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AUSTRALIAN NUCLEAR SCIENCE
AND TECHNOLOGY ORGANISATION

LUCAS HEIGHTS RESEARCH LABORATORIES

RADIOACTIVE AIRBORNE EFFLUENT WORKING PARTY

REPORT ON

A REVISED RADIOACTIVE AIRBORNE EFFLUENT DISCHARGE LIMIT FOR THE LUCAS HEIGHTS RESEARCH LABORATORIES

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SUMMARY

The Australian Nuclear Science and Technology Organisation, formerly the Australian Atomic Energy Commission, is authorised under the NSW Radioactive Substances Act to release limited quantities of radioactive airborne effluent into the atmosphere from its facilities at the Lucas Heights Research Laboratories (LHRL). This authorisation is about twenty years old.

This report proposes a revised site-wide airborne effluent discharge limit for the LHRL. The revised discharge limit is based upon the panoply of current International Comission on Radiological Protection (ICRP) and National Health Medical Research Council (NH & MRC) recommendations. It takes account of the operational changes at the LHRL and developments in radiation dosimetry and meteorology. The development and technical basis of the revised discharge limit, together with its relation to the ICRP recommendations, is briefly given.

The formal discharge limit is to be approved by the NSW Radiological Advisory Council. The discharge limit consists of three components. First, a definition of the discharge limit expressed in terms of a fraction of the recommended ICRP dose limits. This limit is supported by, second, a compliance procedure and, third, a reporting procedure.

In addition to the revised discharge limit, a number of operational and safety measures have to be further developed under the direction of ANSTO Management. The development of 'reference levels' recommended by the ICRP is briefly described. In the present context, two reference levels for the quantities of activity released from each source will be established. The levels operate effectively like quality control measures in industry. They require certain operator actions if they are exceeded. The doses to individuals which are estimated for releases at the reference levels of releases of activity are well within the revised dose limits. From an operational point of view, these levels will vary with changing operations.

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1. INTRODUCTION

The Australian Nuclear Science and Technology Organisation (ANSTO), formerly the Australian Atomic Energy Commission, is authorised under the NSW Radioactive Substances Act to release limited quantities of radioactive airborne effluent into the atmosphere from its facilities at the Lucas Heights Research Laboratories (LHRL). This authorisation is about twenty years old. A revised site-wide discharge limit is now proposed. The revised discharge limit and supporting measures are framed in terms of the panoply of current International Commission on Radiological Protection (ICRP) and the National Health & Medical Research Council (NH & MRC) recommendations, and on International Atomic Energy Agency (IAEA) advice to Member States.

There are two aspects to the overall approach to the formulation of this revised discharge limit. First is the definition of a formal discharge limit (the 1988 discharge limit) to be approved by the NSW Radiological Advisory Council (RAC). Second is the internal establishment and operation of investigation and intervention reference levels for daily or weekly monitoring and control of sources of airborne radioactivity. These levels are elaborated upon in general for information and completeness, however, it is emphasised that these reference levels are for internal audit purposes only and are not proposed for authorisation by the RAC.

The proposed discharge limit is given in **section 2** and its features of the discharge limit are elaborated in **section 3**. The following sections contain background information on the overall approach.

2. THE REVISED SITE-WIDE 1988 DISCHARGE LIMIT

The 1988 discharge limit consists of three features: first, a definition of limit expressed in terms of individual dose limits; second, a procedure for demonstrating compliance with the limit; and finally a reporting procedure. The formal statement, to be presented to the RAC for authorisation is as follows.

The 1988 Discharge Limit

(a) Definition of Discharge Limit

The annual limit on airborne radioactivity discharged to the atmosphere in the course of normal operations from the LHRL and its buffer zone is any mixture of airborne radioactivity discharged such that the sum of the effective dose equivalent and the committed effective dose equivalent to any member of the public arising from the discharge is

(i) 0.5 mSv per year if chronically exposed; or

(ii) 2.5 mSv per year if not chronically exposed.

(b) Compliance Procedure for the Discharge Limit

Compliance with this discharge limit shall be made by evaluating the sum of the effective dose equivalent and the committed effective dose equivalent to any individual by taking account of the quantity of airborne radioactivity discharged during any twelve-month period, together with local meteorological and relevant radiation dosimetry data. This evaluation shall be supported by measurements of the effective dose equivalent.

(c) Reporting Procedure for the Discharges

The evaluated radiation doses to relevant individuals shall be reported at three-monthly intervals to the NSW Radiological Advisory Council together with routinely monitored release data.

3. FEATURES OF THE 1988 DISCHARGE LIMIT

3.1 General

The dose limits specified in section (a) of the *1988 discharge limit* definition are *half* the recommended ICRP [1977,1985b] and the NH & MRC [1978, 1985] dose limits of 1 and 5 mSv per year, respectively. By applying only half of these ICRP recommended dose limits to radioactive airborne effluent discharges, provision is made for future non-atmospheric releases from both LHRL sources and non-LHRL sources.

Specific features of the revised discharge limit are that it

- allows any source or nuclide to be included when appropriate, hence the need for subsequent amendments would be largely circumvented by avoiding the specificity of the present discharge authorisation;
- embraces the underlying approach adopted in the previous discharge authorisation without its inherent approximations and limitations and utilises resources and data not previously available;
- is consistent with current ICRP radiological safety concepts, recommended dose limits and dosimetric data, and also the current recommendations of the NH & MRC;
- utilises improved local meteorological data collected at the LHRL;

- provides ANSTO Management with a greater degree of flexibility over operations at the LHRL which involve radioactive airborne effluent;
- provides management with a tool with which to assess the impact of any proposed or altered operations;
- provides a range of dose interjacent to the dose implied by the reference levels, which are discussed below, and the doses defined in the 1988 discharge limit (this is a useful 'dose buffer zone').

