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ENVIRONMENTAL MONITORING REPORT
FOR CALENDAR YEAR 1988

BY

J.R. STENCEL

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By
Joseph R. Stencel

May 1989

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FOR CALENDAR YEAR 1988

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ABSTRACT

The results of the 1988 environmental monitoring program for the Princeton Plasma Physics Laboratory (PPPL) are presented and discussed. Two of three large tokamak machines, the Princeton Beta Experiment Modification (PBX-M) and the Tokamak Fusion Test Reactor (TFTR), were in operation during the year.

The Environmental Committee, which is a standing committee of the Executive Safety Board (ESB), continued to review items of environmental importance. During CY88, no adverse effects to the environment or public resulted from any operational program activities at PPPL, and the Laboratory was in compliance with all applicable federal, state, and local environmental regulations. Over the last two years the Department of Energy conducted major environmental audits at all of its facilities, including PPPL. No significant environmental concerns were noted as a result of the inspection and sampling at PPPL.

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1.0 INTRODUCTION

1.1 General

This report gives the results of the environmental monitoring program at the Princeton Plasma Physics Laboratory (PPPL) for Calendar Year 1988 (CY88). The report is prepared to provide the U.S. Department of Energy (DOE) and the public with information on the level of radioactive and nonradioactive pollutants, if any, added to the environment as a result of PPPL operations. The objective of the environmental monitoring report is to document evidence that DOE facility environmental protection programs adequately protect the environment and the public health.

PPPL has engaged in fusion energy research since 1951 and in CY88 had two of its three large tokamak devices in operation; namely, the Princeton Beta Experiment - Modification (PBX-M) and the Tokamak Fusion Test Reactor (TFTR). The third machine, the Princeton Large Torus (PLT), was not in operation. A new machine, the Compact Ignition Tokamak (CIT), is under conceptual design and is presently in the final stages of finishing its draft Environmental Assessment (EA) report required by the National Environmental Policy Act (NEPA). The goal of the Magnetic Fusion Energy Research Program is to develop and demonstrate the practical application of fusion power as an alternate energy source.

The PBX, after achieving a $>5\%$ beta (ratio of plasma pressure/magnetic pressure) in CY84 experiments, was shut down at the end of 1985 to undergo modifications to permit further examination of theoretical predictions on plasma shaping. The addition of new coils and stabilizer plates within the vessel, new power supplies, and a new control system began in 1986. The modified device, PBX-M (Fig. 1), came back into operation in October 1987. In CY88, an indentation of the

plasma of 25% was achieved, lower $q(a)$ values obtained, and H-modes at lower power attained. In CY89, the effectiveness of the passive plates in stabilizing kink modes and access to higher plasma pressure will be assessed. A Safety Assessment Document (SAD) was published for the PBX in 1984 [Fl84] which indicated that the PBX did not pose any potential environmental concerns. A new SAD published for the PBX-M reached the same conclusion [St88a].

The TFTR (Fig. 2), which had its first full year of operation in CY83, had an increase in total neutron production in CY87 to a yearly total of 3×10^{18} [He88] and in CY88 to a yearly total of 9.04×10^{18} [He89]. The higher neutron production increased the activation level of the machine to the point where health physics surveys were required in the test cell following a machine run and before any personnel entry was permitted for inspection, routine maintenance, or installation work. In addition, tritium from D-D reactions, which was absorbed in graphite and measured during the opening of the vessel in 1987, posed the first known health physics contamination challenges for any tokamak operations. The experience gained from the 1987 opening was beneficial for a similar opening in 1988.

The TFTR is a toroidal device in which a deuterium-tritium (D-T) plasma will be magnetically confined and heated to extremely high temperatures by neutral beam injectors. D-T operations were scheduled to begin in 1990; however, reprogramming and a budget cut announced in November 1988 has resulted in a 2-3 year schedule delay for D-T operations. Ion Cyclotron Radio-Frequency (ICRF) heating became operational in 1988. A major achievement in 1986 was an increase in neutron production and fusion power by operating in what is now called the "supershot" pulse mode. Using this technique, a new record temperature of >300 million degrees Celsius was achieved. The safety analysis completed for this program are addressed in Safety Analysis Reports for the Project [PSAR78 and FSAR82]. The Final Safety

Analysis Report (FSAR) is being updated to reflect operational requirements and parameters using tritium. The initial reviews for the update which began in CY88 have been put on hold after the announced budget reduction.

Although PPPL operates as an unfenced site, with access controls for security purposes, it is considered to be open to the public for environmental purposes. This free access has necessitated a thorough evaluation of the on-site discharges as well as the potential for off-site releases of radioactive and toxic nonradioactive effluents. An extensive monitoring program, tailored to these needs, has been instituted and expanded over recent years. The PPPL radiological environmental monitoring program generally follows the guidance given in two DOE reports; namely A Guide for: Environmental Radiological Surveillance at U.S. Department of Energy Installations [Co81] and Environmental Dose Assessment Methods for Normal Operations at DOE Nuclear Sites (PNL-4410) [St82]. This includes adherence to the standards given in DOE Orders, in particular, DOE Order 5480.1A, Chapter XI (DOE81), which pertains to permissible doses and concentration guides, and gives guidance on maintaining exposures "to as low as reasonably achievable" (ALARA). Additional interim criteria were forwarded by memo [Mi85] and are expected to become an official part of the order in the near future. Specific criteria for implementing these standards on TFTR are contained in a TFTR Operational Safety Requirement (OSR/TFTR/0-2F-C) (see Table 1).

An environmental survey was conducted in June 1988 by DOE/HQ as part of an intensive look at all DOE sites. No significant environmental concerns surfaced at PPPL as a result of this audit.

The emphasis of the monitoring program has been placed on exposure pathways appropriate to fusion energy projects at

PPPL. These pathways include external exposure from direct penetrating radiation and eventually from airborne radionuclides, such as ^{41}Ar , ^{13}N , ^{16}N , and internal exposure from radionuclides, such as ^3H in air and water. Six major critical pathways are considered as appropriate (see Table 2). Prompt radiation, i.e., that which is emitted immediately during operations, was also considered and is being measured. The monitoring program, as envisioned by the TFTR Final Safety Analysis Report (FSAR82), has been updated to reflect the current environment around TFTR (see Table 3). At present, the radioactive pollutant potential to the environment by any pathway is essentially nonexistent. Small amounts of tritium produced from D-D reactions (approximately 435 mCi total in 1988 if all neutrons were D-D produced) are not easily measured outside the TFTR facility because quantities released at any particular time are on the order of ambient background. Low levels of tritium (exempt quantities, i.e., less than levels defined as radioactive materials by the Department of Transportation) are now detectable in pump oils. Also, HTO was detectable in the vacuum vessel air during the 1987 maintenance and upgrade period [St88b] and the subsequent 1988 opening.

Preliminary meteorological considerations and associated methodology, which were established at the time of the installation of PPPL's first meteorological tower, were reported in Section 2 of the TFTR FSAR. Subsequently, improved methodologies were implemented and a new meteorological tower was erected and began operation in November 1983 [Mc83]. The improved measurements and methodologies are being included in the updated FSAR being prepared for tritium operations. Data have been collected for five years using the monitors on the new tower. Wind rose plots from the data for the first four years (1984-86) are shown in Figs. 3 and 4. A tracer gas-release test was conducted during the period from July to September 1988 to look at site-specific air diffusion parameters. These tests were commissioned to determine actual

site conditions versus model predications in relation to future activities.

1.2 Description of the Site

PPPL is located at the C- and D-sites of the James Forrestal Research Campus of Princeton University (Figs. 5 and 6). As shown in Fig. 7, the location is in central New Jersey within Middlesex County. The site is surrounded by undisturbed areas with virgin forest, open grass areas, an airplane runway, and a small brook (Bee Brook) running next to its eastern boundary. The closest urban centers are New Brunswick, 14 miles to the northeast, and Trenton, 12 miles to the southwest. Major metropolitan areas, including New York City, Philadelphia, and Newark, are within 50 miles of the site. As shown in Fig. 8, the municipalities of Princeton, Plainsboro, Kingston, West Windsor, and Cranbury, among others, are in the immediate vicinity of the site. Also, the main campus of Princeton University, located primarily within the borough of Princeton, is approximately three miles to the west of the site. The general layout of the facilities at the C- and D-sites of Forrestal Campus is indicated in Fig. 9; the specific location of TFTR is at D-site.

A demographic study was completed in CY87 as part of the requirement for the Environmental Assessment for the Compact Ignition Tokamak (CIT) [Be87a]. Other information gathered and updated from previous TFTR studies included socioeconomic information [Be87b] and an ecological survey [En87]. The demographic data were based on the 1980 census and show both estimated and projected data out to the year 2010 (Tables 4 to 16 and Figs. 10 to 19) in a zone from 1 mile out to 50 miles. The site is in the center of a highly urbanized region extending from Boston, Massachusetts, to Washington, D.C. The previous population projections for the States of New Jersey, New York, and Pennsylvania had indicated a substantial population increase within 50 miles of the PPPL site. The actual change

from 1970 to 1980, as indicated by the census in these two years, was not as large as had been expected. In fact, the population in New York City and Philadelphia decreased. The Princeton area continues to experience a substantial increase in new business moving into the Route 1 corridor near the site. This increase, however, has not been as great as the projections had indicated. As a summary, population data were divided into annular sectors. It was prepared in 1986 for use with several standard codes used for the determination of off-site dose due to the release of airborne activated nuclides and tritium [Ko86b]. Table 16 shows data supplied by the Princeton Forrestal Center on the population within one mile of the TFTR site. The numbers indicated have been divided by 4 to obtain an equivalent exposure for habitation [Ko86b].

2.0 SUMMARY

During CY88, there were no accidents, incidents, or occurrences that had a significant impact on PPPL facilities, program operations, or the environment. Small oil spills occurred in 1988, but were promptly controlled and cleaned up so that they had minimal impact on the environment and are discussed in the individual spill reports [St88c, St88d, St88e]. The most significant of these allowed approximately 20 gallons of mineral oil from a transformer leak to reach the detention basin. A chronic oil contamination from delivery truck fuel-oil spills over many years is being looked at in some detail and will be reported next year. Weed control and grass fertilizer were previously applied under the direction of the Princeton University Buildings and Grounds Department. The work was done by University personnel or certified contractors in accordance with EPA regulations. In 1988, this work was carried out by PPPL staff utilizing subcontractors. Transformers and capacitors containing PCB oils are being removed from service and disposed of in accordance with prepared schedules and EPA

regulations. The Laboratory has an ongoing program to monitor, inventory, and dispose of PCB and other potentially toxic materials.

Surface water analyses for both radioactive and nonradioactive pollutants have shown nothing above normally expected background values. The initial phase of a program for ground water analysis was initiated in 1985. The U.S. Geological Survey (USGS) finished their drilling programs in 1986, but continue to monitor a bromine (NaBr) tracer test initiated in the fall of 1986. Ambient tritium levels at less than 100 pCi/l (3.7 Bq/l) were measured in D-site well water. These data are in agreement with previous measurements by PPPL and the USGS (St88g). Soil and vegetation samples were collected and analyzed as part of the continuing baseline studies.

Radiation exposure via airborne effluents into the environment is still at a concentration that is too low to be measurable under present operations. From known D-D reactions, less than 435 mCi (16.1 GBq) was released in 1988. This included controlled tritium releases to the air and less than 0.3 mCi (11.1 MBq) to the sanitary sewer. Prompt radiation is detectable at extremely low levels during high power pulses from TFTR. The integrated level at the Exclusion Zone Boundary (EZB) around TFTR, from TFTR operations, was less than 1 mrem (0.01 mSv) for CY88 for measured prompt radiation plus postulated tritium releases and air activation [Gi89].

Off-site surface water, soils, and biota continued to be analyzed for radioactive baselines in CY88. In addition, real-time activated air and particulate monitors, and passive particulate and tritium air monitors were installed at the EZB. The passive tritium monitors were tested on-site in 1986 and tested in a field modeling experiment in Canada in 1987 [Gr88a]. Off-site placement of these monitors has been delayed by budget constraints resulting in program delays.

3.0 MONITORING, ENVIRONMENTAL PROGRAM INFORMATION, DATA COLLECTION, ANALYSES, AND EVALUATION

The monitoring program implementation has followed a phased approach commensurate with the potential hazards and the needs of an expanding program. Nonradioactive water-pollutant monitoring has been conducted for many years. A more extensive program, which began in 1979, presently includes eight surface water-sampling points (four on-site and four off-site), four ground-water sites (two former drinking water wells and two wells near the TFTR liquid effluent-collection tanks), and the potable water-supply source. Monitoring for sources of potential radiological exposures is quite extensive. Real-time prompt gamma/neutron environmental monitoring began on the TFTR site in 1981 to establish baselines prior to machine operation. Four monitoring stations are located at the TFTR EZB. Neutron monitors were added at these locations at the end of CY84. Passive tritium monitors were added in CY87. Radiological water samples are being collected at the same locations as the nonradioactive-sample points (see Figs. 20 and 21). Soil and biota samples are also being analyzed for tritium baselines.

