THE CLEAN AIR ACT ASSESSMENT PACKAGE-1988
(CAP-88)
A DOSE AND RISK ASSESSMENT METHODOLOGY FOR RADIONUCLIDE EMISSIONS TO AIR

VOLUME 1

USER'S MANUAL

Prepared By:

Deborah A. Beres
SC&A, Inc.
1311 Dolley Madison Blvd.
McLean, VA 22101

Contract No. 68-D9-0170
Work Assignment 1-28

Prepared For:

U.S. Environmental Protection Agency
Office of Radiation Programs
401 M Street, S.W.
Washington, D.C. 20460

Larry Gray
Work Assignment Manager

October 1990

CONTENTS

LIST OF TABLES ii

LIST OF FIGURES iii

1. INTRODUCTION 1-1
1.1 ENVIRONMENTAL TRANSPORT 1-1
1.2 ESTIMATION OF DOSE AND RISK 1-1
1.3 LIMITATIONS OF THE CAP-88 METHODOLOGY 1-2
1.4 VERIFICATION OF THE CAP-88 METHODOLOGY 1-2
1.5 REFERENCES FOR PROGRAMS INCLUDED IN CAP-88 1-3

2. HARDWARE/SOFTWARE REQUIREMENTS 2-1

3. CAP-88 PACKAGE CONTENTS 3-1

4. RUNNING THE CAP-88 PACKAGE 4-1
4.1 PREPAR/AIRDOS-EPA INPUT DATA 4-1
4.2 PREDA/DARTAB INPUT DATA 4-30
4.3 IMPORTANT DIFFERENCES BETWEEN CAP-88 AND EARLIER VERSIONS OF AIRDOS-EPA 4-39

5. CAP-88 OUTPUT 5-1

6. BACKGROUND INFORMATION AND AIDS TO THE USER 6-1

6.1 EPA ENVIRONMENTAL PATHWAY MODELING ASSUMPTIONS 6-1
6.2 CALCULATION OF Q_H FOR PLUME RISE 6-11
6.3 POPULATION CENSUS FILES 6-11
6.4 STABILITY ARRAYS 6-12
6.5 CALCULATION OF DAUGHTER INGROWTH FACTORS 6-16

7. REFERENCES 7-1

APPENDIX A: AIRDOS-EPA (AIRDOS2.FOR) PROGRAM FILE

APPENDIX B: PREPAR (PREPAR2.FOR) PROGRAM FILE

APPENDIX C: DARTAB (DARTAB2.FOR) PROGRAM FILE

APPENDIX D: PREDA (PREDA.FOR) PROGRAM FILE

APPENDIX E: SAMPLE.JCL FILE

APPENDIX F: ALLRAD88 DATA FILE

APPENDIX G: SAMPLE PREPAR INPUT ARRAY

APPENDIX H: PRDPOP PROGRAM FILE

APPENDIX I: SAMPLE CAP-88 OUTPUT FILES

CONTENTS
(continued)

APPENDIX J: SAMPLE.SYNOPSIS FILES

APPENDIX K: SECPOP PROGRAM FILES

APPENDIX L: AVAILABLE STAR DATA SETS

APPENDIX M: CHAIN PROGRAM FILES

LIST OF TABLES

Table 3-1. Elements of CAP-88 3-2

Table 4-1. Run identification data 4-2

Table 4-2. Data type names and associated NAMELIST names used by PREPAR for scalar and vector variables 4-4

Table 4-3. Scalar and vector variable names along with default values and associated NAMELIST names 4-5

Table 4-4. Definitions of the PREPAR/AIRDOS-EPA options 4-12

Table 4-5. Input variables used in PREPAR/AIRDOS-EPA 4-14

Table 4-6. Input variables used in PREPAR. 4-23

Table 4-7. Data type names used by PREPAR for array input 4-27

Table 4-8. Definition of arrays input using PREPAR 4-28

Table 4-9. NAMELIST STAR variables 4-29

Table 4-10. Cattle densities and vegetable crop distributions for use with AIRDOS-EPA 4-31

Table 4-11. Valid PREDA NAMELIST and variable names 4-33

Table 4-12. Possible table types output by DARTAB 4-38

Table 6-1. Presumed sources of food for urban and rural sites 6-1

Table 6-2. AIRDOS-EPA parameters used for generic site assessments . . . 6-3

Table 6-3. Default values used for element dependent factors 6-5

Table 6-4. Fatal cancer risk factors for selected radionuclides 6-8

Table 6-5. Sample STAR data file 6-13

Table 6-6. JCL for creating STAR file from National Climatic Data Center data tapes 6-15

LIST OF FIGURES

Figure 3-1. CAP-88 program flow chart 3-4

1. INTRODUCTION

The Environmental Protection Agency's Office of Radiation Programs has developed a set of computer programs, databases, and associated utility programs that implements the mathematical model for assessing dose and risk due to radionuclide emissions to the air. The software, referred to as the Clean Air Act Assessment Package-1988 (CAP-88), estimates health impacts from the inhalation, ingestion, air immersion and ground surface irradiation pathways, and tabulates results for maximally exposed individuals and regional populations. Information is provided in a concise, easy-to-read format.

1.1 ENVIRONMENTAL TRANSPORT

The computer program that models environmental transport in CAP-88 is AIRDOS-EPA. The source file for AIRDOS-EPA has been named AIRDOS2.FOR on the magnetic tape. A listing of the program is presented in Appendix A.

This program uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six sources. The sources may be either elevated stacks, such as smokestacks, or uniform area sources, such as a pile of uranium mill tailings. Plume rises can be calculated assuming either a momentum-driven or buoyancy-driven plume. Assessments are done for a circular grid within a radius of 80 kilometers (50 miles) around the facility.

AIRDOS-EPA computes radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food, and intake rates to people from inhalation of air and ingestion of food produced in the assessment area. The radionuclide concentrations in produce, leafy vegetables, milk, and meat consumed by humans are estimated by coupling the output of the atmospheric transport models with the U.S. Nuclear Regulatory Guide 1.109 terrestrial food chain models (NRC77).

The computer program PREPAR is used to prepare the input data for AIRDOS-EPA. This is done to ensure proper formatting of the large arrays required for environmental transport calculations. These arrays include the agricultural productivity data, population distributions, and meteorological data. PREPAR also passes on information concerning the fraction of food assumed to be home-grown, taken from production within the 80-kilometer assessment area, and imported from outside the assessment area.

The source file for PREPAR has been named PREPAR2.FOR on the magnetic tape. A listing of the program is presented in Appendix B.

1.2 ESTIMATION OF DOSE AND RISK

Dose and risk factors are provided for the pathways of ingestion and inhalation intake, ground level air immersion, and ground surface irradiation. Factors are further broken down by particle size, solubility class, and digestion transfer factors. These factors were generated using the computer program RADRISK (ORNL80, ORNL81a) and stored in the RADRISK.BIN binary file.

RADRISK calculates organ dose factors for progeny using their own metabolic properties. For the progeny of lead-210 and bismuth-210, organ dose factors are included in RADRISK.BIN which were calculated, per the methodology in ICRP-30 (ICRP79), using the metabolic properties of the parent. Calculations use the ICRP organ dose factors for these progeny.

Dose and risk are estimated by the program DARTAB, which combines the inhalation and ingestion intake rates, and the air and ground surface concentrations output from AIRDOS-EPA with the dose and risk factors from the RADRISK database. DARTAB lists the dose and risk to the maximum individual, the average individual, and the collective population. Doses and risks are further tabulated as a function of radionuclide, pathway, location, and organ.

DARTAB also tabulates the number of people in each risk category as well as the number of health effects from each risk category. Risk categories represent the lifetime risk and are computed by powers of ten from one in ten (1E-1) to one in a million (1E-6).

The source file for DARTAB has been named DARTAB2.FOR on the magnetic tape. A listing of the program is presented in Appendix C.

The input data sets used by DARTAB are created using the computer program PREDA. The source file for PREDA has been named PREDA.FOR on the magnetic tape. A listing of the program is presented in Appendix D.

1.3 LIMITATIONS OF THE CAP-88 METHODOLOGY

There are some limitations in the mathematical dispersion models that are available in CAP-88.

While up to six stack or area sources can be modeled, all the sources are modeled as if co-located at the same point; that is, stacks or area sources cannot be located in different areas of a facility. No correction for the diffusion introduced by tip downwash can be made. Building wake can be accounted for by reducing the stack height (1 meter is recommended). Also, area sources are treated as uniform sources. Variation in radionuclide concentrations due to complex terrain cannot be modeled; all assessments assume a flat plane.

Errors arising from these assumptions will have a negligible effect in assessments where the distance to the exposed individuals is large compared to the stack height, area, or facility size.

1.4 VERIFICATION OF THE CAP-88 METHODOLOGY

The Gaussian plume model used in CAP-88 to estimate dispersion of radionuclides in air is one of the most commonly used models. Its results agree with experimental data as well as with results of other models, it is fairly easy to work with, and it is consistent with the random nature of turbulence.

The Office of Radiation Programs has compared predictions of annual-average ground-level concentration to actual environmental measurements and found very good agreement. In the recent paper "Comparison of AIRDOS-EPA Prediction of Ground-Level Airborne Radionuclide Concentrations to Measured Values," environmental monitoring data at five Department of Energy (DOE) sites were compared to AIRDOS-EPA predictions. EPA concluded that AIRDOS-EPA predictions are usually within a factor of two of actual concentrations.

1.5 REFERENCES FOR PROGRAMS INCLUDED IN CAP-88

The following references are available from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia, 22161. The phone number for NTIS is (703) 487-4650.

EPA 520/1-79-009	AIRDOS-EPA, A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides, December 1979.
ORNL/TM-7105	A Combined Methodology for Estimating Dose Rates and Health Effects from Exposures to Radioactive Pollutants, March 1980.
ORNL-5692/DE81030434	DARTAB, A Program to Combine Airborne Radionuclide Environmental Exposure Data with Dosimetric Health Effects Data to Generate Tabulations of Predicted Health Impact, August 1981.
ORNL-7745/DE82002486	Estimates of Health Risk from Exposure to Radioactive Pollutants, November 1981.
ORNL-5952/DE84016731	PREPAR, A User-Friendly Preprocessor to Create AIRDOS-EPA Input Data Sets, August 1984.

2. HARDWARE/SOFTWARE REQUIREMENTS

The EPA version of CAP-88 is written in FORTRAN77 and has been compiled and run on an IBM 3090 under OS/VS2 using the IBM FORTRAN compiler. Memory regions for execution on an IBM 3090 system under MVS are as follows:

PREPAR	1,200 K
AIRDOS-EPA	900 K
PREDA	300 K
DARTAB	800 K

A complete run, including PREPAR, AIRDOS-EPA, PREDA, and DARTAB, for an individual assessment requires approximately one minute of CPU time on an IBM 3090 processor. A population assessment requires about two minutes of CPU time.

3. CAP-88 PACKAGE CONTENTS

Table 3-1 lists the main programs, databases, and utility routines that make up CAP-88. The source files, data libraries, and sample output files are written in EBCIDIC card images on the magnetic tape. Listings of the various files are presented in Appendices A through M.

A program flow chart is shown in Figure 3-1. The figure does not show that, in addition to the temporary files created by each program and the output files created by DARTAB, each file writes data to ERROR.OUTPUT. These data allow the user to trace the operation of the four programs. Error messages concerning the data are also written to this file. A sample ERROR.OUTPUT file is presented in Appendix I.

Table 3-1. Elements of CAP-88.

Name	Type	Description of Program or Database
PREPAR2.FOR	Program	A preprocessor used to create AIRDOS-EPA (AIRDOS2) input data sets.
AIRDOS2.FOR	Program	Estimates radionuclide environmental exposure data for use as input to DARTAB (DARTAB2).
PREDA.FOR	Program	A preprocessor used to create DARTAB (DARTAB2) input data sets.
DARTAB2.FOR	Program	Provides tabulations of predicted health impacts from radioactive airborne effluents by combining environmental exposure data (output from AIRDOS2) with dosimetric and health effects data (provided in RADRISK.BIN).
SAMPLE.JCL	JCL	Sample listing of job control language used to run CAP-88 on an IBM 3090 computer.
ALLRAD88.DAT	Data	Provides element- and radionuclide-specific data for use by AIRDOS-EPA (AIRDOS2).
SAMPLE.STAR	Data	Sample of meteorological data file in STAR (STability ARray) format; used by AIRDOS-EPA (AIRDOS2).
SAMPLE.POP	Data	Sample of population data file; used by AIRDOS-EPA (AIRDOS2).
PRDPOP.DAT	Data	Input file to PREDA; selects calculations to be performed by DARTAB and determines output options.
RADRISK.BIN	Data	Binary file which provides dose and risk factors used by DARTAB (DARTAB2).
SAMPLE.OUTPUT	Output	Sample CAP-88 (DARTAB2) output file.
SAMPLE.SYNOPSIS	Output	Sample CAP-88 (DARTAB2) summary output file.
GETSTAR	JCL	Job control language used to create stability array data file (STAR format) from data obtained from the National Climatic Data Center.
ERROR.OUTPUT	Output	Traces program flow; used to record error messages.
GETPOP	JCL	Job control language used to run SECPOP3A.

Table 3-1. Elements of CAP-88 (continued).

Name	Type	Description of Program or Database
SECPOP3A	Utility	Program that creates the population data array (see SAMPLE.DAT) using 1980 census database files.
CHAIN	Utility	Program used to calculates the ingrowth factors (F1-F5) used by AIRDOS-EPA (AIRDOS2) to account for progeny ingrowth at a given time subsequent to the release of the parent.

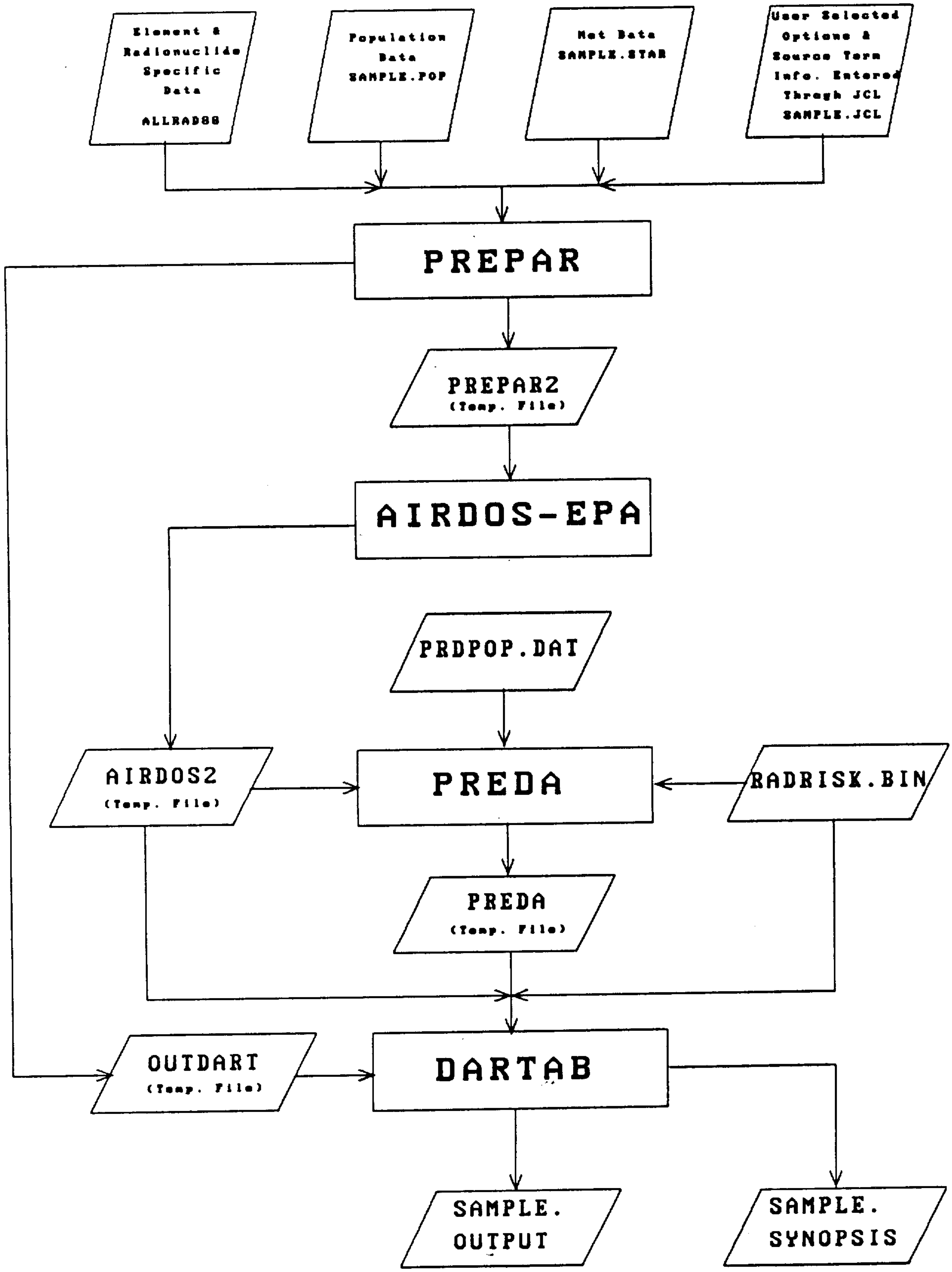

Figure 3-1. CAP-88 program flow chart.

