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Subject Expert(s): Milton Gorden, Amir S. Mosbasheran, Brian P. Gleckler, Tracy A. Ikenberry

Approval:	Signature on File Brian P. Gleckler, Document Owner	Approval Date:	07/13/2011
Concurrence:	Signature on File John M. Byrne, Objective 1 Manager	Concurrence Date:	07/13/2011
Concurrence:	Signature on File Edward F. Maher, Objective 3 Manager	Concurrence Date:	07/13/2011
Concurrence:	Vickie S. Short Signature on File for Kate Kimpan, Project Director	Concurrence Date:	07/14/2011
Approval:	Signature on File James W. Neton, Associate Director for Science	Approval Date:	07/15/2011

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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
04/05/2005	00	First approved issue. Initiated by Mark D. Notich.
07/15/2011	01	This technical basis document was predominantly revised to address SC&A's issues with the document, as identified in SCA-TR-TASK1-0015. In addition, the bases for the annual environmental intakes and the annual onsite ambient external doses were redone. This included redoing the atmospheric dispersion calculations that each of them were based on. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Brian P. Gleckler.

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ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
Bq	becquerel
CFR	*Code of Federal Regulations*
Ci	curie
d	day
DOE	U.S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ft	foot, feet
g	gram
gal	gallon
GE	General Electric Company
GEND	GE Neutron Devices
GENDD	GE Neutron Devices Department
GEPP	GE Pinellas Plant
GEXF	GE X-ray Division in Florida
H	hydrogen (^{1}H or protium)
HT	tritium gas (also denoted as T_2)
HTO	tritium oxide (also denoted as T_2O)
JFD	joint frequency distribution
keV	kilovolt-electron, 1,000 electron volts
L	liter
m	meter
MDL	minimum detection level
MEE	maximally exposed employee
ml	milliliter
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
POC	probability of causation
POTW	Publically Owned Treatment Works
RTG	radioisotopically-powered thermoelectric generator
T	tritium (^{3}H)
TBD	technical basis document
U.S.C.	United States Code
wk	week
yr	year
µCi	microcurie
§	section or sections

4.0 OCCUPATIONAL ENVIRONMENTAL DOSE

4.1 INTRODUCTION

Technical basis documents and site profile documents are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historic background information and guidance to assist in the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist NIOSH staff in the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy [DOE] facility" as defined in the Energy Employees Occupational Illness Compensation Program Act [EEOICPA; 42 U.S.C. § 7384l(5) and (12)]. EEOICPA defines a DOE facility as "any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the Department of Energy (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)" [42 U.S.C. § 7384l(12)]. Accordingly, except for the exclusion for the Naval Nuclear Propulsion Program noted above, any facility that performs or performed DOE operations of any nature whatsoever is a DOE facility encompassed by EEOICPA.

For employees of DOE or its contractors with cancer, the DOE facility definition only determines eligibility for a dose reconstruction, which is a prerequisite to a compensation decision (except for members of the Special Exposure Cohort). The compensation decision for cancer claimants is based on a section of the statute entitled "Exposure in the Performance of Duty." That provision [42 U.S.C. § 7384n(b)] says that an individual with cancer "shall be determined to have sustained that cancer in the performance of duty for purposes of the compensation program if, and only if, the cancer … was at least as likely as not related to employment at the facility [where the employee worked], as determined in accordance with the POC [probability of causation[1]] guidelines established under subsection (c) …" [42 U.S.C. § 7384n(b)]. Neither the statute nor the probability of causation guidelines (nor the dose reconstruction regulation, 42 C.F.R. Pt. 82) define "performance of duty" for DOE employees with a covered cancer or restrict the "duty" to nuclear weapons work (NIOSH 2010).

The statute also includes a definition of a DOE facility that excludes "buildings, structures, premises, grounds, or operations covered by Executive Order No. 12344, dated February 1, 1982 (42 U.S.C. 7158 note), pertaining to the Naval Nuclear Propulsion Program" [42 U.S.C. § 7384l(12)]. While this definition excludes Naval Nuclear Propulsion Facilities from being covered under the Act, the section of EEOICPA that deals with the compensation decision for covered employees with cancer [i.e., 42 U.S.C. § 7384n(b), entitled "Exposure in the Performance of Duty"] does not contain such an exclusion. Therefore, the statute requires NIOSH to include all occupationally-derived radiation exposures at covered facilities in its dose reconstructions for employees at DOE facilities, including radiation exposures related to the Naval Nuclear Propulsion Program. As a result, all internal and external occupational radiation exposures are considered valid for inclusion in a dose reconstruction. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction. NIOSH, however, does not consider the following exposures to be occupationally derived (NIOSH 2010):

- Background radiation, including radiation from naturally occurring radon present in conventional structures
- Radiation from X-rays received in the diagnosis of injuries or illnesses or for therapeutic reasons

[1] The U.S. Department of Labor (DOL) is ultimately responsible under the EEOICPA for determining the POC.

4.1.1 Overview

This TBD is Part 4 of the Pinellas Plant's Site Profile. A site profile provides a summary of information about a site that is relevant to the dose reconstruction process.

The Pinellas Plant has been known by several names throughout its history. Those names include: 908 Plant, Pinellas Peninsula Plant, GE X-ray Division-Florida (GEXF), GE Neutron Devices Department (GENDD), GE Neutron Devices (GEND), GE Pinellas Plant (GEPP), and the Pinellas Plant.

The General Electric Company built and operated the Pinellas Plant for DOE from its initial startup in January 1957 until June 1992. In June 1992, Martin Marietta Specialty Components, Inc. (MMSC) took over as the managing and operating contractor for the Pinellas Plant. In 1994, Lockheed merged with Martin Marietta and the managing and operating contractor for the Pinellas Plant was renamed Lockheed Martin Specialty Components (LMSC). The Pinellas Plant completed its war reserve fabrication of neutron generators at the end of September 1994, and began the transition from a defense mission to an environmental management mission. That transition included a number of decontamination and decommissioning activities that allowed the Plant to be turned over for commercial uses. LMSC continued as the managing and operating contractor until decontamination and decommissioning activities ended in 1997 (ORAUT 2011j).

The Plant was built to manufacture neutron generators, a principal component in nuclear weapons. The neutron generators consisted of a miniaturized linear ion accelerator assembled with pulsed electric power supplies. The ion accelerator, or neutron tube, required ultraclean, high-vacuum technology; hermetic seals between glass, ceramic, glass-ceramic, and metal materials; and high-voltage generation and measurement technology. The Plant manufactured only neutron generators for its first 10 years of operation. It later manufactured other products including neutron detectors, radioisotopically-powered thermoelectric generators (RTGs), high-vacuum switch tubes, specialty capacitors, and specialty batteries (Weaver 1990). As part of its program to promote commercial uses of the site, DOE sold most of the Plant to the Pinellas County Industry Council in March 1995 and leased back a portion through September 1997 to complete safe shutdown and transition activities (LMSC 1996b).

4.1.2 Purpose

This TBD provides the basis for assessing the occupational environmental doses at the Pinellas Plant. The information in this TBD can be used in dose reconstructions for the EEOICPA.

4.1.3 Scope

This document provides supporting technical data to evaluate the total Pinellas occupational radiation dose that can reasonably be associated with the worker's radiation exposure. Occupational environmental doses result from exposures to onsite sources of ambient radiation and onsite levels of environmental airborne radioactivity. Also included are techniques to assess the dose that might have occurred while an employee was not monitored. Over the years, new and more reliable scientific methods and protection measures have been deployed. The methods needed to account for these changes are also identified in this document.

This TBD describes the radiological conditions in the onsite environment and the environmental monitoring program at the Pinellas Plant. This includes environmental monitoring data, the practices and policies at the Plant, and the approaches used for measuring the levels of radiation and/or radioactivity in the environment at the Plant. The information provided in this TBD is based on the

available literature on the site, which consists primarily of environmental monitoring reports and site environmental reports published between 1971 and 1995.

4.2 HISTORIC SOURCES OF ONSITE ENVIRONMENTAL RADIOACTIVITY

The radionuclides released to the environment at the Pinellas Plant included tritium (^{3}H), ^{14}C, and ^{85}Kr. Encapsulated sources of plutonium were also present at the Plant in significant quantities, but a review of the environmental monitoring reports for the site indicates that no plutonium was ever released to the environment. Tritium and ^{14}C emit very-low-energy beta particles, whereas ^{85}Kr emits high-energy beta particles. The exposure pathways for these radionuclides are explained in the sections below.

Tritium was the primary radionuclide used at the Pinellas Plant. While it can exist in all compounds that contain normal hydrogen, two of the more common forms are (1) tritium gas (denoted as HT) and (2) tritium oxide (denoted as HTO) in either the liquid or the vapor state. With a physical half-life of 12.3 years, tritium emits low-energy beta particles and decays to ^{3}He. The emitted beta particles have an average energy of 5.7 keV (Kocher 1981). Because electrons below 15 keV do not have sufficient energy to penetrate the epidermal layer of the skin (NIOSH 2007), tritium is not considered an external radiation hazard. Therefore, tritium contributes only to internal dose (LMSC 1995a). In comparison to tritium oxide (which readily exchanges with the body's water), the internal dose from an intake of tritium gas is one ten thousandth the dose of an equivalent intake of tritium oxide (NIOSH 2003).

Krypton-85, which exists only in the gaseous state, has a half-life of 10.72 years. Its most common decay (99.6%) is by beta particle emission with an average energy of 251.4 keV. Its alternative decay scheme (0.43%) is by beta particle emission (average energy of 47.5 keV) followed by gamma ray emission (energy of 514 keV) (Kocher 1981).

A 1983 environmental assessment indicated the small quantities of ^{14}C labeled solvents were used in a laboratory testing operation in Building 100 from 1979 to 1983 (DOE 1983). Because ^{14}C emits a low-energy beta particle (average energy of 49.5 keV), radiation doses result primarily from internal deposition (DOE 1983).

4.3 ONSITE MONITORING PRACTICES

Only the onsite monitoring practices that provide an indication of what the unmonitored workers at the Pinellas Plant were potentially exposed to are included in this section. Onsite monitoring practices such as vegetation, milk, and groundwater monitoring were not included because radioactivity in these media would not contribute to worker doses received at the site. The effluent monitoring for discharges to an offsite location, such as the Publically Owned Treatment Works (POTW), is another example of a potential source of environmental radioactivity that would not contribute to worker doses received at the site.

Figure 4-1 identifies the primary onsite environmental monitoring locations for the Pinellas Plant.

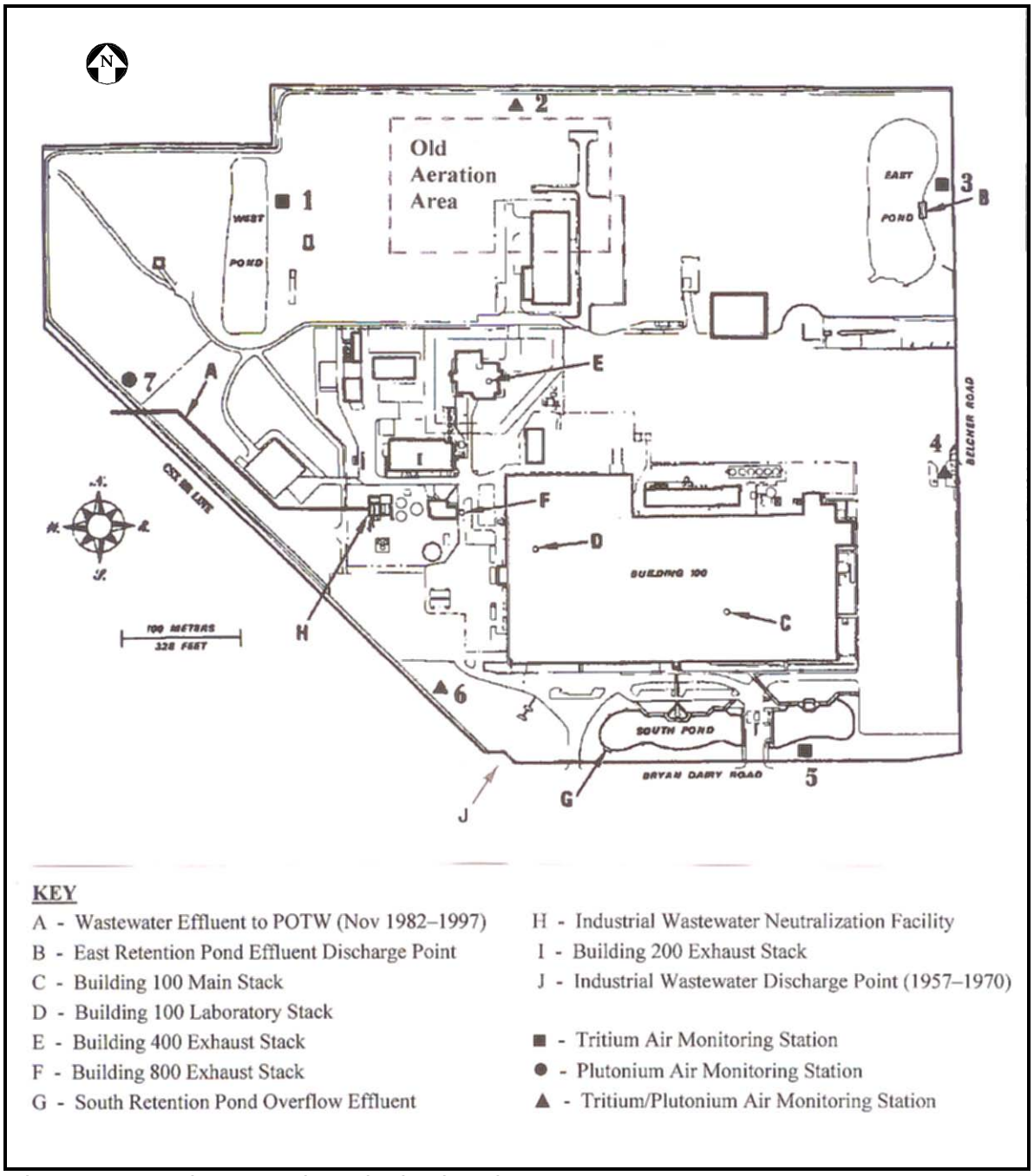

Figure 4-1. Environmental monitoring locations.

