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A Radiological Environs Study at a Fuel Fabrication Facility

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A RADIOLOGICAL ENVIRONS STUDY AT A FUEL FABRICATION FACILITY

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U. S. ENVIRONMENTAL PROTECTION AGENCY

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Foreword

The Office of Radiation Programs (ORP) of the U.S. Environmental Protection Agency carries out a national program designed to evaluate population exposure to ionizing and nonionizing radiation and to promote development of controls necessary to protect the public health and safety. In-depth field studies of various radiation sources (e.g., nuclear facilities, uranium mill tailings, and phosphate mills) provide technical data for environmental impact statement reviews as well as needed information on source characteristics, environmental transport, critical pathways for population exposure, and dose model validation.

The staff of ORP's Eastern Environmental Radiation Facility, Montgomery, Alabama, was responsible for assessing the release to the environment of uranium effluents from a nuclear fuel fabrication plant. This work was in direct support of ORP's overall evaluation of the uranium fuel cycle of which nuclear fuel fabrication is an integral part.

I encourage readers of this report to inform us of errors or omissions. These or requests for further information may be forwarded to:

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Preface

The Eastern Environmental Radiation Facility (EERF) participates in the identification of solutions to problem areas as defined by the Office of Radiation Programs. The facility provides analytical capability for evaluation and assessment of radiation sources through environmental studies, surveillance, and analysis. The EERF provides technical assistance to state and local health departments in their radiological health programs and provides special analytical support for Environmental Protection Agency Regional Offices and other federal government agencies as requested.

The fuel fabrication plant described in this report is one of a series of field studies designed to provide a data base for use in evaluating the environmental impact of uranium fuel cycle elements.

Charles R. Porter
Director
Eastern Environmental Radiation Facility

Acknowledgement

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The authors also recognize this report is a product of the entire staff of the Eastern Environmental Radiation Facility (EERF). Significant individual cooperation and team efforts contributed directly to make this work possible.

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Abstract

The Environmental Protection Agency and the Nuclear Regularory Commission conducted joint field studies to detect environmental contamination from fuel fabrication plant effluents. The plant chosen for study was operated by the General Electric Company, Nuclear Field Division, at Wilmington, NC.

The facility operates continuously using the ammonium diuranate (ADU) process to convert 2.0 to 2.2% enriched UF_6 to UO_2 fuel. Environmental uranium from plant effluents was distinguished from naturally occurring uranium by using specific isotopic analyses and statistical interpretations. Continuous air samplers at five sites measured the concentrations of ^{234}U and ^{238}U in air for 36 one-week intervals. River water was sampled at nine locations above and below the plant discharge point during each of three field surveys.

The atmospheric concentrations of ^{234}U and ^{238}U appeared to vary according to a log-normal distribution. Data points clearly off the distribution curve were indicative of contamination by plant effluent. Comparisons of the isotopic ratios also indicated samples with significant contamination from plant effluent. The annual facility release of approximately 2 to 3 mCi uranium to the atmosphere would add from 0.01 to 0.2 fCi/m^3* uranium in the atmospheric environs. An individual residing continuously at the nearest residence is predicted to receive a 50-year dose commitment of 0.9 mrem to the lung.

The approximately 1 Ci/yr of uranium liquid effluent released would increase the uranium concentration in Northeast Cape Fear estuary about 3 kilometers downstream by 0.3 pCi/liter. Although this water is not potable and is not used for any potable water supply, ingestion of water containing uranium at this concentration for a year would deliver a 3-mrem dose commitment to the bone.

*fCi = femtocurie + 10^{-15} Ci

Introduction

The assessment of the radiological impact of the total uranium fuel cycle by the Office of Radiation Programs indicates that members of the general population may receive significant radiation doses from the operation of facilities in the cycle other than reactors (1). One such facility is the fuel fabrication plant. Prior to this study, its radiological impact had been estimated using facility operational data and theoretical dispersion formulae. These preliminary studies (1) indicate that the fuel fabrication operation can deliver a measurable dose even though it may only constitute about 2 percent of the population dose from the fuel supply portion of the uranium fuel cycle. Although studies of reactors (2,3) and reprocessing plants have been reported (4-8), basic environmental measurements required to confirm the environmental effects of radioactive effluents from a fuel fabrication facility are lacking. Since this indicated a need for definitive field data to assess the presence of radioactive effluents in the environs of a fuel fabrication facility, the Eastern Environmental Radiation Facility was assigned the responsibility of designing and implementing a field study of such a facility which would measure the radiological impact of plant effluents on its environs.

A joint Environmental Protection Agency - Nuclear Regulatory Commission field study was initiated at the General Electric Company, Nuclear Fuel Division, fuel fabrication plant, Wilmington, North Carolina, July 1974. The study was conducted with the full cooperation of the General Electric Company. This plant was selected as representative of current engineering technology in fuel fabrication. The construction of this plant began in 1967 and production operations began in 1969. Since several plants had been operating for about 8 years prior to the construction of this plant, their operating experience was incorporated in the design of this facility. During the five years of operation, General Electric has further improved their waste treatment systems.

The study of this fuel fabrication plant was designed to provide information for evaluating the radiological component of the environmental impact and to estimate the population dose.

The specific objectives of the study were:

1. to determine off-site concentrations of radioisotopes of uranium which are released through plant operations,

2. to estimate from these concentrations the dose commitment to individuals residing in the vicinity of this fuel fabrication plant,

3. to evaluate the relationship between effluent discharges and dose commitment, and

4. to evaluate the relevance of radiation dose pathways and to validate existing pathway dose models for this facility.

Study Design

Basic Premise

The overall study design was built around the significant pathways of radioactive effluents to man. Figures 1 and 2 describe a generalized summary of radionuclide pathways to man via air and water, respectively.

These pathways apply to all nuclides, but the significance of a pathway may vary depending on the particular nuclide studied. The predominate plant radioactive effluent is uranium which is released into the air and water. Consequently, the study was designed to make measurements in the most significant pathways in air and water due to the release of uranium.

Since uranium occurs naturally in components of these pathways, additional characteristics were necessary to delineate the impact of plant effect from natural environmental radionuclide content. The characteristic most heavily relied upon for this study was that of the uranium-234/uranium-238 activity ratio. Naturally occurring uranium is usually found in equilibrium with its daughters having a uranium-234/uranium-238 ratio of one. The plant effluent is enriched uranium. Although enrichment refers to uranium-235, uranium-234 is also enriched during the diffusion process. The plant effluent has a characteristic uranium-234/uranium-238 ratio of 3.5. Other distinctive characteristics could be elevated uranium-thorium ratios and ^{235}U content.

Air Pathway Sampling

The first measurements in the air pathway (figure 1) occurred at the release point where the plant operators sampled to determine the quantity of radioactivity released. The plant operators continuously monitored individual vent releases and provided the weekly release data for this study.

From the vents the airborne radioactivity follows one of the three major routes - inhalation, deposition, and direct radiation - to deliver a radiation dose to man.

The major effort of the study was directed at the inhalation route, since preliminary evaluations indicated it to be the dominant exposure pathway. This effort involved measuring uranium concentrations of environmental air. In the

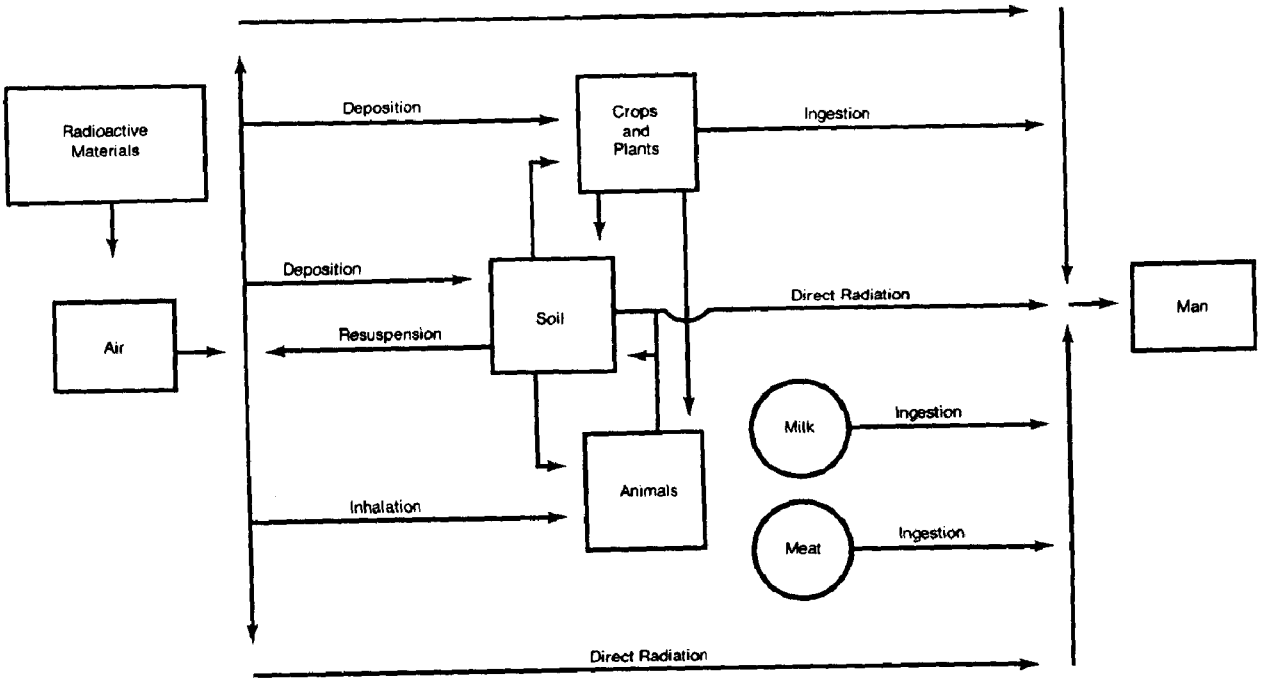

Figure 1. Pathways between radioactive materials released to the atmosphere and man

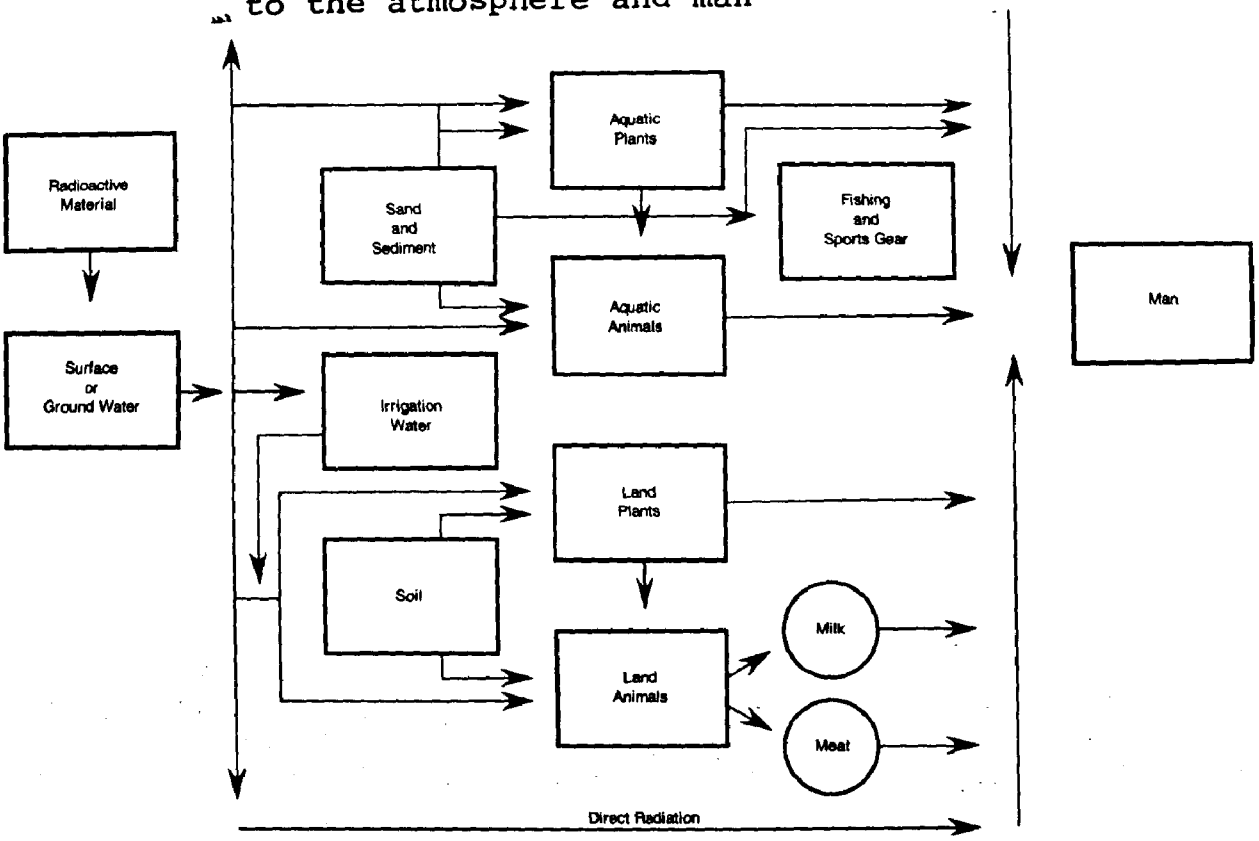

Figure 2. Pathways between radioactive materials released to surface waters and man

sampling of these air concentrations for the effect of plant releases, it was recognized that the relatively small plant effect would be difficult to discern from natural uranium background. In the hopes of optimizing sensitivity for plant effluents, we designed two sampling systems.

A plume monitoring system was designed using four downwind sampling systems and one background system each controlled by windvane. This system was operated during each of three field surveys of the study. This system detected plant effluent, but an appropriate background was not measurable. The details of sampling and the resulting data are given in Appendix A.

A second monitoring system consisted of five continuous samplers which ran for the duration of the study. Four samplers were within 2 kilometers of the facility to determine plant effluent characteristics. A fifth sampler was 7 kilometers from the facility to characterize background. The samples were collected weekly and analyzed for isotopes of uranium and thorium. The concentration of uranium and thorium and the isotopic ratios were used to characterize and distinguish between background and plant effluent.

The segment of the air pathway involving deposition and subsequent ingestion through the consumption of locally grown food crops was considered much less significant than inhalation. (See figure 1.) There are few farm crops grown in the area and uranium does not concentrate in plants or vegetation (11). The removal of uranium from the air pathway by deposition was monitored. Fallout trays and rain collectors were used at the continuous air sampling sites for the duration of the study. Soil and vegetation were collected at these sites during field surveys to evaluate these routes.

The inhalation or ingestion of uranium by animals and later ingestion of milk and meat by man was not monitored since exposures in this pathway would be several orders of magnitude below the more direct ones described above.

Water Pathway Sampling

The release of radioactivity into surface water was monitored by plant operators. The plant operators sampled the released liquid continuously and provided weekly release data to this study. Selected liquid release samples were split for cross-check analysis by EERF.

The major effort of monitoring the water exposure pathway was directed at the ingestion route (figure 2) even

though the water is not used for potable purposes. A Geological Survey study (9) performed in 1969 described the dispersion and transport of soluble pollutants in the Northeast Cape Fear estuary. Every effort was made to duplicate the sampling sites of this study to facilitate the use of their empirical model.

The uptake of uranium from the Northeast Cape Fear River by plants and animals was not considered a significant exposure pathway to man (10). Most of the fish removed from these waters were migrating through rather than living in the river. Removal of uranium from the water pathway was monitored by collection of sediment and vegetation at water sampling sites.

This estuarine water is not used for irrigation and this pathway was not monitored.

Direct radiation was not monitored since there is practically no swimming in the area, boating personnel would not be exposed to alpha radiation, and exposure to direct radiation would be expected to be negligible in light of historical effluent release data for the fuel fabrication plant.

The Study Site

Plant Description

The General Electric Nuclear Fuel Division plant (9) is situated on a 6.74 square kilometer site, approximately 10 kilometers north of the city of Wilmington, North Carolina. This location is in the southeastern corner of the coastal plains region of the state. The area around the site is sparsely populated, and the land is characterized by heavily timbered tracts. Farms, single family dwellings and limited commercial activities are located chiefly along major highways.

Of the total 6.74 square kilometers, only about .61 square kilometer has been developed. The developed area consists of landscaping, storage, parking, and waste treatment facilities. There are five major buildings: (1) fuel manufacturing operations (FMO); (2) equipment services operations (ESO), (3) fuel components operations (FCO), (4) maintenance (MAINT) building, and (5) office building. The FMO is the only building in which uranium is processed and is, therefore, the point at which all radioactive waste is generated.

The Fabrication Process

The fuel manufacturing process produces fuel for light water nuclear reactors. The process begins with the receipt of slightly enriched uranium (up to 4 percent uranium-235) in the form of a uranium hexafluoride (UF_6). The final product is a fuel assembly of uranium dioxide pellets encapsulated in a zircaloy cladding ready for insertion into a particular reactor core.

Operations involving chemical processing (figure 3) include conversion of UF_6 to UO_2 and the recovery of uranium from scrap and waste by chemical processing in the uranium purification system (UPS). The chemical conversion of UF_6 to UO_2 utilizes the ammonium diuranate (ADU) process. Enriched uranium hexafluoride is received in 76 centimeter diameter cylinders, each contained within a protective shipping fixture (11). The nominal cylinder capacity is 2,275 kg of UF_6. A cylinder is placed within a vaporization chamber and heater by recirculating heated air. Vaporized uranium hexafluoride flows through piping connected to the cylinder valve into a tank containing water where it is hyrdolized to uranyl

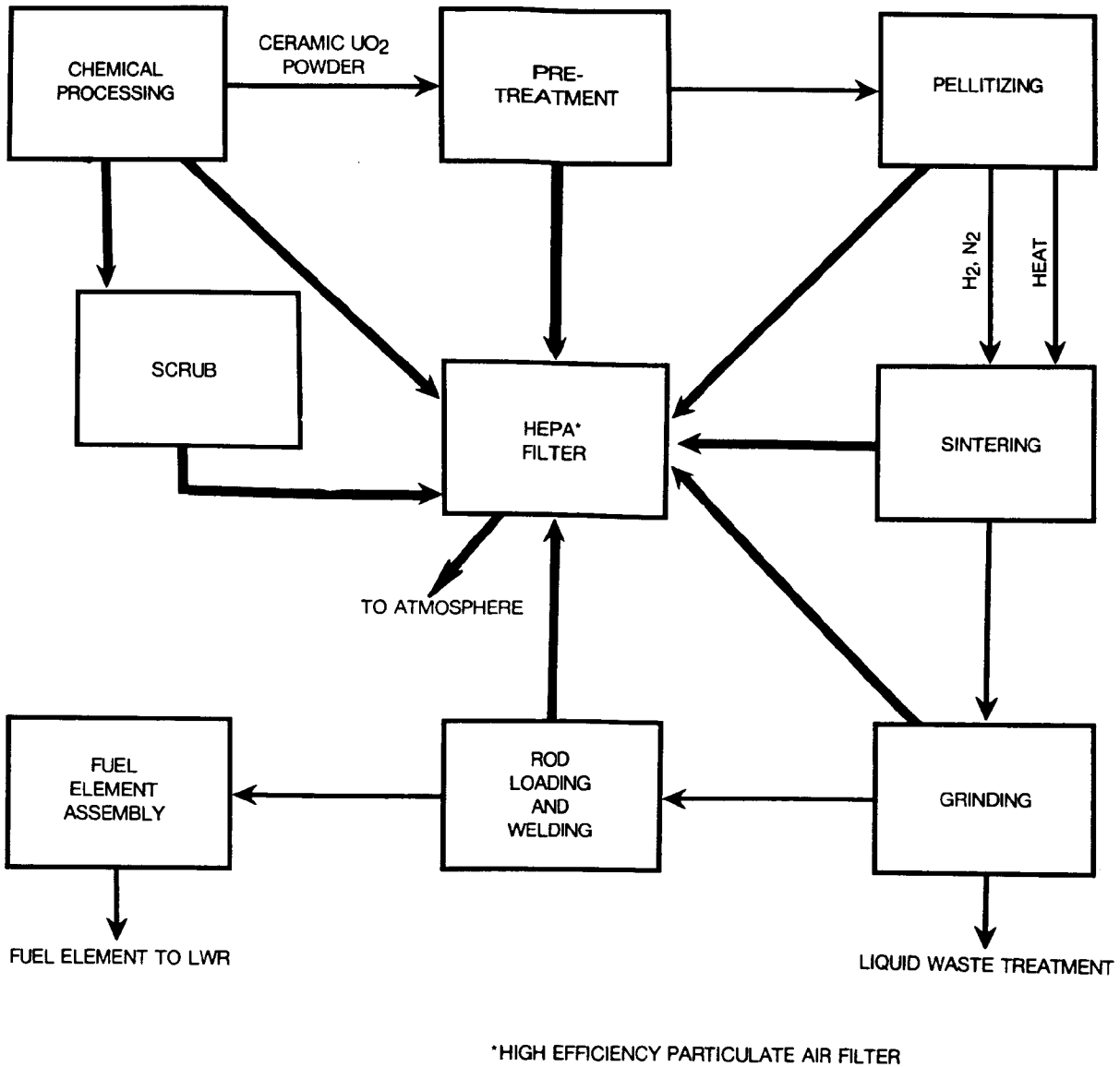

Figure 3. Fuel fabrication-Chemical processing block diagram

fluoride (UO_2F_2) and hydrofluoric acid (HF).

Ammonium diuranate [$(NH_4)_2U_2O_7$] is precipitated from uranyl fluoride upon contact with ammonium hydroxide (NH_4OH). Centrifugation separates the liquid phase (water) from the resulting ADU slurry. The separated liquid is processed in a second high speed centrifuge to obtain more complete removal of uranium. The liquid is then quarantined, sampled, and released to the final waste treatment system. The ADU solid flows continuously into a horizontal gas-fired defluorinatorcalciner where it dries at about 670°C and reduces to uranium dioxide in a second similar furnace. Off-gas from the defluorinator is scrubbed to remove uranium compounds and routed to the main scrubber filter ventilization system. Uranium dioxide discharged from the calciner is stored as feed for the mechanical processing.

The uranium purification system (UPS) reprocesses certain process materials which do not meet the required specifications for the uranium dioxide product. These materials are first dissolved in nitric acid (HNO_3). The resulting uranyl nitrate [$UO_2(NO_3)_2$] solution is then filtered and cooled. Reaction with hydrogen peroxide (H_2O_2) and ammonium hydroxide (NH_4OH) precipitates the uranium as the tetroxide ($UO_4 \cdot 2H_2O$) which is dewatered by centrifugation. After drying, the tetroxide powder goes to the calciner where it is converted to uranium dioxide (UO_2). This recovered product is also utilized as feed for the mechanical process. Waste liquids from the UPS are collected in a quarantine tank, sampled, and routed to the waste treatment system.

The uranium dioxide powder is pressed into pellets (figure 4) which are normally 1.27 centimeters in diameter by 1.27 centimeters long. After sintering in a reducing atmosphere at 1670°C the pellets are ground to a standard diameter, purity tested, dried, and loaded into zircaloy tubes. The tubes have been previously fitted with a welded end plug at one end. After filling, the second end plug is welded into place. The loaded tubes or rods are assembled in 49- or 64-rod bundles or fuel assemblies and packaged for shipment to the customers' nuclear reactor sites.

Waste Treatment

Liquid waste:

Liquid wastes are generated by several in-plant operations but only the fuel manufacturing operation in the FMO building generates waste containing uranium

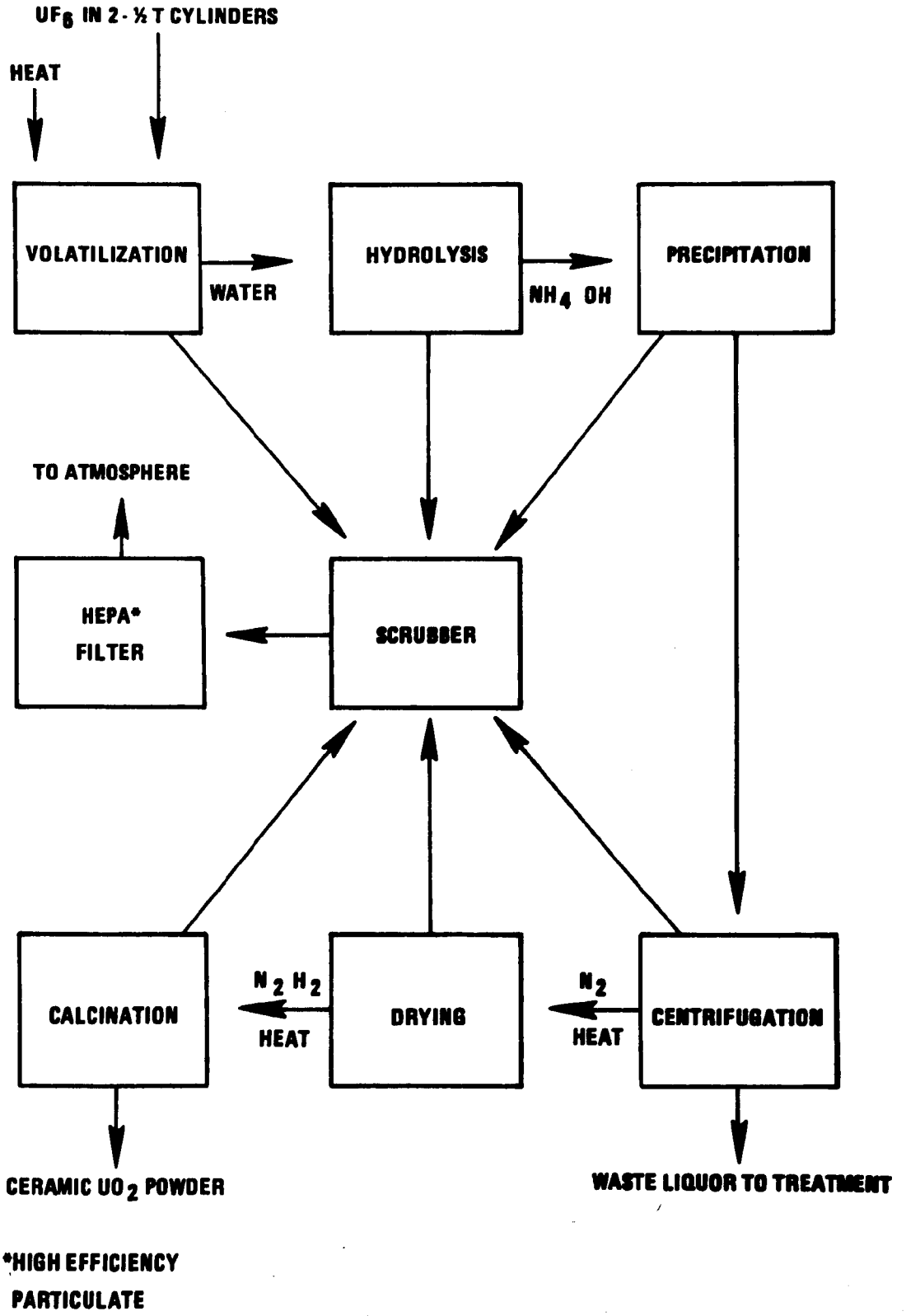

Figure 4. Fuel fabrication-Mechanical processing block diagram

contaminants. The liquid wastes at the FMO are classified and treated separately as fluoride, nitrate, or radwaste.

