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Preliminary Environmental Review

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ANSTO's Radioactive Waste Management Policy

Preliminary Environmental Review

by

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Phase 2 report have been assessed (DPIE 1995) and the next step is for one region to be identified for a more detailed investigation and selection of a suitable site. A comprehensive public consultation process is planned during the selection and investigation of a preferred site.

The design of the waste repository is still under discussion and will not be finalised until a site is selected and the need for additional barriers can be evaluated. The criteria being used for site selection are those required for an engineered trench structure excavated below the original ground level on a 1.5 km^2 site.

It is recommended that ANSTO provide technical support for the establishment of the national repository for low-level and short-lived, intermediate-level radioactive waste.

The repository site is expected to:

- have annual rainfall less than 500 mm,
- have annual pan evaporation greater than 2500 mm,
- have a water table more than 50 m below the bottom of the waste,
- be in a region where bore water is saline and water bores have low supply rates, and
- have a deeply weathered profile.

The long-term dose to members of the public from waste disposal at the repository will depend on the total site inventory of radionuclides. At this time, the radionuclide composition of waste for disposal is poorly characterised. As well as intruder scenarios, which were covered in developing the limits provided in the Code of Practice, another potential exposure pathway is transport of the radionuclides by infiltrating water to the water table. In the arid regions being considered for the facility, the deep water table and the very low water flux in the vadose zone are important barriers to the release of radionuclides from the repository into the biosphere.

A one-dimensional advection-dispersion model developed by ANSTO provides useful results for the preliminary assessment of releases from a low-level radioactive disposal facility. The results are sensitive to some parameters for which site specific data are needed to ensure that calculated doses are realistic upper limits. Data on the inventory of radionuclides at site closure and site specific measurements of geochemistry and water velocity in the unsaturated zone are needed to provide more reliable estimates of concentrations and long term exposures.

Results from the model indicate that for a shallow land disposal site in the arid zone, only a few long-lived radionuclides might appear in measurable amounts in the groundwater beneath the site. The low inventory of radionuclides in the repository, the low recharge rates in arid regions and the depth to the water table mean that effective doses from the use of groundwater from the repository site are expected to be very low.

In order to satisfy the above requirements for disposal of ANSTO's wastes, **it is recommended** that conditioning/packaging processes for ANSTO's radioactive waste be assessed for compliance with international best practice, the transport code, storage requirements and expected acceptance criteria for disposal. **It is further recommended** that waste conditioning procedures be developed and tested for those wastes identified as requiring conditioning prior to disposal.

3.7.2 ANSTO Wastes Suitable for Disposal at the Low Level Radioactive Waste Repository

It is expected that all the low level radioactive waste at ANSTO will be suitable for disposal at the national facility, and much of the intermediate level waste will be short lived enough to be acceptable. The balance of the waste is Category S waste which is not suitable for near surface disposal. Category S wastes will have to be stored until a national geological facility is established for intermediate level (Category S) wastes. The amount of Category S wastes in Australia is relatively small, and it is possible that a national storage facility will be established to store this waste until there is enough to warrant a geological disposal facility.

It is recommended that the quantities and activities of ANSTO waste that meet category A, B and S disposal criteria be determined as part of the waste inventory project (see Section 3.6).

Decommissioning HIFAR is estimated to generate about 2500 m^3 of low-level waste and about 150 m^3 intermediate-level waste if the reactor is dismantled soon after ceasing operations.

Any conditioning of historic ANSTO radioactive wastes and the continuing treatment of current wastes will meet the requirements laid down in the NHMRC code.

3.7.3 Site Selection Process

The site selection process for the national repository is being managed by the Department of Primary Industries and Energy (DPIE). In Phase 1, the National Resource Information Centre (NRIC) developed a methodology based on a geographic information system (GIS) to assemble large amounts of geographical information on a continental scale and rank regions based on the suitability of attributes for a radioactive waste repository (NRIC 1992). Public comments were sought on the methodology and a report was issued responding to the comments received (DPIE 1993).

In Phase 2, the GIS methodology was re-applied on a country-wide basis and eight regions were characterised for their potential as suitable sites (NRIC 1994). The identified regions were between 11,000 and 67,000 square kilometres in area and were characterised by annual rainfall less than 500 mm, high pan evaporation, low population densities, no intensive agriculture and low productivity aquifers. Public comments on the

TABLE 3.5
Concentration Limits (MBq per kg) for Disposal of Radioactive Wastes at an Arid Remote Site (NHMRC 1992)

Radionuclides	Category	100 year control	200 year control
Tritium	Category A	500	100,000
	Category B	10,000	5,000,000
Carbon-14	Category A	10	10
	Category B	50	50
α-emitters (inc. ^{238}U, ^{239}Pu, ^{241}Am)	Category A	0.1	0.1
	Category B	10	10
Radium-226	Category A	0.005	0.005
	Category B	0.5	0.5
β/γ emitters with half-life > 5 y	Category A	0.5	5
	Category B	100	1000
β/γ emitters with half-life ≤ 5 y	Category A	1000	1000
	Category B	no limit	no limit

Section 2.6.6 of the Code lists the qualitative physical, biological and chemical requirements for waste to be acceptable for disposal. In summary, these requirements are:

- Waste shall not contain corrosive materials: waste containing inorganic acids, alkalis and corrosive salts shall be treated to neutralise them,
- Where practicable flammable or combustible materials such as paper, plastics, cloth or resins shall be separated from non-flammable solids and packaged, contained and labelled in a proper manner,
- Waste shall not contain or be capable of generating gaseous materials in quantities that might lead to the release of harmful vapours or fumes,
- Waste shall not contain material that can undergo a vigorous exothermic reaction,
- Waste shall be treated to render it non-flammable,
- Liquid waste shall be solidified to be acceptable for disposal, the final waste form shall comply with the stability requirement,
- As far as practicable the waste should be free of biological materials,
- Waste contaminated with toxic, pathogenic or infectious material shall be treated to minimise the risks and hazard,
- Waste containing chelating agents shall be treated to reduce possible long term effects of leaching by water.

The amount of short-lived radioactive waste in Australia is about 3400 m^3, made up of 1200 m^3 from ANSTO (see Section 3.7.2 for more information on ANSTO wastes suitable for the repository), 60 m^3 from Department of Defence, 100 m^3 from States and Territories and 2000 m^3 CSIRO, with a generation rate of about 50 m^3 per year (NRIC 1992). The total amount of radioactive waste in Australia is small compared to that of countries with nuclear power programs, and small compared with other toxic wastes in Australia. The decommissioning of HIFAR and Moata, the cleanup of contaminated sites, and consumer products, such as smoke detectors, could be additional sources of low-level and short-lived intermediate-level waste.

3.7.1 NHMRC Code of Practice for the Near-Surface Disposal of Radioactive Waste

A national repository for short-lived radioactive waste in Australia has been under discussion for many years. In 1992, the National Health and Medical Research Council (NHMRC) issued a *Code of Practice for the Near-Surface Disposal of Radioactive Waste in Australia* (NHMRC 1992). The Code defines three categories of waste (A, B and C) acceptable for near-surface disposal and one category (S) unsuitable for near-surface disposal. The minimum cover thickness for Category A material is 2 m between the top of the waste and the top surface of the cover, and for Category B and C materials the minimum cover thickness is 5 m. Category C waste is bulk materials with similar activity limits to Category B.

Generic activity limits were provided in the Code for a remote arid site where there is no significant release by groundwater (Table 3.5). These limits were derived from an evaluation of potential intruder scenarios that might occur after the end of the institutional control period (Camilleri *et al.* 1989). A site specific safety analysis will be part of the environmental assessment for establishing a repository. However, the allowed limits at the repository are expected be no more restrictive than the generic limits in Table 3.5.

Waste for the repository will have to be conditioned to meet the requirements of the Code (Section 2.6.5):

(a) Treatment of Category A waste shall be carried out to reduce the waste volume and to minimise voids. The minimum requirement shall be consolidation and compaction of the waste. Bulk waste in which the levels of radioactive contamination are low may meet the criteria for Category A in which case the waste shall be required to meet the stability requirements of Category C bulk waste.

(b) For disposal of Category B or Category C waste, the waste shall be in a form which will maintain its physical dimensions and properties under the anticipated conditions of disposal. Factors requiring consideration may include the compressive load of overburden or compaction equipment, and possible structural changes caused by chemical reaction or biodegradation. Waste in either of these two categories shall be structurally stable for a design period of at least 300 years.

To correct this deficiency, an order was recently placed for a gamma scanning system, mainly to determine the inventory of ANSTO's drummed wastes. Standard 200 L drums will be placed in a shielded cabinet for gamma-counting by three germanium detectors. This configuration will permit measurement of γ-emitting radionuclides down to exemption levels (see Section 1.3).

A separate detector (identical to the other three) has been ordered for drums or other items which either have a high activity or are of a non-standard size. The new system should enable accurate measurement of the gamma-emitting radionuclides in most solid wastes at the LHSTC. The activities of pure beta-emitters will be estimated by their known association with gamma-emitting radionuclides (*e.g.* ^{90}Sr with ^{137}Cs).

The scanner is expected to be delivered in November 1996. The system will be housed in a small building adjacent to Building 59.

It is recommended that an inventory of all radioactive wastes at the LHSTC be undertaken over the next four years. It will take approximately two years to characterise all the low level drums currently in storage and another two years to characterise all the other wastes. The inventory should be maintained on a centralised computer database which will allow wastes to be tracked from source to disposal.

Since much of ANSTO's waste is short-lived, it is expected that many drums will contain exempt levels of radionuclides. This means that some ANSTO wastes would be suitable for disposal at authorised municipal landfill sites under the National Health and Medical Research Council (NHMRC) Code of Practice for the Disposal of Radioactive Waste by the User (NHMRC 1985). In practice, however, retrospective "declassification" of radioactive wastes is likely to be difficult since the drum scanner will only be able to detect those radionuclides which are gamma-emitters.

The feasibility of segregating wastes at source should be investigated as part of the Action Plan. This will enable alpha and pure beta-emitters to be identified at source and waste containing short-lived radionuclides to be set aside for decay. After a suitable time, the radioactivity in the drums would be remeasured and, if the levels are below the exemption level, disposal to a authorised landfill would be considered, subject to approval by the regulatory authorities.

3.7 Disposal of Solid Wastes

Australia is establishing a national repository for disposal of low-level and short-lived intermediate-level radioactive wastes (LILW-SL). The site selection process has progressed to the selection of eight regions considered likely to containing suitable sites, one of which will be selected for detailed investigation.

There are about 1600 litres of charcoal in storage and the rate of generation is 200 litres per year. Conditioning options for these wastes are being investigated by Materials Division.

Used high efficiency particulate air (HEPA) filters have been generated in several buildings at the LHSTC over many years. The filters were mainly used for filtration of ventilation exhaust from nominally active areas. There are 650 filters currently in storage; the annual rate of generation is 10-15 per year. They were once stored in building 59 but were transferred to shipping containers on the northern side of building 59 to reduce the stock of flammable materials in that area. There are no data available on the activity levels in these filters. The radionuclides on the HEPA filters could be any long-lived isotope used in buildings with an active ventilation system, including uranium from buildings 2 and 64. Many are believed to have low activity due to the low initial loading and subsequently decay of short-lived radioactivity. The radioactivity of these filters will be determined as part of the waste inventory program (see Section 3.6).

3.5 Contaminated Plant and Equipment

Surplus equipment awaiting decontamination has been stored by Waste Management Section for many years. Presently this waste is stored in five aluminium shipping containers under cover. Other items, presently stored in building 27, include contaminated shields for waste transfers, no longer used by Waste Management Section. They vary in size and weight.

Contaminated centrifuge components originally from building 64 are currently stored in an aluminium shipping container recently repositioned outside building 20 for decontamination. They are expected to be decontaminated by the end of 1996.

Contaminated ducting exists *in situ* in building 2. The ducting is no longer part of the ventilation system and presently blanked off but it needs to be dismantled and decontaminated. There is also contaminated ducting in building 19 which is currently undergoing refurbishing, including upgrading of the active ventilation system. Apart from radioactive contamination, the ventilation system in building 19 contains beryllium contamination. Options for this ducting include complete removal or decontamination and reuse.

3.6 Inventory of Radioactive Solid Wastes

As noted in the preceding sections, wastes have been historically categorised at LHSTC according to dose rate and there is very little information available on levels of radionuclides. Maintenance of inventories of all wastes is a requirement of the ANSTO's policy and is likely to become mandatory under the *International Convention on the Safety of Radioactive Waste Management.*

2. The "B" or retrievable storage pits, commissioned in mid-1990, are a series of eight pits, each holding eight vertical aluminium racks. Each rack has the capacity to hold 17 aluminium storage bins in which waste has been placed at source or after processing by Waste Management Section. These bins have a nominal capacity of 72 litres each. Therefore these pits have a nominal total capacity of approx 78 m^3. Approximately 8.5 m^3 ILS waste has been placed into this facility.

   The array of eight pits have concrete walls and floor. The pits were constructed in an excavated hole and the pit floor sits on the base of that hole. The pit wall is not in contact with the hole walls. That hollow space allows groundwater to be drained from the new pits. It flows by gravity to an external sump which is sampled regularly as part of the site environmental survey. When that sump fills, the water is automatically pumped to the site effluent collection system.

   When the retrievable storage pits were being excavated, a series of holes were drilled into the ground next to the "A" pits to allow groundwater in the rock to be drained toward the new pits.

3.3.2 Current Rates of Production

The generation rates of these wastes have decreased over the past few years as Waste Management Section and, more recently ARI, have implemented a volume reduction and segregation program to achieve better packing in the primary waste containers.

3.4 Contaminated Charcoal and HEPA Filters

The processing of SIAM (Standard Iodine Adsorption Module) filters, used for iodine removal (see Section 5.2), results in the generation of charcoal waste. The filter housings are reused by reloading them with fresh charcoal so there is no routine production of waste from these filters except the charcoal - approximately 18 kg per SIAM filter. Currently, this material is accumulated in four 200 litre steel drums by Health & Safety Ventilation Group and passed to Waste Management when filled for storage as low level solid waste.

ARI have been generating charcoal waste from the noble gas traps in the building 54 hot cells for about 5 years. This waste is removed from the gas traps in-cell and transferred to dedicated storage cans which are filled with water to prevent combustion of the charcoal. These cans are stored at building 54 to allow decay of short-lived radionuclides before being transported to Waste Management Section for long term storage. The waste is transferred to plastic lined steel drums where it continues to be stored under a water cover. The radioactivity levels in this material have not been determined but qualitative analysis by gamma-spectrometry indicates that the major radionuclides present are ^{144}Ce, ^{137}Cs, ^{106}Ru, ^{106}Rh and ^{85}Sr.

TABLE 3.4
Types of Intermediate Level Solid Waste

Source	Waste type	Material(s) of construction	Radioisotopes
HIFAR Operations	HFE cropped ends	Aluminium	^{60}Co, ^{65}Zn
	Silicon irradiation cans	Aluminium	^{60}Co, ^{65}Zn
	Thermocouple wires	Stainless steel	^{60}Co
	Ion-exchange resin	Nuclear grade cationic & anionic resin	Mixed fission products, ^{60}Co
ARI : B23 Production Cells	Irradiation cans	Aluminium & titanium	^{99}Mo, ^{153}Sm, ^{64}Cu, ^{131}Te, ^{90}Y
	Pipettes, funnels, tubing	Plastic	^{99}Mo, ^{153}Sm, ^{64}Cu, ^{131}Te, ^{90}Y
	Beakers, vials, quickfit parts	Glass	^{99}Mo, ^{153}Sm, ^{64}Cu, ^{131}Te, ^{90}Y
	Syringes	Plastic	^{99}Mo, ^{153}Sm, ^{64}Cu, ^{131}Te, ^{90}Y
	Cleaning cloths	Synthetic cloth	^{99}Mo, ^{153}Sm, ^{64}Cu, ^{131}Te, ^{90}Y
	Old equipment	Stainless steel, perspex	^{99}Mo, ^{153}Sm, ^{64}Cu, ^{131}Te, ^{90}Y
ARI: Junior Caves No1	Irradiation cans	Aluminium	^{99}Mo
	Irradiation cans	Titanium	^{131}Te
	Filter paper	Paper	^{99}Mo
	Tubing	Plastic	^{99}Mo
ARI: Junior Caves No2	Beakers	Glass	^{131}I
	Syringes, pipettes	Polypropylene	^{131}I
ARI: B54 Hot Cells	Rocket cans	Aluminium	mixed fission products, ^{65}Zn, ^{54}Mn, ^{46}Sc, ^{60}Co
	Extraction columns	Perspex	mixed fission products
	Alumina powder (in extraction columns)		mixed fission products
	Mesh	Stainless steel	mixed fission products
	Filters	Polypropylene	mixed fission products
	Syringes	Polypropylene	mixed fission products
	10mL bottles	Glass	mixed fission products
	Thermocouple wires	Stainless steel & polyamide	mixed fission products
	Electrical cables	PVC & copper	mixed fission products
	Cartridge heaters	Nickel	mixed fission products
	Charcoal filled cartridges	ABS plastic & stainless steel	
	manipulator bags	PVC	mixed fission products
	O-rings	Epon, Viton, Silicon, Rubber	mixed fission products
	Fittings	High density poly-ethylene, stainless steel	mixed fission products
	Hoses	EPDM, rubber, PVC	mixed fission products
	Uranium dioxide (residues)	powder	mixed fission products
ARI: Co-60 cells	Liquid solutions of sodium aluminate mixed with concrete	Concrete mix in 2 litre steel cans	^{26}Al ^{60}Co
	Titanium irradiation tubes	Titanium	

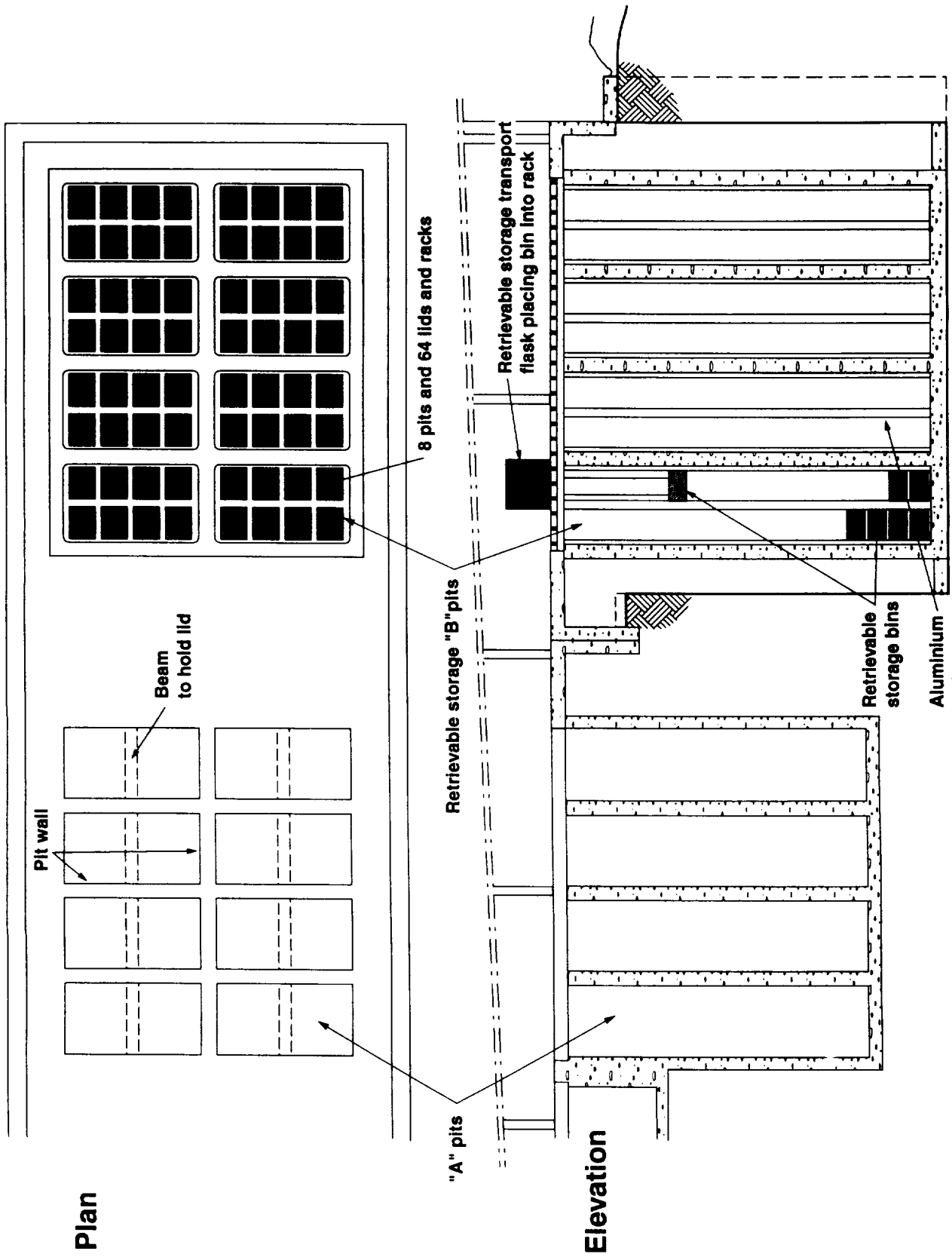

Figure 3.1: Layout of Facilities for Storage of Intermediate Level Solid Wastes (Building 27)

3.3 Intermediate Level Solid Wastes

Intermediate level solid wastes (ILSW) require special shielding during handling and transport. At ANSTO, these wastes contain a range of radioisotopes. Some streams, such as those generated in ARI's production cells contain very little, if any, long-lived radioisotopes. Other streams such as for ARI's hot cells in building 54 contain longer-lived fission products. Currently, essentially all LILW-SL is generated by either ARI (60%) or HIFAR Operations (40%).

ILSW from ARI operations are generally consumables resulting from irradiation of radioisotope target material and processing of that irradiated material. This includes activated metal cans which were the primary containment for the targets during irradiation within HIFAR, contaminated alumina columns used for chemical separation of products, spent ion exchange resins used to purify HIFAR cooling water and highly contaminated filters and glassware.

ILSW from HIFAR operations are generally irradiated materials which are consumables involved in the operation of the reactor. They include activated aluminium end pieces cropped from HIFAR fuel (see Section 7.4), irradiation canisters used in silicon production, thermocouple wires which provide operational data to the control room, and ion exchange resin which purifies the heavy water moderator/coolant.

Table 3.4 lists the various types of waste and the associated radioisotopes that are typically present shortly after production. When produced, the surface dose varies within the range: 0.02-10 Sv per hour.

In order to reduce waste volumes, **it is recommended** that ANSTO assess the usefulness of improved multi-use packaging systems for the major waste streams, particularly for intermediate level wastes.

3.3.1 Facilities for Storage

Intermediate level solid wastes (ILSW) are placed within building 27 in specially-constructed concrete pits for long term storage and future retrieval. Figure 3.1 shows the layout of these facilities. Two types of storage are available:

1. The "A" pits, as they are known, are eight pits constructed in the late 1960s with no internal structure other than the walls that separate adjoining pits. Each pit has dimensions 1.5 m x 2.7 m x 5.9 m deep and a volume of about 190 m^3. The outer walls of the pit is 225 mm concrete with a 20 mm bituminous waterproof membrane. These pits are now virtually full and have not received waste since 1993. Recovery of material from the "A" pits is possible but will require development of a suitable technique. **It is recommended** that the feasibility of recovery of waste from the "A" pits be established and demonstrated.

Further laboratory and larger scale tests would be required, particularly with thorium, before this process could be recommended for treatment of all the scrap waste.

3.2.2.5 Scrap Management Strategy

Of the three options discussed above, the uranium burner can be discarded based on the fact that the existing unit has not functioned properly and its throughput is very low.

The controlled calcination and the hypochlorite methods are both regarded as viable and capable of acceptable processing rates, although there is some doubt about the rate of dissolution of thorium using hypochlorite solution. Wet processing using hypochlorite has the advantage that airborne emissions are of no concern, however, disposal of the kerosene (including that entrained in the wet processing stage) would need to be considered carefully. The final product would be a filter cake which would need to be dried or else immobilised in cement.

ANSTO has considerable experience in calcination because of our R&D on Synroc. Existing equipment could also be used after some modifications. Potential airborne emissions during handling and calcination operations are the main operational issue with the calcination method. However, the oxide product has been found to be free-flowing and fairly coarse. Conceptual methods have been developed to safely load the scrap into the calciner and unload the product.

Of the two methods, controlled calcination is preferred because it can be commissioned in the shortest time and because throughput could be as high as 25-50 kg per day. **It is recommended** that stabilisation of the uranium and thorium scrap by calcination be carried out as part of the Waste Management Action Plan. It is envisaged that, using this method, all the metallic scrap in storage could be stabilised in less than six months of operation.

The product from this process would be an oxide powder. Reuse or resale of this material is not realistic especially since most of the uranium is depleted in ^{235}U. According to the latest international guidelines (IAEA 1994), the material would be classified as LILW-LL waste.

Once stabilised, the volume would be small and the waste could be safety stored in about ten 200 litre drums. In its stabilised, but unconditioned, form, the material would exceed the radioactivity limits for disposal in a near-surface repository (NHMRC 1992). Conditioning in cement would be a practical approach to more secure containment of the waste with a view to prolonged storage or disposal.

a short time by Waste Management Section. The burner's output was 5 kg per 24 hours and because of operational difficulties, due mainly to blocked filters, the unit was closed down.

Modification and recommissioning of the burner was considered as part of this review. However, the fundamental problem is the low throughput which means that it would take several years of fairly intense activity to stabilise the 3.8 tonnes of scrap currently in storage.

Controlled calcination

TGA analyses of uranium swarf showed that the exothermic peak temperature was in the vicinity of 400°C. Using this data, it appeared that uranium swarf could be oxidised in a rotary calciner at 400-450°C using a controlled oxygen atmosphere. Subsequent laboratory experiments using, in sequence, about 100 g, 300 g and 900 g of depleted uranium swarf have successfully oxidised the uranium to either a mixture of U_3O_7 and U_3O_8, or completely to U_3O_8 with additional time at temperature. The exothermic reactions can be effectively controlled by reducing the air flow.

Further TGA analyses using thorium swarf indicated two exothermic peaks at about 490°C and 940°C. In order to be able to use the same calciner for both uranium and thorium, it was decided to perform laboratory tests with a calciner set temperature of 900°C. Using a sample of about 100 g, complete oxidation of the thorium swarf was demonstrated.

Wet chemical oxidation

Los Alamos National Laboratory (LANL) has developed a chemical process to reduce uranium swarf to an inert product (Dziewinskcs *et al.* 1995). The process consists of draining off storage oils or kerosene, treating the scrap with sodium hypochlorite to oxidise the uranium to uranyl hydroxide ($UO_2(OH)_2$), using sodium thiosulphate to reduce hydroxide to the oxide (UO_2) and eventually stabilising the slurry in a cement matrix.

Recently, laboratory trials were conducted using 60 g of depleted uranium swarf to test the feasibility of the method for ANSTO's scrap. The reaction proceeded smoothly and to completion. The slurry was filtered and chemical analysis of the filtrate showed that the uranium content was very low and the aqueous waste from this process would not be classified as radioactive.

A small sample (10 g) of thorium swarf was also tested using the hypochlorite oxidation process. Reaction was very slow (at least 10 times slower than uranium) but appeared to go to completion.

Freshly generated uranium swarf is stored under the administrative control of the Materials Division's active store in the building 3 "FED" bay. This is temporary storage and the uranium is accumulated until moved to a more permanent storage area.

3.2.2.3 Condition of Uranium Scrap in Storage

Recently, samples of depleted uranium scrap were taken from storage to determine whether the flammability of the uranium scrap had changed during storage. Both swarf and fines were examined as well as a sample of freshly machined uranium swarf as a control.

To stimulate accelerated oxidation, Thermal Gravimetric Analysis (TGA) was carried out at temperatures up to 600°C in flowing air. The change in weight was recorded, together with any exothermic reaction. The results showed that finely-divided uranium had mostly been converted to the oxide form after two years storage. Fresh swarf oxidised at a lower temperature than aged swarf, but the weight gain was similar, indicating that only the surface had been oxidised.

This work verified that storage of uranium scrap is most critical during the initial stages of oxidation, *e.g.* immediately after generation. Consequently, a program for uranium scrap stabilisation should concentrate initially on the uranium scrap generated in recent years.

3.2.2.4 Management Options

A number of options for management of the scrap were examined, viz.,

(i) permanent storage,

(ii) recovery by melting,

(iii) alloying with aluminium,

(iv) conversion by burning,

(v) conversion by controlled calcination,

(vi) wet chemical oxidation.

The first option (permanent storage) was rejected because it leaves the scrap in an inherently unstable condition. Options (ii) and (iii) were also discarded because the scrap is partially oxidised which limits recovery and complicates the processing. The remaining options are discussed below.

Stabilisation by burning

There have been a number of studies, over a period of 25 years, of burning as a means of stabilising ANSTO's uranium swarf. The approach was demonstrated on a small scale in the 1970s. Two uranium burners were commissioned. The latest model was operated for

overseas and encased in stainless steel at ANSTO. In future, the turn-over of uranium components is estimated to be only of the order of 0-10 kg per year, of which 30% would be scrap.

TABLE 3.2
Inventory of Thorium and Uranium Metal Scrap

Category	No of containers	Net wt (kg metal)
Depleted uranium	102	1888
Natural uranium	8	480
Uranium (unmarked)	40	770
Natural Thorium	7	138
Scrap (unmarked)	6	106
Unmarked	23	381
Total:	**186**	**3763**

3.2.2.2 Description of Storage Conditions

The current location of the metal scrap is given in Table 3.3. Most is stored in building 57 under the administrative control of Nuclear Technology Division in three enclosed bays, numbers 2, 3 and 5. For reasons of safety in the event of a fire, the bays have been partitioned using cement blocks into smaller areas each containing four drums stacked two high. Because the bays are located in front of the molybdenum-99 waste storage area, they have a relatively high radiation background level.

TABLE 3.3
Location of Metal Scrap

	Location	Net Weight (kg)
Bldg 57	Storage bay 2	1353
Bldg 57	Storage bay 3	916
Bldg 57	Storage bay 5	1235
Bldg 3	Nuclear material store	259
	Total	**3763**

Building 57 is not an entirely satisfactory storage area for this type of waste and the decision has been taken to move it into building 69 when renovations to that building are completed in the near future.

The radiation dose on the surface of these drums is relatively high (400 $\mu Sv\ h^{-1}$) compared with other wastes in building 59. They will be relocated when the building 59 extension is complete in order to reduce the radiation dose at the site boundary and to personnel working in the vicinity. It is proposed to inspect all drums before they are moved and to re-drum where rusting is apparent.

There is very little demand for thorium nowadays and the material must be regarded as waste. According to the latest IAEA criteria (IAEA 1994), this material would be classified as LILW-LL waste (see Section 1.3).

The radionuclide activities in each drum will be determined accurately as part of the planned inventory of all ANSTO wastes. **It is recommended** that conditioning of this waste for storage and/or disposal be carried out as part of ANSTO's waste management action plan. At this stage, it is not possible to determine whether this waste would be suitable for disposal in the national waste repository.

3.2.2 Uranium and Thorium Metallic Scrap

3.2.2.1 Quantities and Form

Approximately 3.8 tonnes of thorium, natural and depleted uranium scrap metal has been generated over the past 35 years from the melting, casting and machining of uranium and thorium in the fabrication of thermal neutron filters, reflectors, blankets or shielding components. The scrap can be categorised as follows:-

(i)	Sawdust	(finely divided particles)
(ii)	Swarf	(machine turnings)
(iii)	Skulls	(both thin and thick metal)
(iv)	"Hot-tops"	(normally thick metal)

Finely-divided uranium and thorium are pyrophoric. For this reason, they are stored under kerosene or, in a few cases, under oil. There are a total of 186 drums, mostly of 20 L capacity, containing either uranium or thorium metal.