4.3.1 Employee Monitoring

An external dosimetry program was started in 1957 to monitor individual personnel working in the production areas for the neutron generators. From 1960 to 1973, the U.S. Atomic Energy Commission (AEC) annual exposure summary reports showed that the Pinellas Plant had 27.5% of its workers wearing dosimetry. In the 1980s, approximately 10% to 14% of workers were monitored for radiation dose. This percentage range appears to be representative of the entire history of monitoring at the Plant (no documentation was found that shows all employees were monitored during any given period). Only employees who performed activities that could have caused them to receive doses greater than radiation protection guidelines were monitored. A smaller percentage of employees were monitored for internal exposures. Therefore, a majority of employees could have received onsite

environmental doses that were not monitored because they did not wear external dosimetry or were not monitored for internal dose.

4.3.2 Environmental External Dose Monitoring

There is no indication that any environmental external dose monitoring was performed at the Pinellas Plant. Based on the activities performed at the Plant and the sources of radiation at the site, external doses outside the Plant buildings were probably too low to warrant monitoring.

4.3.3 Radioactive Airborne Effluent Monitoring

4.3.3.1 Radioactive Airborne Effluent Discharge Points

Exhaust stacks were a primary source for radioactive airborne effluent releases to the environment. Table 4-1 lists the exhaust stacks along with their locations, dimensions, and the nature of their releases. Figure 4-1 shows the locations of the exhaust stacks with radioactive effluents. The stacks that accounted for the vast majority of the site's radioactive airborne effluents were the two Building 100 stacks. Combined, the Building 800 Stack and Building 200 Stack accounted for less than 0.1% of the site's total tritium releases through exhaust stacks. Radioactive emissions were never detected in the Building 400 Stack.

Table 4-1. Exhaust stacks, their dimensions, and their potential radionuclide releases.[a]

Stack name	Applicable Period	Height (m [ft])	Diameter (m [ft])	Potential nuclides in effluent
Bldg. 100 Main Stack	1957–Jun 1981[b]	30.48 [100]	2.44 (8)	HT and HTO Kr-85 1963–1994 only
	Jul 1981–1996[b]	21.34 [70]	2.44 (8)	
Bldg. 100 Laboratory Stack	1965–1995	30.48 [100]	1.52 (5)	HT and HTO C-14 1979–1983 only
Bldg. 800 Stack	1980–1989	6.4 [21][c]	0.25 x 0.33 [0.82 × 1.08][c]	HT and HTO 1980–1997 Kr-85 1996 only
	1990–1997	9.1 [30]	0.51 [1.67]	
Bldg. 200 Stack	1989–1994	17.7 [58]	0.30 [0.98]	HT and HTO
Bldg. 400 Stack	Nov 1975–1994[d]	6.7 [22]	0.41 [1.33]	Plutonium oxide[e]

a. Sources: GE 1972, 1973, 1974a, 1974b, 1975, 1976, 1977, 1978b, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991; MMSC 1992, 1993, 1994; LMSC 1995b, 1996a, 1997a, 1997b; ORAUT 2011b.
b. In July 1981, the height of the Main Stack was reduced to provide more stability in the event of hurricane-force winds (GE 1982).
c. Prior to 1990, this was a rectangular stack with the reported dimensions of 10 in x 13 in (DOE 1983).
d. Even though all plutonium sources were removed from Building 400 by February 1991 (MMSC 1993), plutonium monitoring on the Building 400 Stack continued until 1994.
e. No plutonium emissions were ever detected from this exhaust stack.

4.3.3.2 Monitoring Methods

Because of the differing physical and radiological properties of radioactive airborne effluents, different methods were required to determine the quantity of each radionuclide that was discharged from the Pinellas Plant exhaust stacks.

Until 1974, airborne effluent discharges of tritium gas and tritium oxide were determined using a combination of continuous stack sampling systems and "real-time" stack monitoring systems. Starting in 1974, airborne effluent discharges of both tritium gas and tritium oxide were determined using continuous stack sampling systems. The continuous stack monitoring system used to monitor tritium gas concentrations consisted of a Kanne-type ionization chamber connected to a picoammeter and

recorder. The minimum detection level reported for this type of tritium gas monitoring was 1.3×10^{-5} µCi/mL in 1971 (GE 1972). To collect and analyze airborne effluent samples for tritium oxide, water vapor in the sample stream was originally condensed by a refrigeration device, and the water vapor condensate samples were collected daily (GE 1972). The samples were later analyzed by liquid scintillation spectrometry (GE 1972). The minimum detection level reported for this type of tritium oxide sampling was 8.9×10^{-11} µCi/mL in 1971 (GE 1972).

Starting in 1974, silica gel columns were used to collect both tritium oxide and total tritium samples initially on a weekly basis and later on a monthly basis (GE 1975, GE 1980). The collected tritium was then desorbed from the silica columns and analyzed by liquid scintillation counting (GE 1975). Tritium oxide samples were collected directly by passing a sample stream through a silica gel column. Total tritium samples (i.e., gas and oxide samples combined) were collected by heating a sample stream, and converting any tritium gas in the sample stream to tritium oxide using a catalyst. After all the tritium was converted to tritium oxide, the total tritium samples were collected by passing the sample stream through a silica gel column. Tritium gas concentrations were calculated by subtracting the tritium oxide concentrations from the total tritium concentrations (GE 1972, GE 1991, IT/Radiological Sciences Laboratory, 1986). The minimum detection levels reported for this type of tritium sampling ranged from 4.2×10^{-13} to 1.0×10^{-10} µCi/mL (GE 1972, GE 1975, GE 1991, IT/Radiological Sciences Laboratory, 1986).

Airborne effluent discharges of ^{85}Kr were determined using a continuous stack monitoring system on the Building 100 main stack. The continuous stack monitoring system consisted of a Kanne-type ionization chamber connected to a picoammeter and recorder. The minimum detection levels reported for this type of ^{85}Kr monitoring ranged from 1.3×10^{-7} to 6.4×10^{-6} µCi/mL (GE 1972, GE 1975, GE 1991, IT/Radiological Sciences Laboratory, 1986).

Airborne effluent discharges of ^{14}C were determined from the volumes of ^{14}C containing solvent used during each year (GE 1980, GE 1984).

Although there were no reported plutonium releases at the Pinellas Plant, airborne effluents from the Building 400 stack were sampled for plutonium using a continuous stack sampling system. Particulate air samples were collected on filters that were exchanged monthly and later analyzed for ^{238}Pu and $^{239/240}Pu$ (IT/Radiological Sciences Laboratory, 1986). The method of plutonium analysis consisted of 1) aliquoting a known quantity of ^{242}Pu tracer onto the air filters, 2) introduction and chemical equilibration of the ^{242}Pu tracer for recovery efficiency determination, 3) acid digestion of the combined sample and tracer, 4) plutonium isolation by anion exchange, 5) electrodeposition, and 6) alpha spectrometric analysis (GE 1991). The minimum detection levels reported for this type of plutonium sampling ranged from 5.9×10^{-19} to 3.7×10^{-18} µCi/mL for ^{238}Pu and $^{239/240}Pu$ (IT/Radiological Sciences Laboratory, 1986).

4.3.3.3 Historical Radioactive Airborne Effluent Discharges

Table 4-2 provides a summary of the radioactive airborne effluent releases from Pinellas Plant exhaust stacks. Approximately 82% of the total releases had occurred during the first 4 years of operation, 1957 through 1960.

Table 4-2. Radionuclides released from Pinellas Plant exhaust stacks (Ci/yr).[a]

Year	HT	HTO	Kr-85[b]	C-14[c]
1957	6,660	140	NR[d]	NR
1958	31,920	580	NR	NR
1959	41,070	1,330	NR	NR
1960	6,265	435	NR	NR
1961	504	306	NR	NR
1962	611	249	NR	NR
1963	179	103	4	NR
1964	233	57	47	NR
1965	50	100	153	NR
1966	325	385	49	NR
1967	1,944	213	70	NR
1968	1,586	215	202	NR
1969	3,275	297	55	NR
1970	587	465	44	NR
1971	694	374	12	NR
1972	111	222	15	NR
1973	74	318	1	NR
1974	155	202	4	NR
1975	154	165	1	NR
1976	101	176	20	NR
1977	129	161	28	NR
1978	132	156	5	NR
1979	127	206	5	1.00E-04
1980[e]	140	209	2	2.00E-04
1981	222	195	4	8.46E-05
1982	227	257	8	4.00E-05
1983	259	152	11	1.00E-05
1984	96	206	2	NR
1985	111	149	5	NR
1986	33	161	5	NR
1987	68	138	38	NR
1988	134	124	30	NR
1989[f]	44	60	13	NR
1990	62	61	10	NR
1991[g]	23	88	4	NR
1992	8	32	10	NR
1993	NR	12	19	NR
1994	NR	25	13	NR
1995	NR	26	NR	NR

Year	HT	HTO	Kr-85[b]	C-14[c]
1996	NR	22	6	NR
1997	NR	3	NR	NR

a. Sources: GE 1972, 1973, 1974a, 1974b, 1975, 1976, 1977, 1978b, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991; MMSC 1992, 1993, 1994; LMSC 1995b, 1996a,1996b, 1997a,1997b; ORAUT 2011b.
b. In 1963, the Pinellas Plant began to use Kr-85 for leak detection in Building 100 (Burkhart 1990). Kr-85 was exhausted through the Building 100 Main Stack until 1996 when it was exhausted from the Building 800 stack until all of the Kr-85 was removed from the site in 1996.
c. For the years of 1979–1983, C-14 releases were reported for the Building 100 Laboratory Stack. Rather than monitoring the C-14 releases, the Pinellas Plant estimated its C-14 released based on the amount of C-14 labeled solvent that was used during each years.
d. NR = No recorded release.
e. Releases from the Building 800 stack were first reported during this year.
f. Releases from the Building 200 stack were first reported during this year.
g. In 1991, two minor point sources (chemical hoods) exhausted tritium gas and tritium oxide through two roof openings. These were roof openings 378 (Chemistry Laboratory) and 413 (Environmental Laboratory).
h. The tritium releases for this year were actually reported as total tritium released, but have been reported in this table as HTO released.

As indicated in Table 4-2, mainly tritium gas, tritium oxide and, to a relatively lesser degree, ^{85}Kr comprised the radiological contents of the exhausts from the Pinellas Plant exhaust stacks. The Plant began using ^{85}Kr for leak detection in 1963 (Burkhart 1990). Relatively small contributions of ^{14}C to the overall air releases were reported for 1979 to 1983, as indicated in Table 4-2.

4.3.4 Radioactive Liquid Effluent Monitoring

4.3.4.1 Radioactive Liquid Effluent Discharge Points

From 1957 through 1970 (GE 1974a, 1974b), liquid effluents containing tritium were directed to onsite holdup/collection tanks. After monitoring, the liquid effluents were released into a county drainage ditch that was located at the southwest corner of the site. The liquid effluents travelled through a series of ditches and canals eventually entering Boca Ciega Bay (GE 1974a).

From 1971 through 1972 (GE 1974a, 1974b), drain lines containing liquid industrial effluent were directed to an onsite acid neutralization facility and from there were sent to the 3,250,000-gal east retention pond (also known as the northeast lake) (GE 1974a). Discharges from the east retention pond were made to a county drainage ditch that led to Boca Ciega Bay (GE 1974a).

From 1973 through November 1982 (GE 1974b, 1983), drain lines containing liquid industrial effluent were directed to an onsite acid neutralization facility and from there were sent to the 2,600,000-gal west retention pond (also known as the northwest lake), which was equipped with three floating aerators (GE 1974b). Treated sanitary wastes were also sent to the west retention pond. Water from the west retention pond was pumped to a 9-acre spray irrigation/aeration field, which was at the north end of the site. A subsurface drain system under the irrigation/aeration field collected the liquids and directed them to the 3,250,000-gal east retention pond (also known as the northeast lake) (GE 1974b). Periodic batch discharges from the east retention pond were made to a county drainage ditch

that led to Boca Ciega Bay (GE 1974b, 1983). A third retention pond, the south retention pond (also known as the south lake) was only used for retaining stormwater runoff from the site.

After November 1982, the industrial effluents (after a pH adjustment) were combined with the untreated sanitary wastes sent to the Pinellas County POTW. Stormwater continued to be diverted to the retention ponds, where trace quantities of tritium remained (GE 1983).

4.3.4.2 Monitoring Methods

Tritium was the only radionuclide discharged in Pinellas Plant liquid effluents. From 1957 through 1970 (GE 1957–1973, 1974a, 1974b), liquid effluents in the holdup/collection tanks were discharged into a county drainage ditch after monitoring confirmed that the tritium concentrations were below the permissible concentrations for release into sanitary sewer systems. During 1971, individual daily grab samples of the liquid effluents being discharged from the east retention pond were collected and analyzed for tritium (GE 1972). From 1972 through November 1982, liquid samples were taken from the east retention pond where the pond discharges to the drainage ditch by a proportional sampling system (GE 1983). After November 1982, composite samples were collected by proportional sampling of the discharges to the POTW (GE 1985).

