{-10}	4.4	2.0×10^{-4}	319	6.4×10^{-5}
SE	1.6-3.2	--	--	0	--	--	--	0	--
	3.2-4.8	--	2.1×10^{-10}	55	1.2×10^{-11}	--	1.1×10^{-4}	55	6.0×10^{-6}
SSE	1.6-3.2	4.0	1.7×10^{-10}	61	1.1×10^{-11}	3.4	1.6×10^{-3}	61	9.8×10^{-5}
	3.2-4.8	>4.8	$<10^{-13}$	700	$<10^{-13}$	4.5	1.4×10^{-4}	700	9.8×10^{-5}
S	1.6-3.2	4.4	3.3×10^{-12}	49	1.6×10^{-13}	3.3	2.0×10^{-3}	49	9.8×10^{-5}
	3.2-4.8	>4.8	$<10^{-13}$	885	$<10^{-13}$	4.5	1.4×10^{-4}	885	1.2×10^{-4}
Total					0.107				0.041

* Population data taken from DOE/EIS-0003-D, January 1978 [16].

mRem = 0.00001 Sv.

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