A major feature of this discharge limit is that its relation to the three components of the ICRP system of dose limitation can be readily identified. The first two components of the latter system are *justification*, (*i.e.* that all exposures shall *produce a net positive benefit*) and *optimisation* or *ALARA*, (*i.e.* that all exposures shall be kept *as low as reasonably achievable*). The third component of the system is the specified set of *dose limits*. The revised discharge limit is an application of the third component of the ICRP dose limitation system. The first two components are not discussed in this report. However, the following points should be noted. First, the justification component of the system is met by virtue of the national benefits derived from research activities and radioisotope production for medicine, industry and research. On the other hand, optimisation of doses is achieved by one of many procedures discussed by the ICRP [1983]. Usually, however, optimisation of dose arising from airborne releases is achieved iteratively as an R & D or production operation is developing.

A major feature of the present approach to the control of releases from the LHRL and the limitation of doses to the public by ANSTO is the implementation of a system of reference levels as described by the ICRP [1977]. These levels are discussed in **section 4.**

3.2 Compliance Mechanism

The compliance procedure consists of two components. First, it contains an atmospheric transport, dispersion and dosimetry computer code to evaluate the sum of the effective dose equivalent due to external exposure and committed effective dose equivalent from inhaled and ingested radioactivity at various receptor locations on the basis of measured releases of radioactivity to the atmosphere. This is the primary compliance mechanism. Second, it allows for the measurement of the effective dose equivalent at several, but not necessarily all, receptor locations. A computer code is the simplest means of routinely establishing compliance with the discharge limit, in part because the *committed* effective dose equivalent can only be estimated. Only the effective dose equivalent from external exposure can be monitored. However, although routine and continuous monitoring is not necessary, monitoring provides supporting measurements of the estimated effective dose equivalent at a number of receptor locations, and also provides broad confirmation of the code. It should be noted, however, that current technology provides a cost-effective means of routinely measuring exposures. This is extremely useful not only as a supporting function during normal releases of radioactivity, but also for emergency purposes in the event of an abnormal release of radioactivity. Prototype versions of such measuring devices are under development and testing at the LHRL.

The atmospheric transport, dispersion and dosimetry computer code is described in a separate report Clark and Petersen [1988]. The major features of the code are that

- individual source properties including location, nuclide released, time of release with respect to season and time of day, and duration of release are taken into account by May [1985] and in Health and Safety Division Quarterly Reports;
- atmospheric transport and dispersion processes are evaluated with respect to time of day and season and uses an improved local meteorological data base now extending over eight years [Clark, 1985].
- the behaviour for individuals at various receptor locations are taken into account, including occupation times and likely exposure pathways;
- it uses current ICRP [1982] and other international respected dosimetry data [Kocher 1983];
- the code has been written in FORTRAN 77 and conforms as closely as possible to the ANSI standard so that it can be run on other mainframe computers; the code has been structured to aid internal and external reviewing and includes extensive comments (the RAC can at any time arrange to run the code independently); and
- a number of checks have been included to flag errors in input data when the code is being used routinely by technical staff.

Other features of the code are that it

- provides ANSTO management with a tool with which to assess the impact of any proposed new or altered operations;
- provides results on the various contributions to the dose to an individual such as the proportion from a given source, a particular nuclide or both;
- provides the data from which collective dose estimates can be made to assess whether a proposed change to a particular operation will result in radiation doses being as low as reasonably achievable, *i.e.* that it will comply with the second component of the ICRP system

of dose limitation;

- provides estimates of components of individual doses which may be compared with doses directly measured in the LHRL environment.

As indicated above, the major biosphere pathways for airborne releases which lead to the exposure of individuals in the vicinity of the LHRL, and which are included in the code, are shown in **figure 1**. The locations of the major sources of airborne effluent are listed in **table 1**. The table gives the Building number and the location of the source of airborne effluent as X (metres) corresponding to east, Y (metres) corresponding to north, and the height of the source Z (metres). The origin of the coordinate system used is at ground level in the centre of HIFAR. Similarly, **table 2** gives the ground level location of the points, or receptor locations, where doses are presently estimated. These points are 1.6 and 4.8 km from HIFAR. Several other possible receptor locations are included for completeness. Also shown are several receptor locations within or adjacent to the LHRL site fence. These are routinely checked to provide advice to management regarding exposure of LHRL staff from site operations. It is not difficult to add more or remove either sources or receptors from the data in the code.

Application of the code to the radioactive airborne releases in 1986 is shown in **table 3**. The second column gives the effective whole body dose from both external and internal exposure. The third column gives the dose limit for the appropriate classification of individual at each location. The fourth column gives the ratio of the values in the second column to that in the third column. The table shows that the doses are less than 1% of the appropriate dose limits. The remaining three columns are similar to those just described, however, they have been evaluated for the skin dose. **Table 4** is similar in content to **table 3** and compares the presently formulated discharge limit and the doses implied by the stack discharge limits set out in Cook [1969] and subsequent amendments. It is assumed in this calculation that the relative rates of discharge from each stack specified by Cook are similar to the relative rates of discharge during 1986. The ratios show that Cook's discharge limits are very conservative and that if the LHRL was discharging continuously at Cook's limits, the doses to members of the public would be about 1% of the currently proposed limit. The 1967 discharge limits are discussed more fully below.

3.3 Reporting Mechanism

It is proposed that the reporting of radiation doses to the RAC shall be on a three-monthly basis as a convenient administrative period for review. Quarterly reporting to the RAC would continue according to the present schedule and include routinely monitored release data. It is not intended to imply in any way that a three-monthly or quarterly limit is imposed. The dose limit in the revised discharge limit is specified as an annual limit. This is consistent with the recommendations of the ICRP [1977] in which quarterly dose limits were not retained. A minor advantage of the present proposal is that in exceptional circumstances, if the dose to an individual were to exceed a quarter of the annual dose limit specified above, the release of radioactive airborne effluent could be subsequently restricted so that the annual limit was not exceeded.