Tritium results through 1982 were referenced to the standards set forth in the Rules of the Florida State Board of Health, Chapter 170J-1, "Control of Radiation Hazards," and in AEC Manual Chapter 0524, Standards for Radiation Protection (GE 1973). Sampling results were recorded in the annual environmental reports in terms of microcuries per milliliter. After 1982, all samples were analyzed in accordance with the latest edition of *Standard Methods for the Examination of Water and Wastewater*, published by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation (Eaton and Franson 2005; GE 1983).

4.3.4.3 Historical Radioactive Liquid Effluent Discharges

The tritium oxide released to the retention ponds would naturally evaporate into the atmosphere at the same rate as the water and become a possible internal source of exposure to a worker working adjacent to a retention pond. Tritium-bearing liquid effluents were discharged to the west and east retention ponds. The retention ponds were located a short distance away from other Pinellas Plant facilities and there was no known reason why any workers would be near the retention ponds except to conduct monitoring of the ponds and perform maintenance on the liquid effluent discharge and aeration systems.

The tritium concentration in the liquid contained in the east retention pond and discharged to the drainage ditch was reported in environmental monitoring reports from 1971 through 1994. Table 4-3 summarizes the annual maximum and average concentration of tritium in the retention pond. Because no data is known for the years prior to 1971, the highest concentration for the subsequent years was assumed for 1957–1970. The data in Table 4-3 are reflective of results as measured at the discharge point to the drainage ditch. The actual quantities of tritium sent to the west and east retention ponds from Pinellas Plant manufacturing processes are not known.

The amount of tritium measured in the east retention pond for all years was less than 1% of the concentration guide for tritium in water as set forth in Energy Research and Development Administration Manual Chapter 0524 (ERDA 1977).

After the industrial effluent discharges were rerouted to the POTW in 1982, there was a steady decline in the tritium concentrations measured in the east retention pond. Beginning in 1986, results from tritium analyses in water from the west and south retention ponds were reported. By that time, the reported tritium concentrations in the west and south retention ponds were of the same order of

magnitude as the concentrations in the east retention pond.

Table 4-3. Tritium in the east retention pond.[a]

Year	Maximum concentration in the water (µCi/mL)	Average concentration in the water (µCi/mL)	Minimum detection level (µCi/mL)	Discharge volume (liters of water)	Total curies discharged from pond
1957–1970[b]	NR[c]	NR	NR	NR[c]	NR
1971	5.5E-04	4.6E-05	1.0E-05	NR	NR
1972	1.5E-04	4.7E-05	1.0E-06	1.32E+08	5.6
1973	3.0E-05	8.6E-06	1.0E-06	NR	NR
1974	2.6E-05	9.2E-06	1.0E-06	NR	NR
1975	9.8E-06	6.4E-06	1.3E-07	1.23E+08	0.79
1976	6.7E-06	4.1E-06	1.6E-07	3.9E+07	0.16
1977	6.7E-06	5.0E-06	1.4E-07	1.90E+08	0.95
1978	5.2E-06	4.1E-06	1.4E-07	1.27E+08	0.54
1979	1.1E-05	3.6E-06	1.4E-07	8.72E+07	0.31
1980	8.7E-06	6.0E-06	1.4E-07	9.05E+07	0.54
1981	1.4E-05	1.3E-05	1.6E-07	4.69E+07	0.60
1982	1.2E-05	6.7E-06	1.7E-07	1.09E+07	0.73
1983	5.0E-06	1.4E-06	3.0E-07	2.74E+08	0.37
1984	4.8E-06	8.7E-07	1.7E-07	1.73E+08	0.15
1985	3.2E-06	8.9E-07	8.5E-08	NR	NR
1986	2.1E-06	9.0E-07	5.5E-07	NR	NR
1987	1.05E-06	5.6E-07	7.8E-07	NR	NR
1988	1.3E-06	4.4E-07	6.3E-07	NR	NR
1989	2.8E-06	4.9E-07	5.1E-07	NR	NR
1990	5.1E-07	NR	NR	NR	NR
1991	4.8E-07	NR	NR	NR	NR
1992	2.9E-07	BDL[d]	4.5E-07	NR	NR
1993	NR	BDL	4.8E-07	NR	NR
1994	NR	BDL	4.3E-07	NR	NR
1995	NR	BDL	3.3E-07	NR	NR

a. GE 1972, 1973, 1974b, 1975, 1976, 1977, 1978b, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991; MMSC 1992, 1993, 1994; LMSC 1995b, 1996b.
b. No monitoring data for the east retention pond was available prior to 1971. Because liquid effluent discharges to the pond did not begin until 1971, the tritium levels in the pond were likely insignificant prior to 1971.
c. NR = Not reported.
d. BDL = Below Detection Limit.

4.3.5 Onsite Environmental Air Monitoring

4.3.5.1 Onsite Environmental Air Monitoring Locations and Methods

Environmental air monitoring for tritium gas and oxide was performed at the Pinellas Plant from the very beginning of Plant operations. The earliest background monitoring for radioactivity was performed in April 1957. Four samples from the areas around the Plant were taken to establish background counts before the Plant began operations. Before the mid-1970s, the monitoring program was informal and there were no permanent air monitoring stations. In addition, some monitoring activities were done on an irregular basis. During the mid-1970s, six permanent onsite air monitoring stations were installed for monitoring tritium. With the installation of the permanent air monitoring stations, monitoring was performed on a more regular basis (State of Florida 1994). Starting in 1975, plutonium monitoring was performed at four locations because of the encapsulated plutonium that was present at the Plant as part of RTG operations (State of Florida 1994).

Figure 4-1 above shows the onsite environmental air monitoring locations at the Pinellas Plant.

4.3.5.2 Historical Onsite Environmental Air Monitoring Results

Table 4-4 provides a summary of the tritium results from the onsite environmental air monitoring stations for the years of 1975–1992 (State of Florida 1994).

Table 4-4. Onsite tritium air monitoring results.

Year	Average Annual Tritium Air Concentrations Measured at Onsite Tritium Air Monitoring Stations (E-12 µCi/mL)[a]											
	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6	
	Gas	Oxide	Gas	Oxide	Gas	Oxide	Gas	Oxide	Gas	Oxide	Gas	Oxide
1975	NA[b]	NA	< 5.1	< 8.0	NA	NA	< 44.2	18.4	< 12.0	< 8.5	15.4	< 11.1
1976	< 4.6	< 6.4	< 6.2	< 3.4	< 18.8	< 4.1	< 5.0	< 3.5	< 87.3	< 5.5	< 4.2	< 5.9
1977	< 7.4	< 7.4	< 5.9	< 6.2	< 8.5	< 6.9	< 26.2	< 8.9	< 12.0	< 11.4	< 9.5	9.8
1978	< 5.2	6.0	4.2	< 5.7	< 1.9	5.3	< 5.0	< 4.4	< 5.8	6.2	< 6.0	9.2
1979	< 3.9	10.2	< 3.6	7.1	< 3.1	6.0	< 2.3	20.9	< 6.0	9.9	< 10.8	15.2
1980	< 4.4	7.1	5.9	7.5	< 4.0	5.2	< 6.2	< 10.2	< 4.2	< 8.5	17.2	9.7
1981	< 5.9	16.5	< 7.2	< 13.1	< 9.3	< 6.9	< 5.4	< 11.2	< 11.4	< 12.4	27.4	19.1
1982	< 10.0	23.7	< 5.0	14.2	< 5.0	< 8.0	< 7.9	19.1	< 5.3	25.4	< 13.2	31.2
1983	< 6.8	9.2	27.1	25.8	< 3.6	< 8.0	< 3.3	6.3	< 22.1	14.6	< 12.2	14.1
1984	< 5.9	14.2	< 11.4	28.2	< 2.1	< 10.0	< 2.5	17.5	3.6	14.9	< 8.5	51.7
1985	< 8.4	9.7	< 5.2	21.5	< 4.1	< 8.4	< 17.7	< 19.3	< 13.6	21.5	< 26.4	29.0
1986	< 7.0	< 17.0	< 6.0	30.0	< 6.0	< 8.0	< 4.0	< 32.0	< 10.0	< 18.0	< 7.0	29.0
1987[c]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1988	13.3	4.1	152.0[d]	172.6[d]	48.0	29.6	48.0	8.2	18.6	36.9	5.6	2.9
1989	6.1	11.88	0.68	7.06	3.3	11.45	0.64	6.54	32.56	9.29	36.57	16.46
1990	10.39	5.76	6.37	4.13	11.7	7.34	7.13	4.30	22.65	11.26	27.04	16.11
1991	5.42	1.65	3.84	2.64	2.03	1.54	4.12	2.16	10.69	5.46	15.53	12.66
1992[e]	2.85		1.09		1.45		3.81		8.72		9.47	

a. The values in the table are to be multiplied by 10^{-12} µCi/mL (State of Florida 1994).
b. NA – not available.
c. Air concentrations for individual air monitoring stations were not available for 1987.
d. The individual air monitoring results for Station 2 ranged from 0.44 to 708.6 (10^{-12} µCi/mL) during 1988, and no explanation was provided in the environmental monitoring report for 1988 to explain why several air monitoring results from this station were significantly elevated (GE 1989). The environmental monitoring report for 1988 did indicate that there was no significant difference between the stack emissions for 1988 and the stack emissions from other surrounding years (GE 1989; State of Florida 1994). Therefore, Station 2 elevated air monitoring results for 1988 were most likely attributable to some unidentified localized event or activity occurring near this air monitoring station versus a release from one of the site's stacks.
e. Only total tritium in air results, which include both gas and oxide forms of tritium, were available for 1992.

4.4 POTENTIAL EXPOSURES

Literature surveys revealed very little occupational environmental dose information. No information could be found for the first 15 years of plant operation (1957 to 1971) other than the number of curies released to the environment. For the remaining years (1972 to 1994), the dose to a maximally exposed individual (member of the public) was estimated using a computational model by the Pinellas Plant. Depending on the year calculated, the member of the public could be at the Plant boundary or at a greater distance outside the boundary. Because of the distance from the general Plant work environment and the fact that calculations included dose from ingestion, the dose to the maximally exposed member of the public could not be taken to be representative of the environmental dose to a worker inside the Plant boundary.

4.4.1 Potential Internal Exposures and Doses

Potential onsite environmental internal exposures and subsequent doses to workers at the site were assessed using airborne effluent data, liquid effluent data, and onsite air monitoring data. Because the onsite environmental intakes were relatively small, bounding environmental intakes and internal doses were assessed assuming a 2,600 hour work year versus the standard assumption of a 2,000 hour work year. Bounding potential onsite environmental internal doses were assessed for a hypothetical worker who was employed at the Pinellas Plant from 1957–1997, using the intake information and exposure scenarios described in Sections 4.4.1.1 through 4.4.1.3. For each exposure scenario, the assessment indicated that the total internal dose to all internal organs was <0.001 rem (ORAUT 2011e, 2011f). Calculated annual environmental internal doses that total less than 0.001 rem for a specific radiation type and energy interval are not required to be included in the Interactive RadioEpidemiological Program (IREP) input sheet (ORAUT 2004). For such cases, the dose reconstruction should include appropriate discussions.

4.4.1.1 Potential Intakes Based on Stack Emissions

In this section, the maximum annual radionuclide intakes to a hypothetical maximally exposed employee (MEE) due to radioactive airborne emissions from the Pinellas Plant stacks are assessed. While greater than 95% of the radioactivity released during the history of the Plant was from tritium and therefore potentially contributed to intake, the small amount of ^{14}C emitted could have also contributed to a worker's intake. In addition, ^{85}Kr was also released from the Plant's stacks; however, ^{85}Kr is not an internal dose concern because it is a noble gas.

Maximum annual onsite average air concentrations of HT, HTO, and ^{14}C were calculated by multiplying the annual releases in Table 4-2 by the atmospheric dispersion factors in Table A-8. The basis for the development of the atmospheric dispersion factors is described in detail in Attachment A. The calculated air concentrations were then used to calculate the annual intakes, assuming a 2,600 hour work-year and a breathing rate of 1.2 m^3/hr. A breathing rate of 1.2 m^3/hr is equivalent to the value in ICRP Report 66 for light work (ICRP 1994). In addition, the HTO intakes were adjusted by a factor of 1.5, in accordance with the Technical Information Bulletin: Tritium Calculations with IMBA (ORAUT 2007). The resulting annual intakes are summarized in Table 4-5.

Table 4-5. Annual onsite environmental intakes from stack emissions for a hypothetical MEE.[a]

Year	Total annual inhalation for each radionuclide by a hypothetical MEE (Bq)		
	HT	HTO	C-14
1957	1.46E+04	4.61E+02	NR[b]
1958	7.01E+04	1.91E+03	NR
1959	9.02E+04	4.38E+03	NR
1960	1.38E+04	1.43E+03	NR
1961	1.11E+03	1.01E+03	NR
1962	1.34E+03	8.20E+02	NR
1963	3.93E+02	3.39E+02	NR
1964	5.11E+02	1.89E+02	NR
1965	1.09E+02	3.30E+02	NR
1966	7.14E+02	1.27E+03	NR
1967	4.27E+03	7.03E+02	NR
1968	3.48E+03	7.08E+02	NR
1969	7.19E+03	9.77E+02	NR
1970	1.29E+03	1.53E+03	NR
1971	1.52E+03	1.23E+03	NR
1972	2.43E+02	7.31E+02	NR
1973	1.62E+02	1.05E+03	NR
1974	3.40E+02	6.65E+02	NR
1975	3.37E+02	5.42E+02	NR
1976	2.22E+02	5.80E+02	NR
1977	2.83E+02	5.29E+02	NR
1978	2.89E+02	5.13E+02	NR
1979	2.79E+02	6.77E+02	2.20E-04
1980	3.08E+02	6.89E+02	4.39E-04
1981	3.41E+03	4.50E+03	1.30E-03
1982	3.48E+03	5.93E+03	6.15E-04
1983	3.99E+03	3.51E+03	1.54E-04
1984	1.48E+03	4.75E+03	NR
1985	1.71E+03	3.44E+03	NR
1986	5.14E+02	3.72E+03	NR
1987	1.04E+03	3.19E+03	NR
1988	2.05E+03	2.86E+03	NR
1989	6.73E+02	1.38E+03	NR
1990	9.47E+02	1.40E+03	NR
1991	3.53E+02	2.03E+03	NR
1992	1.25E+02	7.29E+02	NR
1993[b]	NR	2.68E+02	NR
1994[b]	NR	5.76E+02	NR
1995[b]	NR	6.00E+02	NR
1996[b]	NR	5.03E+02	NR
1997[b]	NR	3.44E+02	NR

a. Source: ORAUT 2011c.
b. NR = no release reported.
c. Because only total tritium releases were reported after 1992, it was assumed that tritium released was HTO.