4. RUNNING THE CAP-88 PACKAGE

The file SAMPLE.JCL (see Appendix E) contains an example of the job control language listing used to produce SAMPLE.OUTPUT. The file has the following format:

Lines 1 - 20	General JCL for CAP-88
Lines 21 - 109	PREPAR JCL and user input to PREPAR
Lines 110 - 118	AIRDOS-EPA JCL
Lines 119 - 128	PREDA JCL
Lines 129 - 168	DARTAB JCL

Input to PREPAR, and ultimately AIRDOS-EPA, is placed in the JCL file. In SAMPLE.JCL, lines 37 through 109 comprise input to PREPAR. Input to DARTAB is prepared by PREDA. DARTAB user options are read from the PDRPOP file by PREDA. Section 4.1 discusses user input to PREPAR. Section 4.2 discusses user input to PREDA.

4.1 PREPAR/AIRDOS-EPA INPUT DATA

PREPAR is a FORTRAN program designed to simplify the preparation of the input file for the AIRDOS-EPA computer code. Default values are provided for all variables, so the user need only enter data for which the defaults should be changed. PREPAR writes a data file in the format needed to run AIRDOS-EPA.

The discussion presented here is limited to how the user enters changes to the default values. The user is directed to the Oak Ridge National Laboratory report ORNL-5952 (ORNL84) for more information on the PREPAR program.

Input data to PREPAR consist of data used for identification of a particular run and values which are used by AIRDOS-EPA to perform calculations. Identification data entry is discussed in Section 4.1.1. Scalar and vector data entry is discussed in Section 4.1.2. Array data entry is discussed in Section 4.1.3. Differences between input to PREPAR as documented in ORNL-5952 (ORNL84) are presented in Section 4.1.4.

4.1.1 Run Identification Data

Table 4-1 presents an example of the run identification data read by PREPAR.

Table 4-1. Run identification data.[a]

Starting Column	1 2 3 4 5 12345678901234567890123456789012345678901234567890123
Line 1:	PLEASE GIVE TO ---> JIM HARDIN
Line 2:	PHONE NUMBER: 475-9610
Line 3:	JCL FILE ---> SAMPLE.JCL
Line 4:	ALLRAD FILE ---> ALLRAD88.DAT
Line 5:	POP FILE ---> SAMPLE.POP
Line 6:	STARFILE ---> SAMPLE.STAR
Line 7:	PREDA FILE ---> PRDPOP.DAT
Line 8:	RADRISK FILE ---> RADRISK.BIN
Line 9:	*
Line 10:	ARGONNE NATIONAL LABORATORY
Line 11:	ADDRESS
Line 12:	ARGONNE
Line 13:	IL
Line 14:	ZIP CODE
Line 15:	DOE FACILITIES
Line 16:	YEAR
Line 17:	OPTION

(a) Corresponds to lines 37 through 53 in Appendix E.

Most of Table 4-1 is self explanatory, but several lines must be explained. PREPAR reads 80 columns of data and writes it straight to the output file thus, the information need not start in column 1. This is true for all but the state abbreviation shown as line 13. PREPAR uses the state abbreviation to construct the agricultural data array (see Section 4.1.4). The abbreviation must start in column 1, on the fourth line following the asterisk (*).

OPTION, which appears on line 17 of Table 4-1, signals the end of the run identification data and the start of the AIRDOS-EPA data entry.

4.1.2 Scalar and Vector Data Entry

The general scheme of input to PREPAR is very simple. Most data values are read using NAMELIST read statements. The **data type name** is entered on the first line starting in column one. The data to be entered are placed on the following line in NAMELIST format. NAMELIST input requires a blank in column 1 of each line, an **&<NAMELIST name>**, the data, in the form of **<variable name = value>**, separated by commas (<,>), and an **&END**. One NAMELIST of data can continue for several lines. The following is an example of NAMELIST input.

```
Columns:    12345678901234567890123456789012345678901234567890
Line1  :    METEOROLOGICAL DATA
Line2  :     &METE LID=700.0,RR=80.0,TA=10.0 &END
```

where

data type name: METEOROLOGICAL DATA
NAMELIST name : METE
variable names: LID, RR, and TA

When the variable is a vector, the vector elements are entered separated by commas. Two consecutive commas means that the default value for the element in that position is not changed. In the following example, the variable OPTION is dimensioned to have nine elements.

```
Columns:    12345678901234567890123456789012345678901234567890
Line1  :    OPTION
Line2  :     &OPTI OPTION=0,1,,1,,0,0,1,1,LIPO=1 &END
```

where

data type name: OPTION
NAMELIST name : OPTI
variable names: OPTION and LIPO

PREPAR was written utilizing, whenever possible, the same input variable names as AIRDOS-EPA. The input data have been organized into data type categories so that the individual NAMELIST input lists are not very long. Table 4-2 presents the data type names and the associated NAMELIST names used by PREPAR to enter data for scalar and vector variables. Only the first four letters of the data type name are read; thus, the data type names and the NAMELIST names are almost always the same. The exceptions are **OPTIONS** and **AG DT**.

Table 4-3 presents the variables and their default values which are associated with each NAMELIST name in Table 4-2. Tables 4-4 through 4-6 define the variables listed in Table 4-3.

For two of the data type names in Table 4-2, Physical Source and Radionuclides, multiple NAMELIST sets may be input. Thus, for these two data type names, the line immediately following the data type name contains the number of NAMELIST sets that are to be read. This number should be an integer value starting in the first column. The following is an example.

```
Columns:    12345678901234567890123456789012345678901234567890
Line1  :    RADIONUCLIDES
Line2  :    2
Line3  :     &RADI NUC='AR-41',REL=1.46E+0 &END
Line4  :     &RADI NUC='C-11',REL=9.00E+1 &END
```

where

data type name: RADIONUCLIDES
NAMELIST name : RADI
variable names: NUC and REL

Table 4-2. Data type names and associated NAMELIST names used by PREPAR for scalar and vector variables.

Data Type Name[a]	NAMELIST Name	Data Type
OPTIONS[b]	OPTI	User options
INITIALIZATION	INIT	Reinitialization of some PREPAR variables
GRID	GRID	Assessment grid definition
PLUME RISE	PLUM	Plume rise
METEOROLOGY[c]	METE	Meteorological data (except wind data)
PHYSICAL SOURCE[d,e]	PHYS	Source physical data
RADIONUCLIDES[e]	RADI	Source radionuclide data
AG DATA	AGDT	Agricultural data (except arrays)
USAGE	USAG	Usage data
POOL	POOL	Depth of water to be used for water immersion doses and time spent swimming
MODIFICATIONS[f]	MODI	Modifications to nuclide data from the nuclide file

(a) Underlined portion is actual data type name.
(b) Data type OPTIONS must be entered first.
(c) METEOROLOGICAL data must be entered before data for data type RADIONUCLIDES.
(d) PHYSICAL SOURCE data must be entered before the nuclide data since the number of release terms is entered with the PHYSICAL SOURCE data.
(e) The line entered following this data type name, starting in column 1, is the number of NAMELIST input sets of this type.
(f) MODIFICATIONS data will be ignored if not entered after the RADIONUCLIDE data.

Table 4-3. Scalar and vector variable names along with default values and associated NAMELIST names.

NAMELIST Name	Variable Name	Number of Elements	Default Value	Units	Description Location
OPTI	OPTION	9	0	-	(a)
	LIST	20	0	-	(a)
	LIPO	1	0	-	(a)
	NNTB	1	0	-	(a)
	NRTB	1	0	-	(a)
	NSTB	1	0	-	(a)
	NTTB	1	0	-	(a)
	NUTB	1	0	-	(a)
	TSUBB	1	1	years	(a)
	GSFAC	1	1.0	-	(a)
	IMPFIX	1	1	-	(b)
INIT	IUNIT	1	-[d]	-	(c)
	IWIND	1	-[e]	-	(c)
	ISUMR	1	-[f]	-	(c)
	PH	1	10	m	(b)
	VEL	1	0	m/s	(b)
	QH	1	0	cal/s	(b)
	DIA	1	0	m	(b)
	KFLAG	1	0	-	(b)
	IFLAG	1	0	-	(b)
	RD1	NNUCS	0	-	(b)
	RD2	NNUCS	0	-	(b)
	RW1	NNUCS	0	-	(b)

Table 4-3. Scalar and vector variable names along with default values and associated NAMELIST names (continued).

NAMELIST Name	Variable Name	Number of Elements	Default Value	Units	Description Location
INIT(cont)	RW2	NNUCS	0	-	(b)
GRID	NOL	1	1	-	(b)
	NOU	1	16	-	(b)
	NRL	1	1	-	(b)
	NRU	1	20	-	(b)
	IDIST	20	1000-20000	m	(b)
	BOUND	20	0	m	(b)
PLUM	PR	7	0	m	(b)
METE	LIDAI	1	1000	m	(b)
	RR	1	100	cm/y	(b)
	TA	1	20	K	(b)
	TG	3	0.0728	K/m	(b)
	Z	1	10	m	(c)
	ZO	1	0.01	m	(c)
	JO	1	5.0	mm/h	(c)
	DF	1	1E-5	m^2/s	(c)
PHYS	PH	1	10	m	(b)
	DIA	1	0	m	(b)
	VEL	1	0	m/s	(b)
	QH	1	0	cal/s	(b)
	AREA	6	0	m^2	(b)
RADI	NUC[g]	NNUCS[h]	'TYPO'	-	(b)
	REL	NNUCS·NUMST[i]	1	Ci/y	(b)

Table 4-3. Scalar and vector variable names along with default values and associated NAMELIST names (continued).

NAMELIST Name	Variable Name	Number of Elements	Default Value	Units	Description Location
RADI(cont)	SC	NNUCS[h]	Computed[j]	s^{-1}	(b)
	VD	NNUCS[h]	Computed[j]	m/s	(b)
	VG	NNUCS[h]	Computed[j]	m/s	(b)
	NUMORG	NNUCS[h]	11[k]	-	(b)
	KFLAG	NNUCS[h]	0	-	(b)
	IFLAG	NNUCS[h]	0	-	(b)
	RD1	NNUCS[h]	0	-	(b)
	RD2	NNUCS[h]	0	-	(b)
	RW1	NNUCS[h]	0	-	(b)
	RW2	NNUCS[h]	0	-	(b)
	ISOL	NNUCS[h]	Blank	_	(b)
	AMAD	NNUCS[h]	0.5	μm	(b)
	F1INH	NNUCS[h]	0.2	-	(b)
	I1 to I5	1	0	-	(b)
	F1 to F5	1	0	_	(b)
	F1ING	NUCS	0.2	_	(b)
	SEQWL	1	0.7	-	(b)
	RHO	1	1.0	g/cm^3	(c)
	PDIA	1	1.0	μm	(c)
	ORGAN	NUMORG	Blank	-	(c)
	UNIT	1	'Ci'	-	(c)
	CUTOFF	1	0.01	m/s	(c)
	ANLAMO	1	-	d^{-1}	(c)

Table 4-3. Scalar and vector variable names along with default values and associated NAMELIST names (continued).

NAMELIST Name	Variable Name	Number of Elements	Default Value	Units	Description Location
RADI(cont)	IAN	1	-	-	(c)
	ANLAM	NNUCS[h]	Nuclide Specific	d^{-1}	(b)
AGDT	LAMW	1	0.0029	h^{-1}	(b)
	TSUBH1	1	0	h	(b)
	TSUBH2	1	2160	h	(b)
	TSUBH3	1	336	h	(b)
	TSUBH4	1	336	h	(b)
	TSUBE1	1	720	h	(b)
	TSUBE2	1	1440	h	(b)
	YSUBV1	1	0.28	kg/m^2	(b)
	YSUBV2	1	0.716	kg/m^2	(b)
	FSUBP	1	0.4	-	(b)
	FSUBS	1	0.43	-	(b)
	QSUBSF	1	15.6	kg/d	(b)
	TSUBF	1	2	d	(b)
	TSUBS	1	20	d	(b)
	FSUBG	1	1	-	(b)
	FSUBL	1	1	-	(b)
	P	1	215	kg/m^2	(b)
	TAUBEF	1	0.00381	d^{-1}	(b)
	MSUBB	1	200	kg	(b)
	VSUBM	1	11	liters/d	(b)

Table 4-3. Scalar and vector variable names along with default values and associated NAMELIST names (continued).

NAMELIST Name	Variable Name	Number of Elements	Default Value	Units	Description Location
AGDT(cont)	R1	1	0.57	-	(b)
	R2	1	0.2	-	(b)
	F1V	1	1	kg	(c)
	F2V	1	0	kg	(c)
	F3V	1	0	kg	(c)
	F1M	1	1	kg	(c)
	F2M	1	0	kg	(c)
	F3M	1	0	kg	(c)
	F1B	1	1	kg	(c)
	F2B	1	0	kg	(c)
	F3B	1	0	kg	(c)
	FOODARRAY_GEN_AUTO	1	TRUE	-	(c)
USAG	DD1	1	0.5	-	(b)
	BRTHRT	1	8035.28	cc/yr	(b)
	UV	1	176	kg/y	(b)
	UM	1	112	liters/y	(b)
	UF	1	85	kg/y	(b)
	UL	1	18	kg/y	(b)
POOL	DILFAC	1	1	cm	(b)
	USEFAC	1	0	-	(b)
MODI	NAMNUC[l]	NNUCS[h]	'TYPO'	-	(c)
	ANLAM	NNUCS[h]	Nuclide Specific[m]	d^{-1}	(b)

Table 4-3. Scalar and vector variable names along with default values and associated NAMELIST names (continued).