Table 3.2 gives the inventory of scrap on an elemental and enrichment basis (natural uranium or uranium depleted in ^{235}U). The quantity of thorium metal (138 kg) is relatively small. The identification is incomplete; 40 containers are labelled uranium without specifying the enrichment and 29 containers have no identification at all. The contents of these drums will be identified during a complete radionuclide inventory of ANSTO's wastes (see Section 3.6).

During 1995, approximately 220 kg of depleted and natural uranium swarf were generated from the machining of billets into four uranium shells for fabricating shielded isotope transport containers. Forward planning in ARI, does not include purchase of any more shielded containers. In all probability, future uranium shells may be purchased

^{137}Cs 7-270 Bq g^{-1}	^{134}Cs 0.05-30 Bq g^{-1}	^{144}Ce 1-34 Bq g^{-1}	^{60}Co 0.3-11 Bq g^{-1}
^{106}Rh 0.3-40 Bq g^{-1}	^{241}Am 0.2-10 Bq g^{-1}	^{238}U 0-4 Bq g^{-1}	^{153}Gd 0-1 Bq g^{-1}
^{65}Zn 0-1 Bq g^{-1}	^{51}Cr 0-0.5 Bq g^{-1}	^{224}Ra 0-0.3 Bq g^{-1}	^{226}Ra 0-0.2 Bq g^{-1}

3.1.3 Waste Storage

Low level solid waste is being stored until a suitable radioactive waste repository becomes available. The drums were inspected in the mid 1980s and those showing signs of corrosion were segregated. Approximately 200 were overpacked into oversize (330 litre) drums; another 110 drums have yet to be overpacked.

Most of the drums are stored on pallets (four drums per pallet) in building 59. Currently, the pallets are stacked on top of each other up to five pallets high at the centre of the building. This method of storage has been identified as potentially unsafe and access to the area is being strictly controlled until a new shelving system is installed. The recommended limit for stacked pallets is two pallets high adjacent to pedestrian access areas with adjacent stacks increasing in a pyramid fashion away from the aisles.

Building 59 is currently being extended to facilitate better storage of nuclear materials. When this construction is complete, **it is recommended** that a shelving system be installed to allow more efficient storage of the low-level waste drums while maintaining safety and ease of handling.

3.2 Uranium and Thorium Wastes

3.2.1 Thorium-bearing Wastes

ANSTO has 816 drums (standard 200 litre size) of thorium-bearing residues derived from the processing of mineral sand concentrates over twenty years ago. The majority of the drums (668) contain thorium hydroxide powder. There are also 130 drums of thorium hydroxide slurry, 14 drums of thorium oxalate slurry and 4 drums of a monazite concentrate. Most of the drums are stored in Building 59.

The thorium in these wastes is in a chemically-stable form. However, the drums are unlined and have now been in storage for 26 years. The water associated with those wastes in slurry form is acidic in some drums and alkaline in others. Previously, some of the drums leaked and, in 1975, the contents of those drums were transferred into new polyethylene-lined drums.

A recent limited inspection of the drums has shown that some are badly rusted and will require re-drumming. A method for transfer of the contents to new plastic-lined drums has been developed and successfully tested.

The shredding and compaction equipment is housed in a sealed enclosure and maintained below atmospheric pressure to prevent escape of contaminated dust into the work area. This is achieved by extraction of air from the enclosure and exhausting it through high efficiency particulate filters to atmosphere. Leaks in the housing, therefore, only allow inflow of air.

3.1.2 Quantities and Activities

Approximately 4,500 steel drums of low level solid waste were in storage as of 30 April 1996. These drums have been placed on pallets and stacked in storage areas (mostly building 59) at LHSTC. The maximum on-contact dose rates on all drums was measured at the time of production and this reading was written on the side of each drum. Because much of this waste contains short lived radionuclides, the dose rates will have decreased significantly over time.

The rate of production of 200 litre drums has varied annually but the average is in the order of 150 drums per year. The production of dried sludge has decreased by 40-50% over the last few years due to changes in effluent operations. The discharge pond (HT7) is rarely used nowadays and, consequently, there is little sludge accumulation from this source.

For administrative purposes, low level solid wastes are divided into two categories - low level solids (LS) and very low level solids (VLS) - on the basis of radiation dose rate at contact. Table 3.1 gives the number of drums in each category and the radiation dose at time of measurement.

TABLE 3.1
Number and dose rates from drummed low level solid waste

Drummed Waste Category	Very Low Level Solids (VLS)	Low Level Solids (LS)
No. in storage	2807	1691
Current annual generation rate	115	35
Possible range of contact dose-rate	5-25 $\mu Sv\ hr^{-1}$	25-2000 $\mu Sv\ hr^{-1}$
Estimated average contact dose-rate	<10 $\mu Sv\ hr^{-1}$	250 $\mu Sv\ hr^{-1}$

There is very little available data on the radioactivity level (in terms of becquerels) in compacted waste. However, dried sludge was sampled recently and gamma spectra data were analysed. Typically, activities were in the following ranges:

SECTION 3
SOLID WASTES

3.1 Low-level Solid Wastes

The term "low level solid waste" refers to solid waste containing low levels of beta- and gamma-emitting radionuclides and very low levels of alpha-emitting radionuclides. At ANSTO, there are three types of low level solid waste:

1. **Compactable solid waste**. This is produced in many ANSTO work areas but the greatest volume is generated during the production of radioisotopes and various support activities, such as decontamination and waste processing. It includes a variety of items such as cleaning materials (paper towels, tissues, rags, mops *etc.*), personal protection consumables (plastic gloves, clothing) and slightly contaminated processing items (vials, pipettes, plastic tubing *etc.*). Over 100 drums of this waste are produced annually.
2. **Sludge** produced in the treatment of waste waters. This is predominantly the solid precipitate from the alum flocculation process described in Section 6.2. It is dried to a hard cake in evaporation ponds and then transferred to plastic-lined 200 litre steel drums for storage. On average, about 20 drums are produced annually.
3. **Contaminated items** that cannot be compacted such as pipes, machinery parts *etc.* These are packed into plastic-lined steel drums.

Most of the above wastes would be classified as LILW-SL according to the latest IAEA criteria (see Section 1.3), although some may have decayed to exemption levels.

3.1.1 Handling and Compacting Facilities

Contaminated consumables are discarded at source into plastic-lined fibreboard drums which are sealed when filled and then checked for external contamination and radiation level. The sealed packages are collected by ANSTO's Waste Management staff each week and transported to a storage area until they can be compacted into 200 litre steel drums.

In preparation for compaction, the bagged waste is removed from the fibreboard drums and conveyed to the shredder. The shredded material is collected in a steel drum. When that drum is full, the shredded waste is compacted into the drum using an hydraulic ram. This process continues until the drum is filled with compacted waste. Typically, the waste volume reduction during compaction is 6:1. The filled drum is then removed and sealed.

The NHMRC has promulgated a *Code of Practice for the Disposal of Radioactive Waste by the User (1985).* ANSTO has not been able to adopt this Code of Practice for its solid radioactive waste management because of the absence of a approved municipal landfill disposal site in NSW for this type of very low level waste. The recommendation for sewage disposal (Section 4.4) states that "Unless the statutory authority deems otherwise, the user may discharge as sewage effluent into an approved sewage system an activity of each radionuclide not exceeding twenty times the Annual Limit on Intake by Ingestion for radiation workers as recommended by the International Commission on Radiological Protection in any period of seven days".

2.5 Future Waste Management Regulatory Framework

Following the release of the Report of the Commonwealth Government Research Reactor Review in August 1993 (McKinnon 1993), the former Government approved the formation of a new regulatory organisation to licence and regulate practices involving the use of radioactive materials or radiation by Commonwealth bodies including ANSTO. This new body, the Australian Institute for Radiation Protection (AIRP), was planned to be formed from the amalgamation of the Nuclear Safety Bureau and the Australian Radiation Laboratory, Melbourne.

At time of writing, the establishment of AIRP has yet to be endorsed by the current Government. In that context, the Report of the Senate Select Committee on the Dangers of Radioactive Waste will need to be considered (Commonwealth of Australia 1996). This report, makes five recommendations related to the functions and structure of AIRP.

Until the regulatory situation is clarified, the Australian Radiation Laboratory will continue to carry out an auditing role in relation to waste management matters at LHSTC.

Future licensing and regulatory requirements for ANSTO's waste treatment and storage facilities are uncertain at this stage. However, it is expected that these requirements will be consistent with international standards and practices as developed in the IAEA's RADWASS series of documents (see Section 1.2). Commonwealth codes such as the *Code of Practice for the Disposal of Radioactive Waste By the User (1985),* which is set down for revision, and the *Code of Practice for the Near-Surface Disposal of Radioactive Wastes in Australia (1992)* would most likely be applied by the new regulatory body to the management of ANSTO's radioactive wastes.

ANSTO's liquid effluent discharges meet WHO drinking water guidelines at the Cronulla Sewage Treatment Plant ensures compliance with IAEA recommendations for discharges from the Potter Point ocean outfall.

Australia has signed a regional convention on hazardous and radioactive wastes, the *Waigani Convention to Ban the Importation into Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement and Management of Hazardous Wastes within the South Pacific Region.*

Australia is also party to the IAEA *Convention on the Early Notification of a Nuclear Accident* which requires parties to notify affected or potentially affected states in the event of an accident involving or likely to involve a transboundary release of radioactive material.

ANSTO is subject to the International Atomic Energy Agency *Code of Practice on the International Transboundary Movement of Radioactive Waste* which the Australian Government has adopted. Marine transport of radioactive materials is subject to the *International Maritime Dangerous Goods Code* which adopts the IAEA Safe Transport Regulations. The International Maritime Organisation's *Code of Practice for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High Level Wastes in Flasks on Board Ships (1993)* is applicable to the overseas shipment of HIFAR Research Reactor spent fuel and specifies, *inter alia*, the standards for ships to be used for these classes of materials.

Australia is currently participating in the drafting of an international *Convention on the Safety of Radioactive Waste Management.* The convention will require the establishment of a legislative and regulatory framework to govern the safety of radioactive waste management and spent fuel storage as well as a regulatory body provided with adequate authority, competence and resources to fulfil its assigned responsibilities. A system of licensing of waste management activities, as well as appropriate institutional control, regulatory inspection, documentation and reporting is also required.

2.4 Codes of Practice and Guidelines

ANSTO policy is to comply with all relevant Commonwealth codes of practice or guidelines. Of particular relevance to waste management are the Commonwealth *Code of Practice for the Safe Transport of Radioactive Substances (1990)*, the National Health and Medical Research Council (NHMRC) *Code of Practice for the Near-Surface Disposal of Radioactive Waste in Australia (1992)*, the NHMRC *Recommendations for Limiting Exposure to Ionising Radiation (1995)* and the National Occupational Heath and Safety Commission, *National Standard for Limiting Occupational Exposure to Ionising Radiation (1995).*

2.2.4 Sydney Water Trade Waste Agreement 1995

ANSTO's discharges to the sewer are subject to a Trade Waste Agreement with Sydney Water Corporation which is renegotiated every three years, although the agreement may be varied at any time within that period. The last renegotiation took place in 1995 when it was agreed that the radioactive component of ANSTO's discharges to the sewer would continue to comply with the concentration limits in the repealed 1959 NSW Regulations. However, a further condition was proposed by ANSTO, and accepted by Sydney Water, whereby activity concentrations in effluent leaving the ANSTO treatment plant would be restricted to a level which ensures that the radionuclide concentration in treated effluent discharged by the Cronulla Sewage Treatment Plant would comply with the radionuclide reference level proposed in the 1993 World Health Organisation guidelines for drinking water. This requirement has had the effect of restricting the concentration level of tritium in ANSTO discharges by a factor of 20 below that which could be discharged under the 1959 NSW Regulations.

ANSTO must also comply with the Sydney Water requirements for the non-radioactive components of the discharged effluent, including limits on contaminants associated with the leachate from the Lucas Heights landfill (No.2 Waste Management Centre) which enters the sewer system via the ANSTO treatment plant. The agreement also specifies daily discharge volume limits, stipulates an effluent sampling regime and allows for random audit monitoring by Sydney Water inspectors.

2.3 International Conventions

ANSTO is also subject to the requirements of a number of international conventions and treaties to which Australia is a party. Australia is party to the *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention)* which has been amended to ban the dumping of radioactive wastes at sea. Australia fulfils its obligations under the Convention through the *Environment Protection (Sea Dumping) Act (1981)* and *Environment Protection (Sea Dumping) Amendment Act (1986)* which prohibits the dumping of radioactive material into the sea from vessels, aircraft or platforms and the incineration at sea of radioactive material.

Australia has ratified the *South Pacific Nuclear Free Zone Treaty* which prohibits the dumping by signatories of radioactive waste at sea anywhere within the South Pacific Nuclear Free Zone and by anyone within the territorial waters of signatories to the Treaty.

Australia has ratified the *Convention for the Protection of Natural Resources and the Environment of the South Pacific Region (SPREP)*. This Convention prohibits the dumping of radioactive wastes or other radioactive matter from vessels, aircraft or man-made structures at sea. It also requires that, for discharges from outfall structures, the parties should use their best endeavours to comply with appropriate standards and recommendations established by competent international organisations including the IAEA. For purposes of the STREP Convention, the current requirement that

2.2.2 NSW Radiation Control Act (1990) and Regulation (1993)

The NSW *Radioactive Substances Act (1957)* was repealed and replaced by the *Radiation Control Act (1990)* while the *Radioactive Substances Regulations (1959)* were replaced by the *Radiation Control Regulation (1993)*. Under the new Act, the former Radiological Advisory Council was expanded and renamed the Radiation Advisory Council. The new Regulation addresses the matter of disposal of radioactive substances in Section 21 (i) which simply states "A person must not dispose of any radioactive substance except with the consent of the Director General" *i.e.* Director General of the NSWEPA.

In the current Regulation, there are no equivalent schedules to those in the repealed Regulations which listed generic radionuclide activity concentration limits for radioactive discharges to air and the sewer. A "radioactive substance" is defined as "any natural or artificial substance whether in solid, liquid or gas/vapour form which emits ionising radiation spontaneously with a specific activity greater than 100 Bq g^{-1} and which consists of, or contains more than, the prescribed activity of any radioactive element whether natural or artificial." The prescribed activities are given in Schedule 1 of the Regulation. On the basis of this definition, it could be argued that ANSTO's liquid effluent discharges do not contain radioactive substances. However, in the absence of generic activity concentration limits in the current Regulation, ANSTO has continued to comply with the limits in the repealed 1959 Regulations pending the establishment of any new Commonwealth standards or limits.

2.2.3 NSW Clean Waters Act (1970) and Regulations (1972)

The *Clean Waters Act (1970)* prohibits the pollution of "waters' by stormwater runoff or other liquid discharged from premises. Waters are defined as "rivers, stream, lake, lagoon swamp, wetlands, unconfined surface water, natural or artificial watercourse, dam or tidal water (including the sea), or part thereof and includes water stored in artificial works, water in water mains, water pipes and water channels, and any underground or artesian water, or any part thereof."

The *Clean Waters Regulations (1972)* specify concentration limits for restricted substances including gross alpha and gross beta activity, for liquid discharges into waters of various specified classes. For class C waters, to which the water catchments around LHSTC belong, the gross alpha and beta activity limits are 1.1 Bq L^{-1} and 11.1 Bq L^{-1} respectively. In order to assess ANSTO's compliance with these regulations, sampling points were selected in consultation with the then State Pollution Control Commission on Bardens Creek and two small streams, known locally as Strassman and MDP Creeks, which receive most of the stormwater runoff from the LHSTC area. The results from this sampling program are published in ANSTO's annual environmental survey reports.

as amended, as well as the *Clean Waters Act (1970)* and *Clean Waters Regulations (1972)*. ANSTO also complies with the requirements of its Trade Waste Agreement with Sydney Water Corporation for the discharge of liquid effluent to the sewer.

2.2.1 NSW Radioactive Substances Act (1957) and Regulations (1959)

Since the 1960s the AAEC, and then ANSTO, have discharged radioactive effluents from LHSTC in compliance with authorisations approved at various times by the NSW Radiological Advisory Council (NSWRAC) in accordance with the *NSW Radioactive Substances Regulations (1959)* as amended. The early authorisations specified waterborne radionuclide activities that could be discharged to the Woronora River each month (Fry 1966). Following the connection of the LHSTC to the Water Board sewer when it became available in 1980, liquid effluent discharges had to comply with the activity concentration limits specified in the schedules to the *Radioactive Substances Regulations (1959)*.

Initially, radionuclide activity levels that could be discharged to the air from specific stacks at LHSTC were authorised by the NSWRAC based on the safety assessments of Cook (1969). A revised authorisation for the discharge of airborne radioactive effluents from the site, which was based on limiting doses to 0.5 mSv per year for members of the general public, was also approved by the Radiological Advisory Council in 1988 subject to certain conditions. More recently, ANSTO has adopted a dose constraint of 0.3 mSv per year for members of the public for airborne related pathways, following a recommendation made during the Research Reactor Review (1993). The individual stack working levels set in the earlier authorisation continue to be used by ANSTO to monitor discharge trends (see Section 6.3)

ANSTO carries out compliance monitoring on all stack and liquid effluent discharges with the results reported to the appropriate state authorities, the SRC and ARL. Environmental monitoring results are made available to interested parties and are also publicly available through ANSTO's annual environmental survey reports.

Until 1993, weekly audit monitoring of ANSTO stack discharges and quarterly liquid effluent monitoring was undertaken by the then Radiation Health Services Branch of the NSW Department of Health and, for a short time, by its successor, the Radiation Control Branch of the NSW Environment Protection Authority (NSWEPA). Following the amendments to the *ANSTO Act* (1987) in 1992, the NSWEPA advised that, since it had no regulatory function in relation to the operations of ANSTO, it would henceforth cease audit monitoring of ANSTO effluent discharges.

The auditing role has since been assumed by the Australian Radiation Laboratory pending the establishment of the Australian Institute for Radiation Protection (see Section 2.5).

2.1.1 Safety Review Committee

The Safety Review Committee (SRC) was established under the *ANSTO Act (1987)*. This Committee consists of up to six persons appointed by the Minister. Reports of the SRC may be laid before each house of the Parliament if the Minister considers that the report is of sufficient importance to justify the report being brought to the attention of the Parliament. The SRC also prepares an annual report which is tabled in both Houses of Parliament by the Minister.

The functions of the SRC include the review and assessment of the effectiveness of the standards, practices and procedures adopted by ANSTO to ensure the safety of its operation (Section 26(2)(a)). The SRC pays particular attention to matters associated with the management of radioactive wastes by ANSTO, including on-going reviews of potential radiological impacts to members of the general public from effluent discharges and on-site waste storage facilities.

2.1.2 Nuclear Safety Bureau

The Nuclear Safety Bureau (NSB) was established as a body corporate under the *ANSTO Amendments Act (1992)*. Among the functions of the NSB, specified in Section 37A(1)(a), is the function to monitor and review the safety of any nuclear plant owned or operated by ANSTO and to report on this function to the Minister administering the Act. "Nuclear plant" is defined in the Act as "a nuclear reactor or assembly of fissionable material in respect of which criticality is contemplated or possible."

ANSTO operates its nuclear plant under the provisions of an Authorisation which is effectively a licence from the NSB. Schedule Item 8.3 of the Authorisation covers the treatment, storage and disposal of radioactive solid, liquid and gaseous wastes generated by nuclear plant. It places a requirement on the Executive Director to make arrangements for the treatment, safe storage and disposal of radioactive wastes from the reactor in accordance with established ANSTO procedures and agreements with outside authorities, including the limits on the discharge of airborne effluents agreed previously between ANSTO and the NSW State Radiological Advisory Council.

Schedule 4.5 of the Authorisation covers quality management, which, according to Section 8.3, includes the management of wastes.

2.2 State Acts and Regulations

Notwithstanding that ANSTO has immunity from State laws, the organisation has adopted a policy of complying with relevant State statutes. The statutes related to radioactive waste management and environment protection include the *Radioactive Substances Act (1957)* and *Radioactive Substances Regulations (1959)* and following their repeal, the *Radiation Control Act (1990)* and *Radiation Control Regulation (1993)*

SECTION 2
LEGISLATIVE, REGULATORY AND RELATED ISSUES

2.1 ANSTO Act (1987) and ANSTO Amendment Act (1992)

ANSTO is a body corporate established by the *ANSTO Act (1987)* as amended by the *ANSTO Amendment Act (1992)*. The functions and powers of the Organisation include, in Section 5(1)(ba):

"To condition, manage and store radioactive materials and radioactive wastes arising from;

(i) the Organisation's activities (including the production of radioactive materials for other persons).

(ii) the activities of companies in which the Organisation has a controlling interest.

(iii) the use by other persons of radioactive materials produced by the Organisation or such companies.

(iv) the activities of other persons who are specified in the regulations."

During the period that the predecessor of ANSTO, the Australian Atomic Energy Commission (AAEC), operated under the *Atomic Energy Act 1953* and when ANSTO was first established under the *ANSTO Act (1987)*, there had been an uncontested understanding with the NSW Government that AAEC/ANSTO had immunity from certain State laws. However, following a 1991/92 challenge by Sutherland Shire Council in the NSW Land and Environment Court concerning the storage of non-ANSTO radioactive wastes at LHSTC, the *ANSTO Act (1987)* was amended by the Government to specifically provide the organisation with immunity from such State and Territory laws including, *inter alia*, the environmental consequences of the use of land or premises and radioactive materials or dangerous goods (Section 7A(3)(b) and (c)).

The 1992 amendments require that the conditioning, management and storage of radioactive material and radioactive wastes by ANSTO arising from the activities of other persons specified in regulations "must not have the effect of authorising the premises on which the Lucas Heights Research Laboratories are situated to become a national nuclear waste repository."

TABLE 1.1
Typical Characteristics of Waste Classes (from IAEA 1994)

Waste class	Typical characteristics	Disposal options
1. Exempt waste (EW)	Activity levels at or below clearance levels which are based on an annual dose to members of the public of < 0.01 mSv	No radiological restrictions
2. Low and intermediate level waste (LILW)	Activity levels above clearance levels and thermal power below about 2 kW m^{-3}	
2.1 Short lived waste (LILW-SL)	Restricted long-lived radionuclide concentrations (limitation of long-lived alpha emitting radionuclides to 4000 Bq g^{-1} in individual waste packages and to an overall average of 400 Bq g^{-1} per waste package)	Near surface or geological disposal facility
2.2 Long-lived waste (LILW-LL)	Long lived radionuclide concentrations exceeding limitations for short lived waste	Geological disposal facility
3. High level waste (HLW)	Thermal power above 2 kW m^{-3} and long lived radionuclide concentrations exceeding limitations for short lived waste	Geological disposal facility

1.4 Scope of this Review

This report reviews the status of radioactive waste management at ANSTO, including spent fuel management, treatment of effluents and environmental monitoring. It gives, *inter alia*, details of:

- relevant legislative, regulatory and related requirements,
- sources and types of radioactive waste generated at ANSTO,
- waste quantities and activities (both cumulative and annual arisings),
- existing practices and procedures for waste management and environmental monitoring,
- recommended broad strategies for dealing with radioactive waste management issues.

Separate sections are devoted to regulatory issues, spent fuel, solid wastes, liquid wastes, airborne emissions, treatment of low level liquid wastes and environmental monitoring.

Recommendations for action are given where appropriate in the document. Detailed proposals on how these recommendations should be implemented is the subject of a companion internal document: *Implementation of ANSTO's Radioactive Waste Management Policy - Action Plan 1996-2000.*

The most widely used classification divides waste into three categories, low-level waste (LLW), intermediate level waste (ILW) and high level waste (HLW). These descriptions are often used loosely but the IAEA definition has been as follows (IAEA 1970, 1981):

Low level waste

Waste which, because of its low radionuclide content, does not require shielding during normal handling and transportation.

Intermediate level waste

Waste which, because of its radionuclide content requires shielding but needs little or no provision for heat dissipation.

High level waste

1. The radioactive liquid containing fission products and some actinides which is separated during chemical processing of irradiated fuel (*i.e.* aqueous waste from the first solvent extraction cycle in reprocessing), or
2. Any other waste with radioactivity levels sufficient to generate significant quantities of heat by radioactive decay, or
3. Spent reactor fuel, if it is declared as waste.

Another important classification is based in the half-life and/or radiotoxicity of specific radionuclides since these affect the design criteria for a waste repository. **Long lived waste** is radioactive waste that will not decay to ar acceptable activity level du ing the time which administrative controls can be expected to last (IAEA 1994). Clearly both half-life and activity are important in this definition since naturally-occurring materials often contain low levels of long-lived radionuclides such as uranium and thorium.

Recently, and as part of the IAEA's RADWASS program, the IAEA has reviewed and modified its classification system (IAEA 1994). In the new classification, which focuses on disposal criteria, no distinction is made between low and intermediate level waste, but the combined low and intermediate waste (LILW) class is divided into two sub-classes, short lived waste (LILW-SL) and long lived waste (LILW-LL). Table 1.1 lists the typical characteristics according to the new classification system. Under this classification, most of ANSTO's wastes would fall within the LILW category.

In this report, wastes are classified primarily according to their physical form. Thus separate sections are devoted to solid wastes, liquid wastes and airborne emissions. The second level classification is according to waste composition or radioactivity level. The terms "low level" and "intermediate level" are used occasionally because of their historical use at ANSTO to indicate whether operating personnel need to be shielded from the waste. In such cases, the classification of wastes according to the new IAEA system will also be indicated.

3. **Protection beyond national borders**
   Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account.

4. **Protection of future generations**
   Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.

5. **Burden on future generations**
   Radioactive waste shall be managed in such a way that will not impose undue burdens on future generations.

6. **National legal framework**
   Radioactive waste shall be managed within an appropriate national legal framework including clear allocation of responsibilities and provision for independent regulatory functions.

7. **Control of radioactive waste generation**
   Generation of radioactive waste shall be kept to the minimum practicable.

8. **Radioactive waste generation and management interdependencies**
   Interdependencies among all steps in radioactive waste generation and management shall be appropriately taken into account.

9. **Safety of facilities**
   The safety of facilities for radioactive waste management shall be appropriately assured during their lifetime.

The above principles have been incorporated into ANSTO's Waste Management Policy which makes a commitment to comply with all RADWASS standards and guides by the year 2000 (see Appendix A).

In a separate but related initiative, an *International Convention on the Safety of Radioactive Waste Management* is being drafted under the auspices of the IAEA. Australia is participating in the drafting of the Convention and ANSTO staff, in preparing ANSTO's Waste Management Action Plan, have taken account of Australia's likely obligations under this convention.

1.3 Classification of Radioactive Wastes

Classification systems for radioactive waste may be derived from different perspectives, such as protection of personnel, operational practices and conventions, or regulatory requirements. An important "natural" classification is the physical form of the waste — solid, liquid or airborne — since this affects the mobility of the waste in the environment.

7. New paradigms for environmental management have emerged in recent years which focus on cleaner production technology and waste minimisation rather than end-of-pipe treatment. Furthermore, interim standards have been published to systematise environmental management (AS/NZS 1995) within a quality management regime. These new methodologies need to be incorporated into ANSTO's procedures, practices and culture.

8. The Senate has recently completed an inquiry into the *Dangers of Radioactive Waste* (Commonwealth of Australia 1996).

1.2 Development of International Radioactive Management Standards

The International Atomic Energy Agency (IAEA) is responsible for the development of international standards for the safe and peaceful use of nuclear technology. Over the years, the IAEA has published a number of Safety Series documents dealing with the management of radioactive wastes. In 1989, the IAEA undertook to carry out a major and comprehensive review of its safety-related activities and introduced a hierarchical structure for Safety Series publications, as follows:

Safety Fundamentals, stating basic objectives, concepts and principles to ensure safety.

Safety Standards, stating basic requirements which must be fulfilled for particular activities.

Safety Guides, containing recommendations related to the fulfilment of the basic requirements.

Safety Practices and detailed methods which can be used in implementing the Safety Standards and Guides.

The IAEA's Radioactive Waste Safety Standards (RADWASS) program aims to establish a coherent and comprehensive set of principles, guides and practices for the safe management of radioactive waste. As of April 1996, only a few documents have been published but many are at the drafting stage. Staff from ANSTO and other government organisations in Australia are involved in the drafting and review of the various documents. All the documents in the series should be published by the year 2000.

The Safety Fundamentals document - *The Principles of Radioactive Waste Management* - has already been published (IAEA 1995). This document sets out the following nine principles:

1. **Protection of human health**
   Radioactive waste shall be managed in such as way as to secure an acceptable level of protection for human health.

2. **Protection of the environment**
   Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.

SECTION 1
INTRODUCTION

1.1 Background

For over forty years, radioactive wastes have been generated by ANSTO (and its predecessor, the AAEC) from the operation of nuclear facilities, the production of radioisotopes for medical and industrial use, and from various research activities. The quantities and activities of radioactive waste currently at the Lucas Heights Science and Technology Centre (LHSTC) are very small compared to many other nuclear facilities overseas, especially those in countries with nuclear power programs. Nevertheless, in the absence of a repository for radioactive wastes in Australia, the waste inventory has been growing steadily.

The primary purpose of this report is to review ANSTO's waste management and associated environmental monitoring operations as a prerequisite to development of a five-year Waste Management Action Plan. In addition, this review is particularly timely because:

1. A process is underway to establish a national repository for low level and short lived intermediate level radioactive waste. The repository will allow ANSTO to safely dispose of much of its waste.
2. Some of ANSTO's waste storage facilities are approaching capacity and there is a need to consider, for each type of waste, the options for conditioning and disposal, waste reduction and/or expansion of storage facilities.
3. Inevitably, there has been, over time, some deterioration in waste containers. Furthermore, plant and equipment built for early AAEC waste management operations are no longer optimal for the changed operations and programs of ANSTO. There is a need to identify the deficiencies in the current system so that appropriate corrective actions can be taken.
4. ANSTO's practices and procedures need to be reviewed in the light of the emerging IAEA RADWASS standards and safety guides.
5. There is a need to identify and correct deficiencies in ANSTO's inventory of radioactive waste in accordance with the requirements of the *International Convention on the Safety of Radioactive Waste Management*, now being drafted.
6. The regulatory regime in which ANSTO operates is in a state of transition.

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FOREWORD

In July 1995, the ANSTO Board endorsed an ambitious and far reaching policy for the management of ANSTO's wastes. The declared policy is as follows:
"ANSTO will manage its radioactive waste in a manner that protects human health and the environment now and in the future. In doing so, ANSTO is committed to:

- complying with all relevant legislative and regulatory requirements, in particular,

  ensure that all discharges are within authorised limits,

  monitor and report regularly radioactive releases to the environment;
- ensuring that radiation exposures will be kept as low as reasonably achievable (ALARA), economic and social factors taken into account;
- disposing of wastes when appropriate disposal routes are available;
- being in accord with international best practice."

The objectives of ANSTO's Radioactive Waste Management Policy are:

"1. Safe treatment and storage of radioactive wastes, taking into account the need to minimise dose uptake to operators and economic factors;
2. Minimisation of radioactive waste generated and stored;
3. Maintenance of inventories of all waste from source to disposal;
4. Consistency, by the year 2000, with best practice as identified in the RADWASS Standards and Safety Guides currently under development within the International Atomic Energy Agency (IAEA);
5. Broad public understanding and acceptance of ANSTO policy and practices."

A full statement of the ANSTO's policy, including specific strategies and actions, is given in Appendix A.

Before ANSTO's Waste Management Policy can be implemented, it was considered necessary to carry out a Preliminary Environmental Review to determine the current status of radioactive waste management at ANSTO including related issues such as spent fuel management, management of airborne and waste water effluents, and environmental monitoring.

Most importantly, this Preliminary Environmental Review is the reference point for the Radioactive Waste Management Action Plan which is the blueprint for implementation of the ANSTO's policy. The Action Plan is an internal and dynamic document that will be reviewed and updated each year.

18 It is recommended that a detailed survey be undertaken to identify all major tritium sources entering the waste water circuit. Following this survey, operational procedures and practices should be modified if possible to reduce the quantity of tritium entering the water treatment circuit.