4.4.1.2 Potential Intakes Based on Liquid Effluent Data

An approach similar to that described in Section 4.4.1.1 for calculating the intake by a hypothetical MEE from stack emissions was performed for a hypothetical MEE located near the east retention pond. However, only annual HTO intakes were calculated because HTO would have been the only

emission from the pond. Annual HTO intakes were only estimated for the years of 1971–1992. Prior to 1971, no tritium monitoring data was available, which was likely because liquid effluents were not discharged to the east retention pond until 1971. After 1992, the reported tritium concentrations in the pond were all below the detection limits. Therefore, the tritium levels in the pond and any potential emissions from the pond were assumed to be negligible during the years of 1957–1970 and 1993–1997.

Annual HTO releases from the east retention pond were estimated by assuming that 100% of the tritium inventory in the pond was released for a given year, to ensure that the annual intakes were overestimated. The annual tritium inventories in the pond were calculated by multiplying the pond's reported annual average tritium concentrations by the volume of water in the pond. It was assumed that the pond had a constant volume of 3.25×10^6 gallons. Maximum annual onsite air concentrations of HTO were calculated by multiplying the annual releases by the maximum onsite atmospheric dispersion factor in Table A-9 (i.e., 1.3×10^{-4} s/m^3). The basis for the development of the atmospheric dispersion factors is described in detail in Attachment A. The calculated air concentrations were then used to calculate the annual intakes, assuming a 2,600 hour work-year and a breathing rate of 1.2 m^3/hr. A breathing rate of 1.2 m^3/hr is equivalent to the value in ICRP Report 66 for light work (ICRP 1994). The HTO intakes were also adjusted by a factor of 1.5, in accordance with the Technical Information Bulletin: Tritium Calculations with IMBA (ORAUT 2007). Based on this approach and these assumptions, the maximum HTO intake attributable to the east retention pond emissions would be 413 Bq/yr, and would only be applicable for the years of 1971–1992 (ORAUT 2011d).

4.4.1.3 Potential Intakes Based on Onsite Air Monitoring Data

Because stack emissions and emissions from the east retention pond do not account for the tritium emissions from some other sources (e.g. west retention pond, aeration area, and other fugitive emissions sources), potential intakes were assessed using the results from the onsite tritium air monitoring stations, which were at various locations near the property boundary for the Plant.

Potential intakes were calculated using the highest annual tritium air concentrations provided in Table 4-4 and the inhalation and exposure assumptions used in Section 4.4.1.2. Because the highest annual air concentrations for Station 2 in 1988 were more than 3 times higher than the next highest set of annual air concentrations, the 1988 air concentrations for Station 2 were used only to calculate the intakes for 1988. As a result, tritium gas and oxide intakes for 1988 were calculated based on concentrations of 152.0 and 172.6 (10^{-12} µCi/mL), respectively. For all other years, tritium gas and oxide intakes were calculated based on concentrations of <8.5 and 51.7 (10^{-12} µCi/mL), respectively, which were measured at Station 6 in 1984. The calculated air concentrations were then used to calculate the annual intakes, assuming a 2,600 hour work-year and a breathing rate of 1.2 m^3/hr. A breathing rate of 1.2 m^3/hr is equivalent to the value in ICRP Report 66 for light work (ICRP 1994). In addition, the HTO intakes were adjusted by a factor of 1.5, in accordance with the Technical Information Bulletin: Tritium Calculations with IMBA (ORAUT 2007). The annual tritium intakes estimated for each year of operation are summarized in Table 4-6. Given that only the highest annual concentrations for any tritium air monitoring station were used for the intake estimates and given that it is unlikely that a worker spent a significant amount of time near the property boundary for the Plant, this approach overestimates a worker's potential environmental intakes.

Table 4-6. Estimated annual tritium intakes based on air monitoring results (Bq).[a]

Year	H-3 gas intake	H-3 oxide intake
1957–1987	< 981	8,952
1988	17,547	29,887
1989–1997	4,222	2,850

a. Source: ORAUT 2011i.

4.4.2 Potential External Doses

As indicated in Section 4.3.2, no environmental external dose monitoring appears to have been performed at the Pinellas Plant, which was most likely due to the low potential for workers to encounter significant sources of external radiation outdoors at the Plant. However, based on the available information, small external doses could have been received by workers from the ^{85}Kr emissions from the Plant stacks. Therefore, potential annual environmental external doses were assessed for a hypothetical MEE inside the plant boundary using the ^{85}Kr airborne effluent data for the stacks. In addition, ^{14}C emissions from the Pinellas Plant stack could have also contributed to the environmental external dose. However, the contributions to the environmental external doses from ^{14}C emissions were negligible compared to the contributions from ^{85}Kr emissions, because ^{14}C releases were at least 1/10,000th of the ^{85}Kr releases and because ^{14}C emits much lower energy beta particles than ^{85}Kr. Plutonium could have contributed to the environmental external doses; however, plutonium was never released to the environment at the Plant. In addition, emissions from the area sources (i.e., the ponds and aeration area) would not have contributed to the environmental external doses at the site because tritium was the only emission from the area sources.

The annual onsite ambient external doses were calculated in a manner similar to the approach used for the environmental intake estimates, which was based on airborne effluent data. Maximum air concentrations were calculated from the annual ^{85}Kr releases using the atmospheric dispersion factors in Table A-8 of Attachment A. Dose rates in units of Sv/s were then calculated using the maximum dose coefficient for air submersion found in Federal Guidance Report 12 (EPA 1993). For ^{85}Kr, the highest dose coefficient is for the skin, and its use will overestimate the onsite ambient doses for organs that are not affected by non-penetrating radiation by about two orders of magnitude. The calculated dose rates were then multiplied by the number of seconds in a 2,600 hour working year to estimate the bounding annual onsite ambient doses. The onsite ambient external doses that were calculated using this approach are summarized in Table 4-7. Doses were calculated only for the years that ^{85}Kr releases were reported. Because ^{85}Kr was not present at the site until 1963, there were no ^{85}Kr releases prior to 1963.

Table 4-7. Potential annual onsite environmental external doses.[a]

Year	Total Kr-85 released from stacks[b] (Ci)	Total annual external dose (mrem)
1957–1962	NR[c]	NR
1963	4	3.48E-05
1964	47	4.09E-04
1965	153	1.33E-03
1966	49	4.26E-04
1967	70.3	6.11E-04
1968	201.7	1.75E-03
1969	55	4.78E-04
1970	44	3.83E-04
1971	11.85	1.03E-04
1972	15.46	1.34E-04
1973	1.36	1.18E-05
1974	3.67	3.19E-05
1975	1.15	1.00E-05
1976	19.92	1.73E-04
1977	27.62	2.40E-04
1978	5.29	4.60E-05
1979	4.66	4.05E-05
1980	1.85	1.61E-05
1981	3.64	2.22E-04
1982	7.77	4.73E-04
1983	11.33	6.90E-04
1984	1.97	1.20E-04
1985	5	3.04E-04
1986	5	3.04E-04
1987	38	2.31E-03
1988	30	1.83E-03
1989	12.9	7.85E-04
1990	10.1	6.15E-04
1991	4	2.44E-04
1992	10	6.09E-04
1993	18.74	1.14E-03
1994	12.9	7.85E-04
1995	NR	NR
1996	6	2.96E-03
1997	NR	NR

a. Source: ORAUT 2011g.
b. All Kr-85 releases were from the Building 100 Main Stack with the exception of the 1996 releases, which were from the Building 800 Stack.
c. NR = no release recorded.

The low onsite environmental external doses summarized in Table 4-7 are representative only of unmonitored external doses that a worker at the Pinellas Plant could have received outdoors. Because potential unmonitored external doses for Plant workers could have been significantly greater due to incidental radiation exposures while inside any of the Plant buildings, the unmonitored external doses for a worker who entered a Plant building should not be limited to the onsite environmental external doses. Therefore, dose reconstructors should assign the more favorable-to-claimant unmonitored external doses prescribed for unmonitored workers in the Occupational External Dose TBD (ORAUT 2011k) in lieu of the onsite environmental external doses.

4.5 UNCERTAINTY

There are many sources of uncertainty involved in calculation of doses from airborne emissions sources. The sources of uncertainty range from the magnitude of the emissions, to the amount of dispersion, to the location and behavior of the receptor. Each individual uncertainty is reflected in some degree in the uncertainty in the annual intake calculations. To account for those uncertainties, favorable to claimant values, parameters, and assumptions were used for the atmospheric dispersion and intake calculations.

Uncertainty in Amount of Effluent Release: The amount of effluent released directly affects the amount of dose for a given receptor. Assuming all other parameters remain constant, the resultant dose is proportional to the amount of effluent.

Uncertainty in Amount of Dispersion: The amount of dispersion is dependent on many factors including the release height above ground, the height of the surrounding buildings, the distance from the release location to the receptor, and the local meteorological parameters such as wind speed, frequency of wind direction, and frequency of atmospheric stability. The release height affects the ground-level concentrations; the higher the release height, the lower the ground-level concentration at a given location. The distance between the release location and the receptor affects the amount of dispersion. For an elevated release, the ground-level concentrations initially increase as the distance from stack increases, until the effluent plume touches the ground; then the ground-level concentration decreases as the distance from stack increases. To account for some of the uncertainties associated with atmospheric dispersion calculations, 9-year and 10-year meteorological data sets were used for the atmospheric dispersion calculations.

Uncertainty in Location and Behavior of the Receptor: The location of the receptor was determined by selecting the distance and direction that would result in the maximum onsite concentration. In addition, it was assumed that the receptor was outdoors and exposed to the maximum on-site environmental air concentrations for 100% of the assumed 2,600 hour work-year. Furthermore, it was assumed that the same worker was exposed to the maximum air concentrations calculated from the stack emissions data, onsite ambient air monitoring data, and liquid effluent monitoring data, which would mean the worker was in three different locations at one time.

4.6 ATTRIBUTIONS AND ANNOTATIONS

All information requiring identification was addressed via references integrated into the reference section of this document.

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GLOSSARY

background radiation
Radiation from cosmic sources, naturally occurring radioactive materials including naturally occurring radon, and global fallout from the testing of nuclear explosives. Background radiation does not include radiation from source, byproduct, or Special Nuclear Materials regulated by the U.S. Nuclear Regulatory Commission. The average individual exposure from background radiation is about 360 millirem per year.

becquerel (Bq)
International System unit of radioactivity equal to 1 disintegration per second; 1 curie equals 37 billion (3.7×10^{10}) Bq.

beta radiation
Charged particle emitted from some radioactive elements with a mass equal to 1/1,837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is a positron.

dosimetry
Measurement and calculation of internal and external radiation doses.

exposure
(1) In general, the act of being exposed to ionizing radiation. (2) Measure of the ionization produced by X- and gamma-ray photons in air in units of roentgens.

gamma radiation
Electromagnetic radiation (photons) of short wavelength and high energy (10 kiloelectron-volts to 9 megaelectron-volts) that originates in atomic nuclei and accompanies many nuclear reactions (e.g., fission, radioactive decay, and neutron capture). Gamma photons are identical to X-ray photons of high energy; the difference is that X-rays do not originate in the nucleus.

neutron
Basic nucleic particle that is electrically neutral with mass slightly greater than that of a proton. There are neutrons in the nuclei of every atom heavier than normal hydrogen.

radiation
Subatomic particles and electromagnetic rays (photons) with kinetic energy that interact with matter through various mechanisms that involve energy transfer.

radioactivity
Property possessed by some elements (e.g., uranium) or isotopes (e.g., ^{14}C) of spontaneously emitting energetic particles (electrons or alpha particles) by the disintegration of their atomic nuclei.

radioisotopically-powered thermoelectric generator (RTG)
Generator that obtains its power from passive (natural) radioactive decay using thermocouples to convert the heat of decay into electricity.

rem
Traditional unit of radiation dose equivalent that indicates the biological damage caused by radiation equivalent to that caused by 1 rad of high-penetration X-rays multiplied by a quality factor. The sievert is the International System unit; 1 rem equals 0.01 sievert. The word derives from roentgen equivalent in man; rem is also the plural.

thermoluminescent dosimeter (TLD)

Device for measuring radiation dose that consists of a holder containing solid chips of material that, when heated by radiation, release the stored energy as light. The measurement of this light provides a measurement of absorbed dose.