3.1 Radioactivity

3.1.1 Penetrating Radiation

Operation of the Princeton Beta Experiment Modification (PBX-M) results in the production of some penetrating radiation (primarily bremsstrahlung X rays and neutrons). Because the PBX-M has no roof shield, skyshine radiation (primarily neutron) is seen at the TFTR EZB site monitoring stations. The shielding installed for the PBX-M machine has kept the total exposure

dose equivalents* in occupied areas below occupational-exposure guidelines. Skyshine radiation from the neutron production by PBX-M, tempered by limited operation of the device in CY88, added less than 1 mrem (0.01 mSv) to the D-site environs [Gi89].

It is stated Laboratory policy that when occupational exposures have the potential to exceed 1000 mrem y^{-1} (10 mSv y^{-1}), the appropriate project manager must petition the PPPL Executive Safety Board (ESB) for an exemption. In addition, the Laboratory applies the DOE ALARA policy to all its operations. This philosophy for control of occupational exposure means that environmental radiation levels, as a result of experimental device operation, are also very low and acceptable. To illustrate this point, a 1000 mrem exposure dose from direct radiation at the outer TFTR test cell wall will result in less than 10 mrem at the EZB.

The design objective for TFTR is to stay below 10 mrem y^{-1} (0.1 mSv y^{-1}) above natural background from all sources of radiation at the EZB. The TFTR, like other tokamaks, produces bremsstrahlung radiation from the electrons striking internal hardware at the end of a pulse. These X rays, in the range of 0 to 20 MeV, also produce photoneutrons.

Injection of deuterium neutral beams began at the end of CY84. With these D-D runs the neutron fluxes have increased each year as the neutral beam heating power has increased. In CY85 the neutron production was on the order of 5×10^{16} for the entire year. This number increased to 2.4×10^{18} in CY86, to 3×10^{18} during a short run year in CY87, and to 9.04×10^{18} in CY88. Additional shielding was added to the TFTR test cell walls in the middle of CY85. This added shielding has prevented the addition of any significant penetrating radiation to the environs due to

*In all cases used in this report, the whole body is the critical organ and the term dose equivalent can be considered to be synonymous with the term effective dose equivalent.

TFTR operation. Radiation levels (μR) were recorded for some pulses outside the test cell, with the total exposure dose equivalent at the TFTR EZB being less than 1 mrem (0.01 mSv) for CY88 [Gi89].

The TFTR real-time site boundary monitors are Reuter-Stokes Sentri 1011 pressurized ionization chambers and He-3-moderated neutron detectors. The electronics in the ionization chambers were modified to allow the integration of any prompt radiation resulting from a TFTR machine pulse which may be above natural background. These data are stored and processed using the Central Instrumentation Control and Data Acquisition (CICADA) computer system. Four of these monitoring stations are placed at the EZB (see Fig. 20). An additional eight ionization chambers of lower sensitivity paired with neutron monitors are located nearer the TFTR device (four outside the test cell wall, three in the basement, and one on the roof). These eight detector locations are for personnel safety and are not considered environmental detectors per se. However, data collected from them are used to help correlate the environmental measurements. Besides the moderated He-3 and fission neutron detectors, Bonner-type-moderated LiI(Eu) detectors were also used for monitoring neutron doses at various locations throughout the TFTR facility.

3.1.2 Special Surveys

In August 1980, EG&G Idaho, Inc., under DOE contract, conducted an aerial radiological survey of PPPL and surrounding areas [St81]. The detection system consisted of 20 sodium iodide detectors, a multichannel analyzer, and a magnetic tape recording system. The nominal gamma-ray exposure rate range observed was 8 to 10 $\mu\text{R h}^{-1}$. Detected radioisotopes were consistent with normal background emitters. Since conditions have not changed at C or D-sites since 1980, there is no need at this time to repeat the survey.

Other special surveys included a ground-water study by the U.S. Geological Survey (USGS) which began in 1985 and was completed in 1987 [Le87]. Figure 22 shows the potentiometric surface of the bedrock aquifer from this report. The report also indicated that the sumps under the TFTR complex create a cone of depression (Fig. 23). The USGS also presented PPPL some data developed in an unrelated study on natural occurring radioactivity in the ground. Uranium-enriched rocks can be a source of radioactivity in ground water [Sz87, Za87].

A comprehensive environmental survey was conducted by DOE/HQ utilizing outside subcontractors during the month of June 1988. This survey was a part of a DOE program which looked at 45 of their facilities. No significant environmental impact findings were noted at PPPL during this survey. A plan of action for findings was forwarded to DOE (St88f), and most of the findings have already been closed out. Several of the longer term action items restated projects that PPPL had already initiated. Soil sampling for petroleum hydrocarbons from former spills and for chromium in soils from previous use in cooling towers was accomplished in November 1988 (DOE88).

The Air Resources Laboratories Field Research Division (ARLFRD) of the National Oceanic and Atmospheric Administration (NOAA), Idaho Falls, Idaho, conducted atmospheric dispersion studies using tracer gases from July through September 1988. This group specializes in air quality by doing research on the physics of the lower atmosphere with emphasis on the processes contributing to atmospheric transport, dispersion, and deposition, and on the development of numerical models using the results of this research. This study will be used to understand and predict human influence on the environment, especially with regard to the atmospheric transport and diffusion of toxic effluents.

While Nuclear Regulatory Commission (NRC) standard approved gaussian models, normally used to calculate atmospheric diffusion to support radiological dose assessments, are appropriate for sites in open terrain, they underestimate atmospheric dilution for sites like PPPL where potential sources of release are located in the midst of a complex of buildings. These buildings generate mechanical turbulence which increases atmospheric dilution and reduces dose. The field tests conducted by NOAA were performed to obtain a more realistic empirical description of actual atmospheric diffusion at PPPL in relation to TFTR and the future CIT. While the final report will be available in 1989, the initial results indicate a factor of 16 less potential dose than that calculated by using NRC models.

3.1.3 Airborne Radioactivity

Radioactivation of air and release of tritium in measurable concentrations are not expected until TFTR D-T operations. A silica gel environmental tritium monitor was tested in 1986 and was placed in operation during the summer of 1987. With experience gained in a Canadian release modeling experiment and in the field, the monitor is now using molecular sieve in place of silica gel [Gr88b]. Based on D-D neutron production during CY88, it is estimated that a maximum of approximately 435 mCi (16.1 GBq) of tritium could have been added to the environs outside the TFTR facility. This is essentially nonmeasurable because it is not produced and released all at once. However, our actual experience with the absorption and adsorption of tritium in TFTR vessel-graphite tiles in 1987 indicates that most of the tritium produced over the last few years by D-D reactions has been retained in the tiles [St88b]. The projected dose at the site boundary from 435 mCi is less than 2 μ rem (20 nSv).

In November 1983, a three-level, 60 meter tower was installed for gathering meteorological data. Five years' worth of data have now been collected. The wind rose data for the first five years of tower operation are shown in Figs. 3 and 4. Analysis indicates that the site is dominated by neutral to moderately stable conditions, with moderately unstable to extremely unstable conditions occurring less than a few percent of the time. Average surface winds are about 2.1 m/s and rise to about 4.1 m/s at 60 m (Ko86a). Based on data from this tower and NOAA tracer gas release-modeling, χ/Q values will be recalculated for the updated TFTR FSAR before D-T operations. The data were also checked for consistency by the Idaho National Engineering Laboratory (INEL) in their preparation of an Environmental Assessment (EA) for the CIT project.

3.1.4 Waterborne Radioactivity

3.1.4.1 Surface Water

Surface water samples at eight locations (four on-site and four off-site) have been analyzed for tritium and photon emitters. Five of these locations have been monitored since CY82. Downstream sampling occurs after mixing of effluent and ambient water is complete. Locations are indicated on Figs. 20 and 21.

Sample analysis has shown no unusual background radionuclides. Tritium analysis by liquid scintillation methods has shown tritium values to be less than 100 pCi/l (3.7 Bq/l) on all samples analyzed to date. Tritium enrichment procedures are used on some samples to detect lower levels. Rain water samples collected and analyzed ranged from 34 to 105 pCi/l, which was similar to the 1985 range of 45 to 160 pCi/l, the 1986 range of 40 to 140 pCi/l, and the 1987 range of 26 to 144 pCi/l. The reason for this variation can be explained as follows: HT and

HTO, mainly from prior world-wide, above-ground weapons tests, go into the stratosphere and are returned to the troposphere by turbulence. HT slowly converts to HTO. The residence time in the atmosphere is on the order of years. There is a variation of HTO in rain water as the stratosphere slowly turns over, with very little exchange between the stratosphere and troposphere in the winter months (Os88).

In 1988, PPPL initiated collection of precipitation and monitored levels starting with the second quarter. The levels shown in Figure 24 indicate a relatively dry year for the Princeton area.

3.1.4.2 Ground Water

Two existing on-site wells, W4 and W5 on C-site (Fig. 20), were sampled. As a part of continuing efforts to characterize the site, a more comprehensive ground-water program was initiated in June 1985 through the U.S. Geological Survey. This program entailed the drilling of several monitoring wells on the TFTR site in order to help profile the ground-water system. The final survey report was issued in 1987 [Le87]. This report indicates a cone of depression created by the TFTR sump system (Fig. 23). The samples collected from two of the wells (W1 and W10 at D-site) were analyzed for tritium by PPPL. The sample results were consistent with previous testing accomplished by PPPL and the USGS and indicated tritium levels less than 100 pCi/l (3.7 Bq/l) (see Tables 29 and 30). These values are consistent with surface-water measurements.

3.1.4.3 Drinking Water

Potable water is supplied by the public utility, Elizabethtown Water Co. In April 1984, a sample point at the input to PPPL was established (E1 location, Fig. 20) to provide baseline data for water coming onto the site. Radiological analysis has included gamma spectroscopy and tritium-level determination. Tritium

levels are similar to surface and well waters with measurements indicating less than 100 pCi/l (3.7 Bq/l); also, there are no unusual gamma-emitting radioisotopes. Radium and radon levels have not been measured.

3.1.5 Foodstuffs

Because there are so few dairy farms in this area, milk is not a viable analysis medium around the site. Also, the fish population is very scarce to nonexistent in Ditch 5 and Bee Brook, which carry the runoff from the site. DOE agreed in 1986 that a substitute of vegetables and other biota from the surrounding area can be used for reference data. Sampling of various biota in 1988 indicated tritium levels below 100 pCi/l (3.7 Bq/l) [Gi89]. These levels are indicative of tritium in the environment.

3.1.6 Soil, Grass, and Vegetation

Off-site sample locations were established in late 1985 (see Fig. 25). Soil and grass samples collected on-site and off-site in 1988 indicated tritium levels below 100 pCi/l (3.7 Bq/l). Laboratory techniques for doing these analyses were perfected in CY84 [Gr85], and the techniques are documented in the Radiological Environmental Monitoring Laboratory Handbook [REML86]. These baselines are being established since surface soils and vegetation are among the best indicators of the presence of tritium after a release [Jo74], [Mu77], [Mu82]. The present detected levels are indicative of tritium in the environment. Gamma spectroscopy indicated low levels of ^{137}Cs , which is believed to result from the Chernobyl fallout.

3.2 Nonradioactive Pollutants

3.2.1 Airborne Effluents [Ki89]

PPPL has a New Jersey Department of Environmental Protection (NJDEP) permit for its C-site boilers and fuel tank vents. The seven permit certificates, numbered 061294 through 061300, were renewed in 1987 and will next expire on March 31, 1992. New air permits applied for and received include the CAS building degreaser, the Field Coil and Power Conversion (FCPC) building degreaser, the TFTR emergency generator diesel engine, an 8,000 gallon unleaded gasoline tank vent (#E2), and a 15,000 gallon diesel tank vent (E#8). The application for the TFTR diesel engine is still pending.

Measurements of actual boiler emissions are not required. Emissions were initially calculated using formulas supplied by the NJDEP. These formulas are based solely on the percent sulfur and the number of gallons of oil burned per hour in each boiler. In the last quarter of CY87, PPPL purchased a combustion-efficiency analyzer. This device indicates boiler efficiency, oxygen content, flue-gas temperature, and carbon-dioxide content of the stack gas for both oil and natural-gas fuels. This information is recorded and entered into a log book on a monthly basis [Ki88].

3.2.2 Water Utilization [Ki89]

3.2.2.1 Drinking Water

Potable water is supplied by the public utility, Elizabethtown Water Co. PPPL used approximately 22.3 million gallons in CY88. This is a significant reduction from years prior to 1987 because of the changeover to Delaware & Raritan (D&R) Canal water for cooling-water systems. Water quality analysis at the input to PPPL was initiated in CY84 to measure nonradioactive

pollutants (Table 23, E-1 location) as well as to measure potential radioactive pollutants exclusive of radium or radon.

3.2.2.2 Process (nonpotable) Water

Nonpotable water is pumped by PPPL from the D&R Canal as authorized by a permit agreement with the New Jersey Water Supply Authority. The present agreement gives PPPL the right to draw up to one million gallons of water per day for process and fire-fighting purposes for the period beginning July 1984 and ending on September 30, 1991. Renewal is expected at the end of the present contract. Filtration to remove suspended solids is the primary treatment. In 1986, a multimedia sand filter was installed to allow the source of the D-site cooling tower make-up water to be changed from potable water to process-water supply. PPPL used approximately 65 million gallons of canal water during CY88. The sampling point (C-1) was established to provide baseline data for process water coming on-site. Table 20 indicates results of water quality analysis at the canal.