Spent Reactor Fuel

19 It is recommended that the following strategy be employed in the management of ANSTO's spent fuel inventory:

- take up the UK offer of a four-year reprocessing program for the UK-origin spent fuel,
- after that four year period, ship the remaining (US-origin) HIFAR and Moata spent fuel to the US over a seven year period,
- if appropriate, prepare a proposal for the domestic conditioning of spent fuel from HIFAR and any replacement reactor.

20 It is recommended that priority be given to refurbishment of the Dounreay flasks and regular inspection of all ANSTO's facilities for spent fuel storage. It is further recommended that an early opportunity be taken to phase out the use of the "Dounreay" flasks for storage, once the expected program of overseas shipments of spent fuel is underway.

Organisational Issues

21 It is recommended that the Waste Management Action Plan be implemented under a formalised management regime in accordance with the Standard for Quality Management and Quality Assurance (AS/NZS ISO 9001), the Standard for Environmental Management (AS/NZS ISO 14001) and the IAEA RADWASS documents.

22 It is recommended that an ANSTO Waste Minimisation Working Party be established, with the goal of minimising waste generation through segregation at source, volume reduction and cleaner production technologies.

23 It is recommended that a formal program be initiated to educate and train staff in the underlying science and technologies relevant to radioactive waste management.

24 It is recommended that brochures, exhibits and other information be prepared to inform the public about radioactive waste management and environment protection at ANSTO.

9 It is recommended that the highest priority be given to the solidification of the intermediate level liquid waste from molybdenum-99 production including modification of the current process to remove the safety hazard associated with the presence of ammonium nitrate in the liquid waste.

10 It is recommended that a project addressing the long term immobilisation of the molybdenum-99 waste be initiated. This project should consider leach resistant waste forms suitable for eventual disposal, including cement and titanate-based waste forms (such as Synroc).

11 It is recommended that the present method of molybdenum-99 production be reassessed from a cleaner production viewpoint. This would involve consideration of modifications to the current process to eliminate ammonium salts in the waste and, more radically, assessment of alternative technologies with the aim of reducing liquid waste volumes and/or activities.

12 It is recommended that appropriate technology be assessed for the treatment of non-aqueous and contaminated oily wastes.

Airborne Emissions

13 It is recommended that, in accordance with the ALARA principle, radionuclide releases from the most significant sources - buildings 15A, 23A and 54 - be reviewed to look for ways of reducing airborne radionuclide releases by changing procedures and/or by providing improved air cleaning technology, if available.

14 It is recommended that the Atmospheric Dispersion and Dosimetry Code (ADDCOR) be updated and refined as necessary to take account of changes in dose conversion factors and experimental measurements as they become available.

15 It is recommended that, through consultation with regulatory authorities, a more appropriate set of working levels be established for airborne releases from LHSTC.

Low Level Liquid Effluents

16 It is recommended that a full technical and economic assessment be carried out of alternative processes for treatment of low level waste waters. Following completion of the assessment and any necessary testing, a new facility for treatment of ANSTO's low level waste waters should be designed, constructed and commissioned.

17 It is recommended that developmental work be undertaken to improve the current process for treatment of special low level liquid wastes.

RECOMMENDATIONS

Solid Wastes

1 It is recommended that an inventory of all radioactive wastes at the LHSTC be undertaken over the next four years. The quantities and activities of ANSTO waste that meet category A, B and S disposal criteria should be determined as part of this project. The inventory should be maintained on a centralised database which will enable wastes to be tracked from source to disposal.

2 It is recommended that uranium and thorium metal scrap be stabilised by calcination.

3 It is recommended that ANSTO provide technical support for the establishment of the national repository for low-level and short-lived, intermediate-level radioactive wastes.

4 It is recommended that conditioning/packaging processes for ANSTO's radioactive wastes be assessed for compliance with international best practice, the transport code, storage requirements and expected acceptance criteria for disposal. It is further recommended that waste conditioning procedures be developed and tested for those wastes identified as requiring conditioning prior to disposal.

5 It is recommended that ANSTO assess the usefulness of improved multi-use packaging systems for the major waste streams, particularly for intermediate level wastes.

6 It is recommended that a shelving system be installed in building 59 to allow more efficient storage of the low-level waste drums while maintaining safety and ease of handling.

7 It is recommended that the feasibility of recovery of intermediate level waste from the "A" pits be established and demonstrated.

Liquid Wastes

8 It is recommended that a system be installed to allow continuous monitoring for leaks from the intermediate level waste tanks in building 57.

Organisational Issues

Waste management and associated activities involve a number of Divisions within the organisation. There is a need for an organisational framework to ensure that the ANSTO's Radioactive Waste Management Policy is achieved and the Action Plan is implemented successfully. It is proposed that the Action Plan be coordinated through a Manager. Individual tasks would be managed by staff drawn from across the organisation in accordance with the expertise required.

A Waste Minimisation Working Party should be established from staff in waste production areas, waste management operations and other interested parties. The goal of this Working Party would be to make recommendations on methods of waste minimisation at ANSTO based on waste reduction, segregation at source, volume reduction and cleaner production technologies.

The Action Plan should be implemented under a Quality Management regime based on ISO 9001, the new Standard for Environmental Management, ISO 14001 and the IAEA's RADWASS series of standards and guides.

In May 1996, the USA formally announced its decision to accept all US-origin spent research reactor fuel over a 13-year period. The USA will accept responsibility for all wastes generated from reprocessing or conditioning of research reactor fuel.

ANSTO also has 191 irradiated fuel plates from the Moata reactor which ceased operation in May 1995. All of the irradiated fuel is currently stored in the Moata fuel storage block. The fuel will be returned to the USA when the opportunity arises.

Regular testing of spent fuel storage facilities is undertaken. A recent inspection of the dry storage facility has shown no significant deterioration of the fuel. Testing of the "Dounreay" flasks has revealed that some of the seals are in need of replacement. Refurbishment of these flasks needs to be undertaken in the near future. The use of "Dounreay" flasks for storage should be phased out since they were designed to older standards and are unlikely to be licensed for transport purposes.

The need for additional interim storage will depend on whether the international opportunities to accept spent research reactor fuel proceed as expected. Three methods have been identified to provide additional storage from 1998 onwards, if required as a fallback option:

1. installing an additional 40 lined storage tubes in the dry storage facility to increase the capacity by 880 elements,
2. cutting the fuel elements into their component plates using an industrial laser would allow twice as many fuel elements to be stored in the existing dry storage facility.
3. manufacturing dual purpose transport/storage casks to the LHRL-120 cask design to provide additional interim dry storage. This option has high initial costs but would prepare the fuel for transport to another site.

Environmental Monitoring

A comprehensive program of environmental monitoring has been carried out by the AAEC/ANSTO since 1959. The monitoring program includes collection and analysis of various air, water and solid samples from the immediate vicinity of the site as well as more limited sampling from further afield. The results of ANSTO's environmental monitoring program are detailed in annual environmental reports.

The environmental monitoring program at ANSTO has recently been reviewed. The revised program is similar to that carried out in the past except that routine monitoring is now proposed in the vicinity of Potter Point where ANSTO's effluents are released after passing through the Cronulla sewage treatment plant. The revised sampling program will be submitted to the Australian Radiation Laboratory for comment.

potential to greatly reduce the volume of water requiring treatment and hence the capital cost of a new plant.

In addition to the low level waste water which is treated, there is a further 46,000 m^3 of trade waste which may contain some radioactivity but at a level so low that treatment is unnecessary.

Tritium (a very low energy beta emitter present in the heavy water moderator) is not removed by the treatment process. Tritium release in the liquid effluent has been reduced over the last few years by better housekeeping. In accordance with the ALARA principle, the feasibility of further reducing the tritium source term should be investigated.

ANSTO has a Trade Waste Agreement with Sydney Water which sets discharge rates for radioactive and chemical wastes. The effluent discharges have always been within the limits set by NSW regulations.

Spent Reactor Fuel

As at mid-May 1996, ANSTO had some 1580 spent fuel elements from the operation of HIFAR in interim storage at Lucas Heights. Each year 37 elements are discharged from the reactor. After cooling for one year, each fuel element is cropped and the section containing the fuel is stored under water until the heat generation has decreased sufficiently to permit dry storage. The elements are then removed from the pond in shielded transfer flasks and placed into dry storage, as available.

The HIFAR Spent Fuel Storage Facility is an engineered dry storage facility built in 1968. This interim facility consists of 50 holes, 16 metres in depth, drilled into sandstone and lined with stainless steel tubes. It now contains 1086 fuel elements and is effectively full. There are also 288 elements in underwater pond storage and 175 elements in seven "Dounreay" transport flasks.

All these facilities are monitored and IAEA inspectors periodically verify that there has been no unauthorised movement of fuel. With the recent shipment to the UK and re-racking of spent fuel in the pond, ANSTO will have sufficient interim storage capacity for all spent fuel discharged from HIFAR through to 1998.

The current strategy for spent fuel management is based on reprocessing in the UK and return to the USA wherever possible. In April 1996, 114 spent fuel elements were shipped to the UK. Processing of further UK-origin fuel is dependent on continued operation of the Dounreay reprocessing plant. Domestic conditioning of spent fuel is an alternative to overseas shipments.

Wastes from reprocessing of spent HIFAR fuel at Dounreay would be incorporated into cement. The agreement for reprocessing specifies that the intermediate level cement waste will be returned to Australia within 25 years.

Because of processing complexity, the solvent extraction process was abandoned in favour of a simpler process in which the waste is concentrated to a point where uranium nitrate hexahydrate solidifies from the solution after cooling. Equipment to carry out this operation has been installed in the hot cells in building 41. The product of the process is a dry solid cake contained within sealed stainless steel storage vessels.

Recently the presence of low concentrations of ammonium nitrate in the waste has been identified as a potential safety hazard during the evaporation process. Removal of the ammonium ion will require installation of additional equipment in the cell. Once this problem is overcome and the plant is commissioned with active solutions, it will take about 30 months of routine operation to solidify the waste. This time could be shortened considerably if the plant were operated on a 24-hour shift basis.

The solidified waste from the evaporation process is suitable for medium term storage (40-50 years) but not for disposal since it is leachable. Consideration needs to be given to immobilisation of this waste in a leach resistant waste matrix such as Synroc or cement.

The present method of molybdenum-99 production should be reassessed from a cleaner production viewpoint. This will involve consideration of modifications to the process to eliminate ammonium salts in the waste and, more radically, assessment of alternative technologies with the aim of reducing liquid waste volumes and/or activities.

Airborne Emissions

ANSTO releases small amounts of gaseous and volatile radionuclides generated during reactor operation and production of radioisotopes. The most significant of these emissions are argon-41 from irradiation of air in HIFAR rigs, noble gases (xenon and krypton) from molybdenum-99 processing and iodine-131 from radioisotope processing. The radiation dose rate to the public from these emissions is estimated to be less than 2% of the 0.3 mSv per year dose constraint used by ANSTO. Nevertheless, there may be scope for reduction in airborne emissions and changes in procedures or improved air cleaning technology should be assessed in accordance with the ALARA principle.

Low Level Liquid Effluents

ANSTO generates about 3,000-6,000 m^3 of low level waste water annually. This volume is treated by a batch process based on alum flocculation. The solid from the plant is thickened by centrifuging and then pumped into concrete-lined solar evaporation ponds for drying. The dried sludge is manually shovelled into drums and placed in interim storage on site.

The waste water treatment plant, which is almost 40 years old, currently removes only 35-50% of the alpha and beta activity. The existing plant will have high maintenance costs in the future and needs to be replaced within the next five years. A study of the feasibility of segregating waste waters at their source needs to be undertaken because this has the

There are a variety of other radioactive solid wastes stored at ANSTO including thorium-bearing residues, ion exchange resins, charcoal, HEPA filters as well as contaminated plant and equipment.

Most of ANSTO's solid radioactive wastes would be suitable for disposal in the proposed national repository for low-level and short-lived intermediate-level radioactive wastes. The site selection process has now progressed to the identification of eight regions containing possible sites. The next stage of the process is choice of one region for more detailed study and it is anticipated that ANSTO will provide technical support for government during the site selection process.

ANSTO plans to compile a complete inventory of its radioactive wastes in accordance with the Waste Management Policy and in preparation for disposal of some of these wastes at the national waste repository. A gamma-scanning system has recently been ordered to carry out this task. It will take approximately two years to characterise the 4,500 drums of low level waste currently in storage.

Liquid Wastes

The production of molybdenum-99 generates an acidic, intermediate-level liquid waste containing uranium and mixed fission products. ANSTO has about 6,000 litres of this waste stored in five shielded tanks in building 57. ANSTO's Safety Review Committee has identified this intermediate level liquid waste as having the potential for off-site impact should there be an uncontrolled release following a seismic event or major fire.

Underneath each tank there is a large stainless steel tray which serves as a catch tank. Visual inspection of the tanks is not possible because they are heavily shielded, however, on a monthly basis, the storage and catch tanks are checked remotely. Installation of a continuous monitoring system is currently being investigated. If a leak were to occur, the contents of the tank and the catch tray could be transferred to one of three empty tanks in the area.

The waste is of two types, primary and secondary. The more radioactive primary waste is stored in stainless steel tanks each with a working capacity of about 850 litres. The secondary waste is stored in glass-lined steel tanks each with a working capacity of 1,850 litres.

It is highly desirable that the molybdenum-99 liquid waste be solidified as soon as possible since storage as a solid provides a much higher assurance of containment. The processing of these wastes by solvent extraction (to remove the uranium) followed by concentration by evaporation was studied in the 1980s and developed to near production scale.

EXECUTIVE SUMMARY

A technical review of radioactive waste management at ANSTO has been completed, including related issues such as management of airborne and liquid effluents, spent fuel management, and environmental monitoring. The primary purpose of the review has been to identify and prioritise the actions required to fulfil ANSTO's Radioactive Waste Management Policy. This report is a companion document to the Radioactive Waste Management Action Plan 1996-2000 which provides details of the tasks to be undertaken, milestones and resource requirements.

For over forty years, radioactive wastes have been generated by ANSTO (and its predecessor, the AAEC) from the operation of nuclear facilities, the production of radioisotopes for medical and industrial use, and from various research activities. The quantities and activities of radioactive waste currently at Lucas Heights are very small compared to many other nuclear facilities overseas, especially those in countries with nuclear power programs. Nevertheless, in the absence of a repository for nuclear wastes in Australia and guidelines for waste conditioning, the waste inventory has been growing steadily.

Solid Wastes

ANSTO is currently storing approximately 4,500 drums of low level solid waste. About 150 drums of this waste are generated each year. The majority of these drums contain compacted waste from the production and processing of radioisotopes for medical use. The dose rates on the surface of the drums were measured at the time of drumming but little information is available on the radionuclides present or their radioactivity.

About 3.8 tonnes of thorium and uranium scrap metal has been generated over the past 35 years. Currently this material is stored under kerosene to prevent oxidation. A number of options for stabilisation have been investigated and controlled calcination has been identified as the most appropriate method. The current inventory of metal scrap could be converted into a stable oxide in less than six months of processing using a rotary calciner.

Intermediate level solid wastes require shielding during handling and transport. At ANSTO, they mainly arise from materials that have been irradiated in the HIFAR reactor. These wastes are currently stored in concrete-lined pits in building 27. The early pits, constructed in the early 1960s, are now virtually full. Methods for recovery of material from these pits need to be established and demonstrated. The second pits, commissioned in mid-1990, were designed for retrievable storage.

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The following descriptors have been selected from the INIS Thesaurus to describe the subject matter of this report for information retrieval purposes. For further details please refer to IAEA-INIS-12 (INIS: Manual for Indexing) and IAEA-INIS-13 (INIS: Thesaurus) published in Vienna by the International Atomic Energy Agency.

ANSTO; AUSTRALIA; ENVIRONMENT; GASEOUS WASTES; HIFAR REACTOR; INTERMEDIATE LEVEL RADIOACTIVE WASTES; INVENTORIES; LIQUID WASTES; LOW-LEVEL RADIOACTIVE WASTES; MINIMIZATION; PLANNING; RADIOACTIVE EFFLUENTS; RADIOACTIVE WASTE MANAGEMENT; RADIOACTIVE WASTE STORAGE; RADIOACTIVE WASTES; RADIOACTIVITY; SOLID WASTES; SPENT FUEL STORAGE.

3.8 Recommendations - Solid Wastes

- It is recommended that an inventory of all radioactive wastes at the LHSTC be undertaken over the next four years. The quantities and activities of ANSTO waste that meet category A, B and S disposal criteria should be determined as part of this project. The inventory should be maintained on a centralised database which will enable wastes to be tracked from source to disposal.
- It is recommended that uranium and thorium metal scrap be stabilised by calcination.
- It is recommended that ANSTO provide technical support for the establishment of the national repository for low-level and short-lived, intermediate-level radioactive wastes.
- It is recommended that ANSTO assess the usefulness of improved multi-use packaging systems for the major waste streams, particularly for intermediate level wastes.
- It is recommended that conditioning/packaging processes for ANSTO's radioactive wastes be assessed for compliance with international best practice, the transport code, storage requirements and expected acceptance criteria for disposal. It is further recommended that waste conditioning procedures be developed and tested for those wastes identified as requiring conditioning prior to disposal.
- It is recommended that a shelving system be installed in building 59 to allow more efficient storage of low-level waste drums while maintaining safety and ease of handling.
- It is recommended that the feasibility of recovery of intermediate-level waste from the "A" pits be established and demonstrated.

SECTION 4
LIQUID WASTES

4.1 Intermediate Level Wastes from Molybdenum-99 Production

4.1.1 Production of Molybdenum-99

Technetium-99m is the most widely used radionuclide in modern diagnostic nuclear medicine. An important characteristic of technetium-99m is its short half-life (6.02 h), which results in relatively low radiation exposures to patients. However, the short half-life presents a supply problem for hospitals distant from the production centre. This problem can be overcome by production and separation of molybdenum-99 (half-life 66 hours) which decays to technetium-99m. Devices known as generators, which produce technetium-99m from molybdenum-99, on demand, have been marketed by ANSTO/AAEC for more than 25 years.

At ANSTO, molybdenum-99 is produced by the fission product route. Uranium dioxide pellets, 2% enriched in uranium-235, are irradiated for up to seven days in aluminium containers known as 'rocket cans'. The small gap between the fuel pellet and can is filled with magnesium oxide which assists in dissipating the heat produced in the pellet during the fission process.

A simplified flowsheet for molybdenum-99 production is presented in Figure 4.1. Following irradiation, the 'rocket can' is transported from the reactor (HIFAR) to building 54 where the contents are removed and the pellets separated from the bulk of the magnesium oxide powder by sieving. The uranium dioxide, containing the molybdenum-99 and other fission products, is dissolved in concentrated nitric acid. The resulting solution is then passed through a column packed with alumina where the molybdenum-99 is adsorbed onto the alumina and the uranium-rich waste solution containing most of the unwanted fission products is collected separately as the Primary Liquid Waste (PLW).

The alumina column containing the molybdenum-99 is then washed in sequence with nitric acid, water and dilute ammonia solution to remove residual traces of uranium, fission products and other contaminants. The wash solutions are accumulated as Secondary Liquid Waste (SLW) which contains lower levels of radioactivity than the PLW.

TABLE 6.4
Annual Volumes And Activity Levels of Low Level Waste Liquids
"B" Line Waste Waters

Year	Volume Treated (m^3)	Alpha Activity in Mixing Tanks		Beta Activity in Mixing Tanks	
		MBq	$kBq.m^{-3}$	MBq	$kBq.m^{-3}$
1993	5690	96	15.60	3239	527
1994	2860	4	1.30	1036	337
1995	2731	22	8.06	1765	646

"C" Line Waste Waters

Year	Volume (m^3)	Alpha Activity in Holding Tanks		Beta Activity in Holding Tanks	
		MBq	$kBq.m^3$	MBq	$kBq.m^3$
1993	40,642	69	1.70	1,078	26.5
1994	43,712	44	1.09	432	10.7
1995	53,878	65	1.21	1116	20.71

The mixing tank contents are then discharged to a centrifuge to remove the precipitated solids. The solids removed by the centrifuge are transferred to one of 2 × 4 m^3 holding tanks and finally directed to one of 4 concrete-lined solar evaporation ponds for drying. Each of the solar ponds can accept 3.6 m^3 of sludge and all have a common electrically-driven mobile roller cover for protection from rain and wind. The dried sludge is manually shovelled into 200 litre plastic-lined steel drums for interim storage on site. The current stock of the dried sludge forms part of the ANSTO low level solid waste inventory of which the majority is stored building 59 (see Section 3.1).

Table 6.5 shows data for 1995 on the activity before and after treatment of "B" Line effluent through the mixing tanks. The data indicates that only 35-50% of the α/β radioactivity is removed. Nevertheless, because of the low levels in the waste waters, the activity in the effluent from the site is generally well below the limits set in the Trade Waste Agreement (see Table 6.7).

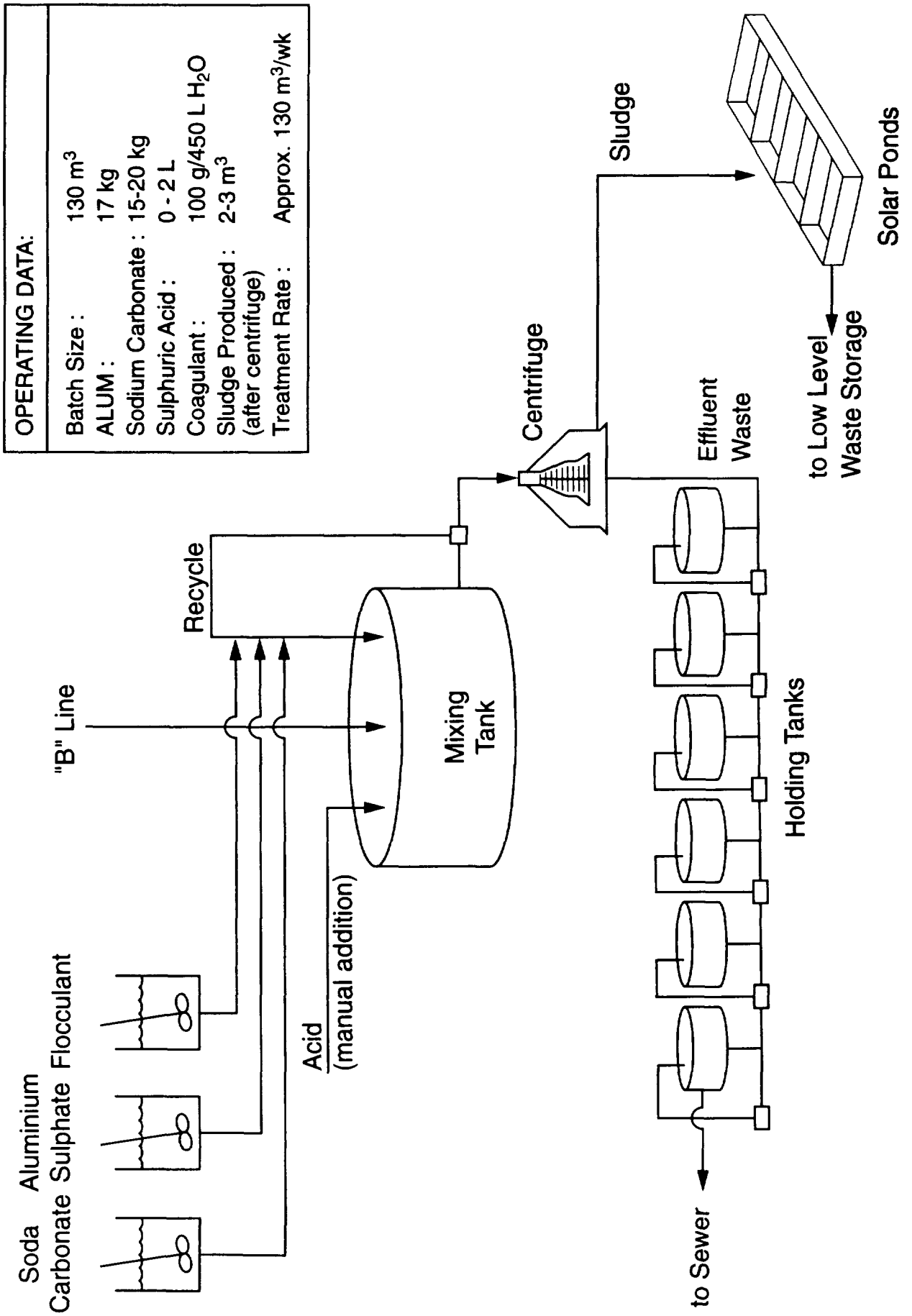


Figure 6.2: "B" Line Low Level Waste Water Batch Treatment Process

TABLE 6.3
Typical Volumes and Activities of "B" Line Major Sources

Building No.	Annual Volume (m^3)	α-Activity kBq m^{-3}	β-Activity kBq m^{-3}	γ-Activity kBq m^{-3}
11 Laundry and decontamination	1200-1500	1-4	10-500	^{106}Ru 5-50 ^{60}Co 5-300 ^{137}Cs 2-30 ^{51}Cr 50-800 ^{131}I 5-75
19 Research area where radioisotopes are handled	300-600	1-10	5-200	^{137}Cs 3-12 ^{99}Mo 0-12 ^{69}Zn 0-6 ^{67}Ga 0-7
23 Radioisotope production	1500-1800	2-20 Peaks up to 100	50-1000 Peaks up to 10,000	^{153}Gd 50-1800 ^{51}Cr 50-4000 ^{60}Co 20-200 ^{103}Ru 5-30 ^{99}Mo 20-4500 ^{144}Ce 10-100

6.2 Low Level Liquid Treatment

Table 6.4 shows the volumes and contained activity from the "B" and "C" lines over the last three years. Between 2,500 and 6,000 m^3 of "B" waste water are treated annually.

The treatment of low level waste waters is based on an alum (aluminium sulphate) treatment process. The treatment consists of batch operations as shown in Figure 6.2. The "B" line effluent can be pumped to one of five mixing tanks which have effective working volumes of 130 m^3. Mixing of the tank contents is carried out by one of five centrifugal pumps rated at 18 m^3 per hr. After circulation to ensure thorough mixing, a sample is taken and analysed for pH and gross alpha and beta activity. The results obtained provide the information for the chemical treatment process.

Prior to any alum addition, the pH is adjusted to <6.2 using sulphuric acid. A calculated dissolved quantity of the alum is then pumped into the mixing tank (at a rate of 0.13 kg alum m^{-3} of effluent). This provides a solution with the desired aluminium ion (Al^{3+}) concentration. The pH is then again checked and adjusted to between 6.1-6.8 using a solution of sodium carbonate. Finally a cationic coagulant is pumped into the mixing tank at a rate to ensure an optimum level of 0.5-1.5 ppm and the tank is mixed by recirculation for 12-20 hours.

All "C" line waste waters flow into a "C" line collection pit and then to one of 6 × 230 m^3 holding tanks where waste water is sampled and analysed. If the analysis indicates an activity level above the authorised discharge level (refer to Section 6.4), three options are available, depending on the radioactivity, viz.,

a. circulate and mix with other holding tanks to dilute,

b. transfer to other holding tanks and dilute with incoming "C" line waters, or

c. pump to mixing tanks for chemical treatment.

TABLE 6.2
Details of Pit and Delay Tanks for Waste Water Collection

Building No.	Pit Tanks no. x volume	Delay Tanks no. x volume	Line Connections
2	2 off x 4.5 m^3	2 off x 27 m^3	"B" and "C"
3	2 off x 4.5 m^3	2 off x 45 m^3	"B" and "C"
3 "C" Pit	1 off x 3.3 m^3	-	"C"
16 "C" Pit	1 off x 5.5 m^3	-	"C"
11, 12 and 20 27 57	Direct to Delay Tank 1 off x 4.5 m^3 1 off x 2.3 m^3	3 off x 27 m^3 for Bld 11	"B"
19 and 56	1 off x 4.5 m^3	1 off x 27 m^3	"B"
64	1 off x 4 m^3	Pumps to Bld 19	"B"
21, 22 and 53	-	-	Direct to Bld 11 "C" Pit
23	1 off x 4.5 m^3	2 off x 13.6 m^3	"B"
Reactor North	1 off x 4.5 m^3	3 off x 27 m^3 1 tank used for secondary coolant blowdown	"B" and "C"
Reactor South	2 off x 4.5 m^3	2 off x 27 m^3	"B" and "C"
54	1 off x 4.5 m^3 2 off x 0.5 m^3	-	Tanker transfer
11 Settling Pit	1 off x 10 m^3	-	"C"
9	1 off x 2 m^3	-	Tanker transfer

The site sewage effluent is pumped automatically to a sewage plant for biological treatment and then to the holding tanks for discharge to the sewer system.

Table 6.3 shows typical volumes and radionuclide concentrations in the major "B" line sources. Overall, about 90% of the radioactivity in the waste waters arises from the production of radioisotopes and the remainder from the research laboratories.

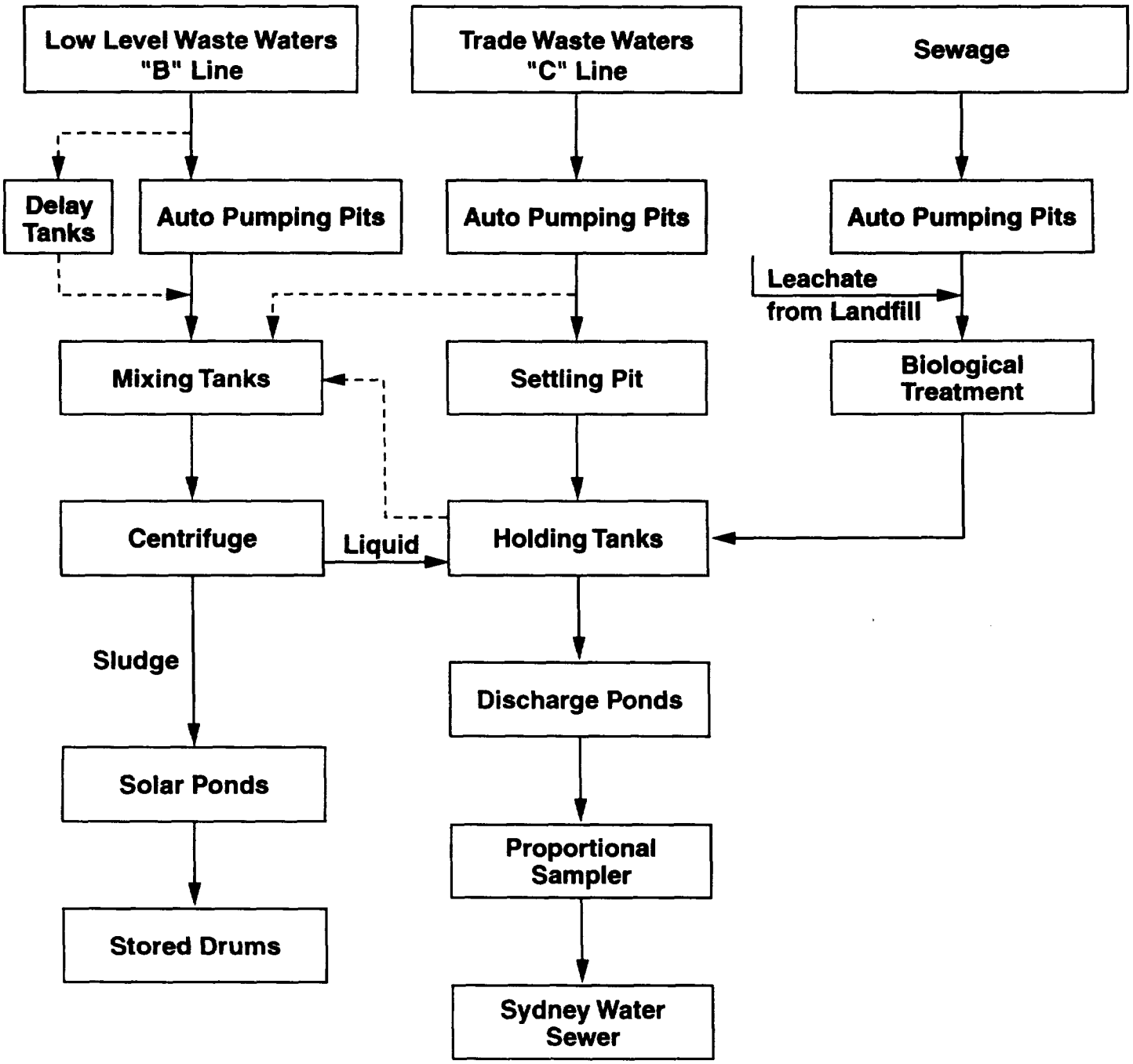


Figure 6.1: General Schematic Diagram of Waste Water Collection and Treatment System

SECTION 6
LOW LEVEL LIQUID EFFLUENTS

6.1 General Site Waste Waters

To facilitate treatment, waste waters at LHSTC are segregated into three categories:

- Waste waters from "active" drains in laboratories where radioactive materials are routinely handled. They normally contain low levels of beta and gamma emitting radionuclides. The pipeline that transports these waters is known as the "B" line.
- Trade waste effluents arising from laboratories and workshops in which radioactive materials are not normally handled. The pipeline that transports these waters is known as the "C" line.
- Non-radioactive sewage from the LHSTC and leachate from the Lucas Heights landfill.