ATTACHMENT A
BASIS FOR ATMOSPHERIC DISPERSION CALCULATIONS
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BASIS FOR ATMOSPHERIC DISPERSION CALCULATIONS
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A-1 Introduction

This attachment describes the methodology and assumptions used to estimate the atmospheric dispersion of radionuclides released from air emission point sources (stacks) and area sources (ponds and aeration areas) at the Pinellas Plant during its operation from 1957 through 1997. Atmospheric dispersion factors can be used to estimate the air concentration of radionuclides around the Pinellas Plant and to further estimate the potential radiation dose that may have been received from various applicable exposure pathways such as inhalation of the airborne radionuclide. This attachment includes a description of the computer model, meteorological data, and the assumptions made in estimating air dispersion factors that were used to estimate radionuclide intakes and doses received by a hypothetical maximally exposed employee (MEE) at the Pinellas Plant for Section 4.4 of this TBD. Dispersion factors were also calculated to estimate atmospheric dispersion at the locations of six tritium monitoring stations to compare the relative contributions of the various sources to the measured air monitoring results.

A-2 Computer Model

The GENII computer model (Version 2.10) is a powerful environmental assessment code that can be used to estimate radiation dose to an exposed individual or a population from a variety of potential exposure pathways (Napier et al. 2004, Napier 2010). Only a small portion of the GENII capability was used to develop the atmospheric dispersion factors presented here. GENII allows for input of site-specific information that affect air emissions, and site-specific Pinellas Plant information was input into the code where available. Important site-specific data that were available and used included meteorological data (discussed below), stack parameters including stack area (from given diameters), height, exhaust velocity (on an annual basis for many years), ambient stack gas temperature, and ambient site temperature. Annual radionuclide release data from the Plant (given in Table 4-2) were also considered along with other operational and infrastructure information such as exhaust volume, exhaust velocity, stack height and stack diameter.

A-3 Meteorological Data

With the exception of the outdoor ambient temperature data, the meteorological data used for the determination of atmospheric dispersion factors were obtained from the US Environmental Protection Agency's Center for Exposure Assessment Modeling (CEAM) website (ORAUT 2011a). The CEAM website provides hourly meteorological data from 1961 to 1990 for the Tampa International Airport which is representative of meteorology at the Pinellas Plant. Based on information in the Pinellas Plant's 1995–1997 Radionuclide Air Emissions Report, the mean annual temperature is approximately 22^{o}C (72^{o}F) (LMSC 1996a, 1997a, 1997b).

The data from 1961, 1962, and 1963 were evaluated and it was determined that these data were structured in such a way that only 15 sectors of a polar grid (rather than 16) were represented. Therefore, the data from these three years were not used. The GENII Version 2 User's Guide (Napier 2010) provides information on how to access the CEAM, and the GENII code contains a meteorological data processor that can be used to convert the CEAM data into a format usable by GENII. The individual annual files can be combined to provide a longer-term representation of meteorological data.

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Because the main stack was shortened from 30.5 m (100-ft) to 21.3 m (70-ft) during the middle of 1981, two sets of atmospheric dispersion factors were generated for each of the Building 100 stacks (i.e., one set that is applicable to the years prior to 1981 and another set that is applicable to 1981 and later). As a result, two multi-year meteorological data files were developed to calculate atmospheric dispersion factors for the Pinellas Plant. One file included hourly data from 1964 through 1973, and was used to assess the chronic atmospheric releases from 1957 through 1980. The second meteorological data file included data from 1982 through 1990, and was used to assess the chronic atmospheric releases from 1981 through 1997.

A-4 Atmospheric Dispersion Factors for Stacks

Atmospheric dispersion factors were calculated using the GENII computer model, the multi-year meteorological data files discussed above, and building-specific characteristics of the most important air emission points (stacks) at the Pinellas Plant (i.e., the 100 Building Main Stack, 100 Building Lab Stack, and 800 Building Stack). As previously indicated, two sets of atmospheric dispersion factors were generated for each of the Building 100 stacks (i.e., one set that is applicable to the years prior to 1981 and another set that is applicable to 1981 and later), because the main stack was shortened from 30.5 m (100-ft) to 21.3 m (70-ft) during the middle of 1981.

Average stack emission velocities were calculated for the periods corresponding to the meteorological data. The majority of the annual average effluent velocities for each stack were calculated by dividing the annual total volume of air discharged by the total number of seconds in a calendar year. For the Main Stack and the Lab Stack, flow data from 1964 to 1973 were used to represent the 1957 through 1980 period, and flow data from 1982 to 1990 were used to represent the 1981 through 1996 period. Although the Building 800 Stack operated from 1980 through 1997, the atmospheric dispersion factors associated with the Building 800 Stack were only assessed for 1997, because the Building 800 Stack releases were insignificant compared to Main Stack and Lab Stack releases during earlier years. As a result, the stack emission velocity reported for 1997 was only used for the Building 800 Stack dispersion calculations.

The stack parameters used are summarized in Table A-1.

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Table A-1. Pinellas Plant stack parameters used in the determination of atmospheric dispersion factors.

Parameter	Bldg. 100 Main Stack		Bldg. 100 Lab Stack		Bldg. 800 Stack
Applicable operating years	1957–1981	1981–1996	1965–1981	1981–1996	1997
Met data years	1964–1973	1982–1990	1964–1973	1982–1990	1982–1990
Diameter (m)[a]	2.44[b]	2.44	1.52[b]	1.52	0.51
Area (m^2)[c]	4.68	4.68	1.81	1.82	0.204
Height (m)[d]	30.5	21.3	30.5	nc	9.1
Effluent Velocity (m/s)[d,e]	4.16	3.20	7.82	6.65	3.3
Stack gas temperature[f]	26ºC, 79ºF	26ºC, 79ºF	26ºC, 79ºF	26ºC, 79ºF	26ºC, 79ºF

a. Sources: LMSC 1996a, 1997a, 1997b.
b. There is no indication that this stack's diameter ever changed, so the same diameter is applicable for the earlier years.
c. Calculated using the reported diameter for the stack (ORAUT 2011b).
d. Sources: GE 1972, 1973, 1974a, 1974b, 1975, 1976, 1977, 1978b, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991; MMSC 1992, 1993, 1994; LMSC 1995b, 1996a, 1997a, 1997b.
e. For the Building 100 stacks, the average effluent velocities were calculated using the 1964–1973 and 1982–1990 flow data for the stacks. For the Building 800 Stack, the reported stack velocity for 1997 was used (ORAUT 2011b).
f. Because effluent temperatures that are close to the average onsite ambient outdoor temperature have little impact on the dispersion modeling and because of the limited amount of effluent temperature data, an approximate temperature of 26°C (79°F) was used for all stacks and all years. The selected temperature is consistent with the limited effluent temperature data that is available for each stack.

Calculations were performed using GENII for the three stacks and the time periods noted above by using a 1 Curie per second (Ci/s) unit release of tritium gas (HT) as the basis for determining atmospheric dispersion. A comparison of the dispersion factors calculated for HT and tritium oxide (HTO) releases indicated that the differences were negligible, but HT did produce a slightly higher dispersion factor for some sectors and distances. Therefore, all dispersion factors were calculated based on HT releases. Plume rise was included in all calculations since stack-specific data were available. Adjacent buildings were considered and assumed to have a height of 10 m. Releases were modeled using a chronic Gaussian plume atmospheric dispersion model and several different sets of dispersion parameters available in GENII to determine which best represented the Pinellas Plant conditions. The tritium monitoring station data presented in Table 4-5 were used to assist in selecting the "best" model. Straight Pasquill-Gifford atmospheric stability without enhanced dispersion from building wake was first evaluated, followed by Pasquill-Gifford and Briggs urban condition parameters using enhanced dispersion of the Pasquill-Gifford building wake model. Both of the enhanced dispersion models were better performers than the straight Pasquill-Gifford model, as both resulted in significantly higher dispersion factors at closer distances from lower stack heights that was indicated by tritium monitoring station data. Selection of one of these models would also be favorable to the claimant since near-field concentrations were higher than straight Pasquill-Gifford while the farther-field concentrations were similar and much lower among all the models. The Pasquill-Gifford model with enhanced dispersion was selected to develop the atmospheric dispersion factors for this TBD because it is also used in Version 3 of the Industrial Source Complex computer model (ISC3) distributed by the US Environmental Protection Agency.

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Results of the calculations are presented as “Chi over Q” (X/Q) atmospheric dispersion factors with units of seconds per cubic meter (s/m^3) in Tables A–2 through A–6. These factors are estimates of the long-term atmospheric dispersion represented as activity concentration (e.g., Ci/m^3, Bq/m^3, etc…) divided by activity release rate (e.g., Ci/s, Bq/s, etc…).

Examination of the calculated atmospheric dispersion factors in Tables A–2 through A–6 shows the locations of the largest onsite atmospheric dispersion factors (least atmospheric dispersion), which would result in the highest onsite air concentrations and the highest potential dose to a Pinellas Plant worker. Table A–7 provides a summary of the maximum atmospheric dispersion factors found in Tables A–2 through A–6.

Table A-2. Atmospheric dispersion factors (s/m^3) for the Building 100 Main Stack, applicable 1957 through 1980 .[a,b,c]

Direction (Deg.)[d]		Distance from the Building 100 Main Stack, m									
		100	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
N	(0.0°)	5.7E-09	1.0E-07	2.2E-07	2.9E-07	3.2E-07	3.2E-07	3.0E-07	2.8E-07	2.6E-07	2.4E-07
NNE	(22.5°)	5.4E-09	1.0E-07	2.2E-07	2.9E-07	3.1E-07	3.1E-07	2.9E-07	2.6E-07	2.4E-07	2.2E-07
NE	(45.0°)	6.6E-09	1.0E-07	1.9E-07	2.3E-07	2.5E-07	2.4E-07	2.3E-07	2.1E-07	1.9E-07	1.8E-07
ENE	(67.5°)	7.5E-09	1.4E-07	2.6E-07	3.3E-07	3.4E-07	3.3E-07	3.1E-07	2.8E-07	2.6E-07	2.4E-07
E	(90.0°)	9.0E-09	1.8E-07	3.7E-07	4.7E-07	4.9E-07	4.8E-07	4.4E-07	4.0E-07	3.6E-07	3.3E-07
ESE	(112.5°)	2.3E-09	5.9E-08	1.6E-07	2.4E-07	2.8E-07	2.8E-07	2.7E-07	2.5E-07	2.3E-07	2.1E-07
SE	(135.0°)	1.4E-09	4.0E-08	1.3E-07	2.1E-07	2.5E-07	2.5E-07	2.5E-07	2.3E-07	2.2E-07	2.0E-07
SSE	(157.5°)	1.5E-09	3.6E-08	1.1E-07	1.7E-07	2.1E-07	2.1E-07	2.0E-07	1.9E-07	1.8E-07	1.7E-07
S	(180.0°)	1.5E-09	3.8E-08	1.1E-07	1.6E-07	1.9E-07	1.9E-07	1.9E-07	1.8E-07	1.7E-07	1.6E-07
SSW	(202.5°)	2.0E-09	5.7E-08	1.5E-07	2.2E-07	2.6E-07	2.7E-07	2.6E-07	2.4E-07	2.3E-07	2.1E-07
SW	(225.0°)	2.7E-09	8.7E-08	2.5E-07	3.6E-07	4.2E-07	4.3E-07	4.1E-07	3.9E-07	3.6E-07	3.4E-07
WSW	(247.5°)	3.7E-09	1.3E-07	3.4E-07	4.9E-07	5.7E-07	5.8E-07	5.6E-07	5.3E-07	4.9E-07	4.6E-07
W	(270.0°)	4.5E-09	1.4E-07	3.7E-07	5.3E-07	**6.0E-07**	6.1E-07	5.9E-07	5.6E-07	5.2E-07	4.8E-07
WNW	(292.5°)	4.6E-09	1.2E-07	3.0E-07	4.2E-07	4.8E-07	4.9E-07	4.7E-07	4.5E-07	4.2E-07	3.9E-07
NW	(315.0°)	5.0E-09	1.2E-07	2.7E-07	3.7E-07	4.1E-07	4.1E-07	3.9E-07	3.6E-07	3.3E-07	3.1E-07
NNW	(337.5°)	5.5E-09	1.1E-07	2.4E-07	3.1E-07	3.4E-07	3.4E-07	3.2E-07	3.0E-07	2.8E-07	2.6E-07

a. Shaded areas represent areas outside the boundary of the Pinellas Plant site or the Building 100 roof.
b. Bold box represents the onsite location with the highest dispersion factor.
c. Dispersion factors are based on the 1964–1973 meteorological data set.
d. The direction in degrees is for the center of each sector with north starting at 0° or 360°.