3.2.2.3 Storm Sewage

Storm sewage, which includes cooling tower and boiler blowdown, is discharged into surface waters and is governed at C- and D-sites by National Pollutant Discharge Elimination System (NPDES) Permit No. NJ0023922 (effective date November 1, 1984 - expiration date October 31, 1989). All process water and most runoff water from C- and D-sites now pass through a detention basin. Upgrades to the detention basin, including an oil-spill detection and alarm system, were completed in 1986. As a result of minor problems following the transformer-oil leak in 1988, another analysis of this system is now under way. Quarterly water-chemistry reports, compiled from the data of Table 22, were submitted to the State of New Jersey in 1988 in accordance with NJDEP requirements. PPPL was well within the

allowable limits for all testing parameters during CY88.

Cooling-water treatment was changed from a chromate-based corrosion inhibitor to a nonchromate inhibitor in June 1983. Water analyses downstream and ground water tests (see Tables 18-30) have not indicated concentrations of any environmental pollutants above applicable codes, regulations, or standards. As a result of the initial improvements made to the detention basin in 1986, the NJDEP required an application for discharge to ground water. After the application for this permit was filed in 1986, the NJDEP proposed the addition of monitoring wells around the detention basin. NJDEP and PPPL met in December 1988 to discuss the best approach to meet these new proposed requirements while at the same time providing meaningful data in a cost-efficient manner. It is expected that a new permit will be issued in 1989 with new requirements.

An updated Spill Prevention Control and Countermeasures (SPCC) Plan was received from an environmental consultant in January 1985 and will be upgraded in CY89. The final update was delayed until after the EPA issued the Final Regulations for Underground Storage Tanks (UST). Expected New Jersey regulations for UST will also be reviewed when they are issued. All major action items of the plan have been addressed. While the SPCC response team meets quarterly for training sessions, to improve their response efficiency in case a spill were to be detected, the Laboratory's first response capabilities lie with the HAZMAT team of the Emergency Services Unit (ESU).

3.2.2.4 Sanitary Sewage

Sanitary sewage is discharged to the publicly owned treatment works operated by South Brunswick Township at the Stony Brook Regional Authority. Flow rates are measured by the PPPL sanitary sewage metering station and indicated a total volume discharge of approximately 21.8 million gallons in CY88.

Sampling of PPPL discharges, performed by the publicly owned treatment works, has determined that pretreatment is unnecessary. Therefore, PPPL is in compliance with the EPA Pretreatment Standard, 40 CFR Part 403.

3.2.2.5 Ground Water

Monitoring of ground water was accomplished by using former production wells, W4 and W5 (see Table 27 and 28), and wells TW#1 and TW#10 established by the USGS to study ground water flow characteristics (see Tables 29 and 30). USGS results from TW#1 and TW#10 (see Table 17) indicated some trace chemicals. The USGS also had results showing higher concentration in W#3 at B-site of the Forrestal Campus which is not a part of DOE leased land (Table 17). A program has been proposed to further define ground water flow patterns so that a determination can be made on whether the trace contamination in TW#1 and TW#10 is due to on-site activities or is a function of activities beyond our site boundaries.

3.2.2.6 Surface Water

Surface water is monitored for potential non-radioactive pollutants both on-site and at surface water discharge pathways (upstream and downstream) off-site (See Fig. 20-21 and Tables 18-26).

3.2.3 Spills

Several oil spills were recorded in CY88. Those which posed a potential threat to the environment were reported to the NJDEP in accordance with their reporting requirements. A transformer leak allowed approximately 20 gallons of mineral oil to reach the detention basin before it was detected (St88c). Overflow of an underground fuel-oil tank occurred during a fill procedure (St88d). A subcontractor poured 2.5 gallons of diesel fuel onto

the ground (St88e). All oil spills are responded to immediately by in-house HAZMAT personnel, and subcontractors are utilized to aid in clean-up if required. Because of the prompt internal response and vigilance by employees, the 1988 oil spills resulted in no impact to the environment [St88c, St88d, St88e].

3.2.4 Herbicides, Fertilizer, and Pesticides [Ra88]

During CY88, the use of herbicides, pesticides, and fertilizers, which was formerly done by Princeton University buildings and grounds maintenance personnel, was taken over by PPPL utilizing an outside contractor. These materials are applied in accordance with state and federal regulations. Herbicides are applied by a certified applicator. Table 32 lists the quantities applied during CY88.

3.2.5 Polychlorinated Biphenyls (PCBs)

Beginning in CY82, PPPL started a program to dispose of PCB containing capacitors, transformers, and other similarly contaminated items. During the early phases of the program, all stored items in a GSA Warehouse in Belle Mead, NJ, were discarded through approved disposal contractors. Remaining PCB items were labeled, as required by EPA regulations, and an inventory, inspection, and status report program was initiated. A Hazardous Material Coordinator was appointed to ensure that any newly identified leaking capacitors or transformers would be dispositioned promptly and properly. At the beginning of CY84, PPPL still had 15 PCB transformers and 6005 large capacitors containing PCBs. In CY84, 375 large and 54 small PCB capacitors were disposed of as well as the oil and containers of two transformers. In 1985, an additional 1330 large capacitors and 22 small capacitors were properly removed from the site. In 1986, a few small capacitors but no transformers were discarded. In 1987, two transformers containing 700 gallons of PCB fluid were disposed of. In addition, 1145 gallons of < 500

ppm PCB fluid were generated from rework/classification of six PCB transformers to non-PCB transformers, and 391 capacitors were disposed of. PCB capacitors are being disposed of as they are taken out of service. In 1988, 1,769 capacitors and four small transformers were removed. PCB materials amounted to 172,465 pounds and 45 gallons of liquid of disposal volume. Transformer replacement has been initiated and is scheduled to meet the EPA requirements. Depending on funding approval, the present plan is to have all PCB transformers removed by October 1989.

3.2.6 Hazardous Wastes

Responsibility for this program rests with the PPPL Hazardous Material Coordinator under the Materiel Control Office. A facility was set up in CY82 for temporary storage of hazardous materials. A new area was built in 1986. This facility has concrete floors with containment walls, fire alarms and security surveillance, fire extinguishers, an eye-wash station, an emergency shower, and telephones. Improvements to the facility, following experience gained from operational needs, were made in CY88.

The Hazardous Waste Generator Annual Report (EPA ID number NJ1960011152) has been submitted for 1988 in accordance with EPA requirements [St89]. During 1988, 274,493 pounds of solid materials and 8755 gallons of liquid waste were disposed of at EPA-certified treatment, storage, and disposal facilities. These totals included 172,465 pounds (including packaging material) and 45 gallons of PCBs (oil plus containers). These numbers reflect actual waste, plus containers and packing materials. It should be noted that a significant fraction of the waste was oil-contaminated soil from oil-spill cleanup.

3.3 Environmental Impact

3.3.1 Assessment of Radiation Dose to the Public

PPPL is located in one of the less densely populated, but also one of the fastest growth areas in the metropolitan region between New York City and Philadelphia. Census data indicate that approximately 16 million people live within 80 km (50 miles) of the site and approximately 212,000 within 16 km (10 miles) of PPPL. The detailed distribution of population as a function of distance is given in Tables 4-16. Because of ever-increasing commercial growth in this area, a demographic update was planned for TFTR but was completed as a requirement for the CIT Environmental Assessment [Be87a].

The overall integrated exposure-dose equivalent from all sources (excluding natural background), to a hypothetical individual residing at the PPPL site boundary 24 h/day, 365 d/y, was estimated to be less than 1 mrem (0.01 mSv) for CY88 (Gi89). Detailed person-rem calculations for the surrounding population were not performed, because the value would be insignificant in comparison to the approximately 100 mrem (1 mSv) each individual receives from the natural background, exclusive of radon, in New Jersey.

3.3.2 Assessment of Nonradioactive Pollutants

There were no activities during CY88 that created problems with respect to nonradioactive pollutants. Oil spills were detected and cleaned up with no significant environmental impact.

Polychlorinated biphenyls (PCB's) and other toxic materials continue to be disposed of in accordance with EPA requirements. Herbicides, pesticides, and fertilizers were used in very limited quantities and are not expected to have any noticeable negative impact on the environment.

4.0 QUALITY ASSURANCE FOR LABORATORY ANALYSIS

Analysis of water samples for radioactivity was accomplished in-house. In general, in-house procedures follow the HASL-300 Manual [Vo82]. In-house procedures adopt accepted techniques and are documented in the REML manual [REML86]. PPPL participates in the EPA (Las Vegas) program and has reinitiated its analyses of samples provided by the DOE Environmental Measurements Laboratory (EML) in New York City. These programs provide blind samples for analysis and subsequent comparison to values obtained by other participants, as well as to known values. Results are shown in Table 33.

In CY84, PPPL initiated a program to have its radiation-counting laboratory certified by the State of New Jersey through the EPA QA program. In March 1986, the Laboratory facilities and procedures were reviewed and inspected by EPA/Las Vegas and the NJDEP. The laboratory was certified for tritium analysis in urine and water and recertified in these areas in 1988. The goal in the coming year is to extend this certification to gamma spectroscopy and all other procedures and techniques.

The vendor used for nonradioactive water quality analysis participates in a State of New Jersey QA program and has a quality assurance plan [Al85]. A blind split-sample was also sent for analysis (Table 31).

5.0 FUTURE PROGRAM EXPANSION

5.1 Meteorological

A meteorological tower was installed in November 1983. Data from this system are being used in updating dose calculations for the updated version of the TFTR FSAR. Data were also evaluated

by the CIT project in relation to siting the CIT at PPPL. Several dose-assessment codes are being employed by PPPL to utilize the data from this tower in the calculation of projected doses. These codes include the required DOE standard AIRDOS-EPA, as well as PANVAN, XOQDOQ, and an Ontario Hydro version of TRITMOD. Future plans include considerations of hooking up a real-time output of the meteorological data. These plans have been put on hold with recent budget cuts.

5.2 Water Quality

The initial phases of a ground-water monitoring program began in CY85. Analysis of water samples from two D-site wells was added to the monitoring program in CY86 utilizing USGS data. PPPL took over the water quality program on these two wells in December 1987. New wells will most likely be added in response to new state requirements for a ground-water discharge permit. In addition, an expanded ground-water program is being planned to more fully understand our regional ground-water flow, surrounding area (off-site) ground-water contamination, and in anticipation of requirements for CIT.

5.3 Radioactive Effluents

5.3.1 Air, Gaseous and Particulates

Based on collected data, a decision was made in CY84 to limit the specific air and particulate real-time monitors at the EZB to a beta detector only. Environmental tritium monitors tested in CY86 were deployed at the EZB in CY87. These were to be extended to an off-site location in CY88 but were delayed because of budget reductions at the end of the year.

5.3.2 Off-Site Radiological Monitoring

An off-site grab sample water-analysis program is well established. Whether more sampling points will be added in the future depends on reevaluation of the program, which is done annually. Locations for off-site tritium and particulate monitoring stations were negotiated in CY86. Placement of hardware at these sites was expected to be finished in CY88 but has been extended into CY89. Soil and vegetation sampling is under way and will continue.

5.4 Nonradioactive Effluents

Air-effluent standards will continue to be met by following the guidelines of the NJDEP. Any potential toxic materials will be monitored and disposed of in accordance with applicable regulations and accepted guidelines. With respect to the detention basin, application has been made for a ground-water discharge permit. Also, because of the addition of an oil separator on the detention basin, the NJDEP had requested that we apply for a treatment works permit. A permit application was made and a subsequent waiver was granted for the treatment works permit [Ku86]. Upgrades to the detention basin are under consideration by an outside vendor based on experience gained from actual oil spills which reached the basin.

6.0 REGULATIONS AND SAFETY CRITERIA

The appropriate Radiation Protection Standard for penetrating radiation was taken from DOE Order 5480.1A, Chapter XI. Specific criteria for implementing these standards on TFTR are contained in TFTR Operational Safety Requirements, in particular, OSR/TFTR/0-2F-C. The concentration guides, used in the analyses of surface water samples for radioactivity, were taken from DOE Order 5480.1A, Chapter XI, Table II, Column 2

(Water in Uncontrolled Areas). The concentration guides for airborne activity are taken from the same DOE Order, Table I, Column 1 (Concentration in Air in Uncontrolled Areas). Tritium, for example, is listed as $2 \times 10^{-7} \mu\text{Ci/ml}$. The Laboratory was also in compliance with the new DOE draft Order 5480.11, from which some interim requirements on dose to the public were established by a DOE letter [Mi85].

Air and Water Pollution Standards for nonradioactive pollutants were taken from the New Jersey Administrative Code (NJAC), Department of Environmental Protection 7:1-1, et seq and 7:27-1, et seq. The appropriate regulations for PCBs and hazardous waste are found in the U.S. Code of Federal Regulations, 40 CFR 761 and 40 CFR 260-265, respectively.

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Table 1

TFTR Radiation Exposure Criteria

The research facility radiation exposure criteria itemized in this table shall be invoked for the TFTR only and shall not be construed as being applicable to subsequent fusion test facilities, research facilities, or reactor projects. The values quoted are for whole body exposures, however, the DOE manual requirements for other organs (hands, arms, bones, etc.) and other time periods (quarterly) are also applicable to TFTR and reductions between limits and design objective shall be consistent with those of the table.