NAMELIST Name	Variable Name	Number of Elements	Default Value	Units	Description Location
MODI(cont)	LAMRR	NNUCS(h)	Nuclide Specific(m)	d^{-1}	(b)
	CFSBA	NNUCS(h)	Nuclide Specific(m)	rem-cc/μCi-h	(b)
	CFSBW	NNUCS(h)	Nuclide Specific(m)	rem-cc/μCi-h	(b)
	CFSUR	NNUCS(h)	Nuclide Specific(m)	rem-cm^2/μCi/h	(b)
	TDCF	NNUCS(h)	6.18 (H^3) 0 otherwise	rem-cc/pCi-y	(b)
	TDCW	NNUCS(h)	0.057 (H^3) 0 otherwise	rem-cc/pCi-y	(b)
	FROG	11·NNUCS(h)	Nuclide Specific(m)	-	(b)
	FSUBMI	NNUCS(h)	Nuclide Specific(m)	d/liter	(b)
	FSUBFI	NNUCS(h)	Nuclide Specific(m)	d/kg	(b)
	BSUBV1	NNUCS(h)	Nuclide Specific(m)	-	(b)
	BSUBV2	NNUCS(h)	Nuclide Specific(m)	-	(b)
	LAMSUR	NNUCS(h)	Nuclide Specific(m)	d^{-1}	(b)
	LAMH2O	NNUCS(h)	Nuclide Specific(m)	d^{-1}	(b)
	CFINHA	NNUCS·NUMORG(h)	Nuclide Specific(m)	rem/μCi	(b)
	CFINGA	NNUCS·NUMORG(h)	Nuclide Specific(m)	rem/μCi	(b)
	F1ING(m)	NNUCS(h)	0.2	-	(b)

Table 4-3. Scalar and vector variable names along with default values and associated NAMELIST names (continued).

NAMELIST Name	Variable Name	Number of Elements	Default Value	Units	Description Location
MODI(cont)	F1INH	NNUCS[h]	0.2	-	(b)
	ISOL[k]	NNUCS[h]	Blank	-	(b)
	AMAD[k]	NNUCS[h]	1.0	μm	(b)
	PDIA[k]	-	1.0	μm	(c)
	RHO[k]	-	1.0	g/cc	(c)
	IAN	-	0	-	(c)
	VD	NNUCS[h]	Computed[j]	m/s	(b)
	VG	NNUCS[h]	Computed[j]	m/s	(b)
	SC	NNUCS[h]	Computed[j]	s^{-1}	(b)

(a) See Table 4-4.
(b) See Table 4-5.
(c) See Table 4-6.
(d) Unit from which array input is read if it is not on the main input unit.
(e) Unit from which STAR or wind data is read.
(f) Unit onto which the executive summary is written.
(g) See Appendix F for list of valid nuclides.
(h) NNUCS is number of nuclides in the source term. Default value is 0. NUMORG is number of organs. Default value is 11.
(i) NUMST is the number of stacks or areas. Default value is one.
(j) Computed by PREPAR if value is not entered.
(k) DARTAB only uses 8 organs (GONADS, BREAST, R MAR, LUNGS, THYROID, ENDOST, RMNDR, and EFFEC). See descriptions of variables NORGN and ORGN under Namelist ORGAN in Table 4-11.
(l) Member of key list. Modifications are made to all nuclides that match the key list.
(m) Default value is specific to each nuclide. See Appendix F for values.

Table 4-4. Definitions of the PREPAR/AIRDOS-EPA options.

Variable	Value	Definition
GSFAC	-	A scaling factor used to correct ground surface dose factors for surface roughness.
IMPFIX	0	Fractions are computed in AIRDOS-EPA, F3VEGM, F3BEFM, and F3MLKM input are the minimum values used.
	1	F3VEGM, F3BEFM, F3MLKM are used as the imported fraction of each food type.
LIPO	0	Individual dose.
	1	Population dose.
LIST(20)	0	Print concentrations for ith distance.
	1	Suppress printing.
NNTB	-	Number of individual nuclide dose tables printed by location and pathway.
NRTB	0	Omit punching.
	1	Punch doses by nuclide, organ, and pathway.
NSTB	0	No print or binary file of environmental concentrations and intake rates.
	1	Print and write binary file of environmental concentrations and intake rates.
	2	Write binary file of environmental concentrations and intake rates.
NTTB	0	Do not print dose summary table.
	1	Print dose summary table.
NUTB	0	Do not print ^{222}Rn working levels.
	1	Print ^{222}Rn working levels.
OPTION(1)	0	Run CONCEN and DOSEN.
	1	Run CONCEN only.
	3	Run DIRECT and DOSEN.
OPTION(2)	0	Square grid. (Warning! Program will accept this as an option but the results will not be valid!)
	1	Circular grid.
OPTION(3)	0	Sector-averaging.
	1	Plume centerline computations.

Table 4-4. Definitions of the PREPAR/AIRDOS-EPA options (continued).

Variable	Value	Definition
OPTION(4)	0	Buoyant plume rise (heated).
	1	Momentum plume rise (fan driven, no heat).
	2	Plume rise entered by user (entered by user as 0 if no momentum).
OPTION(5)	0	No VDCOEF entered.
	1	Array VDCOEF entered to modify deposition velocity by direction and distance. Use only if OPTION(2) = 1 (circular grid).
OPTION(6)	0-36	The number of nuclides for which concentrations and deposition rates are punched. See Appendix F for list of valid nuclides.
OPTION(7)	0	Point source.
	1	Area source.
OPTION(8)	0	Print main CONCEN table.
	1	Do not print main CONCEN table.
OPTION(9)	0	Print χ/Q tables.
	1	Do not print χ/Q tables
TSUBB	-	Years of long-term buildup in soil.

Table 4-5. Input variables used in PREPAR/AIRDOS-EPA.

Variable Name	Type[a]	Number of Values	Units	Definition
ACON	R	400	pCi/cm^3	Concentration in air at ground level for each environmental location (20 x 20 array)
AMAD	R	NNUCS	pm	Activity median aerodynamic diameter of particulate nuclide.
ANLAM	R	NNUCS	d^{-1}	Effective radiological decay constant in the plume.
AREA	R	6	m^2	Surface area of a uniform circular source; value must be greater than 10 m^2.
BOUND	R	20	m	First value is upper bound of area represented by first IDIST value and lower bound of area represented by second IDIST value, and continuing for all 20 possible IDIST values [BOUND, VDCOEF, and LIST values are to be entered only if Option(5) = 1].
BRTHRT	R	1	cm^3/h	Breathing rate of man.
BSUBV1	R	NNUCS	-	Concentration factor for uptake of nuclide from soil for pasture and forage (pCi/kg dry weight per p/Ci/kg dry soil).
BSUBV2	R	NNUCS	-	Concentration factor for uptake of nuclide from soil by edible parts of crops (pCi/kg wet weight per pCi/kg dry soil).
CFINGA	R	NUMORG x NNUCS	rem/pCi	Organ dose conversion factor for ingestion.
CFINHA	R	NUMORG x NNUCS	rem/pCi	Organ dose conversion factor for inhalation.
CFSBA	R	NNUCS	$rem\text{-}cm^3/pCi\text{-}h$	Body surface dose conversion factor for submersion in air.
CFSBW	R	NNUCS	$rem\text{-}cm^3/pCi\text{-}h$	Body surface dose conversion factor for submersion in water.

Table 4-5. Input variables used in PREPAR/AIRDOS-EPA (continued).

Variable Name	Type[a]	Number of Values	Units	Definition
CFSUR	R	NNUCS	rem-cm^2/pCi-h	Body surface dose conversion factor for surface exposure.
DD1	R	1	-	Fraction of radioactivity retained on leafy vegetables and produce after washing.
DIA	R	NUMST	m	Diameter of stack.
DILFAC	R	1	cm	Depth of water to be used for water immersion doses.
DIM	R	NUMST	-	Diameter of area source.
F	R	5	-	An array alias for F1-F5.
F1-F5	R	1	-	Surface input rate for the nuclide resulting from decay of a parent (I1-15) per unit aerial deposition rate of that parent.
F1ING	R	NNUCS	-	Gastrointestinal uptake fraction for ingestion.
F1INH	R	NNUCS	-	Gastrointestinal uptake fraction for inhalation.
F3BEFM	R	1	-	The minimum fraction of ingested beef which is imported into the assessment area. The code may compute a higher value to be used unless IMPFIX = 1.
F3MLKM	R	1	-	Same as F3BEFM except applied to milk.
F3VEGM	R	1	-	Same as F3BEFM except applied to vegetables.
FRAW	R	112	-	Frequencies for Pasquill stability categories (each of 16 directories).
FROG	R	NNUCS x 11	-	Dose correction factors for whole body and each reference organ to multiply by external doses for body surface. The order of the organs is given under NAMORG in this table.

Table 4-5. Input variables used in PREPAR/AIRDOS-EPA (continued).

Variable Name	Type[a]	Number of Values	Units	Definition
FSUBFI	R	NNUCS	d/kg	Fraction of animal's daily intake of nuclide which appears in each kg of flesh.
FSUBG	R	1	-	Fraction of produce ingested grown in garden of interest.
FSUBL	R	1	-	Fraction of leafy vegetables grown in garden of interest.
FSUBMI	R	NNUCS	d/L	Fraction of animal's daily intake of nuclide which appears in each liter of milk.
FSUBP	R	1	-	Fraction of year animals graze on pasture.
FSUBS	R	1	-	Fraction of daily feed that is pasture grass when animals graze on pasture.
GCON	R	400	pCi/cm^2-s	Rate of deposition on ground surface for each environmental location (20 x 20 array).
I1-I5	I	1	-	Index integer for a parent radionuclide contributing to surface buildup.
IDIST	I	20	m	Distances from source to be used with circular option.
IFLAG	I	NNUCS	-	0 for normal run; 1 if special values RD1 and RD2 are to be used instead of R1 and R2; 2 if special values RD1 and RD2 for dry deposition processes and special values RW1 and RW2 for wet deposition (scavenging) processes are to be used.
II	I	5	-	An array alias for I1-I5.
IMPFIX	I	1	-	A 1 fixes the fraction of each food type imported into the assessment area at the minimum fraction specified as F3VEGM, F3BEFM, and F3MLKM.

Table 4-5. Input variables used in PREPAR/AIRDOS-EPA (continued).

Variable Name	Type[a]	Number of Values	Units	Definition
INTFC	R	400	m^2	Area of vegetable crop production for each environmental location (20 x 20 array).
INTPA	R	400	-	Population for each environmental location (20 x 20 array).
INTWA	I	400	-	Identification as to whether an environmental location contains significant water areas, 1 for does 0 for does not (20 x 20 array)
ISOL	A1	NNUCS	-	Clearance class for nuclide (D = days; W = weeks; Y=years; * gas
KFLAG	I	NNUCS	-	Usually 0; a value of 1 is used for a radionuclide which is a daughter product assumed to have an effective decay constant in the plume (ANLAM) equal to the decay constant of its longer-lived parent, and it is desired to use the ANLAM value to calculate its decay on ground surfaces and in water instead of its true decay constant, LAMRR.
LAMH2O	R	NNUCS	d^{-1}	Environmental decay constant for water areas for the radionuclide.
LAMRR	R	NNUCS	d^{-1}	Radioactive decay constant for the radionuclide.
LAMSUR	R	NNUCS	d^{-1}	Environmental decay constant for land surface for the radionuclide.
LAMW	R	1	h^{-1}	Removal rate constant for physical loss by weathering.
LID	R	1	m	An alias for LIDAI.
LIDAI	I	1	m	Height of lid; i.e., depth of tropospheric mixing layer.
LIPO	I	1	-	1 for population dose; 0 for individual dose.

Table 4-5. Input variables used in PREPAR/AIRDOS-EPA (continued).

Variable Name	Type[a]	Number of Values	Units	Definition
LIST	I	20	-	0 to print concentrations for distance corresponding to IDIST 1 to suppress printing for IDIST distance.
MSUBB	R	1	kg	Muscle mass of meat producing animal at slaughter.
NAMNUC	A8	NNUCS	-	Name of nuclide, such as I-131 or RU-103.
NAMORG[b]	A8	NUMORG x NNUCS	-	Name of organ, to be written as follows; TOT.BODY, R MAR, LUNGS, ENDOST, S WALL, LLI WALL, THYROID, LIVER, KIDNEYS, TESTES, OVARIES.
NNTB	I	1	-	Number of individual radionuclide dose tables by grid location and pathway to be printed. Used to suppress printing.
NNUCS	I	1	-	Number of nuclides in source term.
NOBCT	I	400	-	Number of meat producing animals for each environmental location (20 x 20 array)
NOL	I	1	-	Lower grid limit, first direction (circ.) or west (square).
NOMCT	-	400	-	Number of dairy cattle for each environmental location (20 x 20 array).
NOU	I	1	-	Upper grid limit, last direction (circ.) or east (square).
NRL	I	1	-	Lower grid limit, first distance (circ.) or south (square).
NRTB	I	1	-	1 for punching on cards doses by nuclide, organ, and pathway. 0 for omitting the above.

Table 4-5. Input variables used in PREPAR/AIRDOS-EPA (continued).

Variable Name	Type[a]	Number of Values	Units	Definition
NRU	I	1	-	Upper grid limit, last distance (circ.) or north (square).
NSTB	I	1	-	1 for printing and unformatted output of environmental concentrations and intake rates by mane for each nuclide, 0 for omitting the above (2 for unformatted output without printing, in modified AIRDOS-EPA).
NTTB	I	1	-	1 for printing dose summary tables 0 for omitting the above
NUC	A8	NNUCS	-	An alias for NAMNUC.
NUMORG	I	NNUCS	-	Number of organs considered for the radionuclide.
NUMST	I	1	-	Number of stacks or release areas.
NUTB	I	1	-	1 for printing working level concentrations of ^{222}Rn decay products if it is in the source term, 0 for omitting the above.
P	R	1	kg/m^2	Effective surface density of soil (dry weight) (assumes 15-cm plow layer).
PERD	R	16	-	Wind direction frequency.
PH	R	NUMST	m	Physical height of stack.
PR	R	7	m	Specific plume rise for each Pasquill category.
QH	R	NUMST	cal/s	Heat release from stack.
QSUBF	R	1	kg/d	Consumption rate of contaminated feed or forage by an animal (dry weight).
R1	R	1	-	Deposition interception fraction for pasture.

Table 4-5. Input variables used in PREPAR/AIRDOS-EPA (continued).

Variable Name	Type[a]	Number of Values	Units	Definition
R2	R	1	-	Deposition interception fraction for vegetable crops.
REEF	R	1	-	The fraction representing the quantity of ingested beef produced at the environmental location divided by the total quantity ingested which is produced throughout the assessment area.
RD1, RW1	R	NNUCS	-	Special values for R1 as defined in IFLAG.
RD2, RW1	R	NNUCS	-	Special values for R2 as defined in IFLAG.
REL	R	NNUCS x NUMST	Ci/y	Release rate of radionuclide from stack.
RMLK	R	1	-	Same as RBEF except applied to milk.
RR	R	1	cm/y	Annual average rainfall rate.
RVEG	R	1	-	Same as RBEF except applied to meat.
SC	R	NNUCS	s^{-1}	Scavenging coefficient.
SEQWL	R	1	-	Assumed fraction of equilibrium for the short-life progeny of ^{222}Rn.
SCSD	R	1	m	The exact length of the side of each grid square when using the square gird configuration. A value of SQSD must also be used for the circular option which corresponds to the approximate length of each grid square in a 20 x 20 grid superscribed on the circular assessment area.
T	R	1	d	Buildup time allotted for surface deposition.
TA	R	1	K	Average air temperature.
TAUBEF	R	1	d^{-1}	Fraction of meat producing herd slaughtered per day.

Table 4-5. Input variables used in PREPAR/AIRDOS-EPA (continued).