The average volumes and activity levels of the above waste waters over the last three years (1993-1995), are shown in Table 6.1. A general schematic diagram of the waste water collection and treatment system is shown in Figure 6.1. The sewage stream includes approximately 8,000 m^3 of leachate received annually from the Lucas Heights landfill site.

TABLE 6.1
Average Waste Water Source Volumes and Activities for 1993-95

Volume or Activity	B-Line	C-Line	Sewage
Annual Volume	3,800 m^3	46,000 m^3	39,000 m^3
Daily Volume	10 m^3	130 m^3	110 m^3
Average Beta Activity	470 kBq m^{-3}	6.5 kBq m^{-3}	Nil
Maximum Beta Activity	4500 kBq m^{-3}	70 kBq m^{-3}	Nil

Low level waste waters are collected in local inground catchment tanks and pumped directly via the "B" and "C" lines to the mixing and holding tanks, respectively. The use of delay tanks (see Figure 6.1) for storage and decay of low level radioactive liquids occurs only if known effluents of higher than normal activity are likely to be discharged by the various generators. Table 6.2 shows the number and capacities of the delay tanks.

5.6 Recommendations - Airborne Emissions

- It is recommended that, in accordance with the ALARA principle, radionuclide releases from the most significant sources - buildings 15A, 23A and 54 - be reviewed to look for ways of reducing airborne radionuclide releases by changing procedures and/or by providing improved air cleaning technology, if available.
- It is recommended that the ADDCOR model be updated and refined as necessary to take account of changes in dose conversion factors and experimental measurements as they become available.
- It is recommended that, through consultation with regulatory authorities, a revised set of working levels be established for stack emissions from LHSTC.

TABLE 5.4
Estimated Effective Doses from Airborne Discharges in 1995
(Hoffmann *et al.* 1996)

Receptor Location	Effective Dose (mSv per yr)	% Site Dose Constraint
Main Gate	0.0072	2.2
Outside HIFAR	0.0013	0.4
Woronora Valley*	0.00095	0.3
Waste Services Depot*	0.0054	1.8
1.6 km radius from HIFAR - North	0.0049	1.6
1.6 km radius from HIFAR - South	0.0020	0.7
1.6 km radius from HIFAR - East	0.0044	1.5
1.6 km radius from HIFAR - West	0.0019	0.6

* These locations are off-site but well within the ANSTO 1.6 km buffer zone.

Nevertheless, in accordance with the ALARA concept, **it is recommended** that radionuclide releases from the most significant sources - buildings 15A, 23A and 54 - be reviewed to look for ways of reducing airborne radionuclide releases by changing procedures and/or by providing improved air cleaning technology, if available.

5.5 Current and Future Directions

Current improvements occurring in the Airborne Effluent Monitoring Program include upgrading of all HEPA filter bank pressure measurement gauges, creation of a single information source on the current condition and vital statistics of each filter bank, and the writing of a set of Standard Operating Procedures for Stack Sampling and Analysis in QA format. Also, Engineering Division has undertaken to conduct a survey of all active ventilation systems at LHSTC and the National Medical Cyclotron to ensure the ventilation data about these systems are current and to identify any issues that need to be addressed.

ADDCOR is currently being examined to determine the updating required to take account of changes in IAEA dose conversion factors. Historical time release data is also being reviewed to ensure its accuracy. **It is recommended** that the ADDCOR model be updated and refined as necessary to take account of changes in dose conversion factors and experimental measurements as they become available.

The current method of comparing airborne releases against working levels from individual stacks needs to be replaced by a system based on calculation of dose rates using atmospheric models such as ADDCOR. **It is recommended** that, through consultation with regulatory authorities, a revised set of working levels be established for stack emissions from LHSTC.

5.4 Calculations of Dose from Airborne Emissions

In 1982, an AAEC Radioactive Airborne Effluent Working Party (RAEWP) was formed to review airborne radioactive effluents at the LHSTC and to draft a revised airborne radioactive effluent authorisation for consideration by the NSW Radiological Advisory Council. After extensive study, the RAEWP produced a computer model known as ADDCOR (an Atmospheric Dispersion & Dosimetry Code for Operators & Regulators), (Petersen *et al.* 1989, Petersen 1994). This model calculates the annual doses to hypothetical continuously exposed members of the public at designated receptor locations by taking into account all sources (tall stacks, short stacks and ventilation exhausts) on site and all radioisotopes from those sources.

The RAEWP proposal was submitted to the 11 November 1988 meeting of the NSW Radiological Advisory Council for approval (Petersen *et al.* 1989). The NSW RAC accepted the proposal in principle but, given the complexity of the proposal and the fact that it was based on a computer code, requested that it be fully checked and appraised by an independent expert (Fleischmann 1988). This independent assessment was completed on 18 February 1993 (Lyons 1993). ADDCOR has been used since 1992 to confirm that LHSTC radioactive airborne effluents are in compliance with the discharge authorisation (Petersen *et al.* 1989, SRC 1993, SRC 1994).

The radiation doses received at various locations in and around LHSTC are calculated using the ADDCOR Code. Hypothetical members of the public are assumed to be present 24 hours per day, 365 days per year at each of 32 receptor locations around the 1.6 and 4.8 km radius from HIFAR on the sixteen compass points and at a receptor location in the Woronora Valley. There is an assumed occupancy at the BMX track (which is within the 1.6 km zone) of 10 hours each day at weekends and at the Waste Services site, for 10 hours per day every weekday (Petersen *et al.* 1989, Petersen 1994). Dose estimates are also made at specific receptor locations within the LHSTC site to allow for assessment of doses from the airborne discharges to LHSTC staff not on the personal dosimetry service, as well as members of the public visiting the site. These results are compared with the National Health and Medical Research Council annual dose limit for members of the public of 1 mSv and the site dose constraint of 0.3 mSv/yr.

Table 5.4 shows the doses received in 1995 at various receptor locations as calculated by the ADDCOR program. It can be seen from these results that the dose rates on the 1.6 km boundary are less than 2% of the 0.3 mSv/yr dose constraint in use at the LHSTC. Thus, there is no reason to believe there are any negative health effects from the radioactive airborne emissions from the LHSTC.

The two areas that are releasing activities close to the working levels are:

- Building 54 where the noble gases (xenon and krypton) are released during the separation of molybdenum-99 from other fission products.
- HIFAR active ventilation system where the level of argon-41 produced by the irradiation of the reactor spaces cooling air is approaching 100% of the working level. The increased use of HIFAR for silicon irradiations has led to an increase in irradiated air and higher levels of argon-41. Currently, a number of approaches are being examined to reduce argon-41 production within the rigs.

TABLE 5. 3
Airborne Radioactive Emissions in 1994 from Individual Discharge Points expressed as Percentages of Working Levels (Hoffmann *et al.* 1995)

Bld No	Gross α % of working level	Gross β % of working level	^{131}I % of working level	^{3}H % of working Level	Noble gases % of working level	Other Activity % of working level
54/2	0.0014	0.000041	3.34	-	71.3	0.68
3	0.35	0.008	0.006	-	-	-
15A	0.006	0.002	0.01	0.29	97.3	0.1
19	0.006	0.0016	0.015	-	-	0.023
20	0.26	0.06	0.012	2.32	-	-
21A	0.2	0.10	0.017	-	-	-
21B	LLD	0.03	LLD	-	-	-
23A	0.081	0.022	29.8	-	-	-
23B	0.015	0.0048	0.006	-	-	-
41	0.5	0.26	0.08	-	-	-
56	0.15	0.034	0.004	-	-	-
57	0.32	0.08	0.03	4.9	-	-

Notes:

LLD = Less than the limit of detection, which varies with each stack and type of activity.

The working levels referred to above are self-imposed operational levels which are used to assess trends in the airborne discharges. Doses resulting from the discharges during the period were calculated to be well below the public dose limits and the site dose constraint of 0.3 mSv per year. See Table 5.5 in Hoffmann *et al.* (1995) report for details.

Since December 1994, ARL has been providing independent surveillance of the effluent discharges from the LHSTC. Random weekly sets of samples have been sent to ARL when requested for re-measurement and to provide a cross comparison of the data obtained by ANSTO. This includes a full set of Maypacks, particulate filters and tritium samples for re-analysis. ARL compare its results with those from ANSTO to ensure accurate determination of airborne releases.

5.3 Regulatory Limits and Working Levels

The authorised limits for airborne discharges are based on consideration of a conservative set of exposure scenarios and associated pathways through which a member of the public might be exposed to radiation doses or are adapted from NSW Acts and associated Regulations. Compliance with these discharge limits is continuously monitored by ANSTO and independently checked by ARL.

Recommendations on dose limits for exposure of members of the public to ionising radiation and for occupational exposure are given by the International Commission on Radiological Protection, ICRP (1990) and the IAEA (1996), which form the basis of the National Health and Medical Research Council (NHMRC) *Recommendations for Limiting Exposure to Ionising Radiation*, NHMRC (1995) and National Occupational Health and Safety Commission (NOHSC) *National Standard for Limiting Occupational Exposure to Ionising Radiation*, NOHSC (1995). To ensure compliance with these Standards, limits on the quantities of airborne radioactivity the LHSTC is authorised to discharge into the environment were agreed with the appropriate NSW State Authorities (Rolland 1988, Fleischmann 1988, Petersen *et al.* 1989). These quantities are such that subsequent doses from environmental discharges do not exceed the NHMRC dose limits.

In addition to complying with dose limits, ANSTO has adopted the practice of comparing discharges from individual stacks with self-imposed working levels. These levels are chosen so that all stacks could discharge continuously at 100% of the working level and still be under the dose limits. This approach is very conservative because there are negligible emissions from a number of stacks.

Compliance with operational working levels for stack discharges is verified by continuously sampling (ANSTO 1992). Stack sampling techniques depend on the radioisotopes that could be emitted from that building and include use of the following devices:

- **Maypack**: A proportion of the stack exhaust is drawn through a combined particulate filter (to trap alpha/beta particulates) and charcoal trap (for collecting gamma-emitting gaseous emissions).
- **Bubbler**: A proportion of the stack flow is drawn through a set of bubblers containing water which trap any tritiated water present in this exhaust air sidestream.
- **Flask**: A proportion of the stack flow is continuously drawn through a specially shaped glass flask located in a shielded space containing a gamma-ray detection and counting system to quantify the amount of noble gas emissions (Xe, Kr, Ar).

The activities being released from these stacks are compared with the working levels discussed above and reported annually. Table 5.3 shows the discharges for 1994 as a percentage of these working levels.

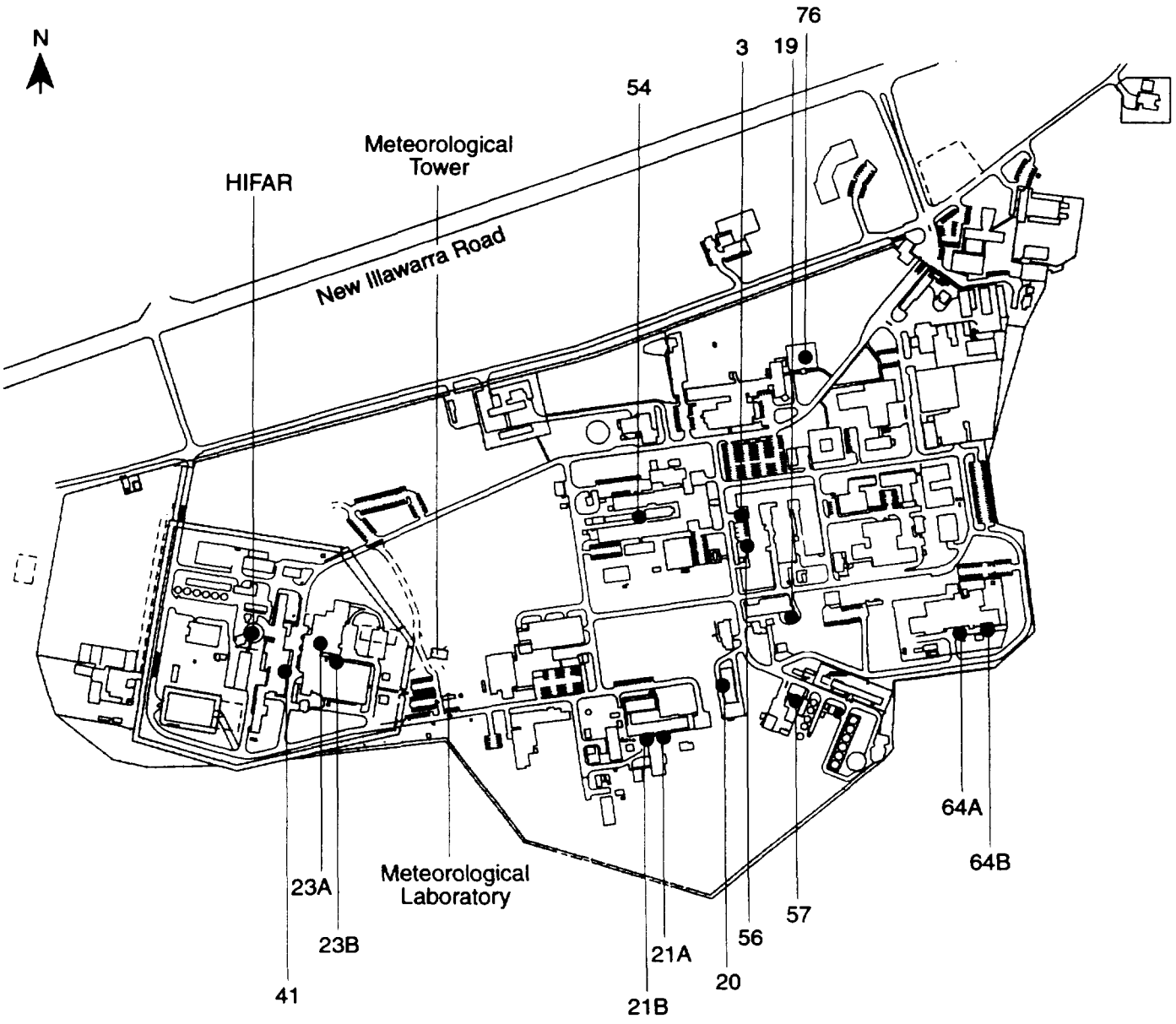


Figure 5.2: Location of Airborne Effluent Release Stacks at Lucas Heights Science and Technology Centre

The effluent stacks routinely monitored at the LHSTC are listed in Table 5.2, along with details of stack height, design flow rate and radionuclides that can potentially be found in each stack. Figure 5.2 shows the location of stacks on the site plan.

TABLE 5.2
Stack Sampling Status (1996)

Building Stack	Height (m)	Flow rate ($m^3 s^{-1}$)	Sampler type(s)	α/β	^{131}I	^{3}H	Noble gases	Other radionuclides possible
3	9	4.5	Maypack	✔	✔			
15 active HIFAR	23	0.8	Maypack Bubbler ^{41}Ar Cts	✔	✔	✔	✔	^{197}Hg, ^{203}Hg, ^{76}As, ^{82}Br
15 main HIFAR	23	1.6	Maypack Bubbler ^{41}Ar Cts	✔	✔	✔	✔	
19 stack	33	17.8	Maypack	✔	✔			^{123}I, ^{198}Au
19 duct	33	1	Maypack	✔	✔			^{82}Br
20	8	5.5	Maypack Bubbler	✔	✔	✔		
21A	15	1.8	Maypack	✔	✔			
21B	16	0.2	Maypack	✔	✔			
23A	26	11.5	Maypack	✔	✔			^{197}Hg, ^{203}Hg, ^{99}Mo, ^{99m}Tc
23B	18	1.1	Maypack	✔	✔			
41A	26	3.7	Maypack	✔	✔			
41B	26	3.6	Maypack	✔	✔			
54/2	40	7.6	Maypack Xe/Kr Cts	✔	✔		✔	^{132}I, ^{133}I
56	9.1	11.6	Maypack	✔	✔			
57	8.5	2	Maypack Bubbler	✔	✔	✔		
76	7	0.6	Maypack	✔	✔			^{123}I, ^{18}F

Cts = Continuous sampling through a glass flask/detector system

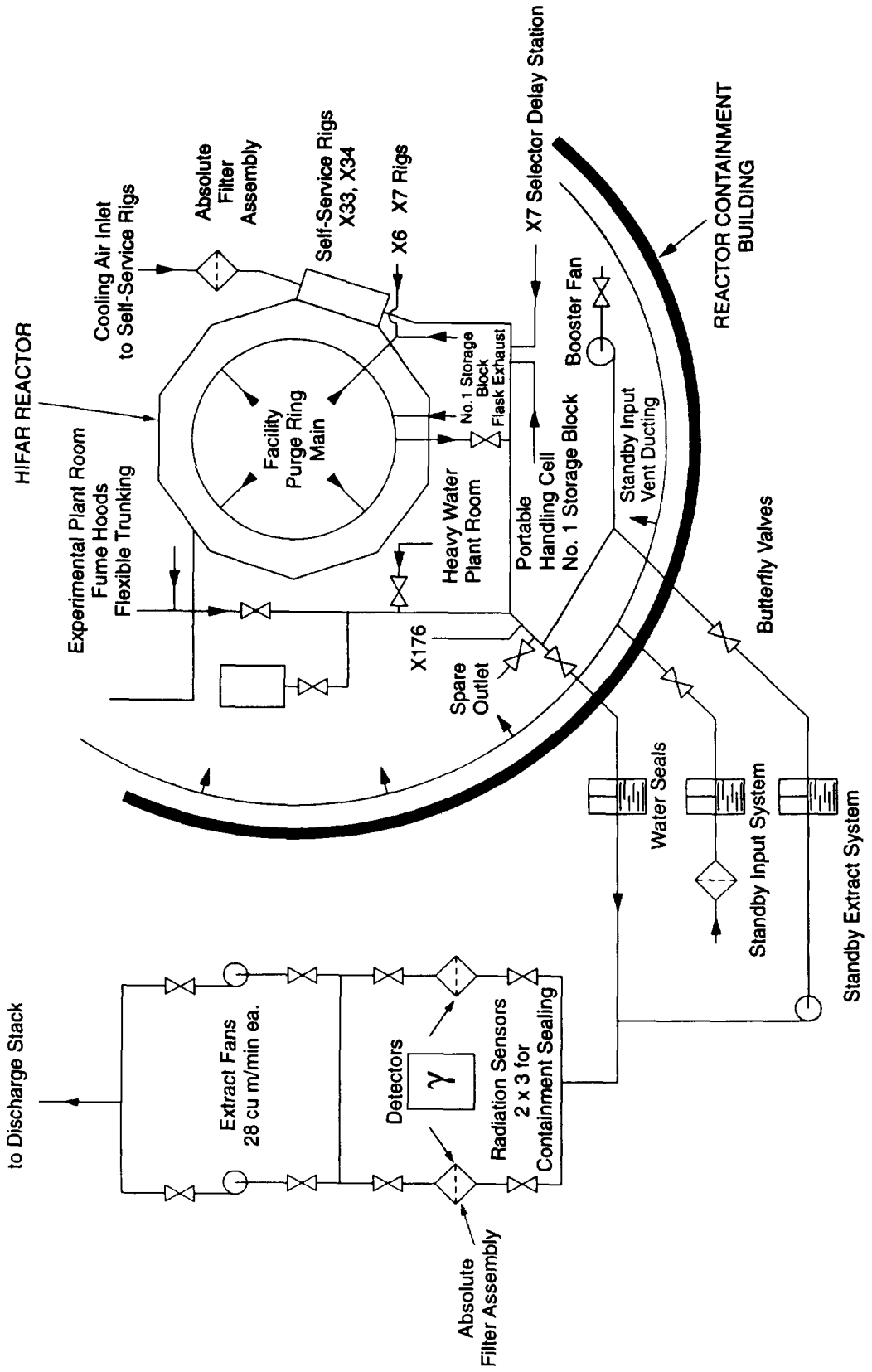


Figure 5.1: HIFAR Active and Standby Ventilation System

TABLE 5.1
Stack Discharges of Radioactivity at LHSTC ... continued

Radioactive Nuclide	Half life	Stack	Form of Release	Comment
Iodine-131	8 days	Bld 54	Organic Iodine Vapour	Iodine-131 is also released during technetium-99m extraction from fresh fission products. Iodine is very volatile even at room temperature and about 3% escapes from the enclosed apparatus. To prevent this quantity of iodine being released to the atmosphere, the exhaust from the hot cell passes through sixteen beds filled with a specially impregnated charcoal, which was developed in England to trap all forms of airborne iodine, even at high humidity. The beds are tested regularly and are replaced whenever the efficiency falls below 99.9%. The most penetrating form of airborne radio-iodine has been found to be the vapour of an organic compound, methyl iodide, formed when the extremely dilute radioactive iodine reacts with traces of organic vapours.
Iodine-131	8 days	Bld 23A	Vapour	Iodine-131 is an important medical isotope in its own right, being used in the treatment of thyroid cancer. It is produced by the irradiation of a tellurium target in HIFAR, before being processed in a small shielded hot cell in Bld 23. The exhaust from the group of cells passes through three charcoal beds similar to the ones in Bld 54.

An example of a complex exhaust ventilation system - the HIFAR active system - is shown in the Figure 5.1. Air is extracted from several different areas around the reactor including various irradiation rigs, the plant rooms and the fuel storage block. The extract air is collected and flows out of the containment building and through a set of water seals (which would only be filled in an emergency) followed by a set of HEPA filters to remove any particulates and finally through a 23 m high stack. The predominant radionuclide in the exhaust is argon-41 formed by irradiation of air containing naturally-occurring argon-40.

Filtration systems are regularly monitored to ensure correct operation. All active ventilation systems are connected to the site control centre and alarms are triggered in the case of ventilation failure due to fan breakdown, power loss, *etc.* The pressure drop across the HEPA filters and prefilters is continuously measured to indicate if they are becoming blocked with particulate material (radioactive and otherwise) and need replacement. SIAMs are replaced when breakthrough of radioiodines is detected by the stack sampler.

TABLE 5.1
Stack Discharges of Radioactivity at LHSTC ... continued

Radioactive Nuclide	Half life	Stack	Form of Release	Comment
Tritium	12 yrs	Bld 57	Water vapour	Bld 57 is where the spent resin beds, used to purify the HIFAR coolant water, are regenerated or replaced. Most of the tritiated water on the resin beds is trapped before the drying gas is discharged to the stack.
Mercury-197 Mercury-203	64 hrs 47 days	HIFAR	Vapour	Slight traces of mercury vapour in the air within the HIFAR containment are activated by neutrons. The mercury probably comes from a thermometer dropped at some time in the containment building.
Arsenic-76	26 hrs	HIFAR	Arsenic vapour	Very slight traces of arsenic vapour in the air within the HIFAR containment are activated by neutrons. The arsenic vapour is being slowly emitted from wood, treated with preservative, which was used a few years ago when renewing the thermal cladding of the containment building.
Iodine-131	8 days	HIFAR	Vapour	Even though there are only traces of iodine-131, if any, in the exhaust from HIFAR under normal operation, the effluent is continuously sampled for iodine, since it is the most important activity released in a serious accident.
Xenon-133 Xenon-'35 Xenon-135m Krypton-87 Krypton-85m Krypton-88	5.3 days 9.2 hrs 15 mins 76 mins 4.5 hrs 2.8 hrs	Bld 54	Gas	These are all "fission product noble gases". The radio-nuclide most often used as a diagnostic tracer in nuclear medicine is technetium-99m, extracted from fresh fission products. Small uranium targets are irradiated in HIFAR for a few days before they are dissolved in nitric acid in a fully enclosed apparatus in one of the heavily shielded "Hot Cells" in Bld 54. The noble gases which are released during dissolution are trapped on a large charcoal bed in the next cell. When the targets are completely dissolved the charcoal bed is isolated and the noble gases allowed to decay while trapped on the bed. However, additional noble gases are formed in the nitric acid solution, from radioactive gases released from the apparatus as the liquid is manipulated into different parts of the equipment by means of vacuum lines. The exhaust gases from the vacuum lines pass through small charcoal beds to trap most of the iodine-131. About 90% of the noble gases are trapped during dissolution leaving only 10% to be released during processing.

TABLE 5.1
Stack Discharges of Radioactivity at LHSTC

Radioactive Nuclide	Half life	Stack	Form of Release	Comment
Iodine-131	8 days	All	Vapour	All stacks are continuously sampled for iodine-131, even though only a few are routinely releasing it. This is partly because of the importance of iodine in any accidental release of mixed fission products and partly because it has sometimes been used in tracer experiments, so that small amounts might occasionally appear in any stack effluent.
Strontium-90	29 yrs	All	Particulate	The same sampler that measures the iodine release discharges, also measures the particulate activity, both alpha and beta. The filter paper which traps the airborne particles is counted the day after its removal from the stack and again after a delay of 3 months to allow the short-lived alpha and beta activity to decay. Any long-lived beta activity on the filters is conservatively assumed to be strontium-90, even though this nuclide is not a likely candidate. Note that all the exhaust gases have passed through high efficiency particulate air filters which are better than 99.97% efficient.
Argon-41	1.8 hrs	HIFAR	Gas	Air is used to cool some of the irradiation rigs in HIFAR. The naturally occurring argon-40 in air becomes activated in passing through the reactor by the absorption of a neutron to form radioactive argon-41 which decays to stable potassium-41. The argon-41, being a noble gas, does not deposit on any surface or chemically react. It is a beta-gamma emitter which is easy to detect.
Tritium	12 yrs	HIFAR	Water vapour	The primary coolant and neutron moderator in HIFAR is "heavy water" or deuterium oxide. Deuterium is a naturally-occurring isotope of hydrogen with an additional neutron over the common isotope of hydrogen. In the reactor, a few of the deuterium atoms capture another neutron, to form tritium which emits low energy beta radiation. If anyone is exposed to tritiated water vapour, some of the tritium will enter the body fluids by diffusion through the skin and lungs. However, the rate of turnover of water in the body is so high that the effective or biological half-life is only about 12 days. The tritiated water vapour is released by evaporation from equipment, which is wet by the coolant, when it is removed from the reactor.
Tritium	12 yrs	Bld 20	Water vapour	Bld 20 is the decontamination centre and occasionally handles coolant pumps removed from the reactor for maintenance.

SECTION 5
AIRBORNE EMISSIONS

5.1 Sources of Airborne Radioactivity

During normal operation of nuclear facilities there are small emissions of airborne radioactivity to the environment. Most commonly, the emissions contain radionuclides of elements that are gaseous (such as the noble gases, argon, xenon and krypton) or volatile (such as iodine, tritium and, less commonly, arsenic and mercury). Airborne particulates are sometimes generated but these are almost completely removed by high efficiency filters that are part of the ventilation exhaust and stack discharge systems. Table 5.1 lists the radionuclides that could be released as airborne emissions from the LHSTC.

5.2 Ventilation Systems at LHSTC

All operations at the LHSTC that could lead to airborne releases of radioactivity operate under appropriate ventilation controls so that fugitive emissions are collected by an active extract system. Specialised handling cells, glove boxes and other ventilated enclosures are used to prevent exposure of staff. The active exhaust from these units is then passed through a filtering system to collect radionuclides that may be present. The active exhaust from the buildings with an active ventilation system is first passed through a set of prefilters - to collect the relatively large particulate material - and then through HEPA (High Efficiency Particulate Air) filters to remove particulates with an efficiency of >99.97%.

Some operations that also have the potential to release volatile radioiodines (in the form of a vapour) also pass their exhaust air through a set of activated charcoal traps called SIAMs (Standard Iodine Adsorption Module) which adsorb and retain iodine vapours.

Building 54 uses specially-designed charcoal traps to adsorb xenon and krypton released during dissolution of uranium dioxide pellets to produce molybdenum-99 (see Section 4.1). The charcoal delays the release of the noble gases sufficiently to allow decay of the short-lived isotopes (see Table 5.1).

- It is recommended that a project addressing the long term immobilisation of the molybdenum-99 waste be initiated. This project should consider leach resistant waste forms suitable for disposal, including cement and titanate-based waste forms (such as Synroc).
- It is recommended that the present method of molybdenum-99 production be reassessed from a cleaner production viewpoint. This would involve consideration of modifications to the current process to eliminate the ammonium salts in the waste and, more radically, assessment of alternative technologies with the aim of reducing liquid waste volumes and/or activities.
- It is recommended that appropriate technology be developed and implemented for the treatment of non-aqueous and contaminated oily wastes.

Modification of the molybdenum-99 production process, whereby the concentrated ammonia-rich condensate waste stream is kept separate from the SLW waste, is currently under review. This would greatly reduce the levels of ammonium nitrate in future wastes from molybdenum-99 production and allow direct solidification without concerns about the hazards associated with ammonium nitrate

The UNH cake from the process is not a suitable waste form for disposal because this solid is leachable. The stainless steel vessels proposed for storage of UNH have a life expectancy of at least 50 years. While the solidification process will address the issues relating to the hazards associated with liquid storage and provide a medium-term solution, **it is recommended** that a project addressing the long term immobilisation of the molybdenum-99 waste be initiated. This project should consider leach resistant waste forms including cement and titanate-based waste forms (including Synroc).

In a broader context, **it is recommended** that the present method of molybdenum-99 production be reassessed from a cleaner production viewpoint. This would involve consideration of modifications to the process to eliminate the ammonium salts in the waste and, more radically, assessment of alternative technologies with the aim of reducing liquid waste volumes and/or activities.

4.2 Other Liquid Wastes

Waste Management Section stores small quantities of other liquid wastes contaminated with low levels of radioactivity. Currently, there are five 200 litre drums of contaminated oils and four 200 litre drums containing large numbers of small glass vials (about 10 mL capacity) filled with radioactive liquids of various kinds.

Although these wastes are small in volume, they are troublesome, especially those containing organic liquids. Waste management options include incineration, distillation/evaporation or continued indefinite storage. It is recommended that appropriate technology be developed and implemented for the treatment of non-aqueous and contaminated oily wastes.

4.3 Recommendations - Liquid Wastes

- It is recommended that system be installed to allow continuous monitoring for leaks from the intermediate level waste tanks in building 57.
- It is recommended that the highest priority be given to the solidification of the intermediate level liquid waste from molybdenum-99 production, including modification of the current process to remove the safety hazard associated with the presence of ammonium nitrate in the liquid waste.