Liquid removed by centrifugation in the conversion of uranium hexafluoride to uranium dioxide is classified as fluoride waste. Each batch collected in the FMO quarantine tanks is sampled and analyzed for its uranium content. Upon verification of adequate uranium removal (including recycling when necessary), these liquids are pumped to a 245,000-liter storage tank. Liquids from this tank are pumped to the 378,500-liter tank in the waste treatment facility. The latter tank is constructed with a conical (funnel-shaped) bottom which effects a further settling of particulate residue as material is pumped through. The settled residue is periodically removed and returned for rework and recovery of the uranium.

Lime is added to the liquid fraction on a batch basis causing the fluorides to precipitate as calcium fluoride and freeing the ammonia for subsequent removal by aeration. The resulting slurry goes to a series of final treatment lagoons in which calcium fluoride settles and ammonia is dissipated.

Liquid wastes from the UPS and nitric acid residues from equipment cleaning operations are collected in quarantine vessels and are classed as nitrate wastes. In the waste treatment system, the addition of lime precipitates the calcium uranate. The precipitated slurry is centrifuged to remove the calcium uranate which is returned to the fuel manufacturing for recovery. The clarified nitrate solution is routed to nitrate retention lagoons for final treatment.

Water from protective clothing washing machines, laboratory sinks, floor washings, equipment decontamination, and similar fuel building services is collected in radwaste accumulator tanks. After the solids have been removed by centrifugation, the clarified water is sampled, analyzed and either recycled or released to the discharge lagoons. These lagoons discharge the liquid effluent through a weir overflow. Aliquots proportional to the flow are collected at the weir continuously. The aliquots are combined on a daily basis and analyzed for chemical concentration of uranium. The uranium discharged in liquid effluent is reported on a weekly basis.

Airborne waste:

Operations within the FMO also produce airborne radioactive waste. The FMO has several different operations which have separate venting systems. The ventilation systems installed are designed to filter all air from zonesused to handle or process uranium through High Efficiency Particulate Aerosol (HEPA) filters prior to release.

The ventilation systems for operationswhich could result in the release of uranium as soluble mists or gases incorporate water scrubbing prior to HEPA filtration. In these systems, water is sprayed into the air stream to wash out the contaminant mist or gas. The air stream is then heated prior to passing through the final HEPA filters.

The ventilation systems for operations that could result in release of only particulate uranium incorporate two successive stages of HEPA filtration.

Each release vent is equipped with a sampling device which continuously draws a sample of the vent exhaust through a Hollingsworth & Vose #70 filter. The filters are changed and analyzed for uranium weekly.

There are 21 vents protruding approximately 2 meters above the roof of the three-story FMO. These vents are located in a 900 m^2 area.

Uranium contaminated, combustible waste is reduced to ash in a specially designed incinerator. The offgas is treated by water scrubbing and HEPA filtration. The incinerator is located approximately 50 meters west of the FMO.

Plant Environs

Demography:

Although the General Electric plant is located near Wilmington which has a population of 46,000, the nearest community, Castle Hayne, is five kilometers north of the plant and has a population of 700. The population density, within an eight-kilometer radius of the plant, was 18 persons per square kilometer in 1973 (figure 5, table 1).

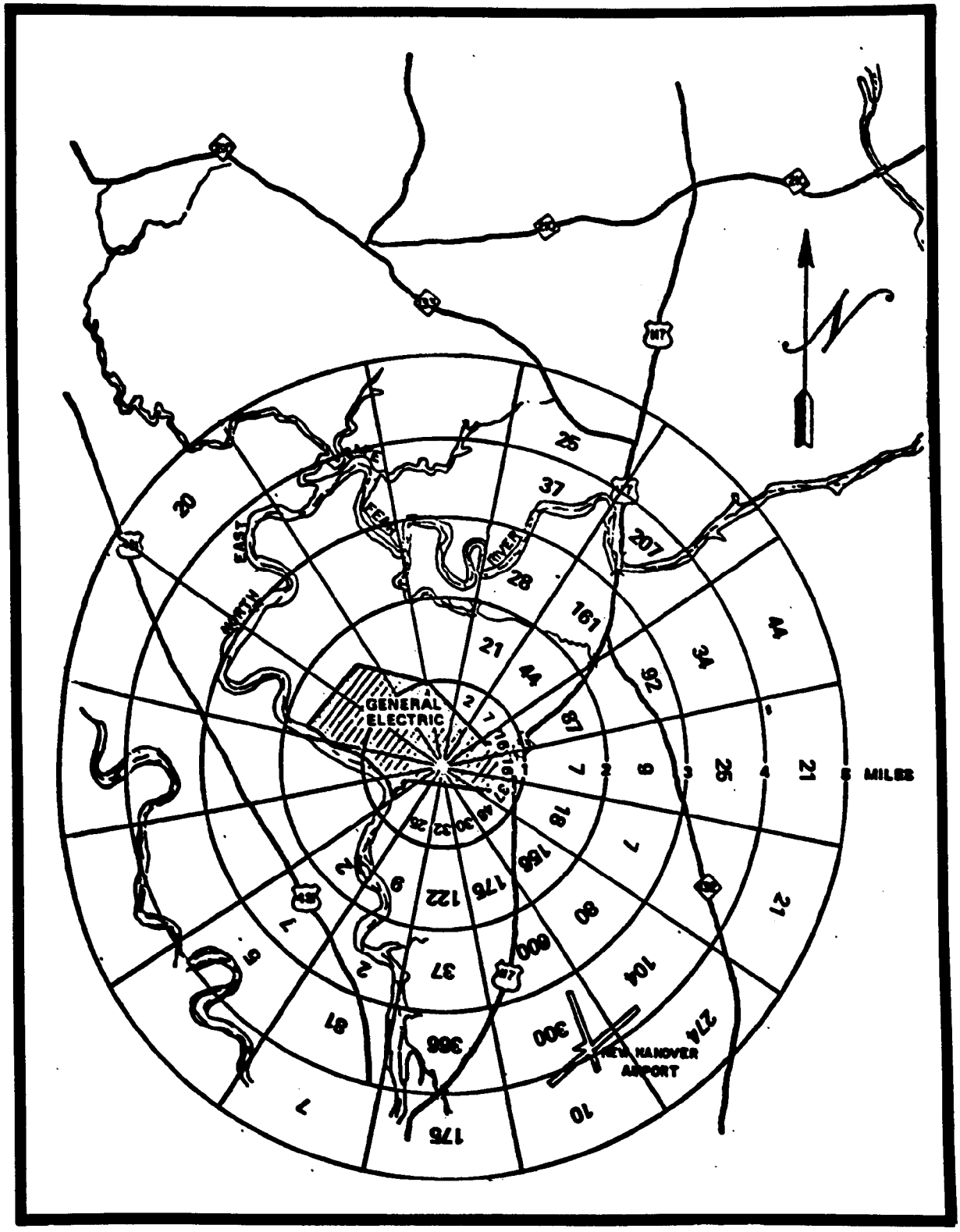

Figure 5. Population distribution in the plant environs

Table 1

Population Distribution in the Plant Environs

INHABITANTS PER SECTOR

(1973)

Compass Sector	Population: kilometers from FMO stack 0-1.6	1.6-3.2	3.2-4.8	4.8-6.4	6.4-8.0	Total No. of Inhabitants per Subsector
	No. of Inhabitants per Subsector					
N	0	0	0	0	0	0
NNE	2	21	28	37	25	113
NE	7	44	161	207	0	419
ENE	16	87	92	34	44	273
E	16	7	9	25	21	78
ESE	37	18	7	0	21	83
SE	48	156	80	104	274	662
SSE	30	175	600	300	10	1115
S	32	122	37	366	175	732
SSW	25	9	2	81	7	124
SW	0	2	7	5	0	14
WSW	0	0	0	0	0	0
W	0	0	0	0	0	0
WNW	0	0	0	0	0	0
NW	0	0	0	0	20	20
NNW	0	0	0	0	0	0
						3633

Hydrology:

The Northeast Cape Fear River, at the western boundary of the plant site, receives all surface storm water and treated waste drainage from the plant site. The Northeast Cape Fear River originates about 160 kilometers north of the plant site. The river meanders approximately 200 kilometers from its origin to its confluence with the Cape Fear at Wilmington. The confluence is 10 ¼ kilometers south of the plant. From this point, the Cape Fear widens into an estuary and discharges to the Atlantic Ocean about 30 kilometers further south.

The flow characteristics of the Northeast Cape Fear River, at the plant site, are complex because of its estuarine characteristics. Dilution and transit times are a function of both tidal influence and fresh water inflow. The U. S. Geological Survey conducted a special study to determine the dispersive and assimilative characteristics of this type flow at the request of and in cooperation with the North Carolina Department of Water and Air Resources and General Electric (9).

The study determined that the volume of water passing the site during a particular ebb and flood tidal cycle was 6×10^9 liters and 9×10^9 liters, respectively, whereas the fresh water inflow was estimated at only 3×10^8 liters during the same period. This study, based on fluorescent dye tracing, showed that the Northeast Cape Fear River quickly disperses a solute both vertically and horizontally.

Extrapolation of the study shows that at the maximum fresh water inflow for the period of record, the transit time from the plant site to the confluence with the Cape Fear River would be about 12 hours. Based on the water year, October 1969 - September 1970, a more normal transit time would be 10 days.

Three significant aquifers contain potable water in the G. E. Wilmington Plant environs. They are located in the shallow surface sands, the Peedee formation, and the Castle Hayne formation. Deeper strata contain saline water. The Peedee formation which provides the potable well water for the plant is separated from the saline aquifers by 30 to 50 meters of impervious clay sediments. The major recharging source of near-surface waters is rainfall.

Water use:

Residential, industrial, and commercial facilities outside the Wilmington Water District draw their water from individual wells. The plant site water is supplied by a series of strategically placed wells on the site.

The Wilmington Water District serves the city of Wilmington and obtains supply water from the Cape Fear River. The supply point for the district is about 30 km above the confluence of the Cape Fear and the Northeast Cape Fear Rivers. The supply point is also above the dam and navigational Lock #1. Therefore, the Wilmington water supply is unaffected by the G. E. Wilmington plant discharges. There appears to be no potable or commercial use of the Northeast Cape Fear water within the area affected by plant discharge.

AIRBORNE EXPOSURE PATHWAY

Sampling

Continuous monitoring of gaseous effluent is a routine part of the operation of the General Electric fuel fabrication. The gaseous effluent consists of gas and the particulates which pass through High Efficiency Particulate Aerosol (HEPA) filters. Approximately 21 separate vents release gaseous effluent from the processes in the FMO building. Each stack is continuously sampled by pumping a portion of the released gas through a Hollingsworth & Vose #70 filter paper. The filters are replaced weekly for analysis. Essentially all of the airborne uranium which is in the gaseous effluent is considered to be in the particulate form. Only streams containing UF_6 carry the contaminant in a gaseous form. Since all UF_6 streams pass through water scrubbers and driers prior to final filtration and since the air stream at final filtration is at temperatures below the volatization temperature of UF_6, the assumption that airborne contaminants are in a particulate state seems valid.

Half of the in-plant samples collected during each field survey were analyzed for specific isotopes of uranium for the Nuclear Regulatory Commission by the Health Services Laboratory. These analyses were performed after plant analyses for total uranium were completed. Five of these samples were split for cross-check analysis by the EERF. This was to provide added assurance of the accuracy of release data.

As a part of each field survey, pairs of air samplers were set up at four locations in the predominant downwind direction from the plant. Each pair was controlled by its own wind vane such that under optimum wind conditions one sampler ran; for any other condition the other sampler ran. This was an effort to increase the chances of sampling the plume at ground level. This system and its data are described in Appendix A. The resultant data did not produce any significantly useful information.

The continuous sampling system was initiated July 15, 1974, when four continuous air particulate samplers were set up 1.4 to 2 kilometers from the plant in the north, east, south, and west quadrants. To obtain background airborne uranium concentration, a fifth air particulate sampler was loacted 7.5 kilometers in a predominantly upwind direction, south southeast of the plant. Except for minor sampler breakdowns, this sytem operated until March 21, 1975.

The samplers filtered airborne particulates at 0.8 cubic meters per minute for 7 days using an MSA type H filter which is 99.98% efficient for 0.3 μm DOP (dioctyl phthalate) particles. The filters were then changed for the next sampling period.

As shown in figure 6, the samplers were located at the following distances and direction from the FMO: C_N at 1.4 kilometers and 55^0, C_E at 1.7 kilometers and 90^0, C_S at 2 kilometers and 190^0, C_W at 1.7 kilometers and 260^0, and C_B at 7.5 kilometers and 150^0.

Analysis

Air particulate sampling filters were gamma scanned on a Ge(Li) spectrometry system prior to chemical processing. The filters were then ashed in a muffle furnace and put into solution for chemical separation of uranium and thorium. Uranium and thorium were separated using liquid extraction (12) and coprecipitation (13) with lithium fluoride (LiF). The uranium or thorium precipitates were filtered through membrane filters having a pore size of .45 micrometers. The precipitate was washed with alcohol and dried. This extremely thin sample affords practically no self-absorption. The samples were counted with silicon surface barrier alpha spectrometry systems to determine the activity of the specific isotopes of uranium and thorium.

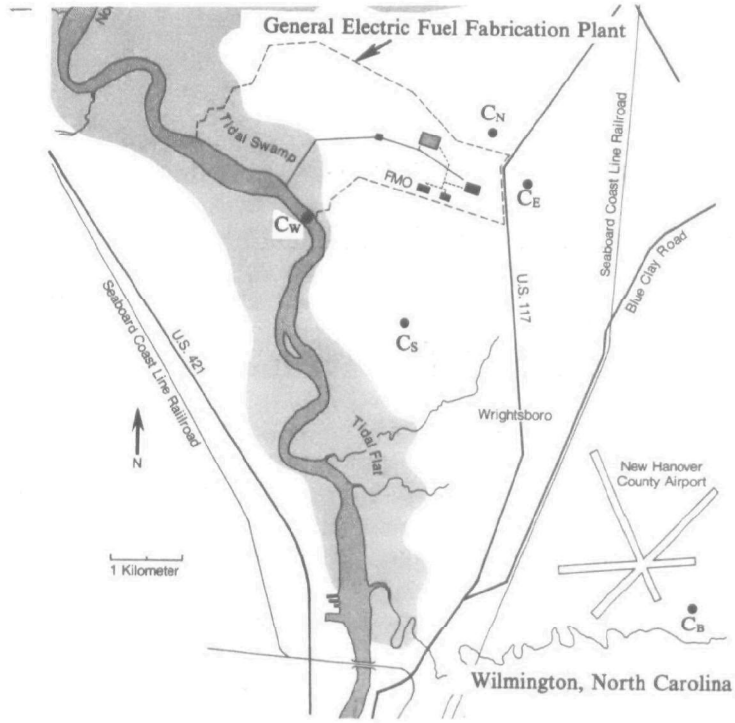

Figure 6. Plant site and location of air monitoring stations

Airborne Plant Effluents

The airborne release from selected stacks is given in table 2 (Field Survey 1), table 3 (Field Survey 2), and table 4 (Field Survey 3). A comparison of the two independent analyses (HSL, GE) was statistically tested. The data according to the paired "t" statistic are not significantly different at the 5 percent significance level. It can be seen in tables 2-4 that the uranium is enriched in ^{234}U and has an average uranium-234/uranium-238 ratio of 3.5.

The total airborne release data provided by GE (table 5) are used in modeling plant effect. Although the average release rate during the study, July 15, 1974, to March 21, 1975, was 45 μCi per week, the weekly releases do vary significantly from the average. The minimum weekly release was 7 μCi per week while the maximum was 298 μCi per week.

Environmental Air Monitoring Data

Continuous air sampling generated approximately 36 weekly samples for each sampling location. The data tabulated in appendix B are illustrated in figures 7-11. The average uranium concentrations for the 36-week study period, given in

Table 2

Airborne Radioactive Waste Release (July 12 - 19, 1974)

Health Services Laboratory Data

Process or Stack*	fCi/m³ U-234	fCi/m³ U-235	fCi/m³ U-238	μCiU/week	General Electric μCi/week
SEGM	32.2	1.4	8.4	0.139	0.224
SLUG	175	4.9	52.5	0.787	1.03
PEL-1	17.2	0.6	3.5	0.045	0.123
PEL-2	96.7	3.8	31.9	0.134	0.287
FURN	14.7	0.5	2.8	0.064	0.418
GADO	13.5	0.5	3.5	0.068	0.140
UPSE	260	1.8	73.6	1.32	2.25
INEX	1470	54.3	421	1.30	1.10
POWS	17.3	0.6	4.9	0.046	0.075
#5 MILL	1020	39.4	326	0.703	1.03
CHMN	4730	315	1576	56.0	19.0

*

STACK CODE	PROCESS DESIGNATION
CHMN	Chemical Process (North)
CHMS	Chemical Process (South)
SEGM	Pellet Grinding
SLUG	Powder Pressing
POWS	Powder Storage
PEL-1	Pelletizing
PEL-2	Pelletizing
FURN	Sintering Furnaces
GADO	Powder to Pellet Line
BAGH	Baghouse Exhaust
CLAB	Laboratory

STACK CODE	PROCESS DESIGNATION
MANT	Maintenance Area
INEX	Incinerator
WTCR	Centrifuge Room-Waste Treatment
WTLB	Laboratory-Waste Treatment
#5 MILL	Mill System
UPSE	Drying Ovens
NDRE	NDF Decontamination Facility
INEX	End Incinerator Rm.
INCN	End Incinerator Rm.
INCS	Incinerator Room

Table 3

Airborne Radioactive Waste Release (October 18 - 24, 1974)

Health Services Laboratory Data

Process or Stack	fCi/m³ U-234	fCi/m³ U-235	fCi/m³ U-238	μCiU/week	General Electric μCi/week
CHMN	4040	149	1190	4.96	5.578
CHMS	501	17.7	151.8	5.14	3.543
SLUG	846 (836)	37.9 (40.6)	265 (271)	4.66	3.957
PEL-2	138	6.5	39.8	0.189	0.221
BAGH	346	14.7	99.4	0.197	0.230
CLAB	225	10.2	68.6	0.659	0.117
INEX	4940 (4180)	179 (254)	1470 (1470)	4.44	2.942
WTCR	17.9	0.6	5.5	0.001	0.002
WTLB	276	7.6	57.8	0.069	0.100
#5 MILL	395	18.9	163	0.330	0.391
UPSE	783 (731)	36.3 (39.2)	284 (253)	4.09	5.749
MANT	108	3.8	32.5	0.825	0.176

Numbers in parentheses are EERF cross-check data.

Table 4

Airborne Radioactive Waste Release (March 14 - 21, 1975)

Health Services Laboratory Data

Process or Stack	fCi/m³ U-234	fCi/m³ U-235	fCi/m³ U-238	μCiU/week	General Electric μCi/week
CHMN	3210 (2930)	134 (132)	807 (769)	9.02	16.380
CHMS	1350 (1190)	54.4 (52.9)	355 (322)	11.2	3.348
SLUG	96.9	4.1	30.6	0.545	0.608
PEL-2	28.0	1.2	9.8	0.055	0.274
BAGH	414	14.9	108.2	0.358	0.608
#5 MILL	134	5.4	38.3	0.102	0.279
UPSE	49.2	2.2	13.8	0.261	0.494
NDRE	10.0	0.3	3.2	0.043	0.276
INCN	43.3	2.1	14.0	0.034	0.042
INCS	20.5	0.8	6.1	0.030	0.109

Numbers in parentheses are EERF cross-check data.

Table 5

Airborne Radioactive Waste Release

Summary: July 1974 - March 1975 (11)

Date	µCi U/wk	pCi U/sec	Date	µCi U/wk	pCi U/sec
7/12-19/74	27.0	44.7	10/25-11/1/74	74.2	122.8
7/19-26/74	21.2	35.1	11/1-8/74	50.1	82.8
7/26-8/2/74	11.9	19.7	11/8-15/74	35.2	58.2
8/2-9/74	13.2	21.8	11/15-22/74	33.2	54.9
8/9-16/74	11.1	18.4	11/22-29/74	26.6	44.0
8/16-23/74	42.2	69.8	11/29-12/6/74	20.2	33.3
8/23-30/74	16.9	27.9	12/6-13/74	14.7	24.4
8/30-9/6/74	15.7	26.0	12/13-20/74	53.9	89.1
9/6-13/74	27.1	44.9	12/20-27/74	77.7	128.4
9/13-20/74	25.9	42.7	12/27-1/3/75	39.8	65.7
9/20-27/74	24.8	41.1	1/3-10/75	39.8	65.7
9/27-10/4/74	86.5	143.0	1/10-17/75	60.3	99.6
10/4-11/74	197.6	326.8	1/17-24/75	32.0	53.0
10/11-18/74	61.7	102.0	1/24-31/75	28.2	46.6
10/18-25/74	35.5	58.7	1/31-2/7/75	298.4	493.5

Table 5 - Continued

Airborne Radioactive Waste Release

Summary: July 1974 - March 1975 (11)

Date	µCi U/wk	pCi U/sec
2/7-14/75	7.2	11.9
2/14-21/75	7.4	12.2
2/21-28/75	8.9	14.7
2/28-3/7/75	28.7	47.4
3/7-14/75	44.5	73.5
3/14-21/75	30.7	50.7

table 6, show an extreme variability as seen from the range of concentrations.

Table 6

Summary of Uranium-234 and Uranium-238 Concentrations in Air

	U-234 (fCi/m^3)		U-238 (fCi/m^3)	
	(average)	(range)	(average)	(range)
C_N	0.11	0.02 - 0.46	0.06	0.01 - 0.25
C_E	0.23	0.01 - 4.04	0.09	0.01 - 1.19
C_S	0.18	0.02 - 1.46	0.08	0.01 - 0.51
C_W	0.10	0.01 - 0.31	0.06	0.01 - 0.26
C_B	0.09	0.09 - 0.43	0.05	0.01 - 0.15

Using the 2-σ confidence level intervals, the following values were determined to be outliers which are indicative of contamination by plant effluent (table 7).

The airborne particulate sampler set up to collect a background sample was located 7.5 kilometers from the plant and in a less frequent downwind direction. But, as shown in figure 11, the samples were influenced by the plant effluent on three occasions. Therefore, an effort to determine background levels for the area was based on statistical analysis of the data itself.

The data were plotted on cumulative normal and log normal probability paper to examine the distribution present. Visual examination of the plot on normal probability paper (figure 12) indicates the data vary widely from a normal distribution since the plot is markedly concave upward. The plot on log normal paper (figure 13) is a straight line indicating the data fit a log normal distribution. Statistical tests described in appendix C show that the data do fit a log normal distribution and the sampling sites are statisti-

cally different. Thus, the data for each site were analyzed separately to identify any possible outliers or suspiciously high values which would be indicative of contamination by plant effluent.

Table 7

Statistical Outliers of the Air Samples

Site & Date	Measured Air Concentrations fCi/m^3 ^{234}U	^{235}U	^{238}U
North 1/27-31/75	0.46	0.02	0.25
East 12/16-26/74	> 4.04	> 0.17	> 1.19
10/21-24/74	0.88	0.03	0.32
South 10/21-24/74	1.46	0.09	0.51
West	No outlier values		
Background 12/2-9/74	0.43	0.02	0.12

To determine which air samples are affected by plant effluent, several characteristics of the effluent should be investigated. Since the plant effluent contains enriched uranium with little or no ingrowth of thorium-230, other indicators of plant effect are the uranium-234/uranium-235 ratio, and uranium-234/thorium-230 ratio.

Natural uranium in the environment is usually assumed to be in equilibrium, and the uranium-234 concentration equals the uranium-238 concentration. Thus, the ratio of uranium-234 to uranium-238 would be expected to be one. Environmental Radiation Ambient Monitoring System (ERAMS) uranium in air data (14-17) show the ratio is experimentally one in most cases.