Variable Name	Type[a]	Number of Values	Units	Definition
TDCF	R	NNUCS	rem-cm^3/pCi-y	Dose conversion factor for food; always 0 except for tritium.
TDCW	R	NNUCS	rem-cm^3/pCi-y	Dose conversion factor for drinking water; always 0 except for tritium.
TG	R	3	K/m	Vertical temperature gradient for Pasquill categories E, F, and G.
TSUBB	R	1	y	Period of long-term buildup for activity in soil.
TSUBE1	R	1	h	Period of exposure during growing season - pasture grass.
TSUBE2	R	1	h	Period of exposure during growing season - crops or leafy vegetables.
TSUBF	R	1	d	Transport time from animal feed-milk-man.
TSUBH1	R	1	h	Time delay - ingestion of pasture grass by animals.
TSUBH2	R	1	h	Time delay - ingestion of stored feed by animals.
TSUBH3	R	1	h	Time delay - ingestion of leafy vegetables by man.
TSUBH4	R	1	h	Time delay - ingestion of produce by man.
TSUBS	R	1	d	Average time from slaughter of meat animal to consumption.
UDAV	R	112	m/s	Arithmetic-average wind speeds (7 Pasquill categories, 16 directions).
UDCAT	R	112	m/s	Harmonic-average wind speeds (7 Pasquill categories, 16 directions).
UF	R	1	kg/y	Rate of ingestion of meat by man.
UL	R	1	kg/y	Rate of ingestion of leafy vegetables by man.

Table 4-5. Input variables used in PREPAR/AIRDOS-EPA (continued).

Variable Name	Type[a]	Number of Values	Units	Definition
UM	R	1	L/y	Rate of ingestion of milk by man.
USEFAC	R	1		Fraction of time spent swimming.
UV	R	1	kg/y	Rate of ingestion of produce by man.
VD	R	NNUCS	m/s	Dry deposition velocity.
VDCOEF	R	(NOU-NOL+1) (NRU-NRL+1)	-	Factor to be multiplied by VD to give dry deposition velocity representative of the area for a specific compass direction and IDIST value.
VEL	R	NUMST	m/s	Velocity of stack gases.
VG	R	NNUCS	m/s	Gravitational (or settling) velocity.
VSUBM	R	1	L/d	Milk production of cow.
YSUBV1	R	1	kg/m^2	Agricultural productivity (grass-cow-milk pathway).
YSUBV2	R	1	kg/m^2	Agricultural productivity (produce or leafy vegetables).

(a) I = integer; R = real; An = alphanumeric, n characters long
(b) The organ names are reset in PRDPOP.DAT to the following: GONADS, BREAST, R MAR, LUNGS, THYROID, ENDOST, RMNDR, and EFFEC.

Table 4-6. Input variables used in PREPAR.

Variable Name	Type[(a)]	Units	Definition
FOODARRAY_GEN_AUTO	L	-	Controls calculation of agricultural data by PREPAR.
ANLAMO	R	d^{-1}	Minimum value of ANLAM passed to AIRDOS-EPA.
CMT	A80	-	Any comments the user wishes to have printed in the PREPAR report.
CUTOFF	R	m/s	Minimum value of VG passed to AIRDOS-EPA.
DF	R	m^2/s	Gaseous diffusion constant for scavenging coefficient calculation.
F1V, F1M, F1B	R	kg	The relative amount of vegetables, milk, and meat, respectively, in an individual's diet that are home produced at an individual's location.
F2V, F2M, F2B	R	kg	The relative amount of vegetables, milk, and meat, respectively, in an individual's diet that are from supplies produced within the local assessment area, excluding that which is produced at an individual's location.
F3V, F2M, F2B	R	kg	The amount of vegetables, milk, and meat, respectively, in an individual's diet that are imported from outside the assessment area.
FV, FM, FB	R	kg	Array (3) aliases for the above three sets of variables.
GSCFAC	R	-	A scaling factor used to correct ground surface dose factors for surface roughness.
GSFAC	R	-	Alias for GSCFAC.
IAN	I	-	An index to reference the ANLAM of a previous nuclide.
IS	I	-	Indices of the AIRDOS-EPA stability class in which to sum the ith input stability category.
ISUMR	I	-	Unit onto which the executive summary is written.

Table 4-6. Input variables used in PREPAR (continued).

Variable Name	Type[a]	Units	Definition
IUNIT	I	-	Unit from which array input is read if it is not on the main input unit.
IWIND	I	-	Unit from which STAR or wind data are read.
JO	I	m/h	Instantaneous rainfall rate.
NS	I	-	Number of STAR stability categories entered.
NW	I	-	Number of STAR wind speed categories entered.
ORGAN[b]	A8	-	List of organ names.
PDIA	R	pm	Physical diameter of particle.
RHO	R	gm/cm^3	Particle density.
UNIT	A2	-	- 'CI' if releases are entered in Curies (default) - 'BQ' if releases are entered in Becquerels
VGO	R	m/s	Alias for CUTOFF.
WDCS	R	-	Joint frequency of occurrence of a given wind direction, stability class, and wind speed category.
WS	R	m/s	Wind speed of each wind speed category.
Z	R	m	Height of wind speed measurement.
ZO	R	m	Surface roughness length.

(a) L - logical; R - real; An - alphanumeric, n characters long.
(b) The organ names are reset in PRDPOP.DAT to the following: GONADS, BREAST, R MAR, LUNGS, THYROID, ENDOST, RMNDR, and EFFEC.

The NAMELIST type MODI is used to modify the data from the radionuclide file and any nuclide data that are computed within PREPAR. The modifications are keyed to the nuclide name (NAMNUC), the uptake fraction for ingestion (F1ING), the solubility class (ISOL), the activity median aerodynamic diameter (AMAD), the particle diameter (PDIA), and the particle density (RHO). The modifications entered are made to all the nuclides that match the key list. For example, if a particle density of one is the only key entered, then that list of modifications will be applied to every nuclide with a particle density equal to one. On the other hand, if a nuclide name, an uptake fraction, and a solubility class are entered as keys, it is likely that only one nuclide will match the key list thus, those modifications will apply only to that one nuclide. The ALLRAD88 data file (see Appendix F) contains the default element and nuclide specific data used by AIRDOS-EPA.

Almost all of the variables entered using PREPAR have exactly the same meaning as the variables of the same name in AIRDOS-EPA. The only difference is that within the nuclide data, I1-I5 have different meanings. The I1-I5 values are indices to the parent nuclides contributing to daughter buildup. The corresponding F1-F5 values are defined as the surface input rate of the progeny from parent decay per unit aerial deposition rate of the parent. In AIRDOS-EPA, the variables I1-I5 denote absolute indices within the list of radionuclide names. For example, an I1 of 2 would point to the second nuclide in the input nuclide list. In PREPAR, they denote relative indices. Using variables I1 and F1 to represent all five of each variable, if no F1 value is entered, then I1 is always set to 0. If a negative value is entered, then I1 is set to point back that many nuclides. For example, if the current nuclide is fifth in the input nuclide list and an I1 of -2 is entered, this corresponds to an AIRDOS-EPA I1 value of 3. Subsequent nuclides with values for F1 will refer to the same AIRDOS-EPA value of I1 (i.e., 3) until a new value for I1 is entered. If no value for I1 has been entered, entering a value for F1 will cause I1 to be set to a relative index of -1. Note that the value of I1 has no effect on the values of I2 through I5.

Some AIRDOS-EPA variables are computed in PREPAR from other input values. SQSD is computed from IDIST. DIM is computed from AREA. RMLK, F3MLKM, etc., are computed from F1M, F2M, F3M, etc., SC, VG, and VD are computed from particle size, particle density, and meteorological parameters if the user does not enter these values. The computations are discussed in Section 2 of ORNL-5952 (ORNL84).

4.1.3 Array Input

All array data, other than population data, may either be read from the same unit as the scalar data (i.e., included in the JCL listing) or read from user-prepared files. Population data must be read from a file. This is a departure from earlier editions of PREPAR, which allowed input of population data in the JCL listing. An infinite loop will occur if population data is entered in the JCL in this version of CAP-88. Please note that the population files generated by running SECPOP3A contains the array distances in the first three lines. These distances are used by CAP-88 to generate the agricultural arrays and to set the distances used in the assessment for a population run.

SAMPLE.POP (see Appendix G) is an example of a file containing population array data. The format for entering array data from a file follows.

Line 1:

Data arrays may be entered using either default or user-supplied formats. For each data type, enter the type name on the first line.

Line 2:

If the array data are not to be read from the same unit as the scalar data (IUSER), then the next line is **'FILE nn'**, where nn is the unit number. Subsequent array data from the same file may be accessed using a **'FILE'** statement with no unit number. Once an array file is opened, it is not rewound until a new array file is selected. Any unwanted records may be passed over with a **'SKIP nn'** statement which will skip nn records before reading the array. Selecting a new array file causes the old one to be closed before the new file is opened. The value for nn is entered as an integer value in the eight columns following FILE or SKIP. Note that for WIND arrays, the file number nn defaults to IWIND (see Tables 4-3 and 4-6); therefore this line need not be used for wind data (see lines 64 through 66 in Appendix E).

Line 3:

The selected format type must be entered on the line following the FILE number (WIND arrays are the exception, see Section 4.1.3.1). The input type may be **'DEFAULT'** for accepting the default format, 'USER' for entering your own format, or 'LIST' for using list-directed input.

Line 4:

If USER was selected as the format type, the format is entered on this line.

Line 5:

The data is entered on this line unless they are being read from the unit entered with the **FILE** command.

The following is an example of the statements used to input array data:

```
Columns:     1234567890123456789012345678901234567890
Line 1 :     POPULATION ARRAY
Line 2 :     FILE 24
Line 3 :     SKIP 3
Line 4 :     USER
Line 5 :     (8(I9,1X))
```

Table 4-7 presents the data type names used for array input. The arrays are defined in Table 4-8.

Table 4-7. Data type names used by PREPAR for array input.

Data Type Name	Array Name	Default Format
WIND		
- STAR	WDCS	(T8,6F7.5)
- AIRDOSE	PERD	(16F5.0)
	UDCAT	(16F5.0)
	UDAV	(16F5.0)
	FRAW	(7F10.0)
POPULATION	INTPA	(10I6)
WATER AREAS	INTWA	(10I6)
DEPOSITION VELOCITY	VDCOEF	(8E10.4)
CONCENTRATIONS	ACON	(8E10.4)
	GCON	(8E10.4)
COMMENTS	CMT	(20A4)

Table 4-8. Definition of arrays input using PREPAR.

Array Name	Type[a]	Number of Units	Units	Definition
ACON	R	400	pCi/cc	Concentration in air at ground level for each environmental location (20 x 20 array)
CMT	A80	-	-	Any comments the user wishes to have printed in the PREPAR report.
FRAW	R	112	-	Frequencies for Pasquill stability categories (each of 16 directions).
GCON	R	400	pCi/cm^2-s	Rate of deposition on ground surface for each environmental location (20 x 20 array).
INTPA	R	400	-	Population for each environmental location (20 x 20 array).
INTWA	I	400	-	Identification as to whether an environmental location contains significant water areas: 1 for does and 0 for does not (20 x 20 array).
PERD	R	16	-	Wind direction frequency.
UDAV	R	112	m/s	Arithmetic-average wind speeds (7 Pasquill categories, 16 directions).
UDCAT	R	112	m/s	Harmonic-average wind speeds (7 Pasquill categories, 16 directions).
WDCS	R	896	-	Joint frequency of occurrence of a given wind direction, stability class, and wind speed category.

4.1.3.1 Comments Concerning Array Data Entry

The wind data type has special features. The line following the data type name 'WIND' is not the FILE command but rather either **'STAR'** for entering STAR data or **'AIRDOS'** for entering wind data in AIRDOS-EPA arrays. If the entered STAR data does not have stability classes and wind classes that are consistent with the PREPAR defaults, the user may enter reorganizing information on the line following the 'STAR' line. These data are entered in NAMELIST 'STAR'. The variables available are defined in Table 4-9. If the data are entered as STAR data, the AIRDOS-EPA arrays needed are computed by PREPAR. If the AIRDOS-EPA format is selected, the four arrays, PERD, UDCAT, UDAV, and FRAW, are entered. When users-defined formats are used, an additional format must be entered before the array, FRAW.

Table 4-9. NAMELIST STAR variables.

Variable	Default	Meaning
NS	7	Number of input stability categories (max=8).
IS(8)	1,2,..7,0	Indices of AIRDOS-EPA stability categories in which to sum the ith input category.
NW	7	Number of input wind speed categories.
WS(7)		Wind speed (m/s) of each of the wind speed categories.

One array, the COMMENT data type, is entered to be used only in PREPAR. If you wish to have any special commentary material to be printed at the beginning of the PREPAR report and in the executive summary, enter these data via the 'COMMENT' data type. Enter an '*' in the first column of the line following the end of the comments.

4.1.4 Changes to PREPAR Input as Documented in ORNL-5952

Dairy and beef cattle distributions and vegetable crop area fractions are now calculated by PREPAR by default. To avoid calculating agricultural data, set NAMELIST AGDT variable FOODARRAY_GEN_AUTO = FALSE.

The number of cattle and beef per unit area, by state, were derived from data developed by NRC (NRC75). A constant cattle density is assumed except for the area closest to the source, or stack in the case of a point source, i.e., no cattle are assumed within 500 meters of the source. Milk production density in units of liters/day-square mile was converted to number of dairy cattle/square kilometer by assuming a milk production rate of 11.0 liters/day per dairy cow. Meat production density in units of kilograms/day-square mile was changed to an equivalent number of beef cattle/square kilometer by assuming a slaughter rate of .00381 day-1 and 200 kilograms of beef/animal slaughtered. A 180-day grazing period was assumed for dairy and beef cattle.

A certain fraction of the land within 80 kilometers of the source is used for vegetable crop production and is assumed to be uniformly distributed throughout the entire assessment area with the exception of the first 500 meters from the source. Information on the vegetable production density in terms of kilograms (fresh weight)/day-square mile was obtained from NRC data (NRC75). The vegetable crop fractions by state were obtained from the production densities by assuming a production rate of 2 kilograms (fresh weight)/year-square meter (NRC77).

Cattle densities and vegetable crop distributions used by PREPAR are presented in Table 4-10.

4.2 PREDA/DARTAB INPUT DATA

DARTAB is the FORTRAN program that combines the airborne radionuclide exposure data from AIRDOS-EPA with the dosimetric and health effects data provided in RADRISK.BIN to generate tabulations of predicted health impacts. A complete description of the calculation performed by the code, including sample tables, may be found in ORNL-5692 (ORNL81a).

PREDA is a FORTRAN program that prepares input data for the DARTAB code. PREDA searches the dose rate and health risk data set (RADRISK.BIN) for data corresponding to the nuclides in the AIRDOS-EPA data set (AIRDOS2). In addition, PREDA reads DARTAB table option data from a user prepared file (PRDPOP). The data necessary for input to DARTAB are written to a temporary file (PREDA) which is then read by DARTAB.

An example PRDPOP file is presented in Appendix H. The input is provided in NAMELIST format. Unlike PREPAR data entry, a data type name is not used (see Section 4.1.3). The NAMELIST format used by PREDA is as follows:

```
Columns:     1234567890123456789012345678901234567890
Line 1 :      &INPUT IHEAD=1, ICRP=1,
Line 2 :          ILOC=0, JLOC=100 &END
```

where

NAMELIST name : INPUT
Variable names: IHEAD, ICRP, ILOC, JLOC

NAMELIST and variable names used by PREDA are presented in Table 4-11. Table 4-12 presents the table types output by DARTAB from which the user may select.

Table 4-10. Cattle densities and vegetable crop distributions for use with AIRDOS-EPA.