4. INVESTIGATION AND INTERVENTION REFERENCE LEVELS

The development of investigation and intervention levels for particular sources of radioactivity is an essential part of the overall management and control of atmospheric releases of airborne radioactivity. Such levels are established from time to time by the operational and safety management at a site as aids to prevent dose limits from being exceeded. These levels were introduced by the ICRP in 1977. The NH & MRC has also adopted these recommendations. The ICRP states inter alia that "a reference level is not a limit and is used to determine the course of action when the value of a quantity exceeds or is predicted to exceed the reference level". The concept is quite general and is applicable both to normal and operational releases and to substantial or emergency releases. The three reference levels defined by the ICRP are 'recording', 'investigation' and 'intervention'. The 'action' required when the investigation level is exceeded is 'investigate the cause of the exceedance and take action to eliminate it'. The 'action' required when the intervention level is exceeded is to 'interrupt the operation and take action to eliminate the cause of the exceedance' [ICRP 1977]. The ICRP does not make specific recommendations for these levels; it is a matter for the local operational and safety management.

By their nature and function the investigation and intervention levels should be related to the normally expected rates of release and variations in the rates of release of activity after optimisation of the radiation protection for a given operation. As suggested below, the 1967 discharge limits effectively functioned as investigation levels. This can be seen in **table 4** which shows the estimated doses of airborne discharges from all sources at the LHRL were continuous at the levels indicated by the 1967 discharge limits.

5. THE 1967 DISCHARGE LIMITS

The 1967 discharge limits were formulated by Cook [1967, 1969] as working limits for stack discharges. These limits were approved by the RAC under the NSW Radioactive Substances Act (1957) and specifically Section 13(2) of the Radioactive Substances Regulations (1959). These limits were based upon

- the recommendations of the ICRP [1959a],

- dosimetry data from the Report of ICRP Committee II [1959b],
- the existing operations at the LHRL,
- specifically nominated sources at the LHRL,
- specifically nominated nuclides, and
- the limited amount of meteorological data and atmospheric transport models then available.

Essentially, the 1967 discharge limits provided an 'authorised limit' of activity of specific nuclides which may be released from specific stacks. The approach did not specifically allow for the diurnal or seasonal variation in releases of radioactivity from particular stacks. Hence varying atmospheric dispersive conditions were not specifically taken into account. There are two additional assumptions which make these limits more conservative than is necessary. First is the assignment of 'members of the public' status to ANSTO staff and second is the application of a pessimistic model of plume downwash and the use of the semi-infinite cloud approximation for individuals in the vicinity of particular stacks. Even with these assumptions, it is estimated that the doses to members of the public are generally less than 1% of the ICRP dose limits.

Two inherently conservative aspects of the atmospheric transport and dosimetric basis of the 1967 discharge limits were the application of a pessimistic model of plume downwash and the use of the semi-infinite cloud approximation for individuals in the vicinity of particular stacks. These limitations have been removed in the current atmospheric and dosimetry code. The details are discussed in Clark and Petersen [1988].

Since 1967, operational changes have occurred at the LHRL which have had a bearing on the sources and nuclides specified in the authorisation. There has been a substantial increase in the quantity and quality of meteorological data available. Atmospheric transport models are better understood and support facilities such as computing resources have also increased. These aspects have been taken into account when formulating the 1988 discharge limit.

Another fundamental aspect of the 1967 discharge limits should be noted. The derivation of individual stack limits from the basic dose limits is an 'inversion problem'. In general, an inversion problem is mathematically a much more difficulty problem to solve than a 'direct problem' for most non-trivial systems. This additional degree of difficulty exists irrespective of the accuracy of the physics of a model and data available to describe a system. Because of the greater difficulty of the inversion problem, it is typical in these situations for inherently conservative assumptions to be made and, consequently, overly conservative solutions are obtained.

6. PRESENT ICRP AND NH & MRC RECOMMENDATIONS

In the following, the recommendations of the NH & MRC are not discussed in detail as they largely follow those of the ICRP, to which they refer extensively. The recommendations of the ICRP have undergone two revisions since 1959; first in 1966 and more significantly in 1977. These changes clarify underlying concepts and correct misapplications of previous recommendations. The recommendations which form the background of the revised discharge limit are as follows.

First, the system of dose limitation [ICRP 1977, paragraph 12] is summarised as three components, namely,

(i) The *justification* of the practice, *i.e.* no practice shall be adopted unless its introduction produces a positive net benefit.

(ii) The *optimisation* of the radiation protection, *i.e.* all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account.

(iii) The *dose limits* for individuals, *i.e.* the dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the ICRP.

Second, the notion of an annual limit of intake (ALI) [ICRP 1977, paragraph 79] for ingestible and inhalable radioactivity has been introduced to replace the too frequently misused concept of maximum permissible concentration and data in ICRP [1959]. The ICRP [1982] published limits for intakes by workers for radionuclides for the evaluation of committed effective dose equivalents.

Third, derived limits and authorised limits are described at paragraphs 147 and 148 of ICRP [1977]. Derived limits are usually specific occupational or environmental limits derived from the basic dose equivalent limits. Authorised limits are laid down by a competent authority or by the management of an institution. The 1967 discharge limits are examples of authorised limits. However, the 1988 discharge limit does not quite meet the ICRP definition of an authorised limit.

Fourth, reference levels may be established for any quantity and are described at paragraphs 149 through 152 of ICRP [1977]. A reference level is not a limit; rather it is a level which determines a course of action when the value of a quantity exceeds the level. The three levels considered in increasing magnitude are *recording, investigation and intervention.* Of these levels, the latter two are the more important.

Finally, the relevant dose limits recommended by the ICRP [1977, 1985a,b] for individuals are as follows:

(i) 1 mSv for individual members of the public for 'repeated exposures over prolonged periods'. This exposure regime is referred to as "chronic exposure".