Condition	Off-Site ≥125 m		On-Site <125 m	
	Limit	Design Objective	Limit	Design Objective
Routine Operation mrem/yr [footnotes (a), (b) & (e)]	500 to an individual (e)	≤100 to an individual (b)	500 in an uncontrolled area	≤100 in an uncontrolled area
	170 average population member (e)	≤35 average population member	5000 in a controlled area	<1000 in a controlled area
Accident rem [footnotes (c) and (d)]	25	5 (d)	25	25

- (a) Routine operation consist of:
- 1) Normal component operation including shutdown, repair, maintenance, checkout, adjustment, etc.
 - 2) Operational occurrences such as leaks, loss of power, and component malfunctions that are likely to occur once or more during the life of the facility.
- (b) For normal operation, defined in (a) 1) above, the off-site design objective shall be 10 mrem/yr.
- (c) Accident conditions consist of:
- 1) Very low probability events such as "most intense predicted" phenomena.
 - 2) Low probability events such as "most probable" natural phenomena and other component failure events that are not likely to occur during the life of the facility.
- (d) For those accident conditions defined by (c) 1) above, the off-site design objective shall be 5 rem and that for (c) 2) above, 1 rem.
- (e) For emission of airborne radionuclides, the off-site limit on dose equivalent is 25 mrem/yr to the whole body and 75 mrem/yr to the critical organ.

Table 2

Critical Pathways

<u>Path I.D.</u>	<u>Discharge Pathway</u>	
A1	Atmospheric --->	Whole Body Exposure
A2	Atmospheric --->	Inhalation Exposure
A3	Atmospheric --->	Deposition on Soil & Vegetation, Ingestion, Whole Body Exposure
L1	Liquid Water Way --->	Drinking Water Supply --> Man
L2	Liquid Water Way --->	External Exposure
L3	Liquid Water Way --->	Fish ---> Man

Table 3

Monitoring Program Covering Critical Pathways

Type of Sample	Critical Path I.D.	Sample Point Description	Sampling Frequency	Analysis
Surface	L1,L2,L3 & A3	1) Cooling Water Discharge Drainage 2) Bee Brook Upstream & Downstream 3) D&R Canal	Monthly	Tritium Gamma Spectroscopy
Soil & Sod	A3	Within 1 km radius	4 times per year	Tritium Gamma Spec.
Biota (Fruits & Vegetables)	A3	Within 1 km radius	Seasonal	Tritium Gamma Spec.
Surface Water	L1,L2	Liquid Effluent Collection Tanks	As Required by Filling	Tritium Gamma Spec. Volume
Air	A1-A3	Test Cell	Continuous	Activated Air (Gross β) ^3H (HT & HTO)
Air	A1-A3	Vault	Continuous	^3H (HT and HTO)
Air	A1-A3	HVAC Discharge (Stack)	Continuous	Activated Air (Gross β) HT & HTO. Particulates, Volume
Direct & Air (on-site)		4 Locations at EZB on-site	Continuous	γ , n, ^3H (HT and HTO), Gross β for Activated air & particulates with Gamma Spec., TLD
Direct & Air (off-site)		6 Locations off-site within 1 km radius	Continuous (integrated)	^3H (HT & HTO) TLD for air γ Gamma spec. for particulates

Table 4⁺

Population of Municipalities Within 0 - 10 Miles of PPPL

1985 - 2010

Municipality	1985 (1)	1995	2000	2005	2010	
Mercer County (Total) (2)	317,685	349,700	359,400	364,200	377,100	Mercer County (Total)
Mercer County (Part)	190,683	219,550	223,100	230,550	240,500	Mercer County (Part)
East Windsor Twp.	22,682	24,750	25,000	26,350	29,350	East Windsor Twp.
Hightstown B.	4,494	5,050	5,100	5,100	5,100	Hightstown B.
Hamilton Twp.	85,766	88,950	90,000	91,200	94,450	Hamilton Twp.
Hopewell Twp.	11,040	13,025	15,000	15,200	16,200	Hopewell Twp.
Hopewell B.	2,013	2,075	2,100	2,100	2,100	Hopewell B.
Pennington B.	2,232	2,300	2,300	2,350	2,400	Pennington B.
Lawrence Twp.	22,804	31,100	33,900	34,000	34,100	Lawrence Twp.
Princeton Twp.	14,202	14,550	14,700	14,900	15,400	Princeton Twp.
Princeton B.	12,031	12,650	12,700	12,700	12,700	Princeton B.
Washington Twp.	3,719	8,650	8,800	8,900	9,200	Washington Twp.
West Windsor Twp.	9,700	16,550	17,500	17,750	19,500	West Windsor Twp.
Middlesex County (Total) (2)	626,703	695,432	726,510	760,800	791,800	Middlesex County (Total)
Middlesex County (Part)	121,984	171,183	192,396	202,000	219,100	Middlesex County (Part)
Cranbury Twp.	2,765	5,695	8,033	8,450	8,800	Cranbury Twp.
East Brunswick Twp.	40,770	43,630	44,753	47,000	50,900	East Brunswick Twp.
Helmetta B.	973	965	949	950	950	Helmetta B.
Monroe Twp.	19,255	28,711	34,737	36,500	38,200	Monroe Twp.
Jamesburg B.	4,402	4,723	4,805	5,050	5,050	Jamesburg B.
North Brunswick Twp.	25,427	31,495	33,916	35,600	37,000	North Brunswick Twp.
Plainsboro Twp.	9,040	15,662	17,161	18,000	20,700	Plainsboro Twp.
South Brunswick Twp.	19,972	40,304	48,042	50,450	57,500	South Brunswick Twp.
Somerset County (Total) (2)	210,318	250,025	263,200	279,765	295,730	Somerset County (Total)
Somerset County (Part)	65,276	89,280	97,820	106,610	115,400	Somerset County (Part)
Franklin Twp.	33,952	47,945	52,790	57,790	62,790	Franklin Twp.
Hillsborough Twp.	22,652	28,485	30,700	33,375	35,850	Hillsborough Twp.
Montgomery Twp.	7,970	12,145	13,420	14,725	16,030	Montgomery Twp.
Rocky Hill B.	702	705	710	720	730	Rocky Hill B.
Monmouth County (Total) (2)	530,913	568,100	591,400	604,300	613,450	Monmouth County
Millstone Twp.	4,234	5,617	7,300	9,286	11,571	Millstone Twp.

(1) New Jersey Department of Labor. Population Estimates for New Jersey, July 1, 1985.

(2) See methodology in Appendix for details on the source and derivation of County and Municipal Projections.

* Taken from Bc87a

Table 5^{*}

Population of Counties Within 10 - 50 Miles of PPPL

1985 - 2010

County	1985 Estimates	1995 Projections	2000 Projections	2005 Projections	2010 Projections
New Jersey (1)	7,562,000	8,154,000	8,450,300	8,685,200	8,895,700
Atlantic	205,100	265,100	260,100	272,300	283,200
Bergen	841,200	861,800	878,700	891,900	904,000
Burlington	380,100	437,100	467,200	494,900	521,300
Camden	488,100	555,400	577,200	597,300	616,700
Essex	845,700	794,000	795,500	779,900	762,300
Gloucester	207,100	234,500	249,100	263,500	277,400
Hudson	555,900	560,100	548,100	528,500	507,300
Hunterdon	92,300	104,500	113,000	121,900	131,000
Mercer	317,700	349,700	359,400	364,200	377,100
Middlesex	626,700	695,432	724,610	760,300	791,800
Monmouth	530,900	568,100	591,600	604,300	613,450
Morris	417,100	479,900	510,500	540,800	570,500
Ocean	380,000	449,600	484,400	515,800	545,900
Passaic	461,400	468,600	469,100	466,500	462,000
Somerset	210,300	250,025	263,300	279,765	295,730
Sussex	119,600	146,100	159,500	172,900	185,700
Union	506,700	534,500	539,700	540,900	540,000
Warren	85,200	92,700	96,200	99,300	101,900
New York (2)	17,783,000	18,314,022	18,543,262	18,750,076	18,948,273
Bronx	1,198,598	1,199,410	1,205,047	1,213,270	1,224,052
Kings	2,248,139	2,228,361	2,232,335	2,242,890	2,254,228
Nassau	1,332,393	1,344,197	1,333,458	1,315,938	1,292,437
New York	1,435,619	1,454,633	1,454,251	1,456,292	1,456,707
Queens	1,917,172	1,919,057	1,925,510	1,933,829	1,953,634
Richmond	371,679	419,706	443,048	465,818	489,111
Pennsylvania (3)	11,263,674	12,100,149	12,101,253	12,161,780	12,222,306
Bucks	512,705	576,716	601,168	636,276	673,345
Chester	334,311	379,733	395,958	418,726	442,302
Delaware	557,180	541,442	531,068	525,279	519,554
Lehigh	277,914	291,083	294,836	300,762	306,808
Monroe	78,967	104,133	117,583	134,162	153,079
Montgomery	663,164	692,521	698,281	712,566	727,344
Northampton	231,430	244,668	249,000	255,275	261,707
Philadelphia	1,637,434	1,599,620	1,513,574	1,472,959	1,433,333

(1) Office of Demographic and Economic Analysis, N.J. Department of Labor and Industry, 1986.

(2) State Data Center, New York State Department of Commerce, 1985.

(3) State Data Center, Pennsylvania Department of Commerce, 1986. See methodology in Appendix for details on 2005 and 2010 projections.

* Taken from Be87a

Table 6 **

Population of Metropolitan Areas Within 50 Miles of PPPL

Metropolitan Areas*	1980 Census	July 1985 Estimate	Percent Change
Allentown-Bethlehem MSA (N J Portion)	84,429	85,200	0.9%
Jersey City, N J PMSA	556,972	555,900	-0.2%
Morrmouth-Ocean PMSA	849,211	910,900	7.3%
Middlesex-Somerset-Hunterdon PMSA	886,383	929,300	4.9%
New York, N Y CMSA	8,274,961	8,410,058	1.6%
Newark, N J PMSA	1,379,147	1,889,000	0.5%
Bergen-Passaic PMSA	1,292,970	1,302,500	0.7%
Philadelphia, P A PMSA (N J Portion)	1,034,109	1,073,300	4.0%
Trenton, N J PMSA	307,863	317,700	3.2%

* MSA = Metropolitan Statistical Area
 CMSA = Consolidated Metropolitan Statistical Area
 PMSA = Primary Metropolitan Statistical Area

** Taken from Be87a

Source: State of New Jersey, Department of Labor.
 New York State Department of Commerce.

Table 7*

1985 Population Estimates Within Annular Sectors, 0 - 10 Miles

SECTOR	Total						SECTOR
	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	
N	0	100	289	0	68	4,666	N
NNE	0	20	290	2,497	4,334	9,600	NNE
NE	0	0	0	0	0	16,799	NE
ENE	0	1,160	204	200	100	3,792	ENE
E	0	0	200	100	10	10,238	E
ESE	0	100	1,600	1,200	219	3,469	ESE
SE	113	1,200	0	253	161	18,964	SE
SSE	362	50	150	0	600	8,255	SSE
S	0	734	3,837	2,312	1,760	4,156	S
SSW	3	0	2,500	600	100	27,788	SSW
SW	0	803	10	250	50	18,523	SW
WSW	0	739	1,000	1,019	1,449	8,095	WSW
W	0	1,735	5,820	6,777	2,384	6,253	W
WNW	40	437	772	3,139	0	2,013	WNW
NW	0	1,020	866	300	350	3,526	NW
NNW	0	600	499	200	502	7,093	NNW
Totals	518	8,700	18,037	18,847	12,089	153,232	Totals

*Taken from Be87a

Table 8*

1995 Population Projections Within Annular Sectors, 0 - 10 Miles

SECTOR	Total							SECTOR
	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	0-10 Miles	
N	0	134	387	0	91	6,241	6,853	N
NNE	0	27	388	3,340	5,242	12,841	21,838	NNE
NE	0	0	0	486	902	21,084	22,472	NE
ENE	0	1,551	273	268	689	5,072	7,853	ENE
E	0	0	268	134	1,678	13,695	15,775	E
ESE	0	827	2,140	1,605	2,235	5,195	12,002	ESE
SE	151	1,605	291	338	493	20,928	23,806	SE
SSE	484	1,454	894	166	803	11,042	14,843	SSE
S	0	982	4,675	3,093	2,354	5,559	16,663	S
SSW	4	188	3,344	2,522	2,908	32,176	41,142	SSW
SW	0	1,077	332	544	2,796	21,450	26,199	SW
WSW	0	989	2,328	1,130	1,594	10,828	17,369	WSW
W	0	2,321	6,005	6,963	2,487	9,277	27,053	W
WNW	53	585	800	3,256	128	4,438	9,260	WNW
NW	0	1,365	398	335	468	4,716	7,782	NW
NNW	0	803	668	268	671	9,487	11,897	NNW
Totals	692	13,908	24,191	24,448	23,539	194,029	282,807	Totals

*Taken from Be87a

Table 9^{*}

2000 Population Projections Within Annular Sectors, 0 - 10 Miles

SECTOR	Total							SECTOR
	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	0-10 Miles	
N	0	146	421	0	99	6,792	7,458	N
NNE	0	29	422	3,435	5,560	13,974	23,620	NNE
NE	0	0	0	656	1,217	22,582	24,455	NE
ENE	0	1,688	297	292	895	5,520	8,692	ENE
E	0	0	292	146	2,261	14,904	17,603	E
ESE	0	1,081	2,329	1,747	2,940	5,799	13,896	ESE
SE	164	1,747	393	368	609	21,615	24,896	SE
SSE	527	1,945	1,154	224	874	12,016	16,740	SSE
S	0	1,069	4,568	3,366	2,562	6,050	18,015	S
SSW	4	254	3,439	3,269	3,890	33,710	45,366	SSW
SW	0	1,172	252	440	4,566	22,473	28,932	SW
WSW	0	1,076	2,354	1,165	1,645	11,784	18,025	WSW
W	0	2,526	6,070	7,028	2,522	10,334	28,480	W
WNW	58	637	810	3,297	173	5,286	10,261	WNW
NW	0	1,485	909	347	509	5,132	8,382	NW
NNW	0	874	727	292	730	10,316	12,939	NNW
Totals	753	15,729	25,037	26,905	31,052	208,287	307,763	Totals