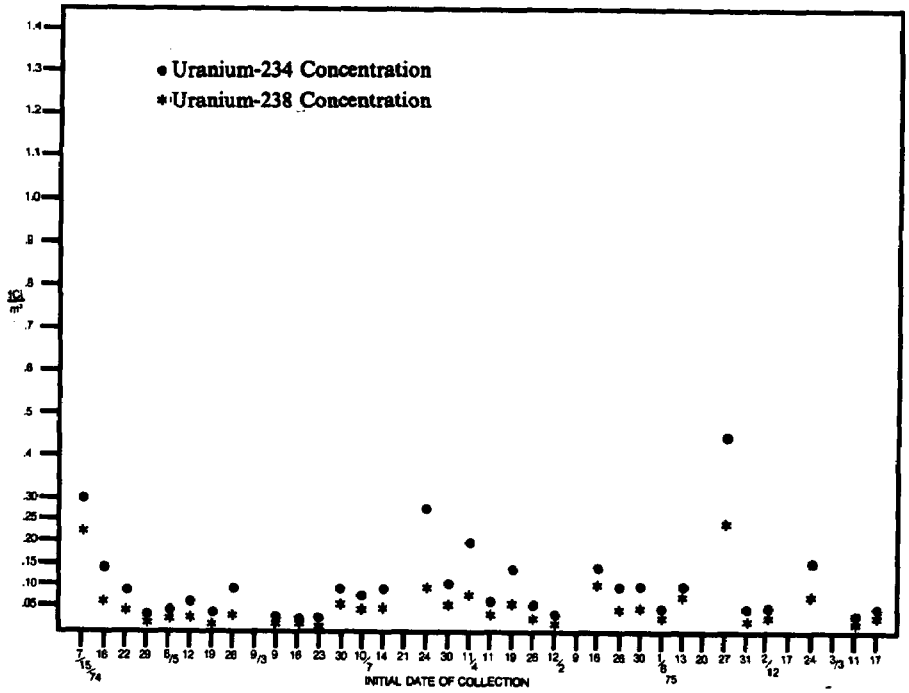

Figure 7. Weekly concentration of ^{234}U and ^{238}U in air at C_N

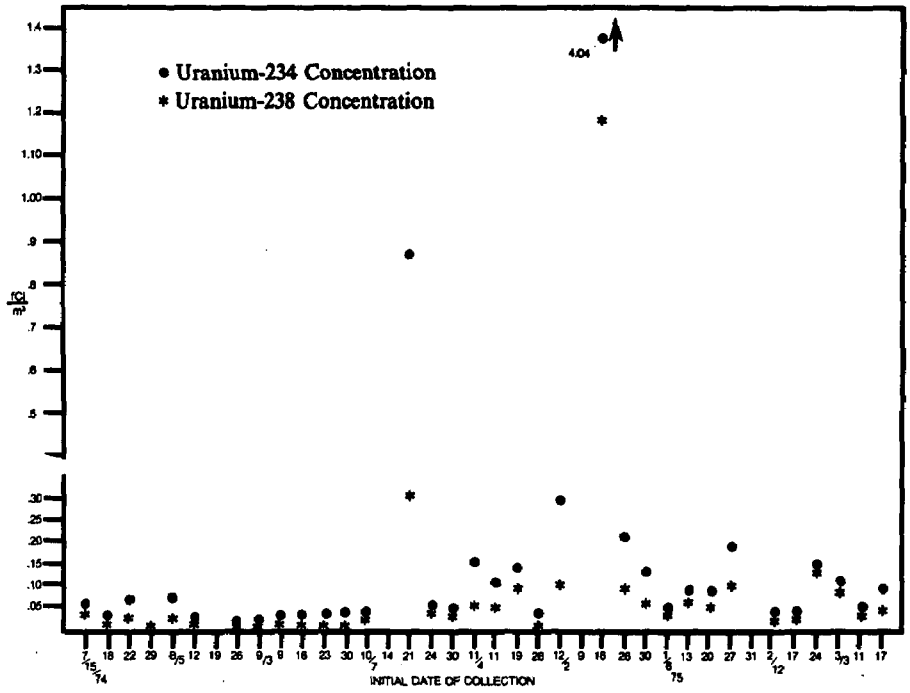

Figure 8. Weekly concentration of ^{234}U and ^{238}U in air at C_E

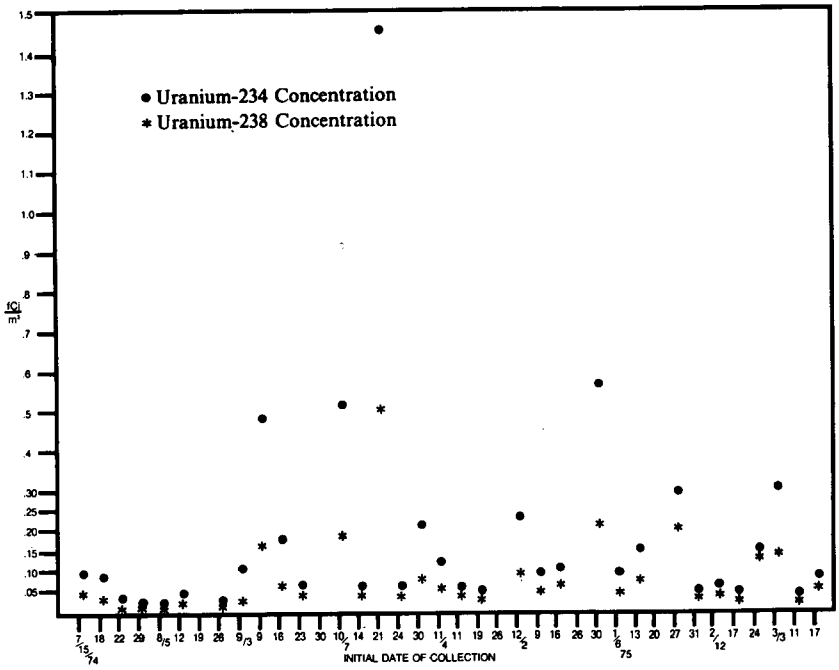

Figure 9. Weekly concentration of ^{234}U and ^{238}U in air at C_S

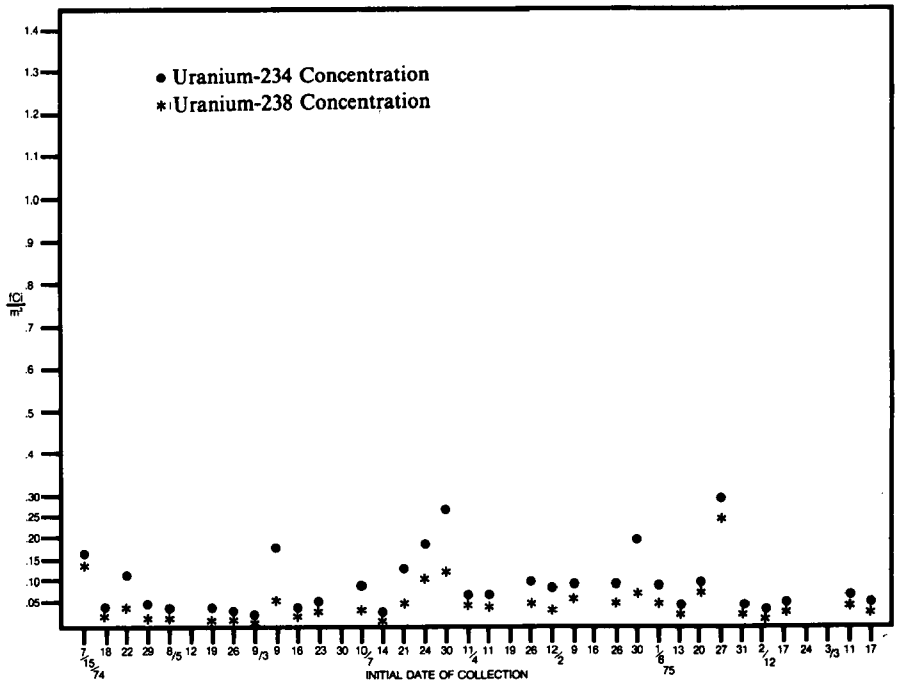

Figure 10. Weekly concentration of ^{234}U and ^{238}U in air at C_W

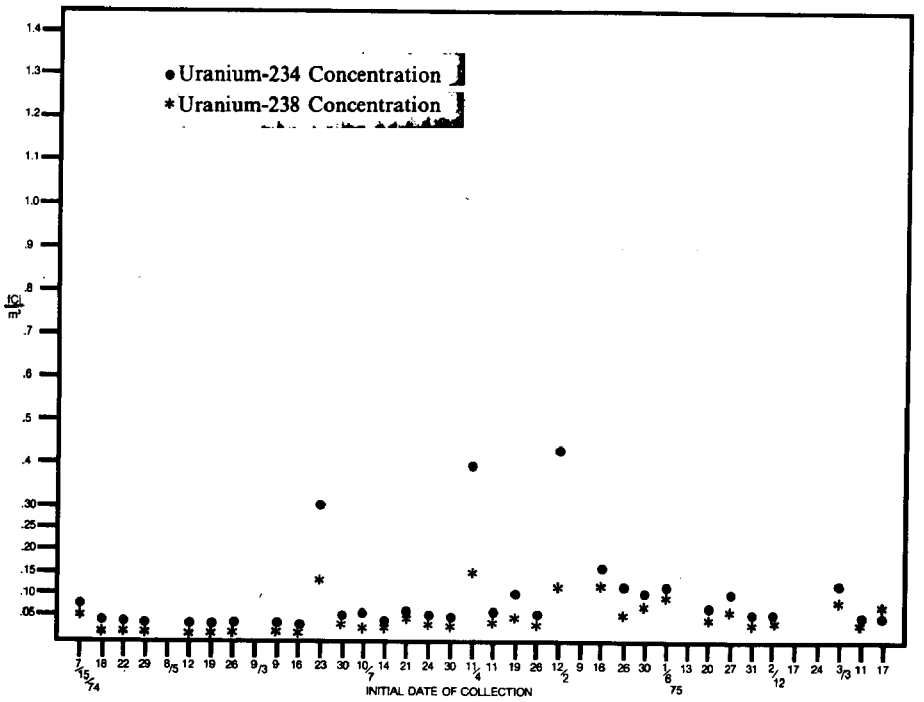

Figure 11. Weekly concentration of ^{234}U and ^{238}U in air at C_B

Las Vegas, Nevada, is an exception with a ratio of two. The plant effluent is enriched in uranium-234 and the mean ratio is 3.5 (table 2-4). Statistical analysis of the ratios for the continuous air particulate samples collected during this study shows that the median ratio is 1.8 and the median plus one sigma is 2.3. Figure 14 is the frequency distribution of uranium-234/uranium-238 ratio.

Natural uranium contains 0.7% uranium-235 and the ratio of uranium-235 activity to uranium-238 activity is 0.046. The measured values of uranium in air particulates are more often 0.09 (16-19). Even with the large-volume samples collected in this study, uranium-235 values were usually nondetectable. Since the few measured values had large errors, this ratio is not used to identify plant affected samples.

Little data are available on the experimental ratio of uranium-234 to thorium-230, although a ratio of one (equilibrium) would be expected. The air particulate samples collected in this study have a median ratio of 3.4 and the median plus one sigma is 7.2. Figure 15 is the frequency distribution of U-234/Th-230.

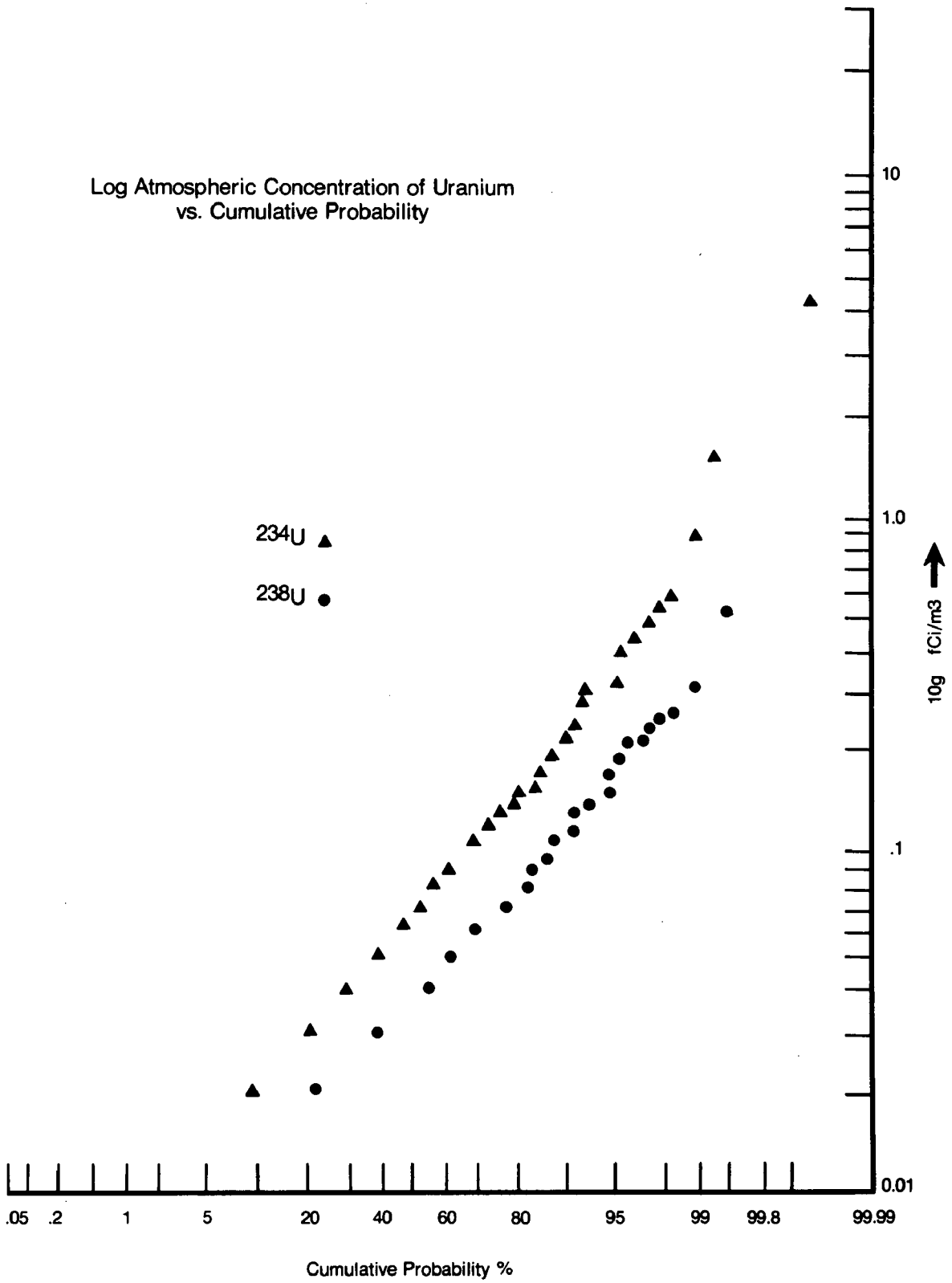

Figure 12. Probability curve of uranium concentrations for the East continuous sampling site (Normal Distribution)

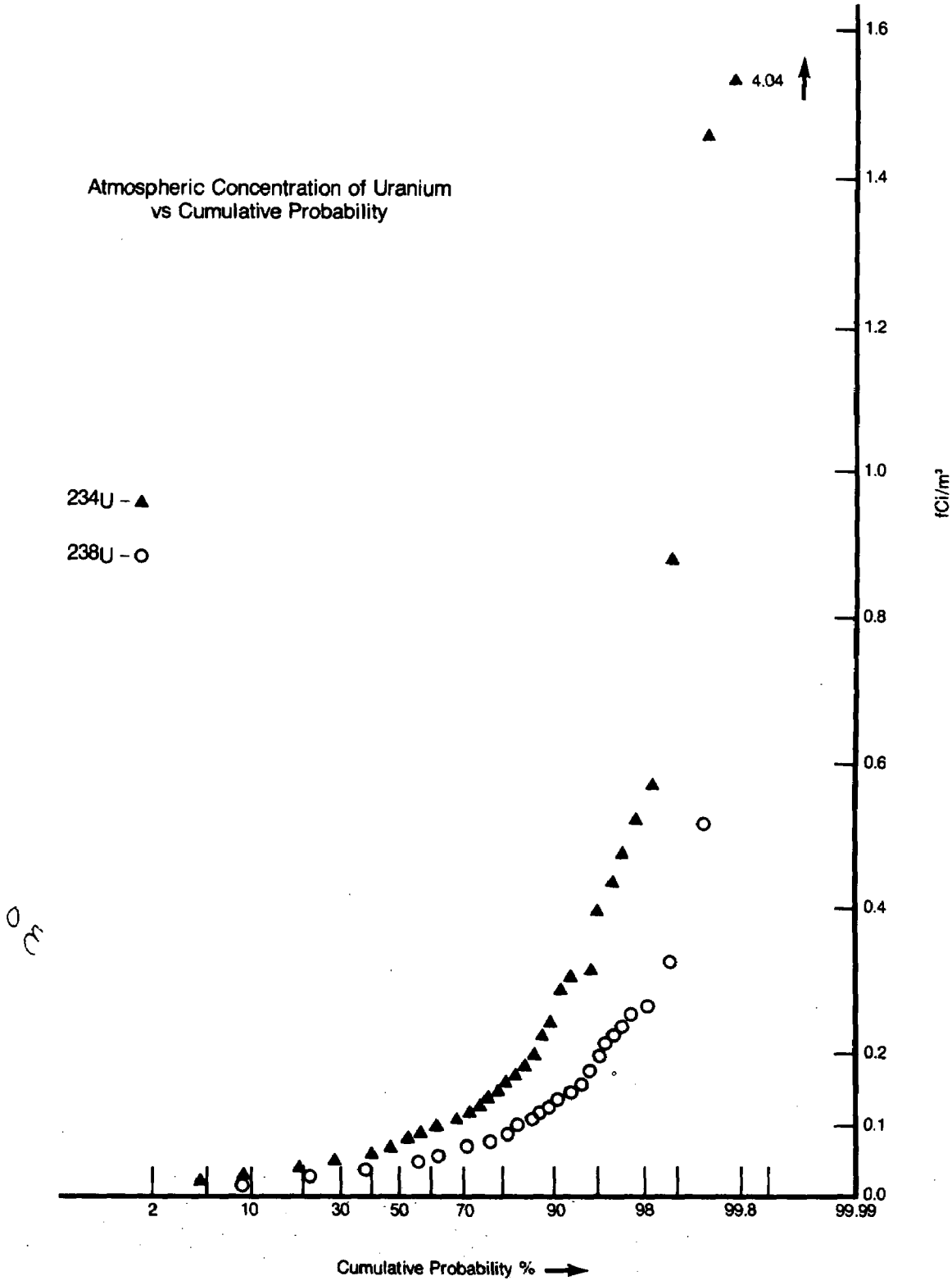

Figure 13. Probability curve of uranium concentration for the East continuous sampling site (Log-Normal distribution).

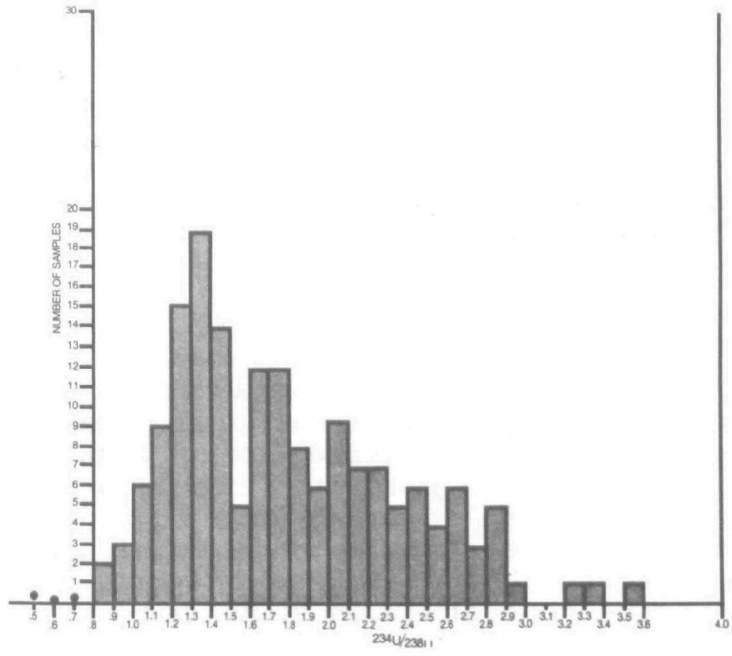

Figure 14. Frequency distribution of $^{234}U/^{238}U$ ratios

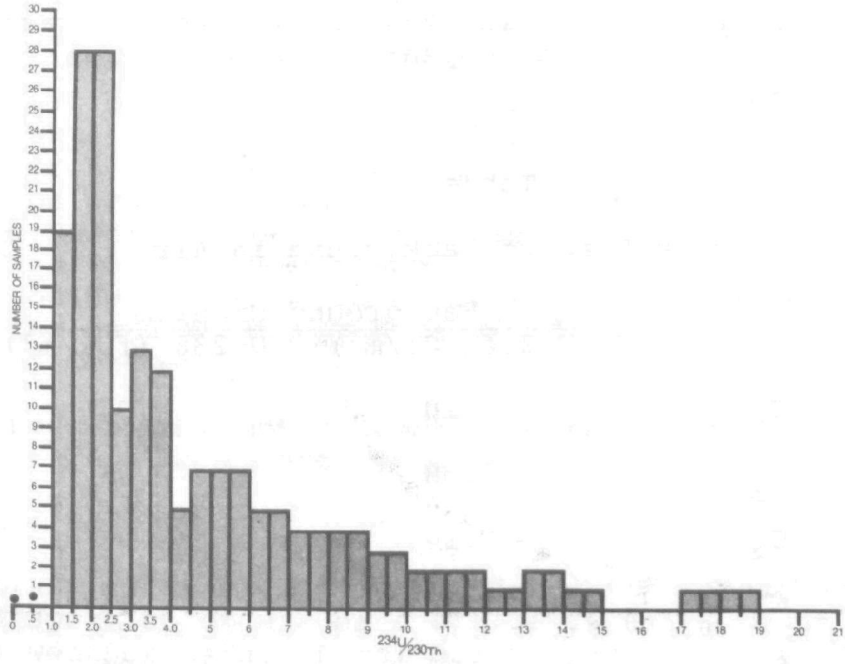

Figure 15. Frequency distribution of $^{234}U/^{230}Th$ ratios

The samples containing uranium from plant effluent can be identified using three characteristics of plant effluent: (1) uranium concentration, (2) uranium-234 to uranium-238 ratio, and (3) uranium-234 to thorium-230 ratio. For purposes of this study, plant affected samples are defined as those samples which have all three characteristics greater than the median value plus one sigma. The remaining samples are assumed to be background and the average backgrounds for each location are given in table 8.

The usual error term does not apply in this table since the data do not follow a normal distribution. An error term also implies a statistical random variation only. The background varies due to physical or meteorological factors as well as randomness. The measured variation of background is greater than statistical variation predicts. Table 8 is the average concentration of the samples which were considered background samples. Table 9 is the average concentration of the samples which were considered to contain mostly plant effluent uranium rather than average concentration above background.

It is interesting to note that the C_B location was apparently not representative of the background at the plant site, although one way analysis of variance shows no significant difference in the other locations after plant effect samples are removed.

Also, the normal uranium-234 to uranium-238 ratio is one, yet even the samples which appear to be only background have a ratio of 1.7.

Table 8

Average Uranium Background in Air

	Background Uranium	
	U-234 (fCi/m^3)	U-238 (fCi/m^3)
C_N	.10	.06
C_E	.08	.05
C_S	.10	.06
C_W	.09	.06
C_B	.06	.04

The average concentrations above background are given in table 9.

Table 9

Uranium Concentration in Air above Background

	Plant Effect	
	U-234 (fCi/m^3)	U-238 (fCi/m^3)
C_N	.01	.00
C_E	.15	.04
C_S	.08	.02
C_W	.01	.00
C_B	.03	.01

Gamma spectral analyses were performed on the air particulate samples in order to monitor any other radionuclides in the effluent stream which might affect our study or otherwise require consideration. Such analyses revealed only fallout products. Uranium daughters were below the detection limits. Cerium-144, ruthenium-rhodium-106, and zirconium-niobium-95 were present at concentrations ranging from 5 to 50 fCi/m^3. Cesium-137 concentrations were from 1 to 5 fCi/m^3. Beryllium-7 was the predominate isotope at 50-200 fCi/m^3. During the first week in August fresh fission products were found. Apparently these fresh fission products originated in the atmospheric nuclear test of the Peoples Republic of China, June 17, 1974. There were 12 fCi/m^3 of barium-lanthanum-140 and 2 fCi/m^3 of iodine-131. The iodine became nondetectable by the middle of September while the barium-lanthanum remained just detectable until the first of October.

The gross beta counting confirmed the presence of fission products but gave no further information.

Air Exposure Model

The AIREM program (18) is a model which describes the expected dispersion of airborne effluents using plant parameters and weather data. Local climatological data, 3-hour intervals, were obtained for the New Hanover Airport which is 7 kilometers south-southeast of the plant site. General Electric provided gaseous release data and pertinent plant parameters. The χ/Q values in Table 10 for various distances and

directions drom the plant were computed based on the average weather conditions during the 36-week period of the study. Using the average release for the study of 75 pCi of uranium per second, the predicted concentrations of uranium contributed by the plant at the continuous air particulate sampling sites were computed to be those in table 10. The measured uranium concentrations above background (table 9) are compared to the predicted values.

The air particulate sample collected at C_E during December 16, 1974, to December 26, 1974, was unusually high in uranium-234 (40 times background) and had a uranium-234 to uranium-238 ratio equal to plant effluent. The other samples of that time period were not unusual and the release data do not explain the high activity. The weather records show that weather parameters were conducive to transport of effluent from the plant to the sampler for only a short period of less than 24 hours. This short-term apparent non-routine release would not be predicted by the AIREM model and is not included in table 10.

Table 10

Observed and Predicted Uranium Concentrations
(Above Background)

	χ/Q (sec/m^3)	Predicted U(fCi/m^3)	Observed U(fCi/m^3)	Observed / Predicted
C_N	1×10^{-6}	0.08	0.01	0.1
C_E	5×10^{-7}	0.04	0.06	1.5
C_S	7×10^{-7}	0.05	0.10	2.0
C_W	7×10^{-7}	0.05	0.01	0.2
C_B	3×10^{-8}	< .01	0.04	> 4.0

The model predicts the average uranium concentrations during the 36 weeks of the study to be .22 fCi uranium per cubic meter at the nearest residence (600 meters south-southeast of the plant) due to plant effluent. The ratio of observed

values to predicted values ranges from .1 to > 4 and, therefore, the average concentration at the nearest residence was probably between 0.02 and 0.44 fCi uranium per cubic meter.

Discussion of Air Monitoring Data

The detection of contamination from plant effluent in the environs is difficult not only because the concentrations are very low, but also because the natural uranium in the environs interferes with plant effluent detection. Isotopic analyses of gaseous and liquid effluents show that uranium-234 is 3.5 times the activity of uranium-238. Natural uranium in equilibrium has equal activities of uranium-234 and -238. This characteristic distinguished plant effluent from natural background. Usually small amounts of plant effluent were added to the naturally occurring uranium such that the samples could not be classified as only background or only plant effluent. This is especially true of samples collected for a 1-week period. The plant effluent may be sampled for 1 to 3 days and masked by the 7-day background.

Statistical analyses of the data show that 8 percent of the continuous air samples showed predominantly contamination by plant effluent material. The average concentrations of the remaining 92 percent of the air samples were 0.09 fCi/m^3 uranium-234 and 0.06 fCi/m^3 uranium-238. These averages seem to be reasonable estimations of background at the plant site.

Of the 8 percent plant-affected samples, the highest values were observed in the eastern sector. The average uranium concentrations during the study as measured at C_E were 0.15 fCi/m^3 uranium-234 and 0.04 fCi/m^3 uranium-238 at 1.7 kilometers from the plant. One sample collected from December 16-26, 1974, accounts for 75 percent of the effect. When the filter at C_E was replaced on December 26, 1974, the sampler was not operating. If one assumes the sampler operated properly until immediately prior to collection, the uranium-234 was 4.04 fCi/m^3, uranium-235 was 0.17 fCi/m^3, and the uranium-238 was 1.10 fCi/m^3. The concentrations may have been higher and the sampler operated for a shorter period of time. This one anomalous sample is twice the total effect seen at C_E from the remaining routine operations of the 36 weeks. An annual anomaly of this magnitude would have environmental impact comparable to routine operation for the year.

Terrestrial Deposition

The deposition of plant effluent on soil and vegetation and the uptake of activity by vegetation was monitored by collecting

soil, vegetation, rain, and fallout trays. Rain collectors and fallout trays were placed at the continuous air monitoring sites. The rain was collected in a 32-gallon galvanized metal garbage can. A faucet was welded at the bottom. Thus, rainwater was drained by gravity into a cubitainer for collection. To prevent large foreign objects (i.e., leaves) from stopping the drain, a screen was placed inside the top of the can. A fallout tray of adhesive cellulose was placed on this screen.

The pressure sensitive adhesive cellulose was mounted on a 30-cm by 30-cm by 0.5-cm lucite plate. The trays were changed each month. The exposed trays were returned to the laboratory where the adhesive sheets were removed and analyzed for specific uranium and thorium content. Again, there was no evidence of plant effluent uranium deposition (fallout) from the air (Appendix D).

Soil and vegetation were collected at the continuous air monitoring sites during the field surveys. Soil was collected from a 30-cm by 30-cm area to a depth of 4 cm. Vegetation consisted of grass clippings, leaves, and weeds as available. The soil and vegetation samples showed no effect of plant effluent. The data in Appendix E show the variability associated with soil and vegetation sampling.