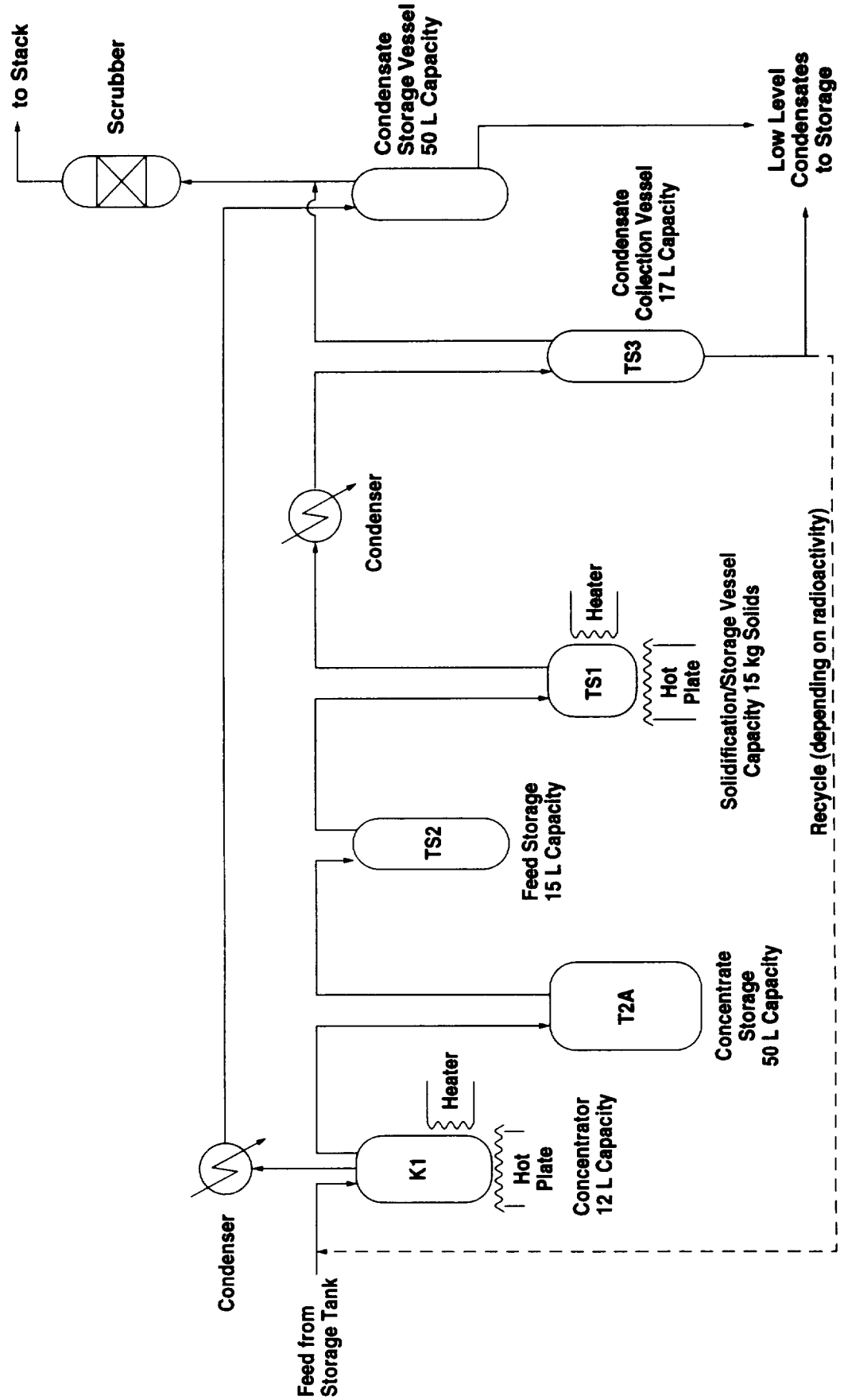


Figure 4.5: Schematic Flow Diagram for Molybdenum-99 Waste Concentration & Solidification

The solvent extraction process was abandoned in favour of a simpler process which uses some of the in-cell equipment used in the earlier process. Figure 4.5 shows a schematic diagram of the process. Liquid from the feed storage tank is transferred to a kettle concentrator (K1) where the solution is concentrated by boiling. The liquor generated from this operation is transferred to a separate trace-heated storage tank (T2A) awaiting the accumulation of sufficient volume for the second stage of the process. The liquor is then pumped at a controlled rate into the solidification vessel (TSI) which is heated by external electric elements. Uranium is concentrated to a point where uranyl nitrate hexahydrate (UNH) will solidify from the solution upon cooling. Up to 15 kg of solid can be contained within each solidification vessel. The product of the process is a dry solid cake contained within the stainless steel solidification/storage vessel. This vessel would be transported in a shielded flask to the solid waste retrievable storage facility located in building 27. Retrieval of the solidified cake from the vessels would be achieved by remelting the UNH at moderate temperatures and extracting the waste as a solution.

As of May 1996, equipment to carry out this operation has been assembled and tested in a hot cell in building 41. The volumetric reduction from the proposed process is expected to be of the order of 15 to 20 fold for the combined PLW and SLW streams. While results of trials have confirmed the practicality and efficiency of the evaporation and solidification process, commissioning has been delayed due to safety hazards associated with the project, as described in detail in Section 4.1.5 below.

The future transfer of liquid waste from the storage tanks, located in building 57, to the hot cell area will be accomplished by means of a specially-constructed shielded transport flask. The transfer, transport and subsequent handling operations involved will all employ the same stringent safety provisions as currently used for the movement of this waste from building 54 to the existing storage tanks.

4.1.5 Strategy for Dealing with Intermediate Level Wastes

The presence in the intermediate level waste of varying concentrations of ammonium nitrate in combination with nitric acid and other potential sensitising agents (such as metal nitrates) has led to concerns of an explosion hazard during the boiling/solidification processes. An external review of the proposed process, by ICI Engineering, confirmed the potential safety hazard and outlined various strategies required to overcome the problem.

It is recommended that the highest priority be given to the solidification of the intermediate level liquid waste from molybdenum-99 production including modification of the current process to remove the safety hazard associated with the presence of ammonium nitrate in the liquid waste.

TABLE 4.2

Inventory and Associated Activity of Stored Intermediate Level Liquid Wastes

(LLD indicates below limit of detection)

Tank No.	Gamma-Ray Activity (MBq L^{-1})											Waste Category	Volume (litres)
	^{141}Ce	^{144}Ce	^{134}Cs	^{137}Cs	^{60}Co	^{155}Eu	^{95}Nb	^{103}Ru	$^{106}Ru/^{106}Rh$	^{91}Y	^{95}Zr		
1	LLD	2000	LLD	4400	0.6	LLD	42	LLD	170	LLD	22	PLW	847
2	1.3	10200	7.9	8100	1.3	93	79	1.5	970	125	50	PLW	761
3	0.8	680	0.5	860	0.2	5.5	23	LLD	62	LLD	16	SLW	1772
4	LLD	500	LLD	1550	0.1	LLD	16	LLD	55	LLD	9.5	SLW	1827
13	9.3	2125	1.0	1500	1.0	10.9	375	13.8	150	163	213	SLW	859
												TOTAL PLW	**1608**
												TOTAL SLW	**4458**

Note:

LLD = Less than limit of detection

TABLE 4.1
Chemical Composition of Intermediate Level Liquid Wastes

Tank No.	Chemical Assay				
	U $g L^{-1}$	Mg gL^{-1}	Fe $g L^{-1}$	NH_4^+ $mg L^{-1}$	HNO_3 (M)
1	70	1.1	0.37	390	0.81
2	194	N/D	N/D	75	0.68
3	9.0	0.14	0.97	430	0.70
4	20	N/D	N/D	730	0.60
13	21	N/D	N/D	390	0.79

N/D = Not Determined

4.1.4 Solidification of Liquid Wastes

The storage of PLW and SLW wastes in a liquid form within tanks at building 57 is seen as an interim measure. It is highly desirable that the molybdenum-99 liquid waste be solidified as soon as possible since storage as a solid provides a much higher assurance of containment. The Safety Review Committee has identified this intermediate level liquid waste as having the potential for off-site impact should there be leakage or uncontrolled release. The tanks have been in service for in excess of 23 years and due to the radioactivity of the contained wastes, inspection of their internal condition is not feasible.

The processing of these wastes by solvent extraction (to remove the uranium) followed by concentration by evaporation was studied in the 1980s and developed to a near production scale in the hot cells in building 41. Consideration was given to incorporation of the uranium-free concentrated waste into Synroc. Indeed, a small quantity of this waste, at a low waste loading, was used to manufacture Synroc specimens for performance testing purposes. However, after solvent extraction and evaporation, the concentration of magnesium in the waste would have been very high. At that time development of a process to accommodate high concentrations of magnesium was not considered appropriate to the commercial development of Synroc since reprocessing wastes do not normally contain magnesium.

Underneath each tank there is a large stainless steel tray which serves as a catch tank. On a monthly basis, the storage facilities are checked using the following procedures:

1. **Level Gauging**. The level within each tank is measured manually with the aid of a computer monitoring system and the readings compared to the previous month's value. Also, for every transfer into or out of a storage tank, the volume is accounted for and the level cross checked by the same method. Variations of ± 3% between calculated and measured values are acceptable. Results outside of this range are investigated.

2. **Catch Tank Sampling**. A vacuum is applied to each of the sample/transfer lines from each catch tank, in turn, in order to draw up any liquid waste that they may contain. The presence of any liquid waste would be detected by either visual observation, using a sight glass located within the line, or by audible response of a gamma detector located adjacent to the sample line.

These procedures, carried out on a regular basis, have shown that none of the tanks have leaked.

In addition to the above procedures, **it is recommended** that a system be installed to allow continuous monitoring for leaks from the intermediate level waste tanks in building 57. The system would provide liquid sensing probes to all catch tanks (currently only installed to tanks 14 and 16), ensuring that any leaks are detected immediately and an audible/visual alarm system activated. Upon confirmation of a leak from any tank, the contents of either that tank and/or its accompanying catch tank would be transferred across to any one of the three spare holding tanks via the liquid vacuum transfer system.

4.1.3 Waste Contents

The available information on the chemical composition of the liquid in each tank is given in Table 4.1. Ammonium ion and free acid (nitric) determinations were recently carried out on each of the five tanks in building 57. The data for the major constituents of tanks 1 (PLW) and 3 (SLW) are based on historic values obtained from the report by Lethlean (1992). The values for uranium content in the remaining tanks were determined from theoretical calculations based on mass balances from the molybdenum-99 process. There is a need to carry out more analyses to fill in the gaps in the data and to verify concentrations calculated from mass balances. An atomic absorption system that can handle radioactive solutions is available for this purpose.

Table 4.2 shows the volume of liquid waste in each tank and the radionuclide activities as measured recently by gamma-spectrometry.

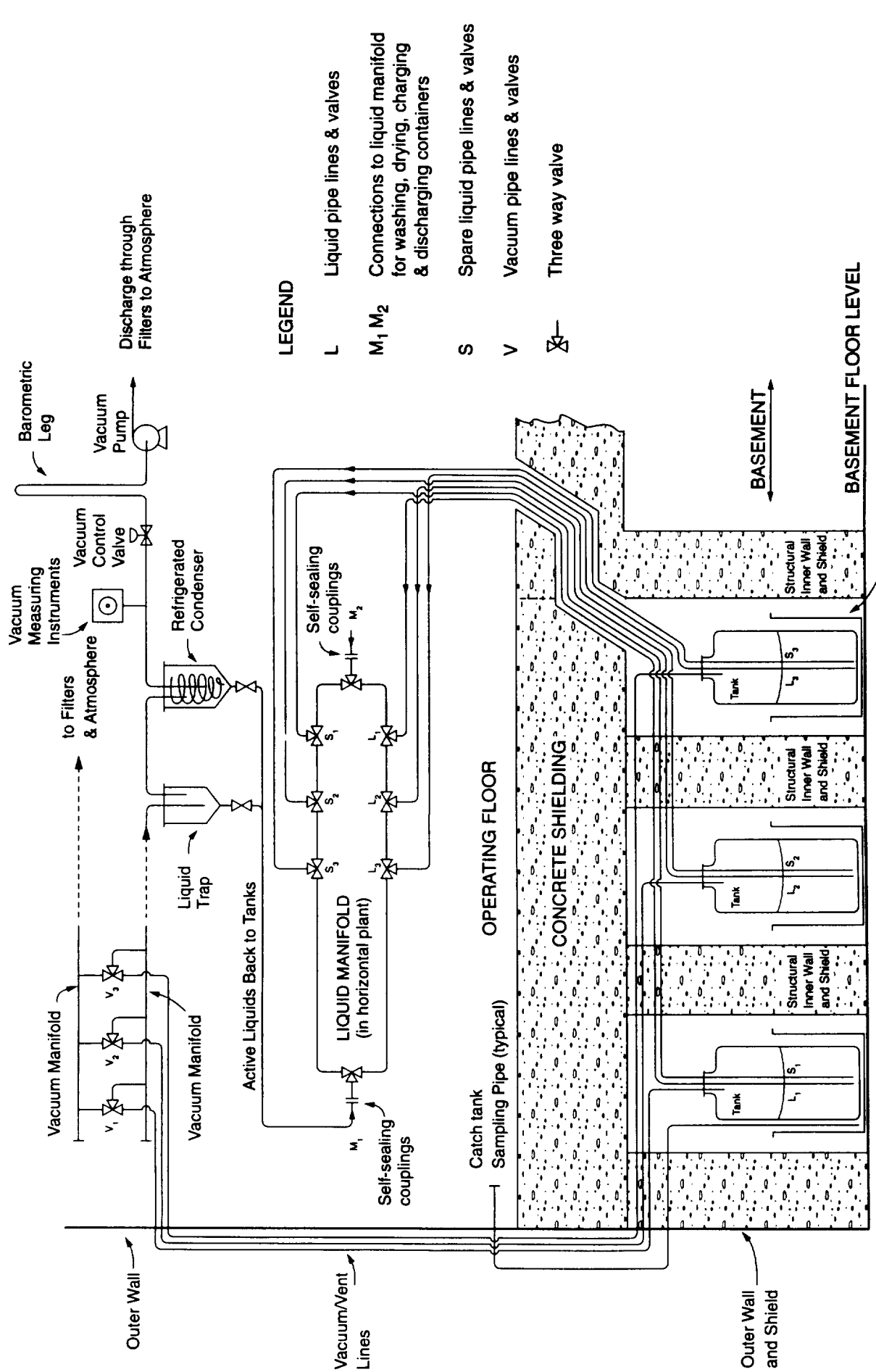


Figure 4.4: Diagrammatic Presentation of the Vacuum Operated Liquid Transfer System for Intermediate Level Liquid Wastes

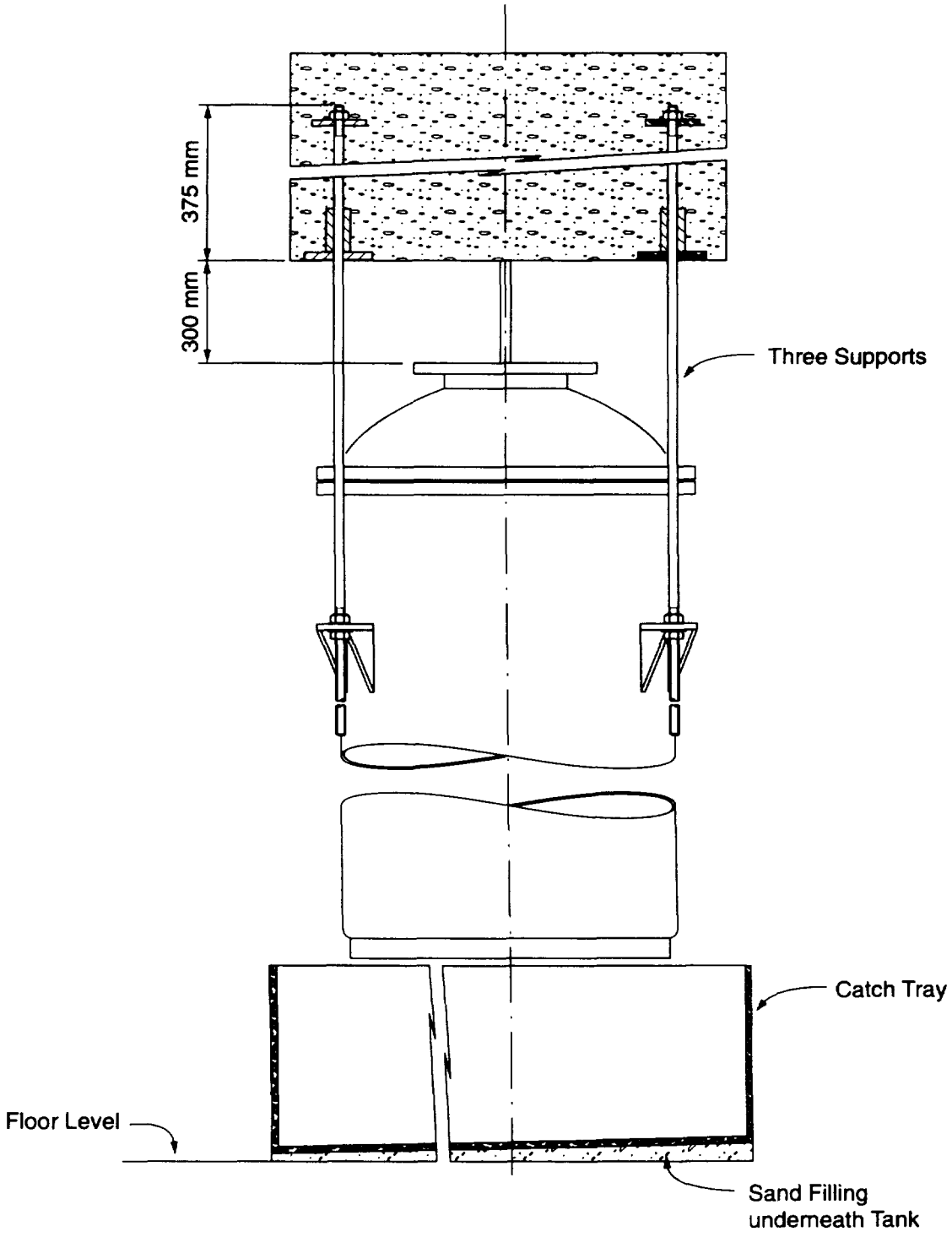


Figure 4.3: Primary Liquid Waste Tank and Catch Tray Installation

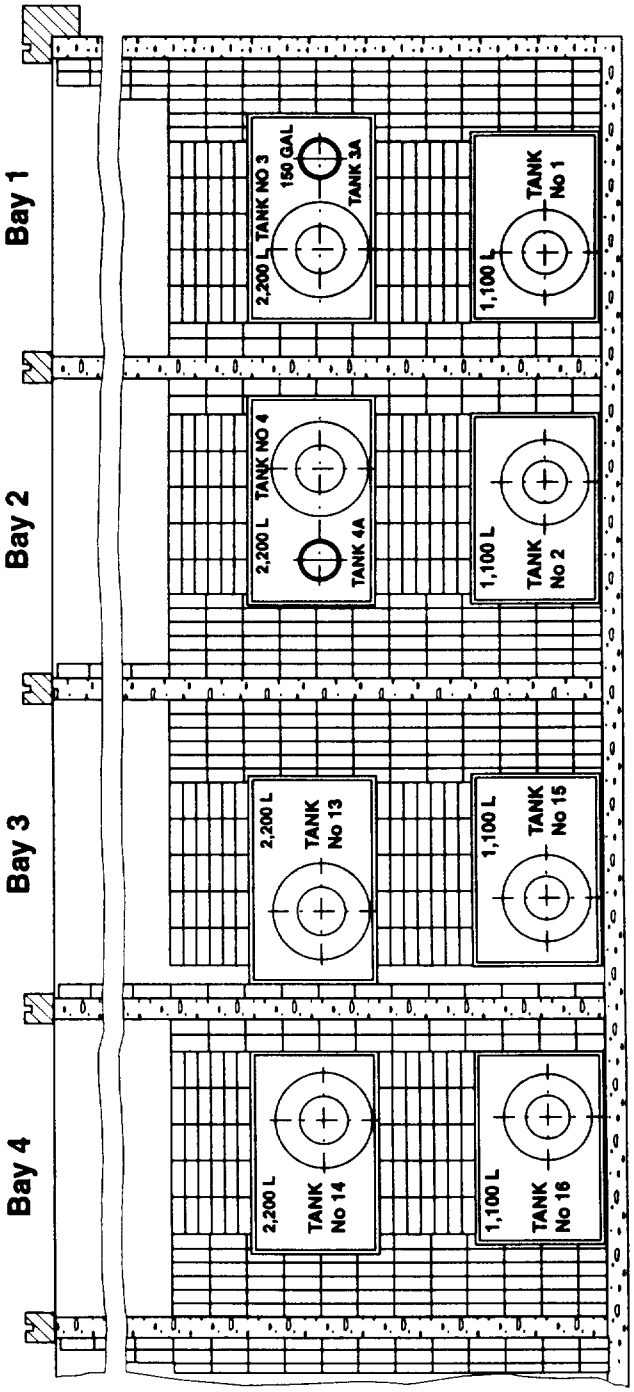


Figure 4.2: Storage Tank Layout for Intermediate Level Liquid Waste (Building 57)

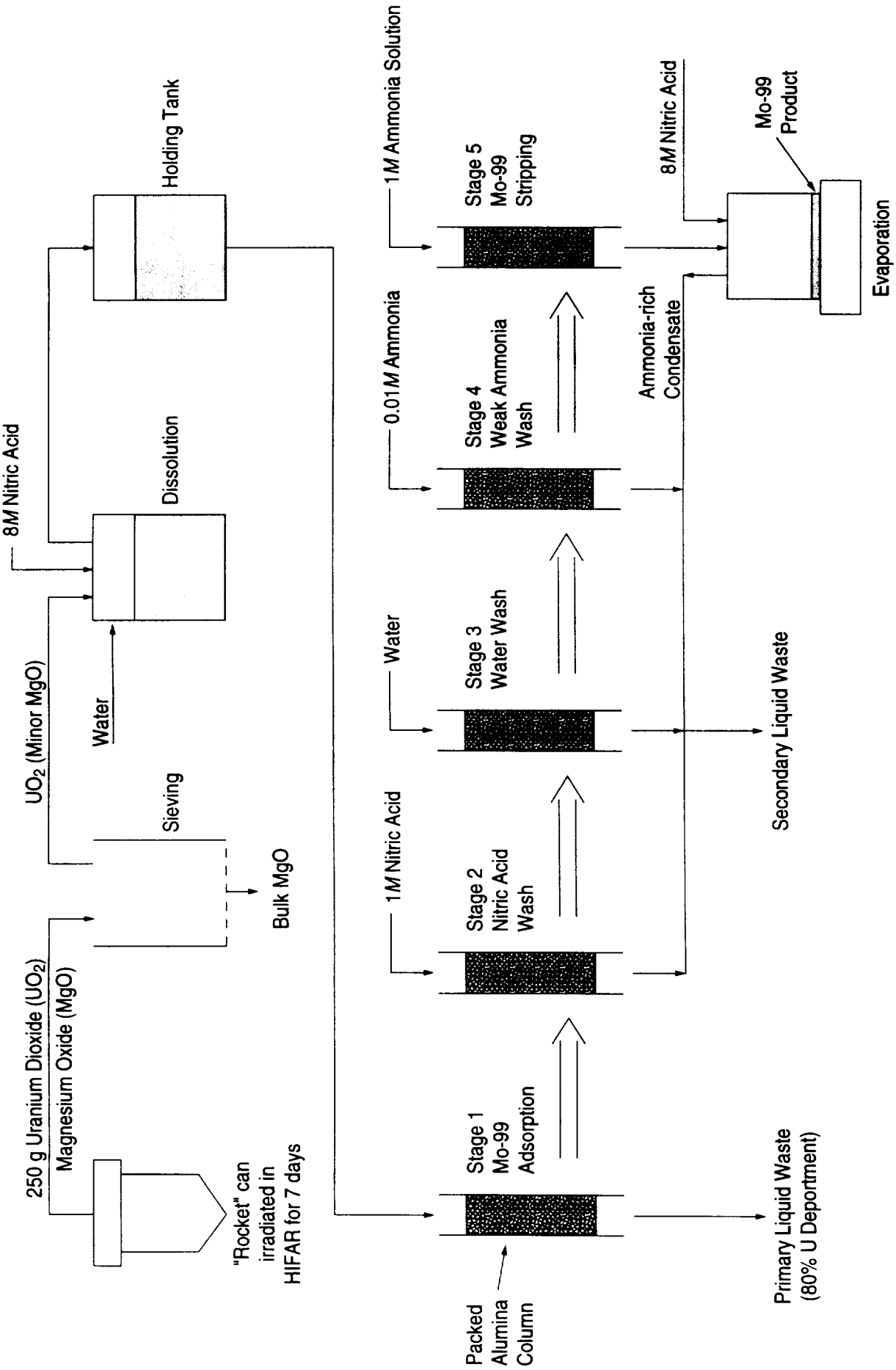


Figure 4.1: Schematic Process for Molybdenum-99 Production

The final stage of the process involves stripping the purified molybdenum-99 from the alumina packed column using concentrated ammonia solution. The ammonia and other residual radionuclides (essentially radioiodine and ruthenium-103) are finally removed by boiling the solution. The ammonia-rich condensate from this boiling operation is added to the SLW waste stream (see Figure 4.1).

The current PLW and SLW liquid waste streams are stored at building 54 in 50 litre shielded flasks for 10-12 months to provide adequate decay time before being transferred to building 57 (Waste Management) for longer-term liquid storage. On average, 90 litres of PLW and 230 litres of SLW are produced per year.

4.1.2 Handling and Storage of Intermediate Level Wastes

Both the PLW and SLW streams fall within the category of intermediate level liquid wastes and their handling, transportation and storage are strictly controlled. The wastes are moved from building 54 to 57 in special shielded transport flasks. The special provisions for the transfer, transportation and storage of these wastes is performed under the supervision of the Waste Management Section.

There are eight large waste storage tanks in the basement of building 57 divided into four specially shielded bays as shown in Figure 4.2. The smaller tanks shown in Figure 4.2 are not in use.

The four tanks for PLW are manufactured from stainless steel and have a capacity of 1100 litres (effective working capacity is about 850 litres). One of these tanks is full and a second has sufficient capacity remaining for about two years operation. The other two tanks are empty.

The four tanks for the SLW are manufactured from glass-lined steel and have a capacity of 2200 litres (effective working capacity is about 1850 litres). Two of these tanks are full and the third has sufficient capacity for up to five years operation. It is essential to maintain one PLW and one SLW tank empty at all times to allow it to receive liquid transfers should any of the other tanks leak. Thus the current storage system is adequate for another five years.

Each tank is suspended from the one metre thick concrete floor slab above as shown in Figure 4.3. The combination of removable concrete blocks around the tanks and the floor slab above provide the necessary shielding for operators. All transfers of the acidic waste solutions, to and from the tanks, are carried out from the active handling area located on the floor directly above. The tanks are classified as pressure vessels because liquid transfers are achieved by application of a vacuum to either the supply or drain lines within a tank. Figure 4.4 shows a diagrammatic presentation of the liquid transfer system.

TABLE 6.5
Mixing Tank Activity Removal Efficiency (1995)

Mixing Tank Batch		α-activity MBq		β-activity MBq	
Month	Volume m^3	Before Treatment	After Treatment	Before Treatment	After Treatment
Jan	387	2.34	2.10	608.0	259.9
Feb	130	0.40	0.40	23.8	13.6
Mar	129	0.31	0.15	29.2	13.5
April	272	5.75	1.41	344.2	223.7
May	137	0.40	0.06	19.3	11.4
June	149	0.33	0.06	37.5	13.0
July	-	-	-	-	-
Aug	268	0.20	0.10	43.1	14.6
Sep	509	6.71	5.49	240.6	201.0
Oct	250	0.78	0.72	134.1	83.3
Nov	256	0.63	0.60	122.1	83.7
Dec	244	0.75	0.43	109.6	43.2
Total	**2731**	**18.60**	**11.6**	**1723.4**	**990.9**

Activity Removal Efficiency
1. For Gross Alpha = 37.8%
2. For Gross Beta = 42.5%

6.3 Special Low Level Liquid Wastes (LLLW)

Liquid wastes that contain significantly higher activity levels than normal "B" line waste waters are segregated at source into approved containers and transported to building 57 for storage and treatment. Segregation of these wastes at the source facilitates their handling and treatment because;

- the major fraction of the radioactivity remains concentrated within relatively small volumes which can be individually treated,
- effluents not compatible with the operation of the low level effluent plant can be excluded from the normal system,
- toxic and non-aqueous wastes can be treated and disposed of individually.

The annual volume of LLLW produced is about 8 m^3 and contains 1,000 kBq m^{-3} alpha activity and up to 400,000 kBq m^{-3} of beta/gamma activity. Table 6.6 lists the various sources, typical volumes and activity levels for these LLLW.

TABLE 6.6
Properties of Special Low Level Liquid Wastes

Source	Waste Type	Annual Volume (litres)	Typical Activity Level (kBq L^{-1})	Commonly Found Radioisotopes
Bld 23	Methyl Ethyl Ketone	400	4000	^{65}Zn, ^{95}Nb, ^{51}Cr
	Caustic Potash / Saline	200	4000	^{95}Nb, ^{95}Zr, ^{144}Ce, ^{137}Cs
	Titanium Can	3500	4000	^{103}Ru, ^{99}Mo, ^{99m}Tc, ^{106}Ru
Bld 54	Washwater	800	50	^{95}Nb, ^{95}Zr, ^{144}Ce, ^{137}Cs
	Delay Tank Effluent	3000	4000	^{95}Nb, ^{95}Zr, ^{144}Ce, ^{137}Cs
	Caustic Soda (amp tank)	100	4000	^{131}I, ^{103}Ru, $^{106}Ru/Rh$ ^{137}Cs

Treatment of these liquids is currently carried out in building 57 on a batch basis. Prior to 1990, the treatment process consisted of chemical precipitation using potassium ferrocyanide (for caesium-137 removal), ferrous sulphate, tannic acid and a ferric chloride solution. The control of the pH and the addition of a polyelectrolyte for flocculation were also part of the treatment process. The supernate was syphoned off and directed to a mixing tank for further decay and treatment. The precipitated sludge was discharged into transfer flasks and taken to the solar ponds for evaporation.

This treatment process was discontinued in 1990 due to poor and variable activity removal efficiencies. The current treatment process also treats these effluents on a batch basis but consists of a simple aluminium sulphate treatment based on the same principle as the main low level effluent treatment plant. However, in this process the combined supernate and the precipitate are removed and transferred to the solar ponds for evaporation. Although this achieves absolute separation of LLLW activity from the liquid effluent system, it is not a satisfactory arrangement since the entire volume must be evaporated. **It is recommended**, therefore, that assessment and developmental work be undertaken, as necessary, to improve the current process for treatment of special low level liquid wastes.

6.4 Discharge Volumes and Limits

As mentioned in Section 2.2.4, ANSTO has a formal Trade Waste Agreement with the Sydney Water Corporation to meet specified discharge limits (ANSTO/Sydney Water 1994). Compliance with the license conditions is monitored by Sydney Water (for non-radioactive components) and ARL (for radionuclides).

be initiated (as required by ANSTO's waste management policy) with alternate presentations by research and operations staff.

ANSTO's Radioactive Waste Management Policy requires development of an integrated plan to inform the public about issues involving radiation and radioactive waste management. Staff regularly address community groups to explain how ANSTO manages its wastes and protects the environment. ANSTO has a number of brochures dealing with radiation but none specifically address the management of ANSTO's wastes. **It is recommended** that brochures, exhibits and other information be prepared to inform the public about radioactive waste management and environmental protection at ANSTO. Development of an integrated plan for dissemination of information on waste management and related issues should be the responsibility of the Director, Communications, with technical support from the Manager, Waste Management Action Plan.

9.3 Recommendations - Organisational Issues

- It is recommended that the Waste Management Action Plan be implemented under a formalised management regime in accordance with the Standard for Quality Management and Quality Assurance (AS/NZS ISO 9001), the Standard for Environmental Management (AS/NZS ISO 14001) and the IAEA RADWASS documents.
- It is recommended that an ANSTO Waste Minimisation Working Party be established, with the goal of minimising the generation of waste through waste reduction, segregation at source, volume reduction and cleaner production technologies.
- It is recommended that a formal program be initiated to educate and train staff in the underlying science and technologies relevant to radioactive waste management.
- It is recommended that brochures, exhibits and other information be prepared to inform the public about radioactive waste management and environment protection at ANSTO.