* Taken from Be87a

Table 10*

2005 Population Projections Within Annular Sectors, 0 - 10 Miles

Total								
SECTOR	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	0-10 Miles	SECTOR
N	0	151	435	0	102	7,014	7,702	N
NNE	0	30	436	3,754	5,688	14,431	24,339	NNE
NE	0	0	0	725	1,344	23,187	25,256	NE
ENE	0	1,743	307	302	978	5,701	9,031	ENE
E	0	0	302	151	2,496	15,392	18,341	E
ESE	0	1,184	2,405	1,804	3,224	6,043	14,660	ESE
SE	169	1,304	434	390	654	21,892	25,335	SE
SSE	544	2,143	1,259	247	903	12,409	17,505	SSE
S	0	1,104	5,086	3,476	2,646	6,248	18,560	S
SSW	4	281	3,758	4,211	4,286	34,329	46,869	SSW
SW	0	1,210	277	492	5,038	22,986	30,003	SW
WSW	0	1,111	2,496	1,185	1,666	12,170	18,628	WSW
W	0	2,609	6,096	7,054	2,536	10,761	29,056	W
WNW	60	658	814	3,313	191	5,628	10,664	WNW
NW	0	1,534	913	352	526	5,300	8,625	NW
NNW	0	903	751	302	754	10,651	13,361	NNW
Totals	777	16,465	25,769	27,748	33,034	214,142	317,935	Totals

* Taken from Be87a

Table 11^{*}

2010 Population Projections Within Annular Sectors, 0-10 Miles

Total								
SECTOR	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	0-10 Miles	SECTOR
N	0	161	465	0	109	7,505	8,240	N
NNE	0	32	466	4,016	5,971	15,441	25,926	NNE
NE	0	0	0	875	1,625	24,521	27,021	NE
ENE	0	1,865	328	322	1,161	6,099	9,775	ENE
E	0	0	322	161	3,016	16,468	19,967	E
ESE	0	1,411	2,574	1,930	3,852	6,580	16,347	ESE
SE	182	1,930	525	407	759	22,503	26,306	SE
SSE	582	2,580	1,491	300	965	13,278	19,196	SSE
S	0	1,181	5,347	3,719	2,831	6,685	19,763	S
SSW	5	339	4,021	4,965	5,161	35,696	50,187	SSW
SW	0.00	1,295	333	542	6,080	23,797	32,047	SW
WSW	0	1,189	2,808	1,219	1,711	13,021	19,948	WSW
W	0	2,791	6,154	7,112	2,560	11,703	30,328	W
WNW	64	703	822	3,349	230	6,383	11,551	WNW
NW	0	1,641	923	363	563	5,671	9,161	NW
NNW	0	965	803	322	807	11,408	14,305	NNW
Totals	833	18,083	27,382	29,602	37,409	226,759	340,068	Totals

* Taken from Be87a

Table 12*

1985 Population Estimates Within Annular Sectors, 10 - 50 Miles

Total						
SECTOR	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	10-50 Miles	SECTOR
N	66,118	36,704	181,881	68,882	353,586	N
NNE	134,835	226,290	341,211	488,415	1,190,754	NNE
NE	178,403	431,968	1,293,973	3,522,231	5,426,575	NE
ENE	142,397	220,455	1,076,490	1,449,544	2,888,886	ENE
E	52,020	121,342	75,175	0	249,037	E
ESE	38,489	41,729	135,843	0	216,061	ESE
SE	14,219	81,760	179,854	5,852	281,685	SE
SSE	2,924	13,262	20,520	36,784	73,492	SSE
S	5,446	57,129	11,859	2,908	77,342	S
SSW	54,390	61,310	117,286	196,892	429,878	SSW
SW	230,879	361,455	1,147,177	1,032,046	2,771,556	SW
WSW	52,379	151,542	311,433	299,453	814,807	WSW
W	13,955	39,888	106,238	64,611	224,693	W
WNW	8,287	12,555	15,439	252,047	288,328	WNW
NW	13,920	18,653	66,682	86,917	186,172	NW
NNW	26,092	13,716	34,241	22,704	96,753	NNW
Totals	1,034,758	1,890,257	5,115,303	7,529,287	15,569,605	Totals

* Taken from Be27a

Table 13*

1995 Population Estimates Within Annular Sectors, 10 - 50 Miles

Total						
SECTOR	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	10-50 Miles	SECTOR
N	77,600	43,286	209,380	82,344	413,110	N
NNE	151,656	244,555	345,449	501,569	1,243,229	NNE
NE	189,192	466,816	1,282,528	3,531,064	5,469,602	NE
ENE	149,614	244,189	1,075,798	1,444,205	2,913,807	ENE
E	48,224	130,379	80,443	0	259,046	E
ESE	33,170	44,653	147,906	0	225,728	ESE
SE	15,551	95,456	212,796	6,924	330,726	SE
SSE	3,462	15,491	24,278	43,521	86,953	SSE
S	3,798	65,656	13,638	3,437	86,568	S
SSW	58,457	70,504	134,375	224,101	487,438	SSW
SW	254,358	385,409	1,167,023	1,035,758	2,842,548	SW
WSW	55,741	167,298	319,088	309,761	851,889	WSW
W	13,209	44,869	115,585	68,595	242,258	W
WNW	9,332	14,133	17,280	265,316	306,061	WNW
NW	15,675	21,005	72,663	91,959	201,302	NW
NNW	29,653	15,445	38,640	25,334	109,071	NNW
Totals	1,108,692	2,069,384	5,257,370	7,633,889	16,069,335	Totals

* Taken from Be87a

Table 14*

2000 Population Estimates Within Annular Sectors, 10 - 50 Miles

SECTOR	Total					SECTOR
	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	10-50 Miles	
N	81,590	45,762	223,566	89,117	440,035	N
NNE	158,049	250,338	354,421	507,150	1,269,959	NNE
NE	193,977	478,786	1,286,928	3,538,387	5,498,078	NE
ENE	152,903	256,310	1,081,795	1,447,794	2,938,803	ENE
E	47,314	135,772	83,771	0	266,857	E
ESE	31,627	46,500	154,983	0	233,110	ESE
SE	16,320	102,409	229,267	7,460	355,455	SE
SSE	3,730	16,906	26,158	46,890	93,683	SSE
S	3,687	70,220	14,577	3,655	92,139	S
SSW	40,661	75,359	142,235	234,143	512,399	SSW
SW	262,872	389,374	1,137,316	1,011,964	2,801,526	SW
WSW	57,234	172,994	316,136	311,387	857,751	WSW
W	13,585	46,771	118,755	69,700	248,812	W
WNW	10,091	15,112	18,138	269,393	312,733	WNW
NW	16,950	22,713	75,734	93,637	209,035	NW
NNW	31,170	16,701	40,885	26,602	115,358	NNW
Totals	1,141,761	2,142,027	5,304,664	7,657,280	16,245,732	Totals

* Taken from Be87a

Table 15*

2010 Population Estimates Within Annular Sectors, 10 - 50 Miles

SECTOR	Total					SECTOR
	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	10-50 Miles	
N	91,018	51,262	250,373	102,263	494,916	N
NNE	172,722	258,377	362,497	510,623	1,304,220	NNE
NE	209,361	499,736	1,260,255	3,552,301	5,522,153	NE
ENE	164,784	277,228	1,099,303	1,464,153	3,005,468	ENE
E	47,676	140,787	86,865	0	275,327	E
ESE	30,472	48,217	163,259	0	241,978	ESE
SE	17,263	114,276	258,374	8,407	398,321	SE
SSE	4,203	19,552	29,479	52,363	105,577	SSE
S	4,009	78,351	16,265	4,007	102,632	S
SSW	65,172	84,086	156,390	252,607	558,255	SSW
SW	284,516	410,918	1,123,253	998,753	2,817,440	SW
WSW	61,714	190,521	321,293	322,263	895,791	WSW
W	15,357	52,386	128,998	73,384	270,605	W
WNW	11,698	17,340	20,389	281,867	331,295	WNW
NW	19,650	26,331	81,471	98,437	225,889	NW
NNW	34,761	19,362	45,199	28,849	128,171	NNW
Totals	1,234,356	2,288,731	5,403,694	7,731,059	16,678,339	Totals

* Taken from B337a

TABLE 16 (Ku86b)
SECTORIZED POPULATION DATA TO 1 MILE

		radial distances (m)*				
		<u>50</u>	<u>125</u>	<u>375</u>	<u>1105</u>	<u>2416</u>
S	n	0	0	0	377	486
	nnw	0	0	63	0	469
	nw	0	0	0	20	416
E	wnw	0	0	0	800	830
	w	0	0	103	0	1587
C	wsW	0	0	116	192	749
	sw	0	0	116	317	12
T	ssw	0	0	0	950	247
	s	0	0	317	317	820
O	sse	0	0	0	0	3848
	se	0	0	18	0	64
R	ese	0	0	73	0	60
	e	0	0	73	0	30
	ene	0	0	18	34	17
	ne	0	0	0	250	66
	nne	0	0	0	186	25

* The radii shown are midpoints of the sector radial boundaries.

Table 17. USGS Well Water Results CY88

	Location of Well -->	B-Site #3	B-Site #2	B-Site #3	D-Site TW1	D-Site TW10
	Collection Date -->	5/18/88	5/18/88	5/18/88	8/11/88	8/11/88
	Time -->	1:50 PM	2:40 PM	3:40 PM		
Units	Parameter					
ug/L	1,1 Dichloroethane	<.2	<.2	<.2	<.2	<.2
ug/L	1,1 Dichloroethylene	5.1	4.3	4.2	<.2	<.2
ug/L	1,1,1 Trichloroethane	7.2	7	6.1	0.9	<.2
ug/L	1,1,2 Trichloroethane	<.2	<.2	<.2	<.2	<.2
ug/L	1,1,2,2 Tetra. C. Ethane	<.2	<.2	<.2	<.2	<.2
ug/L	1,2 Dibromoethylene	<.2	<.2	<.2	<.2	<.2
ug/L	1,2 Dichloroethane	<.2	<.2	<.2	<.2	<.2
ug/L	1,2 Transdichloroethylene	8	9.3	9.2	<.2	<.2
ug/L	1,2-Dichlorobenzene	<.2	<.2	<.2	<.2	<.2
ug/L	1,2-Dichloropropane	<.2	<.2	<.2	<.2	<.2
ug/L	1,3-Dichlorobenzene	<.2	<.2	<.2	<.2	<.2
ug/L	1,3-Dichloropropane	<.2	<.2	<.2	<.2	<.2
ug/L	1,4-Dichlorobenzene	<.2	<.2	<.2	<.2	<.2
ug/L	2-Chlo.Ethyl.Vyl.Eth	<.2	<.2	<.2	<.2	<.2
ug/L	Benzene, Total	<.2	<.2	<.2	<.2	<.2
ug/L	Bromoform Total	<.2	<.2	<.2	<.2	<.2
ug/L	Carbon Tetra Total	1.4	1.4	<.2	<.2	<.2
ug/L	Chloro Benzene	<.2	<.2	<.2	<.2	<.2
ug/L	Chlorodibromometh T	<.2	<.2	<.2	<.2	<.2
ug/L	Chloroethane	<.2	<.2	<.2	<.2	<.2
ug/L	Chloroform Total	<.2	0.5	<.2	<.2	<.2
ug/L	Cis 1,3-Dich Propene	<.2	<.2	<.2	<.2	<.2
ug/L	DiChlorobromometha T	<.2	<.2	<.2	<.2	<.2
ug/L	DiChlorodifluoromethane	<.2	<.2	<.2	<.2	<.2
ug/L	Ethyl-Benzene	<.2	<.2	<.2	<.2	<.2
ug/L	Methyl-Bromide	<.2	<.2	<.2	<.2	<.2
ug/L	Methyl Chloride	<.2	<.2	<.2	<.2	<.2
ug/L	Methylene Chloride	<.2	<.2	<.2	<.2	<.2
ug/L	Styrene, Total	<.2	<.2	<.2	<.2	<.2
ug/L	Tetrachloroethylene	270	240	240	<.2	1.4
ug/L	Toluene	<.2	<.2	<.2	<.2	<.2
ug/L	Trans-1,3-Di	<.2	<.2	<.2	<.2	<.2
ug/L	Trichloroethylene	360	320	320	0.3	0.2
ug/L	Trichlorofluoromethane	<.2	<.2	<.2	5.3	<.2
ug/L	Vinyl Chloride	<.2	<.2	<.2	<.2	<.2
ug/L	Xylene, Total Rec.	<.2	<.2	<.2	<.2	<.2