The precipitation samples collected at C_E and C_W, August 19 through September 16, 1974, showed high uranium-234 concentrations. The ratios of uranium-234 to uranium-238 were also greater than 2 (Appendix E). The sample collected at C_B, January 27 through February 24, 1975, also showed these characteristics. The total uranium washed out of the atmosphere was not determined since the area of rainfall was not measurable. Since the probability of rain is independent of the effluent release rate, over an extended period time, high and low release rates will average to appear relatively uniform on an annual basis. The washout effect would represent a removal rate roughly equivalent to the fraction of time that rain occurred. During the study period from July 1974 to March 1975, rain fell less than 10 percent of the time. Hence, the washout effect should not be expected to remove more than 10% of the airborne contamination from plant effluents.

WATER EXPOSURE PATHWAY

Sampling

A second major effort of the field studies was to evaluate the signficance of the water exposure pathway of uranium to man from this facility. This evaluation was based on the collection and analyses of water samples from four locations upstream of the plant and four locations downstream of the plant and one location near the liquid waste discharge point.

On each field trip two samples of 10 liters each were collected at these nine locations. The samples were collected at different depths and distances from the bank to assure samples representative of the location. Since these waters are estuarine and tide effects are noticeable more than 10 kilometers upstream of the plant, the first location, Position I-background, was 40 kilometers upstream of the liquid waster discharge point (figure 16). Position II was also considered background and was 25 kilometers upstream. Position III and IV were in an area of potential tidal effect and could have waters affected by the effluent releases. They were 15 km and 3 kilometers upstream, respectively. Position V was 1 kilometer downstream from the point of discharge. This was relatively close to the source but remote enough to insure thorough mixing. Positions VI and VII were 3 and 9 kilometers downstream, respectively. Position VIII, 11 kilometers downstream, was near the confluence of the Northeast Cape Fear and Cape Fear Rivers, but the samples were collected in the Northeast Cape Fear River. Position IX was 18 kilometers downstream from the point of discharge and was in the Cape Fear River.

Analyses

Water samples were gamma scanned prior to processing and then filtered for separate analysis of dissolved and undissolved solids. The filtrate water was evaporated and counted for gross alpha and beta activity. The undissolved solids which were filtered from the water were dried and also counted for gross alpha and beta activity. Thereafter, the dissolved solids and the undissolved solids were ashed and chemically separated to count U and Th by alpha spectroscopy.

Liquid Plant Effluents

The liquid waste is discharged in equal proportions from two lagoons into an on-site creek. Aliquots of the discharge are collected daily for analysis.

The Department of Interior, Geological Survey (9) study of the Northeast Cape Fear estuary in October 1969 showed that discharges that occurred several days prior to river

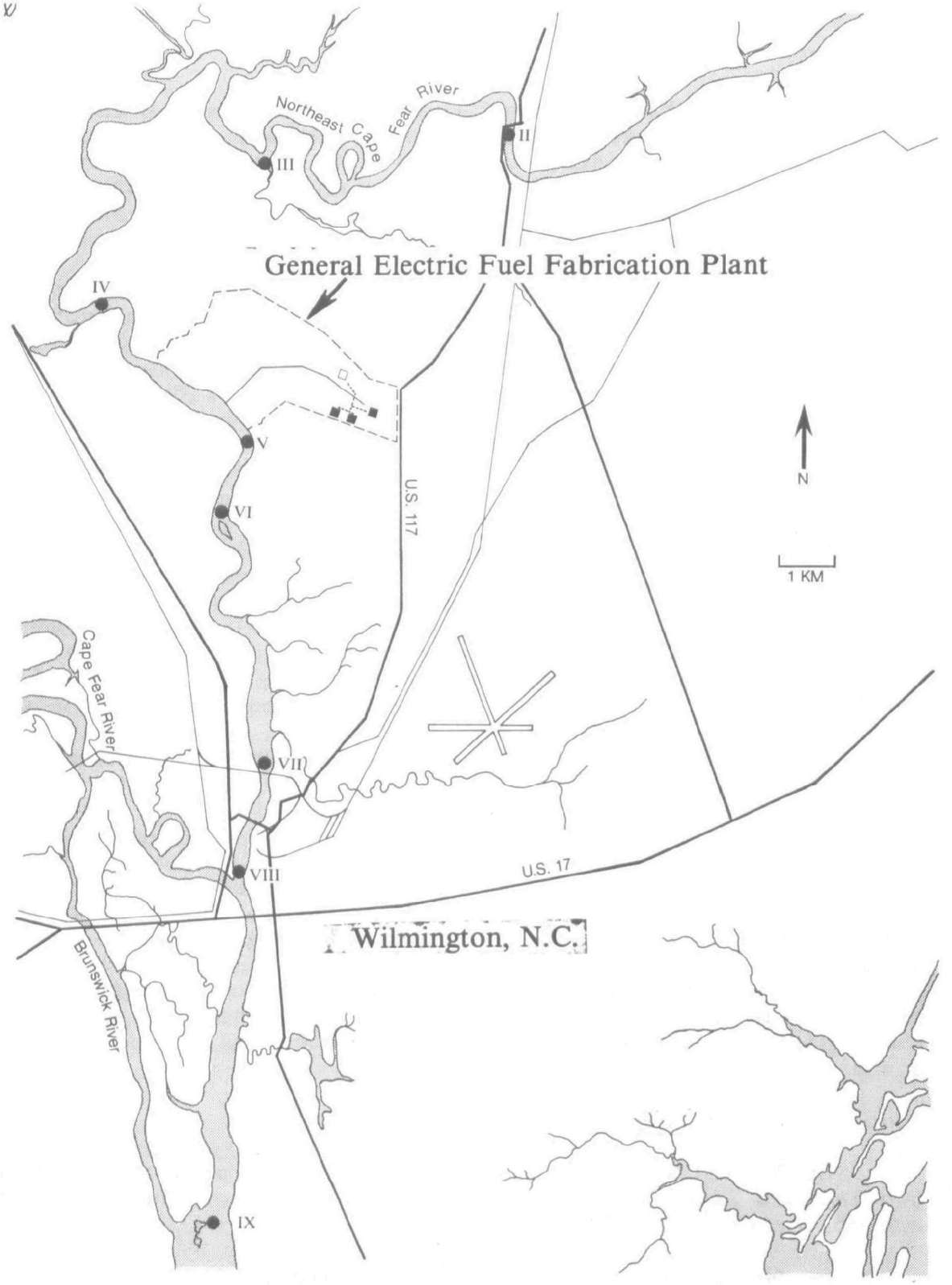

Figure 16. River sampling locations map

sampling could effect the concentration of radionuclides in the river at time of sampling. Therefore, samples of the discharge liquid were obtained for one or two weeks prior to a field survey. The samples were composited such that a sample represented the average concentration of discharge liquid for the week.

Table 11 gives the average weekly concentrations of uranium isotopes and the total uranium discharged weekly for periods prior to each field survey. Appendix F gives the G.E. reported uranium discharges by week for 1974 and the first quarter of 1975. The average weekly discharge for 1974 is 13.6 kg/wk. No given weekly discharge was greater than twice this average.

A paired t test of the EERF analyses compared to the G.E. analyses shows no significant difference, thus, G.E. release data in appendix F are used in predictive models.

River Sampling Data

The analyses of environmental liquid samples are tabulated in appendix G. Although the field surveys were at different times in the year and under differing river flow conditions, a general impression of the behavior of the plant liquid effluent can be seen from a comparison of the average uranium concentration at each location (table 12).

Figure 17 shows the concentration of uranium versus the distance from the discharge point.

As one would expect, the concentration of uranium is greatest immediately below the discharge point. Also, the ratio of U-234 to U-238 is indicative of enriched uranium at Positions V-VII (1-9 km from the discharge point). The figure shows the highest concentration three kilometers below the discharge point.

Aqueous Transport Model

The Geological Survey model (9) of the dispersion of a soluble material (fluorescent dye) is used to predict the concentration during the field surveys at positions IV, V, VI, and VII. The model predicts the maximum daily concentration as a function of location, fresh water flow rate, and soluble material release rate, equation (1).

Table 11

Uranium Concentrations of Liquid Effluent During Field Surveys

Dates	EERF Analysis						GE Report
	pCi/liter (+17%)			Average Discharge Liters/day	Total U µCi/wk	Kg U/wk	Kg U/wk
	U-234	U-235	U-238				
7/8/74-7/14/74	896	44	250	2.21×10^6	18416	13.3	6.7
10/8/74-10/14/74	1806	76	550	1.87×10^6	31880	23.1	16.0
10/15/74-10/21/74	1164	51	360	2.09×10^6	23059	16.7	15.8
3/5/75-3/10/75	1604	58	477	2.16×10^6	32343	23.4	12.4
3/11/75-3/17/75	1672	70	522	2.00×10^6	31696	23.3	23.0
3/18/75-3/20/75	1103	47	344	2.36×10^6	24681*	17.9	18.7

*Assuming days composited were typical or average.

Table 12

Uranium Concentration in the Waters

of the Northeast Cape Fear River

Position	U-234 (pCi/ℓ) $\bar{x} \pm 2s_x$	U-238 (pCi/ℓ) $\bar{x} \pm 2s_x$	U-234/U-238
I	.05 ± .03	.04 ± .02	1.09
II	.07 ± .07	.04 ± .02	1.75
III	.05 ± .02	.04 ± .03	1.23
IV	.08 ± .03	.05 ± .02	1.64
V	.18 ± .07	.08 ± .03	2.33
VI	.35 ± .17	.17 ± .07	2.10
VII	.19 ± .10	.10 ± .05	1.81
VIII	.15 ± .10	.10 ± .06	1.47
IX	.21 ± .13	.17 ± .12	1.26

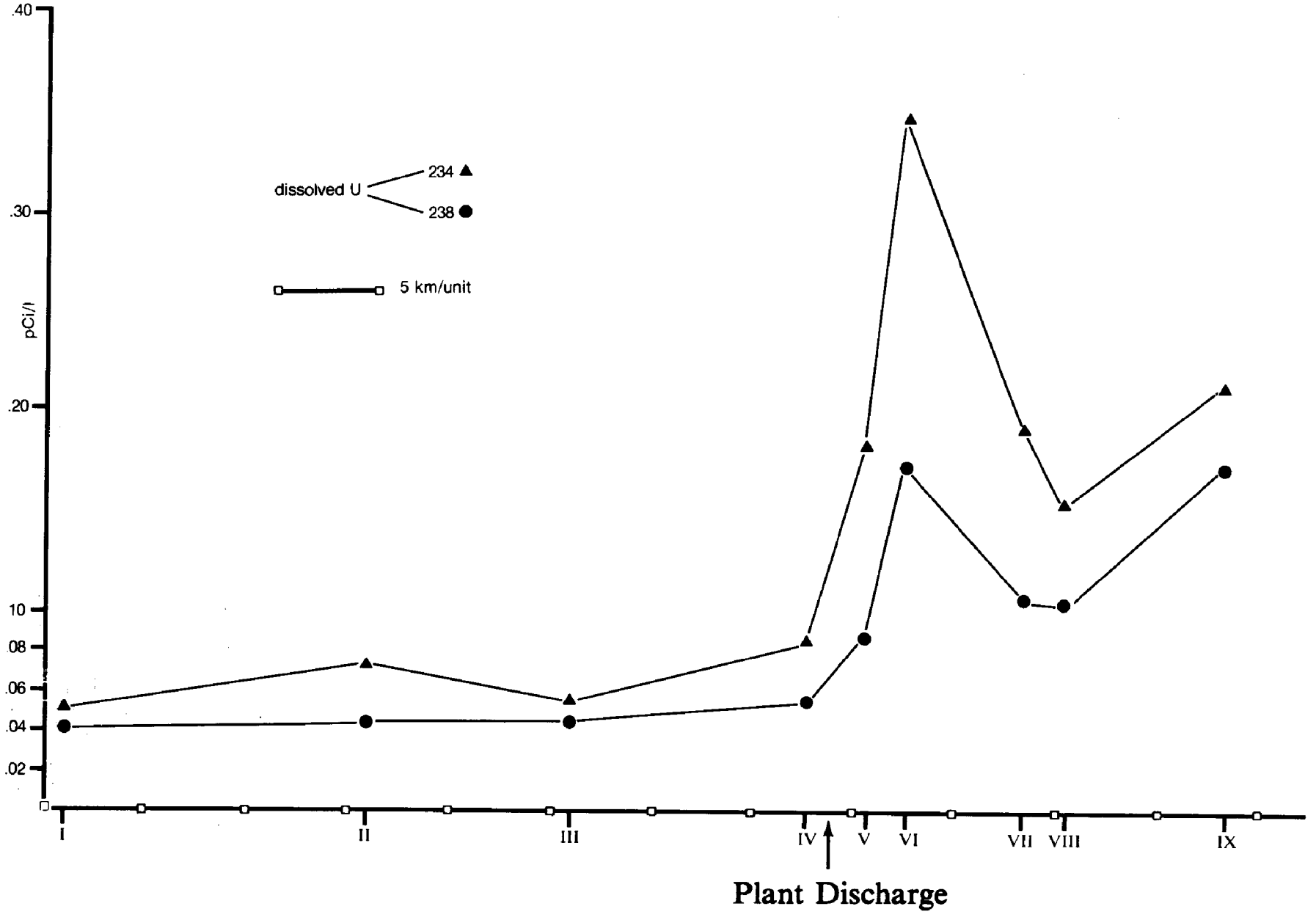

Figure 17. Uranium concentration profile in Northeast Cape Fear River

$$Cj = K_j \Sigma L_i/Q_i \quad (1)$$

where: Cj is the maximum daily concentration at position j, K_j is the constant of proportionality for position j. L_i is the average daily release of solute on the ith day Q_i is the average daily fresh water flow rate for the ith day.

It must be noted that the model predicts maximum daily concentrations and was developed during a period when the flow rates were 200 cfs. The present study collected grab samples of water at various stages of tidal movement, thus the samples were not necessarily representative of maximum daily concentrations. The freshwater flow rates during the study were usually greater than 200 cfs and occasionally as much as 2000 cfs.

Table 13 gives the predicted concentrations due to plant effluent. The observed concentrations are the average of the two samples collected at that date and location minus the background obtained at Position I, II, and III. Only the dissolved uranium is used in this comparison.

Using the model, an average uranium concentration for the year 1974 can be calculated. The average concentration at Position VI for 1974 is predicted to be 0.6 pCi/ℓ. Using the comparison in Table 13, the average observed concentration at Position VI would be near .4 pCi U/ℓ for 1974.

Since the samples were taken at different depths at each location, the data were tested to determine mixing characteristics of the river. A paired t test of total uranium and dissolved U-238 each showed no significant difference of samples at different depths. The paired t test of dissolved U-234 data did show the deeper samples to have a statistically higher concentration but the average difference ($\bar{D}$ = .026) was less than the analytical error of the data. If one compares the U-234 in solution in samples near the right bank to the values in samples near the left bank, the paired t test shows no significant difference. The river appears to be generally well mixed.

Aquatic Environment

Although the exposure pathway of radioactive material to sediment to vegetation to man was considered of minor consequence,

Table 13

A Comparison of the Observed and Predicted Uranium Concentrations in the Waters of the Northeast Cape Fear River (above background)

Position	Date	Predicted pCi U/ℓ	Observed pCi U/ℓ	Ratio of Observed / Predicted
IV	7/16/74	.87	.03	.03
IV	10/22/74	.84	.09	.11
IV	3/19/75	.13	.01	.08
V	7/16/74	1.29	.26	.20
V	10/22/74	1.66	.13	.08
V	3/19/75	.26	.12	.46
VI	7/16/74	1.01	.31	.31
VI	10/22/74	1.70	.72	.42
VI	3/19/75	.25	.29	1.16
VII	7/16/74	.36	.25	.69
VII	10/22/74	1.05	.36	.34
VII	3/19/75	.15	< .01	--

samples of sediment and vegetation were collected to determine any major removal of uranium from the water by deposition in sediment or uptake in vegetation. Samples were collected at the position of water sample collection. Thus, for each field survey nine vegetation and nine sediment samples were collected, one at each position as mentioned earlier.

The samples were dried and counted for gamma emitters by gamma spectroscopy and also counted for gross alpha and beta activity. The samples were then ashed and dissolved for

chemical separation of U and Th which were counted by alpha spectroscopy. The data are tabulated in Appendix H.

The uranium-234 to uranium-238 ratio of the vegetation samples averaged 1.4 ± .9. The vegetation samples collected at Position V in July 1974 and October 1974 and at Position VI in July 1974 have uranium-234 and uranium-238 ratios of 2.4, 2.0, and 2.3, respectively. But the ratios are not statistically different from the average. The uranium-234 to thorium-230 ratios of these samples are also higher than the average implying possible uptake of plant effluent by vegetation. The amount of uranium in the vegetation does not indicate a concentrating effect by the vegetation (10). Therefore, vegetation does not appear to be a major means for removal of uranium from the water pathway.

DOSE CALCULATIONS

Air

In order to relate an airborne concentration of a radionuclide to a dose commitment for an individual exposed to such a concentration, it is necessary to develop a descriptive pathway from environmental air through the body. This development requires numerous assumptions as to the pathway parameters. The end product of such a description or model is known as a dose conversion factor. Citing a dose conversion factor is incomplete without providing sufficient information to allow a user to comprehend the significant elements of the model.

The model chosen for this study begins with the assumption that the effluent material is essentially all insoluble particulates of respirable sizes. Such an assumption seems appropriate since the first process in the fuel fabrication is the conversion of UF_6 to UO_2F_2 and then to insoluble $(NH_4)_2U_2O_7$. Once in the insoluble form the uranium fuel receives most of the handling and processing that is necessary to produce the final product material. During the entire time the uranium is processed at the fabrication plant only an insignificant fraction of the gaseous effluent waste could occur as other than insoluble particulates. The initial assumption appears to be warranted.

The next assumption is that the lung is the critical organ.

This appears valid since pathway models for bone, whole-body, and other components do not suggest a dose conversion factor nearly as large as the one for the lung.

The simplified mathematical expression which describes the dose commitment over the next fifty years due to continuous accumulation of a radionuclide for one year is:

$$D^{50}_{(rem)} = 51.1 \left(\frac{A_o f_a}{\lambda_{eff} m} \right) \Sigma EF \, (1 - e^{-\lambda_{eff} t}) \quad Q.F. \quad D.F.$$

Equation (1)

where:

$D^{50}_{(rem)}$ = dose (rem)

t = 50 years x 365 days/yr. = 18.25×10^3 days

A_o = total radionuclide intake (μCi)

f_a = fraction of radionuclide intake which is deposited in the organ (lung)

m = mass of the organ (lung)

λ_{eff} = effective decay constant of the radionuclide from the organ

ΣEF = energy deposited in the organ per disintegration (MeV)

Q.F. = Quality Factor

D.F. = Distribution Factor

This expression simplifies further to:

$$D_{(rem)} = 51.1 \left(\frac{A_o f_a}{\lambda_{eff} m} \right) \Sigma EF (W.F.) D.F. \qquad \text{Equation (2)}$$

since:

$T_{1/2\ eff}$ = 500 days (assumed) (23)

$$_{eff} = .693/500 \text{ days} = .00139 \text{ days}^{-1}$$

$$t = 18.25 \times 10^3 \text{ days}$$

Equation (2) is of the form of a one-shot exposure model. This is due to the long effective half-life which enables simplification of the model for exposure times of a year or less without introducing an appreciable amount of error.

In order to conveniently relate equation (2) to a dose conversion factor, the commitment dose is calculated for a 1 fCi/m^3 exposure for one year to an adult male (19).

$$\text{Breathing rate} = 23 \text{ m}^3/\text{day}$$

$$1 \text{ fCi/m}^3 = 10^{-9} \mu\text{Ci/m}^3$$

$$A_o = 1 \text{ fCi/m}^3 \times 10^{-9} \mu\text{Ci/fCi} \times 23 \text{ m}^3/\text{day} \times 365 \text{ days/yr.}$$

$$A_o = 8.40 \times 10^{-6} \mu\text{Ci/year}$$

In addition to the assumption of respirable quality, the particles are also assumed to have a 1-μm Activity Mean Aerodynamic Diameter (AMAD). No experimental data are available concerning particle sizes in the environment. It is known that the most penetrating particles through the HEPA filter are .05 to .10 μm AMAD (21). It is believed that for particles of this size agglomeration occurs in the environment and thus increases the AMAD significantly. The main parameter selected for the calculation of the dose commitment is as follows:

The $f_a = .25(.6) = .15$, since 25% of the uranium of 1 μm AMAD reaches the pulmonary region and 60% of that is retained for more than a day (20). The m (mass of the pulmonary region) is 570 g (19). The ΣEF is 4.9 MeV since most of the activity is uranium-234 (24). The quality factor is ten for alpha radiation and the distribution factor is 1 in the lung.

$$D^{50} = 51.1 \left[\frac{8.4 \times 10^{-6}(.15)}{\frac{.693}{500}(570)} \right] 4.9\ (10)\ 1$$

$$D^{50} = 4.0 \times 10^{-3} \text{ rem} = 4.0 \text{ mrem}$$

Thus, the dose commitment factor is 4 mrem/fCi/m^3 to the lung.

Assuming the airborne uranium concentrations in table 9 are the average effect of plant discharges for the year, the dose commitments to an individual residing at C_N, C_E, C_S, C_W, and C_B are .04 mrem, .76 mrem, .40 mrem, .04 mrem, and .16 mrem, respectively.

Water

These estuarine waters are not potable and are independent of any existing municipal drinking water supply. If these waters were ingested, the following calculated dose should be considered as additive to other pathway exposures.

The uranium in liquid effluent is assumed to be soluble since precipitated uranium is removed prior to discharge and the conservative assumption seemed prudent. The critical organ for ingestion of soluble uranium is bone (23). As in air an acute or one shot exposure is assumed by mathematical simplification. A similar equation applies:

$$D_o^{50} = 51.1 \left(\frac{A_o\ f_w}{\lambda_{eff}^m} \right) \Sigma EF\ (Q.F.)\ D.F.$$

A = 1 pCi/l X 2 liters/day X 365 days/yr X 10^{-6} μCi/pCi

o = .73 X 10^{-3} μCi

$f_w = f_1 f_2^1$

f_1 = .1 (fraction from G. I. tract to blood) (24-26)

f_2^1 = .11 (fraction from blood to bone) (27)

λ_{eff} = .693/500 days (27)

$m = 5000$ g (19)

$\Sigma EF = 4.9$ MeV for uranium-234 (23)

$Q.F. = 10$ for α

$D.F. = 5$ in bone

$$D_o^{50} = 51.1 \left[\frac{.73 \times 10^{-3} \ (.011)}{.693/500 \times 5000} \right] 4.9 \ (10) \ 5$$

$$D_o^{50} = 8.5 \times 10^{-3} \text{ rem/pCi/l} = 8.5 \times 10^{-3} \text{ rem/pCi/l} \times 10^3 \text{ mrem/rem}$$

$$= 8.5 \text{ mrem/pCi/l}$$

The predicted average concentration of uranium at Position IV was .3 pCi/l. This would result in a 2.6 mrem dose commitment to the bone if the water were potable. It should be noted that if the river were a water supply source, standard water treatment by a municipality might remove a significant amount of uranium and reduce the exposure to any consuming public.

The concentration of uranium in seafood in the Cape Fear Bay area is not available. The dose commitment can be estimated using the concentration factors, mass consumption, and dose commitment factors of the nuclear regulatory guide (28). The dose commitment to the bone due to ingestion of seafood is 1/40 the dose commitment due to ingestion of the water.

CONCLUSIONS AND RECOMMENDATIONS

The detection of contamination from plant effluent in the ambient environs is difficult since natural uranium is also present. Using the characteristics of uranium concentration and uranium daughter equilibrium, 8% of the continuous air samples were identified as having measurable amounts of contamination from plant discharges. These samples indicated that the plant added 0.01 to 0.2 fCi/m^3 of uranium to the average measured concentrations in the environs. The plant effluent in the Northeast Cape Fear River was more identifiable since upstream background concentrations could be measured. The tidal inflow holds the uranium in the river and the plant effect was most noticeable 3 kilometers downstream of the discharge point. The plant effluent added 0.3 pCi/l of uranium at the downstream point.

Since the water is not potable, only the airborne pathway of exposure is considered significant at this plant site. The dose commitment to individuals residing at the continuous monitoring locations would be less than a millirem. The predicted uranium concentration at the nearest residence due to plant operations was 0.22 fCi/m^3 resulting in a dose commitment of 0.9 mrem to an individual residing continuously at this location.

The plant discharges 2-3 mCi of airborne uranium per year and approximately 700 kg (0.96 Ci) of uranium as liquid waste. This results in a dose commitment of less than a millirem via the airborne exposure pathway and a potential dose commitment of less than 3 millirem if the water were potable. The results of this study compare favorably with the estimates in the Environmental Analysis of the Uranium Fuel Cycle (1) when standardized computational models are used.

To evaluate the significance of the radiation dose pathways, portions of the pathways were monitored to detect and quantitate contamination from plant releases in the atmosphere. The portions of the pathway monitored were affluents (airborne and liquid), atmosphere, river water, and deposition. The most significant pathways were inhalation of air particulates or ingestion of water containing uranium.

This facility operation and radioactive release patterns are typical of facilities using the ammonium diuranate process. A facility using the direct conversion fluid bed (DCFB) process may have radically different release patterns. Thus the dose commitment due to a DCFB process could be different than found in this study.

This study points out the difficulty of accurately modeling at these low release levels relative to a variable background. The environmental forces which disperse and transport contaminants are changing continuously. A good example of this was that the plant effluent plume was detected seven kilometers away even though the dispersion model predicted that such detection was highly improbable. Short-term releases are not predicted in this study but these can obliterate long-term averaged effects.

In a study of this type continuous monitoring in the environment is recommended for estimating the potential dose committed to the population. When such monitoring is used, special detailed evaluations should be performed to determine background concentrations of each sampling site. The use of short sampling periods (i.e., three and one-half days) may be necessary for a clear distinction of plant effect and background.

Although laboratory analyses may seem standardized, each environmental sample may have differences which affect the analysis. Initial surveys should collect duplicate samples to confirm laboratory methodology.

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Appendix A

Plume Monitoring Data

The plume monitoring system was operated by an EPA field team during each of the three field surveys. These were conducted July 15-18, 1974; October 21-24, 1974; and March 17-21, 1975. The system consisted of four sampling locations in the predicted downwind direction from the plant and one in the upwind location. Two air particulate samplers were placed at each location. Each sampler used an MSA type H filter which is 99.98% efficient for .3 μ DOP. The samplers operated at the sampling rate of approximately 1.7 cubic meters per minute. A timer recorded the running time of each sampler. A wind vane was set up 6 meters above the ground where the paired samplers were located. The primary air particulate sampler operated while the wind vane indicated the wind direction was from the plant toward the sampler location. When the wind vane rotated to a direction indicating the wind was not from the plant toward the sample location, the primary sampler shut off and a secondary (background) air sampler began sampling. Thus a primary air sample was collected when the sampler was downwind from the plant. The secondary sampler represented air particulates that were likely non-plume particulates. The upwind background air particulate sampler set was located 7.5 kilometers south southeast of the plant to insure the collection of a background sample.