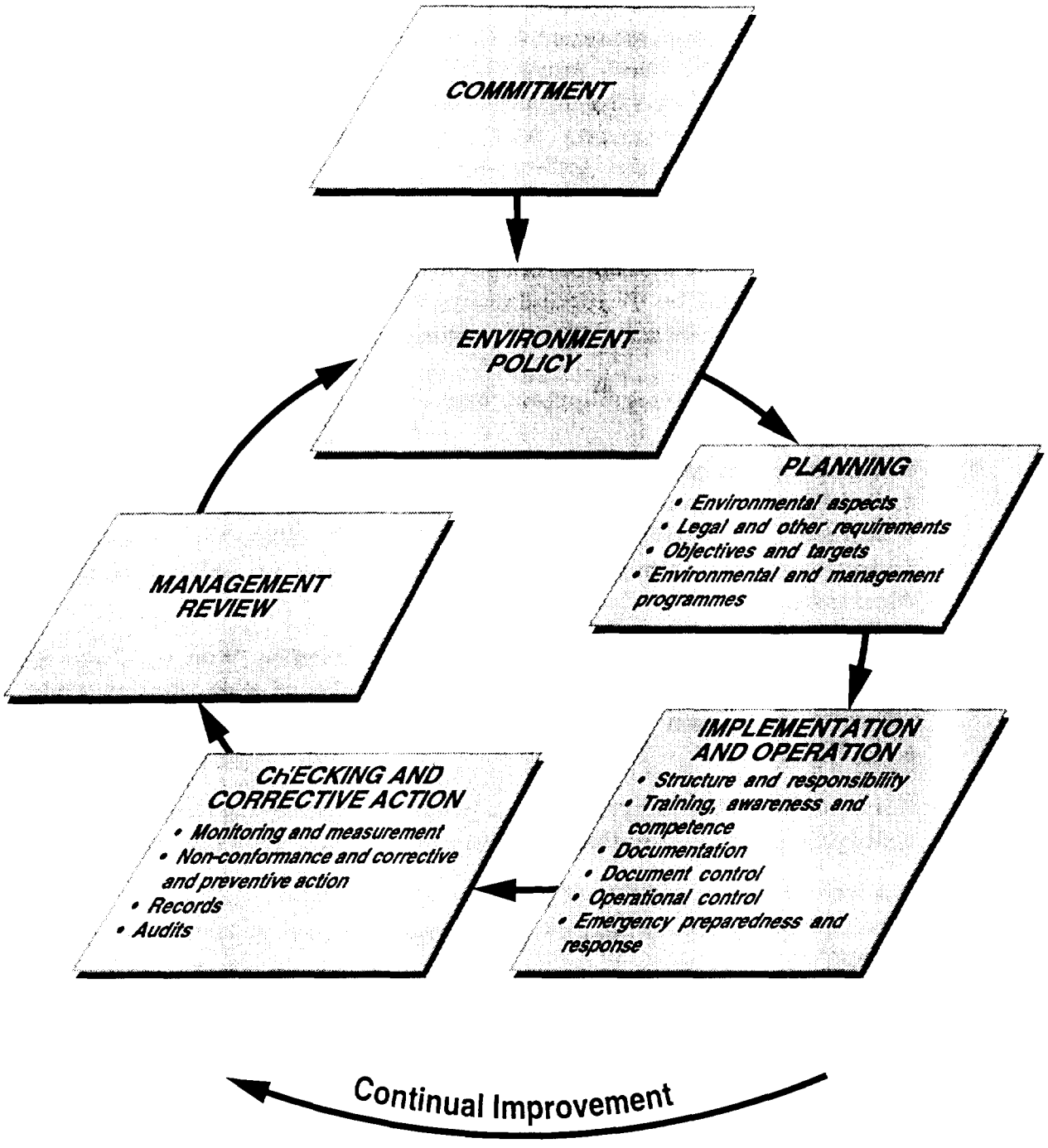


Figure 9.1: Environmental Management Model as recommended in AS/NZS ISO 14001 (1995)

being more advanced. For example, Engineering Division has achieved third party certification. Other Divisions are still in the early stages of formalising a system.

In 1995, a new Standard for Environmental Management (ISO 14001) was released in draft form. The ISO 14000 series of standards describe the basic processes for an effective environmental management system, including formulation of an environmental policy, setting objectives and targets, implementing a program to achieve those objectives, monitoring and measuring its effectiveness, and correcting problems. Figure 9.1 depicts this process which is based on continual review and improvement.

It is recommended that the Waste Management Action Plan be implemented under a formalised management regime in accordance with the Standard for Quality Management and Quality Assurance (AS/NZS ISO 9001), the Standard for Environmental Management (AS/NZS ISO 14001) and the IAEA RADWASS documents.

ANSTO's Waste Management Policy correctly places emphasis on waste minimisation through a number of measures including volume reduction, segregation at source and adoption of cleaner production technologies. There needs to be a forum for identification of opportunities for waste minimisation and for monitoring the successfulness of any implementation measures. To achieve this goal, **it is recommended** that a Waste Minimisation Working Party be established, chaired by the Manager, Waste Management Action Plan, and composed of staff from waste producers, waste management staff and other interested parties. Meetings of the Working Party should be advertised and open to anyone in the organisation who wishes to make suggestions or contribute ideas.

The need for training of ANSTO staff in radioactive waste management is a current priority due to retirement of professional staff in key positions over the last few years. These positions have been filled by professionals with no previous experience in the nuclear industry. To overcome this deficiency, **it is recommended** that a formal education and training program be initiated in radioactive waste management. This program should be organised by the Manager, Waste Management Action Plan in collaboration with ANSTO Training. It is suggested that the program be put together in collaboration with an overseas university which offers graduate courses in nuclear technology. It is anticipated that courses would involve major contributions from one or two overseas lecturers supplemented by ANSTO staff as appropriate. Both operational and research staff at ANSTO working in the waste management and environment protection areas should attend these courses. In addition, some funds should be made available for senior professional staff to attend specialist courses overseas.

ANSTO has a major R&D effort in radioactive waste management, mainly related to development of the Synroc process. Some of the science and technology developed from the Synroc program has a wider application (see Section 5.1.5). There is a need for closer links between researchers and operations staff to allow ANSTO's R&D to be applied to ANSTO's own wastes. To facilitate these links, regular waste management seminars will

In 1994, a Waste Management Strategies Working Party was formed to review ANSTO's policies and practices. That Working Party prepared a draft Waste Management Policy for consideration by the ANSTO Board.

Following Board approval of ANSTO's Waste Management Policy in July 1995, a Manager, Waste Management Action Plan was appointed. This currently is a part time position reporting to the Executive Director. The manager assembled a team of staff from five Divisions (Nuclear Technology, Environment, Government and Public Affairs, Materials and Safety) to carry out this review and to prepare the Action Plan itself. In addition, the manager has co-ordinated ongoing effort on waste management legacy issues and reported on progress to the SRC.

9.2 Future Needs

This review does not envisage any need to change the current responsibilities of the various organisational units for routine waste management and environmental monitoring operations. There is, however, a need to provide an organisational framework to ensure that the Radioactive Waste Management Policy is carried out and the Action Plan is implemented successfully.

Implementation of the Action Plan will require co-ordination of staff in most of ANSTO's Divisions. It is proposed that this be the responsibility of the Manager, Waste Management Action Plan. Individual tasks, as outlined in the Action Plan, would be managed by staff drawn from across the organisation in accordance with the expertise required. The management of these tasks would be a part-time responsibility carried out in addition to normal line responsibilities.

In the proposed structure, the Action Plan Manager would report to the Executive Director (the current situation). The overall direction of the Action Plan would be overseen by a Waste Management Steering Committee composed of appropriate Division Directors and the Action Plan Manager.

In implementing the Radioactive Waste Management Action Plan, ANSTO needs to provide its stakeholders with confidence that ANSTO's radioactive waste are, and will continue to be, managed in accordance with best international practice. This requires development of a management system in accordance with statutory regulations, relevant quality assurance standards and international standards for radioactive waste management, including the IAEA's RADWASS series of documents (see Section 1.2).

ANSTO has an ongoing commitment to the achievement of the quality system requirements as set out in AS/NZS ISO 9001. Although procedures are being developed for ANSTO as a whole, the responsibility for the development and implementation within Divisions rests with the respective Division Director. Currently, the level of development within ANSTO varies from Division to Division, the more routine operational Divisions

SECTION 9
ORGANISATIONAL ISSUES

9.1 Current Arrangements and Responsibilities

The current organisational arrangements for waste management and environment protection at LHSTC are set out in the document "ANSTO Safety Regime" (Information Circular No. 29/1994, issued 23/12/1994). Under this arrangement, spent fuel, waste storage and effluent discharge are the operational responsibilities of the Nuclear Technology Division which operates HIFAR and ANSTO's waste management facilities. Internal monitoring and review is carried out by Safety Division. The Government and Public Affairs Division is responsible for administrative arrangements for spent fuel management and regulatory issues including the Trade Waste Agreement with Sydney Water. External and regulatory arrangements have been described in Section 2 of this report.

The handling, transport, treatment and storage of radioactive wastes at LHSTC is the responsibility of the Waste Management Section which is part of the Nuclear Technology Division. This section currently comprises 19 staff including a Section Head, two Process Area Leaders and 16 plant operators. One Process Area Leader is responsible for liquid and solid wastes, spent fuel storage and effluent treatment. The other Leader is responsible for analytical and decontamination operations, which include routine low level liquid and effluent analyses, analytical support for HIFAR, active area cleaning, equipment decontamination, laundry operations and disposal of non-radioactive chemicals.

On-site monitoring is the responsibility of Safety Division in respect of airborne emissions and Environment Division for solid and liquid monitoring. Recently, responsibility for routine use of the ADDCOR computer program (described in Section 6.4) has been transferred from Environment Division to Safety Division.

The Environment Division is responsible for off-site environmental monitoring, including preparation of the Annual Environment Monitoring Report. Two staff (one of whom is part time) are dedicated to sample collection, preparation and environmental reporting. Radiochemical analyses are undertaken by the Environmental Monitoring Laboratory which is part of the Environment Division. The Environmental Monitoring Strategy Working Party (comprising professional staff from four Divisions) has been set up to review the monitoring program and to make recommendations to the Director, Environment Division.

TABLE 8.1
The ANSTO Environmental Monitoring Program ... continued

Sample	Station	Frequency	Collection Details	Sample preparation and analysis
Sand/soil	LFBG	If indicated by annual dose rate survey	1 kg, from surface	Gamma spectrometry on sieved and ashed sample. Gross α, β counting.
	Effluent pipeline	If indicated by six monthly dose rate survey	1 kg, from surface	as above
	T2: Bardens and Mill Creek (above junction)	Yearly	From creek bed	as above
Sewage sediment	Cronulla Sewage Treatment Plant	six-monthly	1 kg sample	Gross α, β counting, γ spectrometry
Biological samples	off Potter Point, and appropriate reference samples	six monthly	Blackfish (*Luderick*): Barnacles; Green Alga (*Enteromorpha*)	Samples are dried and counted for γ activity
gamma survey (dose rate)	Effluent Pipeline	Six monthly	Pipe joints and ground surveyed. Soil is sampled if indicated by dose rate survey.	If collected, soils are sieved and ashed and counted for α, β, γ activity
	LFBG	Yearly	Burial trench surveyed in 1 m wide sweeps. Soil is sampled if indicated by dose rate survey	as above

TABLE 8.1
The ANSTO Environmental Monitoring Program

Sample	Station	Frequency	Collection Details	Sample preparation and analysis
Bund water	Three bunds	Monthly	1 L, sampled by bottle at the surface	Distilled for tritium; remainder of sample acidified and archived
Bund sediments	Three bunds	When cleared; minimum annually	Sampled from 200 L drum	assayed for gross α, gross β and γ activity
Creek water	MDP Creek (60m from outlet No 1)	Weekly	3 L, sampled with a polythene bottle	Weekly samples evaporated to dryness, the residue combined to form a monthly composite sample for α, β, γ counting. 250 mL collected weekly and distilled for tritium.
	Bardens Creek weir	Weekly	250 mL sampled from weir overflow	Distilled for tritium
	Weirs on Bardens Ck & MDP Ck; Strassman Ck	Monthly	1 L sampled after rain	Gross α, β according to Clean Waters Act Regulations
	Forbes Creek	Monthly	1 L sampled after rain	Distilled for tritium
	T2: Bardens & Mill Creek (above junction)	Yearly	5 L of surface water	Evaporated to dryness, residue counted for α, β, γ activity.
Estuary water	Woronora R	Monthly	250 mL sampled by bottle at the surface	Distilled for tritium
Sea water	Off-Potter Point	Six-monthly	1 L sampled at known positions	Distilled for tritium
Groundwater	Little Forest Burial Ground (LFBG)	Six monthly	MB Series bore holes; pumped dry, allowed to refill and sampled from the bottom of the bore	10 L sample evaporated to dryness; residue counted for α, β, γ counting. 250 mL distilled for tritium
Dust on air filters	LFBG	Quarterly	Duplicate samples on 0.8 mm aerosol filters	Sub-sampled for Be assay. Composite of quarterly samples for ^{239}Pu analysis by α spectrometry

8.4 External Radiation

Levels of external gamma radiation are measured at and in the vicinity of LHSTC using thermoluminescent (TLD) dosimeters issued by the Australian Radiation Laboratory (ARL). These dosimeters are placed at various points around the perimeter fence and at private houses in Barton Ridge, Engadine and Woronora. After exposure for four months, the TLDs are collected and returned to ARL for determination of absorbed dose in air.

In 1995, the dose rates at the perimeter fence varied from 0.9 to 2.4 mSv per year. The elevated doses at the southern and western side of the HIFAR fence are due mainly to nuclear materials in building 59. The upgrading of this building and movement of some waste materials will reduce this dose rate.

The dose rates in private homes ranged from 0.9 to 1.1 mSv per year, which is close to the average for capital cities around Australia (Hoffman *et al.* 1995).

8.5 Future Environmental Monitoring Program

The future monitoring program, as recommended by ANSTO's Environmental Monitoring Strategy Committee, is summarised in Table 8.1. The program is similar to that currently being carried out except that regular monitoring is proposed at the Cronulla STP and near the Potter Point outfall (see Section 8.3.1), and the monitoring of stormwater has been modified following the construction of new bunding systems (see Section 8.3.3). These recommendations will be submitted to ARL for comments.

8.3.3 Run-off from LHSTC

It is conceivable that contaminated water could be released following a spill of radioactivity within the LHSTC and subsequent rainfall. In this case, the water would, most probably, be released through the stormwater system. There are three discharge points (see Figures 8.1 and 8.3) for stormwater from the LHSTC:

(i) to MDP Creek which flows into the Woronora river,

(ii) to Strassman Creek which also flows into the Woronora river,

(iii) to Bardens Creek which flows into the Georges river via Mill Creek.

These small local streams are classified as class 'C' waters under the NSW Clean Waters Regulations (1972). In 1975, the then State Pollution Control Commission required that the stormwater be sampled periodically at selected locations in order to demonstrate compliance with the activity limits specified in the Clean Waters Regulations. Sampling points on Strassman Creek, Bardens Creek and MDP Creek are sampled and analysed for gross alpha and beta activity. The results are reported in the annual environmental reports (*e.g.* Hoffman 1996). No radiologically-significant releases have occurred.

In 1995, following a review of the stormwater system, small capacity concrete stormwater retention dams were constructed on the three main stormwater outlet points from the LHSTC (see Figure 8.1). The bunds are designed for the on-site containment and treatment of any small accidental spills or releases of contaminated liquid which enter the site stormwater system. They will also be used as environmental monitoring points.

The bunds are discharged daily in normal weather conditions in order to leave capacity for any spills that may occur. The bunds are left to discharge during rain periods. They are cleared of accumulated sediments every six months or as required. Many of the stormwater pipes were re-routed to ensure that as much as possible of the stormwater passes through one of the three bunds.

The construction of the bunds has eliminated the necessity for sampling at the former stormwater sampling points. Accordingly, the following sampling program has been introduced:

Bund water: Water from each of the three bunds is sampled monthly and measured for tritium. The residues from the tritium distillation will be archived in case later sediment assays show above-background levels of activity.

Sediments from bunds: The sediments will be assayed for gross α, gross β and γ spectra. In the unlikely event that the assays indicate significant levels of radionuclides, the sediment will be treated as low level waste. Otherwise they will be disposed of in a trench on site.

Airborne contamination at LFBG could potentially occur through wind suspension/resuspension of radioactive particulates at the ground surface. Surface contamination could arise following erosion of cover material, or the movement of contaminated groundwater to the surface, followed by precipitation of radionuclides. The airborne particulate pathway requires special consideration at LFBG since the site was also used for the disposal of beryllium oxide. Beryllium is not radioactive but is chemically toxic if inhaled as a fine dust.

The vegetative and clay/shale trench cover at LFBG is regularly inspected, and any sign of erosion or deterioration is remedied as soon as possible.

The radiation levels over the disposal trench area are close to background levels. Direct exposure to external radiation from buried waste would only become a consideration if the waste was exposed through erosion or subsidence of the cover, or transport of dissolved radionuclides to the surface by groundwater.

Based on the environmental pathway analysis presented above, the environmental monitoring program at LFBG is as follows:

Radiation survey: Annual surveys of the burial trenches are carried out using field dose rate monitors to check for surface contamination.

Soil: Soil samples are collected for assay if the gamma radiation survey indicates areas significantly above background.

Groundwater Monitoring: Groundwater samples from monitoring bores located inside the LFBG and outside the fenced area are analysed for tritium, gross alpha, gross beta and gamma activities every six months.

Creeks receiving runoff from the LFBG area: Annual samples of surface water and sand are collected from creeks just above the confluence of Mill Creek and Bardens Creek, (station T2, Figure 8.3), as a check on possible movement of contaminants from the LFBG. The results of gross alpha and beta, tritium and gamma analyses on these samples are published in the Annual Survey Reports.

Air sampling: Aerosol filters from the air sampling station near the burial trenches are assayed for beryllium and plutonium-239. No activity was detected in 1995 (Hoffman *et al.* 1996).

No changes to the environmental monitoring at LFBG are proposed although the situation will be regularly reviewed based on the results of ongoing measurements.

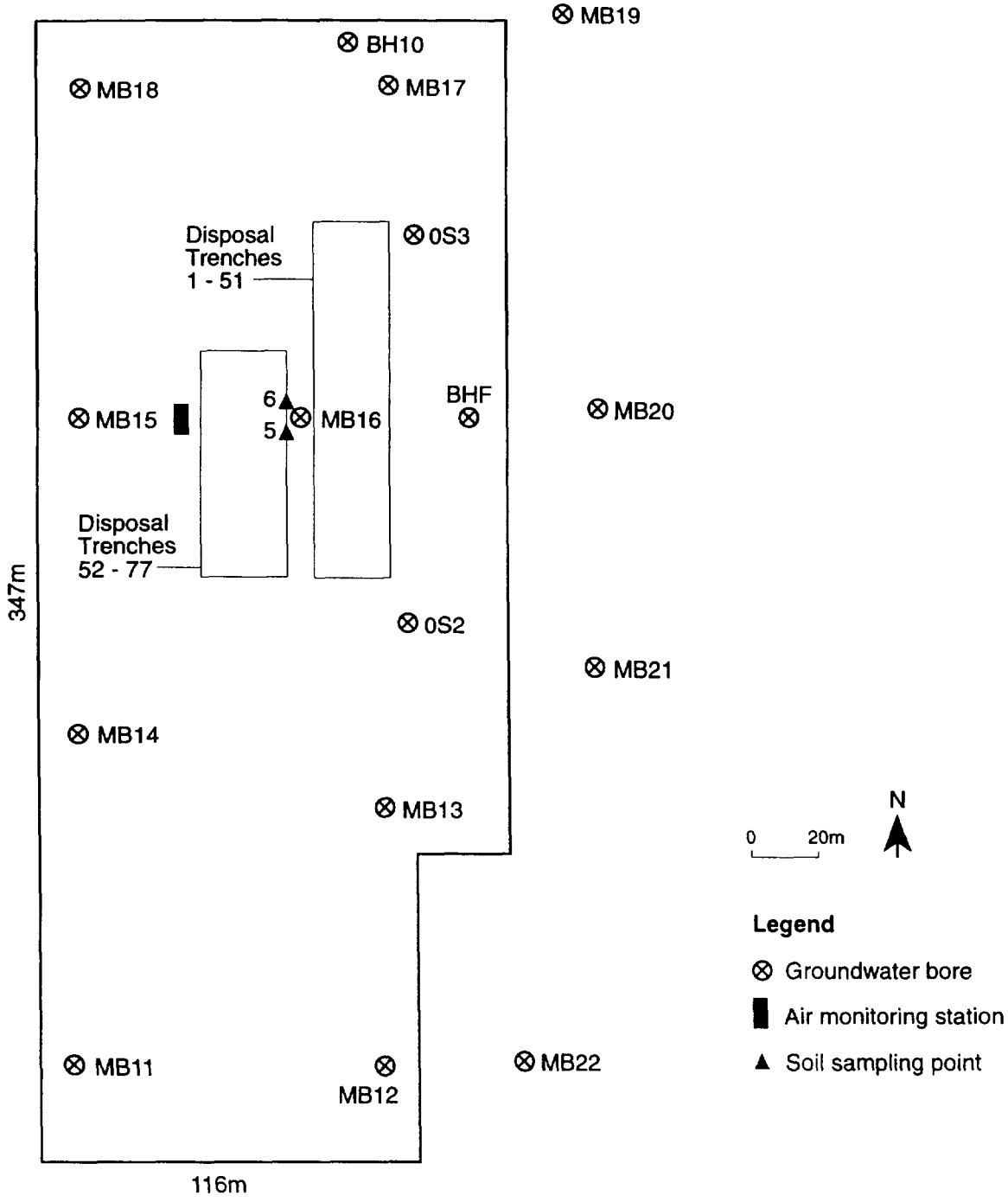


Figure 8.4: Little Forest Burial Ground - Location of Trenches, Groundwater Bores and Soil Sampling Points

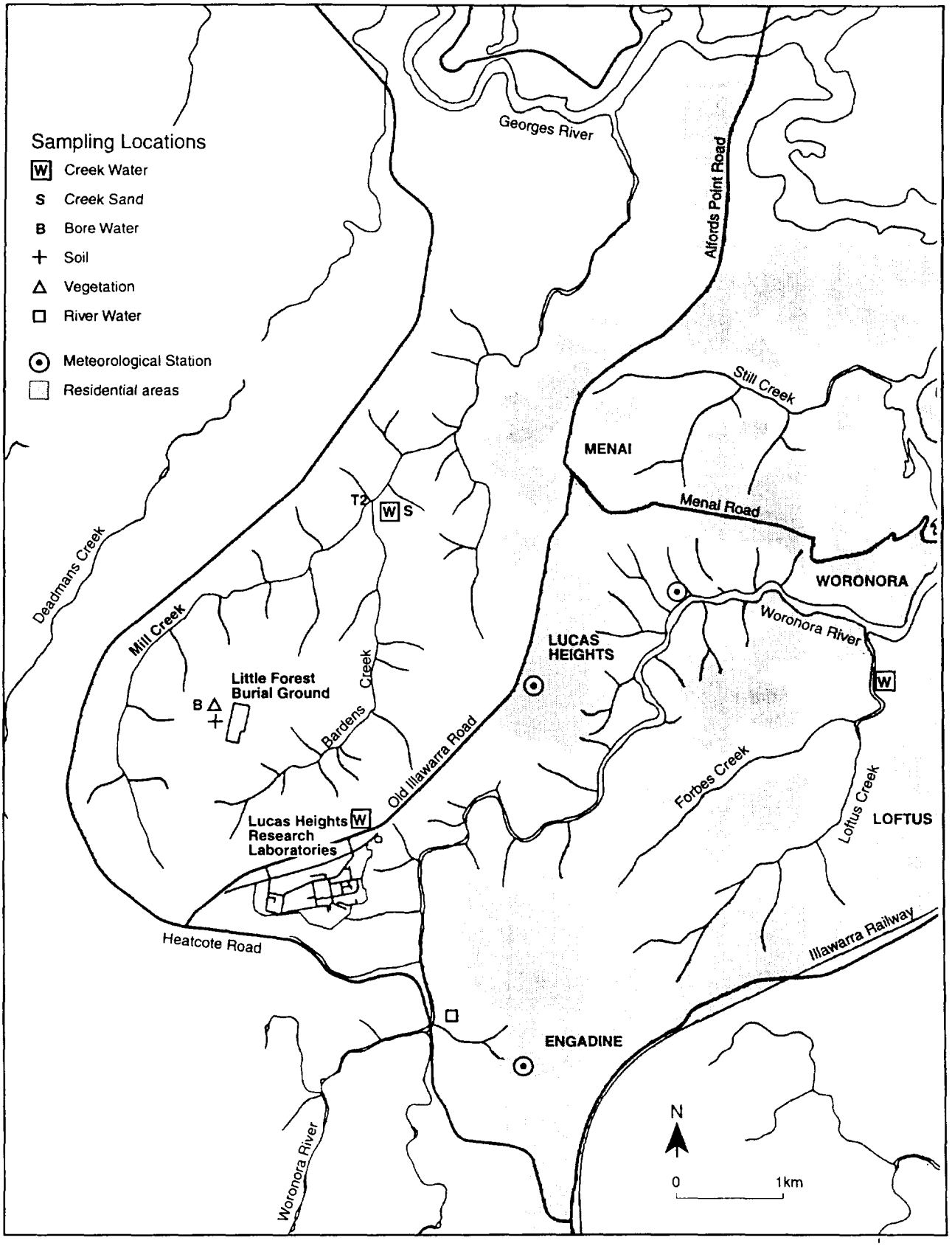


Figure 8.3: Location of Off-site Sampling Points

Seawater: Seawater samples will be collected every six months for tritium assay. The results will be correlated with the output of the three-dimensional model of the plume from the Potter Point outfall developed by Australian Water and Coastal Studies Ltd.

Biological sampling: The most likely scenario for exposure of members of the public would involve ingestion of fish or mussels containing radionuclides from the area near the Potter Point outfall. The recommended biological sampling program is one which is likely to maximise the chances of detecting radionuclides in environmental samples across a range of trophic levels. The following samples will be collected bi-annually and assayed for α, β and γ-emitting isotopes.

1. Blackfish (*Luderick*) being probably the fish most commonly caught from the rocks close to the outfall;
2. Barnacles being filter feeders which live very close to the outfall and are known to have relatively high bioaccumulation factors for a number of radionuclides; and
3. Green alga (*Enteromorpha*) being material which grows luxuriantly in the nutrient enriched environment near to the outfall. This alga is only a couple of cell layers thick and is therefore thoroughly exposed to any radionuclides dissolved in the sewage plume. Also, being a primary producer, algae represents a contrasting trophic level to the fish and barnacles.

The levels will be compared with those in appropriate reference standards.

8.3.2 The Little Forest Burial Ground (LFBG)

Between 1960 and 1968, the AAEC used a small area locally known as Little Forest (see Figures 8.3 and 8.4) for the disposal by burial of solid waste containing low levels of radioactivity. Areas adjacent to LFBG also have been used by various government agencies and private companies for the disposal of liquid industrial wastes, solid municipal wastes and nightsoil. The area was mined for clay and shale for brick making.

Possible human exposure scenarios associated with off-site transport of radionuclides would include the use of contaminated surface/ground waters for drinking purposes and watering of vegetable gardens, eating of contaminated freshwater, saltwater fish or shellfish, and inhalation of toxic or airborne particulate matter containing radioactivity.

Ground water and surface water associated with the LFBG and surrounding area is not currently utilised as a potable water supply, and the ephemeral nature of the streams excludes their use for any large scale irrigation of crops. The hydrogeological conditions at LFBG ensure that groundwater movement in the immediate area of the low-level wastes is very slow and most radionuclides, with the exception of tritium, are readily adsorbed onto the clay subsoil of the LFBG site.

In order to address these concerns, ANSTO, in 1993, initiated systematic studies of the dynamics of effluent flow from LHSTC through the sewer system to the Cronulla STP, and thence to the cliff face ocean outfall at Potter Point. The studies found that,

- The average transit time between the LHSTC and the Cronulla STP varies between 9.6 and 14 hours and dilution factors vary between 27 and 38.
- The transit time from the Cronulla STP to the Potter Point Outfall is about one hour.
- The observed dilution factor between the Cronulla STP and the Potter Point outfall is between 20 and 25 due, principally, to immediate mixing after discharge.
- The observed dilution factor between the cliff face outfall and the ocean sampling location varies between 2.5 and 21 depending on the ocean conditions.
- The overall dilution factor between the LHSTC and the ocean sampling location, therefore, varies between 1,500 and 14,000. Because ANSTO discharges are infrequent, the average dilution factor over one month would be much higher.
- The maximum concentration of gamma-emitting isotopes measured at the Cronulla STP were very low and, taking account of the various further dilutions, the levels of alpha, beta and gamma emitters are below the detection limits and well below WHO drinking water levels.
- Because of the large volumes involved, most of the alpha-activity passing through the Cronulla STP is derived, not from ANSTO, but from naturally-occurring radioactivity in domestic and industrial sources.
- The maximum level of tritium measured in the plume off Potter Point was 40 Bq L^{-1} at the surface under very calm conditions. More typical values are below 1 Bq L^{-1} which is similar to the tritium levels in rainwater throughout Australia. These values should be compared with the WHO reference concentration for tritium in drinking water (7600 Bq L^{-1}).

ANSTO has contracted Australian Water and Coastal Studies Ltd to model the plume dispersion from the outfall on the days in which the radioisotope monitoring is undertaken. The purpose of the modelling is for interpretation of measured tritium results.

The large dilution factors in both the sewer system and the ocean, ensure that the levels of radioactivity in the water near the Potter Point outfall are of no radiological significance to members of the public or workers at the Cronulla STP.

After reviewing the results of the investigations at the Cronulla STP and Potter Point, the following future sampling program has been recommended by ANSTO's Environmental Monitoring Strategy Committee.

Sewage sludge Cronulla STP: Samples of sewage sludge will be collected every six months and assayed for gross α, gross β and γ-spectra.