(ii) 5 mSv for individual members of the public where exposures are not repeated over prolonged periods. This exposure regime is referred to as 'not chronically exposed' or 'infrequent exposure'.

(iii) 15 mSv for occupational exposure of individuals in Working Condition B, which includes any exposures as a member of the public (see paragraph 161 of ICRP [1977]). Area monitoring of occupational exposures in this working condition is usually regarded as adequate, provided individual workers are 'most unlikely' to exceed this limit.

It should be noted that in effect the 1967 discharge limits, based as they are on ICRP [1959] have the status of authorised limits but actually function as coincident investigation and intervention levels. Only quite substantial exceedances of these limits would lead to the exceedance of basic dose limits; refer to **table 4.**

7. OPERATIONS AT THE LHRL

From the perspective of this report the operations at the LHRL consist of a mixture of research and isotope production. These operations have varied over time with respect to type and duration. There is no reason to expect that variations in the mix of research and isotope production activities at the LHRL will not occur in the future. There is one reason for the 1967 discharge limits becoming outmoded. It is also a reason why the proposed 1988 discharge limit is expressed as a 'site-wide' formulation. The formulation is specifically designed to encompass future variations in LHRL activities by focussing on the essential dose limits and not on a smorgasbord of specific source limits.

A specific factor which contributed to the inherently conservative nature of the 1967 discharge limits was the assignment of 'members of the public' status to LHRL staff. However, it was decided by the joint ANSTO and CSIRO Board of Management, on July 14, 1986 that all ANSTO, CSIRO and other staff at the LHRL shall be designated as radiation workers Class A or Class B as appropriate and not as members of the public [ICRP 1977, paragraph 161]. This decision was taken in light of the role of the LHRL as a major national laboratory at which nuclear reactors and particle beam accelerators are operated, isotopes are produced, and the use of radiation sources is widespread.

8. SOURCES, PATHWAYS, DOSE LIMITS AND THE EXPOSURE OF INDIVIDUALS

The sources of radioactivity considered here are the various stacks and vents at the LHRL, and other significant sources in the LHRL buffer zone from which airborne radioactivity is discharged into the atmosphere. The airborne activity is transported in the prevailing meteorological conditions downwind to receptor locations where the exposure of individuals may occur. This aggregate of sources and the airborne pathway is referred to as the 'LHRL airborne pathway'.

Monitored sources of discharge of airborne radioactivity to the atmosphere are shown in **table 1**. The last source, denoted as Bldg X, is a nominal source for all other minor unmonitored sources. The activity discharged from these sources is limited by the amount and volatility of activity which can be safely handled in fume cabinets. Elemental iodine-131, a fairly volatile material, has been selected to represent the activity from these unmonitored sources. A judgement has been made of the upper limit on the quantity of 'equivalent' iodine-131 which would be available for discharge on the basis of approvals granted by ANSTO's Safety Assessment Committee. The judgement is considered to be quite conservative. This inclusion does not significantly alter the estimated individual doses.

Members of the public exposed to the LHRL airborne pathway may also receive radiation doses arising from other LHRL sources and pathways, or from non-LHRL sources of radioactivity, either at some point in the future or presently unidentified. The Lucas Heights Burial Ground contains waste material with low level concentrations of radioactivity. The Metropolitan Water Sewerage and Drainage Board (MWS & DB) receives waste water from the LHRL which previously was discharged under NSW Government approval to the Woronora River. This water contains low concentrations of radioactivity. The LHRL environmental survey reports (see **appendix A**) have indicated that neither of these minor sources of activity contribute more than a minute fraction of the dose to individuals compared with the LHRL airborne pathway.

In these circumstances it is not appropriate to specify a discharge limit for the LHRL airborne pathway in terms of the *whole* of the two dose limits for members of the public given in **section 3** above. To allow for the possibility of other pathways or sources of radiation, either now or in the future, the discharge limit for the LHRL airborne pathway has been specified in terms of a *fraction* of the two dose limits for members of the public given in **section 3**. The ICRP has not made specific recommendations for the choice of the magnitude of this fraction. As there are no other current or foreseeable sources and pathways, a conservative assumption of 0.5 will be used for this fraction. For Class B radiation workers, the situation is in principle the same. However, there are other potential sources and pathways to which members of the public are not exposed. A factor of 0.333 has been judged to be sufficiently conservative for this group. This gives a dose limit of 0.333 × 15 mSv for these receptor locations, *i.e.* 5 mSv for Class B radiation workers for the LHRL airborne pathway.

The overall LHRL airborne pathway contains a number of sub-pathways depending largely on the chemical properties of specific nuclides. These are shown in **figure 1**. By far the most important of the pathways shown in the figure are those leading to external gamma and beta exposure and the inhalation of activity from contaminated air. The sources which contribute most to these pathways arise from the operation of HIFAR, the resulting discharge of ^{41}Ar, and the production of radioisotopes for medicine, industry and research which results in the discharge of a mixture of Kr and Xe fission gases. These gases are non-depositing with the result that the soil, vegetable and animal pathways come into consideration only for the small quantities of other depositing nuclides which escape from stack-mounted filters.

The receptor locations are shown in **table 2**; all receptor locations are with reference to HIFAR as the origin. The last 32 receptor locations listed are at 1.6 and 4.8 km on the sixteen compass points. A hypothetical individual located at each of these receptor locations has been classified as a chronically exposed member of the public if present at this location for 365 days a year. Occupation is assumed for 24 hours and all paths shown in **figure 1** are considered. Individuals at the receptor locations in the Woronora Valley are treated similarly. An individual using the BMX bicycle track has been classified as a non-chronically exposed member of the public with the exposure occurring on the weekends from 08:00 to 18:00 hours. The MWDA represents the recently opened Metropolitan Waste Disposal Authority Depot at Lucas Heights to the northwest of HIFAR. Workers there are classified as non-chronic members of the public with weekday exposure between 08:00 to 18:00 hours.