Table 18. Water Quality Monitoring Data

		Forrestal Campus, Princeton University Station: B1 (Boa Brook)											
Collection Date -->		1/29/88	2/22/88	3/22/88	4/25/88	5/31/88	6/13/88	7/29/88	8/22/88	9/19/88	10/25/88	11/23/88	12/19/88
Units	Parameter	12:45 PM	3:00 PM	4:40 PM	3:45 PM	3:30 PM	2:05 PM	2:05 PM	4:00 PM	6:30 PM	12:50 PM	1:00 PM	2:00 PM
mg/l CaCO ₃ eq	Alkalinity	13	9	13	10	19	59	35	66	56	36	11	17
mg/l O ₂	BOO5	5	3	2	2	3.9	3.2	1	41	6	2.2	2.8	1.8
mg/l CaCO ₃ eq	Calcium Hardness	21	19	13	13	21	51	44	86	70	46	14	13
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O ₂	COD	<2.0	14	<2.0	15	5	35	14	27	11	16	29	18
mg/l Cu	Copper	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O ₂	Dissolved Oxygen	9.5	9.5	10.8	9.4	8.8	8.9	8.2	7.4	8.8	8	9	9.4
mg/l Cu eq	EDTA	0.05	0.08	0.6	0.09	0.5	0.31	0.9	0.15	0.22	0.05	0.4	0.15
MPN/100 ml	Total Coliform Count	920	540	17	920	1600	>1600	>1600	>1600	1600	1600	1600	130
l/3/sec	Flow	Frozen	0.29	0.12	0.11	0.08	0.21	0.04	0.02	0.03	0.01	0.065	0.04
mg/l Fe	Iron	0.12	0.22	0.2	0.52	0.45	0.027	0.51	0.43	0.21	0.38	0.48	0.17
mg/l N	Nitrogen, Total Kjeldahl	<0.1	0.8	<0.1	0.5	0.5	0.75	1.2	0.7	<0.1	0.6	0.1	0.1
mg/l N	Nitrogen, Nitrate	0.1	0.95	0.95	0.66	1	0.52	1.1	0.14	0.24	0.45	0.23	0.93
mg/l	Oil & Grease	0.7	3.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	4	1.4
unit	pH	7	6.8	7.2	6.95	7	7.5	7.5	7.4	7.05	7	6.5	7
mg/l P	Phosphate, Total	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.18	0.7	<0.1	0.3	<0.1	<0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1	<0.1	<0.1	0.08	0.6	<0.1	0.1	<0.1	<0.1	<0.1
mg/l	Solids - Dissolved	149	109	53	81	114	153	130	280	126	122	89	120
mg/l	Solids - Suspended	<1	5	1	4	18	8	<1	10	6	8.5	3	4
mg/l SO ₄	Sulfate	25	21	22	15	24	19	80	60	32	18	34	20
DegC	Temperature	0.5	7	6	16	20	19	25	21	22	11	8	2
NTU	Turbidity	2.1	5.1	2.7	5.7	7.5	5.3	5.3	4.3	3	3.2	4.2	2.9
mg/l Zn	Zinc	0.03	0.03	0.03	0.02	<0.01	<0.01	0.036	0.03	0.03	0.02	0.04	0.02
	Clarity	Clear	Clear	Clear	Clear	Clear	Clear	Sl. Cloudy	Sl. Cloudy	Clear	Clear	Clear	Clear

Table 19. Water Quality Monitoring Data

		Forrestal Campus, Vincennes University Station: B2 (Bee Brook)											
Collection Date -->		1/29/88	2/22/88	3/22/88	4/25/88	5/31/88	6/13/88	7/29/88	8/22/88	9/19/88	10/25/88	11/23/88	12/19/88
Units	Parameter	12:15 PM	2:30 PM	4:30 PM	4:00 PM	3:10 PM	1:35 PM	11:25 AM	3:15 PM	6:00 PM	12:30 PM	12:30 PM	1:30 PM
mg/l CaCO ₃ eq	Alkalinity	29	31	44	43	44	56	55	80	52	72	35	35
mg/l O ₂	BOD ₅	7	4	2.7	<1	4	2.6	1	<1	3.6	<2	5	1.6
mg/l CaCO ₃ eq	Calcium Hardness	56	39	42	44	49	47	59	83	71	64	21	33
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O ₂	COD	10	16	<2	<2	16	26	14	15	26	7	18	29
mg/l Cu	Copper	0.03	<0.02	0.23	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O ₂	Dissolved Oxygen	9.2	9.2	10	9	9	8.6	8.6	9.2	9	9	9.2	8.8
mg/l Cu eq	EMPA	0.14	0.09	0.8	0.24	0.41	0.54	0.45	0.94	0.2	0.25	0.22	0.14
MPN/100 ml	Total Coliform Count	110	220	13	350	500	>1600	>1600	>1600	300	900	220	1600
lit/sec	Flow	0.25	0.34	0.25	0.29	0.28	0.49	0.14	0.07	0.1	0.09	0.19	0.13
mg/l Fe	Iron	0.2	0.38	0.23	0.37	0.48	0.022	0.3	0.12	0.22	0.27	0.39	0.21
mg/l N	Nitrogen, Total Kjeldahl	0.1	<0.1	0.45	0.15	0.8	0.3	0.7	0.5	0.9	<0.1	0.4	0.3
mg/l N	Nitrogen, Nitrate	0.17	1.65	1.2	1.9	1.2	0.51	1.4	1.95	2.8	1	0.33	1.1
mg/l	Oil & Grease	2.6	3.1	1.4	1.1	0.7	<0.5	2.2	<0.5	<0.5	<0.5	2.6	1.2
unit	pH	6.95	7.15	7.9	7.15	7.2	7.55	7.5	7.9	7.35	7.55	6.8	7.3
mg/l P	Phosphate, Total	0.25	0.45	0.5	0.5	0.4	0.3	0.44	1.2	0.9	0.85	<0.1	0.4
mg/l P	Phosphate, Ortho	0.1	0.15	<0.1	0.5	0.25	0.2	0.29	0.8	0.65	1.5	<0.1	0.2
mg/l	Solids - Dissolved	189	161	129	124	268	157	153	234	199	173	115	132
mg/l	Solids - Suspended	<1	6	<1	6	821	6	<1	8	4	7	1	5
mg/l SO ₄	Sulfate	28	22	27	21	61	20.5	75	41	43	29	42	26
Deg C	Temperature	6.5	7	8.5	16.5	19.5	19.5	24	24	22	13	9	6
NTU	Turbidity	2.2	11	1.8	4	8.8	4.2	5.6	5.6	2.8	3	3.5	2.7
mg/l Zn	Zinc	0.06	0.04	0.04	0.02	0.03	<0.01	0.038	0.02	0.04	0.02	0.04	0.02
	Clarity	Clear	Sl Cloudy	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear

Table 20. Water Quality Monitoring Data

		Forrestal Campus, Princeton University Station C1 (Canal)											
Collection Date -->		1/29/88	2/22/88	3/22/88	4/25/88	5/31/88	6/13/88	7/29/88	8/22/88	9/19/88	10/25/88	11/23/88	12/19/88
Units	Parameter	1:25 PM	2:45 PM	6:00 PM	5:00 PM	1:10 PM	4:50 PM	5:15 PM	6:25 PM	4:25 PM	1:30 PM	4:15 PM	3:40 PM
mg/l CaCO ₃ eq	Alkalinity	34	17	31	43	28	42	30	53	46	37	22	54
mg/l CaCO ₃ eq	Calcium Hardness	18	27	32	41	28	36	32	58	44	36	24	46
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu	Copper	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu eq	EDTA	0.05	0.06	0.5	0.33	0.36	0.36	0.21	0.2	0.1	0.05	0.25	0.18
mg/l Fe	Iron	0.27	0.48	0.24	0.54	0.45	0.023	0.92	0.54	0.4	0.54	0.7	0.29
mg/l N	Nitrogen, Nitrate	0.38	1.45	1.3	2.7	0.83	0.84	1.3	1.5	2.5	0.86	0.6	1.4
mg/l	Oil & Grease	1.9	0.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3.4
unit	pH	7.3	7	7.5	7.45	6.95	7.8	6.85	7.35	7.35	6.95	0.2	7.3
mg/l P	Phosphate, Total	<0.1	0.1	<0.1	<0.1	0.1	0.13	0.1	0.1	0.2	<0.1	0.2	<0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.1	<0.1
mg/l	Solids - Dissolved	144	133	89	98	105	118	111	172	151	141	116	157
mg/l	Solids - Suspended	<1	11	1	25	45	22	28	15	16	12	2	4
mg/l SO ₄	Sulfate	27	24	19	22	19	20	28	32	27	6	18	28
NTU	Turbidity	2.5	20	3.6	8.2	9.9	8.3	25	8.3	6	8.2	29	3.9
mg/l Zn	Zinc	0.03	0.02	0.04	0.01	0.01	<0.01	0.02	0.02	0.02	0.02	0.05	0.03
	Clarity	Clear	Mod.Cldy	Clear	Sl.Cldy	Sl.Cldy	Sl.Cldy	Sl.Cldy	Sl.Cldy	Sl.Cldy	Sl.Cldy	Sl.Cldy	Sl.Cldy

Table 21. Water Quality Monitoring Data

		Forrester Campus, Princeton University											
		Station: D1 (Drainage Ditch)											
Collection Date -->		1/29/88	2/22/88	3/12/88	4/25/88	5/31/88	6/13/88	7/28/88	8/22/88	9/19/88	10/25/88	11/23/88	12/19/88
Units	Parameter	1:30 PM	1:55 PM	3:30 PM	2:35 PM	2:10 PM	3:55 PM	12:30 PM	2:25 PM	4:05 PM	1:40 PM	11:30 AM	12:20 PM
mg/l CaCO ₃ eq	Alkalinity	30	20	28	45	23	38	30	49	43	47	27	45
mg/l O ₂	BOD ₅	2	4	2.9	1	2.8	4.8	<2	<2	1.4	2	4.2	2
mg/l CaCO ₃ eq	Calcium Hardness	42	32	30	37	28	36	33	62	44	46	38	42
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l O ₂	COD	<2	14	<2	13	23	29	<2	8	13	<2	10	43
mg/l Cu	Copper	0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	<0.02
mg/l O ₂	Dissolved Oxygen	9.2	8.6	9.8	9	9.4	8.9	8.8	7.4	8.7	9.2	9.4	8.5
mg/l Ca eq	EDTA	0.02	0.1	0.5	0.19	0.48	0.7	0.27	0.44	0.16	0.07	0.36	0.11
MPN/100 ml	Total Coliform Count	<2	5	<2	170	48	300	900	>1600	50	>1600	240	<2
lit/sec	Flow	0.04	0.075	0.04	0.06	0.1	0.06	0.1	0.06	0.05	0	0.05	0.04
mg/l Fe	Iron	0.51	0.24	0.3	0.42	0.38	0.033	0.31	0.35	0.31	0.3	0.8	0.2
mg/l N	Nitrogen, Total Kjeldahl	0.15	0.2	0.7	<0.1	0.9	0.5	<0.1	0.5	1.1	0.3	0.6	0.6
mg/l N	Nitrogen, Nitrate	0.14	0.8	1.4	2.4	0.83	0.73	1	2	2.6	1.4	0.99	1.8
mg/l	Oil & Grease	<0.5	1.1	<0.5	2.9	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	4.3	4.1
unit	pH	6.9	6.7	7.1	7.25	6.75	7.2	7.5	7.65	7.35	7.3	6.9	7.2
mg/l P	Phosphate, Total	0.5	1.4	1.3	1.9	0.4	2	2.07	1.8	1.8	1.9	0.95	2.1
mg/l P	Phosphate, Ortho	0.2	0.35	0.65	1.5	0.25	0.8	0.78	0.9	0.8	0.55	0.35	0.75
mg/l	Solids - Dissolved	160	168	125	114	128	149	88	143	163	120	116	15C
mg/l	Solids - Suspended	<1	12	1	13	34	10	10	14	13	1C	2	8
mg/l SO ₄	Sulfate	25	23	21	20	23	19	15	31	28	38	32	32
DegC	Temperature	9	10	11.5	13	18.5	19.5	25	27	23	17	14	11
NTU	Turbidity	3.2	26	1.3	4.2	8.3	8.6	11	6.7	4.6	2.6	12	2.1
mg/l Zn	Zinc	0.03	0.05	0.03	0.01	0.02	<0.01	0.035	0.02	0.02	0.03	0.03	0.02
	Clarity	Clear	Sl. Cloudy	Clear	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Clear