State	Dairy cattle density #/km^2	Beef cattle density #/km^2	Vegetable crop fraction km^2/km^2
Alabama	7.02E-1	1.5E+1	4.16E-3
Arizona	2.80E-1	3.73	2.90E-3
Arkansas	5.90E-1	1.27E+1	1.46E-3
California	2.85	8.81	1.18E-2
Colorado	3.50E-1	1.13E+1	1.39E-2
Connecticut	2.50E-1	3.60	7.93E-3
Delaware	2.72	6.48	5.85E-2
Florida	1.37	1.28E+1	6.92E-3
Georgia	8.63E-1	1.43E+1	2.17E-3
Idaho	8.56E-1	7.19	7.15E-2
Illinois	2.16	3.33E+1	2.80E-2
Indiana	2.80	3.34E+1	2.72E-2
Iowa	3.14	7.40E+1	2.43E-2
Kansas	8.00E-1	2.90E+1	5.97E-2
Kentucky	2.57	2.65E+1	3.98E-3
Louisiana	9.62E-1	1.08E+1	4.35E-2
Maine	8.07E-1	7.65E-1	5.97E-2
Maryland	6.11	1.09E+1	1.11E-2
Massachusetts	3.13	2.90	4.96E-3
Michigan	3.51	7.90	1.70E-2
Minnesota	4.88	1.85E+2	3.05E-2
Mississippi	8.70E-17	1.75E+1	1.07E-3
Missouri	1.89	3.43E+1	8.14E-3
Montana	9.27E-2	7.29	8.78E-3
Nebraska	8.78E-1	3.50E+1	2.39E-2
Nevada	5.65E-2	1.84	8.92E-3
New Hampshire	1.58	1.40	6.69E-2
New Jersey	3.29	4.25	1.82E-2
New Mexico	1.14E-1	4.13	1.38E-3
New York	8.56	5.83	1.88E-2
North Carolina	1.26	1.02E+1	6.32E-3
North Dakota	6.25E-1	1.18E+1	6.29E-2
Ohio	4.56	2.03E+1	1.70E-2
Oklahoma	7.13E-1	2.68E+1	2.80E-2
Oregon	4.53E-1	4.56	1.59E-2

Table 4-10. Cattle densities and vegetable crop distributions for use with AIRDOS-EPA (continued).

State	Dairy cattle density #/km^2	Beef cattle density #/km^2	Vegetable crop fraction km^2/km^2
Pennsylvania	6.46	9.63	1.32E-2
Rhode Island	2.30	2.50	4.54E-2
South Carolina	7.02E-1	8.87	1.84E-3
South Dakota	8.85E-1	2.32E+1	1.20E-2
Tennessee	2.00E-1	2.11E+1	2.72E-3
Texas	5.30E-1	1.90E+1	5.77E-3
Utah	4.46E-1	2.84	1.83E-3
Vermont	8.88	4.71	1.08E-3
Virginia	1.84	1.31E+1	8.70E-3
Washington	1.50	5.62	5.20E-2
West Virginia	6.00E-1	6.23	1.16E-3
Wisconsin	1.43E+1	1.81E+1	1.78E-2
Wyoming	5.79E-2	5.12	1.58E-3

Table 4-11. Valid PREDA NAMELIST and variable names.

NAMELIST	Variables	Default	Units	Description
INPUT	IHEAD	1	-	Flag controlling how many fields are to be read for each record in the RADRISK file. The only valid value for the current version of CAP-88 is 1.
	ICRP	1	-	Flag used to select organ dose factors calculated assuming that parents and progeny behave metobolically the same (ICRP methodology) or that the progeny behave metobolically like themselves (EPA methodology). In the current version, ICRP values are only available for the progeny of lead-210 and bismuth-210. For Clean Air Act assessments, ICRP = 1 must be used for these progeny. IRCP = 0 EPA methodology, ICRP = 1 ICRP methodology (progeny of ^{210}Pb and ^{210}Bi only).
	ILOC	0	-	ILOC is the direction indices for the desired location of the exposure array to use for the individual tables.
	JLOC	0	-	ILOC is the distance indices for the desired location of the exposure array to use for the individual tables.
	PLOC	100	-	PLOC is the percentile of the total risk to use in choosing the location for the exposure array used for the individual tables. If PLOC=p, then the location used will be the one associated with the [p/100]th ordered value of the risk array. Note that if both ILOC and JLOC equal zero, PLOC will be used to choose the location.
	AGEX	70.7565	years	The average lifetime expectancy.
	ILET(1) ILET(2)	1 1	- -	ILET is an array dimensioned by two. ILET(I)=0 indicates that only separate high- and low- LET tables will be output; 1 indicates only a combined table will be output; 2 indicates both sets of tables will be output. For ILET(1), dose rate tables are output. For ILET(2), health risk tables are output.

Table 4-11. Valid PREDA NAMELIST and variable names (continued).

NAMELIST	Variables	Default	Units	Description
	DTABLE(1) DTABLE(2) DTABLE(3) DTABLE(4) DTABLE(5) DTABLE(6) DTABLE(7)	0 0 0 0 0 0 0	- - - - - - -	DTABLE indicates which of the seven possible dose rate tables (see Table 4.2-2) will be output. The value of each position indicates the type of table: DTABLE(I) = 0 none of this type of table are to be output, = 1 output the table for an individual, = 2 output the table for a mean individual, = 3 output the table for the collective group, = 4 output all three types of the above tables.
	RTABLE(1) RTABLE(2) RTABLE(3) RTABLE(4) RTABLE(5) RTABLE(6) RTABLE(7)	0 0 0 0 0 0 0	- - - - - - -	RTABLE indicates which of the seven possible health risk tables (see Table 4.2-2) will be output. The value of each position indicates the type of table: RTABLE(I) = 0 none of this type of table are to be output, = 1 output the table for an individual, = 2 output the table for a mean individual, = 3 output the table for the collective group, = 4 output all three types of the above tables.
	FTABLE(1) FTABLE(2) FTABLE(3) FTABLE(4) FTABLE(5) FTABLE(6) FTABLE(7)	0 0 0 0 0 4 0	- - - - - - -	FTABLE indicates which of the seven possible risk equivalent tables (see Table 4.2-2) will be output. The value of each position indicates the type of table: FTABLE(I) = 0 none of this type of table are to be output, = 1 output the table for an individual, = 2 output the table for a mean individual, = 3 output the table for the collective group, = 4 output all three types of the above tables.
	OUTPUT	'FALSE'	-	OUTPUT is a logical variable which governs whether the dose factors will be output.
	GSCFAC	-	-	GSCFAC is a ground surface correction factor. All ground surface quantities are multiplied by this factor to account for surface roughness.
ORGAN	ORGN[a]	Blank	-	ORGN are the alphanumeric names (8 characters) of the NORGN organs.

(a) The organ names are set in PRDPOP.DAT to the following: GONADS, BREAST, R MAR, LUNGS, THYROID, ENDOST, RMNDR, and EFFEC.

Table 4-11. Valid PREDA NAMELIST and variable names (continued).

NAMELIST	Variables	Default	Units	Description
	NORGN[b]	0	-	NORGN is the number of organs to be considered in the dose rate tables.
	TIME	70	years	TIME is the time associated with the dose commitment factor.
QFACTOR	HLET	20	-	HLET is the relative biological effectiveness factor to use for the high-LET dose rates to convert absorbed dose (rad) to dose equivalent (rem).
	LLET	1	-	LLET is the relative biological effectiveness factor to use for the low-LET dose rates to convert absorbed dose (rad) to dose equivalent (rem).
CANCER	CANC	W BODY[c]	-	CANC are the alphanumeric names (8 characters) of the NCANC cancers.
	NCANC	1	-	NCANC is the number of cancers to be output for the risk and risk equivalent factors.
	RELABS	1	-	RLABS indicates whether the absolute (RLABS=1) or relative (RLABS=2) risk model is to be used for each cancer.
GENETIC	GENEFF	-	-	GENEFF is a logical variable which indicates whether or not genetic effects are to be output.
	GEN	-	-	GEN are the alphanumeric names (8 characters) of the organs to be considered for genetic effects.
	NGEN	-	-	NGEN is the number of organs identified in GEN.
	GRFAC(1) GRFAC(2)	-	genetic effects per rad/million	GRFAC are the risk conversion factors. GRFAC(1) is for low-LET doses; GRFAC(2) is for high-LET doses.
	REPPER	0.014133	$year^{-1}$	REPPER is the replacement rate for the population.
	GLLET	-	-	GLLET is the relative biological effectiveness factor to use for the low-LET genetic doses to convert absorbed dose (rad) to dose equivalents (rem), NGEN values for GEN organs.

(b) The value for NORGN is set to 0 in PREDA.FOR; however, in PRDPOP.DAT the value must be set to 8.
(c) In PRDPOP.DAT, CANC names are set to LEUKEMIA, BONE, THYROID, BREAST, LUNG, STOMACH, BOWEL, LIVER, PANCREAS, URINARY, and OTHER.

Table 4-11. Valid PREDA NAMELIST and variable names (continued).

NAMELIST	Variables	Default	Units	Description
	GHLET	-	-	GHLET is the relative biological effectiveness factor to use for the high-LET genetic doses to convert absorbed dose (rad) to dose equivalents (rem), NGEN values for GEN organs.
RNUCLD	NUCLID	-	-	NUCLID is the alphanumeric names (8 characters) of the NONCLD radionuclides.
	NONCLD	-	-	NONCLD is the number of radionuclides to be considered.
	PSIZE	-	AMAD	PSIZE is the activity median aerodynamic diameter (AMAD) of the aerosol distribution associated with each radionuclide.
	RESP	-	-	RESP is the respiratory clearance class associated with each radionuclide.
	GIABS	-	-	GIABS are the GI absorption factors (f_1 parameter for each segment of the gastrointestinal tract) to be associated with each radionuclide.
LOCTAB	NTLOC	-	-	NTLOC is the number of location tables ($\leq$ 10) to be output. For each table RNLOC, OGLOC, PTLOC, FALOC, HLLOC, AND LTABLE must be defined.
	RNLOC	-	-	RNLOC is the radionuclide to use. Specifying SUM will result in the sum of all nuclides in the run. Specifying WORKLEVL will result in working level calculations. Specifying WLSUM will result in the total risk for all nuclides, including those based on the working level.
	OGLOC	-	-	OGLOC is the organ or cancer to use. Specifying SUM will result in the sum of all cancers.

Table 4-11. Valid PREDA NAMELIST and variable names (continued).

NAMELIST	Variables	Default	Units	Description
	PTLOC	-	-	PTLOC = 1 for ingestion pathway. PTLOC = 2 for inhalation pathway. PTLOC = 3 for air immersion pathway. PTLOC = 4 for ground surface exposure pathway. PTLOC = 5 for internal pathway (1+2). PTLOC = 6 for external pathway (3+4). PTLOC = 7 for total (1+2+3+4).
	FALOC	-	-	FALOC = 1 for dose factor. FALOC = 2 for risk factor. FALOC = 3 for risk equivalent factor.
	HLLOC	-	-	HLLOC = 0 separate low- and high-LET tables printed. HLLOC = 1 combined low- and high-LET table printed. HLLOC = 2 all three tables printed.
	LTABLE	-	-	LTABLE = 1 table printed is for selected individual. LTABLE = 2 table printed is for the mean individual. LTABLE = 3 table printed is for the collective population.
ORGAN F	NORGB	-	-	NORGB is the number of organ dose weights to use to combine dose rates.
	ORGB	-	-	ORGB are the NORGB organs to be used in combining the dose rates.
	ORGDAT(d)	-	-	ORGDAT are the organ dose weighting factors.
	IPATH	-	-	IPATH is the exposure pathway effected. IPATH = 1 ingestion, IPATH = 2 inhalation, IPATH = 3 air immersion, IPATH = 4 ground surface, IPATH = 5 all pathways.

(d) In PRDPOP.DAT, the organ dose weighting factors are set as follows: Gonads - 0.25, Breast - 0.15, Red Marrow - 0.12, Lungs - 0.12, Thyroid - 0.03, Endosteum - 0.03, Remainder - 0.30.

Table 4-12. Possible table types output by DARTAB.

Table Type	Variable: Column Label	Variable: Row Label	Constant
1	Organs or cancers	Radionuclides	Individual pathways
2	Organs or cancers	Radionuclides	External & internal
3	Organs or cancers	Radionuclides	All pathways
4	Radionuclides	Pathways	Organs or cancers
5	Organs or cancers	Pathways	Radionuclides
6	Organs or cancers	Pathways	Summed over radionuclides
7	Compass direction	Distance in meters	User-specified

4.3 IMPORTANT DIFFERENCES BETWEEN CAP-88 AND EARLIER VERSIONS OF AIRDOS-EPA

There are a few differences between CAP-88 and earlier versions of AIRDOS, PREPAR and DARTAB. CAP-88 is optimized for doing population assessments. It is assumed that population arrays supplied to the program are generated with SECPOP, and that maximally-exposed individuals are on the supplied array. Direct user input of concentrations has been eliminated. Instead, to reduce human error, CAP-88 uses the distances in the population array to determine the distances for which concentrations are calculated. Only circular grids now produce valid results. Agricultural arrays are set to be generated automatically, as a function of state-specific productivity data, requiring the user to supply only the State abbreviation.

CAP-88 has been modified to do either "Radon-only" or "Non-Radon" runs, in order to conform with the format of the 1988 Clean Air Act NESHAPS Rulemaking. Assessments with only Radon-222 in the source term automatically include working level calculations; any other source term ignores working levels. Synopsis reports customized to both formats are automatically generated.

Organs and weighting factors have been modified to follow the ICRP 26/30 Effective Dose Equivalent calculations, which eliminated flexibility on specifying organs and weighting factors. The calculation of deposition velocity and scavenging coefficients has also modified to incorporate current EPA policy.

Organs and Weighting Factors

Only 7 organs are valid for the new Effective Dose Equivalent. They are:

Organ	Weight
GONADS	0.25
BREAST	0.15
R MAR	0.12
LUNGS	0.12
THYROID	0.03
ENDOST	0.03
RMNDR	0.30

Only these 7 organs are valid. Changing the organs and weights will invalidate the results!

They are stored in the ALLRAD file: CBNRACS.CAA88.DATA(ALLRAD88).

Population Arrays

Population arrays must now be entered only as a file. In the 1985 CAAC version, population arrays could be entered as instream data in PREPAR. This will now cause an infinite loop.

The distances in the population file, used and listed by SECPOP, are used by CAP-88 to determine the distances used in the assessment. This was added to the program to eliminate human error in mis-matching the distances used to calculate concentrations with the distances used to generate the population array. Distances used for calculating concentrations are now automatically set in CAP-88 so as to calculate concentrations for the midpoint of each sector.

Distances

In population assessments, distances used to calculate concentrations (IDIST) are calculated automatically as a function of the distances in the population array file. CAP-88 is written to ignore user assignments of IDIST in the PREPAR input file for population runs.

Agricultural Arrays

Arrays of milk cattle, beef cattle and agricultural crop area are now automatically generated by the code. The arrays are made to match the distances used in the population arrays supplied to the code, and use State-specific agricultural productivity values. The state name (standard two letter abbreviation) must be provided to the variable STATE. It is read in from the instream data and must be the only entry on the fourth line of the facility information.

This feature may be disabled by setting FOODARRAY_GEN_AUTO to FALSE and USERARRAY to TRUE.

Radon-Only Runs

Assessments for Radon-222 now automatically include Working Level calculations. CAP-88 does this automatically when a single source term of Radon-222 is provided.

To use this option the user must put only "Rn-222" in the source term. Input of any additional radionuclides, even Rn-220, will cause CAP-88 to omit working level calculations.

Square Grids

Option 2 in AIRDOS allows users to choose either a square (0) or circular grid (1). While this option is still available, CAP-88 requires a circular grid for population assessments. Using a square grid will produce invalid results.