The first four receptor locations specified in **table 1** represent LHRL staff, Class B radiation workers. For convenience, exposure is considered from 08:00 to 18:00 hours on weekdays. Where this classification does not apply, LHRL staff are provided with a personal dosimeter and effectively qualify as Class A radiation workers, although they may not strictly work in conditions set for this class.

Finally, the Stevens Hall receptor location could represent either Sutherland Shire Credit Union staff or Australian Staff Canteens Organisation staff. The former group can probably be classified as members of the public who are not chronically exposed with weekday exposure occurring between 08:00 and 18:00 hours and with a limit on some of the **figure 1** pathways. Conversely, the latter group can probably be classified as members of the public who are chronically exposed members of the public with 24 hours per day exposure. This group is the most limiting. However, this group could be treated as both Class B radiation workers by virtue of their relation to the LHRL, or alternatively, as infrequently exposed members of the public given the frequency of staff turnover at Stevens Hall. For the present, the first alternative has been selected. More importantly, the classification of particular groups of exposed individuals is not critical at the present levels of exposure, as can be seen from the data in **tables 3** and **4**.

9. CONCLUSIONS

A revised Radioactive Airborne Effluent Discharge Limit for the Lucas Heights Research Laboratories has been formulated to take account of the operational releases associated with the wide variety of activities at a nuclear facility. The activities embrace research, development and radionuclide production. The approach adopted in this formulation adheres to current recommendations of the ICRP. An atmospheric transport, dispersion and dosimetry code has been developed to support the revised discharge authorisation and provides the means to take account of all revelant source, transport and dosimetric factors to ensure that appropriate dose limits are not exceeded.

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TABLE 1

SOURCE PARAMETERS

	X(M)	Y(M)	Z(M)
HIFAR	0.0	0.0	23.0
Bld 2	424.0	132.0	40.0
Bld 3	550.0	146.0	9.0
Bld 19	589.0	18.0	33.0
Bld 23A	80.0	0.0	26.0
Bld 23B	74.0	-24.0	18.0
Bld 41	34.0	-40.0	26.0
Bld 56	550.0	86.0	9.0
Bld 57	582.0	-69.0	9.0
Bld 64	75.0	0.0	8.0
Bld X	400.0	0.0	0.0
All Blds	400.0	0.0	0.0
Bld Y	0.0	0.0	0.0
Bld Z	0.0	0.0	0.0

TABLE 2

RECEPTOR LOCATIONS

		X(M)	Y(M)
1	Library	5.450D + 02	2.180D + 02
2	Outside HIFAR	4.500D + 01	0.000D + 00
3	ASNT - Bld 9	2.770D + 02	2.430D + 02
4	Main Gate	7.340D + 02	4.110D + 02
5	Stevens Hall	8.470D + 02	4.750D + 02
6	MWDA Depot	-5.000D + 02	5.800D + 02
7	BMX Track	-2.250D + 02	8.580D + 02
8	Woronora Valley	4.000D + 03	4.000D + 03
9	Receptor X	0.000D + 00	0.000D + 00
10	Receptor Y	0.000D + 00	0.000D + 00
11	North,1.6 km	0.000D + 00	1.600D + 03
12	NNE,1.6 km	6.123D + 02	1.478D + 03
13	NE,1.6 km	1.131D + 03	1.131D + 03
14	ENE,1.6 km	1.478D + 03	6.123D + 02
15	East,1.6 km	1.600D + 03	0.000D + 00
16	ESE,1.6 km	1.478D + 03	-6.123D + 02
17	SE,1.6 km	1.131D + 03	-1.131D + 03
18	SSE,1.6 km	6.123D + 02	-1.478D + 03
19	South,1.6 km	0.000D + 00	-1.600D + 03
20	SSW,1.6 km	-6.123D + 02	-1.478D + 03
21	SW,1.6 km	-1.131D + 03	-1.131D + 03
22	WSW,1.6 km	-1.478D + 03	-6.123D + 02
23	West,1.6 km	-1.600D + 03	0.000D + 00
24	WNW,1.6 km	-1.478D + 03	6.123D + 02
25	NW,1.6 km	-1.131D + 03	1.131D + 03
26	NNW,1.6 km	-6.123D + 02	1.478D + 03
27	North,4.8 km	0.000D + 00	4.800D + 03
28	NNE,4.8 km	1.837D + 03	4.435D + 03
29	NE,4.8 km	3.394D + 03	3.394D + 03
30	ENE,4.8 km	4.435D + 03	1.837D + 03
31	East,4.8 km	4.800D + 03	0.000D + 00
32	ESE,4.8 km	4.435D + 03	-1.837D + 03
33	SE,4.8 km	3.394D + 03	-3.394D + 03
34	SSE,4.8 km	1.837D + 03	-4.435D + 03
35	South,4.8 km	0.000D + 00	-4.800D + 03
36	SSW,4.8 km	-1.837D + 03	-4.435D + 03
37	SW,4.8 km	-3.394D + 03	-3.394D + 03
38	WSW,4.8 km	-4.435D + 03	-1.837D + 03
39	West,4.8 km	-4.800D + 03	0.000D + 00
40	WNW,4.8 km	-4.435D + 03	1.837D + 03
41	NW,4.8 km	-3.394D + 03	3.394D + 03
42	NNW,4.8 km	-1.837D + 03	4.435D + 03