The plume monitoring system was designed to provide samples of airborne particulates which had a higher probability of containing some of the uranium released from the plant. This was collected by the primary sampler (noted "p" in table A-1, 2, 3). A secondary sampler (noted "s" in tables) operated when the wind was not from the plant to the sampler. On the July 1974 field survey, plant effluent was apparent on the primary sampler at the station nearest to the plant at 1 kilometer to the northeast. Samples from the other three downwind stations did not demonstrate a clear accumulation of plant released material.

In October 1974, plant effluent was detected at the three stations nearest the plant: 1 kilometer northeast and 2 kilometers south. The plant effluent was, however, evident on the secondary sample as well as on the primary sample. Thus, background for a given location was not available. Although the sampling system 1 kilometer from the plant was in a pine grove and wind eddies could violate the wind direction control, the sampling systems 2 kilometers from the plant were in open areas and wind control should have been proper. The light and variable wind conditions may have caused difficulty with this sampling technique.

In March 1975, the plume was sampled 1.5 kilometers east of the plant, but samples 1 kilometer northeast and 2 kilometers south of the plant show no evidence of the plume. Although plume sampling is feasible, a more definitive background sample than provided by the matched secondary sampler is necessary. An independent means of determining the plume location is desirable.

Table A-1

Plume Monitoring System Samples

7/15-18/74

Location	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
925 meters @ 50°p	.25 ± 21%	.01 ± 65%	.08 ± 27%	3.0	.02 ± 46%	.03 ± 34%	.03 ± 37%	8.3
925 meters @ 50°s	.12 ± 22%	<.01	.07 ± 27%	1.8	<.01	.04 ± 36%	.02 ± 39%	3.0
2150 meters @ 65°p	.14 ± 20%	.01 ± 62%	.06 ± 26%	2.3	<.01	.04 ± 36%	.04 ± 39%	3.3
2150 meters @ 65°s	.04 ± 39%	<.01	.02 ± 53%	2.1	.02 ± 47%	.03 ± 36%	.03 ± 39%	1.3
3400 meters @ 55°p	.07 ± 23%	<.01	.06 ± 24%	1.2	.02 ± 30%	.05 ± 20%	.02 ± 32%	1.5
3400 meters @ 55°s	no sample				no sample			
3000 meters @ 23°p	.04 ± 35%	.01 ± 69%	.04 ± 35%	1.0	.05 ± 43%	.05 ± 43%	.05 ± 45%	0.8
3000 meters @ 23°s	.01 ± 65%	<.01	.02 ± 54%	0.6	<.01	.02 ± 45%	.03 ± 37%	0.5
7500 meters @ 150°p	.02 ± 47%	<.01	.01 ± 56%	1.6	.01 ± 58%	.02 ± 46%	.01 ± 60%	0.7
7500 meters @ 150°s	.01 ± 57%	<.01	.02 ± 44%	0.6	<.01	.02 ± 38%	.04 ± 35%	0.7

Table A-2

Plume Monitoring System Samples

10/21-24/74

Location	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
925 meters @ 50°p	.40 ± 28%	.04 ± 58%	.16 ± 35%	2.6	.01 ± 63%	.05 ± 27%	.03 ± 34%	8.0
925 meters @ 50°s	1.32 ± 12%	.06 ± 23%	.42 ± 13%	3.1	.01 ± 46%	.03 ± 27%	.01 ± 41%	39.5
2150 meters @ 65°p	.23 ± 20%	.01 ± 65%	.14 ± 12%	1.6	.03 ± 37%	.09 ± 22%	.04 ± 32%	2.6
2150 meters @ 65°s	.42 ± 15%	.02 ± 35%	.21 ± 17%	2.0	.02 ± 31%	.10 ± 15%	.04 ± 23%	4.2
3400 meters @ 55°p	.28 ± 19%	.01 ± 57%	.12 ± 23%	2.4	.01 ± 52%	.08 ± 22%	.05 ± 28%	3.6
3400 meters @ 55°s	.26 ± 26%	<.01	.12 ± 31%	2.3	.02 ± 34%	.06 ± 21%	.03 ± 28%	4.7
2000 meters @ 190°p	2.05 ± 15%	.11 ± 22%	.68 ± 16%	3.0	.05 ± 24%	.10 ± 16%	.07 ± 20%	20.8
2000 meters @ 190°s	1.14 ± 14%	.05 ± 25%	.39 ± 15%	2.9	.01 ± 40%	.06 ± 18%	.05 ± 22%	17.8
7500 meters @ 150°p		no sample				no sample		
7500 meters @ 150°s	.08 ± 32%	<.01	.05 ± 35%	1.6	.01 ± 36%	.05 ± 19%	.02 ± 32%	1.7

Table A-3

Plume Monitoring System Samples

3/17-21/75

Location	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
925 meters @ 50°p	.07 ± 15%	<.01	.04 ± 18%	2.0	.02 ± 22%	.02 ± 14%	.02 ± 20%	3.1
925 meters @ 50°s	.03 ± 35%	<.01	.03 ± 37%	1.1	.02 ± 42%	.02 ± 38%	.02 ± 38%	1.3
2150 meters @ 65°p	.06 ± 21%	<.01	.04 ± 23%	1.4	.01 ± 63%	.04 ± 24%	.04 ± 22%	1.6
2150 meters @ 65°s	.08 ± 17%	.01 ± 46%	.05 ± 20%	1.7	.02 ± 26%	.03 ± 23%	.04 ± 20%	2.7
2000 meters @ 190°p	.10 ± 15%	.01 ± 41%	.07 ± 17%	1.6	.01 ± 35%	.05 ± 15%	.02 ± 23%	2.0
2000 meters @ 190°s	.09 ± 18%	<.01	.09 ± 19%	1.0	.03 ± 22%	.08 ± 14%	.03 ± 24%	1.2
1460 meters @ 90°p	.18 ± 17%	.01 ± 44%	.06 ± 22%	3.0	.02 ± 24%	.02 ± 24%	.02 ± 21%	9.9
1460 meters @ 90°s	.07 ± 36%	<.01	.07 ± 30%	1.0	<.01	.02 ± 32%	.01 ± 44%	3.0
7500 meters @ 150°p	no chemical recovery				.01 ± 55%	.02 ± 37%	.03 ± 35%	--
7500 meters @ 150°s	.07 ± 22%	<.01	.07 ± 22%	1.0	.02 ± 26%	.06 ± 15%	.03 ± 22%	1.2

Appendix B

Continuous Air Monitoring Data
Continuous Monitoring System Samples - C_N

Date	fCi/m³ U-234	fCi/m³ U-235	fCi/m³ U-238	Ratio: U-234/U-238(2)	fCi/m³ Th-232	fCi/m³ Th-230	fCi/m³ Th-228	Ratio: U-234/Th-230(2)
7/15-7/18/74	.31 ± 16%	.02 ± 39%	.23 ± 17%	1.4	.01 ± 60%	.08 ± 18%	.02 ± 36%	3.9
7/18-7/22/74	.14 ± 17%	.01 ± 57%	.07 ± 20%	2.0	<.01	.04 ± 20%	.02 ± 29%	3.5
7/22-7/29/74	.09 ± 16%	.01 ± 43%	.05 ± 19%	1.8	<.01	.02 ± 23%	.01 ± 30%	4.3
7/29-8/5/74	.03 ± 22%	<.01	.02 ± 28%	1.8	<.01	.01 ± 32%	.02 ± 23%	2.9
8/5-8/12/74	.04 ± 20%	<.01	.03 ± 46%	1.3	.01 ± 33%	.02 ± 22%	.02 ± 26%	1.6
8/12-8/19/74	.07 ± 15%	.01 ± 50%	.03 ± 22%	2.2	.01 ± 43%	.02 ± 23%	.02 ± 25%	3.2
8/19-8/26/74	.04 ± 20%	<.01	.02 ± 25%	2.1	<.01	.01 ± 35%	.01 ± 31%	4.7
8/26-9/3/74	.10 ± 15%	.01 ± 43%	.04 ± 19%	2.3	.01 ± 27%	.02 ± 22%	.02 ± 20%	5.3
9/3-9/9/74	volume unknown				volume unknown			
9/9-9/16/74	.03 ± 22%	<.01	.02 ± 29%	2.1	.01 ± 45%	.01 ± 29%	.01 ± 33%	2.1
9/16-9/23/74	.02 ± 24%	<.01	.01 ± 32%	1.8	<.01	.01 ± 35%	.01 ± 35%	3.2
9/23-9/30/74	.03 ± 20%	<.01	.01 ± 22%	2.9	.01 ± 42%	.02 ± 25%	.01 ± 34%	2.0
9/30-10/7/74	.10 ± 16%	.01 ± 37%	.06 ± 19%	1.8	.02 ± 23%	.02 ± 19%	.02 ± 24%	4.1
10/7-10/14/74	.08 ± 17%	<.01	.05 ± 20%	1.7	.02 ± 22%	.04 ± 16%	.03 ± 19%	2.1
10/14-10/21/74	.10 ± 28%	.01 ± 52%	.05 ± 30%	2.1	.01 ± 39%	.03 ± 19%	.01 ± 25%	3.8
10/21-10/24/74	no sample				no sample			

CONTINUED

Continuous Monitoring System Samples - C_N (Continued)

Date	fCi/m³ U-234	U-235	U-238	U/234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
10/24-10/30/74	.28 ± 13%	.02 ± 25%	.10 ± 16%	2.8	.01 ± 39%	.03 ± 22%	.02 ± 25%	10.0(1)
10/30-11/4/74	.11 ± 29%	<.01	.06 ± 35%	1.9	.01 ± 39%	.02 ± 29%	.02 ± 28%	4.6
(1) 11/4-11/11/74	.21 ± 20%	<.01	.08 ± 25%	2.7	.02 ± 28%	.04 ± 21%	.02 ± 25%	6.0
11/11-11/19/74	.07 ± 28%	<.01	.04 ± 33%	1.7	.01 ± 37%	.02 ± 20%	.02 ± 22%	2.7
11/19-11/26/74	.14 ± 16%	.01 ± 52%	.06 ± 20%	2.2	.01 ± 46%	.03 ± 20%	.02 ± 27%	4.6
11/26-12/2/74	.06 ± 28%	.01 ± 56%	.03 ± 37%	2.3	<.02	.03 ± 56%	.05 ± 49%	1.8
12/2-12/9/74	.03 ± 24%	<.01	.02 ± 26%	1.4	.01 ± 38%	.01 ± 30%	.01 ± 27%	2.7
12/9-12/16/74	volume unknown				volume unknown			
12/16-12/26/74	.15 ± 14%	.01 ± 38%	.11 ± 15%	1.3	<.01	.01 ± 22%	.01 ± 31%	10.9
12/26-12/30/74	.11 ± 18%	.01 ± 59%	.05 ± 25%	2.4	<.01	.02 ± 31%	.02 ± 32%	6.7
12/30-1/6/75	.11 ± 15%	.01 ± 42%	.05 ± 19%	2.3	.01 ± 37%	.02 ± 23%	.02 ± 28%	4.7
1/6-1/13/75	.05 ± 22%	<.01	.04 ± 25%	1.4	.01 ± 41%	.01 ± 34%	.01 ± 33%	4.5
1/13-1/20/75	.11 ± 15%	.01 ± 41%	.08 ± 16%	1.3	.03 ± 22%	.06 ± 16%	.03 ± 22%	1.9
1/20-1/27/75	volume unknown				volume unknown			
1/27-1/31/75	.46 ± 13%	.02 ± 29%	.25 ± 14%	1.9	.04 ± 21%	.12 ± 12%	.06 ± 17%	3.7
1/31-2/12/75	.04 ± 17%	<.01	.02 ± 20%	1.5	.01 ± 28%	.02 ± 19%	.01 ± 27%	2.2
2/12-2/17/75	.05 ± 22%	<.01	.03 ± 25%	1.5	.01 ± 32%	.02 ± 27%	.03 ± 25%	2.4
2/17-2/24/75	Volume unknown				volume unknown			

Continuous Monitoring System Samples - C_N (Continued)

Date	fCi/m³				fCi/m³			
	U-234	U-235	U-238	U-234/U-238	Th-232	Th-230	Th-228	U-234/Th-230
2/24-3/3/75	.16 ± 14%	<.01	.08 ± 17%	2.1	.03 ± 24%	.06 ± 16%	.04 ± 18%	2.9
3/3-3/11/75		volume unknown				volume unknown		
3/11-3/17/75	.03 ± 23%	<.01	.02 ± 26%	1.3	.01 ± 35%	.02 ± 26%	.01 ± 32%	1.8
3/17-3/21	.05 ± 18%	<.01	.03 ± 22%	1.7	.01 ± 27%	.02 ± 23%	.01 ± 29%	2.5

(1) plant affected sample

(2) ratio calculated from raw data before rounding

Appendix B

Continuous Monitoring System Samples - C_E

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
7/15-7/18/74	.07 ± 24%	<.01	.04 ± 29%	1.7	.03 ± 45%	.03 ± 28%	.02 ± 31%	2.2
7/18-7/22/74	.03 ± 27%	<.01	.02 ± 31%	1.4	.01 ± 52%	.02 ± 32%	.02 ± 31%	2.0
7/22-7/29/74	.08 + 17%	.01 ± 41%	.03 ± 23%	2.8	<.01	.01 ± 29%	.01 ± 32%	7.7
7/29-8/5/74	.01 ± 31%	<.01	.01 ± 42%	1.9	.01 ± 43%	.01 ± 39%	.01 ± 29%	2.1
(1) 8/5-8/12/74	.08 ± 16%	.01 ± 40%	.03 ± 21%	2.7	<.01	.01 ± 41%	.02 ± 29%	13.9
8/12-8/19/74	.03 ± 21%	<.01	.02 ± 26%	1.8	<.01	.01 ± 31%	.01 ± 29%	3.0
8/19-8/26/74	volume unknown				volume unknown			
8/26-9/3/74	.02 ± 21%	<.01	.02 ± 24%	1.4	.01 ± 32%	.01 ± 24%	.02 ± 22%	1.6
9/3-9/9/74	.03 ± 21%	<.01	.01 ± 26%	2.2	<.01	.01 ± 42%	.01 ± 34%	5.4
9/9-9/16/74	.03 ± 22%	<.01	.02 ± 25%	1.4	.01 ± 35%	.01 ± 26%	.02 ± 25%	2.1
(1) 9/16-9/23/74	.04 ± 19%	<.01	.02 ± 28%	2.5	<.01	<.01	.01 + 27%	8.4
9/23-9/30/74	.04 ± 19%	<.01	.02 ± 22%	1.7	<.01	.01 ± 27%	.01 ± 27%	3.2
9/30-10/7/74	.04 ± 19%	<.01	.02 ± 22%	1.6	.01 ± 32%	.02 ± 22%	.02 ± 23%	2.0
10/7-10/14/74	.04 ± 18%	<.01	.03 ± 22%	1.4	.01 ± 31%	.02 ± 21%	.02 ± 21%	1.9
10/14-10/21	volume unknown				volume unknown			

CONTINUED

Continuous Monitoring System Samples - C_E (Continued)

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
10/21-10/24/74	.88 ± 13%	.03 ± 28%	.32 ± 14%	2.7	.01 ± 39%	.03 ± 30%	.02 ± 36%	33.8(1)
10/21-10/24/74*	.98 ± 12%	.05 ± 21%	.34 ± 13%	2.9	.01 ± 32%	.03 ± 23%	.02 ± 31%	33.4(1)
10/24-10/30/74	.06 ± 32%	<.01	.04 ± 35%	1.4	.01 ± 28%	.03 ± 19%	.02 ± 23%	1.7
10/30-11/4/74	.06 ± 20%	.01 ± 53%	.04 ± 23%	1.6	.01 ± 31%	.04 ± 18%	.03 ± 23%	1.4
11/4-11/11/74	.17 ± 14%	.01 ± 34%	.07 ± 16%	2.3	.02 ± 26%	.03 ± 20%	.03 ± 21%	5.3
11/11-11/19/74	.12 ± 16%	.01 ± 39%	.06 ± 19%	2.2	.01 ± 27%	.03 ± 19%	.02 ± 22%	4.9
11/19-11/26/74	.15 ± 19%	.02 ± 28%	.10 ± 15%	1.5	.01 ± 58%	.02 ± 42%	.02 ± 42%	9.0
11/26-12/2/74	.04 ± 20%	<.01	.02 ± 24%	1.6	.01 ± 45%	.02 ± 25%	.01 ± 28%	2.3
12/2-12/9/74	.31 ± 12%	.01 ± 29%	.11 ± 15%	2.9	.01 ± 37%	.02 ± 27%	.02 ± 23%	18.3(1)
12/9-12/16/74		volume unknown				volume unknown		
12/16-12/26/74	≥4.04	≥.17	≥1.19	3.4	<.01	≥.03 ± 15%	≥.01 ± 22%	125.3(1)
(1) 12/26-12/30/74	.23 ± 15%	.01 ± 43%	.10 ± 18%	2.2	.01 ± 52%	.02 ± 28%	.02 ± 31%	10.6
12/30-1/6/75	.14 ± 15%	.01 ± 43%	.07 ± 18%	2.0	.02 ± 22%	.04 ± 17%	.04 ± 15%	3.7
1/6-1/13/75	.05 ± 18%	<.01	.05 ± 19%	1.1	.01 ± 35%	.02 ± 30%	.02 ± 31%	3.2
1/13-1/20/75	.09 ± 16%	<.01	.07 ± 18%	1.3	.03 ± 25%	.04 ± 20%	.02 ± 29%	2.2
1/20-1/27/75	.09 ± 15%	.01 ± 43%	.06 ± 17%	1.4	.03 ± 21%	.04 ± 19%	.04 ± 19%	2.5
1/27-1/31/75	.20 ± 16%	.01 ± 45%	.11 ± 18%	1.8	.04 ± 20%	.11 ± 13%	.06 ± 17%	1.9
1/31-2/12		volume unknown				volume unknown		

CONTINUED

Continuous Monitoring System Samples - C_E (Continued)

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
2/12-2/17/75	.05 ± 19%	<.01	.03 ± 25%	1.9	.01 ± 34%	.01 ± 30%	.03 ± 24%	3.5
2/17-2/24/75	.04 ± 19%	<.01	.03 ± 21%	1.3	.01 ± 27%	.03 ± 19%	.02 ± 23%	1.4
2/24-3/3/75	.16 ± 15%	.01 ± 42%	.14 ± 16%	1.1	.05 ± 14%	.08 ± 11%	.06 ± 13%	2.0
3/3-3/11/75	.12 ± 15%	.01 ± 37%	.09 ± 16%	1.3	.03 ± 17%	.08 ± 11%	.03 ± 18%	1.5
3/11-3/17/75	.05 ± 20%	<.01	.04 ± 22%	1.3	.01 ± 32%	.02 ± 24%	.02 ± 27%	2.1
3/17-3/21/75	.10 ± 15%	.01 ± 41%	.05 ± 18%	2.1	.01 ± 27%	.03 ± 18%	.02 ± 22%	4.0

* Sampling rate double usual rate

Appendix B

Continuous Monitoring System Samples - C_S

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
7/15-7/18/74	.09 ± 26 %	<.01	.04 ± 35 %	2.3	<.01	.05 ± 25 %	.02 ± 41%	1.9
7/18-7/22/74	.08 ± 20 %	<.01	.03 ± 21 %	2.7	<.01	.01 ± 33 %	.02 ± 33%	5.5
7/22-7/29/74	.03 ± 26 %	<.01	.01 ± 36 %	2.5	.01 ± 33 %	.02 ± 26 %	.01 ± 28%	2.2
7/29-8/5/74	.02 ± 25 %	<.01	.01 ± 37 %	2.6	<.01	.01 ± 31 %	.01 ± 27%	1.7
8/5-8/12/74	.02 ± 39 %	<.01	.01 ± 46 %	1.4	.01 ± 31 %	.01 ± 30 %	.01 ± 26%	1.4
8/12-8/19/74	.04 ± 20 %	<.01	.02 ± 23 %	1.5	.01 ± 32 %	.02 ± 23 %	.02 ± 20%	2.0
8/19-8/26/74		volume unknown				volume unknown		
8/26-9/3/74	.03 ± 21 %	<.01	.02 ± 23 %	1.2	.01 ± 35 %	.02 ± 20 %	.01 ± 25%	1.2
(1) 9/3-9/9/74	.11 ± 16 %	.01 ± 35 %	.03 ± 22 %	3.3	<.01	.01 ± 44 %	.01 ± 39%	18.0
9/9-9/16/74	.48 ± 12 %	.03 ± 22 %	.17 ± 14 %	2.9	.01 ± 40 %	.02 ± 24 %	.01 ± 31 %	24.6(1)
(1) 9/16-9/23/74	.18 ± 14 %	.01 ± 31 %	.07 ± 18 %	2.5	.01 ± 35 %	.01 ± 27 %	.02 ± 24 %	14.5
9/23-9/30/74	.07 ± 16 %	<.01	.04 ± 20 %	2.0	.01 ± 40 %	.02 ± 24 %	.01 ± 29 %	4.7
9/30-10/7/74		volume unknown				volume unknown		
10/7-10/14/74	.52 ± 14 %	.03 ± 24 %	.19 ± 16 %	2.7	.03 ± 20 %	.04 ± 16 %	.03 ± 18 %	12.0(1)
10/14-10/21/74	.07 ± 22 %	.01 ± 54 %	.04 ± 26 %	1.7	.01 ± 33 %	.02 ± 23 %	.01 ± 30 %	3.1

CONTINUED

Continuous Monitoring System Samples - C_S (Continued)

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
10/21-10/24/74	1.46 ± 15%	.09 ± 21%	.51 ± 16%	2.9	.01 ± 42%	.07 ± 19%	.05 ± 23%	22.1(1)
10/21-10/24/74*	1.28 ± 19%	.07 ± 27%	.42 ± 20%	3.0	.01 ± 31%	.04 ± 18%	.03 ± 21%	32.0(1)
10/24-10/30/74	.06 ± 22%	<.01	.04 ± 26%	1.5	.01 ± 28%	.04 ± 17%	.03 ± 20%	1.5
10/30-11/4/74	.22 ± 21%	.01 ± 53%	.08 ± 26%	2.5	.02 ± 30%	.03 ± 25%	.03 ± 25%	6.6
11/4-11/11/74	.13 ± 19%	.01 ± 44%	.06 ± 23%	2.4	.02 ± 31%	.03 ±+21%	.03 ± 23%	4.0
11/11-11/19/74	.06 ± 30%	.01 ± 66%	.04 ± 32%	1.3	.01 ± 29%	.03 ± 18%	.03 ± 19%	1.9
11/19-11/26/74	.06 ± 26%	<.01	.03 ± 33%	2.0	.01 ± 37%	.02 ± 24%	.02 ± 24%	3.7
11/26-12/2/74	volume unknown				volume unknown			
12/2-12/9/74	.24 ± 13%	.01 ± 29%	.10 ± 15%	2.4	.01 ± 32%	.02 ± 27%	.02 ± 23%	13.1(1)
12/9-12/16/74	.10 ± 16%	<.01	.05 ± 19%	1.9	.01 ± 35%	.04 ± 17%	.02 ± 23%	2.7
12/16-12/26/74	.11 ± 14%	<.01	.07 ± 16%	1.5	.01 ± 29%	.06 ± 11%	.01 ± 23%	1.8
12/26-12/30/74	Lost in Laboratory				Lost in Laboratory			
12/30-1/6/75	.57 ± 11%	.03 ± 22%	.22 ± 13%	2.6	.06 ± 16%	.06 ± 15%	.05 ± 17%	9.3(1)
1/6-1/13/75	.09 ± 17%	<.01	.04 ± 20%	2.0	.01 ± 33%	.01 ± 29%	.01 ± 32%	6.3
1/13-1/20/75	.16 ± 13%	.01 ± 43%	.08 ± 15%	1.9	.03 ± 22%	.07 ± 14%	.03 ± 21%	2.3
1/20-1/27/75	volume unknown				volume unknown			
1/27-1/31/75	.30 ± 13%	.01 ± 41%	.21 ± 14%	1.4	.06 ± 17%	.13 ± 12%	.06 ± 14%	2.3

CONTINUED

Continuous Monitoring System Samples - C_S (Continued)

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
1/31/2/12/75	.04 ± 20%	<.01	.04 ± 20%	1.0	no chemical recovery			
2/12-2/17/75	.07 ± 18%	<.01	.04 ± 23%	2.0	.01 ± 38%	.02 ± 27%	.03 ± 22%	3.6
2/17-2/24/75	.04 ± 20%	<.01	.03 ± 23%	1.1	.01 ± 30%	.02 ± 22%	.02 ± 21%	1.6
2/24-3/3/75	.15 ± 16%	.01 ± 44%	.14 ± 16%	1.0	.04 ± 15%	.07 ± 11%	.06 ± 13%	2.1
3/3-3/11/75	.31 ± 13%	.02 ± 27%	.14 ± 15%	2.2	.01 ± 18%	.07 ± 11%	.03 ± 18%	4.4
3/11-3/17/75	.03 ± 21%	<.01	.03 ± 22%	1.2	.01 ± 31%	.02 ± 24%	.01 ± 29%	1.8
3/17-3/21/75	.09 ± 15%	<.01	.06 ± 16%	1.5	.02 ± 24%	.06 ± 13%	.03 ± 19%	1.6

Appendix B

Continuous Monitoring System Samples - C_W

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
7/15-7/17/74	.18 ± 18%	.01 ± 54%	.15 ± 19%	1.2	.03 ± 41%	.08 ± 24%	.03 ± 41%	2.3
7/18-7/22/74	.05 ± 22%	<.01	.04 ± 25%	1.5	<.01	.04 ± 21%	.02 ± 27%	1.4
(1) 7/22-7/29/74	.13 ± 14%	.01 ± 35%	.05 ± 18%	2.7	<.01	.02 ± 24%	.01 ± 33%	7.8
7/29-8/5/74	.06 ± 18%	<.01	.03 ± 21%	1.8	.01 ± 32%	.02 ± 23%	.01 ± 26%	3.3
8/5-8/12/74	.05 ± 19%	<.01	.03 ± 23%	1.8	.01 ± 24%	.02 ± 23%	.01 ± 27%	2.3
8/12-8/19/74		volume unknown				volume unknown		2.5
8/19-8/26/74	.05 ± 18%	<.01	.02 ± 23%	2.1	<.01	<.01	.01 ± 25%	10.0
8/26-9/3/74	.03 ± 21%	<.01	.02 ± 23%	1.3	<.01	.02 ± 20%	.01 ± 27%	1.4
9/3-9/9/74	.01 ± 31%	<.01	.01 ± 36%	1.3	.01 ± 45%	.01 ± 34%	.01 ± 29%	1.3
9/9-9/16/74	.19 ± 14%	.01 ± 35%	.07 ± 17%	2.8	.01 ± 43%	.02 ± 24%	.01 ± 26%	12.0
9/16-9/23/74	.04 ± 19%	<.01	.03 ± 23%	1.7	<.01	.01 ± 26%	.01 ± 31%	3.1
9/23-9/30/74	.06 ± 17%	<.01	.04 ± 19%	1.4	.01 ± 41%	.02 ± 22%	.02 ± 24%	3.1
9/30-10/7/74		volume unknown				volume unknown		
10/7-10/14/74	.10 ± 17%	<.01	.04 ± 21%	2.3	.01 ± 33%	.02 ± 20%	.04 ± 19%	4.0
10/14-10/21/74	.03 ± 20%	<.01	.02 ± 22%	1.4	.01 ± 38%	.02 ± 22%	.01 ± 31%	1.4
10/21-10/24/74	.14 ± 24%	<.01	.06 ± 31%	2.4	.01 ± 55%	.04 ± 27%	.03 ± 30%	4.0
10/21-10/24/74*	.18 ± 17%	.01 ± 43%	.07 ± 20%	2.5	.02 ± 31%	.03 ± 23%	.03 ± 24%	6.0