Table 22. Water Quality Monitoring Data

Forestal Campus, Princeton University Station: D2 (Drainage Ditch)												
Collection Date -->	1/29/88	2/22/88	3/22/88	4/25/88	5/31/88	6/13/88	7/29/88	8/22/88	9/19/88	10/25/88	11/23/88	12/19/88
Units	12:55 PM	3:30 PM	5:30 PM	4:00 PM	3:50 PM	2:35 PM	2:30 PM	4:40 PM	6:45 PM	2:00 PM	1:30 PM	2:30 PM
Parameter	12:55 PM	3:30 PM	5:30 PM	4:00 PM	3:50 PM	2:35 PM	2:30 PM	4:40 PM	6:45 PM	2:00 PM	1:30 PM	2:30 PM
mg/L CaCO ₃ eq	Alkalinity	125	48	64	61	58	68	71	80	72	76	57
mg/L O ₂	BOD ₅	4	3	2.7	<1	3	2	1	<1	1	2.4	3
mg/L CaCO ₃ eq	Calcium Hardness	227	57	60	57	59	54	65	79	71	70	75
mg/L Cr	Chromium - Total	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02
mg/L Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/L O ₂	COD	35	15	<2	<2	5.5	22	14	28	4.2	9	<2
mg/L Cu	Copper	9.3	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/L O ₂	Dissolved Oxygen	8.8	8.4	9.2	8.6	9.2	9.6	9.2	11.2	9.2	10	8.2
mg/L Cu eq.	EDTA	0.04	0.09	0.6	0.22	0.6	0.52	0.32	0.22	0.32	0.49	0.06
MPN/100 ml	Total Coliform Count	<2	33	2	28	240	>1800	>1800	>1800	900	1600	900
ft ³ /sec	Flow	0.18	0.21	0.11	0.10	0.12	0.13	0.1	0.06	0.05	0.05	0.05
mg/L Fe	Iron	0.23	0.54	0.23	0.34	0.28	0.034	0.11	0.13	0.24	0.27	0.2
mg/L N	Nitrogen, Total Kjeldahl	1.4	<0.1	0.2	0.25	1.3	0.4	0.8	0.5	0.7	0.7	0.2
mg/L N	Nitrogen, Nitrate	0.71	1.2	1.5	1.8	1.4	0.47	1.0	1.9	2.9	1.4	0.91
mg/L	Oil & Grease	2.53	1.1	4.4	<0.5	1	<0.5	3.05	0.7	1	1.5	1.2
unit	pH	6.9	7.05	7.6	7.2	7	7.15	7.45	7.9	7	7.45	6.8
mg/L P	Phosphate, Total	0.35	0.6	0.8	1.1	0.45	0.9	0.9	0.9	1.1	1.2	0.65
mg/L P	Phosphate, Ortho	<0.1	0.3	0.45	0.9	0.3	0.5	0.59	0.8	0.75	0.65	0.25
mg/L	Solids - Dissolved	1810	225	248	160	254	180	191	242	241	198	168
mg/L	Solids - Suspended	35	8	<1	11	24	<1	<1	9	16	2	<1
mg/L SO ₄	Sulfate	100	20	30	26	5	26.5	15	42	38	37	25
Deg C	Temperature	10.5	10.5	11	16	19	22	25	27	23	16	14
NTU	Turbidity	15	18	3.1	2.9	6.9	5.6	11	2.3	2.6	3.4	5.1
mg/L Zn	Zinc	0.72	0.06	0.06	0.02	0.03	<0.01	0.035	0.03	0.03	0.02	0.03
	Clarity	St. Cloudy	St. Cloudy	Clear	Clear	Clear	Clear	St. Cloudy	Clear	Clear	Clear	Clear

Table 23. Water Quality Monitoring Data

Forrestal Campus, Princeton University													
Station: E1 (Elizabethtown Water)													
	Collection Date -->	1/29/88	2/22/88	3/22/88	4/25/88	5/31/88	6/13/88	7/29/88	8/22/88	9/19/88	10/25/88	11/23/88	12/19/88
Units	Parameter	1:10 PM	1:30 PM	3:15 PM	2:18 PM	1:50 PM	3:40 PM	1:10 PM	2:00 PM	3:45 PM	1:20 PM	11:00 AM	12:00 PM
mg/l CaCO3 eq	Alkalinity	58	63	70	72	90	56	63	70	75	102	37	56
mg/l CaCO3 eq	Calcium Hardness	77	59	58	78	71	64	76	93	71	76	61	57
mg/l Cu	Copper	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
MPN/100 ml	Total Coliform Count	<2	<2	<2	0	<2	<2	<2	<2	<2	<2	<2	<2
mg/l Fe	Iron	0.11	0.05	0.06	0.24	0.07	<0.02	0.04	0.03	0.02	0.11	0.05	0.06
mg/l N	Nitrogen, Total Kjeldahl	0.3	0.15	<0.1	0.2	0.3	0.4	0.2	0.2	0.2	<0.1	0.8	0.3
mg/l N	Nitrogen, Nitrate	0.19	1.9	1.3	1.4	2.5	0.58	3.2	1.3	3.4	2.6	1.6	2.4
unit	pH	7.2	7.2	7.1	6.95	6.9	7.05	7.35	7.15	6.95	6.95	7	6.8
mg/l P	Phosphate, Total	<0.1	<0.1	<0.1	0.15	0.1	0.1	0.13	<0.1	0.15	<0.1	0.15	<0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1	0.15	<0.1	0.1	0.19	<0.1	0.15	<0.1	0.1	<0.1
mg/l	Solids - Dissolved	229	175	201	193	222	193	196	274	255	227	150	207
mg/l Mn	Manganese	<0.01	0.01	<0.01	0.01	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
mg/l Cl	Chloride	22	22	25	27	26	30	29	29	26	33	15	24
mg/l SO4	Sulfate	45	32	39	43	44	54	110	65	39	30	39	23
Deg C	Temperature	4	10	7	11	14	18	25	22	20	15	13	9
NTU	Turbidity	0.23	0.45	0.5	0.52	0.72	0.65	0.67	0.3	0.29	0.19	0.38	0.36

Table 24. Water Quality Monitoring Data

Forrestal Campus, Princeton University Station: M1 (Millstone River)													
Collection Date -->		1/29/88	2/22/88	3/22/88	4/25/88	5/31/88	6/13/88	7/29/88	8/22/88	9/19/88	10/25/88	11/23/88	12/19/88
Units	Parameter	1:05 PM	2:55 PM	6:20 PM	5:15 PM	1:30 PM	5:10 PM	7:00 PM	9:45 PM	4:40 PM	1:40 PM	4:30 PM	4:00 PM
mg/L CaCO ₃ eq	Alkalinity	12	10.4	12	19	18	21	16	27	20	14	11	28
mg/L CaCO ₃ eq	Calcium Hardness	26	22	25	25	26	28	18	31	28	27	22	15
mg/L Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/L Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/L Cu	Copper	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/L Cu eq.	EDTA	0.1	0.08	0.5	0.61	0.38	1.2	0.24	0.28	0.2	<0.04	0.08	0.12
mg/L Fe	Iron	0.6	0.71	0.55	0.78	1.3	0.1	0.93	0.3	0.24	0.47	1.3	0.55
mg/L N	Nitrogen, Nitrate	0.34	2.1	4.2	4	2.2	1.1	1.3	2.9	5.7	2.3	1.3	3.6
mg/L	Oil & Grease	9	2.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7
unit	pH	6.5	6.65	6.8	7	6.7	6.95	6.55	7	6.85	6.5	6.6	6.8
mg/L P	Phosphate, Total	0.2	0.25	0.3	0.2	0.35	0.3	0.22	0.2	0.15	0.2	0.2	0.2
mg/L P	Phosphate, Ortho	0.1	<0.1	0.15	0.3	0.25	0.2	0.11	0.1	<0.1	0.1	0.15	0.1
mg/L	Solids - Dissolved	127	119	114	118	130	110	70	111	130	114	99	116
mg/L	Solids - Suspended	4	12	1	9	32	<1	4	11	30	9	9	5
mg/L SO ₄	Sulfate	20	22	24	19	21	25	14	10	19	18	22	26
NTU	Turbidity	7.9	24	9.1	5.4	9.1	4	16	3.7	3	4.9	1.8	5.6
mg/L Zn	Zinc	0.03	0.03	0.4	0.01	0.01	<0.01	0.022	0.01	<0.01	0.02	0.03	0.02
	Clarity	Sl. Cloudy	Clear	Sl. Cloudy	Sl. Cloudy	Clear	Clear	Sl. Cloudy	Clear	Clear	Sl. Cloudy	Clear	Clear

Table 25. Water Quality Monitoring Data

Forrestal Campus, Princeton University													
Station: P1 (Off-Site Location)													
	Collection Date -->	1/29/88	2/22/88	3/22/88	4/25/88	5/31/88	6/13/88	7/29/88	8/22/88	9/19/88	10/25/88	11/23/88	12/19/88
Units	Parameter	12:30 PM	2:15 PM	5:40 PM	4:25 PM	12:20 PM	4:10 PM	5:30 PM	5:45 PM	3:55 PM	12:55 PM	3:35 PM	3:00 PM
mg/l CaCO3 eq	Alkalinity	9	8.7	12	15	18	77	18	39	37	25	16	7
mg/l CaCO3 eq	Calcium Hardness	26	21	24	21	19	26	18	40	30	23	22	28
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu	Copper	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu eq	EDTA	0.02	0.07	0.7	0.41	0.19	0.68	0.16	0.6	0.32	0.27	0.16	0.13
mg/l Fe	Iron	0.43	0.71	1.3	1.6	2	0.1	1.5	1.5	0.97	1.4	0.71	1.4
mg/l N	Nitrogen, Nitrate	0.48	1.85	3.4	2.8	1	1.4	0.96	1.2	2.7	1.8	0.84	3.5
mg/l	Oil & Grease	1.6	3.5	<0.5	0.9	<0.5	<0.5	<0.5	1.3	<0.5	<0.5	2.5	2.9
unit	pH	6.5	6.5	6.7	7.15	6.75	6.85	6.55	7	6.85	6.65	6.7	6.4
mg/l P	Phosphate, Total	<0.1	0.2	0.15	<0.1	0.35	0.2	0.35	0.15	0.15	0.2	0.3	<0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.15	<0.1
mg/l	Solids - Dissolved	203	79	112	108	117	23	90	125	147	127	90	132
mg/l	Solids - Suspended	2	4	12	21	51	76	28	8	3	16	15	5
mg/l SO4	Sulfate	33	22	24	24	21	21	12	2.2	22	10	11	31
NTU	Turbidity	8.6	20	8.4	16	17	13	22	8.8	7.8	6.2	40	13
mg/l Zn	Zinc	0.04	0.03	0.01	0.01	0.02	<0.01	0.022	<0.01	0.01	0.02	0.02	0.02
	Clarity	Clear	Sl. Cloudy	Sl. Cloudy	Mod. Cldy	Sl. Cloudy	Sl. Cloudy	Mod. Cldy	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Sl. Cloudy	Clear

Table 26. Water Quality Monitoring Data

Forrestal Campus, Princeton University													
Station: P2 (Off-Site Location)													
	Collection Date -->	1/29/88	2/22/88	3/22/88	4/25/88	5/31/88	6/13/88	7/29/88	8/22/88	9/19/88	10/25/88	11/23/88	12/19/88
Units	Parameter	12:45 PM	2:30 PM	5:20 PM	4:40 PM	12:40 PM	4:30 PM	5:45 PM	6:05 PM	4:10 PM	1:10 PM	3:55 PM	3:15 PM
mg/l CaCO3 eq	Alkalinity	12	8.6	14	10	17	23	8.2	26	20	21	9.1	18
mg/l CaCO3 eq	Calcium Hardness	16	12	17	9.6	15	20	11	26	22	22	12	14
mg/l Cr	Chromium - Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu	Copper	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
mg/l Cu eq	EDTA	0.08	0.06	0.6	0.56	2.3	0.81	0.66	0.18	0.14	0.1	0.18	0.18
mg/l Fe	Iron	0.43	0.23	0.37	0.93	1.5	0.047	0.81	0.37	0.34	0.48	1.1	0.32
mg/l N	Nitrogen, Nitrate	0.25	0.95	0.06	2.3	0.39	1.7	6.1	3.8	5.7	3.6	0.88	3.6
mg/l	Oil & Grease	2.2	0.9	3	<0.5	<0.5	<0.5	0.88	<0.5	<0.5	<0.5	4.7	3
unit	pH	8.55	8.55	8.7	7.05	6.5	6.85	6.15	7.15	6.75	6.45	6.4	6.6
mg/l P	Phosphate, Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
mg/l P	Phosphate, Ortho	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.06	<0.1	<0.1	<0.1	<0.1	<0.1
mg/l	Solids - Dissolved	81	79	80	66	93	99	59	104	109	104	66	87
mg/l	Solids - Suspended	<1	4	<1	10	13	<1	52	9	7	6	5	9
mg/l SO4	Sulfate	14	13	12	8	5	9	24	3	14	11	20	12
NTU	Turbidity	3.4	10	2.7	3.2	4.1	25	14	2.4	2.4	1.8	17	2.6
mg/l Zn	Zinc	0.02	0.03	0.05	0.01	0.02	<0.01	0.018	0.01	0.02	0.01	0.04	0.02
	Clarity	Clear	Sl. Cloudy	Clear	Clear	Clear	Clear	Sl. Cloudy	Clear	Clear	Sl. Cloudy	Clear	Clear

Table 27. Water Quality Monitoring Data

Forrestal Campus, Princeton University					
Station: W4 (C-Site Underground Well)					
	Collection Date -->	2/26/88	5/31/88	8/22/88	11/23/88
Units	Parameter	2:00 PM	2:40 PM	5:20 PM	2:00 PM
mg/l CaCO ₃ eq.	Alkalinity	111	106	154	99
mg/l CaCO ₃ eq.	Calcium Hardness	61	64	105	66
mg/l Cu	Copper	0.04	<0.02	<0.02	<0.02
MPN/100 ml	Total Coliform Count	<2.0	<2	80	8
mg/l Fe	Iron	4.5	0.53	0.04	<0.02
mg/l N	Nitrogen, Total Kjeldahl	0.15	0.75	<0.1	<0.1
mg/l N	Nitrogen, Nitrate	0.11	0.24	0.08	0.11
unit	pH	7.5	7.35	7.35	7.3
mg/l P	Phosphate, Total	0.4	0.45	0.2	0.15
mg/l P	Phosphate, Ortho	0.1	<0.1	<0.1	0.1
mg/l Mn	Manganese	173	163	178	144
mg/l Cl	Chloride	0.26	0.11	0.04	0.1
mg/l	Solids - Dissolved	10	10	9	12
mg/l SO ₄	Sulfate	13	17	20	20
Deg C	Temperature	13	13	15	13
NTU	Turbidity	10.5	9.9	4.3	2.6