TABLE 3

ANNUAL DOSES (Sv) FROM THE LHRL AIRBORNE RELEASES
1986 ROUTINE DISCHARGES
SUMMARY OF DOSES RELATIVE TO DOSE LIMITS

	Airborne WB Dose Estimate	Airborne WB Dose Limit	Ratio	Airborne SK Dose Estimate	Airborne SK Dose Limit	Ratio
Library	6.4D-06	5.0D-03	1.3D-03	1.1D-05	5.0D-02	2.3D-04
Outside HIFAR	8.4D-07	5.0D-03	1.7D-04	1.4D-06	5.0D-02	2.9D-05
ASNT - Bld 9	8.6D-06	5.0D-03	1.7D-03	1.5D-05	5.0D-02	3.1D-04
Main Gate	6.2D-06	5.0D-03	1.2D-03	1.1D-05	5.0D-02	2.2D-04
Stevens Hall	5.6D-06	2.5D-03	2.3D-03	1.0D-05	2.5D-02	4.0D-04
MWDA Depot	4.9D-06	5.0D-04	9.9D-03	8.8D-06	5.0D-03	1.8D-03
BMX Track	6.0D-06	2.5D-03	2.4D-03	1.1D-05	2.5D-02	4.3D-04
Woronora Valley	7.4D-07	5.0D-04	1.5D-03	1.4D-06	5.0D-03	2.7D-04
Receptor X	8.4D-07	5.0D-04	1.7D-03	1.4D-06	5.0D-03	2.9D-04
Receptor Y	8.4D-07	5.0D-04	1.7D-03	1.4D-06	5.0D-03	2.9D-04
North,1.6 km	4.0D-06	5.0D-04	8.1D-03	7.5D-06	5.0D-03	1.5D-03
NNE,1.6 km	4.6D-06	5.0D-04	9.2D-03	8.5D-06	5.0D-03	1.7D-03
NE,1.6 km	3.2D-06	5.0D-04	6.4D-03	5.9D-06	5.0D-03	1.2D-03
ENE,1.6 km	3.9D-06	5.0D-04	7.7D-03	7.1D-06	5.0D-03	1.4D-03
East,1.6 km	3.3D-06	5.0D-04	6.7D-03	6.1D-06	5.0D-03	1.2D-03
ESE,1.6 km	2.0D-06	5.0D-04	4.0D-03	3.7D-06	5.0D-03	7.4D-04
SE,1.6 km	1.9D-06	5.0D-04	3.8D-03	3.5D-06	5.0D-03	7.0D-04
SSE,1.6 km	1.8D-06	5.0D-04	3.6D-03	3.3D-06	5.0D-03	6.6D-04
South,1.6 km	1.8D-06	5.0D-04	3.5D-03	3.2D-06	5.0D-03	6.4D-04
SSW,1.6 km	1.6D-06	5.0D-04	3.2D-03	2.9D-06	5.0D-03	5.8D-04
SW,1.6 km	1.7D-06	5.0D-04	3.3D-03	3.0D-06	5.0D-03	6.0D-04
WSW,1.6 km	1.7D-06	5.0D-04	3.3D-03	3.0D-06	5.0D-03	6.0D-04
West,1.6 km	1.7D-06	5.0D-04	3.3D-03	3.0D-06	5.0D-03	6.0D-04
WNW,1.6 km	1.4D-06	5.0D-04	2.9D-03	2.6D-06	5.0D-03	5.2D-04
NW,1.6 km	2.4D-06	5.0D-04	4.9D-03	4.4D-06	5.0D-03	8.8D-04
NNW,1.6 km	3.2D-06	5.0D-04	6.4D-03	5.8D-06	5.0D-03	1.2D-03
North,4.8 km	1.1D-06	5.0D-04	2.2D-03	1.9D-06	5.0D-03	3.9D-04
NNE,4.8 km	1.2D-06	5.0D-04	2.4D-03	2.2D-06	5.0D-03	4.4D-04
NE,4.8 km	9.1D-07	5.0D-04	1.8D-03	1.7D-06	5.0D-03	3.3D-04
ENE,4.8 km	1.2D-06	5.0D-04	2.3D-03	2.2D-06	5.0D-03	4.3D-04
East,4.8 km	1.0D-06	5.0D-04	2.0D-03	1.8D-06	5.0D-03	3.7D-04
ESE,4.8 km	5.9D-07	5.0D-04	1.2D-03	1.1D-06	5.0D-03	2.2D-04
SE,4.8 km	5.7D-07	5.0D-04	1.1D-03	1.1D-06	5.0D-03	2.1D-04
SSE,4.8 km	5.1D-07	5.0D-04	1.0D-03	9.4D-07	5.0D-03	1.9D-04
South,4.8 km	4.8D-07	5.0D-04	9.6D-04	8.7D-07	5.0D-03	1.7D-04
SSW,4.8 km	4.9D-07	5.0D-04	9.8D-04	8.8D-07	5.0D-03	1.8D-04
SW,4.8 km	4.9D-07	5.0D-04	9.9D-04	9.0D-07	5.0D-03	1.8D-04
WSW,4.8 km	4.9D-07	5.0D-04	9.8D-04	8.7D-07	5.0D-03	1.7D-04
West,4.8 km	4.9D-07	5.0D-04	9.8D-04	8.8D-07	5.0D-03	1.8D-04
WNW,4.8 km	4.2D-07	5.0D-04	8.5D-04	7.9D-07	5.0D-03	1.6D-04
NW,4.8 km	7.3D-07	5.0D-04	1.5D-03	1.3D-06	5.0D-03	2.6D-04
NNW,4.8 km	8.6D-07	5.0D-04	1.7D-03	1.6D-06	5.0D-03	3.2D-04

WB = Whole Body, SK = Skin.