Table A-3. Atmospheric dispersion factors (s/m^3) for the Building 100 Main Stack, applicable 1981 through 1996 .[a,b,c]

Direction (Deg.)[d]		Distance from the Building 100 Main Stack, m									
		100	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
N	(0.0°)	1.7E-06	1.2E-06	9.6E-07	7.7E-07	6.3E-07	5.3E-07	4.6E-07	4.0E-07	3.5E-07	3.1E-07
NNE	(22.5°)	2.0E-06	1.4E-06	1.1E-06	8.4E-07	6.8E-07	5.6E-07	4.7E-07	4.1E-07	3.6E-07	3.2E-07
NE	(45.0°)	1.7E-06	1.3E-06	9.7E-07	7.7E-07	6.2E-07	5.1E-07	4.3E-07	3.8E-07	3.3E-07	3.0E-07
ENE	(67.5°)	2.1E-06	1.5E-06	1.1E-06	8.9E-07	7.0E-07	5.7E-07	4.8E-07	4.1E-07	3.6E-07	3.2E-07
E	(90.0°)	2.6E-06	1.8E-06	1.3E-06	1.0E-06	7.9E-07	6.4E-07	5.3E-07	4.5E-07	3.9E-07	3.4E-07
ESE	(112.5°)	2.2E-06	1.5E-06	1.1E-06	8.6E-07	7.0E-07	5.8E-07	4.9E-07	4.3E-07	3.8E-07	3.4E-07
SE	(135.0°)	2.1E-06	1.4E-06	1.0E-06	8.5E-07	7.1E-07	6.0E-07	5.3E-07	4.7E-07	4.3E-07	3.9E-07
SSE	(157.5°)	1.7E-06	1.1E-06	8.9E-07	7.1E-07	5.9E-07	5.0E-07	4.3E-07	3.8E-07	3.5E-07	3.2E-07
S	(180.0°)	1.8E-06	1.3E-06	9.9E-07	8.1E-07	6.7E-07	5.7E-07	4.9E-07	4.4E-07	3.9E-07	3.6E-07
SSW	(202.5°)	1.9E-06	1.4E-06	1.1E-06	8.9E-07	7.4E-07	6.3E-07	5.4E-07	4.8E-07	4.3E-07	3.9E-07
SW	(225.0°)	3.2E-06	2.3E-06	1.8E-06	1.5E-06	1.2E-06	1.1E-06	9.3E-07	8.2E-07	7.4E-07	6.7E-07
WSW	(247.5°)	**4.2E-06**	2.9E-06	2.3E-06	1.8E-06	1.5E-06	1.3E-06	1.1E-06	1.0E-06	9.1E-07	8.3E-07
W	(270.0°)	3.4E-06	2.4E-06	1.9E-06	1.5E-06	1.3E-06	1.1E-06	9.4E-07	8.3E-07	7.4E-07	6.8E-07
WNW	(292.5°)	3.0E-06	2.1E-06	1.7E-06	1.4E-06	1.1E-06	9.8E-07	8.5E-07	7.6E-07	6.9E-07	6.3E-07
NW	(315.0°)	2.9E-06	2.0E-06	1.6E-06	1.3E-06	1.0E-06	8.8E-07	7.6E-07	6.7E-07	5.9E-07	5.4E-07
NNW	(337.5°)	2.0E-06	1.5E-06	1.1E-06	9.0E-07	7.4E-07	6.2E-07	5.3E-07	4.6E-07	4.1E-07	3.7E-07

a. Shaded areas represent areas outside the boundary of the Pinellas Plant site or the Building 100 roof.
b. Bold box represents the onsite location with the highest dispersion factor.
c. Dispersion factors are based on the 1982–1990 meteorological data set
d. The direction in degrees is for the center of each sector with north starting at 0° or 360°.

Table A-4. Atmospheric dispersion factors (s/m^3) for the Building 100 Lab Stack, applicable 1965 through 1980 .[a,b,c]

Direction (Deg.)[d]		Distance from the Building 100 Lab Stack, m									
		100	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
N	(0.0°)	9.4E-08	1.1E-07	1.5E-07	2.3E-07	2.5E-07	2.6E-07	2.5E-07	2.4E-07	2.3E-07	2.1E-07
NNE	(22.5°)	1.8E-07	2.0E-07	1.8E-07	2.0E-07	2.1E-07	2.0E-07	1.9E-07	1.8E-07	1.7E-07	1.9E-07
NE	(45.0°)	2.2E-07	2.4E-07	2.8E-07	2.9E-07	2.8E-07	2.7E-07	2.5E-07	1.7E-07	1.6E-07	1.5E-07
ENE	(67.5°)	2.5E-07	3.5E-07	4.0E-07	**4.1E-07**	2.8E-07	2.6E-07	2.4E-07	2.2E-07	2.1E-07	1.9E-07
E	(90.0°)	2.7E-07	3.7E-07	**4.1E-07**	**4.1E-07**	3.9E-07	3.6E-07	3.3E-07	3.0E-07	2.8E-07	2.5E-07
ESE	(112.5°)	1.1E-07	1.8E-07	2.2E-07	2.4E-07	2.3E-07	2.2E-07	2.1E-07	1.9E-07	1.8E-07	1.7E-07
SE	(135.0°)	1.1E-07	1.8E-07	2.2E-07	2.2E-07	2.2E-07	2.1E-07	2.0E-07	1.9E-07	1.8E-07	1.7E-07
SSE	(157.5°)	9.2E-08	1.4E-07	1.9E-07	2.1E-07	2.2E-07	2.2E-07	2.1E-07	1.6E-07	1.5E-07	1.4E-07
S	(180.0°)	5.3E-08	1.1E-07	1.4E-07	1.7E-07	1.8E-07	1.8E-07	1.8E-07	1.7E-07	1.6E-07	1.4E-07
SSW	(202.5°)	3.2E-08	5.8E-08	1.0E-07	1.4E-07	1.6E-07	1.7E-07	1.7E-07	1.7E-07	1.6E-07	1.5E-07
SW	(225.0°)	1.5E-08	2.4E-08	6.0E-08	1.5E-07	2.0E-07	2.3E-07	2.4E-07	2.4E-07	2.3E-07	3.4E-07
WSW	(247.5°)	4.7E-09	3.3E-09	2.8E-08	1.4E-07	2.5E-07	3.3E-07	3.7E-07	5.0E-07	4.9E-07	4.7E-07
W	(270.0°)	1.8E-09	3.6E-14	2.9E-09	9.0E-08	2.8E-07	4.3E-07	5.0E-07	5.3E-07	5.3E-07	5.1E-07
WNW	(292.5°)	5.0E-09	0.0E+00	1.7E-09	7.7E-08	2.2E-07	3.4E-07	4.0E-07	4.2E-07	4.2E-07	4.1E-07
NW	(315.0°)	1.8E-08	3.2E-09	3.3E-08	1.2E-07	2.1E-07	2.7E-07	2.9E-07	3.5E-07	3.4E-07	3.2E-07
NNW	(337.5°)	4.7E-08	5.2E-08	1.1E-07	1.8E-07	2.4E-07	2.7E-07	2.7E-07	2.7E-07	2.6E-07	2.6E-07

a. Shaded areas represent areas outside the boundary of the Pinellas Plant site or the Building 100 roof.
b. Bold box represents the onsite location with the highest dispersion factor.
c. Dispersion factors are based on the 1964–1973 meteorological data set
d. The direction in degrees is for the center of each sector with north starting at 0° or 360°.

Table A-5. Atmospheric dispersion factors (s/m^3) for the Building 100 Lab Stack, applicable 1981 through 1995 .[a,b,c]

Direction (Deg.)[d]		Distance from the Building 100 Lab Stack, m									
		100	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
N	(0.0^o)	1.7E-07	1.9E-07	2.4E-07	2.6E-07	2.8E-07	2.7E-07	2.6E-07	2.4E-07	2.2E-07	2.1E-07
NNE	(22.5^o)	2.1E-07	3.0E-07	2.7E-07	2.8E-07	2.7E-07	2.5E-07	2.3E-07	2.1E-07	1.9E-07	1.9E-07
NE	(45.0^o)	2.6E-07	3.2E-07	3.3E-07	3.2E-07	3.0E-07	2.7E-07	2.5E-07	2.0E-07	1.8E-07	1.7E-07
ENE	(67.5^o)	2.8E-07	3.5E-07	**3.6E-07**	3.5E-07	2.9E-07	2.6E-07	2.4E-07	2.2E-07	2.0E-07	1.8E-07
E	(90.0^o)	2.9E-07	3.5E-07	**3.6E-07**	3.5E-07	3.2E-07	2.9E-07	2.6E-07	2.4E-07	2.1E-07	2.0E-07
ESE	(112.5^o)	1.8E-07	2.5E-07	2.7E-07	2.7E-07	2.6E-07	2.4E-07	2.2E-07	2.1E-07	1.9E-07	1.8E-07
SE	(135.0^o)	1.7E-07	2.4E-07	2.7E-07	2.5E-07	2.5E-07	2.4E-07	2.3E-07	2.1E-07	2.0E-07	1.9E-07
SSE	(157.5^o)	1.6E-07	1.9E-07	2.3E-07	2.5E-07	2.5E-07	2.4E-07	2.3E-07	1.9E-07	1.8E-07	1.7E-07
S	(180.0^o)	9.4E-08	1.6E-07	1.9E-07	2.1E-07	2.2E-07	2.2E-07	2.1E-07	1.9E-07	1.8E-07	2.0E-07
SSW	(202.5^o)	6.4E-08	9.8E-08	1.5E-07	2.4E-07	2.6E-07	2.6E-07	2.5E-07	2.4E-07	2.2E-07	2.1E-07
SW	(225.0^o)	3.5E-08	4.8E-08	1.3E-07	2.4E-07	2.9E-07	3.0E-07	3.0E-07	2.8E-07	2.7E-07	4.1E-07
WSW	(247.5^o)	1.3E-08	1.1E-08	6.9E-08	2.7E-07	4.0E-07	4.7E-07	4.9E-07	5.8E-07	5.5E-07	5.2E-07
W	(270.0^o)	5.6E-09	2.8E-13	1.2E-08	1.9E-07	3.6E-07	4.6E-07	5.0E-07	4.9E-07	4.7E-07	4.4E-07
WNW	(292.5^o)	8.3E-09	0.0E+00	5.7E-09	1.4E-07	3.1E-07	4.0E-07	4.3E-07	4.3E-07	4.1E-07	3.9E-07
NW	(315.0^o)	2.7E-08	9.6E-09	5.8E-08	1.8E-07	2.7E-07	3.0E-07	3.0E-07	4.0E-07	3.8E-07	3.5E-07
NNW	(337.5^o)	1.0E-07	1.0E-07	1.6E-07	2.1E-07	2.5E-07	2.6E-07	2.5E-07	2.4E-07	2.3E-07	2.4E-07

a. Shaded areas represent areas outside the boundary of the Pinellas Plant site or the Building 100 roof.
b. Bold box represents the onsite location with the highest dispersion factor.
c. Dispersion factors are based on the 1982–1990 meteorological data set
d. The direction in degrees is for the center of each sector with north starting at 0^o or 360^o.

Table A-6. Atmospheric dispersion factors (s/m^3) for the Building 800 Stack, applicable 1997 .[a,b,c]

Direction (Deg.)[d]		Distance from the Building 800 Stack, m									
		100	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
N	(0.0°)	4.6E-06	4.3E-06	3.3E-06	2.4E-06	1.9E-06	1.5E-06	1.3E-06	1.0E-06	9.3E-07	7.9E-07
NNE	(22.5°)	4.3E-06	3.4E-06	2.7E-06	2.1E-06	1.8E-06	1.5E-06	1.1E-06	1.1E-06	8.7E-07	7.0E-07
NE	(45.0°)	4.0E-06	2.9E-06	2.5E-06	1.9E-06	1.5E-06	1.3E-06	1.1E-06	8.8E-07	8.6E-07	7.3E-07
ENE	(67.5°)	3.7E-06	2.7E-06	2.0E-06	1.7E-06	1.4E-06	1.1E-06	1.0E-06	8.8E-07	7.2E-07	6.9E-07
E	(90.0°)	3.4E-06	2.6E-06	1.9E-06	1.5E-06	1.3E-06	1.0E-06	8.7E-07	8.1E-07	6.6E-07	6.0E-07
ESE	(112.5°)	4.3E-06	3.4E-06	2.6E-06	2.0E-06	1.9E-06	1.5E-06	1.2E-06	1.2E-06	9.7E-07	8.8E-07
SE	(135.0°)	4.9E-06	3.5E-06	2.6E-06	3.3E-06	2.9E-06	2.1E-06	2.1E-06	1.8E-06	1.4E-06	1.4E-06
SSE	(157.5°)	5.2E-06	5.0E-06	4.1E-06	3.6E-06	2.7E-06	2.5E-06	2.2E-06	1.3E-06	1.4E-06	1.2E-06
S	(180.0°)	7.6E-06	5.5E-06	3.9E-06	2.9E-06	2.6E-06	2.3E-06	1.7E-06	1.7E-06	1.5E-06	1.3E-06
SSW	(202.5°)	7.3E-06	6.1E-06	4.2E-06	4.2E-06	3.3E-06	2.6E-06	2.4E-06	1.9E-06	1.7E-06	1.6E-06
SW	(225.0°)	8.5E-06	5.8E-06	6.7E-06	4.9E-06	4.2E-06	3.5E-06	2.6E-06	2.3E-06	2.0E-06	2.6E-06
WSW	(247.5°)	1.2E-05	1.2E-05	7.9E-06	1.2E-05	8.1E-06	6.6E-06	5.3E-06	5.2E-06	4.3E-06	4.0E-06
W	(270.0°)	1.0E-05	**1.9E-05**	2.8E-05	1.5E-05	9.4E-06	7.1E-06	5.4E-06	4.3E-06	4.0E-06	3.1E-06
WNW	(292.5°)	8.2E-06	1.5E-05	1.6E-05	1.1E-05	9.1E-06	6.5E-06	5.0E-06	4.0E-06	3.6E-06	2.8E-06
NW	(315.0°)	7.3E-06	7.7E-06	6.0E-06	5.1E-06	3.7E-06	3.0E-06	2.3E-06	2.8E-06	2.3E-06	2.1E-06
NNW	(337.5°)	5.8E-06	5.2E-06	4.0E-06	3.3E-06	2.6E-06	2.0E-06	1.6E-06	1.4E-06	1.1E-06	1.2E-06

a. Shaded areas represent areas outside the boundary of the Pinellas Plant site.
b. Bold box represents the onsite location with the highest dispersion factor.
c. Dispersion factors are based on the 1982–1990 meteorological data set
d. The direction in degrees is for the center of each sector with north starting at 0° or 360°.

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Table A-7. Summary of maximum atmospheric dispersion factors for Pinellas Plant stacks.[a]

Stack Id	Applicable Years	Maximum Dispersion Factor (s/m^3)
Bldg. 100 - Main Stack	1957–1980	6.0E-07
	1981–1996	4.2E-06
Bldg. 100 - Lab Stack	1965–1980	4.1E-07
	1981–1995	3.6E-07
Building 800 Stack	1997	1.9E-05

a. Summarized from Tables A-2 through A-6.

