UR/LLW - 87

CODE OF PRACTICE ON THE MANAGEMENT OF RADIOACTIVE WASTES FROM THE MINING AND MILLING OF RADIOACTIVE ORES

GUIDELINE

Development of a Waste Management Program for a Uranium Mining/Milling Operation

Date of adoption or revision:	1984
Primary related Clauses:	5, 6(3), 6(4)
Other related Clauses:	7(1-4)

CONTENTS

INTRODUCTION

1 Radioactive wastes produced as a consequence of uranium mining and milling operations, unless properly treated, will constitute a continuing source of environmental pollution and radiation exposure. Also of concern are the non-radioactive pollutants in the wastes, in particular heavy metals, which can be damaging to the environment and a hazard to man. While this guideline is mainly concerned with the radiological component of the wastes, reference is made where appropriate, to the non-radiological contaminants in the wastes.

2 The effective management of radioactive wastes is an integral part of any operation involving the mining and milling of radioactive ores. To this end the Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores (1982) requires the development, approval and implementation of a waste management program for the life of the operation and more detailed short-term programs for such periods as designated by the appropriate authority (Clause 5(2)). The purpose of such programs is to minimise the potential radiological detriment to people and the environment from such wastes both during the currency of operations and in the long term. Criteria to this end are set out in Part III of the Code, in particular at Clauses 7(1), 7(2), 7(3) and 7(4).

3 The waste management program consists of all the facilities and procedures involved in the handling, treatment, storage and disposal of radioactive wastes - that is, the waste management system as defined in the Code - together with relevant elements of radiation and other monitoring programs, contingency plans for unplanned events and proposals for decommissioning and rehabilitation. In addition, the program should specify the schedules and resource requirements for its implementation, assessment and, as necessary, updating so as to maintain its effectiveness.

4 Integration of the waste management program into the overall mining and milling operation necessitates considerable forward planning and research so as to enable its implementation from the outset of the operation. Accordingly the Code requires the development of an approved waste management program prior to the commencement of the mining/milling operation. As the program must be implemented in accordance with the approvals granted by the appropriate authority (Clause 6(3), it should be structured so that approvals can be expressed in terms with which compliance can be readily demonstrated.

5 In view of the complexity of the program there is need for continuous interaction between the owner, operator and manager and the appropriate authority in defining and updating an approved waste management program for a specific site. This interaction should also ensure that the program reflects the particular requirements of the appropriate authority and incorporates decisions based on the best available site specific data.

6 The Code provides (Clause 4(1)(c)) for, the management of radioactive wastes from mining and milling operations which, at any time, are temporarily suspended. "Temporarily suspended" is not defined in the Code; it is interpreted here as a decision to suspend operations with the clearly demonstrable intention to resume operations at some future date. Prior to the temporary suspension of operations a modified waste management program is required to be submitted to the appropriate authority (Clause 5(4)). This modified program should detail the procedures for managing the radioactive wastes for the period that operations are suspended and should be developed in consultation with the appropriate authority.

7 Any environmental impact statement (EIS) prepared for a proposed uranium mine or mill will include proposals for waste management and site specific information relevant to the waste management program required by the Code. There should therefore be consistency between the EIS and the waste management program, or, where changes are found necessary, documentation of the reasons for the changes.

Purpose of the Guideline

8 This guideline provides an overview of items to be addressed in developing an effective waste management program and the rationale for their inclusion. It should be recognised however that not all aspects will be applicable to each and every project site. Conversely, it may not cover all the topics relevant to the waste management program for a particular site. In some cases the items are considered only in general terms as they are the specific subject of other guidelines to the Radioactive Waste Management (Mining and Milling) Code 1982 or the Radiation Protection (Mining and Milling) Code 1980. In such cases the appropriate cross reference is made in the text.

9 The guideline is in four parts:

- Part I specifies basic principles and concepts of radioactive waste management and their implications for the development of the waste management program.
- Part II discusses data which should be collected and analysed in the development of the waste management program including the data that should be submitted to the appropriate authority.
- Part III lists major elements which should be documented in the waste management program.
- Part IV discusses the development of an Operation and Maintenance Manual.

.10 The guideline does not canvass all items relevant to the extraction of uranium by either in situ leaching or heap leaching. Specific requirements relating to these methods are outlined in the guidelines : Mining of Uranium by In Situ Leaching and The Management of Heap Leach Piles.