Direct Input of Concentrations

In CAP-88, the user may no longer supply concentrations as input. The subroutine DIRECT has been removed from CAP-88.

Scavenging Coefficient

The subroutine SETSC in PREPAR is no longer used. The scavenging coefficient (SC) for iodines and particulates is now calculated by PREPAR as a function of rainfall rate (RR). The formula used is:

SC = RR * 1E-7 (for iodines and particulates) (4-1)

SC = 0 (for gases)

Tritium is considered to be a gas by the program; therefore, PREPAR calculates a value of zero for the scavenging coefficient which is not correct. The user must enter a nonzero value for SC using either NAMELIST RADI or MODI to avoid this problem.

Deposition Velocity

The subroutine SETVD in PREPAR is no longer used to calculate deposition velocity (VD). VD is set as follows:

Class	VD m/sec
Iodine	3.5E-2
Particulate	1.8E-3
Gas	0

Equilibrium Fractions

The capability to vary equilibrium fractions was added. Previously they were set to a constant of 0.7. The new method varies the equilibrium fractions depending on the distance from the source. Linear interpolation is used to determine the equilibrium fractions for distances that do match the set distances given. The equation is as follows:

EFY = EFX + ((EFZ - EFX) * ((Y - X) / (Z - X))) (4-2)

where: X ←——— Y ———→ Z

X and Z are the set distances given and Y is the user given distance (between X and Z). The new method finds the equilibrium fraction for EFX, and EFZ is the SET_EQUIL_FRACTIONS corresponding to the set distances.

DOSMIC Subroutine

DOSMIC was modified to print only Working Levels. Working Levels are only output for RN-222. Checks are performed before DOSMIC is called to determine if Working Levels are needed.

Printing Dose Conversion Factors

The dose conversion factors are no longer printed automatically. To print them, set the variable OUTPUT to '.TRUE.'. The variable OUTPUT is set in the file CAAR.AIRDOS.LIB(JOAPOP) for a population run and CAAR.AIRDOS.LIB(JOAIND) for an individual run.

Water Arrays

Arrays of water areas are no longer used in CAP-88.

NOMA fix

CAP-88 uses a slightly different approach in calculating NOMA, following discovery of a potential error in the 1985 CAAC version of AIRDOS.

In the earlier (1985 CAAC) version, this error caused multiple point sources to be treated as an area source if the nuclides emitted from each stack had identical characteristics. This may cause some differences with previous assessments.

Wind Frequencies

The GETWND routine in PREPAR has been modified to accept wind speeds greater than 10 m/sec. Earlier versions would only accept wind speeds less than 10 m/sec, and there was a problem with some facilities, which had high wind speeds, generating overflow errors in the wind speed arrays.

In order to accommodate higher wind speeds, and remain compatible with existing wind data sets, precision limits force the calculations to truncate the last digit in the wind speed data. This in turn may cause a slight variation in the termination of PERD, the wind frequency for each direction, due to round up. This may cause a variation in concentrations as compared with earlier versions of PREPARE and AIRDOS-EPA.

5. CAP-88 OUTPUT

SAMPLE.OUTPUT, shown in Appendix I, is an example of the output from a run of the CAP-88 programs. While most of the output is in the same format that a user would obtain when running the CAAC version of the programs, a new section, the synopsis report, is now printed at the beginning of the output. The synopsis report is also output as a separate file, SAMPLE.SYNOPSIS, which is listed in Appendix J. The synopsis report contains the following information:

- Run identification information including the date and time of the run, an ID code, facility name and address, source category data, and any general comments.

- Population assessment results which include, for non-radon exposures, the ICRP collective effective and organ dose equivalents. Radon population assessment results are presented as collective exposure in person working levels. The frequency distribution of lifetime fatal cancer risks for the population is presented for both radon and non-radon assessments.

- Exposure and risk information is presented for the individual at maximum risk. For both radon and non-radon assessment, the location of the individual and his lifetime fatal cancer risk are presented. For a non-radon assessment, the ICRP effective and organ dose equivalents are presented. For a radon assessment, the individual's exposure, in working levels and in pCi/liter, are presented.

- Source term information (nuclide, clearance class, AMAD, and release rate) is presented for each stack or area source.

- Site temperature, rainfall, and mixing height information is presented.

- Emission information is presented for each stack or area source. For stack sources, this includes the stack height, diameter, and plume rise information. For an area source, this includes the area height, the area, and the area diameter.

- Local, regional, and imported food supply fractions are included for meat, milk, and vegetables.

- The population array is listed.

- The data file names used in the assessment are listed. See Section 4.1.1 for a description of how this information is passed by the user to CAP-88.

- Finally, a more detailed frequency distribution of lifetime fatal cancer risks is presented.

The remainder of the output file is controlled by user-selected AIRDOS-EPA and DARTAB options.

6. BACKGROUND INFORMATION AND AIDS TO THE USER

6.1 EPA ENVIRONMENTAL PATHWAY MODELING ASSUMPTIONS

This section, taken from Volume I of the "Environmental Impact Statement for Proposed NESHAPS for Radionuclides" dated October 1989, provides a brief overview of some of the key calculational assumptions used by the Environmental Protection Agency to assess the doses and health risk from radiation exposures.

6.1.1 Environmental Pathway Modeling

6.1.1.1 Individual Assessment

The nearby individuals were assessed on the following basis:

(1) The nearby individuals for each source category are intended to represent an average of individuals living near each facility within the source category. The location of one or more persons on the assessment grid which provides the greatest lifetime risk (all pathways considered) was chosen for the nearby individuals.

(2) The organ dose-equivalent rates in the tables are based on the environmental concentrations calculated by AIRDOS-EPA (EPA79). For inhaled or ingested radionuclides, the conversion factors are 50-year committed dose equivalents.

(3) The individual is assumed to home-grow a portion of his or her diet consistent with the type of site. Individuals living in urban areas were assumed to consume much less home-produced food than an individual living in a rural area. It was assumed that in an agriculturally unproductive location, people would home-produce a portion of their food comparable to residents of an urban area, and so the urban fraction is used for such nonurban locations. The fractions of home-produced food consumed by individuals for the generic sites are shown in Table 6-1.

Table 6-1. Presumed sources of food for urban and rural sites.

Food	Urban/Low productivity			Rural		
	F1	F2	F3	F1	F2	F3
Vegetables	.076	.924	0.	.700	.300	0.
Meat	.008	.992	0.	.442	.558	0.
Milk	0.	1.	0.	.399	.601	0.

F1 and F2 are the home-produced fractions at the individuals' location and within the 80 kilometer assessment area, respectively. The balance of the diet, F3, is considered to be imported from outside the assessment area, with negligible radionuclide concentrations due to the assessed source. If there is insufficient production of a food category within the assessment area to provide the non-home-produced fraction for the population, F2 is reduced and F3 is increased accordingly. Fractions are based on an analysis of household data from the USDA 1965-1966 National Food Consumption Survey (USDA72).

6.1.1.2 Collective Assessment

The collective assessment to the population within an 80 kilometer radius of the facility under consideration was performed as follows:

(1) The population distribution around the generic site was based on the 1980 census. The population was assumed to remain stationary in time.

(2) Average agricultural production data for the state in which the generic site is located were assumed for all distances greater than 500 meters from the source. For distances less than 500 meters, no agricultural production is calculated.

(3) The population in the assessment area consumes food from the assessment area to the extent that the calculated production allows. Any additional food required is assumed to be imported without contamination by the assessment source. Any surplus is not considered in the assessment.

(4) The collective organ dose-equivalent rates are based on the calculated environmental concentrations. Fifty-year dose commitment factors (as for the individual case) are used for ingestion and inhalation. The collective dose equivalent rates in the tables can be considered to be either the dose commitment rates after 100 years of plant operation, or equivalently, the incurred doses that will be for up to 100 years from the time of release. Tables 6-2 and 6-3 summarize AIRDOS-EPA parameters used for the assessments (ORNL84).

Table 6-2 summarizes agricultural model parameters, usage factors, and other AIRDOS-EPA parameters which are independent of the released radionuclides. Table 6-3 tabulates element-dependent data. These include the default inhalation clearance class and the fraction of the stable element reacting with body fluids after ingestion. Inhaled clearance classes D, W, and Y correspond to those materials that clear from the lung over periods of days, weeks, and years, respectively. Class * is for gases. Biv_1 and Biv_2 are the soil-to-pasture and soil-to-produce concentration factors, respectively. Both factors are for soil concentration on a dry weight basis. The pasture and produce concentrations are on dry and fresh weight bases, respectively.

F_m and F_f relate the stable element intake rate to the concentration in milk and meat, respectively. The values for the factors in this table are maintained in the PREPAR file ACCRAD (ORNL84).

Table 6-2. AIRDOS-EPA parameters used for generic site assessments.

Variable	Symbolic Description	Value
BRTHRT	Breathing rate (cm^3/h)	9.17E+5
T	Surface buildup time (days)	3.65E+4
DDI	Activity fraction after washing	0.5
TSUBHI	Time delay--pasture grass (h)	0.0
TSUBH2	Time delay--stored food (h)	2.16E+3
TSUBH3	Time delay--leafy vegetables (h)	336.
LAMW	Weathering removal rate factor (h^{-1})	2.10E-3
TSUBE1	Exposure period--pasture (h)	720.
TSUBE2	Exposure period--crops or leafy vegetables (h)	1.44E+3
YSUBV1	Productivity--pasture (dry weight) (kg/m^2)	0.280
YSUBV2	Productivity--crops and leafy vegetables (kg/m^2)	0.716
FSUBP	Time fraction--pasture grazing	0.40
FSUBS	Pasture feed fraction--while pasture grazing	0.43
QSUBF	Feed or forage consumption rate (kg-dry/day)	15.6
TSUBF	Consumption delay time--milk (d)	2.0
UV	Vegetable utilization rate (kg/y)	176.0
UM	Milk utilization rate (kg/y)	112.0
UF	Meat utilization rate (kg/y)	85.0
UL	Leafy vegetable utilization rate (kg/y)	18.0
TSUBS	Consumption time delay--meat (days)	20.0

Table 6-2. AIRDOS-EPA parameters used for generic site assessments (continued).

Variable	Symbolic Description	Value
FSUBG	Produce fraction (garden of interest)	1.0
FSUBL	Leafy vegetable fraction (garden of interest)	1.0
TSUBB	Soil buildup time (y)	100.
P	Effective surface density of soil (kg/m^2)	215.
TAUBEF	Meat herd--slaughter rate factor (d^{-1})	3.18E-3
MSUBB	Mass of meat of slaughter (kg)	200.
VSUBM	Milk production rate of cow (L/d)	11.0
R1	Deposition interception fraction-pasture	0.57
R2	Deposition interception fraction-leafy vegetables	0.20

Table 6-3. Default values used for element-dependent factors.

Element	Inh. Class	Ing. f_1	B_{iv1}	B_{iv2}	F_m (d/L)	F_f (d/kg)
Ac	Y	1.0E-3	3.5E-3	1.5E-4	2.0E-5	2.5E-5
Ag	Y	5.0E-2	4.0E-1	4.3E-2	2.0E-2	3.0E-3
Am	W	1.0E-3	5.5E-3	1.1E-4	4.0E-7	3.5E-6
Ar	*	0.0	0.0	0.0	0.0	0.0
As	W	5.0E-1	4.0E-2	2.6E-3	6.0E-5	2.0E-3
At	D	9.5E-1	1.0	6.4E-2	1.0E-2	1.0E-3
Ba	D	1.0E-1	1.5E-1	6.4E-3	3.5E-4	1.5E-4
Be	Y	5.0E-3	1.0E-2	6.4E-4	9.0E-7	1.0E-3
Bi	W	5.0E-2	3.5E-2	2.1E-3	5.0E-4	4.0E-4
Br	D	9.5E-1	1.5	6.4E-1	2.0E-2	2.5E-2
C	*	9.5E-1	0.0	0.0	0.0	0.0
Ca	W	3.0E-1	3.5	1.5E-1	1.0E-2	7.0E-4
Cd	Y	5.0E-2	5.5E-1	6.4E-2	1.0E-3	5.5E-4
Ce	Y	3.0E-4	1.0E-2	1.7E-3	2.0E-5	7.5E-4
Cf	Y	1.0E-3	0.0	0.0	0.0	0.0
Cm	W	1.0E-3	8.5E-4	6.4E-6	2.0E-5	3.5E-6
Co	Y	3.0E-1	2.0E-2	3.0E-3	2.0E-3	2.0E-2
Cr	Y	1.0E-1	7.5E-3	1.9E-3	1.5E-3	5.5E-3
Cs	D	9.5E-1	8.0E-2	1.3E-2	7.0E-3	2.0E-2
Cu	Y	5.0E-1	4.0E-1	1.1E-1	1.5E-3	1.0E-2
Eu	W	1.0E-3	1.0E-2	1.7E-3	2.0E-5	5.0E-3
F	D	9.5E-1	6.0E-2	2.6E-3	1.0E-3	1.5E-1
Fe	W	1.0E-1	4.0E-3	4.3E-4	2.5E-4	2.0E-2
Fr	D	9.5E-1	3.0E-2	3.4E-3	2.0E-2	2.5E-3
Ga	W	1.0E-3	4.0E-3	1.7E-4	5.0E-5	5.0E-4
Gd	W	3.0E-4	1.0E-2	1.7E-3	2.0E-5	3.5E-3
H	*	9.5E-1	0.0	0.0	0.0	0.0
Hf	W	2.0E-3	3.5E-3	3.6E-4	5.0E-6	1.0E-3
Hg	W	2.0E-2	9.0E-1	8.6E-2	4.5E-4	2.5E-1
Ho	W	3.0E-4	1.0E-2	1.7E-3	2.0E-5	4.5E-3
I	D	9.5E-1	1.0	4.3E-1	1.0E-2	7.0E-3
In	W	2.0E-2	4.0E-3	1.7E-4	1.0E-4	8.0E-3
Ir	Y	1.0E-2	5.5E-2	6.4E-3	2.0E-6	1.5E-3
K	D	9.5E-1	1.0	2.4E-1	7.0E-3	2.0E-2
Kr	*	0.0	0.0	0.0	0.0	0.0
La	W	1.0E-3	1.0E-2	1.7E-3	2.0E-5	3.0E-4
Mn	W	1.0E-1	2.5E-1	2.1E-1	3.5E-4	4.0E-4
Mo	Y	8.0E-1	2.5E-1	2.6E-2	1.5E-3	6.0E-3
N	*	9.5E-1	3.0E+1	1.3E+1	2.5E-2	7.5E-2
Na	D	9.5E-1	7.5E-2	2.4E-2	3.5E-2	5.5E-2

Table 6-3. Default values used for element-dependent factors (continued).