During the years when either of the two Building 100 stacks were operating, the highest atmospheric dispersion factors amongst the two stacks were selected to represent all of the stacks for a given period as a favorable to claimant simplification. The Building 100 Main Stack was the only emission point from 1957 through 1964. The Main Stack also had a larger dispersion factor than the Building 100 Lab Stack during the years that both stacks were operating because of lower stack gas exit velocities and a larger stack cross-sectional area. The shortening of the 100 Main Stack in 1981 also contributed to its dispersion factor being greater than the Building 100 Lab Stack after 1980. During the years of 1980–1996, the Building 800 Stack had higher atmospheric dispersion factors than the Building 100 stacks. However, releases from the Main Stack and the Lab Stack accounted for over 98% of the total radioactive airborne effluents during the years of 1980–1996, and greater than 99% of the HTO released (ORAUT 2011b). During the period of 1980–1996, the Building 800 Stack accounted for less than 2% of total airborne radioactivity released and less than 1% of the total HTO released (ORAUT 2011b). All other sources of atmospheric releases (i.e., Building 200 and roof openings) were negligible contributors and accounted for significantly less than 0.1% of the total radioactivity released during the period of 1980–1996 (ORAUT 2011b). The Building 800 Stack dispersion is overestimated (i.e., the dispersion factor is underestimated) for the period of 1980–1996 by using the Main Stack dispersion factors. However, use of the Main Stack dispersion factors for 1980–1996 underestimates the overall dispersion (i.e., the dispersion for all stacks) by a factor of about 1.5 for this period. The underestimate of the dispersion for the Building 100 Lab Stack releases more than compensates for the overestimate of dispersion for the Building 800 Stack releases, which are relatively small compared to the Building 100 Lab Stack releases. Table A-8 shows the atmospheric dispersion factors that were used for the internal and external environmental dose calculations.

Table A-8. Atmospheric dispersion factors used for Pinellas Plant stack releases.

Applicable Years	Dispersion Factor Used (s/m^3)
1957–1980	6.0E-07
1981–1996	4.2E-06
1997	1.9E-05

A-5 Atmospheric Dispersion Factors for Area Sources

Atmospheric dispersion factors were also calculated for area sources at the Pinellas Plant, namely the east retention pond, west retention pond, and aeration area located across the northern half of the site (see Figure 4-1). As discussed in Section 4.3.4, the ponds and aeration area were active from about 1971 through November 1982. After this, the active aeration was discontinued but the plant continued to use the ponds, which contained trace amounts of tritium for collecting stormwater runoff. The methods used to calculate the dispersion factors were similar to those described for the stacks. A unit release of 1 Curie per second (Ci/s) of tritium oxide (HTO) was modeled from an area source of approximately 6,250 m^2 (≈ 50 m x 125 m) for the east retention pond, 5,080 m^2 (≈ 35 m x 145 m) for the west retention pond, and 30,800 m^2 (≈ 140 m x 220 m) for the aeration area. Tritium gas was not considered for these airborne emissions sources because they would have only contained tritiated water. The area sources were modeled as chronic ground level releases using Pasquill-Gifford atmospheric stability without enhanced dispersion since no buildings were adjacent to these sources. Only the 1982–1990 meteorological data file was used to generate dispersion factors for the area sources because all of the monitoring data was outside of the date range for the other meteorological data file and because the differences between the atmospheric dispersion factors generated by each meteorological data set were small.

Results of the area source calculations are presented in Tables A-9 through A-11 as X/Q atmospheric dispersion factors with units of seconds per cubic meter (s/m^3). Atmospheric dispersion factors were developed for the west retention pond and aeration area. However, at the time this TBD was issued, there was no source term information available for the period that these two area sources were used as part of the site's liquid effluent discharge system. Therefore, these dispersion factors are not currently being used for any calculations and were only developed in the event that sufficient information is found in the future to facilitate their use.

Table A-9. Atmospheric dispersion factors (s/m^3) for the east retention pond, applicable 1971 through 1997 .[a,b,c]

Direction (Deg.)[d]		Distance from the center of the East Retention Pond, m									
		100	200	300	400	500	600	700	800	900	1000
N	(0.0^o)	3.7E-05	2.0E-05	9.4E-06	5.5E-06	3.6E-06	2.6E-06	1.9E-06	1.4E-06	1.2E-06	1.2E-06
NNE	(22.5^o)	3.2E-05	1.7E-05	8.0E-06	4.8E-06	3.1E-06	2.2E-06	1.6E-06	1.3E-06	1.0E-06	1.0E-06
NE	(45.0^o)	3.7E-05	2.0E-05	9.4E-06	5.5E-06	3.6E-06	2.6E-06	1.9E-06	1.5E-06	1.2E-06	1.2E-06
ENE	(67.5^o)	3.6E-05	1.9E-05	8.5E-06	5.3E-06	3.4E-06	2.5E-06	1.8E-06	1.4E-06	1.2E-06	1.2E-06
E	(90.0^o)	3.3E-05	1.8E-05	8.4E-06	4.9E-06	3.2E-06	2.3E-06	1.7E-06	1.4E-06	1.1E-06	1.1E-06
ESE	(112.5^o)	4.9E-05	2.7E-05	1.3E-05	7.5E-06	4.9E-06	3.5E-06	2.6E-06	2.0E-06	1.6E-06	1.6E-06
SE	(135.0^o)	7.2E-05	4.1E-05	2.0E-05	1.1E-05	7.5E-06	5.3E-06	4.0E-06	3.2E-06	2.6E-06	2.6E-06
SSE	(157.5^o)	5.7E-05	3.2E-05	1.5E-05	9.4E-06	6.0E-06	4.2E-06	3.2E-06	2.5E-06	2.0E-06	2.0E-06
S	(180.0^o)	6.3E-05	3.6E-05	1.7E-05	1.0E-05	6.5E-06	4.6E-06	3.4E-06	2.7E-06	2.2E-06	2.2E-06
SSW	(202.5^o)	6.3E-05	3.5E-05	1.6E-05	9.4E-06	6.4E-06	4.5E-06	3.4E-06	2.6E-06	2.1E-06	2.1E-06
SW	(225.0^o)	1.0E-04	6.0E-05	2.8E-05	1.6E-05	1.1E-05	7.7E-06	5.7E-06	4.5E-06	3.7E-06	3.7E-06
WSW	(247.5^o)	**1.3E-04**	7.3E-05	3.5E-05	2.0E-05	1.4E-05	9.4E-06	7.2E-06	5.6E-06	4.5E-06	4.5E-06
W	(270.0^o)	1.0E-04	5.7E-05	2.7E-05	1.6E-05	1.0E-05	7.4E-06	5.5E-06	4.3E-06	3.5E-06	3.5E-06
WNW	(292.5^o)	9.4E-05	5.2E-05	2.5E-05	1.4E-05	9.4E-06	6.7E-06	5.0E-06	3.9E-06	3.2E-06	3.2E-06
NW	(315.0^o)	6.6E-05	3.7E-05	1.7E-05	1.0E-05	6.6E-06	4.7E-06	3.5E-06	2.7E-06	2.2E-06	2.2E-06
NNW	(337.5^o)	4.3E-05	2.4E-05	1.1E-05	6.5E-06	4.3E-06	3.0E-06	2.2E-06	1.8E-06	1.4E-06	1.4E-06

a. Shaded areas represent areas outside the boundary of the Pinellas Plant site. Cross-hatched areas are portions of the sector that are completely obstructed by Building 100, and the onsite dispersion factors in those areas are likely significant overestimates.
b. Bold box represents the onsite location with the highest dispersion factor.
c. Dispersion factors are based on the 1982–1990 meteorological data set. The applicable period for this pond is through 1997 because it likely contained tritium contaminated water through the end of the site's covered employment.
d. The direction in degrees is for the center of each sector with north starting at 0^o or 360^o.

Table A-10. Atmospheric dispersion factors (s/m^3) for the west retention pond, applicable 1973 through 1997 .[a,b,c]

Direction (Deg.)[d]		Distance from the center of the West Retention Pond, m									
		100	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
N	(0.0^o)	4.0E-05	2.0E-05	9.2E-06	5.4E-06	3.6E-06	2.5E-06	1.9E-06	1.5E-06	1.2E-06	9.8E-07
NNE	(22.5^o)	3.5E-05	1.7E-05	8.0E-06	4.7E-06	3.1E-06	2.2E-06	1.6E-06	1.3E-06	1.0E-06	8.5E-07
NE	(45.0^o)	4.1E-05	2.0E-05	9.3E-06	5.5E-06	3.6E-06	2.5E-06	1.9E-06	1.5E-06	1.2E-06	9.9E-07
ENE	(67.5^o)	4.0E-05	1.9E-05	8.9E-06	5.3E-06	3.4E-06	2.4E-06	1.8E-06	1.4E-06	1.2E-06	9.5E-07
E	(90.0^o)	3.7E-05	1.8E-05	8.4E-06	5.0E-06	3.2E-06	2.3E-06	1.7E-06	1.4E-06	1.1E-06	9.0E-07
ESE	(112.5^o)	5.3E-05	2.7E-05	1.3E-05	7.5E-06	4.9E-06	3.5E-06	2.6E-06	2.0E-06	1.6E-06	1.4E-06
SE	(135.0^o)	7.9E-05	4.1E-05	1.9E-05	1.1E-05	7.4E-06	5.3E-06	4.0E-06	3.1E-06	2.5E-06	2.1E-06
SSE	(157.5^o)	6.3E-05	3.2E-05	1.5E-05	9.0E-06	5.9E-06	4.2E-06	3.1E-06	2.5E-06	2.0E-06	1.6E-06
S	(180.0^o)	6.9E-05	3.5E-05	1.7E-05	9.8E-06	6.4E-06	4.6E-06	3.4E-06	2.7E-06	2.2E-06	1.8E-06
SSW	(202.5^o)	6.9E-05	3.5E-05	1.7E-05	9.7E-06	6.4E-06	4.5E-06	3.4E-06	2.7E-06	2.1E-06	1.8E-06
SW	(225.0^o)	1.2E-04	5.9E-05	2.8E-05	1.6E-05	1.1E-05	7.6E-06	5.7E-06	4.5E-06	3.6E-06	3.0E-06
WSW	(247.5^o)	**1.4E-04**	7.3E-05	3.5E-05	2.0E-05	1.3E-05	9.5E-06	7.1E-06	5.6E-06	4.5E-06	3.7E-06
W	(270.0^o)	1.1E-04	5.7E-05	2.7E-05	1.6E-05	1.0E-05	7.4E-06	5.5E-06	4.3E-06	3.5E-06	2.9E-06
WNW	(292.5^o)	1.0E-04	5.2E-05	2.4E-05	1.4E-05	9.4E-06	6.7E-06	5.0E-06	3.9E-06	3.2E-06	2.6E-06
NW	(315.0^o)	7.3E-05	3.6E-05	1.7E-05	1.0E-05	6.6E-06	4.7E-06	3.5E-06	2.7E-06	2.2E-06	1.8E-06
NNW	(337.5^o)	4.8E-05	2.3E-05	1.1E-05	6.5E-06	4.2E-06	3.0E-06	2.2E-06	1.8E-06	1.4E-06	1.2E-06

a. Shaded areas represent areas outside the boundary of the Pinellas Plant site. Cross-hatched areas are portions of the sector that are completely obstructed by Building 100, and the onsite dispersion factors in those areas are likely significant overestimates.
b. Bold box represents the onsite location with the highest dispersion factor.
c. Dispersion factors are based on the 1982–1990 meteorological data set. The applicable period for this pond is through 1997 because it likely contained tritium contaminated water through the end of the site's covered employment.
d. The direction in degrees is for the center of each sector with north starting at 0^o or 360^o.

Table A-11. Atmospheric dispersion factors (s/m^3) for the aeration area, applicable 1973 through 1982.[a,b,c]

Direction (Deg.)[d]		Distance from the center of the Aeration Area, m									
		100	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
N	(0.0^o)	1.8E-05	9.7E-06	6.8E-06	5.4E-06	3.8E-06	2.7E-06	2.0E-06	1.6E-06	1.3E-06	1.0E-06
NNE	(22.5^o)	1.6E-05	8.5E-06	5.9E-06	4.6E-06	3.3E-06	2.3E-06	1.7E-06	1.4E-06	1.1E-06	9.0E-07
NE	(45.0^o)	1.8E-05	9.8E-06	6.9E-06	5.4E-06	3.8E-06	2.7E-06	2.0E-06	1.6E-06	1.3E-06	1.1E-06
ENE	(67.5^o)	1.8E-05	9.5E-06	6.6E-06	5.2E-06	3.7E-06	2.6E-06	1.9E-06	1.5E-06	1.2E-06	1.0E-06
E	(90.0^o)	1.7E-05	8.9E-06	6.2E-06	4.9E-06	3.4E-06	2.4E-06	1.8E-06	1.4E-06	1.2E-06	9.5E-07
ESE	(112.5^o)	2.4E-05	1.3E-05	9.2E-06	7.3E-06	5.3E-06	3.7E-06	2.8E-06	2.2E-06	1.8E-06	1.5E-06
SE	(135.0^o)	3.4E-05	2.0E-05	1.4E-05	1.1E-05	8.0E-06	5.7E-06	4.3E-06	3.3E-06	2.7E-06	2.2E-06
SSE	(157.5^o)	2.7E-05	1.6E-05	1.1E-05	8.8E-06	6.4E-06	4.5E-06	3.4E-06	2.6E-06	2.1E-06	1.8E-06
S	(180.0^o)	3.0E-05	1.7E-05	1.2E-05	9.5E-06	6.9E-06	4.9E-06	3.7E-06	2.9E-06	2.3E-06	1.9E-06
SSW	(202.5^o)	3.1E-05	1.7E-05	1.2E-05	9.5E-06	6.8E-06	4.9E-06	3.6E-06	2.8E-06	2.3E-06	1.9E-06
SW	(225.0^o)	5.2E-05	2.9E-05	2.0E-05	1.6E-05	1.2E-05	8.2E-06	6.1E-06	4.8E-06	3.9E-06	3.2E-06
WSW	(247.5^o)	**6.4E-05**	3.5E-05	2.5E-05	2.0E-05	1.4E-05	1.0E-05	7.6E-06	6.0E-06	4.8E-06	4.0E-06
W	(270.0^o)	5.0E-05	2.8E-05	2.0E-05	1.5E-05	1.1E-05	7.9E-06	5.9E-06	4.7E-06	3.8E-06	3.1E-06
WNW	(292.5^o)	4.5E-05	2.5E-05	1.8E-05	1.4E-05	1.0E-05	7.2E-06	5.4E-06	4.2E-06	3.4E-06	2.8E-06
NW	(315.0^o)	3.3E-05	1.8E-05	1.3E-05	9.9E-06	7.1E-06	5.0E-06	3.8E-06	2.9E-06	2.4E-06	2.0E-06
NNW	(337.5^o)	2.2E-05	1.2E-05	8.1E-06	6.4E-06	4.5E-06	3.2E-06	2.4E-06	1.9E-06	1.5E-06	1.2E-06

a. Shaded areas represent areas outside the boundary of the Pinellas Plant site. Cross-hatched areas are portions of the sector that are completely obstructed by Building 100, and the onsite dispersion factors in those areas are likely significant overestimates.
b. Bold box represents the onsite location with the highest dispersion factor.
c. Dispersion factors are based on the 1982–1990 meteorological data set. Also, the applicable years of the aeration area are limited through 1982, because the source term only existed as potentially contaminated soil after 1982 and because structures were later placed over portions of this source term (see Figure 4-1).
d. The direction in degrees is for the center of each sector with north starting at 0^o or 360^o.