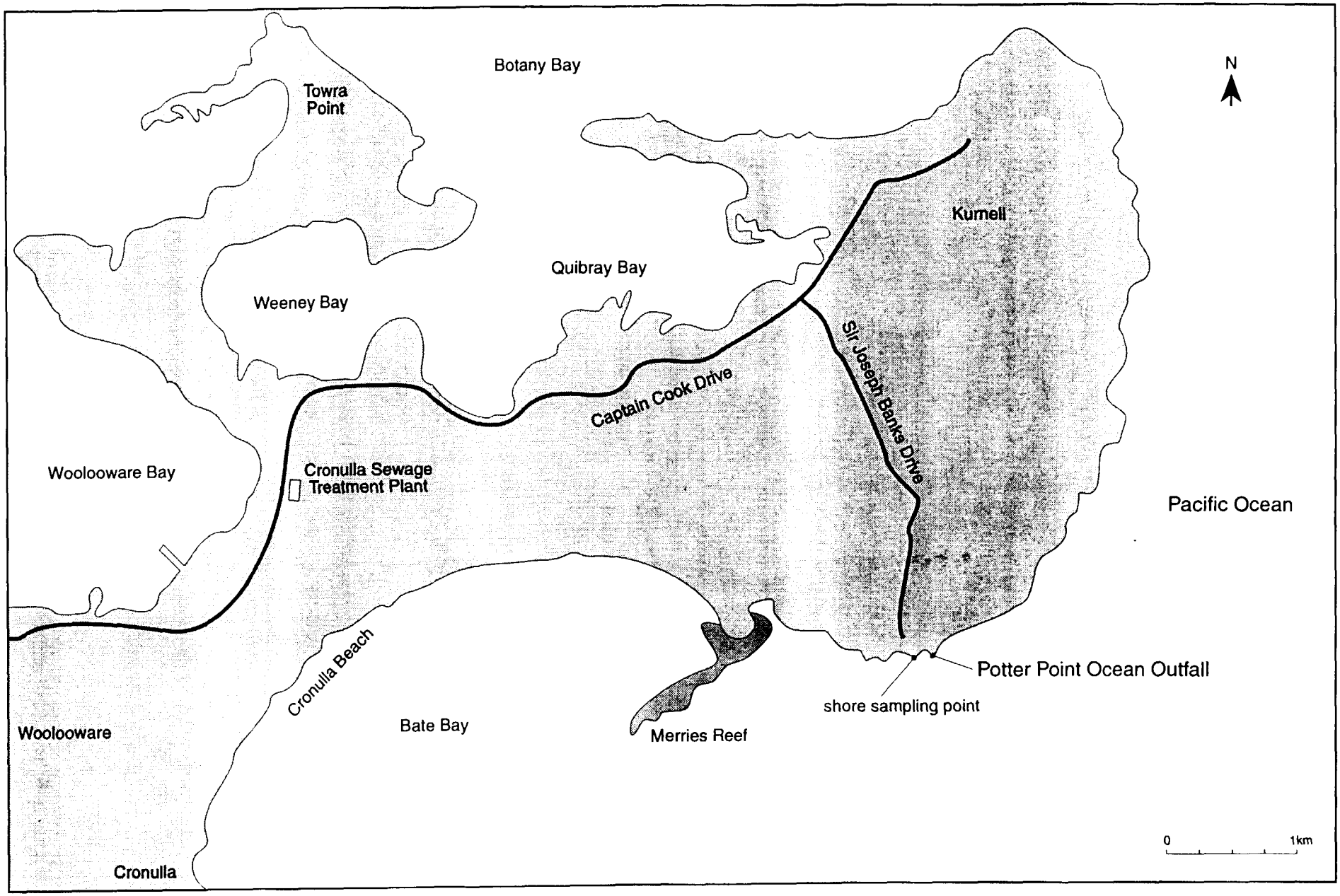
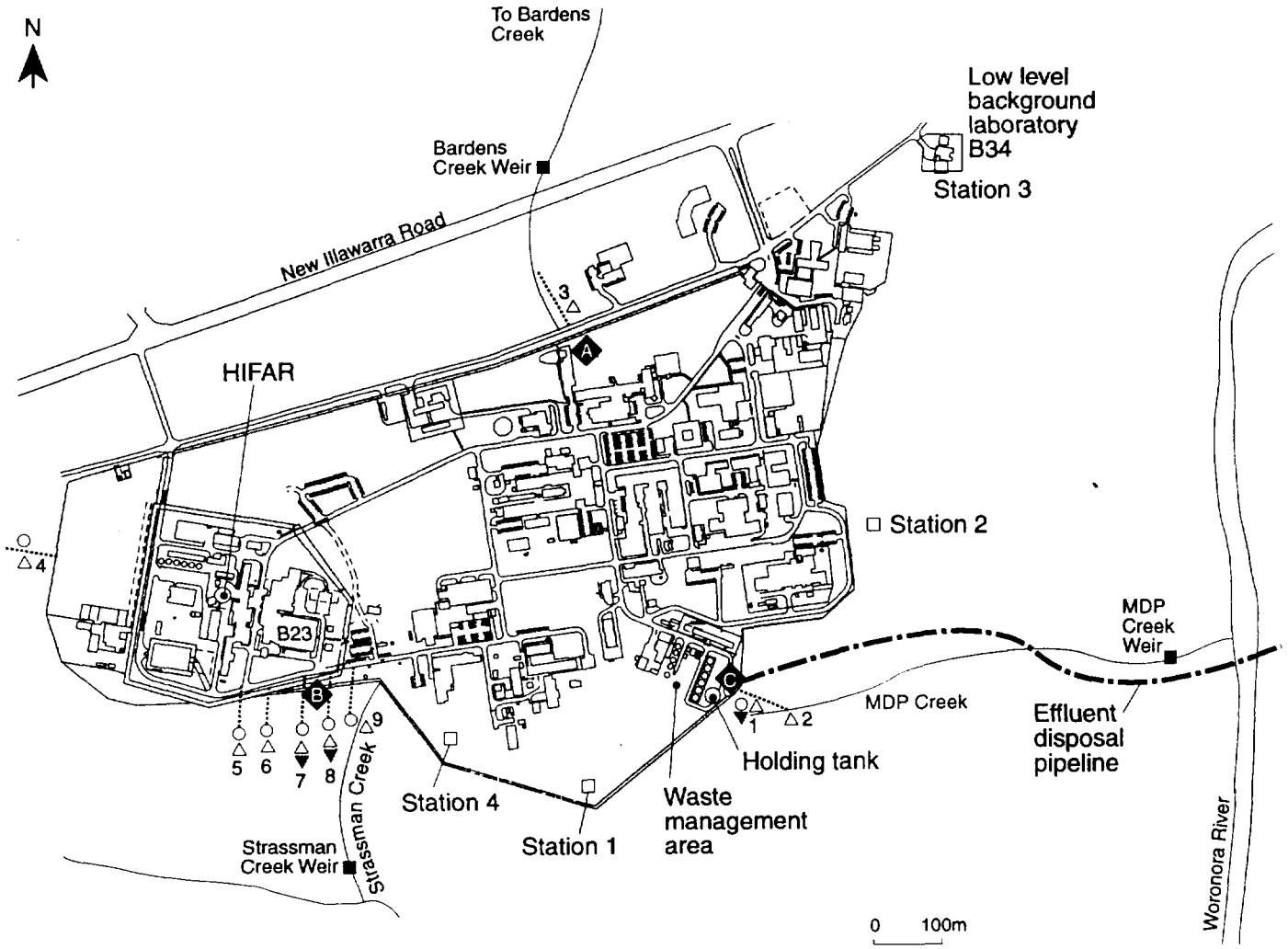


Figure 8.2: Location of Cronulla Sewage Treatment Plant and Ocean Outfall at Potter Point



□ Continuous air sampling stations
■ SPCC sampling point
····· Stormwater drain outlet

Stormwater drain sampling:
○ Soil
△ Water
▼ Vegetation

Stormwater retention dams:
◆A ◆B ◆C

Location of drain sampling points

1 20m downstream of outlet no.1
2 60m downstream of outlet no.1
3 Behind building 1
4 On west fence road
5 Opposite Fermi Street
6 Opposite building 23
7 No. 1 opposite Strassman Crescent
8 No. 2 opposite Strassman Crescent
9 Opposite meteorological tower

Figure 8.1: Location of Stormwater and Air Sampling Points

radionuclides in the environment from ANSTO operations have been very low and of no radiological significance.

8.3 Environmental Pathways

The main pathways by which radionuclides could enter the environment from LHSTC and, therefore, could lead to radiation exposure of members of the general public are:

- atmospheric discharges from stacks (including tritium, fission products, activation products and noble gases released from isotope production facilities, research laboratories and the HIFAR research reactor);
- discharge of low-level liquid effluent, via the Sydney Water Corporation Ltd sewer system and released to the ocean at the cliff face outfall at Potter Point on the Kurnell peninsula;
- radionuclide transport by surface/ground water and/or contaminated airborne particulate dispersion from the Little Forest low-level radioactive waste Burial Ground (LFBG);
- accidental releases or spillages which could be released from the LHSTC by run-off, most probably through the stormwater system.

Atmospheric discharges were discussed in Section 5.

8.3.1 Discharge of Effluent to Sewer and Potter Point Outfall

The low-level liquid effluent generated at the LHSTC is chemically treated and analysed to verify compliance with authorised discharge limits before discharge to the sewer. As indicated in Section 6, the levels of radioactivity in the effluent have always been below the discharge limits.

The ANSTO liquid effluent disposal pipeline, which runs above ground for much of its length, is shown on Figure 8.1. Surveys of dose rates along the pipeline are performed as part of the regular program of inspection and maintenance of the pipeline. The dose rates recorded during 1995 were less than 0.1 μSv per hour, which is consistent with background levels.

The effluent from ANSTO passes through the Cronulla Sewage Treatment Plant (STP) and, along with other effluent from that plant, is discharged to the ocean at the Potter Point outfall (see Figure 8.2).

Until 1993, ANSTO did not undertake regular measurements at Potter Point. However, during the Commonwealth Government Research Reactor Review (McKinnon 1993), public interest groups including the Sutherland Shire Council and the Surfriders Association raised concerns that ANSTO liquid effluent may be a radiation hazard to swimmers and surfers in the vicinity of the Potter Point outfall.

SECTION 8
ENVIRONMENTAL MONITORING

8.1 Background

A comprehensive program of environmental monitoring has been carried out by the AAEC/ANSTO since 1959. The initial sampling program was developed and implemented before HIFAR was commissioned and any radioactive active wastes were produced.

The sampling program was expanded in the mid-1960s because of the need to establish the base levels of background radioactivity which were being perturbed by the fall-out products from atmospheric nuclear weapons testing. It was streamlined in 1970 when the Australian Radiation Laboratory initiated Australia-wide monitoring to observe both short and long-lived radionuclides in fallout. In the early 1980s, the sampling program was further modified so that compliance with limits set under the NSW regulations could be readily demonstrated.

ANSTO's current environmental monitoring strategy is designed to ensure that any radiation or chemical exposure arising from operations at the LHSTC are within the limits set by regulatory requirements and relevant NHMRC and international guidelines (see Section 2).

Following the withdrawal of the NSW EPA from monitoring of the site (see Section 2.2.1) and pending the establishment of the Australian Institute of Radiation Protection (AIRP), an agreement was reached between ANSTO and the Australian Radiation Laboratory (ARL) for the interim monitoring and evaluation of effluent discharges. ARL may request samples from ANSTO, collect samples for assay and/or audit ANSTO's procedures. The Safety Review Committee (SRC) periodically reviews ANSTO's environmental monitoring policy and practices. ARL is represented on the SRC.

8.2 Environmental Monitoring Reports

The results of ANSTO's environmental monitoring program are reported in annual reports. In the latest available report (Hoffman *et al.* 1996), it was concluded that all low level liquid and gaseous effluent discharges complied with existing discharge authorisations and relevant environmental regulations.

The environmental data from 1959 to 1992 was assessed in detail in ANSTO's submission to the Research Reactor Review (ANSTO 1993). In general, the levels of

7.11 Recommendations - Spent Reactor Fuel

- It is recommended that the following strategy be employed in the management of ANSTO's spent fuel inventory:

  * take up the UK offer of a four-year reprocessing program for the UK-origin spent fuel,
  * after that four year period, ship the remaining (US-origin) HIFAR and Moata spent fuel to the US over a seven year period,
  * if appropriate, prepare a proposal for the domestic conditioning of spent fuel from HIFAR and any replacement reactor.

- It is recommended that priority be given to refurbishment of the "Dounreay" flasks and regular inspection of all ANSTO's facilities for spent fuel storage. It is further recommended that an early opportunity be taken to phase out the use of the "Dounreay" flasks for storage, once the expected program of overseas shipments of spent fuel is underway.

7.10 Future Options

The future options for the management of remaining holdings of spent fuel, and for future arisings, are constrained by the fact that HEU spent fuel of the type used in HIFAR cannot be stored indefinitely, or disposed of, without appropriate processing. As a consequence there are only two ultimate options; overseas shipment of the spent fuel for reprocessing or domestic processing.

In the case of overseas shipment, Australia has received an offer to be part of a four-year multi-country program of reprocessing at Dounreay. This program would account for all of the holdings of UK-origin spent fuel. However, to take advantage of this option a firm commitment to the four year program must be made within the next few months and Dounreay must receive sufficient such commitments to justify a commercial decision to keep the Dounreay facility operational. The continuation of Dounreay reprocessing is also dependent upon other UK Government considerations currently being reviewed. In respect of the US-origin fuel elements, the US Department of Energy recent announcement means that in principle all these HIFAR and Moata elements may be returned to the US over the next 13 years. It is a condition of acceptance of these elements that ANSTO enters an agreement with the USDOE on a timescale for conversion of HIFAR within the next 10 years to operation on low enriched uranium fuel.

In addition to the above overseas options, there are a few other countries with the potential capability to reprocess HIFAR-type spent fuel. It is possible that these countries could offer a commercial service subject to non-proliferation and other policy issues being resolved.

As an alternative to overseas shipments, a facility could be built in Australia to condition the spent fuel for ultimate disposal in an intermediate level waste repository. The costs of this alternative are estimated to be comparable to those overseas options. A domestic conditioning facility also has the advantage that it is the only option that would provide for future spent fuel arisings from any replacement reactor to HIFAR, at which time it is expected that the overseas options will be no longer available.

It is recommended that the following strategy be employed in the management of ANSTO's spent fuel inventory:

- take up the UK offer of a four-year reprocessing program for the UK-origin spent fuel,
- after that four year period, ship the remaining (US-origin) HIFAR and Moata spent fuel to the US over a seven year period (this will cover all the spent fuel holdings and arisings up to the current operating horizon of HIFAR, around 2003),
- if appropriate, prepare a proposal for the domestic conditioning of spent fuel from HIFAR and any replacement reactor.

Following a decision of the ANSTO Board, Moata ceased operations in May 1995. The fuel that was used in Moata is generally described as 'irradiated fuel' rather than spent fuel since the burnup achieved is very much less than for HIFAR spent fuel. All of the irradiated fuel is currently stored in the Moata fuel storage block pending development of a comprehensive plan to cover the decommissioning of the reactor and disposition of the fuel.

The irradiated fuel inventory for Moata (Table 7.3) consists of 191 plates of 90% enriched uranium, each containing 21.92 g uranium-235 and with a total mass for all the plates of 4.16 kg uranium-235, all of which was obtained prior to 1965. The HEU for all these plates is of US-origin and the plates were all manufactured in the UK. Nine plates with significant burnup were withdrawn early from service because corrosion and pitting was identified during examination in the hot cells, and two plates with significant burnup were withdrawn following mishandling in a hot cell operation which left the plate cladding intact but badly scored. Two further plates had been withdrawn from service following identification of pitting in the cladding during the initial cold fuel element inspection. These withdrawn plates are included in the 191 plates stored in the reactor storage block.

The lifetime integrated power output of Moata was 626 MWh, equivalent to only 63 hours of HIFAR power output. Hence the radioactivity of the Moata plates is very much lower than that of HIFAR spent fuel.

TABLE 7.3
Moata Irradiated Fuel Plates

No. Plates	Burnup	Comments
166	0.7-5.5 MWh	
9	0.7-1.5 MWh	Withdrawn from use in 1975
2	1.3 & 2.8 MWh	Withdrawn from use in 1982
10	<0.1 kWh	
2	<0.1 kWh	Withdrawn from use in 1969 & 1975
1	<0.1 kWh	
1	<0.1 kWh	
Total 191		

The 191 irradiated fuel plates are equivalent in volume to 15 or 16 HIFAR fuel elements. The options for managing and disposing of Moata irradiated fuel are the same as those for HIFAR spent fuel and the disposition of the Moata fuel will therefore be managed in parallel with the HIFAR fuel. For example, as the irradiated Moata fuel is all of US-origin, it is included in the USDOE proposal to take back foreign research reactor fuel.

international consensus on what methods of direct disposal of spent fuel can be considered "practicably irrecoverable".

Studies on disposal options for high-level waste from reprocessing and for spent power reactor fuel "have demonstrated that safe disposal is feasible in many types of geological media and that both short-term and long-term safety can be evaluated with acceptable confidence" (OECD 1993). Canada, Finland, Spain, Sweden, and United States are planning the direct geological disposal of spent power reactor fuel. Belgium, France, Japan, the Netherlands, Switzerland, and the United Kingdom intend to reprocess spent fuel and then dispose of the resulting high-level waste. Germany is considering both direct disposal and reprocessing options. In one option, research reactor fuel would be stored for 40 years followed by geological disposal in a cask similar to those used for light water reactor fuel.

The sizes of proposed overseas repositories are very large compared to Australia's inventory of research reactor fuel. In the United States, a site at Yucca Mountain is being characterised to determine its suitability for disposal of spent fuel containing over 86,800 tU. The smallest facility being planned by these countries is in Finland. It will have a capacity for fuel elements containing 1,840 tU (OECD 1993). These amounts are much greater than the 0.23 tU in the HIFAR spent fuel.

Many of the long term environmental release criteria for geological repositories are a function of the total inventory in the repository. The comparatively small amount of HIFAR spent fuel means that source terms for evaluating environmental pathways from a potential repository site would be orders of magnitude less than the repositories being considered overseas.

Establishment of a geological repository for the direct disposal of spent fuel in Australia should not be considered until there is a better international consensus on waste packaging and repository design and unless the disposal of spent fuel containing HEU is permitted under international guidelines. Alternatives based on domestic conditioning of the spent fuel or encapsulation of the wastes into SYNROC in a form suitable for disposal as long-lived intermediate level waste offer potential advantages in this respect.

7.9 Moata Spent Fuel

The 100 kW research reactor Moata used twelve fuel elements in its core; each element typically consisting of 12 plates containing highly enriched uranium. The number of fuel plates in the core increased from 139 for the initial cold fuel charge in 1961 to 143 plates in 1993, the increase being required to maintain adequate excess reactivity. Moata essentially used throughout its operating life only the original core loaded in 1961. The construction of the individual fuel plates for Moata is aluminium clad uranium/aluminium fuel similar to those for HIFAR.

There has been no recorded case where a package designed for transporting significant quantities of radioactive materials or spent fuel (a Type B package) has released its radioactive contents following a transport accident. In the 35 years experience of transporting such radioactive materials around the world in accordance with the IAEA Transport Regulations, there have been no deaths or injuries incurred as a result of the radioactive nature of the material.

In late 1992 the public controversy over a shipment of plutonium from France to Japan led the relevant international organisations to re-examine the issue of maritime transport of highly radioactive materials. A Joint IAEA/IMO/United Nations Environment Program (UNEP) Working Group considered a number of issues and prepared a *Code of Practice for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High Level Radioactive Wastes in Flasks on Board Ships*, which was adopted by the IMO in November 1993. The Code sets standards for the design and construction of ships carrying these materials.

ANSTO's LHRL-120 cask is a Type B(U) cask under the IAEA definitions (a category of Type B cask specially certified to carry spent nuclear fuel), belonging to ANSTO and designed and built specially for the carriage of HIFAR spent fuel. The cask holds a valid Competent Authority Certification Approval from the Australian Maritime Safety Authority (Commonwealth Department of Transport and Communications) which certifies, *inter alia*, that the design of the cask meets all relevant provisions of the IAEA Regulations for the Safe Transport of Radioactive Materials. The certification has been validated by the Australian Radiation Laboratory, and by the US and UK Departments of Transportation.

It is noted, however, that there is at present no enabling legislation to give effect to the Transport Code for road or rail shipment in Commonwealth places or by Commonwealth agencies. There is also no Competent Authority formally designated in the Code for surface transport by the Commonwealth. For the purposes of the April 1996 shipment, the Australian Radiation Laboratory (ARL) were designated by the responsible Minister to act as the Competent Authority for the road transport component of the shipment. In respect of any future shipments, action is in hand to amend the Code of Practice to formally designate ARL as a Competent Authority and a regulation is being prepared under the Nuclear Codes Act to give legislative effect to the Transport Code in respect of road transport under Commonwealth jurisdiction in Australia.

7.8 Disposal in Australia

Disposal in Australia is considered as a long-term option for conditioned HIFAR spent fuel as well as for spent LEU fuel from any replacement reactor. Under international safeguards agreements, disposal in a form preventing the application of safeguards is not possible unless the material is considered by the International Atomic Energy Agency (IAEA) to be "no longer usable for any nuclear activity relevant from the point of view of safeguards, or has become practicably irrecoverable" (IAEA 1971). There is as yet no

7.7 Transportation of Spent Fuel

The transport of radioactive materials is governed by the provisions of the "Regulations for the Safe Transport of Radioactive Material" issued by the IAEA. The IAEA Transport Regulations were first issued, at the request of the United Nations, in 1961 and have been updated regularly since. They have been adopted as, or used as the basis for, national regulations in essentially all the member countries of the IAEA including Australia where these Regulations are adopted into the *Australian Code of Practice for the Safe Transport of Radioactive Substances 1990*, produced under the *Environment Protection (Nuclear Codes) Act 1975*, and adopted by States and Territories under their radiation control legislation. The IAEA Regulations have also been incorporated into all the major international conventions and requirements controlling the transport of dangerous materials, including the International Maritime Organisation (IMO) Dangerous Goods Code.

The objective of the IAEA Transport Regulations is to protect the public, transport workers and property from both the direct and indirect effects of radiation during the transport of radioactive materials. The approach also ensures there is no risk to other cargoes carried in the same vessel. This is achieved by limiting the nature and activity of the radioactive material which may be transported in a package of a given design, by specifying design criteria for each type of package, and by recommending simple rules for handling and stowage during transport. Package design is essential to ensuring inbuilt safety.

The designs for Type B packages, which are used for highly radioactive material such as spent nuclear fuel, must enable the packages to withstand the effects of a severe accident without releasing their radioactive contents. They must meet stringent leak tightness provisions and satisfy mechanical and then thermal (crash and fire) tests and a water immersion test. There are drop tests, one from a height of nine metres onto an essentially unyielding surface and the other, a puncture test onto a steel bar. The thermal test subjects the package to a hydrocarbon fuel/air fire with an average flame temperature of 800°C for thirty minutes. The water immersion test is that the package be immersed under a head of water of at least 15 metres for a period of not less than eight hours, and at 200 metres for not less than one hour, and in the attitude for which maximum leakage would be expected.

It is important to note that the IAEA specified tests are not intended to replicate directly any specific transport accident. They are intended to simulate the damage to a package which would result under normal transport conditions or in a severe transport accident as appropriate. As a US Department of Energy (DOE) study has noted, "While one can postulate accidents that fall beyond those covered by the IAEA standards, the likelihood of these accidents is so low that they do not pose a credible threat to public health and safety" (USDOE 1993 p.5).

(22,000 elements). The US would take over ownership of all returned elements and no wastes would be returned to Australia. Foreign research reactor operators in developed countries would pay a fee on delivery to cover all future storage and disposal costs. Shipments to the US could commence by the end of 1996. However, there is still a possibility that legal challenges by opponents of the policy could delay or prevent shipments.

7.6 Shipment for Reprocessing in the UK

In April 1996, 114 spent fuel elements were shipped to Dounreay in the UK for reprocessing and recovery of the valuable unused HEU. Arrangements for this shipment included the conclusion of an Australian/UK Memorandum of Understanding (MOU) on reprocessing. This MOU embodies the acknowledgment by the Australian Government of the principle of the eventual return of the separated wastes from this shipment and any future shipments. It also acknowledged the acceptability to Australia of the specification for the cemented intermediate level waste form resulting from reprocessing.

AEA Technology has offered to reprocess the remaining UK-origin spent fuel from HIFAR at its facility in Dounreay in a proposed four-year reprocessing campaign in combination with fuel from two European customers. A UK Government decision on the future of the Dounreay MTR reprocessing facility is dependent upon this multi-country campaign going ahead. Temporary storage of the waste in the UK for up to 25 years is envisaged. Reprocessing say 500 HIFAR spent fuel elements of non-US origin could produce 140 stainless steel 500-litre drums of intermediate level waste which would need to be shipped in shielded containers. The returned waste would not be suitable for near surface land disposal. A decision on this offer by the UK awaits the outcomes of funding submissions in the context of the Federal budget process.

Reprocessing has the advantage of removing the HEU and converting the remaining material into a well defined waste form suitable for disposal as intermediate level waste. Unlike the spent fuel, which is subject to stringent international safeguards because of its contained HEU, there would be no NPT safeguard requirements on the waste. Hence the waste could be disposed of in a geological repository without the difficult task of proving that the material was practicably irrecoverable, as required under international safeguards agreements.

Sending HIFAR spent fuel for reprocessing in the UK still requires that Australia develop a geological repository for intermediate level waste. Given that, in the context of any new Australian research reactor, it will eventually be necessary to establish an independent domestic solution for spent fuel management, it is appropriate to also consider potential domestic conditioning options for future spent fuel and for any current spent fuel that may be unable to be returned to the USA.

3. manufacturing additional transport/storage casks to the LHRL-120 cask design to provide interim dry storage. Six casks would provide additional storage for 720 elements. This option has high initial costs but would prepare the fuel for transport to another site.

The international use of wet and dry storage facilities for storing spent nuclear fuel has demonstrated that spent fuel can be safely stored for long periods of time under both wet and dry storage conditions (IAEA 1988, 1990, 1991, 1992). Worldwide, over 50,000 tU of spent power reactor fuel is stored at reactors and the remainder at central storage facilities. However, it should be noted that power reactor fuel has a different cladding to research reactor fuel.

The Research Reactor Review, conducted in 1993 to examine the need for a new multi-purpose reactor for Australia, concluded that the present interim storage of spent fuel at the ANSTO site is in conformity with world best practice and is the most practicable and safest short-term storage arrangement. However, the Review identified the need to put in place a clean demonstrable strategy for the long-term management and ultimate disposition of spent fuel (McKinnon 1993).

In response to this recommendation, the Australian Government established an Inter-Agency Committee to review all options for the management of high level wastes/research reactor spent fuel over the longer term. The issues relating to these various options, as presented to the Inter-Agency Committee, are reviewed in the Sections following.

7.5 Shipment for Storage and Disposal in the US

The bilateral Australia/United States treaty under which HEU for HIFAR fuel was supplied to Australia implicitly obliges Australia to keep the spent fuel available for return to the United States should the US exercise their right under the Agreement to recover it. The US has both a non-proliferation policy requirement and a contractual obligation to accept the return of US-origin spent fuel from HIFAR.

In December 1985, the Australian Government approved the shipment to the US of 450 HIFAR spent fuel elements for reprocessing in a US Department of Energy (USDOE) facility. A contract was signed with USDOE for reprocessing the 450 elements and, in late 1988, the US designed and manufactured LHRL-120 Cask was delivered to LHSTC. However, in January 1989, before the first shipment could be prepared, the USDOE announced that no further deliveries of spent fuel would be accepted pending a review of its policy on return of "foreign" research reactor spent fuel.

In July 1993, the USDOE announced the decision to resume accepting foreign research reactor spent fuel containing US origin HEU subject to completion of an Environmental Impact Statement (EIS). This EIS process was completed in February 1996. On 13 May 1996, the USDOE formally announced its decision to take back to the USA over a 13-year period all foreign spent research reactor fuel containing uranium of US origin

Spent fuel is discharged from HIFAR every month and moves through a sequence of storage locations. In mid-May 1996, the number of spent fuel elements in the different locations were:

i) 1086 elements in dry storage in the engineered Spent Fuel Facility in building 27. This facility has maximum capacity for 1100 elements but, for operational reasons and to permit safeguards inspection activities, 1086 elements is regarded as full,

ii) 175 elements in seven "Dounreay" transport flasks. The Dounreay flasks, each with a capacity of 25 elements, were originally built to transport spent fuel to the UK reprocessing facility at Dounreay, Scotland,

iii) 288 elements in underwater storage in a pond. Extra racks are being manufactured to increase the total capacity of the pond to 391 elements, though this pond was never intended for extended storage of spent fuel and its use for storage interferes with its use as a research and service irradiation facility,

iv) 18 elements in a cropping pond and testing pond,

v) 13 elements in reactor storage blocks.

All these facilities are monitored and IAEA inspectors periodically verify that there has been no unauthorised movement of fuel. With the reracking of spent fuel in the pond and the recent spent fuel shipment to Dounreay, ANSTO will have sufficient interim storage capacity at LHSTC for all spent fuel expected to be discharged from HIFAR through to 1998.

Regular testing of the cask seals is undertaken. A recent testing of the Dounreay flasks has revealed that some of the seals are in need of replacement. Refurbishment of these flasks requires that they be unloaded. **It is recommended** that priority be given to refurbishment of the "Dounreay" flasks and regular inspection of ANSTO's other facilities for spent fuel storage. Noting that these flasks were designed to older standards and are unlikely to be licensed for transport purposes, **it is further recommended** that an early opportunity be taken to phase out the use of the "Dounreay" flasks for storage, once the expected program of overseas shipments of spent fuel is underway.

The need for additional storage will depend on whether the international opportunities to accept spent research reactor fuel proceed as expected. Three methods have been identified to provide additional interim storage from 1998 onwards, if required as a fallback option:

1. installing an additional 40 lined storage tubes in the dry storage facility to increase the capacity by 880 elements,
2. cutting the fuel elements into their component plates using an industrial laser. This would allow twice as many fuel elements to be stored in the existing dry storage facility.

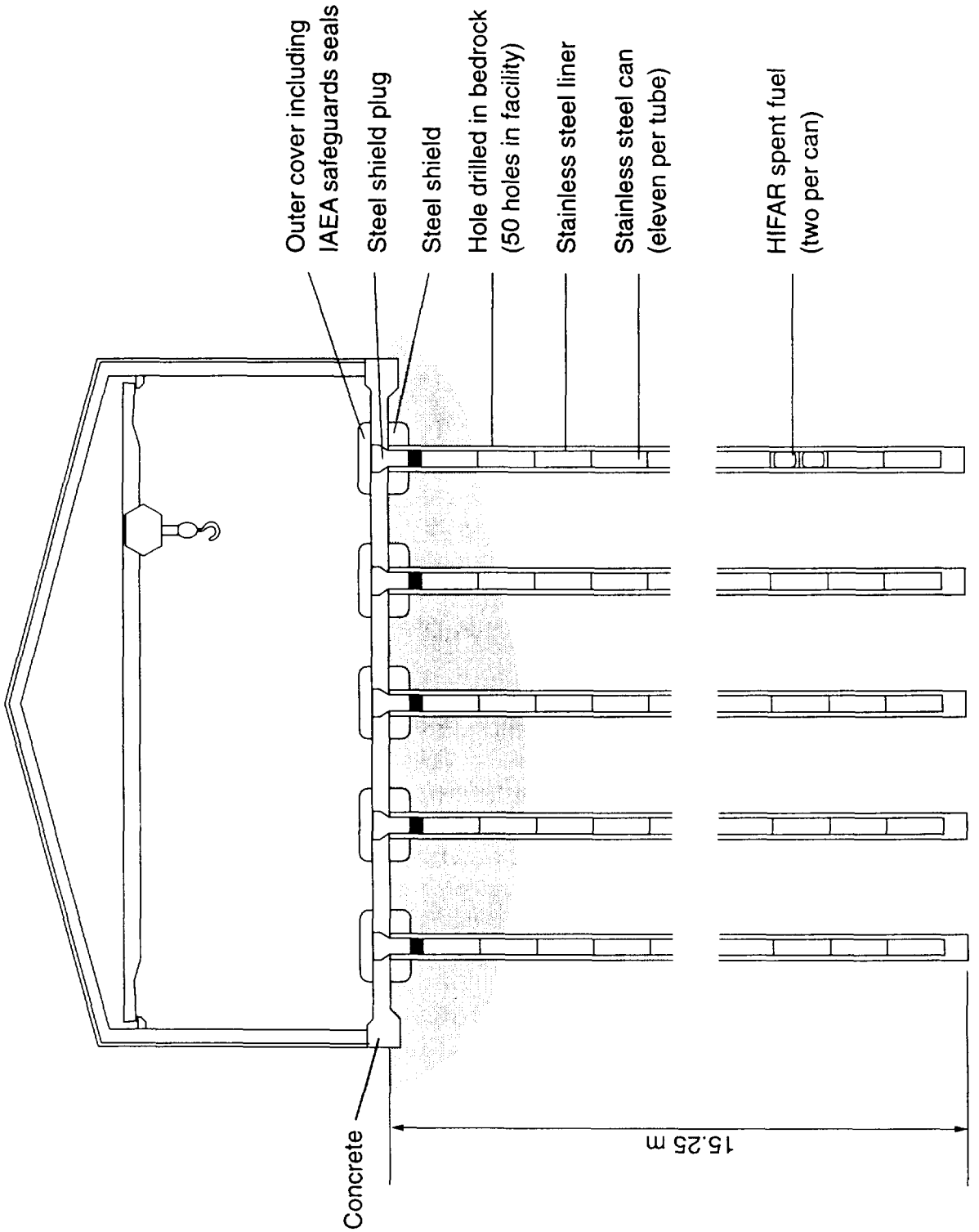


Figure 7.3: Spent Fuel Storage Facility

7.4 Storage Facilities at LHSTC

The fuel discharged from HIFAR is stored under water in the reactor storage block for up to one year. This storage block is an enclosed and shielded tank immediately adjacent to the reactor and within the reactor containment building. The fuel element is then transferred inside a heavy, shielded transfer flask to a cropping pond in a nearby building where the non-fuel containing ends of the element are sheared off ("cropped"). Approximately 5 metres of water depth provides the necessary radiation shielding for this operation and is an excellent heat removal medium for the early period of storage. The cropped ends are sent to the intermediate level waste store while the remaining fuel section is moved underwater into storage racks in the irradiation pond which is connected to the cropping pond. The fuel is stored under water in the irradiation pond for another 3-4 years to permit radioactive decay and until the heat generation has decreased sufficiently to permit dry storage. Most elements are then removed from the pond in shielded transfer flasks and placed into dry storage in the engineered Spent Fuel Storage Facility. Alternatively, they are transferred to another pond where they are loaded underwater into stainless steel transport or storage casks (also known as "flasks"). In this latter case the casks are sealed underwater, removed from the pond, drained and vacuum dried. They are then placed in a secured area with regular surveillance.