CONTINUED

Continuous Monitoring System Samples - C_W (Continued)

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
10/24-10/30/74	.20 ± 13%	.01 ± 35%	.12 ± 15%	1.6	.01 ± 30%	.07 ± 13%	.02 ± 23%	2.9
(1) 10/30-11/4/74	.28 ± 14%	.02 ± 30%	.13 ± 17%	2.2	.01 ± 39%	.05 ± 17%	.02 ± 26%	6.2
11/4-11/11/74	.07 ± 16%	<.01	.06 ± 17%	1.3	.02 ± 27%	.05 ± 16%	.02 ± 27%	1.5
11/11-11/19/74	.08 ± 16%	<.01	.05 ± 18%	1.7	.01 ± 31%	.04 ± 16%	.02 ± 20%	2.2
11/19-11/26/74	volume unknown				volume unknown			
11/26-12/2/74	.11 ± 15%	<.01	.06 ± 18%	1.9	.01 ± 47%	.03 ± 30%	.03 ± 30%	4.3
12/2-12/9/74	.09 ± 23%	.01 ± 54%	.04 ± 29%	2.1	.01 ± 40%	.01 ± 29%	.02 ± 23%	6.4
12/9-12/16/74	.10 ± 16%	<.01	.07 ± 18%	1.5	.01 ± 32%	.05 ± 15%	.02 ± 27%	2.1
12/16-12/26/74	volume unknown				volume unknown			
12/26-12/30/74	.10 ± 19%	<.01	.06 ± 23%	1.7	<.01	.02 ± 28%	.02 ± 28%	4.6
12/30-1/6/75	.21 ± 16%	.01 ± 36%	.08 ± 19%	2.6	.01 ± 33%	.02 ± 26%	.01 ± 31%	8.1(1)
1/6-1/13/75	.10 ± 15%	.01 ± 36%	.06 ± 18%	1.7	.02 ± 26%	.03 ± 19%	.01 ± 29%	3.0
1/13-1/20/75	.05 ± 19%	<.01	.03 ± 23%	1.8	.01 ± 37%	.02 ± 24%	.01 ± 30%	2.5
1/20-1/27/75	.09 ± 15%	<.01	.08 ± 15%	1.2	.05 ± 14%	.07 ± 13%	.06 ± 13%	1.4
1/27-1/31/75	.31 ± 14%	.01 ± 41%	.26 ± 14%	1.2	.03 ± 25%	.20 ± 10%	.08 ± 15%	1.6
1/31-2/12/75	.04 ± 16%	<.01	.03 ± 16%	1.5	<.01	.02 ± 17%	.01 ± 21%	2.0
2/12-2/17/75	.03 ± 24%	<.01	.02 ± 32%	2.1	<.01	<.01	<.01	24.9(1)
2/17-2/24/75	.05 ± 19%	<.01	.04 ± 20%	1.1	.02 ± 20%	.03 ± 20%	.03 ± 18%	1.9
2/24-3/3	volume unknown				volume unknown			

CONTINUED

Continuous Monitoring System Samples - C_W (Continued)

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
3/3-3/11/75		no sample				no sample		
3/11-3/17/75	.07 ± 16%	<.01	.06 ± 17%	1.2	.03 ± 20%	.05 ± 15%	.04 ± 17%	1.5
3/17-3/21/75	.05 ± 19%	<.01	.04 ± 20%	1.2	<.01	.02 ± 22%	.02 ± 22%	2.1

Appendix B

Continuous Monitoring System Samples - C_B

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
7/15-7/18/74	.07 ± 26%	<.01	.04 ± 31%	1.7	.01 ± 44%	.02 ± 38%	.02 ± 41%	3.7
7/18-7/22/74	.02 ± 35%	<.01	.01 ± 39%	1.4	<.01	.01 ± 20%	.02 ± 29%	1.2
7/22-7/29/74	.02 ± 23%	<.01	.01 ± 29%	1.8	<.01	.01 ± 42%	.01 ± 29%	4.0
7/29-8/5/74	.01 ± 33%	<.01	.01 ± 39%	1.3	.02 ± 37%	.01 ± 45%	.03 ± 30%	7.7
8/5-8/12/74		volume unknown				volume unknown		
8/12-8/19/74	.01 ± 30%	<.01	.01 ± 29%	0.9	<.01	.01 ± 31%	.01 ± 28%	1.1
8/19-8/26/74	.01 ± 31%	<.01	.01 ± 32%	1.1	<.01	<.01	.01 ± 39%	2.3
8/26-9/3/74	.01 ± 29%	<.01	.01 ± 32%	1.2	.01 ± 40%	.01 ± 27%	.01 ± 26%	1.1
9/3-9/9/74		volume unknown				volume unknown		
9/9-9/16/74	.02 ± 24%	<.01	.02 ± 27%	1.4	.01 ± 38%	.01 ± 27%	.01 ± 29%	1.7
9/16-9/23/74	.02 ± 32%	<.01	.01 ± 30%	1.7	<.01	.01 ± 60%	.01 ± 26%	1.9
9/23-9/30/74	.30 ± 13%	.03 ± 22%	.13 ± 14%	2.3	.01 ± 32%	.02 ± 20%	.01 ± 13%	12.5(1)
9/30-10/7/74	.04 ± 19%	<.01	.03 ± 22%	1.5	.01 ± 27%	.02 ± 22%	.02 ± 23%	2.2
10/7-10/14/74	.05 ± 21%	<.01	.02 ± 27%	2.1	.01 ± 34%	.02 ± 25%	.02 ± 23%	3.2
10/14-10/21/74	.03 ± 47%	<.01	.03 ± 52%	1.3	.01 ± 36%	.02 ± 25%	.01 ± 26%	2.1
10/21-10/24/74	.06 ± 38%	<.01	.04 ± 45%	1.6	<.01	.04 ± 26%	.04 ± 28%	1.5
10/21-10/24/74*	.11 ± 26%	<.01	.06 ± 30%	1.8	<.01	.04 ± 19%	.03 ± 23%	2.6

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Continuous Monitoring System Samples - C_B (Continued)

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
10/24-10/30/74	.04 ± 20%	<.01	.03 ± 21%	1.1	.01 ± 39%	.01 ± 32%	.01 ± 32%	3.4
10/30-11/4/74	.04 ± 24%	<.01	.03 ± 27%	1.4	.01 ± 36%	.03 ± 16%	.02 ± 26%	1.6
11/4-11/11/74	.39 ± 12%	.03 ± 22%	.15 ± 14%	2.6	.02 ± 46%	.04 ± 31%	.02 ± 45%	9.0(1)
11/11-11/19/74	.05 ± 39%	<.01	.04 ± 44%	1.5	.01 ± 32%	.03 ± 18%	.02 ± 23%	2.1
11/19-11/26/74	.10 ± 17%	.01 ± 46%	.04 ± 22%	2.5	<.01	.02 ± 24%	.01 ± 34%	5.7
11/26-12/2/74	.05 ± 19%	<.01	.03 ± 22%	1.4	<.02	<.02	<.02	
12/2-12/9/74	.43 ± 12%	.02 ± 25%	.12 ± 14%	3.6	.01 ± 37%	.05 ± 17%	.02 ± 28%	8.7(1)
12/9-12/16/74		volume unknown				volume unknown		
12/16-12/26/74	.16 ± 14%	.01 ± 40%	.12 ± 14%	1.3	.01 ± 32%	.07 ± 10%	.01 ± 23%	2.2
12/26-12/30/74	.12 ± 18%	.01 ± 48%	.05 ± 23%	2.4	.01 ± 43%	.02 ± 32%	.02 ± 28%	7.3
12/30-1/6/75	.10 ± 15%	.01 ± 39%	.07 ± 16%	1.5	.02 ± 27%	.03 ± 20%	.02 ± 28%	3.2
1/6-1/13/75	.11 ± 15%	.01 ± 43%	.09 ± 15%	1.2	.03 ± 22%	.06 ± 15%	.02 ± 24%	1.7
1/13-1/20/75		volume unknown				volume unknown		
1/20-1/27/75	.07 ± 16%	<.01	.04 ± 20%	1.9	<.01	.01 ± 28%	.01 ± 29%	5.6
1/27-1/31/75	.10 ± 18%	<.01	.06 ± 23%	1.8	.01 ± 37%	.04 ± 21%	.02 ± 27%	2.4
1/31-2/12/75	.05 ± 15%	<.01	.03 ± 16%	1.5	.01 ± 30%	.02 ± 19%	.01 ± 23%	2.9
2/12-2/17/75	.05 ± 19%	<.01	.04 ± 22%	1.4	<.01	.02 ± 26%	.02 ± 24%	2.7
2/17-2/24/75		volume unknown				volume unknown		

CONTINUED

Continuous Monitoring System Samples - C_B (Continued)

Date	fCi/m³ U-234	U-235	U-238	U-234/U-238	fCi/m³ Th-232	Th-230	Th-228	U-234/Th-230
2/24-3/3/75	volume unknown				volume unknown			
3/3-3/11/75	.12 ± 16%	.01 ± 43%	.08 ± 17%	1.4	.04 ± 16%	.06 ± 12%	.04 ± 15%	2.0
3/11-3/17/75	.04 ± 21%	<.01	.04 ± 21%	1.0	.01 ± 24%	.03 ± 20%	.14 ± 28%	1.4
3/17-3/21/75	.06 ± 20%	.<.01	.07 ± 20%	0.9	.03 ± 19%	.05 ± 16%	.03 ± 19%	1.3

(1) Plant effected sample

* Sampling rate double the usual rate

Appendix C

Statistical Interpretation of Atmospheric Concentration Data

The weekly data obtained from the continuous east sampling station were plotted on cumulative normal and log-normal probability paper to examine the distribution present. These plots are shown in figures C-1 and C-2. By visual examination, the plot on normal paper is markedly concave upward when compared to the plot on log-normal paper. To quantify the goodness-of-fit of the data with respect to the normal and log-normal distribution each distribution was tested with a chi squared test. For the test of the normal distribution the X^2 (13) was evaluated as 131.31 using the Poisson dispersion test for 14 time periods over the sampling interval (1). When compared with a tabulated $X^2(13, .975) = 24.7$, the null hypothesis of good fit was rejected. Therefore, the data varied widely from a normal distribution.

Similarly, the log-normal distribution hypothesis was tested. The observed $X^2(13) = 10.92$ compared with a tabulated value of X^2 (13, .975) = 24.7 and, therefore, the null hypothesis of adequate fit could not be rejected. Therefore, the log-normal distribution appeared to be an adequate description of the data.

Although the above tests indicated that the log-normal distribution appeared to describe the data much more adequately than the normal, subsequent tests were run in duplicate for each type distribution to examine the types of conclusions which could be made from the assumptions of either distribution. In spite of the obvious limitation of using tests based on the normal distribution, the results of such tests are of interest when compared with results of tests performed under the log-normal assumption. This is particularly important when one considers that often analysis of variance is performed on data without careful consideration of the type of assumed distribution which might be most appropriate.

The first set of tests applied was a three-factor analysis of variance design using the factors time, site, and nuclide and including first order and second order interaction. Using the assumption of normally distributed data each F ratio was tested at the 0.01 significance level. Each of the observed F values for interaction was not significant. In contrast each of the several F ratios for site, time, and nuclide was significant. Identical results were obtained under the assumption of log-normally distributed data where each interaction term was not significant and each main effect was significant.

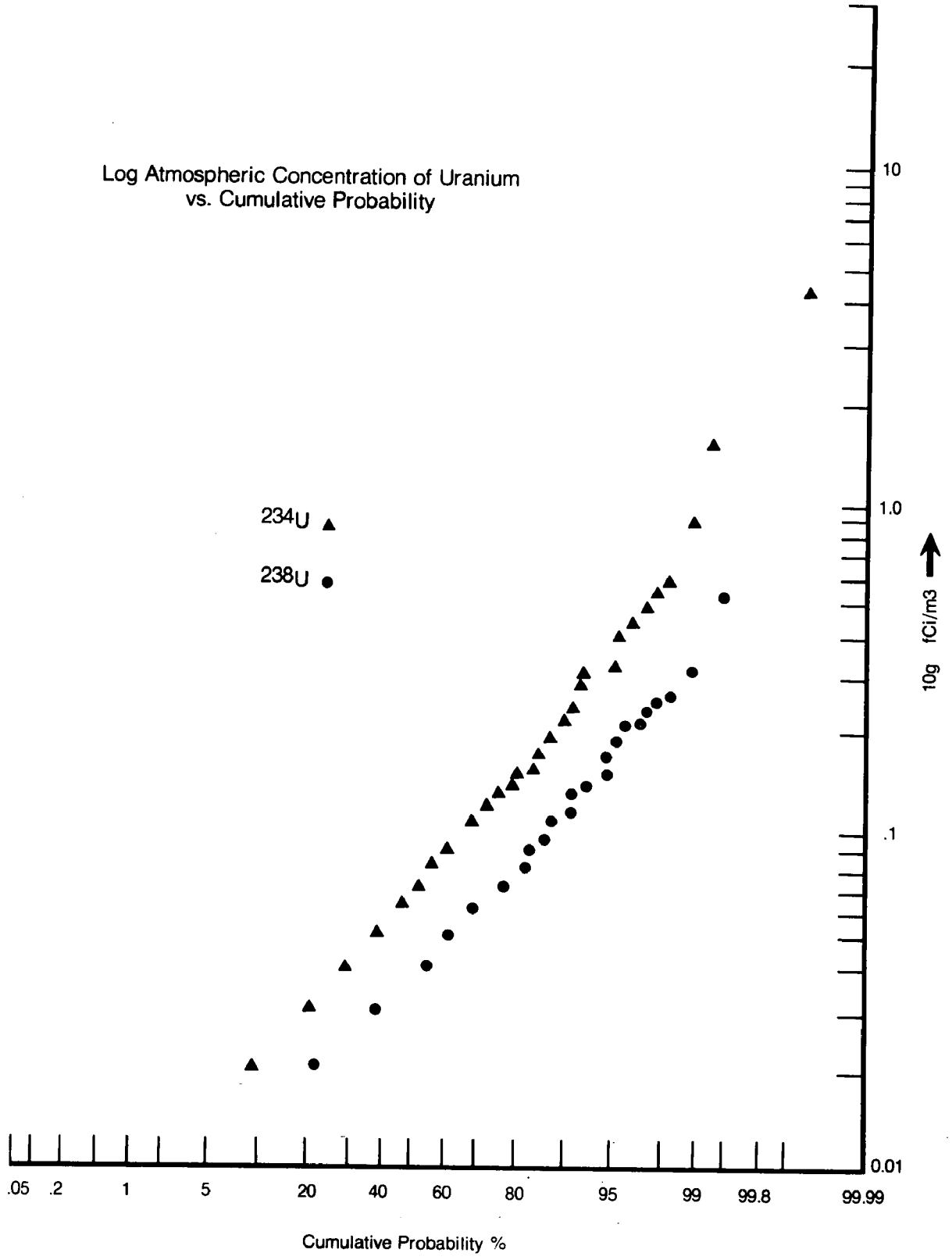

Figure C-1. Probability curve of uranium concentrations for the East continuous sampling site (Normal Distribution)

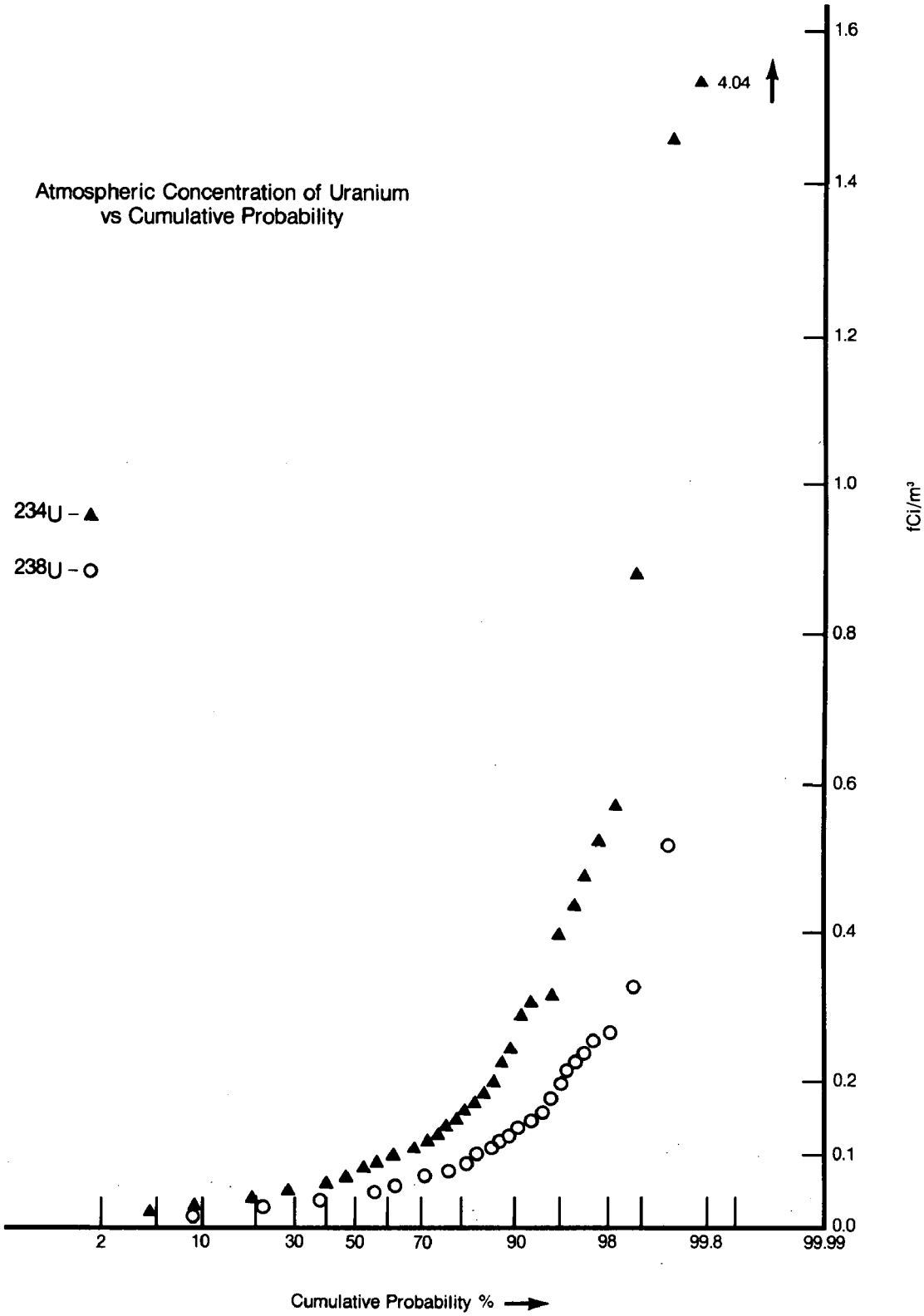

Figure C-2. Probability curve of uranium concentration for the East continuous sampling site (Log-Normal distribution)

Of particular importance in these results was the fact that mean sum of squares due to the nuclide effect dominated the respective F ratios. For example, under the log-normal assumption the respective mean sum of squares for time, site, and nuclide were 6.11, 2.52, and 24.92. Since these results showed that effect of ^{234}U and ^{238}U nuclide difference dominated the design, the data for subsequent tests were separated by nuclide and tested only for time and site effects.

Next a two-way factorial design was set up with the data to study the main effects time and sites and interaction between the two. The results from the normal assumption are as follows. (The 0.01 significance level was used for each test.)

Since the data appeared to follow a log-normal distribution according to the tests run previously, a logarithmic transformation was performed and the two-way analysis of variance tests were rerun. Results of these tests for the assumption of a log-normal distribution are as follows. (The 0.01 significance level was used for each test.)

Table C-1

Results of the Two-way ANOVA for Time and Site Effects

Normal Distribution

	^{234}U	^{238}U
Time & site interaction	F(68,90) = 1.08 Not significant	F(68,90) = 1.00 Not significant
Site	F(4,90) - = 1.51 Not significant	F(4,90) = 1.37 Not significant
Time	F(17,90) = 1.36 Not significant	F(17,90) = 1.79 Not significant

Log-Normal Distribution

	^{234}U	^{238}U
Time & site interaction	F(68,90) = 1.43 Not significant	F(68,90) = 1.27 Not significant
Site	F(4,90) = 4.02 Significant	F(4,90) = 2.07 Not significant

Table C-1 - Continued

Log-Normal Distribution

	^{234}U	^{238}U
Time	F(17,90) = 7.36 Significant	F(17,90) = 7.63 Significant

To briefly summarize the above results under the assumption of normally distributed data, none of the effects tested was significant at the 0.01 level. In contrast, under the assumption of log-normally distributed data the site and time effects were significant for ^{234}U but for ^{238}U only the time effect was significant at the 0.01 level.

Since the analysis of variance had shown that for ^{234}U sites were significantly different under the log-normal assumption, a multiple range test was then used to try to group the ^{234}U site data according to the concept of a significant range between sites. The test employed was the Duncan's New Multiple Range Test, as described in Dixon (2). The results showed that no single site or group of sites was confined to a significant range at the 0.05 level. Therefore, although there is evidence for a significant difference among the sites they are not separable into distinct grouping under the significant range concept.

Since the two-way analysis of variance using a logarithmic transformation showed the sites to be significantly different, transformed data for the 36 weekly measurements for each of the five sites were handled separately in subsequent tests. In order to determine suspiciously high values at each site, confidence intervals at the 2σ level on ^{234}U concentrations were determined at each site using values transformed as $X' = \ln(1000X)$ where X is the measured value. The confidence intervals on transformed values for ^{234}U and ^{238}U are given below.

Calculated Confidence Intervals on Transformed ^{234}U and ^{238}U Data

Site	Confidence interval on transformed ^{234}U values	^{238}U values
	$x^1 + 2\sigma x^1$	$x^1 + 2\sigma x^1$
North	4.29 ± 1.75	3.77 ± 1.75

Calculated Confidence Intervals on Transformed ^{234}U and ^{238}U Data
(Continued)

Site	Confidence interval on transformed ^{234}U values	^{238}U values
	$x^1 + 2\sigma x^1$	$x^1 + 2\sigma x^1$
East	4.38 ± 2.22	3.82 ± 1.92
South	4.63 ± 2.04	3.96 ± 1.84
West	4.34 ± 1.48	3.85 ± 1.34
Background	3.95 ± 2.02	3.54 ± 1.68

Using these confidence intervals the following values were determined to lie outside the $2\sigma x^1$ range.

Measured Air Concentrations
fCi/m^3

Site & Date	^{234}U	^{235}U	^{238}U
North 1/27-31/75	0.46	0.02	0.25
East 12/16-26/74	4.04	0.17	1.19
10/21-24/74	0.88	0.03	0.32
South 10/21-24/74	1.46	0.09	0.51
West	No values outside range		
Background 12/2-9/74	0.43	0.02	0.12

References (Appendix C):

1. Cursie, L. A. On the Interpretation of Errors in Counting Experiments, Analytical Letters, 4, 777-784, 1971.
2. Dixon, W. T., BMD. Biomedical Computer Program, p. 677, UCLA. Health Sciences Computing Facility. 1971.