PART I OBJECTIVES OF WASTE MANAGEMENT AND IMPLICATIONS FOR THE WASTE MANAGEMENT PROGRAM

11 The major objectives in the management of radioactive wastes arising from the mining and milling of radioactive ores are to ensure that:

- exposure to radiation of employees and members of the public from radioactive wastes in or released into the environment is as low as reasonably achievable and below the relevant limits prescribed in Schedules 1,2,3 and 4 of the Radiation Protection (Mining and Milling) Code (1980);

- best practicable technology is used to minimise the release of radioactive materials to the environment;

- the final disposition of the radioactive wastes is such that the need for subsequent inspection, monitoring and maintenance is minimised and preferably rendered unnecessary;

- the environment in general is protected from radiological hazards;

- the waste management practices adopted for radiological wastes should not jeopardise the waste management practices for the non-radiological contaminants;

- as far as possible the waste management practices adopted will not jeopardise the future use of identified resources in the area; and

- minimum area of land is permanently disturbed or allocated to waste disposal site(s).

12 In order to achieve these waste management objectives it is necessary to:

- identify all wastes (arising from all phases of the mining and milling operation) including mine water, surface runoff, tailings, airborne dusts, mill process effluents, below grade ore mineralisation, waste rock, overburden and other sludges and wastes;

- have sufficient information on the characteristics of the wastes (particularly the mill tailings and the waste rock) to enable assessment of their potential for release of contaminants to the environment in both the short term and long term;

- keep abreast of the technologies applicable to the management of radioactive wastes arising from comparable mining and milling operations; develop new technologies appropriate to the site; such technologies would be taken into account in the design of the waste management system;

- obtain sufficient data on the environment in and around the project area so as to provide a basis for assessing the radiological impact of the wastes on the environment;

- have such information so as to enable the identification of the critical group(s) of members of the public;

- take into account the expected and predictable long-term geological, geomorphological, hydrological and climatological processes on the waste disposal sites to ensure the long-term integrity of the wastes. The final design of the waste management system should be such that it would be expected to withstand such forces for the prescribed time period and ideally utilise the environmental processes to enhance the integrity of the system over the long term.

Proper evaluation of these data should enable the development of the optimal waste management program for the particular project.

13 Before proceeding with a discussion of the development of the waste management program, it is necessary to consider a number of important concepts referred to in the Code. Specifically, the following comments are provided on the restricted release zone; the use of best practicable technology; the concepts of storage and disposal of wastes; decommissioning and rehabilitation; and the long term.

Restricted Release Zone

14 The Code requires (Clause 5(1)) that approval be obtained from the appropriate authority for a restricted release zone (RRZ) which is defined as "an approved zone about and below a mine and/or mill from which release of radioactive material shall be minimised in accordance with the requirements of the appropriate authority". In defining the RRZ account also should be taken of the non-radiological contaminants.

15 The purpose of an RRZ is to define a specific area within which waste management processes take place. The zone operates to minimise the area being disturbed by the waste management system and also provides a boundary enabling the appropriate authority and the company to determine if the waste management system is operating according to the program objectives.

16 The RRZ is a three dimensional zone from which the release of all radioactive material (solid, liquid or airborne) is either prohibited or controlled. The release of airborne or liquid effluents from the RRZ is controlled by adhering to agreed discharge limits (Clause 6(4)(h)). The release of radioactive waste not controlled by the formulation of discharge limits (e.g. seepage from a tailings impoundment) should be minimised by the use of best practicable technology and be acceptable to the appropriate authority.

17 The RRZ, while representing a three-dimensional zone, is typically defined in terms of a geographical area and would include all areas where the mining and milling of specified material is proposed, for example:

- the mine pit and its immediate surrounds;
- the haul road(s) to, and the areas of, the ore stockpile(s) and reactive waste rock dump(s);
- the mill site;
- ventilation raises;
- the tailings impoundment(s);
- the seepage collector sump;
- the tailings pipeline corridor and pipeline corridor sump;
- drains, pipelines, conveyors and corresponding corridors connecting any of the above; and
- all ponds to which the above areas drain (retention ponds, runoff ponds, evaporation ponds and tailings ponds).