Element	Inh. Class	Ing. f_1	B_{iv1}	B_{iv2}	F_m (d/L)	F_f (d/kg)
Nb	Y	1.0E-2	2.0E-2	2.1E-3	2.0E-2	2.5E-1
Nd	Y	3.0E-4	1.0E-2	1.7E-3	2.0E-5	3.0E-4
Ni	W	5.0E-2	6.0E-2	2.6E-2	1.0E-3	6.0E-3
Np	W	1.0E-3	1.0E-1	4.3E-3	5.0E-6	5.5E-5
O	*	9.5E-1	0.0	0.0	0.0	0.0
P	D	8.0E-1	3.5	1.5	1.5E-2	5.5E-2
Pa	Y	1.0E-3	2.5E-3	1.1E-4	5.0E-6	1.0E-5
Pb	D	2.0E-1	4.5E-2	3.9E-3	2.5E-4	3.0E-4
Pd	Y	5.0E-3	1.5E-1	1.7E-2	1.0E-2	4.0E-3
Pm	Y	3.0E-4	1.0E-2	1.7E-3	2.0E-5	5.0E-3
Po	W	1.0E-1	2.5E-2	1.7E-3	3.5E-4	3.0E-4
Pr	Y	3.0E-4	1.0E-2	1.7E-3	2.0E-5	3.0E-4
Pu	Y	1.0E-3*	4.5E-4	1.9E-5	1.0E-7	5.0E-7
Ra	W	2.0E-1	1.5E-2	6.4E-4	4.5E-4	2.5E-4
Rb	D	9.5E-1	1.5E-1	3.0E-2	1.0E-2	1.5E-2
Re	W	8.0E-1	1.5	1.5E-1	1.5E-3	8.0E-3
Rh	Y	5.0E-2	1.5E-1	1.7E-2	1.0E-2	2.0E-3
Rn	*	0.0	0.0	0.0	0.0	0.0
Ru	Y	5.0E-2	7.5E-2	8.6E-3	6.0E-7	2.0E-3
S	D	8.0E-1	1.5	6.4E-1	1.5E-2	1.0E-1
Sb	W	1.0E-1	2.0E-1	1.3E-2	1.0E-4	1.0E-3
Sc	Y	1.0E-4	6.0E-3	4.3E-4	5.0E-6	1.5E-2
Se	W	8.0E-1	2.5E-2	1.1E-2	4.0E-3	1.5E-2
Sm	W	3.0E-4	1.0E-2	1.7E-3	2.0E-5	5.0E-3
Sn	W	2.0E-2	3.0E-2	2.6E-3	1.0E-3	8.0E-2
Sr	D	3.0E-1	2.5	1.1E-1	1.5E-3	3.0E-4
Tb	W	3.0E-4	1.0E-2	1.7E-3	2.0E-2	4.5E-3
Tc	W	8.0E-1	9.5E	6.4E-1	1.0E-2	8.5E-3
Te	W	2.0E-1	2.5E-2	1.7E-3	2.0E-4	1.5E-2
Th	Y	2.0E-4	8.5E-4	3.6E-5	5.0E-6	6.0E-6
Tl	D	9.5E-1	4.0E-3	1.7E-4	2.0E-3	4.0E-2
U	Y	2.0E-1	8.5E-3	1.7E-3	6.0E-4	2.0E-4
W	D	1.0E-2	4.5E-2	4.3E-3	3.0E-4	4.5E-2
Xe	*	0.0	0.0	0.0	0.0	0.0
Y	Y	1.0E-4	1.5E-2	2.6E-3	2.0E-5	3.0E-4
Zn	Y	5.0E-1	1.5	3.9E-1	1.0E-2	1.0E-1
Zr	W	2.0E-3	2.0E-3	2.1E-4	3.0E-5	5.5E-3

*(For PU-239, Pu-240, and Pu-242, $F_1 = 1_2.0E-4$)

6.1.2 Dairy and Beef Cattle

Dairy and beef cattle distributions are part of the AIRDOS-EPA input. A constant cattle density is assumed except for the area closest to the source or stack in the case of a point source, i.e., no cattle within 500 meters of the source. These densities were derived from data developed by NRC (NRC75). Milk production density in units of liters/day-square mile was converted to number of dairy cattle/square kilometer by assuming a milk production rate of 11.0 liters/day per dairy cow. Meat production density in units of kilograms/day-square mile was changed to an equivalent number of beef cattle/square kilometer by assuming a slaughter rate of .00381 day-1 and 200 kilograms of beef/animal slaughtered. A 180-day grazing period was assumed for dairy and beef cattle.

6.1.3 Vegetable Crop Area

A certain fraction of the land within 80 kilometers of the source is used for vegetable crop production and is assumed to be uniformly distributed throughout the entire assessment area with the exception of the first 500 meters from the source. Information on the vegetable production density in terms of kilograms (fresh weight)/day-square mile was obtained from NRC data (NRC75). The vegetable crop fractions by state were obtained from the production densities by assuming a production rate of 2 kilograms (fresh weight)/year-square meter (NRC77).

6.1.4 Population

The population data for each generic site were generated by a computer program, SECPOP (At74), which utilizes an edited and compressed version of the 1980 United States Census Bureau's MARF data containing housing and population counts for each census enumeration district (CED) and the geographic coordinates of the population centroid for the district. In the Standard Metropolitan Statistical Areas (SMSA), the CED is usually a "block group" which consists of a physical city block. Outside the SMSAs, the CED is an "enumeration district," which may cover several square miles or more in a rural area.

There are over 250,000 CEDs in the United States with a typical population of about 800 persons. The position of the population centroid for each CED was marked on the district maps by the individual census official responsible for each district and is based only on personal judgment from inspection of the population distribution on a map. The CED entries are sorted in ascending order by longitude on the final data tape.

The resolution of a calculated population distribution cannot be better than the distribution of the CEDs. Hence, in a metropolitan area the resolution is often as small as one block, but in rural areas, it may be on the order of a mile or more.

6.1.5 Risk Conversion Factors

Table 6-4 summarizes the average lifetime fatal cancer risk per unit intake or exposure for most of the radionuclides considered in the assessments. Note that the external exposure factors do not include the

Table 6-4. Fatal cancer risk factors for selected radionuclides (see Table 6-3 for default inhalation class and ingestion f_1 values).

Nuclide	Inhal. (mCi^{-1})	Ingest. (mCi^{-1})	Immer. (m^3/mCi yr)	Surface (m^2/mCi yr)
Ac-227	7.9E-02	3.5E-04	2.0E-07	6.5E-09
Ac-228	2.5E-05	3.2E-07	1.6E-03	3.1E-05
Ag-110	7.6E-10	2.3E-09	5.3E-05	1.0E-06
Ag-110m	6.0E-05	3.5E-06	4.8E-03	9.1E-05
Am-241	3.9E-02	3.0E-04	2.7E-05	8.5E-07
Ar-41	4.9E-10	-	2.3E-03	3.9E-05
Au-198	1.8E-06	6.9E-07	6.7E-04	1.4E-05
Ba-137m	5.1E-10	1.8E-09	1.0E-03	2.0E-05
Ba-140	1.6E-06	1.5E-06	3.1E-04	6.6E-06
Bi-210	7.5E-05	1.0E-06	-	-
Bi-211	1.8E-07	9.4E-09	7.8E-05	1.7E-06
Bi-212	6.2E-06	2.3E-07	3.2E-04	6.0E-06
Bi-214	2.0E-06	1.0E-07	2.8E-03	4.8E-05
C-14	4.1E-09	5.9E-07	0.0E+00	0.0E+00
Ce-144	3.2E-04	3.4E-06	2.8E-05	6.6E-07
Cm-244	2.6E-02	1.9E-04	1.2E-07	2.4E-08
Co-60	1.3E-04	9.7E-06	4.4E-03	7.7E-05
Cr-51	2.7E-07	2.5E-08	5.2E-05	1.1E-06
Cs-134	1.7E-05	2.5E-05	2.7E-03	5.3E-05
Cs-137	1.2E-05	1.7E-05	0.0E+00	0.0E+00
Eu-154	1.3E-04	2.0E-06	2.2E-03	4.1E-05
Fe-59	8.0E-06	1.7E-06	2.1E-03	3.7E-05
Fr-223	4.1E-07	1.6E-07	7.1E-05	1.8E-06
Ga-67	3.0E-07	1.2E-07	2.4E-04	5.3E-06
Gd-152	0.0E+00	0.0E+00	-	-
H-3	4.9E-08	3.4E-08	0.0E+00	0.0E+00
Hf-181	8.6E-06	7.2E-07	9.0E-04	1.9E-05
Hg-197	3.8E-07	1.5E-07	9.3E-05	2.4E-06
Hg-203	4.3E-06	3.8E-07	3.8E-04	8.2E-06
I-123	8.7E-08	1.2E-07	2.6E-04	5.8E-06
I-125	1.8E-06	2.7E-06	1.4E-05	6.3E-07
I-129	1.3E-05	1.9E-05	1.1E-05	5.7E-07
I-131	2.6E-06	3.7E-06	6.7E-04	1.4E-05
I-133	1.5E-06	2.2E-06	1.0E-03	2.1E-05
In-113m	2.6E-08	3.4E-08	4.2E-04	9.0E-06
Ir-192	2.5E-05	9.8E-07	1.4E-03	2.9E-05
K-40	5.0E-06	6.7E-06	2.8E-04	4.7E-06
Kr-83m	4.8E-11	-	1.4E-07	3.4E-08

Table 6-4. Fatal cancer risk factors for selected radionuclides (see Table 6-3 for default inhalation class and ingestion f_1 values) (continued).

Nuclide	Inhal. (mCi^{-1})	Ingest. (mCi^{-1})	Immer. (m^3/mCi yr)	Surface (m^2/mCi yr)
Kr-85	3.5E-10	-	3.7E-06	7.7E-08
Kr-85m	3.7E-10	-	2.6E-04	5.8E-06
Kr-87	1.7E-09	-	1.5E-03	2.5E-05
Kr-88	3.5E-09	-	3.9E-03	6.1E-05
La-140	2.5E-06	1.3E-06	4.2E-03	7.3E-05
Mn-54	4.3E-06	7.3E-07	1.5E-03	2.8E-05
Na-24	7.7E-07	6.9E-07	8.2E-03	1.2E-04
Nb-95	4.4E-06	3.8E-07	1.3E-03	2.6E-05
Ni-63	1.5E-06	1.4E-07	0.0E+00	0.0E+00
P-32	2.5E-06	2.6E-06	0.0E+00	0.0E+00
Pa-231	3.8E-02	1.9E-04	4.9E-05	1.2E-06
Pa-234m	1.5E-09	4.4E-09	2.0E-05	3.8E-07
Pb-210	1.4E-03	5.5E-04	-	-
Pb-211	2.6E-06	1.3E-07	8.8E-05	1.8E-06
Pb-212	4.1E-05	5.0E-06	2.4E-04	5.3E-06
Pb-214	2.7E-06	1.3E-07	4.1E-04	8.8E-06
Po-210	2.4E-03	1.4E-04	1.5E-08	2.9E-10
Po-212	5.7E-16	1.7E-17	0.0E+00	0.0E+00
Po-214	2.7E-13	8.0E-15	1.5E-07	2.8E-09
Po-215	5.3E-12	2.1E-13	2.5E-07	5.2E-09
Po-216	4.5E-10	2.6E-11	2.5E-08	4.9E-10
Po-218	5.4E-07	2.0E-08	0.0E+00	0.0E+00
Pu-238	4.0E-02	2.7E-04	1.3E-07	2.5E-08
Pu-239	3.9E-02	3.0E-05	1.3E-07	1.1E-08
Pu-240	3.9E-02	3.0E-05	1.2E-07	2.4E-08
Pu-241	2.8E-04	4.7E-06	0.0E+00	0.0E+00
Pu-242	3.7E-02	2.8E-05	1.1E-07	2.0E-08
Ra-223	2.9E-03	6.0E-05	2.1E-04	4.8E-06
Ra-224	1.1E-03	3.5E-05	1.7E-05	3.6E-07
Ra-226	2.8E-03	9.4E-05	1.1E-05	2.4E-07
Ra-228	5.8E-04	7.0E-05	1.0E-13	2.2E-14
Rh-103m	3.6E-09	5.0E-09	2.5E-07	2.8E-08
Rh-106	1.1E-09	3.3E-09	3.5E-04	7.0E-06
Rn-220	1.0E-07	-	8.8E-07	1.8E-08
Rn-222	4.7E-07	-	6.5E-07	1.3E-08
Ru-103	7.5E-06	5.1E-07	8.1E-04	1.7E-05
Ru-106	4.1E-04	5.5E-06	0.0E+00	0.0E+00
S-35	1.4E-07	1.4E-07	0.0E+00	0.0E+00

Table 6-4. Fatal cancer risk factors for selected radionuclides (see Table 6-3 for default inhalation class and ingestion f_1 values) (continued).

Nuclide	Inhal. (mCi^{-1})	Ingest. (mCi^{-1})	Immer. (m^3/mCi yr)	Surface (m^2/mCi yr)
Sb-124	2.0E-05	1.7E-06	3.4E-03	6.0E-05
Sc-46	2.4E-05	9.3E-07	3.6E-03	6.6E-05
Se-75	4.8E-06	4.2E-06	6.4E-04	1.4E-05
Sn-113	8.5E-06	5.0E-07	1.2E-05	4.2E-07
Sr-85	6.8E-07	4.9E-07	8.6E-04	1.8E-05
Sr-89	2.4E-06	1.9E-06	2.4E-07	4.6E-09
Sr-90	5.4E-05	3.1E-05	0.0E+00	0.0E+00
Tc-95	1.7E-08	3.3E-08	1.4E-03	2.7E-05
Tc-95m	3.0E-06	6.9E-07	1.1E-03	2.3E-05
Tc-99	7.4E-06	7.4E-07	8.0E-10	1.9E-11
Tc-99m	1.9E-08	2.4E-08	2.1E-04	4.7E-06
Th-227	4.6E-03	2.9E-06	1.7E-04	3.8E-06
Th-228	7.2E-02	1.3E-05	3.1E-06	8.6E-08
Th-230	2.9E-02	2.3E-05	5.9E-07	2.7E-08
Th-231	4.1E-07	2.2E-07	1.7E-05	5.6E-07
Th-232	2.9E-02	2.1E-05	2.8E-07	2.0E-08
Th-234	2.9E-05	2.2E-06	1.2E-05	3.0E-07
Tl-207	4.1E-09	1.0E-08	3.8E-06	7.3E-08
Tl-208	4.4E-09	1.4E-08	6.8E-03	1.0E-04
U-234	2.5E-02	7.5E-05	2.3E-07	2.4E-08
U-235	2.3E-02	7.3E-05	2.5E-04	5.5E-06
U-236	2.4E-02	7.1E-05	1.8E-07	2.2E-08
U-238	2.2E-02	7.4E-05	1.5E-07	1.9E-08
W-187	3.2E-07	3.6E-07	8.0E-04	1.6E-05
Xe-131m	3.1E-10	-	1.2E-05	4.7E-07
Xe-133	3.0E-10	-	5.1E-05	1.4E-06
Xe-133m	3.9E-10	-	4.7E-05	1.2E-06
Xe-135	5.8E-10	-	4.1E-04	8.9E-06
Y-90	4.7E-06	1.7E-06	0.0E+00	0.0E+00
Zn-65	1.3E-05	5.2E-06	1.0E-03	1.9E-05
Zr-95	8.9E-06	5.6E-07	1.3E-03	2.5E-05

contribution from any decay products. For example, the external risk factors for cesium-137 have values of 0, since there is no photon released in its decay. Hence, the exposure due to the cesium-137 decay product barium-137m must be considered in assessing cesium-137. The clearance class and gut-to-blood transfer factor, f_1, values are shown in Table 6-3.

6.2 CALCULATION OF Q_H FOR PLUME RISE

$$Q_H = (T_o - T_a) \cdot V_a \cdot \rho_a \cdot C_p \qquad (6\text{-}1)$$

where

T_o = exit temperature (K),

T_a = ambient temperature (K),

V_a = volume flow rate at T_a (m^3/s),

ρ_a = is the air density at T_a (g/m^3),

and

C_p = is the specific heat of air at constant pressure (cal/g),
= 0.2401 cal/g.

Now $\rho_a \cdot T_a$ = 3.5313E+5 g K/m^3 therefore,

$$Q_H = ((T_o - T_a) \cdot V_a \cdot 8.48E{+}4) \,/\, T_a \qquad (6\text{-}2)$$

6.3 POPULATION CENSUS FILES

Population distributions may be generated with the utility program SECPOP, which uses a database of 1980 Census data (see Section 6.1.4), or created by the user in the format described in Table 6-6. If SECPOP is used, the arrays should be modified with supplemental data obtained from surveys of the population distribution near the site, since the census database is not very precise at estimating population groups close to the facility due to the widely varying size of the census enumeration districts.