A-6 Atmospheric Dispersion at Tritium Monitoring Station Locations

The summarized annual tritium monitoring data presented in Table 4-5 for the period of 1975–1992 provided an opportunity to compare the tritium air concentrations predicted by the atmospheric dispersion modeling to the annual average tritium air concentrations that were measured at several locations on the site. To do this comparison, separate sets of atmospheric dispersion factors were calculated for the distances and directions from each source term to each tritium air monitoring station (i.e., Stations 1–6 in Figure 4-1). Table A-12 presents the calculated atmospheric dispersion factors associated with each source term for each of the six tritium air monitoring stations. The dispersion factors from the area sources have been reduced by a factor of 10 to qualitatively account for building wake effects as the plumes travel through the plant to the monitoring station locations.

Table A-12. Atmospheric dispersion factors at the six tritium monitoring station locations (s/m^3).[a]

Type of source	Source name	Tritium Air Monitoring Stations					
		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Point sources	Bldg. 100 Main Stack	9.4E-07	7.8E-07	8.0E-07	1.2E-06	1.6E-06	2.1E-06
	Bldg. 100 Lab Stack	1.7E-07	2.6E-07	3.0E-07	3.5E-07	2.7E-07	3.6E-08
	Bldg. 800 Stack	4.0E-06	3.0E-06	1.4E-06	1.4E-06	2.8E-06	7.2E-06
Area sources[b]	east retention pond	8.5E-06	1.9E-05	9.4 E-05	2.6E-05	7.5E-07	8.3E-07
	west retention pond	9.8 E-05	1.1E-05	2.2E-06	3.0E-06	4.5E-07	9.6E-07
	aeration area	2.70E-05	2.9E-05	4.9E-06	6.4E-06	5.9E-07	9.5E-07

a. Dispersion factors are based on the 1982–1990 meteorological data set.
b. The shaded areas identify area source dispersion factors that have been reduced by a factor of 10 to qualitatively account for building wake effects during plume transport.

The release of tritium from the effluent ponds and aeration area represent a confounding factor for the period of their operation (until November 1982) and for an unknown period afterward, as tritium levels in the ponds were gradually reduced due to natural removal mechanisms (e.g. radioactive decay, evaporation, dilution by rain and stormwater run-off, etc…) and discharges from the ponds. The dispersion factors in Table A-12 indicate that the area sources could be a significant contributor to the onsite tritium air concentrations. However, at the time this TBD was issued, there was not enough information available to develop a reasonable estimate of the tritium release rates for the area sources. Therefore, the contributions of the area sources to the tritium air concentrations have not been factored into the predicted air concentrations that were calculated. Because the tritium associated with the area sources would have been limited to HTO, the HT concentrations should not have been influenced by the area sources. As a result, the HT concentrations should only be attributable to the stack releases.

Annual average HT and HTO air concentrations were predicted for each calendar year and for each air monitoring station location by multiplying each stack's annual HT and HTO releases by the appropriate dispersion factors. The annual air concentrations produced by each stack were then summed into the predicted HT and HTO air concentrations for each air monitoring station location. Ratios of the predicted air concentrations to the measured air concentrations were then calculated for each calendar year and each air monitoring station location. When the measured tritium results were reported as being less than, "<", a certain value, the "<" symbol was disregarded. This approach for dealing with the less than values potentially causes the predicted-to-measured ratios to be lower than they actually were. For example, when the predicted air concentration is 4×10^{-12} µCi/mL and the measured air concentration is $< 8 \times 10^{-12}$ µCi/mL, a ratio of 0.5 would be calculated even though the

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ratio is potentially 1.0. Because the predicted value is below the reported less than value, the two numbers are still potentially in agreement. The closer that a predicted-to-measured ratio is to 1.00 the better the predicted air concentrations agree with the measured air concentrations. Ratios that are less than 1.00 indicate that the predicted air concentrations are being underestimated and ratios greater than 1.00 indicate that the predicted air concentrations are being overestimated.

Table A-13 shows the annual average ratio of predicted to measured HT concentrations at the six monitoring stations for the years 1975 through 1992. The monitoring station statistics are shown at the bottom of the table.

Table A-13. Ratio of predicted-to-measured tritium gas (HT) concentrations at the tritium air monitoring stations .[a]

Year	Tritium Air Monitoring Stations						Yearly average[b]
	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	
1975	NA[c]	0.51	NA	0.09	0.39	0.35	0.34
1976	0.55	0.35	0.12	0.66	0.05	1.28	0.50
1977	0.35	0.39	0.29	0.13	0.36	0.54	0.34
1978	0.62	0.66	1.52	0.85	0.94	1.15	0.96
1979	0.66	0.65	0.79	1.53	0.73	0.49	0.81
1980	0.80	0.51	0.76	0.72	1.37	0.43	0.77
1981	0.79	0.58	0.46	1.12	0.66	0.34	0.66
1982[d]	0.50	0.88	0.91	0.84	1.58	0.78	0.91
1983	1.00	0.21	1.66	2.67	0.52	1.21	1.21
1984	0.31	0.15	0.84	1.00	0.86	0.43	0.60
1985	0.40	0.54	0.60	0.19	0.33	0.25	0.39
1986	0.11	0.11	0.11	0.24	0.12	0.21	0.15
1987	NA	NA	NA	NA	NA	NA	---
1988	0.23	0.02[e]	0.06	0.08	0.26	1.11	0.29
1989	0.18	1.41	0.29	2.22	0.06	0.06	0.71
1990	0.16	0.22	0.12	0.30	0.12	0.14	0.18
1991	0.09	0.11	0.21	0.15	0.07	0.06	0.11
1992	NR[f]	NR	NR	NR	NR	NR	---
Average	0.45	0.46	0.58	0.80	0.53	0.55	**0.56**
Std. dev.	0.28	0.35	0.50	0.78	0.47	0.42	0.32
Minimum	0.09	0.02	0.06	0.08	0.05	0.06	
Maximum	1.00	1.41	1.66	2.67	1.58	1.28	

a. Source: ORAUT 2011h; The underlined ratios indicate that the annual average air concentration was reported as a less than value, and that the predicted-to-measured ratio may be underestimated. Sixty-three of the ninety-four HT results (67%) in Table 4-5 were reported as less than values.
b. The yearly average is the average ratio for all monitoring stations for a given year.
c. NA - not available, no air monitoring data was available for either this location or this year.
d. After 1982, liquid effluent discharges to the area sources ceased, and the contribution to the airborne HTO concentrations attributable to the areas sources would be expected to decrease after 1982.
e. Significant data outlier.
f. NR - not reported, only total tritium air concentrations were reported for this year and all tritium was assumed to be HTO.

These statistics indicate that the predicted HT air concentrations at the various stations are underestimated by somewhat less than a factor of 1.79 (1/0.56), across the entire period. The main difference for HT during these years was that the stack releases of HT were significantly higher from 1975 through 1985. Prediction of HT concentrations would be expected to be better when higher activities of HT were released, resulting in greater concentrations to be detected at the monitoring stations. In addition, the underestimate of the HT air concentrations is likely smaller than a factor of 1.79 and much closer to a factor of 1.00, if the less than values for the measured results were accounted for in the comparison. Regardless of this unfavorable bias, the comparison indicates that the model is reasonably effective in predicting HT air concentrations.

Table A-14 presents the same type of predicted-to-measured ratios for HTO air concentrations. Overall, the statistics indicate that the predicted HTO air concentrations at the various stations are underestimated by somewhat less than a factor of 2.33 (1/0.43), across the entire period. The emissions from the area sources during 1975–1982 were expected to contribute significantly to measured HTO air concentrations. However, the average predicted-to-measured ratio is actually better during these years than during later years when the ponds and aeration area were no longer being used as part of the site's liquid effluent system. This is counterintuitive, because the predicted-to-measured ratios were expected to increase to values closer to 1.00 after 1982. Apparently the area sources were not as significant contributors to the onsite HTO air concentrations as originally hypothesized. Based on this analysis, the onsite tritium air concentrations appear to be dominated by the annual tritium releases from the stacks. As was the case for HT, the stack releases of HTO were much higher from 1975 through 1986, and prediction of HTO concentrations would be expected to be better when higher activities of HTO were released. In addition, the underestimate of the HT air concentrations is likely smaller than a factor of 2.33 and much closer to a factor of 1.00 if the less than values for the measured results were accounted for in the comparison. Regardless of this unfavorable bias, the comparison indicates that the model is reasonably effective in predicting HTO air concentrations.

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Table A-14. Ratio of predicted-to-measured tritium oxide (HTO) concentrations at the tritium air monitoring stations .[a]

Year	Tritium Air Monitoring Stations						Yearly average[b]
	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	
1975	NA[c]	0.31	NA	0.20	0.50	0.41	0.35
1976	0.58	0.98	0.85	1.44	1.15	1.30	1.05
1977	0.39	0.43	0.41	0.45	0.43	0.57	0.45
1978	0.50	0.48	0.54	0.93	0.81	0.64	0.65
1979	0.39	0.51	0.64	0.26	0.68	0.52	0.50
1980	0.71	0.58	0.85	0.63	0.97	1.08	0.80
1981	0.27	0.30	0.56	0.48	0.56	0.46	0.44
1982[d]	0.21	0.32	0.58	0.34	0.31	0.30	0.34
1983	0.29	0.10	0.33	0.58	0.30	0.36	0.32
1984	0.29	0.13	0.39	0.31	0.46	0.16	0.29
1985	0.33	0.13	0.35	0.22	0.24	0.22	0.25
1986	0.22	0.11	0.42	0.15	0.34	0.26	0.25
1987	NA	NA	NA	NA	NA	NA	---
1988	0.36	0.01[e]	0.06	0.27	0.07	0.78	0.26
1989	0.12	0.18	0.11	0.30	0.27	0.19	0.20
1990	0.30	0.35	0.20	0.51	0.26	0.24	0.31
1991	0.72	0.46	0.84	0.81	0.36	0.16	0.56
1992[f]	0.24	0.55	0.43	0.24	0.13	0.15	0.29
Average	0.37	0.35	0.47	0.48	0.46	0.46	**0.43**
Std. dev.	0.17	0.24	0.24	0.33	0.29	0.33	0.23
Minimum	0.12	0.01	0.06	0.15	0.07	0.15	
Maximum	0.72	0.98	0.85	1.44	1.15	1.30	

a. Source: ORAUT 2011h; The underlined ratios indicate that the annual average air concentration was reported as a less than value, and that the predicted-to-measured ratio may be underestimated. Thirty-one of the 100 HTO results (31%) in Table 4-5 were reported as less than values.
b. The yearly average is the average ratio for all monitoring stations for a given year.
c. NA - not available, no air monitoring data was available for either this location or this year.
d. After 1982, liquid effluent discharges to the area sources ceased, and the contribution to the airborne HTO concentrations attributable to the areas sources would be expected to decrease after 1982.
e. Significant data outlier.
f. Only total tritium air concentrations were reported for this year and all tritium was assumed to be HTO.

A-7 Summary and Conclusions

Hourly meteorological data and Pinellas Plant-specific stack parameters were used to develop atmospheric dispersion factors for the Pinellas Plant. Knowledge of the type, time, and magnitude of the Pinellas Plant radionuclide releases was also used to determine a favorable to claimant set of three atmospheric dispersion factors that cover the entire operating period from 1957 through 1997. Release-point-specific information was not considered for minor release points as these would have

negligible impact on overall employee doses. Potential atmospheric contributions from surface water area sources were also considered.

Measured HT and HTO concentrations from six onsite tritium monitoring stations were used to validate the calculated atmospheric dispersion factors from stack releases. In general, the atmospheric dispersion factors were underestimated by less than a factor of 2.33, even though data presented as “less than” values and contributions from the surface water area sources were confounding factors. The comparisons indicated that the model is reasonably effective in predicting air concentrations based on the site’s stack releases.