TABLE 4

ANNUAL DOSES (Sv) FROM THE LHRL AIRBORNE RELEASES
COOK [1967] DISCHARGE AUTHORISATION
SUMMARY OF DOSES RELATIVE TO DOSE LIMITS

	Airborne WB Dose Estimate	Airborne WB Dose Limit	Ratio	Airborne SK Dose Estimate	Airborne SK Dose Limit	Ratio
Library	1.0D-05	5.0D-03	2.1D-03	1.4D-05	5.0D-02	2.9D-04
Outside HIFAR	2.4D-06	5.0D-03	4.7D-04	3.8D-06	5.0D-02	7.6D-05
ASNT - Bld 9	1.3D-05	5.0D-03	2.6D-03	2.0D-05	5.0D-02	4.0D-04
Main Gate	1.1D-05	5.0D-03	2.1D-03	1.5D-05	5.0D-02	3.1D-04
Stevens Hall	9.4D-06	2.5D-03	3.8D-03	1.5D-05	2.5D-02	5.8D-04
MWDA Depot	7.6D-06	5.0D-04	1.5D-02	1.3D-05	5.0D-03	2.6D-03
BMX Track	1.0D-05	2.5D-03	4.0D-03	1.6D-05	2.5D-02	6.4D-04
Woronora Valley	1.3D-06	5.0D-04	2.7D-03	2.3D-06	5.0D-03	4.6D-04
Receptor X	2.5D-06	5.0D-04	5.1D-03	3.8D-06	5.0D-03	7.7D-04
Receptor Y	2.5D-06	5.0D-04	5.1D-03	3.8D-06	5.0D-03	7.7D-04
North,1.6 km	6.9D-06	5.0D-04	1.4D-02	1.1D-05	5.0D-03	2.3D-03
NNE,1.6 km	8.4D-06	5.0D-04	1.7D-02	1.4D-05	5.0D-03	2.8D-03
NE,1.6 km	5.7D-06	5.0D-04	1.1D-02	9.5D-06	5.0D-03	1.9D-03
ENE,1.6 km	6.8D-06	5.0D-04	1.4D-02	1.1D-05	5.0D-03	2.2D-03
East,1.6 km	6.0D-06	5.0D-04	1.2D-02	9.7D-06	5.0D-03	1.9D-03
ESE,1.6 km	3.7D-06	5.0D-04	7.3D-03	6.1D-06	5.0D-03	1.2D-03
SE,1.6 km	3.5D-06	5.0D-04	7.0D-03	5.8D-06	5.0D-03	1.2D-03
SSE,1.6 km	3.2D-06	5.0D-04	6.4D-03	5.2D-06	5.0D-03	1.0D-03
South,1.6 km	2.9D-06	5.0D-04	5.9D-03	4.9D-06	5.0D-03	9.8D-04
SSW,1.6 km	2.8D-06	5.0D-04	5.6D-03	4.5D-06	5.0D-03	9.0D-04
SW,1.6 km	2.9D-06	5.0D-04	5.7D-03	4.7D-06	5.0D-03	9.5D-04
WSW,1.6 km	2.9D-06	5.0D-04	5.8D-03	4.8D-06	5.0D-03	9.6D-04
West,1.6 km	2.9D-06	5.0D-04	5.8D-03	4.8D-06	5.0D-03	9.6D-04
WNW,1.6 km	2.5D-06	5.0D-04	5.0D-03	4.2D-06	5.0D-03	8.5D-04
NW,1.6 km	3.8D-06	5.0D-04	7.7D-03	6.8D-06	5.0D-03	1.4D-03
NNW,1.6 km	5.3D-06	5.0D-04	1.1D-02	8.8D-06	5.0D-03	1.8D-03
North,4.8 km	1.8D-06	5.0D-04	3.7D-03	3.1D-06	5.0D-03	6.2D-04
NNE,4.8 km	2.3D-06	5.0D-04	4.5D-03	3.9D-06	5.0D-03	7.7D-04
NE,4.8 km	1.6D-06	5.0D-04	3.3D-03	2.8D-06	5.0D-03	5.6D-04
ENE,4.8 km	2.1D-06	5.0D-04	4.1D-03	3.5D-06	5.0D-03	7.1D-04
East,4.8 km	1.8D-06	5.0D-04	3.6D-03	3.0D-06	5.0D-03	5.9D-04
ESE,4.8 km	1.1D-06	5.0D-04	2.3D-03	2.0D-06	5.0D-03	4.0D-04
SE,4.8 km	1.1D-06	5.0D-04	2.1D-03	1.9D-06	5.0D-03	3.7D-04
SSE,4.8 km	9.3D-07	5.0D-04	1.9D-03	1.6D-06	5.0D-03	3.1D-04
South,4.8 km	8.5D-07	5.0D-04	1.7D-03	1.4D-06	5.0D-03	2.8D-04
SSW,4.8 km	8.8D-07	5.0D-04	1.8D-03	1.5D-06	5.0D-03	2.9D-04
SW,4.8 km	9.1D-07	5.0D-04	1.8D-03	1.5D-06	5.0D-03	3.0D-04
WSW,4.8 km	8.9D-07	5.0D-04	1.8D-03	1.5D-06	5.0D-03	3.0D-04
West,4.8 km	8.9D-07	5.0D-04	1.8D-03	1.5D-06	5.0D-03	3.0D-04
WNW,4.8 km	7.8D-07	5.0D-04	1.6D-03	1.4D-06	5.0D-03	2.7D-04
NW,4.8 km	1.2D-06	5.0D-04	2.4D-03	2.1D-06	5.0D-03	4.3D-04
NNW,4.8 km	1.5D-06	5.0D-04	3.0D-03	2.5D-06	5.0D-03	5.1D-04

WB = Whole Body, SK = Skin.