18 Usually all of these components are incorporated in a single RRZ which should be kept to the minimum area possible - this area may be redefined from time to time subject to approval by the appropriate authority. In some cases, depending on site layout, it may be necessary to declare two or more areas as restricted release zones in keeping with the aim of minimising the total area of the RRZ. In interpreting the RRZ boundary on the ground, detailed consideration should be given to the topographical contours and actual catchment areas.

19 In relation to the water management system and the concept of the RRZ, refer further to the guideline: Design and Operation of a Water Management System for a Uranium Mining and Milling Operation. In relation to airborne emissions, refer to the guideline: Management of Airborne Emissions.

Use of Best Practicable Technology

20 The Code requires (Clause 7(1)) that the waste management system proposed for the particular uranium mining and milling operation utilises the best practicable technology. As defined in the Code, best practicable technology is that technology, from time to time relevant to a specific project, which enables radioactive wastes to be managed so as to minimise radiological risks and detriment to people and the environment, having regard to a number of specified factors such as available technology, cost relative to the protection achieved, the adequacy of protection already being achieved, local site conditions and potential hazards of the wastes over the long term.

21 The technology for managing radioactive wastes in comparable mining and milling operations should be examined when choosing the best practicable technology for a specific project. However, this is not meant to imply that current practices represent best practicable technology. Innovative alternatives should be considered if they can be shown to be equal to or better than currently accepted practices.

22 In requiring the use of best practicable technology the Code recognises that this concept must be applied taking into account what is reasonable. In this context 'reasonable' is defined in terms that relate the short and long term benefits to be obtained from the use of a particular technology to the resource investment required to apply that technology. Therefore, the proponent should provide a discussion of how the particular waste management system proposed satisfies the best practicable technology criterion.

Storage and Disposal

23 The concepts of "storage" and "disposal" need to be carefully considered when proposing a particular waste management system. Storage is taken to mean the containment of the wastes in a facility for a limited period of time with the intent that it will be retrieved at a later date for final disposal. Storage criteria should be able to be met by any properly sited and designed facility. In contrast to storage, disposal is defined (in the Code) as "disposal of radioactive waste without the intention of retrieval".

24 The desired waste management objective is disposal therefore with no intent to retrieve and more importantly with no reliance on continued surveillance and maintenance to ensure the integrity of the facility. However, storage may be an appropriate interim measure if, for example, after mining is completed the wastes are to be returned to the pit for disposal.

Decommissioning and Rehabilitation

25 Following termination of the operational period, the mine and/or mill and associated facilities must be decommissioned and the area rehabilitated. The objective of decommissioning and rehabilitation is to make safe mine workings, mill sites and waste disposal sites and restore, as far as is practicable, the potential of the area for other uses. The waste management program should incorporate strategies for decommissioning and rehabilitation bearing in mind that, wherever practicable, rehabilitation should be undertaken progressively throughout the life of the operation (Clauses 5(2) and 15(1)).

26 Since potential contamination can be associated with all aspects of uranium mining and milling, proposals for decommissioning and rehabilitation should canvass:

- the decontamination, retention, and re-use of all buildings and equipment;
- the complete removal of all building foundations and equipment;
- rehabilitation of all roads, ore storage areas and contaminated ground areas; and
- the adoption of such measures and procedures as are necessary to ensure that the radiological impact of the waste disposal sites is reduced to a level consistent with the design objectives.

27 Decisions taken at the design stage will have important implications for the subsequent rehabilitation of a site. Consequently, rehabilitation requirements are an integral part of the development of a waste management program. Proposals for rehabilitation outlined in the initial waste management program should be refined and updated throughout the life of the operation in the light of operating experience. Prior to the permanent cessation of operations, and as required by the Code at Clause 5(7), a final decommissioning and rehabilitation plan should be submitted to the appropriate authority for approval.

28 A reasonable post-decommissioning/rehabilitation period should be allowed in the waste management program to assess the extent to which the decommissioned and rehabilitated site meets the radiological and non-radiological performance objectives established for the long-term disposal of the wastes. The duration of this period will be variable and dependent on operational procedures and site-specific environmental characteristics. Upon satisfactory completion of the final approved rehabilitation works including the post decommissioning/rehabilitation period, it should then be possible for the operator to be released from further responsibility for the site by that authority (Clause 15(3)).