The Spent Fuel Storage Facility (see Figure 7.3) is an engineered dry storage facility built in 1968 at LHSTC to store 1100 spent fuel elements. The facility consists of 50 holes, 16 metres in depth, drilled into sandstone and lined with 140 mm internal diameter sealed stainless steel tubes. HIFAR spent fuel elements are stored, two to a can, and eleven cans in each lined hole.

The tubes in the storage facility are filled with dry nitrogen to inhibit corrosion of the fuel cladding. Periodic monitoring of the nitrogen gas when the nitrogen is replaced shows no traces of krypton-85, a long-lived fission-product gas, except in one hole which contains fuel elements that were sectioned in 1967 for detailed metallurgical examination. The lack of any released krypton-85 in the other holes indicates that there is no significant deterioration of the fuel elements. The sectioned fuel elements, which were in dry storage since 1972, showed no sign of deterioration when subjected to re-examination in a hot cell in 1984.

A special cask, the LHRL-120 Cask, was manufactured in 1987-88 for shipping spent fuel elements. For shipping, the LHRL-120 Cask is surrounded by an impact limiter which is supported on cradles attached to a skid which is bolted to the base of an open topped shipping container. The LHRL-120 cask has a certificate of approval from the Australian Maritime Safety Authority and from the US and UK Departments of Transportation.

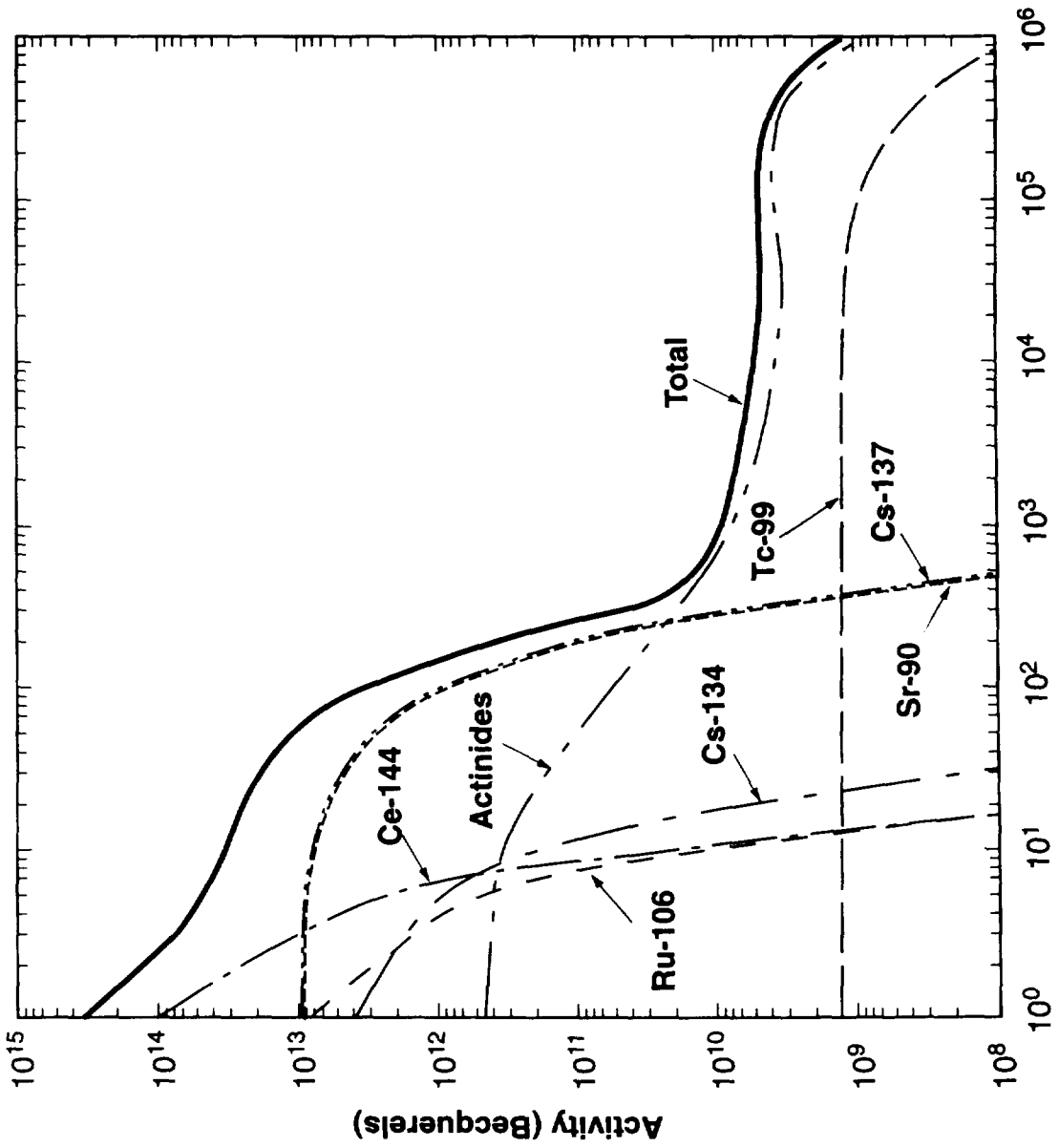


Figure 7.2: Activity of a Mark 4/23 Fuel Element (80 MWd burnup)

After discharge, the top and bottom aluminium sections of the fuel element are cropped to a length of about 600 mm which contains the spent fuel. For transport, the four concentric tubes of the Mark 4 elements, which are separated from the support combs by the cropping operation, are attached together by a clip, as shown in Figure 7.1.

The residual uranium enrichment of the spent fuel varies between 36 and 65% uranium-235, depending mainly on the initial enrichment. The average burnup of the spent fuel is 54.4 MWd per element, although more recent elements have achieved a burnup of 80 MWd. The total mass of all the stored, cropped spent fuel elements is about 4.9 t including the contained 0.23 t of remaining uranium and other heavy metals (such as transuranic elements).

The amount of spent fuel at LHSTC is very small compared to the quantity of spent fuel elements being stored world-wide. Spent fuel elements from power reactors being stored in 1995 contained about 120,000 tonnes uranium and increases by about 10,000 tonnes per year. Even if only research reactors are considered, the 0.23 t heavy metal of spent fuel at LHSTC is a very small fraction of the US-origin highly enriched uranium in use or stored as spent fuel in 51 countries outside the US (Takáts *et al.* 1993).

7.3 Radioactivity in HIFAR Spent Fuel

The HIFAR spent fuel elements are extremely radioactive immediately following removal from the reactor but this radioactivity decays very rapidly in the initial months in the reactor storage block. The fission product activity of any particular fuel element at any particular time after irradiation will be directly proportional to the burnup of that element measured in MegaWatt-days (MWd). Figure 7.2 shows the total radioactivity as a function of time for a burn-up of 80 MWd. Table 7.2 gives the heat output and activities for times up to 1000 years.

TABLE 7.2
Fission Products and Actinides in a Mark IV Fuel Element (containing 170 g uranium-235 irradiated) to a Burnup of 80 MWd (Robinson 1993)

Time Years	Fission Products GBq	Actinides GBq	Heat Output Watts
1	350,000	472	35.9
5	51,300	403	3.9
10	33,300	336	2.6
20	24,300	240	2.0
50	11,800	113	1.0
100	3,700	61	0.34
500	2.5	13	0.01
1000	1.8	7.9	0.007

During reactor operation, the fuel is cooled by heavy water flowing upwards past the fuel elements.

As at mid-May 1996, ANSTO had some 1580 spent fuel elements from the operation of HIFAR in interim storage at the LHSTC site. Each year 37 elements are discharged from the reactor. All HIFAR fuel elements were manufactured by AEA Technology (previously known as the United Kingdom Atomic Energy Authority). The high enriched uranium (HEU) content was supplied by either the UK or the USA. Of the 1677 fuel elements (including new, in-reactor and spent elements) on the LHSTC site, 894 contain US-origin enriched uranium (of which 441 contain mixed US and UK origin HEU), while 783 contain only UK-origin uranium. Of these latter 783 elements, 455 are classed as Australian-origin for safeguards purposes. The enriched uranium in these latter elements was obtained from the UK before the NPT non-proliferation regime started and was accorded an Australian origin. Table 7.1 gives details of all spent fuel elements at the LHSTC site.

TABLE 7.1
HIFAR Fuel Elements (New, In-core and Spent) at LHSTC in May 1996

TYPE	U-235 %	U-235 wt	No. Elements	IRRAD Year	Average Burnup MWd	ORIGIN US	ORIGIN Aust	ORIGIN UK
MK 2	93	115 g	1	1960	0.0		1	
	80	115 g	113	1960-71	37.4		113	
	80	150 g	65	1960-71	51.9		65	
MK 3	93	115 g	1	1962	29.0		1	
	93	115 g	1	-	0.0		1	
	80	115 g	39	1962-63	35.0		39	
	80	150 g	85	1962-70	50.4		85	
	80	150 g	148	1967-71	51.6	148		
MK 4	80	150 g	1	-	0.0	1		
	80	150 g	306	1970-76	49.2	266	40	
	80	115 g	37	1970-76	38.3	37		
	80	150 g	126	1977-84	64.2			126
	80	150 g	152	1980-83	63.9	1	87	64
	75	150 g	103	1983-84	56.5		5	98
	60	150 g	40	1985-86	54.5			40
	60 *	150 g	104	1987-89	58.2	104		
	60 *	170 g	188	1988-93	78.8	188		
	60 *	170 g	149	1993-	-	149**		
MK 6	80	170 g	18	1978	71.6		18	
TOTALS			**1677**			**894**	**455**	**328**

* Note that these elements are manufactured from blended US-origin and UK-origin HEU.

** This batch of elements is the stock currently being drawn upon for use - most is still held as fresh fuel though some was in the core at time of writing. All other elements listed are used (*i.e* spent fuel).

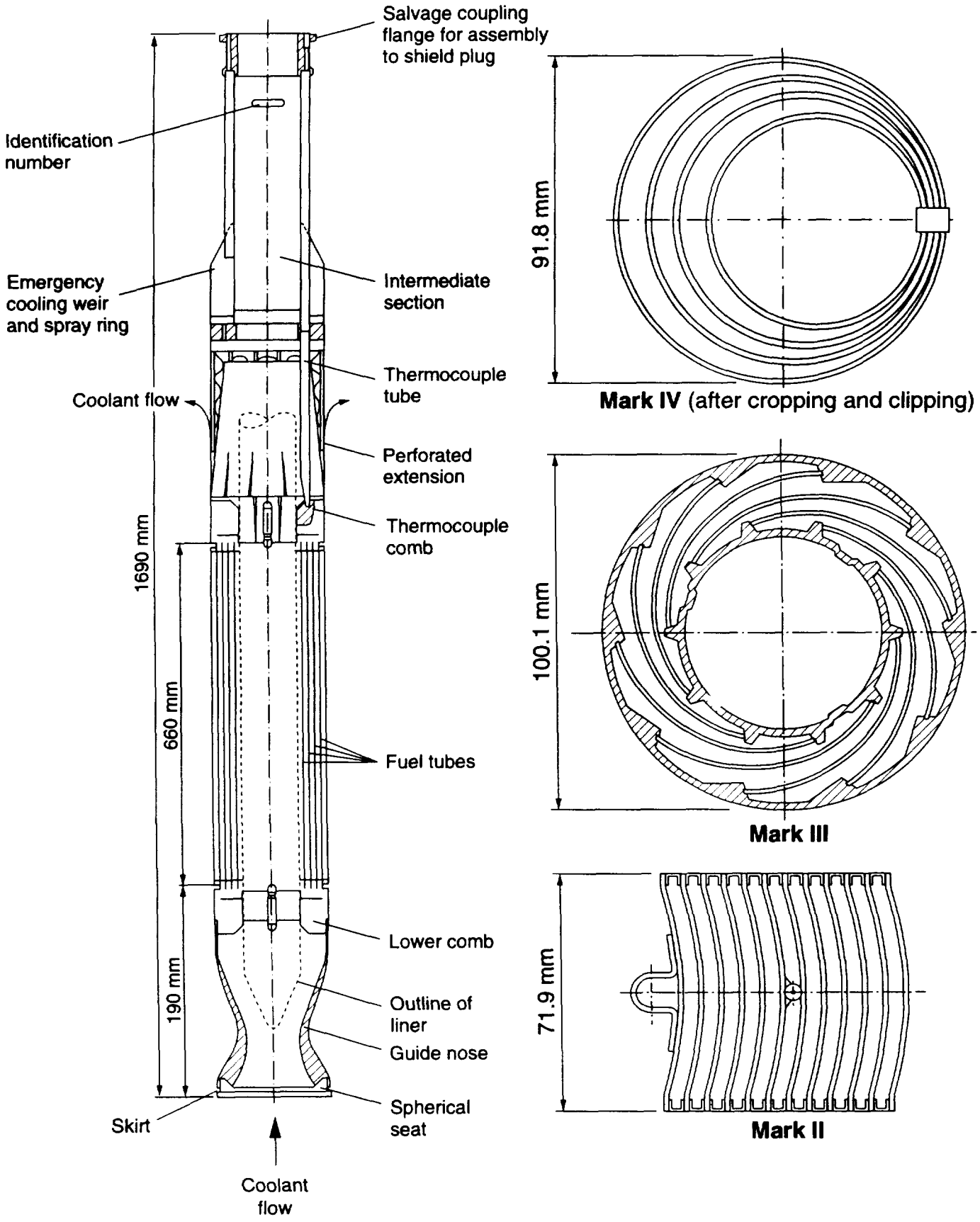


Figure 7.1: HIFAR Mark 4 Fuel Element and Cross-Sectional Views of Marks II, III and IV

SECTION 7
SPENT REACTOR FUEL

7.1 Introduction

Since 1958, ANSTO has operated the 10 MW (thermal) HIFAR reactor at the Lucas Heights Science and Technology Centre. HIFAR is a multi-purpose reactor and is the primary source of radioisotopes and radiopharmaceuticals for Australia, as well as being used for research and commercial applications.

HIFAR is a tank type reactor with heavy water moderator and primary coolant contained within an aluminium reactor tank surrounded by a graphite neutron reflector. The fuel is uranium-aluminium alloy clad in aluminium with a current enrichment of 60% uranium-235.

Most of the spent fuel from the 38 years operation of the HIFAR reactor is still at LHSTC where it is stored in monitored, retrievable facilities in accordance with international standards and guidelines. While storage of spent fuel at LHSTC is conducted to high standards of safety, it is an interim measure and not permanent disposal. The original strategy, at the time the reactors were built, was based on the understanding that spent fuel would be sent to the UK or the US, for reprocessing, recovery and recycling of the residual high enriched uranium (HEU). One shipment of 150 elements was sent to the UK in 1963 and another of 114 elements in April 1996.

A shipment was being prepared for return to the US when, in January 1989, the US suspended acceptance of spent fuel from foreign research reactors pending an environmental review. That review was completed in February 1996 and, on 13 May 1996, the USDOE announced its "Record of Decision" to fully resume the acceptance of US-origin spent fuel from foreign reactors. The policy will operate for a fixed ten-year period from the date of that decision.

7.2 Inventory of Spent Fuel at LHSTC

The HIFAR core contains 25 fuel elements, each some two metres in length and 100 mm in diameter. The amount of uranium-235 in the fuel elements has increased from 115 g in early elements to 170 g in recent elements and the enrichment reduced from 93% to 60% uranium-235. The fuelled section is approximately 600 mm long and, in the Mark 4 elements, consists of four 1.5 mm thick concentric tubes of uranium-aluminium alloy clad in 0.5 mm thick aluminium (see Figure 7.1). The aluminium cladding protects the uranium from corrosion and prevents release of the highly radioactive fission products.

In selecting the appropriate technology for ANSTO, certain criteria need to be considered including decontamination factors for radionuclides, ease of operation, minimisation of secondary wastes, and capital and operating costs. **It is recommended** that a full technical and economic assessment be carried out of alternative processes for treatment of low level waste waters. The study would involve:

1. A detailed characterisation of radioactivity in low level waste water sources,
2. Assessment of alternative treatment processes and flowsheets,
3. Selection of the optimum process,
4. Laboratory and bench scale testing, as necessary, to prove the flowsheet using actual low level wastes containing the full spectrum of radionuclides,
5. Preparation of a specification documents for tender,
6. Selection of a contractor to build the new plant,
7. Plant construction and operation.

A study of the feasibility of segregation of liquid wastes at their source would be an important aspect of this study because it could greatly reduce volume and hence total treatment costs. The treatment or avoidance of special wastes (see Section 6.3) should also be considered as part of this study. A timescale and estimated budget will be provided in the Waste Management Action Plan.

6.6 Recommendations - Low Level Liquid Effluents

- It is recommended that a full technical and economic assessment be carried out of alternative processes for treatment of low level waste waters. Following completion of the assessment and any necessary testing, a new facility for treatment of ANSTO's low level waste waters should be designed, constructed and commissioned.
- It is recommended that assessment and developmental work be undertaken, as necessary, to improve the current process for treatment of special low level liquid wastes.
- It is recommended that a detailed survey be undertaken to identify all major tritium sources entering the waste water circuit. Following this survey, operational procedures and practices should be modified if possible to reduce the quantity of tritium entering the water treatment circuit.

6.5 Upgrading of Facilities

Whilst the existing effluent treatment facility at ANSTO currently meets discharge limits for radioactive substances, it has the following disadvantages:

- Poor removal efficiency for radionuclides (less than 50%),
- Outdated technology and aging equipment,
- Produces a relatively high volume sludge requiring storage as low level solid waste
- An open solar drying facility is undesirable since total confinement cannot be guaranteed,
- The handling of the dried sludge is manual and is an operating safety hazard.

TABLE 6.8
Annual Liquid Effluent Discharged for 1986-1995

Year	Volume (m^3)	Total Alpha (MBq)	Total Beta (MBq)	Total Tritium (GBq)	% of Authorised Limit
1986	95,617	92.0	2,990	2,271	41
1987	87,627	72.2	1,722	1,717	29
1988	93,158	80.6	1,962	1,460	30
1989	92,064	131.7	1,942	3,061	36
1990	121,680	161.9	1,511	3,700	26
1991	93,726	28.9	1,717	6,172	23
1992	99,790	58.9	1,719	4,860	24
1993	89,462	87.1	2,233	648	35
1994	82,978	47.4	795	571	15
1995	94,580	62.0	1,430	680	22

Engineering assessment has indicated that the existing plant will have high maintenance costs and needs to be upgraded or replaced within the next few years. Processes available for treatment of ANSTO waste waters containing radioactivity are based on the following core technologies:

- Adsorption/coprecipitation
- Ion Exchange
- Evaporation
- Solvent Extraction
- Membrane processes, *e.g.* microfiltration, ultrafiltration, nanofiltration, reverse osmosis.

The volumetric discharge and the radioactivity (expressed as percentages of authorised discharge limits) for the 10 year period 1986 to 1995 are given in Table 6.8. Earlier data are reported in ANSTO (1993). The results in Table 6.8 and ANSTO (1993) show that the effluent discharges have always been within the limits set under the NSW State requirements for discharges of radioactive effluents.

TABLE 6.7
Current Waste Effluent Discharge Limits

Pollutant	Discharge Limit - 95 Percentile
Biological Oxygen Demand (BOD5)	85 mg L^{-1}
Suspended Solids	40 mg L^{-1}
Total Grease	30 mg L^{-1}
Ammonia	40 mg L^{-1}
Chromium	2.3 mg L^{-1}
Temperature	38°C (Max)
Colour	Not noticeable at 100 dilutions
pH	7 to 10.0
Max Daily Discharge	1,000 m^3
Average Daily Discharge	300 m^3
Radioactivity	Compliance with former NSW Radioactive Substances Regulations (1959) and WHO (1993) drinking water limits at discharge from CSTP

Tritium (a very low energy beta emitter present at high concentrations in the heavy water coolant) is not removed by the treatment process and its levels are determined by various site operations when heavy water is present and could enter waste water collection systems. One significant source is the fuel storage block circuit from which 150 litres is bled weekly. Tritium release has been reduced over the last few years (see Table 6.8) by better housekeeping.

It should be noted that the quantity of tritium discharged to the sewer is less than 1% of the allowed concentration specified in the former Radioactive Substances and less than 5% of reference levels indicated in the WHO Guidelines for drinking water. Nevertheless, it is possible that some tritium waste sources are avoidable and, in keeping with the ALARA principle, **it is recommended** that a detailed survey be undertaken to identify all major tritium sources entering the waste water circuit. Following this survey, operational procedures and practices should be modified if possible to reduce the quantity of tritium entering the water treatment circuit

The current Trade Waste Agreement with Sydney Water is in place from September 1995 - September 1998. Discharge limits under this agreement are given in Table 6.7. In respective to radioactivity, the liquid effluents must comply on a monthly average with:

1. The former NSW Radioactive Substances Regulations (1959) activity concentration limits at the points of discharge to the sewer. This regulation requires that the concentration of each radionuclide (C_i) must not exceed a particular limit (L_i). Where more than one radionuclide is present, the sum of the allowed concentrations of all radionuclides (expressed as a fraction) must be less than one, *i.e.*

$$\Sigma(C_i/L_i) < 1.$$

   Because analysis of the effluent for each radionuclide is time-consuming and costly, only undifferentiated (gross) alpha and beta analysis is routinely carried out and it is assumed that all alpha and beta radiation comes from the most restrictive radionuclide of each type (the radionuclide with the lowest maximum permissible concentration, viz., radium-226 for alpha-emitting nuclides and strontium-90 for beta-emitting nuclides). As some radioactivity arises from less restrictive isotopes, there is an inbuilt margin of safety and compliance in this approach.

2. The World Health Organisation (WHO) drinking water standards. To ensure compliance at the Cronulla Sewage Treatment Plant (CSTP) with drinking water concentrations for radionuclides, average monthly activity concentrations of discharges to the sewer shall not exceed 25 times the reference activity concentrations for radionuclides as determined by the application of the WHO (1993), "Guidelines for drinking water" which correspond to a dose of 0.1 mSv per year. The factor of 25 allows for the measured dilution between the effluent discharge point at LHSTC and the CSTP (see Section 8.4.1).

The limits for each holding tank are:

(a) not more than 10 kBq m^{-3} for total alpha activity if no beta activity is present.

(b) not more than 125 kBq m^{-3} of total beta activity if no alpha activity is present.

(c) if both alpha and beta radioactivity are present, then the limits are reduced proportionately.

The levels of radioactivity in the treated effluent in a holding tank are measured for compliance before being released to the sewer. A proportional sample is taken of the discharged effluent by a sampling system connected to the discharge line. This gives a representative sample proportional to the volume of effluent discharged to the sewer.

SECTION 10
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POLICY OBJECTIVE: CONSISTENCY BY 2000 OF ANSTO SYSTEM OF RADIOACTIVE WASTE WITH IAEA RADWASS STANDARDS AND SAFETY GUIDES

STRATEGY	*CRITICAL FACTORS*	*ACTIONS*
Adoption of International Best Practice	Australian support for the development of a Convention on Safety of Radioactive Waste Management (RADWASS standards).	Participate actively in the IDC on the Convention. Liaise with relevant policy departments and regulatory bodies to resolve critical issues necessary to implement ANSTO's plan.
	Align ANSTO's plan for waste management with the RADWASS documents.	Develop milestones to ensure ANSTO's system of waste management is consistent with the RADWASS predisposal Standards and Guides by 2000. Seek endorsement of plan by relevant Departments in time for development of budgets for the next triennium. Implement in 1995/96 steps that do not require resolution of regulatory issues, e.g. waste segregation of source.

STRATEGY	*CRITICAL FACTORS*	*ACTIONS*
HIFAR Spent Fuel Management	Government decision on options	Continue to contribute advice to the Interagency Committee
		Cooperate with other research reactor operators to facilitate initiatives for overseas options (Dounreay reprocessing and return to USDOE options).
		Implement Government decisions
	Continued safe operation of spent fuel facilities	Participate in IAEA activities developing guidelines for safe storage, treatment and disposal of research reactor spent fuel.
		Continue to comply with IAEA guidelines on spent fuel storage.
		Complete a comprehensive inspection and perform maintenance of all spent fuel storage facilities by June 1996

STRATEGY	*CRITICAL FACTORS*	*ACTIONS*
R&D	Support for the predisposal waste management plan at ANSTO	Strengthen appropriate R&D projects to support design and operational needs. Review and implement improved methods and techniques for environmental monitoring. Initiate and resource new research programs aimed at the development and demonstration of improved processes for radioactive waste treatment and management at ANSTO that will set best practice standards beyond the year 2000.
Waste Treatment	Consideration of inter-dependencies between waste generation, treatment, storage, transport and disposal.	Maintain active discussions with regulatory agencies on relevant national codes and regulations Develop ANSTO policy, agreed with regulators, on standard waste containers Provide feedback to waste generators to implement changes to processes that facilitate waste treatment.
	Avoidance of unnecessary double handling of waste to minimise operator dose uptake.	Implement on-line waste conditioning, including incompressible wastes and sludges/ion exchange resins from liquid waste treatment. Develop longer term plans and facilities for retrieval and treatment of stored wastes for conditioning.

POLICY OBJECTIVE: SAFE MANAGEMENT OF RADIOACTIVE WASTES

STRATEGY	*CRITICAL FACTORS*	*ACTIONS*
Training	Raise awareness of waste management culture in line with ANSTO policy.	Raise and maintain awareness of the RADWASS system of codes; international best practice; national developments and ANSTO'S waste management strategy and plans through a systematic schedule of seminars to support the waste management plan.
	Expand technical competence in waste processing, characterisation, and monitoring.	Provide a training program to ensure personnel at all levels of operations have the required competence including fundamental and practical aspects of health, safety, radiation protection, equipment operation and emergency procedures. Develop guidelines for preparation of manuals and safety documents; and provide required training program.
Quality Assurance	Continued safety depends on a formal quality assurance program covering all stages of the predisposal management of radioactive wastes at ANSTO.	Review, develop and implement a new QA plan, consistent with the ANSTO Safety Regime set-out in Information Circular No. 29/1994, that addresses the current organisational structure and establishes responsibilities and relationships between various organisational entities. Develop a quality system to facilitate effective communication of the outcomes of the QA programmes and status of resolution of adverse issues.

STRATEGIES	*CRITICAL FACTORS*	*ACTIONS*
	A waste recording and tracking system from source to disposal.	Review current system, identify required improvements
Waste Volume Reduction	Compaction of compressible LLW wastes.	Segregate compressible solid LLW from other wastes.
	Liquid waste treatment	Segregate streams according to radionuclide and other non-radioactive contents.
		Review current process system and cease mixing of liquid wastes.
		Strengthen R&D Programs on alternative liquid waste treatments.
		Implementation of improved processes to reduce the volume of solid wastes arising from treatment.
	Recycle and reuse	Review options for decontamination and recycle taking into consideration the need to minimise secondary waste arisings.
	Decay Storage	Interact with regulatory agencies to secure approval for discharge of exempt wastes.

POLICY OBJECTIVE : WASTE MINIMISATION

STRATEGY	*CRITICAL FACTORS*	*ACTIONS*
Waste Reduction at source	Selection of plant design, materials, equipment, process technology and operating practices	Review all current waste generation processes; identify and quantify secondary waste streams, and if appropriate, cost and recommend alternative strategies. Modify SAC procedures to address waste minimisation in the design of new facilities in operating practices, and in the renewal of safety approvals.
	Segregation of operational activities, equipment and materials to minimise contamination.	Review practices; identify and cost alternative arrangements. Implement re-organisation of operations according to priorities. Implement administrative controls.
Waste Segregation	Segregation of wastes at source into agreed categories	Define the minimum practicable segregation categories for liquid and solid wastes on the basis of subsequent treatment, storage and disposal options taking into account waste origin, physical and chemical factors and radionuclide content. Establish local interim storage facilities where required.
	Characterisation and monitoring of wastes	Provide coded waste containers to all areas where waste is generated. Procure additional monitoring and characterisation instruments and systems for solid, liquid and gaseous wastes

ANSTO RADIOACTIVE WASTE MANAGEMENT POLICY

(Approved by ANSTO Board, July 1995)

ANSTO will manage its radioactive waste in a manner that protects human health and the environment now and in the future. In doing so, ANSTO is committed to:

- complying with all relevant legislative and regulatory requirements, in particular,

  ensure that all discharges are within authorised limits,

  monitor and report regularly radioactive releases to the environment;
- ensuring that radiation exposures will be kept as low as reasonably achievable (ALARA), economic and social factors taken into account;
- disposing of wastes when appropriate disposal routes are available,
- being in accord with international best practice.

OBJECTIVES

The objectives of ANSTO's radioactive waste management are:

- safe treatment and storage of radioactive wastes, taking into account the need to minimise dose uptake to operators and economic factors;
- minimisation of radioactive waste generated and stored;
- maintenance of inventories of all waste from source to disposal;
- consistency by the year 2000 with best practice as identified in the RADWASS Standards and Safety Guides currently under development within the IAEA;
- broad public understanding and acceptance of ANSTO policy and practices.

INTEGRATED WASTE MANAGEMENT PLAN

The implementation of ANSTO's radioactive waste management policy and the achievement of the objectives requires a review of current practices, future waste arisings and the preparation of an integrated predisposal plan. The plan must define milestones, responsibilities of organisational entities and resources required to ensure ANSTO's system of waste management is consistent with the RADWASS predisposal Standards and Guides by the year 2000.

Strategies to achieve the objectives, critical factors for success and actions have been developed by the Waste Management Strategies Working Party as shown below. Responsibilities for the development of the integrated plan are to be defined by the Executive Director.

APPENDIX A

ANSTO RADIOACTIVE WASTE MANAGEMENT POLICY

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POLICY OBJECTIVE: PUBLIC ACCEPTANCE

STRATEGY	*CRITICAL FACTORS*	*ACTIONS*
Public Information	Foster public understanding of issues of radiation and radioactive waste management.	Develop an integrated information plan.
		Commission and update easily understood papers, exhibits and real-time measurement displays.
		Continue and enhance liaison with the community and local interest groups.
	Public access to ANSTO emission and compliance data.	Revise and integrate the program of environmental monitoring and publish promptly Environmental Survey Reports and compliance documents.
Compliance	Secure agreement for the ANSTO waste management plan within relevant Government Departments and regulatory agencies.	Secure agreement with plan that is consistent with ANSTO policy objectives and regulatory requirements.
	Independent confirmation by regulatory agencies of compliance with plan.	Meet regulatory requirements and milestones of the plan.