The listing for SECPOP, along with the JCL needed to run the code, are shown in Appendix K.

6.4 STABILITY ARRAYS

Stability array (STAR) data show the frequencies of occurrence of the wind blowing <u>from</u> a particular direction, at a particular stability, at a particular speed. A sample STAR data file is shown in Table 6-5. The frequencies are in x.xxxxx format, unspaced.

Tabulations of STAR data are on file at the National Climatic Data Center (NCDC). For information contact:

National Climatic Data Center
Federal Building
Asheville, NC 28801
(704) 259-0871
FTS: 672-0871

The tabulations are available as paper copies and/or punched cards. The card images for tabulations produced prior to 1982 are retained on eight 9-track magnetic tapes at 1600 bpi, 80 characters per record, 10 records per block in the NCDC Tape Library. Appendix L presents a partial listing of the STAR tabulations available from the NCDC. For each data set the following information is given:

- a unique identifying number (HDR),
- a station number (WBAN),
- the station name and state,
- the period of time covered,
- the type of summarization (seasonal, monthly, or annually),
- a three character station code (SSS),
- the number of stability classes,
- the number of surface observations used,
- the NCC job number,
- and any appropriate remarks.

EPA user's should be aware that EPA periodically purchases meteorological information from NCDC. Table 6-6 presents the generic JCL used to read data from an EPA tape containing STAR data. Four pieces of information, the SET#, HDR number, WBAN, and station code (SSS), are needed as input to the JCL to identify the desired tape and data set. The user should note that the three character station code is used only to create the file name under which the STAR data is stored and is not used to look up the correct data set on the tape.

A listing of the data sets available to EPA user's is presented in Appendix L. Information on the tapes can be obtained by contacting either C. Nelson (202-475-9640) or B. Parks (702-798-2443).

The user must beware of sets marked as 'DAYNITE' data. These sets contain two D stability classes, one for day and one for night. The JCL shown in Table 6-5 will result in the second D data set being incorrectly labeled set E, set E will incorrectly be labeled as set F, and so forth. The user must correct the data by adding the two D sets of data together and making sure that the following sets are correctly labeled before using the data as input to the CAP-88 code package.

Table 6-5. Sample STAR data file (for HDR = 0282, SSS = ABQ, WBAN = 23050, STAR# = STAR03, Albuquerque, NM).

N	A	0.001020.001030.000000.000000.000000.00000
NNE	A	0.000180.000250.000000.000000.000000.00000
NE	A	0.000730.000300.000000.000000.000000.00000
ENE	A	0.000420.000180.000000.000000.000000.00000
E	A	0.000320.000160.000000.000000.000000.00000
ESE	A	0.000560.000410.000000.000000.000000.00000
SE	A	0.000840.000410.000000.000000.000000.00000
SSE	A	0.000420.000530.000000.000000.000000.00000
S	A	0.001010.001420.000000.000000.000000.00000
SSW	A	0.000790.000890.000000.000000.000000.00000
SW	A	0.001070.001550.000000.000000.000000.00000
WSW	A	0.001040.001320.000000.000000.000000.00000
W	A	0.001260.001280.000000.000000.000000.00000
WNW	A	0.000970.001280.000000.000000.000000.00000
NW	A	0.000770.001050.000000.000000.000000.00000
NNW	A	0.000430.000570.000000.000000.000000.00000
N	B	0.006360.003790.001300.000000.000000.00000
NNE	B	0.002730.002010.000550.000000.000000.00000
NE	B	0.002960.001440.000320.000000.000000.00000
ENE	B	0.001710.000870.000250.000000.000000.00000
E	B	0.001580.000730.000110.000000.000000.00000
ESE	B	0.002280.000820.000300.000000.000000.00000
SE	B	0.003460.001800.000660.000000.000000.00000
SSE	B	0.002710.002030.000820.000000.000000.00000
S	B	0.005760.005210.002990.000000.000000.00000
SSW	B	0.002910.004640.002600.000000.000000.00000
SW	B	0.005450.005980.003770.000000.000000.00000
WSW	B	0.003770.005320.002990.000000.000000.00000
W	B	0.004480.004910.002120.000000.000000.00000
WNW	B	0.004730.004640.001800.000000.000000.00000
NW	B	0.005070.003930.001390.000000.000000.00000
NNW	B	0.004150.003750.000690.000000.000000.00000
N	C	0.001680.006620.006830.000340.000020.00000
NNE	C	0.000730.002530.001510.000050.000000.00000
NE	C	0.000640.001320.001100.000000.000000.00000
ENE	C	0.000540.000570.000480.000090.000000.00000
E	C	0.000370.000480.000840.000230.000020.00000
ESE	C	0.000810.001420.000890.000370.000090.00000
SE	C	0.001450.002790.001510.000270.000000.00000
SSE	C	0.001010.002650.002120.000370.000020.00000
S	C	0.001920.006230.006210.001320.000340.00005
SSW	C	0.000800.003590.005410.001280.000320.00005
SW	C	0.001100.004270.005890.001710.000180.00005
WSW	C	0.000670.003060.004160.001140.000140.00005
W	C	0.000960.003130.002950.000910.000180.00000
WNW	C	0.000840.003110.002990.000620.000230.00000
NW	C	0.001010.003910.002920.000370.000230.00000
NNW	C	0.001920.005020.003930.000410.000050.00016
N	D	0.001470.004960.013730.015420.001990.00016

Table 6-5. STAR data file for HDR = 0282, SSS = ABQ, WBAN = 23050, STAR# = STAR03, Albuquerque, NM (continued).

```
NNE D 0.000580.001920.003520.002150.000110.00002
 NE D 0.000590.001940.002790.001160.000140.00002
ENE D 0.000490.000640.002100.003610.000910.00021
  E D 0.000500.001160.003490.013060.008270.00040
ESE D 0.000590.002120.005710.014000.008080.00260
 SE D 0.001030.003010.005090.004130.001620.00027
SSE D 0.000650.002280.004500.002650.000390.00005
  S D 0.001180.003650.009110.008560.003130.00112
SSW D 0.000220.001830.005390.008240.002400.00032
 SW D 0.000880.002510.005730.006710.002100.00050
WSW D 0.000500.001710.005480.006690.002030.00078
  W D 0.000350.001670.003750.005530.002600.00066
WNW D 0.000690.001640.003360.007420.003200.00096
 NW D 0.000890.002170.003240.008110.003220.00073
NNW D 0.000670.002670.005530.008380.001420.00018
  N E 0.000000.005890.021830.000000.000000.00000
NNE E 0.000000.003330.008200.000000.000000.00000
 NE E 0.000000.002510.002970.000000.000000.00000
ENE E 0.000000.001710.001830.000000.000000.00000
  E E 0.000000.001940.002630.000000.000000.00000
ESE E 0.000000.005530.005440.000000.000000.00000
 SE E 0.000000.008770.005870.000000.000000.00000
SSE E 0.000000.004930.003910.000000.000000.00000
  S E 0.000000.005120.005530.000000.000000.00000
SSW E 0.000000.002630.003240.000000.000000.00000
 SW E 0.000000.002740.003010.000000.000000.00000
WSW E 0.000000.002310.002440.000000.000000.00000
  W E 0.000000.002060.001900.000000.000000.00000
WNW E 0.000000.002220.002530.000000.000000.00000
 NW E 0.000000.002010.003610.000000.000000.00000
NNW E 0.000000.003110.006190.000000.000000.00000
  N F 0.013610.020740.000000.000000.000000.00000
NNE F 0.007730.009980.000000.000000.000000.00000
 NE F 0.009860.009250.000000.000000.000000.00000
ENE F 0.006400.004410.000000.000000.000000.00000
  E F 0.007230.005550.000000.000000.000000.00000
ESE F 0.013480.015350.000000.000000.000000.00000
 SE F 0.017790.022680.000000.000000.000000.00000
SSE F 0.009930.012290.000000.000000.000000.00000
  S F 0.011670.009640.000000.000000.000000.00000
SSW F 0.003820.003330.000000.000000.000000.00000
 SW F 0.005270.003700.000000.000000.000000.00000
WSW F 0.004160.003540.000000.000000.000000.00000
  W F 0.004160.003130.000000.000000.000000.00000
WNW F 0.005340.004220.000000.000000.000000.00000
 NW F 0.005700.005570.000000.000000.000000.00000
NNW F 0.006600.009550.000000.000000.000000.00000
```

Table 6-6. JCL for creating STAR file from National Climatic Data Center data tapes.

```
//BQP  JOB (CAARRDSSP,D013),'B. PARKS',PRTY=4,TIME=(,6)
/*ROUTE PRINT HOLD
// EXEC SAS
//* CHANGE 'SET0' TO SET1-SET8 AS APPROPRIATE
//* CHANGE 'WWWWW' TO WBAN NUMBER
//* CHANGE 'HHHH' TO HDR NUMBER
//* CHANGE 'SSS' TO STATION CODE
//STAR1 DD DSN=CBNRACS.STAR.DATA,DISP=OLD
//STAR2 DD DSN=MGUCAAR.CAA88.STARLIB,DISP=OLD,
//         SPACE=(TRK,(0,10))
//SYSIN DD *
  TITLE 'TRANSFER STAR DATA FROM THE MASTER LIBRARY';
  DATA _NULL_; FILE STAR2(SSSHHHH); INFILE STAR1(SET0);
  INPUT @56 WBAN $CHAR5. @;
  RETAIN FLAG 0;
  IF FLAG EQ 1 AND WBAN NE 'WWWWW' THEN STOP;
  FLAG=1;
  INPUT @81 HDR $4. @;
  IF HDR NE 'HHHH' THEN DELETE;
  INPUT @64 SEA $2.;
  IF SEA NE '17' THEN DELETE;
  PUT _INFILE_;
```

Note: The HDR, SSS (station code), and WBAN may be obtained from the STAR tabulation listing in Appendix L.

6.5 CALCULATION OF DAUGHTER INGROWTH FACTORS

A radionuclide that builds up in the environment following the deposition of a parent radionuclide may contribute significantly to doses from surface exposure, water immersion, or food ingestion. AIRDOS-EPA can include such contributions even though it has no provision to explicitly solve the set of differential equations describing the decay and ingrowth process.

Any significant progeny (decay product) radionuclides must be included in the source term if their concentrations subsequent to the deposition of their parent radionuclides are to be calculated. For example, to calculate the external dose resulting from the deposition of cesium-137, the ingrowth of its decay product barium-137m must be calculated. Therefore, barium-137m must be included in the source term even though the release of barium-137m per se contributes negligibly to its concentration on the ground surface.

Progeny concentrations can include the contributions from up to five parent radionuclides. An ingrowth factor must be provided for each parent radionuclide that can provide a significant contribution to that particular progeny. These ingrowth factors are used to multiply the deposition rate of the parent radionuclide to calculate its contribution to the effective deposition rate of the progeny. These ingrowth factors are <u>not</u> calculated by AIRDOS-EPA; they are input data that must be calculated separately. Since their values depend on the length of time for progeny ingrowth and any environmental removal rates, radioactive decay constants, and decay chain branching fractions, they must be calculated explicitly for each assessment.

Variables I1 through I5 are indices corresponding to the position in the source term list of the parent nuclides to be associated with each of the ingrowth factors F1 through F5. If they have negative values, they denote indices relative to the current (viz. the progeny) radionuclide in the source term list. For example, if the current nuclide is fifth in the source term list and I1=-2 then the third source term nuclide will be considered a parent radionuclide with an ingrowth factor given by the value of F1. Subsequent nuclides with values for F1 but none for I1 will refer to the same parent nuclide (the third one in the list in the example above), until an explicit value for I1 is entered. If a value for F has been entered and there is no explicit or implied value for the corresponding value of I, the value of I is considered to be -1. Note that the values of I for a particular radionuclide have no effect on one another.

The utility program CHAIN (see Section 3.0 and Appendix M) can be used to calculate values for F1 through F5. Appendix M contains a listing of the program, example input data for the uranium and thorium series decay chains, and ingrowth factors calculated by CHAIN for both these examples.

7. REFERENCES

At74 Athey T.W., R.A. Tell, and D.E. Janes, The Use of an Automated Data Base in Population Exposure Calculations, from Population Exposures, Health Physics Society, CONF-74018, October 1974.

EPA79 Moore R.E., C.F. Baes, III, L.M. McDowell-Boyer, A.P. Watson, F.O. Hoffman, J.C. Pleasant, C.W. Miller, AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides, EPA 520/1-79-009, EPA Office of Radiation Programs, Washington, D.C. 20460, December 1979.

EPA89 U.S. Environmental Protection Agency, "Draft Environmental Impact Statement for Proposed NESHAPS for Radionuclides," Vol.I, EPA 520/1-89-006-1, Office of Radiation Programs, Washington, D.C. 20460, October 1989.

Fa85 "Comparison of AIRDOS-EPA Prediction of Ground-Level Airborne Radionuclide Concentrations to Measured Values at Five Facilities", Prepared for USEPA Office of Radiation Programs under Contract 68-02-3853, Work Assignment 9, by Jack Faucett Associates, Inc. and SC&A, JACKFAU-311/4-85, September 30, 1985.

Fa87 "Comparison of AIRDOS-EPA Prediction of Ground-Level Airborne Radionuclide Concentrations to Measured Values", Prepared for USEPA Office of Radiation Programs under Contract 68-02-4375, Work Assignment 1-10, by Jack Faucett Associates, Inc. and SC&A, JACKFAU-341/12-87, 1987.

ICRP79 International Commission on Radiological Protection, "Limits for Intakes of Radionuclides by Workers," ICRP Publication 30, Part 1, Ann. ICRP, 2 (3/4), Pergamon Press, New York, 1979.

NRC75 Memo from K. Eckerman, N. Dayem, R. Emch, Radiological Assessment Branch, Division of Technical Review, Nuclear Regulatory Commission, Code Input Data for Man-Rem Estimates, Washington, D.C., October 15, 1975.

NRC77 U.S. Nuclear Regulatory Commission, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50 Appendix I (Revision 1), Regulatory Guide 1.109, Office of Standards Development, Washington, D.C., October 1977.

ORNL80 Dunning Jr. D.E., R.W. Leggett, and M.G. Yalcintas, "A Combined Methodology for Estimating Dose Rates and Health Effects from Exposures to Radioactive Pollutants," ORNL/TM-7105, March 1980.

ORNL81a Begovich C.L., K.F. Eckerman, E.C. Schlatter, S.Y. Ohr, and R.O. Chester, "DARTAB, A Program to Combine Airborne Radionuclide Environmental Exposure Data with Dosimetric Health Effects Data to Generate Tabulations of Predicted Health Impact, ORNL-5692/DE81030434, August 1981.

ORNL81b Sullivan R.E., N.S. Nelson, W.H. Ellett, D.E. Dunning Jr., R.W. Leggett, M.G. Yalcintas, and K.F. Eckerman, "Estimates of Health Risk from Exposure to Radioactive Pollutants," ORNL-7745/DE82002486, November 1981.

ORNL84 Sjoreen A.L. and C.W. Miller, "PREPAR, A User-Friendly Preprocessor to Create AIRDOS-EPA Input Data Sets," ORNL-5952/DE84016731, August 1984.

USDA72 United States Department of Agriculture, Food Consumption of Households in the United States (Seasons and Year 1965-1966), Household Food Consumption Survey 1965-1966, Report No. 12, Agricultural Research Service, USDA, Washington, D.C., March 1972.