Table 28. Water Quality Monitoring Data

Forrestal Campus, Princeton University					
Station: W5 (C-Site Underground Well)					
Collection Date -->		3/22/88	6/13/88	9/19/88	12/19/88
Units	Parameter	4:05 PM	12:45 PM	7:10 AM	12:55 PM
mg/l CaCO ₃ eq.	Alkalinity	52	54	54	60
mg/l CaCO ₃ eq.	Calcium Hardness	33	31	32	39
mg/l Cu	Copper	<0.02	<0.02	<0.02	<0.02
MPN/100 ml	Total Coliform Count	<2	<2	<2	<2
mg/l Fe	Iron	0.11	<0.02	0.23	0.45
mg/l N	Nitrogen, Total Kjeldahl	0.1	0.4	0.4	0.2
mg/l N	Nitrogen, Nitrate	1.4	0.78	2.5	1.7
unit	pH	6.3	6.05	6.15	6.3
mg/l P	Phosphate, Total	0.2	0.2	0.2	0.2
mg/l P	Phosphate, Ortho	0.15	0.2	0.1	0.15
mg/l	Solids - Dissolved	203	104	117	122
mg/l Mn	Manganese	<0.01	<0.01	0.02	0.05
mg/l Cl	Chloride	8	6	26	7
mg/l SO ₄	Sulfate	24	15	10	13
Deg C	Temperature	11	13.5	14	12
NTU	Turbidity	0.6	1.4	2.3	1.6

Table 29. Water Quality Monitoring Data

Forrestal Campus, Princeton University					
Station: TW1 (Test Well #1 D-Site)					
Collection Date -->		3/22/88	7/29/88	10/25/88	
Units	Parameter	2:00 PM	11:40 AM	12:30 PM	
mg/l CaCO ₃ eq.	Alkalinity	145	150	156	
mg/l CaCO ₃ eq.	Calcium Hardness	40	101	33	
mg/l Cu	Copper	0.02	<0.02	<0.02	
MPN/100 ml	Total Coliform Count	<2	<2	2	
mg/l Fe	Iron	0.5	0.11	0.14	
mg/l N	Nitrogen, Total Kjeldahl	<0.1	0.3	<0.1	
mg/l N	Nitrogen, Nitrate	1.3	0.24	0.2	
unit	pH	7.3	7.15	7.3	
mg/l P	Phosphate, Total	<0.1	0.04	<0.1	
mg/l P	Phosphate, Ortho	<0.1	0.05	<0.1	
mg/l	Solids - Dissolved	0.04	0.05	0.06	
mg/l	Manganese	23	14	17	
mg/l	Chloride	250	232	244	
mg/l	Sulfate	24	43	40	
DegC	Temperature	12	23	13	
NTU	Turbidity	3.3	3.7	1	
		3/22/88	8/4/88	10/26/88	12/29/88
pCi/l	Tritium (HTO)*	65	62	58	48
*PPPL Analysis					

Table 30. Water Quality Monitoring Data

Forrestal Campus, Princeton University					
Station: TW10 (Test Well #10 D-Site)					
	Collection Date -->	3/22/88	7/29/88	10/25/88	
Units	Parameter	1:40 PM	3:05 PM	3:30 PM	
mg/l CaCO ₃ eq.	Alkalinity	145	146	153	
mg/l CaCO ₃ eq.	Calcium Hardness	21	83	107	
mg/l Cu	Copper	<0.02	<0.02	<0.02	
MPN/100 ml	Total Coliform Count	<2	<2	13	
mg/l Fe	Iron	0.46	0.31	0.07	
mg/l N	Nitrogen, Total Kjeldahl	<0.1	<0.1	<0.1	
mg/l N	Nitrogen, Nitrate	0.08	0.02	0.04	
unit	pH	7.5	7.35	7.8	
mg/l P	Phosphate, Total	<0.1	0.06	0.1	
mg/l P	Phosphate, Ortho	<0.1	0.04	<0.1	
mg/l	Solids - Dissolved	0.09	0.12	0.02	
mg/l	Manganese	18	19	16	
mg/l	Chloride	372	221	236	
mg/l	Sulfate	19	28	18	
Deg C	Temperature	12	23	13	
NTU	Turbidity	2.6	4	8.9	
		3/22/88	8/4/88	10/26/88	12/29/88
pCi/l	Tritium (HTO)*	80	57	61	68
	*PPPL Analysis				

Table 31. Water Quality Monitoring Data

Forrestal Campus, Princeton University			
Quality Control Samples			
		QA-1	QA-2
	Collection Date -->	4/26/88	4/26/88
Units	Parameter	11:00 AM	11:00 AM
mg/l CaCO ₃ eq.	Alkalinity	15	13
mg/l O ₂	BOD ₅	2	<2
mg/l CaCO ₃ eq.	Calcium Hardness	24	57
mg/l Cr	Chromium - Total	<0.02	<0.02
mg/l Cr	Chromium - Hexavalent	<0.02	<0.02
mg/l O ₂	COD	7	5
mg/l Cu	Copper	<0.02	<0.02
mg/l O ₂	Dissolved Oxygen	10	9.9
mg/l Cu eq.	EDTA	0	0
MPN/100 ml	Total Coliform Count	94	17
ft ³ /sec	Flow	0	0
mg/l Fe	Iron	0.87	1.3
mg/l N	Nitrogen, Total Kjeldahl	0.3	0.7
mg/l N	Nitrogen, Nitrate	2.5	3.1
mg/l	Oil & Grease	0.95	<0.5
unit	pH	6.95	7.2
mg/l P	Phosphate, Total	<0.1	<0.1
mg/l P	Phosphate, Ortho	<0.1	0.15
mg/l	Solids - Dissolved	77	117
mg/l	Solids - Suspended	48	19
mg/l SO ₄	Sulfate	8	24
Deg C	Temperature	0	0
NTU	Turbidity	2.6	1.1
mg/l Zn	Zinc	0.07	0.04
	Clarity	Clear	Md.Cldy

TABLE 32

FERTILIZER, PESTICIDES, AND HERBICIDE APPLICATION [Ra88]FERTILIZER

<u>DATE</u>	<u>LOCATION</u>	<u>PRODUCT</u>	<u>AMOUNT</u>
5/7/88	C & D Sites	Morral 16-0-4	1000 lbs
9/17/88	C & D Sites	Morral 16-0-4	1000 lbs

PESTICIDES

C Site	No pesticides applied
D Site	No pesticides applied

HERBICIDES

<u>DATE</u>	<u>LOCATION</u>	<u>PRODUCT</u>	<u>AMOUNT</u>
5/7/88	C & D Sites All turfed areas	Trimec 899	1.95 gals. 1 gal. per 100 gal. water
5/7/88	C & D Sites All turfed areas	Pre-M 600G	1.17 gals. 0.9-1.2 oz per gal. water
6/3/88	C & D Sites Non-turfed areas	Round-Up*	4.0 gals. 6.0 ozs. per gal. water
9/17/88	C & D Sites All turfed areas	Trimec 899	1.86 gals. 1 gal. per 100 gal. water
9/17/88	C & D Sites Non-turfed areas	Round-Up*	2.0 gals. 6.0 ozs. per gal. water

* Round-Up applications were done on selected non-turfed areas - primarily stoned parking lots and road shoulders. Round-Up applications were prohibited in the detention basin and areas surrounding it.

TABLE 33

QA/QC EPA LAS VEGAS CROSS-CHECK PROGRAM 1988

<u>SAMPLE DATE</u>	<u>TYPE SAMPLE</u>	<u>KNOWN VALUES HTO CONCENTRATION (pCi/l) PLUS EXPECTED LAB PRECISION</u>	<u>PPPL VALUES (pCi/l)</u>
10/14/88	Water	2316 +/- 350	2337 2361 2337
11/11/88	Urine	3025 +/- 359	2980 3110 2970

QA/QC DOE/EML NEW YORK CITY CROSS-CHECK PROGRAM 1988

<u>SAMPLE DATE</u>	<u>TYPE SAMPLE</u>	<u>ISOTOPE</u>	<u>KNOWN VALUE (pCi/ml)</u>	<u>PPPL (pCi/ml)</u>
9/26/88	Water	HTO	10.6	9.68
	Water	Mn-54	1.66	1.52
	Water	Co-57	3.42	3.36
	Water	Co-60	3.82	3.68
	Water	Cs-134	1.06	0.97
	Water	Cs-137	2.28	1.95

FIG. 1. PBX-M

FIG. 2. TFTR

Figure 3

Wind Rose
 Joint Frequency Data for TFTR
 84/ 1 to 88/12
 Elevation 30 m
 For All Stability Classes (100.0%)

Figure 4

Wind Rose
Joint Frequency Data for TFTR
84/ 1 to 88/12
Elevation 60 m
For All Stability Classes (100.0%)

Wind Speed (m/s)

7.0	■	and above
2.0	■	to 7.0
1.0	■	to 2.0
0.75	■	to 1.0
0.50	■	to 0.75
0.22	■	to 0.50

Center = 0.1m %

FIG. 5. FORRESTAL CAMPUS

FIG. 6. C- AND D-SITES

FIG. 7. 80 km (50-MILE) RADIUS OF SITE

FIG. 8. IMMEDIATE SITE VICINITY
(5-MILE RADIUS)

FIG. 9. PLASMA PHYSICS LABORATORY
JAMES FORRESTAL CAMPUS
PRINCETON UNIVERSITY
PRINCETON, NJ

Princeton Plasma Physics

1985 POPULATION ESTIMATES
WITHIN ANGULAR SECTORS
0 - 10 MILES
Figure 10

*Taken from Be87a

Princeton Plasma Physics

1995 POPULATION PROJECTIONS
 WITHIN AZIMUTHAL SECTIONS
 0 - 10 MILES

Figure 11

*Taken from Be87a

Princeton Plasma Physics

2000 POPULATION PROJECTIONS
WITHIN ANNUAL SECTIONS
0 - 10 MILES

Figure 12

*Taken from B687a

Princeton Plasma Physics

2005 POPULATION PROJECTIONS
WITHIN ANNUAL SECTIONS
B - 10 MILES

Figure 13

*Taken from Be87a

Princeton Plasma Physics

2010 POPULATION PROJECTIONS
MIDDLE AMERICAN ELECTRON
8 - 30 MILES

Figure 14

*Taken From 10-87a

Princeton Plasma Physics

1980 POPULATION ESTIMATES
WITHIN 10-MILE SECTIONS
10 - 36 MILES

Figure 15

*Taken from Bof7a

Princeton Plasma Physics

1985 POPULATION ESTIMATES
WITHIN HAWAIIAN SECTORS
0 - 30 MILES

Figure 16

*Taken From Be87a

Princeton Plasma Physics

2000 POPULATION ESTIMATES
WITHIN AIRPLANE DELTAS
10 - 50 MILES

Figure 17

*Taken from B687a

*Taken from Be8/a

Princeton Plasma Physics

2000 POPULATION ESTIMATES
WITHIN AZIMUTHAL SECTIONS
10 - 30 Mhz

Figure 18

Princeton Plasma Physics

2010 POPULATION ESTIMATES
WITHIN 10-MILE SECTIONS
10 - 50 MILES

Figure 19

*Taken from Bc87a

FIG. 21. Millstone River Basin Offsite Water Sample Locations

Figure 22. Potentiometric surface of the bedrock aquifer, October 30, 1986.
(Taken from Le67)

Figure 23. Schematic representation of hydrogeologic framework and potential flow paths of spilled water. (Taken from Le87).

FIG. 24. 1988 Precipitation by Month and
Yearly Integration
(Shows last 3 quarters of 1988)

1988 Precipitation Data

Weekly Precipitation in Inches						Monthly Precipitation in Inches				
W#	In.	W#	In.	W#	In.	W#	In.	Mon.	In.	Accum.
1	*	14	0.1	27	0	40	0.2	Jan.	*	*
2	*	15	0.4	28	0.95	41	0	Feb.	*	*
3	*	16	0.5	29	*	42	1.8	Mar.	*	*
4	*	17	0.95	30	*	43	0	Apr.	1.95	1.95
5	*	18	0.8	31	0	44	1.05	May	4.65	6.6
6	*	19	0.6	32	0	45	0.43	Jun.	1.03	7.63
7	*	20	1.75	33	0.35	46	3.35	Jul.	0.95	8.58
8	*	21	1.5	34	1.15	47	1.55	Aug.	3.90	12.48
9	*	22	0.75	35	2.4	48	0	Sep.	1.10	13.58
10	*	23	0.05	36	0	49	0	Oct.	2.00	15.58
11	*	24	0.1	37	0.45	50	0	Nov.	6.38	21.96
12	*	25	0	38	0.15	51	0.75	Dec.	0.95	22.91
13	*	26	0.125	39	0.5	52	0.2			

*=no data collection

FIG. 25. OFF-SITE MONITORING LOCATIONS

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