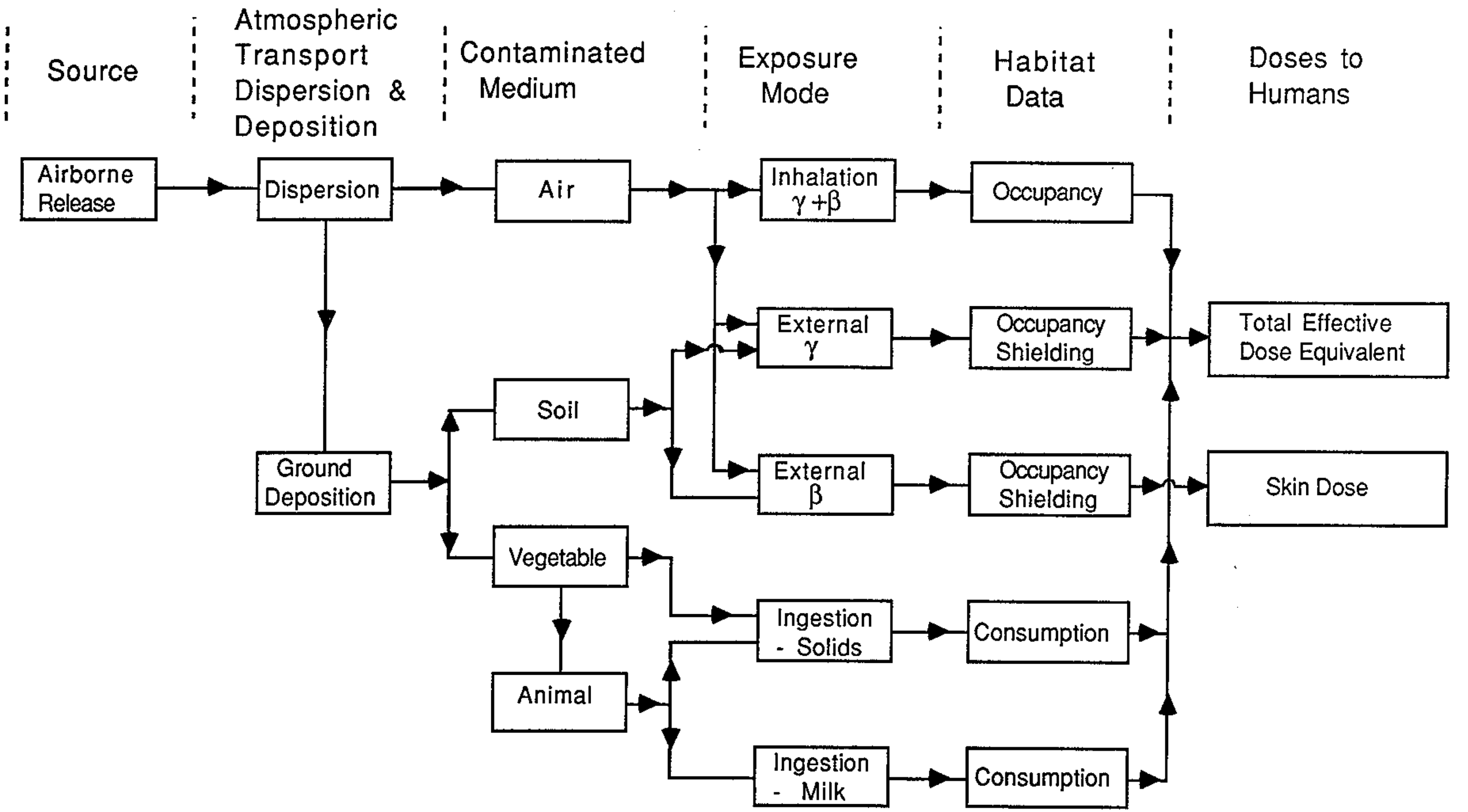

FIGURE 1: Major Atmospheric Pathways

APPENDIX A

PREVIOUS ENVIRONMENTAL SURVEY REPORTS

Giles, M.S., Stockdale, J.A. [1966] - Results of the Lucas Heights Biological Survey, December 1959 - December 1964. AAEC/E151.

Cook, J.E., Dudaitis, A., Giles, M.S. [1969] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1965, 1966 and 1967. AAEC/E151 Supplement No. 1.

Cook, J.E. Dudaitis, A. [1970] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1968. AAEC/E151 Supplement No. 2.

Cook, J.E. Dudaitis, A. [1970] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1969. AAEC/E151 Supplement No. 3.

Conway, N.F., Dudaitis, A. [1972] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for the Period January-July, 1970. AAEC/E246.

Dudaitis, A. [1973] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for the Period August 1970 - December 1971. AAEC/E271.

Dudaitis, A. [1974] - Environmental Survey at the AAEC Research Establishment, Lucas Heights - Results for 1972. AAEC/E301.

Davy, D.R., Dudaitis, A. [1974] - Environmental Survey at the AAEC Research Establishment, Lucas Heights - Results for 1973. AAEC/E335.

Davy, D.R., Dudaitis, A. [1976] - Environmental Survey at the AAEC Research Establishment, Lucas Heights - Results for 1974. AAEC/E375.

Hespe, E.D. [1979a] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1975, 1976 and 1977. AAEC/E467.

Hespe, E.D. [1979b] - Results of the 1978 Environmental Survey at the AAEC Research Establishment, Lucas Heights. AAEC/E494.

Giles, M.S., Dudaitis, A. [1980] - Environmental Survey at the AAEC Research Establishment, Lucas Heights - Results for 1979. AAEC/E508.

Giles, M.S., Dudaitis, A. [1982] - Environmental Survey at the AAEC Research Establishment, Lucas Heights - Results for 1980. AAEC/E542.

Williams, A.R., Dudaitis, A. [1983] - Environmental Survey at the Lucas Heights Research Laboratories, 1981. AAEC/E563.

Giles, M.S., Dudaitis, A. [1984] - Environmental Survey at the Lucas Heights Research Laboratories, 1982. AAEC/E591.

Giles, M.S., Dudaitis, A. [1985] - Environmental Survey at the Lucas Heights Research Laboratories, 1983. AAEC/E622.

Giles, M.S., Dudaitis, A. [1986] - Environmental Survey at the Lucas Heights Research Laboratories, 1984. AAEC/E638.

Giles, M.S., Foy, J.J., Hoffman, E.L. [1988] - Environmental Survey at the Lucas Heights Research Laboratories, 1985. ANSTO/E677.