Appendix D

Terrestrial Vegetation Data

Position	Date	pCi/g ash U-234	U-235	U-238	U-234/U-238	pCi/g ash Th-232	Th-230	Th-228	U-234/Th-230
C_N	Jul 1974	.20 ± 17%	.01 ± 42%	.16 ± 18%	1.3	.09 ± 14%	.13 ± 11%	.13 ± 12%	1.5
C_N	Oct 1974	.34 ± 13%	.02 ± 35%	.34 ± 13%	1.0	.21 ± 9%	.32 ± 7%	.25 ± 8%	1.1
C_N	Mar 1975	.17 ± 16%	.01 ± 53%	.16 ± 16%	1.1	.02 ± 32%	.03 ± 22%	.03 ± 22%	5.1
C_E	Jul 1974	.05 ± 23%	<.01	.06 ± 22%	0.9	.03 ± 23%	.05 ± 15%	.08 ± 15%	1.0
C_E	Oct 1974	.48 ± 13%	.03 ± 27%	.44 ± 13%	1.1	.41 ± 7%	.45 ± 6%	.50 ± 6%	1.1
C_E	Mar 1975	.30 ± 14%	.02 ± 35%	.26 ± 15%	1.2	.11 ± 12%	.16 ± 10%	.69 ± 5%	1.9
C_S	Jul 1974	.22 ± 19%	.02 ± 41%	.21 ± 19%	1.0	.22 ± 14%	.27 ± 8%	.46 ± 6%	0.8
C_S	Oct 1974	.35 ± 14%	.02 ± 33%	.33 ± 14%	1.1	.18 ± 10%	.39 ± 7%	.45 ± 7%	0.9
C_S	Mar 1975	.60 ± 13%	.03 ± 28%	.56 ± 13%	1.1	.31 ± 8%	.53 ± 6%	.37 ± 8%	1.1
C_W	Jul 1974	.22 ± 17%	.02 ± 37%	.18 ± 17%	1.2	.06 ± 17%	.14 ± 11%	.10 ± 14%	1.6
C_W	Oct 1974	.56 ± 13%	.04 ± 25%	.54 ± 13%	1.0	.28 ± 9%	.64 ± 6%	.29 ± 9%	0.9
C_W	Mar 1975	1.41 ± 12%	.22 ± 15%	.75 ± 13%	1.9	.21 ± 9%	.37 + 7%	.51 ± 6%	3.8
C_B	Jul 1974	.94 ± 15%	.08 ± 20%	.92 ± 15%	1.0	.48 ± 7%	.63 ± 6%	.43 ± 7%	1.5
C_B	Oct 1974	.38 ± 14%	.02 ± 33%	.38 ± 14%	1.0	.34 ± 7%	.37 ± 7%	.33 ± 7%	1.0
C_B	Mar 1975	.16 ± 15%	.02 ± 32%	.12 ± 16%	1.3	.02 ± 27%	.07 ± 16%	.64 ± 5%	2.4

Appendix D

Soil Data

Position	Date	pCi/g dry wt. U-234	U-235	U-238	U-234/U-238	pCi/g dry wt. Th-232	Th-230	Th-228	U-234/Th-230
C_N	Jul 1974	.31 ± 15%	.02 ± 30%	.87 ± 14%	0.4	.20 ± 10%	.15 ± 11%	.20 ± 10%	2.0
C_N	Oct 1974	.35 ± 14%	.02 ± 32%	.34 ± 14%	1.0	.28 ± 8%	.37 ± 7%	.26 ± 4%	0.9
C_N	Mar 1975	.21 ± 15%	.02 ± 33%	.22 ± 15%	0.9	.12 ± 13%	.22 ± 10%	.15 ± 11%	1.0
C_E	Jul 1974	.54 ± 15%	.04 ± 25%	.67 ± 15%	0.8	.62 ± 6%	.54 ± 6%	.68 ± 6%	1.0
C_E	Oct 1974	.71 ± 13%	.03 ± 25%	.73 ± 13%	1.0	.97 ± 5%	.84 ± 5%	.82 ± 5%	0.8
C_E	Mar 1975	.82 ± 13%	.04 ± 25%	.83 ± 13%	1.0	.59 ± 6%	.70 ± 6%	.64 ± 6%	1.2
C_S	Jul 1974	.35 ± 17%	.02 ± 33%	.69 ± 16%	0.5	.62 ± 6%	.32 ± 8%	.40 ± 7%	1.1
C_S	Oct 1974	.33 ± 15%	.02 ± 37%	.33 ± 15%	1.0	.11 ± 13%	.41 ± 7%	.34 ± 8%	0.8
C_S	Mar 1975	.49 ± 14%	.03 ± 31%	.50 ± 14%	1.0	.29 + 8%	.39 ± 7%	.34 ± 7%	1.3
C_W	Jul 1974	.50 ± 21%	.07 ± 30%	.44 ± 21%	1.1	.21 ± 9%	.53 ± 6%	.21 ± 9%	0.9
C_W	Oct 1974	1.20 ± 12%	.08 ± 18%	1.28 ± 12%	0.9	<.01	1.34 ± 4%	.36 ± 7%	0.9
C_W	Mar 1975	.37 ± 13%	.02 ± 32%	.34 ± 13%	1.1	.24 ± 9%	.54 ± 6%	.28 ± 8%	0.7
C_B	Jul 1974	.36 ± 17%	.02 ± 34%	.56 ± 16%	0.6	.23 ± 9%	.36 ± 7%	.46 ± 7%	1.0
C_B	Oct 1974	.95 ± 15%	.07 + 24%	.99 ± 15%	1.0	1.26 ± 5%	1.04 ± 5%	1.10 ± 5%	0.9
C_B	Mar 1975	.84 ± 12%	.04 ± 26%	.84 ± 12%	1.0	.68 ± 6%	.78 ± 5%	.80 ± 5%	1.1

Appendix E
Atmospheric Deposition Data
Atmospheric Deposition - Fallout Trays

Position	Date	pCi/m²-mo U-234	U-235	U-238	U-234/U-238	pCi/m²-mo Th-232	Th-230	Th-228	U-234/Th-230
C_N	7/15-8/19/74	2.0 ± 24%	.1 ± 66%	.97 ± 31%	2.0	.4 ± 44%	.8 ± 34%	1.0 ± 30%	2.6
C_N	8/19-9/23/74	3.8 ± 19%	.3 ± 58%	2.6 ± 22%	1.5	2.3 ± 19%	1.3 ± 26%	3.5 ± 16%	2.9
C_N	9/23-10/24/74	5.0 ± 17%	.4 ± 48%	5.2 ± 17%	1.0	4.2 ± 15%	3.7 ± 16%	5.2 ± 13%	1.4
C_N	12/30-1/31/75	4.1 ± 18%	.4 ± 47%	2.4 ± 22%	1.7	.5 ± 42%	.9 ± 31%	.9 ± 32%	4.7
C_N	2/24-3/17/75	1.6 ± 25%	<.1	1.1 ± 31%	1.0	.4 ± 45%	.6 ± 38%	.5 ± 41%	2.6
C_E	7/15-8/19/74	1.8 ± 25%	<.1	1.1 ± 31%	1.6	.4 ± 49%	.3 ± 50%	1.7 ± 22%	5.4
C_E	8/19-9/23/74	2.6 ± 22%	<.1	1.6 ± 27%	1.6	.5 ± 46%	.6 ± 42%	2.1 ± 21%	4.7
C_E	9/23-10/24/74	8.7 ± 15%	.4 ± 48%	7.2 ± 15%	1.2	10.2 ± 10%	6.9 ± 11%	10.2 ± 10%	1.3
C_E	12/30-1/31/75	7.4 ± 16%	.4 ± 51%	4.3 ± 20%	1.7	1.3 ± 26%	2.0 ± 21%	3.0 ± 17%	3.8
C_E	2/24-3/17/75	1.4 ± 28%	<.1	1.3 ± 28%	1.0	.5 ± 42%	1.0 ± 29%	1.0 ± 28%	1.3
C_S	7/15-8/19/74	1.9 ± 25%	.2 ± 60%	1.1 ± 30%	1.7	.6 ± 37%	.6 ± 38%	.8 ± 34%	3.0
C_S	8/19-9/23/74	5.6 ± 18%	.5 ± 46%	4.9 ± 19%	1.1	3.2 ± 17%	1.4 ± 25%	4.8 ± 14%	3.9
C_S	9/23-10/24/74	8.3 ± 15%	.6 ± 42%	6.8 ± 16%	1.2	10.6 ± 10%	6.3 ± 11%	12.6 ± 9%	1.3
C_S	12/30-1/31/75	6.8 ± 16%	.4 ± 51%	5.2 ± 17%	1.3	.9 ± 31%	2.3 ± 20%	1.6 ± 23%	3.0
C_S	2/24-3/17/75	1.6 ± 29%	<.1	1.5 ± 29%	1.0	.8 ± 37%	.7 ± 39%	1.2 ± 30%	2.3

CONTINUED

Appendix E

Atmospheric Deposition - Fallout Trays (Continued)

Position	Date	pCi/m²-mo U-234	U-235	U-238	U-234/U-238	pCi/m²-mo Th-232	Th-230	Th-228	U-234/Th-230
C_W	7/15-8/19/74	4.8 ± 18%	.2 ± 61%	2.0 ± 24%	2.4	.6 ± 40%	.9 ± 32%	1.2 ± 28%	5.5
C_W	8/19-9/23/74	3.1 ± 20%	<.1	2.7 ± 22%	1.1	2.3 ± 19%	1.0 ± 30%	4.0 ± 15%	3.2
C_W	9/23-10/24/74	9.9 ± 15%	.5 ± 44%	9.2 ± 15%	1.1	5.8 ± 12%	5.3 ± 13%	6.8 ± 11%	1.9
C_W	12/30-1/31/75	9.5 ± 16%	.4 ± 53%	4.3 ± 18%	2.2	.5 ± 41%	1.9 ± 11%	1.4 ± 25%	5.0
C_W	2/24-3/17/75	1.9 ± 26%	<.1	1.6 ± 28%	1.2	.4 ± 44%	.4 ± 45%	.8 ± 33%	4.6
C_B	7/15-8/19/74	1.1 ± 31%	.1 ± 66%	1.1 ± 31%	1.0	.6 ± 40%	.8 ± 36%	1.0 ± 31%	1.4
C_B	8/19-9/23/74	1.4 ± 37%	.4 ± 66%	1.2 ± 39%	1.1	2.0 ± 21%	.8 ± 34%	3.1 ± 17%	1.8
C_B	9/23-10/24/74	9.0 ± 15%	.7 ± 37%	7.8 ± 16%	1.2	6.0 ± 12%	4.2 ± 15%	7.4 ± 11%	2.1
C_B	12/30-1/31/75	3.4 ± 19%	.3 ± 57%	2.2 ± 23%	1.5	.5 ± 41%	.6 ± 37%	.9 ± 31%	5.3
C_B	2/24-3/17/75	3.5 ± 20%	.5 ± 47%	2.4 ± 23%	1.4	1.0 ± 30%	.9 ± 32%	1.4 ± 26%	4.0

Appendix E

Atmospheric Deposition - Precipitation

Location/Date	pCi/m² mo (dissolved & undissolved) U-234	U-235	U-238	U-234/U-238
C_N (7/15-8/19/74)	<2	<2	<2	
C_N (8/19-9/16/74)	4.9 ± 28%	<1	2.4 ± 40%	2.0
C_N (9/16-10/14/74)*	> .5	> .1	> .4	1.5
C_N (10/14-11/11/74)	no measurable rain			
C_N (11/11-12/16/74)	1.7 ± 36%	<1	1.1 ± 44%	1.5
C_N (12/16-1/3/75)	1.1 ± 47%	<1	1.0 ± 49%	1.1
C_N (1/6-1/27/75)	2.7 ± 30%	<1	1.3 ± 43%	2.0
C_N (1/27-2/24/75)	3.4 ± 30%	<1	1.8 ± 44%	1.9
C_N (2/24-3/18/75)	3.4 ± 27%	<1	2.8 ± 30%	1.2
C_E (7/15-8/19/74)	<2	<2	<2	
C_E (8/19-9/16/74)	11.2 ± 25%	<1	4.9 ± 35%	2.3
C_E (9/16-10/14/74)*	>.4	<1	>.3	1.6
C_E (10/14-11/11/74)	.5 ± 50%	<1	.5 ± 53%	1.0
C_E (11/11-12/16)	1.4 ± 38%	<1	.9 ± 48%	1.6
C_E (12/16-1/3/75)	.8 ± 46%	<1	.5 ± 57%	1.5
C_E (1/6-2/24/75)	2.0 ± 37%	<1	2.6 ± 53%	0.8
C_E (2/24-3/18)	.3 ± 50%	<1	.6 ± 44%	0.6

* No chemical yield of dissolved portion

NOTE: Th-<1 pCi/m²- mo
except C_S (1/27-2/24/75) 8.6 ± 15% Th-230

Appendix E

Atmospheric Deposition - Precipitation

Location/Date	pCi/m² mo (dissolved & undissolved) U-234	U-235	U-238	U-234/U-238
C_S (7/15-8/19/74)	<2	<2	<2	
C_S (8/19-9/16/74)	<1	<1	<1	
C_S (9/16-10/14/74)*	>.1	<1	>.1	1.2
C_S (10/14-11/11/74)	no measurable rain			
C_S (11/11-12/16/74)	1.1 ± 43%	<1	.8 ± 47%	1.3
C_S (12/16-1/3/75)	1.0 ± 36%	<1	<1	
C_S (1/6-1/27/75)	12.8 ± 36%	7.6 ± 36%	13.5 ± 35%	0.9
C_S (1/27-2/24/75)	2.3 ± 36%	<1	2.1 ± 38%	1.1
C_S (2/24-3/18/75)	1.1 ± 37%	<1	1.1 ± 37%	1.1
C_W (7/15-8/19/74)	<2	<2	<2	
C_W (8/19-9/16/74)	28.5 ± 17%	1.4 ± 40%	10.3 ± 22%	2.8
C_W (9/16-10/14/74)	>.3	<1	>.3	1.0
C_W (10/14-11/11/74)	no measurable rain			
C_W (11/11-12/16/74)	1.5 ± 39%	<1	1.5 ± 39%	1.0
C_W (12/16-1/3/75)	1.9 ± 32%	<1	.7 ± 46%	2.5
C_W (1/6-1/27/75)	3.0 ± 31%	<1	2.0 ± 37%	1.5
C_W (1/27-2/24/75)	3.0 ± 33%	<1	1.5 ± 50%	2.0
C_W (2/24-3/18/75)	.6 ± 55%	<1	.5 ± 45%	1.2

* No chemical yield of dissolved portion

NOTE: Th- <1 pCi/m² - mo
except C_S(1/27-2/24/75) 8.6 ± 15% Th-230

Appendix E

Atmospheric Deposition - Precipitation

Location/Date	pCi/m² mo (dissolved & undissolved)			
	U-234	U-235	U-238	U-234/U-238
C_B (7/15-8/19/74)	<2	<2	<2	
C_B (8/19-9/16/74)	.7 ± 57%	<1	.7 ± 59%	1.1
C_B (9/16-10/14/74)	no measurable rain			
C_B (10/14-11/11/74)	no measurable rain			
C_B (11/11-12/16/74)	.9 ± 51%	<1	1.9 ± 32%	0.5
C_B (12/16-1/3/75)	.7 ± 53%	<1	.5 ± 62%	1.4
C_B (1/6-1/27/75)	1.5 ± 30%	<1	.7 ± 49%	2.2
C_B (1/27-2/24/75)	33.0 ± 30%	9.5 ± 41%	14.7 ± 36%	2.2
C_B (2/24-3/21	1.2 ± 50%	<1	1.1 ± 50%	1.1

NOTE: Th- <1 pCi/m² - mo
except C_S (1/27-2/24/75) 8.6 ± 15% Th-230

Appendix F

Liquid Release Data
(courtesy G.E.)

Date	kg U/wk	mCi U/day	Date	kg U/wk	mCi U/day
12/31/73-1/7/74	12.7	2.52	5/27-6/3/74	17.8	3.53
1/7-1/14/74	15.2	3.02	6/3-6/10/74	16.1	3.20
1/14-1/21/74	10.0	1.99	6/10-6/17/74	10.7	2.12
1/21-1/28/74	7.8	1.55	6/17-6/24/74	13.8	2.74
1/28-2/4/74	14.0	2.78	6/24-7/1/74	11.3	2.24
2/4-2/11/74	12.1	2.40	7/1-7/8/74	9.9	1.97
2/11-2/18/74	14.8	2.94	7/8-7/15/74	6.7	1.33
2/18-2/25/74	20.5	4.07	7/15-7/22/74	10.6	2.10
2/25-3/4/74	16.1	3.20	7/22-7/29/74	11.3	2.24
3/4-3/11/74	15.9	3.16	7/29-8/5/74	3.5	0.70
3/11-3/18/74	16.2	3.22	8/5-8/12/74	4.3	0.85
3/18-3/25/74	26.0	5.16	8/12-8/19/74	2.4	0.48
3/25-4/1/74	14.8	2.94	8/19-8/26/74	3.6	0.71
4/1-4/8/74	17.5	3.48	8/26-9/2/74	13.8	2.74
4/8-4/15/74	11.2	2.22	9/2-9/9/74	15.0	2.98
4/15-4/22/74	11.0	2.18	9/9-9/16/74	19.0	3.77
4/22-4/29/74	13.4	2.66	9/16-9/23/74	11.5	2.28
4/29-5/6/74	12.6	2.50	9/23-9/30/74	16.3	3.24
5/6-5/13/74	9.0	1.79	9/30-10/7/74	13.6	2.70
5/13-5/20/74	13.2	2.62	10/7-10/14/74	16.0	3.18
5/20-5/27/74	12.5	2.48	10/14-10/21/74	15.8	3.14

Appendix F

Liquid Release Data
(Continued)

Date	kg U/wk	mCi U/day
10/21-10/28/74	18.2	3.61
10/28-11/4/74	21.8	4.33
11/4-11/11/74	15.7	3.12
11/11-11/18/74	22.2	4.41
11/18-11/25/74	18.6	3.69
11/25-12/2/74	9.9	1.97
12/2-12/9/74	20.4	4.05
12/9-12/16/74	13.5	2.68
12/16-12/23/74	14.4	2.86
12/23-12/30/74	11.6	2.30
12/30-1/6/75	12.8	2.54
1/6-1/13/75	11.5	2.28
1/13-1/20/75	10.5	2.08
1/20-1/27/75	8.7	1.73
1/27-2/3/75	13.9	2.76
2/3-2/10/75	0.0	0
2/10-2/17/75	0.0	0
2/17-2/24/75	6.3	1.25
2/24-3/3/75	1.6	.32
3/3-3/10/75	12.4	2.46
3/10-3/17/75	23.0	4.57
3/17-3/24/75	18.7	3.71

Appendix G
Water Concentration Data
Water Samples
July 16, 1974

Position	Dissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Dissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
I - 10'	.04 ± 27%	<.01	.07 ± 23%	0.6	.01 ± 43%	.02 ± 32%	.04 ± 24%	1.9
I - 5'	.04 ± 33%	<.01	.02 ± 39%	2.0	.01 ± 55%	.02 ± 33%	.02 ± 31%	1.6
II - 5'	.03 ± 100%	<.01	.03 ± 100%	1.0	.01 ± 50%	.02 ± 35%	.03 ± 27%	1.6
II - 10'	.05 + 100%	<.01	.05 ± 100%	1.0	.01 ± 43%	.02 ± 35%	.03 ± 27%	3.1
III - 20'	.09 ± 60%	<.01	.10 ± 55%	0.9	<.01	.02 ± 41%	.02 ± 33%	4.6
III - 10'	.03 ± 29%	<.01	.04 ± 27%	0.8	<.01	.02 ± 40%	.04 ± 25%	2.3
IV - 5'	.12 ± 57%	<.01	.07 ± 69%	1.7	<.01	.02 ± 38%	.01 ± 43%	6.0
IV - 12'	.06 ± 73%	<.01	.02 ± 100%	3.0	<.01	.02 ± 34%	.02 ± 30%	3.0
V - 25'	.28 ± 38%	<.01	.11 ± 49%	2.5	<.01	.02 ± 40%	.03 ± 39%	14.0
V - 10'	.24 ± 15%	.01 ± 53%	.09 ± 19%	2.7	<.01	.01 ± 47%	.04 ± 22%	24.5
VI - 10'	.32 ± 16%	.03 ± 34%	.14 ± 19%	2.3	.02 ± 31%	.03 ± 27%	.04 ± 25%	11.0
VI - 6'	.25 ± 15%	.02 ± 39%	.11 ± 18%	2.3	<.01	.01 ± 45%	.03 ± 26%	24.6
VII - 10'	.23 ± 19%	.02 ± 60%	.11 ± 25%	2.1	<.01	.01 ± 37%	.01 ± 23%	23.3
VII - 25'	.24 ± 17%	.01 ± 44%	.12 ± 20%	2.0	.01 ± 55%	.01 ± 43%	.03 ± 30%	18.2
VIII - 10'	.12 ± 41%	<.01	.12 ± 40%	1.0	.01 ± 50%	.01 ± 45%	.01 ± 55%	10.7
VIII - 20'	.12 ± 19%	.01 ± 46%	.09 ± 21%	1.3	.01 ± 62%	.01 ± 43%	.02 + 32%	9.8
IX - 5'	.25 ± 38%	<.01	.21 ± 40%	1.2	<.01	.01 ± 50%	.01 ± 50%	25.0
IX - 10'	.17 ± 19%	<.01	.11 ± 22%	1.5	.01 ± 55%	.01 ± 44%	.04 ± 26%	13.2

Appendix G

Water Samples
July 1974

Description	Dissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Dissolved Solids pCi/l Th-232	Th-230	Th-228	U-235/Th-230
Lagoon Composite 7/8-7/15/74	896 ± 15%	44 ± 16%	250 ± 15%	3.6	<.01	.54 ± 39%	<.01	1659
North Lagoon 7/8/74	846 ± 12%	36 ± 13%	236 ± 12%	3.6	<.01	<.01	1.07 ± 32%	
7/9/74	895 ± 12%	42 ± 13%	248 ± 12%	3.6	<.01	<.01	1.04 ± 35%	
South Lagoon 7/8/74	574 ± 12%	25 ± 13%	152 ± 12%	3.8	<.01	.30 ± 57%	1.16 ± 32%	2056
7/9/74	648 ± 12%	30 ± 13%	184 ± 12%	3.5	<.01	<.01	.77 ± 37%	
GE Well - 80'		No chemical recovery						
GE Well (iron removed)	.05 ± 25%	<.01	.07	.07 ± 35%	<.01	.01 ± 60%	.03 ± 29%	7.3
H.W. Well - 35'	.01 ± 45%	<.01	.01 ± 52%	1.0	<.01	.01 ± 64%	.04 ± 25%	2.2
Motel - municipal		No chemical recovery						

Water Samples
October 22, 1974

Position	Dissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Dissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
I - 5'	.07 ± 29%	<.01	.07 ± 29%	1.0	<.01	<.01	<.01	
I - 20'	.11 ± 25%	.02 ± 25%	.07 ± 34%	1.6	<.01	<.01	<.01	
II - 5'	.02 ± 36%	<.01	.03 ± 35%	0.7	<.01	.01 ± 56%	.02 ± 40%	
II - 10'	.18 ± 16%	.01 ± 42%	.07 ± 21%	2.6	.01 ± 52%	.01 ± 43%	.03 ± 27%	15.0
III - 1'	.06 ± 28%	<.01	.04 ± 29%	1.5	<.01	.05 ± 44%	.09 _ 30%	1.1
III - 10'	.04 ± 28%	<.01	.04 ± 29%	1.0	<.01	.06 ± 40%	.06 ± 38%	0.8
IV - 5'	.13 ± 33%	.01 ± 100%	.08 ± 45%	1.6	<.01	.01 ± 45%	.02 ± 35%	9.1
IV - 10'	.11 ± 18%	.01 ± 47%	.07 ± 41%	1.6	.01 ± 56%	.02 ± 39%	.08 ± 16%	7.3
V - 5'	.08 ± 21%	<.01	.04 ± 25%	2.0	.01 ± 50%	.01 ± 47%	.02 ± 34%	6.9
V - 15'	.23 ± 21%	.02 ± 42%	.11 ± 24%	2.1	<.01	<.01	<.01	
VI - 5'	.58 ± 13%	.03 ± 28%	.22 ± 15%	2.6	.01 ± 50%	.02 ± 42%	.14 ± 14%	38.8
VI - 10'	.62 ± 20%	.04 ± 37%	.22 ± 23%	2.8	<.01	<.01	<.01	
VII - 15'	.34 ± 14%	.02 ± 34%	.22 ± 15%	1.6	<.01	.01 ± 49%	.02 ± 34%	34.2
VII - 5'	.24 ± 17%	.01 ± 57%	.14 ± 24%	1.7	<.01	.01 ± 58%	.02 ± 30%	40.0
VIII - 10'	.34 ± 14%	.01 ± 38%	.21 ± 15%	1.6	<.01	<.01	<.01	
VIII - 5'	.23 ± 15%	.01 ± 46%	.14 ± 17%	1.6	.01 ± 48%	.01 ± 56%	.04 ± 28%	25.2
IX - 20'	.44 ± 24%	.02 ± 53%	.39 ± 24%	1.1	.01 ± 49%	.02 ± 35%	.02 ± 32%	23.3
IX - 3'	.33 ± 22%	.02 ± 55%	.24 ± 23%	1.4	<.01	<.01	.01 ± 44%	

Water Samples
October 1974

Description	Dissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Dissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
Lagoon Composite 10/8-10/14/74	1806 ± 16%	76 ± 17%	550 ± 16%	3.3	<.01	<.01	<.01	
10/15-10/21/74	1164 ± 15%	51 ± 16%	360 ± 15%	3.2	<.01	<.01	<.01	
GE Well - 80'	.05 ± 24%	<.01	.06 ± 22%	0.8	<.01	<.01	.02 ± 50%	
GE Well (iron removed)	.06 ± 22%	<.01	.06 ± 22%	1.0	<.01	<.01	<.01	
H.W. Well - 35'	.02 ± 46%	<.01	.01 ± 58%	2.0	<.01	<.01	<.01	
Motel - municipal	.03 ± 35%	<.01	.02 ± 39%	1.5	.01 ± 52%	<.01	.02 ± 37%	
III 20' duplicate	.57 ± 14%	.04 ± 29%	.40 ± 14%	1.4	.01 ± 39%	.02 ± 31%	.02 ± 33%	25.7
5' duplicate	.04 ± 28%	.01 ± 53%	.03 ± 34%	1.3	.03 ± 27%	.02 ± 32%	.03 ± 26%	2.0

Water Samples
March 18, 1975

Position	Dissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Dissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
I - 20'	.02 ± 33%	<.01	.02 ± 35%	1.0	<.01	.02 ± 36%	.04 ± 23%	1.4
I - 3'	.02 ± 39%	<.01	.02 ± 36%	1.0	.01 ± 50%	.01 ± 50%	.03 ± 30%	2.1
II - 25'	.04 ± 29%	<.01	.03 ± 31%	1.3	<.01	.01 ± 42%	.03 ± 28%	3.0
II - 3'	.03 ± 37%	<.01	.03 ± 39%	1.0	.01 ± 49%	.01 ± 46%	.02 ± 31%	2.9
III - 3'	.04 ± 32%	<.01	.02 ± 38%	2.0	.01 ± 39%	.01 ± 53%	.03 ± 25%	4.8
III - 20'	.03 ± 40%	<.01	.02 ± 40%	1.4	<.01	.01 ± 60%	.03 ± 26%	2.9
IV - 15'	.03 ± 32%	<.01	.03 ± 32%	1.0	.01 ± 47%	.01 ± 41%	.03 ± 25%	2.1
IV - 3'	.04 ± 34%	<.01	.03 ± 35%	1.3	<.01	.01 ± 46%	.02 ± 34%	4.0
V - 3'	.13 ± 20%	<.01	.05 ± 27%	2.6	.01 ± 49%	.01 ± 47%	.03 ± 27%	13.2
V - 25'	.11 ± 20%	<.01	.05 ± 26%	2.2	<.01	.02 ± 34%	.04 ± 25%	5.7
VI - 10'	.10 ± 20%	<.01	.04 ± 25%	2.8	<.01	.01 ± 50%	.02 ± 31%	13.0
VI - 3'	.11 ± 18%	<.01	.05 ± 24%	2.2	.03 ± 52%	.05 ± 42%	.10 ± 29%	2.2
VII - 3'	.04 ± 29%	<.01	.02 ± 35%	2.0	.01 ± 40%	.01 ± 45%	.03 ± 26%	3.4
VII - 25'	.03 ± 29%	<.01	.02 ± 34%	1.5	.03 ± 58%	.03 ± 55%	.06 ± 37%	1.1
VIII- 25'	.04 ± 30%	<.01	.02 ± 37%	2.0	.01 ± 39%	.02 ± 35%	.04 ± 24%	2.1
VIII- 3'	.09 ± 21%	<.01	.06 ± 24%	1.5	.01 ± 53%	.02 ± 33%	.04 ± 23%	4.5
IX - 25'	.03 ± 31%	<.01	.02 ± 38%	1.5	.01 ± 46%	.01 ± 58%	.02 ± 37%	2.9
IX - 3'	.03 ± 31%	<.01	.03 ± 35%	1.0	<.01	.01 ± 56%	.02 ± 37%	4.9

Water Samples
March 1975

Description	Dissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Dissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
Lagoon Composite								
3/5-3/10/75	1604 ± 11%	58 ± 13%	477 ± 12%	3.4	<.01	<.01	<.01	
3/11-3/18/75	1672 ± 11%	70 ± 13%	522 ± 12%	3.2	<.01	<.01	<.01	
3/18-3/20/75	1103 ± 11%	47 ± 13%	344 ± 12%	3.2	<.01	<.01	<.01	
GE Well - 80'	.07 ± 27%	<.01	.09 ± 24%	0.8	<.01	<.01	.01 ± 43%	
GE Well (iron removed)	.04 ± 30%	<.01	.04 ± 31%	1.0	<.01	<.01	<.01	
H.W. Well - 35'	.01 ± 48%	<.01	.01 ± 44%	1.0	<.01	<.01	.01 ± 47%	
Motel - municipal	.03 ± 35%	<.01	.02 ± 36%	1.5	<.01	<.01	<.01	
Creek Water								
GE Site	.03 ± 32%	<.01	.02 ± 35%	1.5	<.01	.01 ± 46%	.03 ± 30%	2.2
NE of Site	.03 ± 34%	<.01	.05 ± 28%	0.6	<.01	.01 ± 45%	.02 ± 35%	2.2
S of Site	.02 ± 37%	<.01	.02 ± 38%	1.0	<.01	<.01	.01 ± 47%	
Between IV and V								
15'	.04 ± 27%	<.01	.03 ± 26%	1.3	.03 ± 52%	.04 ± 46%	.12 ± 27%	1.0
3'	.03 ± 34%	<.01	.03 ± 34%	1.0	.04 ± 23%	.02 ± 36%	.07 ± 18%	1.8
Cape Fear River								
25'	.04 ± 31%	<.01	.03 ± 35%	1.3	<.01	.01 ± 50%	.02 ± 40%	3.5
3'	.02 ± 37%	<.01	.02 ± 43%	1.0	.01 ± 49%	.01 ± 50%	.02 ± 42%	2.2

CONTINUED

Water Samples, March 1975 (Continued)

Description	Dissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Dissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
Brunswick & Cape Fear Confluence 25'	.02 ± 44%	<.01	.02 ± 39%	1.0	.01 ± 47%	.01 ± 44%	.02 ± 33%	2.9
3'	.03 ± 33%	<.01	.03 ± 33%	1.0	.01 ± 56%	.01 ± 44%	.03 ± 30%	2.2
Brunswick River 10'	.03 ± 31%	<.01	.02 ± 33%	1.5	<.01	<.01	.01 ± 47%	
3'	.03 ± 33%	<.01	.03 ± 32%	1.0	.01 ± 44%	.01 ± 44%	.02 ± 35%	2.6
VIII 1' duplicate	.04 ± 28%	<.01	.02 ± 38%	2.0	.01 ± 45%	.01 ± 58%	.02 ± 30%	6.0
1' duplicate	.04 ± 28%	<.01	.03 ± 33%	1.3	.01 ± 38%	.02 ± 34%	.03 ± 26%	2.1
Cape Fear 3 mi. above	.02 ± 42%	<.01	.01 ± 55%	1.9	<.01	<.01	.03 ± 27%	
Cape Fear & NE Cape Fear Confluence	.01 ± 50%	<.01	.02 ± 45%	.8	.01 ± 52%	<.01	.02 ± 31%	

Water Samples
July 16, 1974

Position	Undissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Undissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
I - 10'	.01 ± 54%	<.01	.01 ± 52%	1.0	<.01	.01 ± 50%	.02 ± 49%	0.6
I - 5'		No chemical recovery				No chemical recovery		
II - 5'	.02 ± 43%	<.01	.02 ± 42%	1.0	.01 ± 60%	.02 ± 37%	.01 ± 52%	1.1
II - 10'	.01 ± 45%	<.01	.02 ± 37%	0.5	.01 ± 55%	.02 ± 33%	.01 ± 44%	0.6
III - 20'	.02 ± 37%	<.01	.02 ± 37%	1.0	.01 ± 50%	.02 ± 38%	.02 ± 39%	1.0
III - 10'	.03 ± 31%	.01 ± 52%	.03 ± 29%	1.0	.02 ± 34%	.04 ± 22%	.06 ± 19%	0.7
IV - 5'	.02 ± 34%	<.01	.02 ± 35%	1.0	.01 ± 45%	.02 ± 38%	.01 ± 46%	1.6
IV - 12'	.03 ± 32%	<.01	.02 ± 35%	1.5	.01 ± 46%	.02 ± 35%	.02 ± 35%	1.7
V - 25'	.11 ± 24%	<.01	.10 ± 25%	1.1	.02 ± 32%	.04 ± 24%	.03 ± 27%	2.9
V - 10'	.12 ± 20%	.03 ± 35%	.06 ± 26%	2.0	.02 ± 30%	.03 ± 25%	.05 ± 21%	3.7
VI - 10'	.12 ± 21%	.01 ± 50%	.09 ± 23%	1.3	.02 ± 31%	.04 ± 24%	.04 ± 25%	3.1
VI - 6'	.16 ± 19%	.04 ± 30%	.10 ± 21%	1.6	.03 ± 30%	.04 ± 25%	.05 ± 23%	3.9
VII - 10'	.09 ± 22%	.01 ± 54%	.10 ± 21%	0.9	.02 ± 44%	.04 ± 29%	.01 ± 47%	2.4
VII - 25'	.14 + 18%	.02 ± 38%	.08 ± 21%	1.8	.02 ± 39%	.03 ± 30%	.06 ± 19%	5.1
VIII - 10'	.15 ± 20%	.01 ± 52%	.14 ± 20%	1.1	.05 ± 28%	.07 ± 23%	.06 ± 25%	2.2
VIII - 20'	.05 ± 57%	<.01	.05 ± 57%	1.0	<.01	<.01	.18 ± 27%	
IX - 5'	.11 ± 21%	<.01	.13 ± 21%	0.8	.03 ± 29%	.05 ± 22%	.04 ± 26%	2.4
IX - 10'	.06 + 23%	<.01	.05 ± 25%	1.2	.03 ± 27%	.04 ± 24%	.04 ± 25%	1.7

Water Samples
July 1974

Description	Undissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Undissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
Lagoon Composite 7/8-7/15/74		All activity soluble						
North Lagoon 7/8/74	3.86 ± 21%	.22 ± 72%	1.27 ± 31%	3.0	<.01	<.01	1.01 ± 30%	
7/9/74	12.85 ± 14%	.95 ± 32%	4.59 ± 17%	2.8	<.01	<.01	.99 ± 32%	
South Lagoon 7/8/74	3.99 ± 20%	.25 ± 64%	1.33 ± 30%	3.0	<.01	<.01	1.09 ± 28%	
7/9/74	7.25 ± 16%	.47 ± 47%	2.47 ± 23%	2.9	.32 ± 53%	<.01	1.08 ± 29%	
GE Well - 80'		No chemical recovery						
GE Well (iron removed)	<.01	<.01	.01 ± 60%		<.01	.01 ± 60%	.04 ± 24%	
H.W. Well - 35'	.01 ± 51%	<.01	.01 ± 53%	1.0	<.01	.01 ± 64%	.03 ± 27%	1.7
Motel - municipal		No chemical recovery						

Water Samples
October 22, 1974

Position	Undissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Undissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
I - 5'	.02 ± 43%	<.01	.02 ± 44%	1.0	<.01	.01 ± 52%	<.01	1.9
I - 20'	.01 ± 57%	<.01	.01 ± 54%	1.0	.01 ± 49%	.01 ± 58%	.02 ± 33%	1.0
II - 5'	.02 ± 37%	<.01	.02 ± 40%	1.0	.01 ± 45%	.02 ± 32%	.02 ± 35%	0.8
II - 10'	.02 ± 40%	<.01	.02 ± 39%	1.0	<.01	.01 ± 52%	.01 ± 50%	1.4
III - 1'	.62 ± 15%	.04 ± 28%	.55 ± 15%	1.1	.60 ± 6%	.81 ± 5%	.58 ± 6%	0.8
III - 10'	.03 ± 34%	<.01	.03 ± 34%	1.0	.01 ± 49%	.03 ± 29%	.03 ± 29%	1.0
IV - 5'	.04 ± 28%	<.01	.03 ± 29%	1.3	<.01	.03 ± 30%	.02 ± 31%	1.4
IV - 10'	.52 ± 16%	.04 ± 28%	.40 ± 16%	1.3	.10 ± 15%	.36 ± 8%	.25 ± 9%	1.5
V - 5'	.05 ± 26%	<.01	.04 ± 30%	1.2	.03 ± 31%	.03 ± 29%	.04 ± 25%	1.7
V - 15'	.08 ± 23%	<.01	.05 ± 27%	1.6	.03 ± 28%	.03 ± 26%	.03 ± 27%	2.7
VI - 5'	.18 ± 18%	.01 ± 42%	.10 ± 21%	1.8	.03 ± 30%	.06 ± 20%	.04 ± 23%	3.4
VI - 10'	.25 ± 18%	.01 ± 48%	.13 ± 21%	1.9	.02 ± 31%	.08 ± 17%	.06 ± 20%	3.3
VII - 15'	.38 ± 17%	.01 ± 47%	.25 ± 19%	1.5	.11 ± 14%	.14 ± 12%	.10 ± 15%	2.7
VII - 5'	.13 ± 35%	<.01	.08 ± 37%	1.6	.03 ± 29%	.03 ± 27%	.02 ± 31%	4.2
VIII - 10'	.05 ± 35%	<.01	.05 ± 37%	1.0	.01 ± 50%	.01 ± 50%	.02 ± 30%	5.7
VIII - 5'	.08 ± 25%	<.01	.04 ± 31%	2.0	.01 ± 49%	.01 + 44%	.02 ± 34%	6.1
IX - 20'	.05 ± 25%	<.01	.03 ± 30%	1.7	.02 ± 34%	.03 ± 31%	.03 ± 28%	2.0
IX - 3'	.04 ± 31%	<.01	.04 ± 30%	1.0	<.01	.02 ± 43%	.02 ± 39%	1.9

Water Samples
March 18, 1975

Position	Undissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Undissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
I - 20'	.01 ± 49%	<.01	.01 ± 59%	1.0	.01 ± 52%	.01 ± 52%	.01 ± 43%	1.6
I - 3'	.01 ± 44%	<.01	<.01		<.01	.01 ± 40%	.01 ± 43%	1.1
II - 25'	.02 ± 39%	<.01	.01 ± 47%	2.0	<.01	.01 ± 44%	.02 ± 31%	1.5
II - 3'	.02 ± 43%	<.01	.01 ± 57%	2.0	.01 ± 53%	.01 ± 55%	.03 ± 27%	2.1
III - 3'	.01 ± 53%	<.01	<.01		.01 ± 50%	.01 ± 58%	.03 ± 28%	1.3
III - 20'	.01 ± 50%	<.01	.01 ± 53%	1.0	.01 ± 55%	.01 ± 49%	.02 ± 31%	1.2
IV - 15'	.04 ± 30%	<.01	.04 ± 30%	1.0	.01 ± 64%	.01 ± 52%	.02 ± 30%	5.4
IV - 3'	.03 ± 33%	<.01	.01 ± 50%	3.0	.01 ± 52%	.01 ± 44%	.03 ± 26%	2.5
V - 3'	.02 ± 41%	<.01	.01 ± 55%	2.0	<.01	.01 ± 49%	.03 ± 27%	2.0
V - 25'	.02 ± 38%	<.01	.01 ± 50%	2.0	<.01	.01 ± 49%	.03 ± 26%	2.2
VI - 10'		No chemical recovery			.01 ± 60%	.01 ± 64%	.02 ± 38%	
VI - 3'	.02 ± 35%	<.01	.02 ± 42%	1.0	.01 ± 64%	.01 ± 52%	.02 ± 38%	2.8
VII - 3'	.05 ± 29%	<.01	.03 ± 39%	1.7	.01 ± 41%	.01 ± 42%	.02 ± 38%	4.1
VII - 25'	.06 ± 25%	<.01	.02 ± 35%	3.0	.01 ± 44%	.01 ± 43%	.02 ± 40%	4.1
VIII - 25'	.05 ± 23%	<.01	.06 ± 22%	0.8	.04 ± 24%	.06 ± 19%	.05 ± 20%	0.8
VIII - 3'	.08 ± 20%	<.01	.08 ± 21%	1.0	.03 ± 26%	.10 ± 15%	.04 ± 23%	0.8
IX - 25'	.04 ± 29%	.01 ± 54%	.05 ± 28%	0.8	.03 ± 27%	.02 ± 29%	.05 ± 20%	1.8
IX - 3'	.05 ± 52%	<.01	.03 ± 62%	1.7	.01 ± 45%	.01 ± 49%	.02 ± 33%	5.2

Water Samples
March 1975

Description	Undissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Undissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
Lagoon Composite 3/5-3/10/75	3.90 ± 22%	.22 ± 67%	1.98 ± 26%	2.0	<.01	<.01	<.01	
3/11-3/17/75	3.86 ± 22%	.37 ± 59%	1.54 ± 30%	2.5	<.01	<.01	<.01	
3/18-3/21/75	2.39 ± 23%	<.10	1.49 ± 29%	1.6	<.01	<.01	<.01	
GE Well - 80'	.01 ± 62%	<.01	.02 ± 45%	0.5	<.01	<.01	.03 ± 29%	
GE Well (iron removed)	.06 ± 33%	<.01	.02 ± 47%	3.0	<.01	<.01	.02 ± 35%	
H.W. Well - 35'	.03 + 35%	<.01	.03 ± 36%	1.0	<.01	<.01	.03 ± 28%	
Motel-Municipal	.02 ± 38%	<.01	.03 ± 35%	0.7	<.01	.01 ± 60%	.02 ± 42%	3.3
Creek Water GE Site	.02 ± 32%	<.01	.02 ± 30%	1.0	.02 ± 32%	.02 ± 36%	.03 ± 29%	1.2
NE of Site	.02 ± 36%	<.01	.03 ± 32%	0.7	<.01	.01 ± 44%	.02 ± 30%	2.1
S of site	.03 ± 36%	<.01	.02 ± 37%	1.5	.01 ± 39%	.01 ± 42%	.02 ± 33%	2.2
Between IV&V-15'	.01 ± 53%	<.01	.01 ± 59%	1.0	<.01	.01 ± 58%	.01 ± 47%	1.3
" " " 3'	.01 ± 53%	<.01	.01 ± 57%	1.0	.01 ± 53%	.01 ± 43%	.01 ± 44%	0.7
Cape Fear River 25'	.03 ± 30%	<.01	.03 ± 30%	1.0	.01 ± 47%	.01 ± 42%	.02 ± 35%	2.8
3'	.04 ± 29%	<.01	.04 ± 37%	1.0	.02 ± 38%	.02 ± 37%	.02 ± 29%	2.6

CONTINUED

Water Samples, March 1975 (Continued)

Description	Undissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Undissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
Cape Fear and Brunswick Confluence								
25'		no chemical recovery			.03 ± 26%	.02 ± 31%	.05 ± 21%	
3'	.03 ± 36%	<.01	.03 ± 36%	1.0	.01 ± 44%	.01 ± 23%	.03 ± 63%	2.2
Brunswick River								
10'	<.01	<.01	<.01		.01 ± 45%	.01 ± 43%	.01 ± 39%	
3'	<.01	<.01	<.01		.03 ± 28%	.02 ± 30%	.04 ± 22%	
VIII								
1' duplicate	.04 ± 29%	<.01	.03 ± 33%	1.3	.02 ± 44%	.02 ± 42%	.02 ± 38%	2.0
" "	.03 ± 33%	<.01	.02 ± 37%	1.5	.02 ± 32%	.02 ± 37%	.01 ± 43%	1.7
Cape Fear 3 mi. above	.08 ± 25%	<.01	.08 ± 25%	1.0	.02 ± 37%	.02 ± 33%	.05 ± 22%	3.2
Cape Fear, NE Cape Fear Confluence Feb. 20, 1976	.19 ± 21%	<.01	.13 ± 22%	1.4	.01 ± 44%	.01 ± 41%	.05 ± 22%	13.4

Water Samples
October 1974

Description	Undissolved Solids pCi/l U-234	U-235	U-238	U-234/U-238	Undissolved Solids pCi/l Th-232	Th-230	Th-228	U-234/Th-230
Lagoon Composite 10/8-10/14/74		all activity soluble						
10/15-10/21/74		all activity soluble						
GE Well - 80'	.01 ± 43%	<.01	.01 ± 49%	1.0	<.01	.01 ± 55%	.01 ± 63%	1.6
GE Well (iron removed)	<.01	<.01	<.01		<.01	<.01	<.01	
H.W. Well - 35'	.01 ± 51%	<.01	.01 ± 51%	1.0	<.01	<.01	<.01	
Municipal	.01 ± 44%	<.01	.01 ± 42%	1.0	.01 ± 53%	.01 ± 55%	.02 ± 39%	1.5
III 20' duplicate	.03 ± 29%	<.01	.03 ± 29%	1.0	.02 ± 36%	.03 ± 31%	.03 ± 28%	1.2
5' duplicate	.02 ± 36%	<.01	.02 ± 35%	1.0	.01 ± 46%	.02 ± 43%	.02 ± 41%	1.4

Appendix H
Aquatic Vegetation and Sediment Data
Aquatic Vegetation

Position/Date		pCi/g ash U-234	U-235	U-238	U-234/U-238	pCi/g ash Th-232	Th-230	Th-228	U-234/Th-230
I	Jul 1974	.14 ± 17%	.01 ± 41%	.14 ± 17%	1.0	.06 ± 18%	.09 ± 14%	.69 ± 6%	1.4
I	Oct 1974	.75 ± 13%	.08 ± 20%	.79 ± 13%	1.0	.50 ± 6%	.64 ± 5%	.95 ± 4%	1.2
I	Mar 1975	.25 ± 16%	.02 ± 35%	.24 ± 16%	1.0	.11 ± 13%	.18 ± 10%	.45 ± 8%	1.4
II	Jul 1974	.19 ± 16%	.05 ± 22%	.15 ± 17%	1.3	.08 ± 15%	.14 ± 12%	1.30 ± 5%	1.4
II	Oct 1974	.57 ± 14%	.07 ± 23%	.28 ± 15%	2.1	.18 ± 10%	.32 ± 8%	1.52 ± 4%	1.8
II	Mar 1975	.21 ± 17%	.02 ± 40%	.18 ± 16%	1.1	.06 ± 17%	.07 ± 16%	.18 ± 10%	3.1
III	Jul 1974	.29 ± 14%	.03 ± 32%	.18 ± 17%	1.6	.27 ± 9%	.39 ± 8%	.80 ± 6%	0.8
III	Oct 1974	.41 ± 13%	.04 ± 25%	.31 ± 14%	1.3	.10 ± 18%	.21 ± 13%	.82 ± 5%	1.9
III	Mar 1975	.41 ± 13%	.02 ± 32%	.39 ± 13%	1.0	.14 ± 11%	.23 ± 10%	1.47 ± 4%	1.7
IV	Jul 1974	.52 ± 13%	.09 ± 18%	.46 ± 14%	1.1	.20 ± 19%	.36 ± 14%	2.04 ± 7%	1.4
IV	Oct 1974	.82 ± 12%	.05 ± 26%	.42 ± 14%	2.0	.19 ± 10%	.28 ± 8%	.93 ± 4%	3.0
IV	Mar 1975	1.71 ± 12%	.08 ± 20%	.96 ± 12%	1.8	.39 ± 7%	.56 ± 6%	.68 ± 6%	3.0
V	Jul 1974	1.16 ± 14%	.08 ± 20%	.49 ± 15%	2.4	.04 ± 23%	.21 ± 10%	.53 ± 7%	5.6
V	Oct 1974	4.64 ± 13%	.27 ± 16%	2.33 ± 14%	2.0	.76 ± 5%	.99 ± 4%	.73 ± 5%	4.7
V	Mar 1975	1.99 ± 12%	.10 ± 19%	1.06 ± 12%	1.9	.39 ± 7%	.55 ± 6%	.72 ± 5%	3.6
VI	Jul 1974	2.19 ± 14%	.09 ± 20%	.94 ± 15%	2.3	.15 ± 11%	.20 ± 10%	.19 ± 10%	11.1
VI	Oct 1974	1.69 ± 14%	.12 ± 19%	1.01 ± 14%	1.7	.26 ± 9%	.40 ± 7%	.34 ± 8%	4.2
VI	Mar 1975	1.28 ± 12%	.08 ± 20%	.76 ± 12%	1.7	.36 ± 8%	.55 ± 6%	.60 ± 5%	2.3

CONTINUED

Aquatic Vegetation (Continued)

Position/Date		pCi/g ash U-234	U-235	U-238	U-234/U-238	pCi/g ash Th-232	Th-230	Th-228	U-234/Th-230
VII	Jul 1974	1.13 ± 15%	.07 ± 21%	.78 ± 15%	1.4	.49 ± 7%	.70 ± 6%	.44 ± 7%	1.6
VII	Oct 1974	.58 ± 13%	.04 ± 26%	.44 ± 14%	1.3	.12 ± 13%	.24 ± 9%	.18 ± 10%	2.4
VII	Mar 1975	.63 ± 13%	.04 ± 24%	.52 ± 13%	1.2	.09 ± 14%	.10 ± 13%	.09 ± 14%	6.2
VIII	Jul 1974	.98 ± 16%	.08 ± 22%	.89 ± 16%	1.1	.48 ± 6%	.65 ± 5%	.50 ± 6%	1.5
VIII	Oct 1974	.89 ± 13%	.17 ± 17%	.88 ± 13%	1.0	.43 ± 7%	.42 ± 7%	.43 ± 7%	2.1
VIII	Mar 1975	.91 ± 12%	.05 ± 22%	.59 ± 13%	1.5	.14 ± 11%	.20 ± 10%	.28 ± 9%	4.6
IX	Jul 1974	.10 ± 20%	.01 ± 57%	.09 ± 20%	1.1	.03 ± 24%	.04 ± 20%	.06 ± 17%	2.2
IX	Oct 1974	.24 ± 15%	.02 ± 55%	.25 ± 15%	1.0	.13 ± 13%	.10 ± 14%	.10 ± 14%	2.3
IX	Mar 1975	.55 ± 13%	.02 ± 29%	.46 ± 14%	1.2	.20 ± 10%	.20 ± 10%	.18 ± 10%	2.7
VIII-IX	Oct 74	2.32 ± 12%	.11 ± 17%	1.48 ± 12%	1.6	.28 ± 8%	.44 ± 7%	.46 ± 7%	5.3

Appendix H

Sediment

Position/Date		pCi/g dry U-234	U-235	U-238	U-234/U-238	pCi/g dry Th-232	Th-230	Th-228	U-234/Th-230
I	Jul 1974	.12 ± 18%	.01 ± 39%	.13 ± 17%	0.9	.08 ± 15%	.09 ± 15%	.08 ± 15%	1.4
I	Oct 1974	1.04 ± 12%	.06 ± 21%	.92 ± 12%	1.1	.93 ± 7%	1.30 ± 6%	1.04 ± 6%	0.8
I	Mar 1975	1.27 ± 12%	.06 ± 22%	1.30 ± 12%	1.0	.78 ± 5%	.99 ± 4%	.77 ± 5%	1.3
II	Jul 1974	1.05 ± 13%	.05 ± 26%	1.01 ± 13%	1.0	.59 ± 7%	.68 ± 6%	.57 ± 7%	1.6
II	Oct 1974	.56 ± 14%	.02 ± 32%	.56 ± 14%	1.0	.73 ± 5%	.74 ± 5%	.65 ± 6%	0.8
II	Mar 1975	.25 ± 16%	.02 ± 34%	.22 ± 16%	1.1	.19 ± 10%	.28 ± 8%	.24 ± 9%	0.9
III	Jul 1974	.18 ± 17%	.01 ± 42%	.18 ± 17%	1.0	.08 ± 15%	.16 ± 11%	.09 ± 14%	1.1
III	Oct 1974	.97 ± 12%	.05 ± 22%	.85 ± 12%	1.2	.41 ± 7%	1.02 ± 4%	.86 ± 5%	1.0
III	Mar 1975	1.48 ± 12%	.07 ± 21%	1.31 ± 12%	1.1	1.01 ± 4%	1.44 ± 4%	1.09 ± 4%	1.0
IV	Jul 1974	.22 ± 15%	.01 ± 40%	.17 ± 16%	1.2	.11 ± 13%	.16 ± 11%	.14 ± 18%	1.3
IV	Oct 1974	5.77 ± 11%	.50 ± 13%	2.98 ± 12%	1.9	.94 ± 4%	1.20 ± 4%	.77 ± 5%	4.8
IV	Mar 1975	2.37 ± 12%	.10 ± 18%	2.04 ± 12%	1.2	.47 ± 6%	.84 ± 5%	.57 ± 6%	2.8
V	Jul 1974	.36 ± 17%	.02 ± 37%	.24 ± 17%	1.5	.44 ± 6%	.36 ± 7%	.36 ± 7%	1.0
V	Oct 1974	.93 ± 13%	.05 ± 23%	.76 ± 13%	1.2	.31 ± 7%	.58 ± 5%	.26 ± 8%	1.6
V	Mar 1975	1.28 ± 12%	.04 ± 25%	1.15 ± 12%	1.1	.61 ± 6%	.65 ± 6%	.51 ± 6%	2.0
VI	Jul 1974	.43 ± 16%	.02 ± 35%	.39 ± 17%	1.1	.80 ± 5%	.55 ± 6%	.67 ± 5%	0.8
VI	Oct 1974	1.69 ± 12%	.10 ± 20%	1.56 ± 12%	1.1	.96 ± 4%	1.30 ± 4%	1.16 ± 4%	1.3
VI	Mar 1975	1.14 ± 12%	.06 ± 22%	1.06 ± 12%	1.1	1.06 ± 4%	1.11 ± 4%	1.06 ± 4%	1.0

CONTINUED

Sediment (Continued)

Position/Date	pCi/g dry U-234	U-235	U-238	U-234/U-238	pCi/g dry Th-232	Th-230	Th-228	U-234/Th-230
VII Jul 1974	.39 ± 17%	.02 ± 36%	.36 ± 17%	1.1	.11 ± 13%	.42 ± 7%	.56 ± 7%	0.9
VII Oct 1974	.84 ± 12%	.05 ± 21%	.80 ± 12%	1.0	.94 ± 4%	.91 ± 4%	.72 ± 5%	0.9
VII Mar 1975	.61 ± 13%	.03 ± 28%	.53 ± 13%	1.2	.38 ± 7%	.46 ± 6%	.35 ± 7%	1.3
VIII Jul 1974	1.73 ± 20%	.31 ± 23%	1.63 ± 20%	1.1	1.47 ± 4%	1.54 ± 4%	1.22 ± 4%	1.1
VIII Oct 1974	.18 ± 15%	.01 ± 44%	.16 ± 15%	1.2	.21 ± 4%	.25 ± 4%	.18 ± 10%	0.7
VIII Mar 1975	.66 ± 13%	.04 ± 25%	.67 ± 13%	1.0	.28 ± 8%	.45 ± 18%	.38 ± 7%	1.5
IX Jul 1974	.31 ± 14%	.02 ± 33%	.31 ± 14%	1.0	.18 ± 10%	.21 ± 10%	.20 ± 10%	1.5
IX Oct 1974	.60 ± 13%	.02 ± 30%	.53 ± 13%	1.1	.40 ± 7%	.56 ± 6%	.39 ± 7%	1.1
IX Mar 1975	.56 ± 13%	.02 + 31%	.55 ± 13%	1.0	.30 + 8%	.40 ± 7%	.33 ± 8%	1.4

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