29 The cost of decommissioning of the waste management system and rehabilitation of the site is a cost to the project and should be incorporated within the initial project budget. It should be ascertained that adequate finances are available to provide monitoring and maintenance in the decommissioning/rehabilitation period, and to rectify effects not reasonably foreseen at the beginning of the mining/milling operation. Periodic reviews of these cost factors will be necessary.

30 Provided that radiation protection requirements are not compromised, rehabilitated areas should entail a minimum of restrictions on usage. Should on-going monitoring and maintenance systems or institutional controls be necessary, they shall be vested in a governmental authority (Clause 16(1,2) of the Code).

The Long Term

31 A concern in the management of radioactive wastes is the potential for exposure of members of the public to radiation over the long term. The potential sources of this exposure include:

- radon gas exhaled from the surface of rehabilitated waste disposal sites (e.g. the tailings impoundment);
- radioactive substances (e.g. radium) leached from the solid wastes that subsequently contaminate waters external to the disposal site; and
- wastes dispersed into the environment through the action of natural processes.

32 The potential for exposure in the long term arises from the long half-lives of radionuclides such as:

Uranium - 238	-	4.5×10^9 years
Uranium - 234	-	2.5×10^5 years
Thorium - 230	-	8.0×10^4 years
Thorium - 232	-	1.4×10^{10} years
Radium - 226	-	1.6×10^3 years

The radioactive decay series for uranium-238 and thorium-232 are shown in Table 1.

33 The wastes are also of concern as they contain non-radiological pollutants, in particular heavy metals, which can be damaging to the environment and a hazard to man over the long term. An overview of this topic is given in the following publication:

Pidgeon, R.T. - 'Review of the Non-Radiological Contaminants in the Long-Term Mangagement of Uranium Mine and Mill Wastes' in 'Management of Wastes from Uranium Mining and Milling'. IAEA, Viennia, 1982.

34 For the purposes of this guideline, the long term can be considered to commence when the site, or part of the site, is fully stabilised and rehabilitated to design criteria and the owner, operator and manager are relieved of further responsibility. This essentially marks the time when natural systems are relied upon to control the release rates of contaminants from the disposed wastes.

35 Specifying the duration of long term however is extremely difficult and subjective. This situation arises from the difficulty in estimating the impact which natural processes will have on the disposed wastes. Causes and effects of natural processes, both physical and chemical, include: transformation of the land surface by geomorphological and tectonic processes such as denudation and uplift; possible flooding of disposal sites due to climatic changes such as increases in precipitation or changes in sea levels; and changes in chemical processes in the wastes affecting the behaviour of the contaminants.

36 In practice, the period for which some confidence could be realistically assigned to the effects of physical processes is of the order of a few hundred to one thousand years. These estimates should then be taken into account in the design of waste management structures. In this regard a distinction can be made between the design life and the structural life for a given design.

37 "Design life" is the period for which the structure is expected, by the designer, to perform fully in accordance with the objectives of the design, such as rates of releases of contaminants, taking into account the known parameters and influences. The design life is a prediction of the useful life of the structure. A structure, once in service, will usually retain integrity of the materials and components used to build the structure for a period considerably longer than the design life. Such a structure will show signs of deterioration but will be capable of performing the functions of the design to a reduced extent. The "structural life" is therefore the actual measurement of the useful life of the structure in performance. The structural life may be extended by renovation and maintenance of the structure. In the context of this guideline the objective in the engineering of a waste management structure should be to attain a design life of at least 200 years (institutional controls such as record keeping, monitoring and land-use restrictions should operate as an adjunct to design criteria during this time) and a structural life of a substantially longer period, of the order of 200 to 1,000 years, taking into account estimates of geomorphic and climatic influences so as to minimise rates of contaminant release caused by denudation, seepage, and exhalation.

38 From a geochemical point of view it is evident that chemical processes affecting the long-term behaviour of contaminants in the wastes begin immediately the wastes are deposited. To take into account these long-term chemical processes 'passive' management strategies (those management strategies designed to operate after active management ceases), would need to be incorporated at the time the wastes are deposited wherever possible.

39 Thus the concept of the long-term in relation to the disposal of radioactive wastes means, in practice, the adherence to a rigorous overall design concept that fully recognises the potential long-term health risks and environmental hazards associated with the wastes.

PART II - DATA COLLECTION AND EVALUATION

40 In order to develop a waste management program for a particular mining and milling operation it will be necessary to obtain and evaluate all relevant information on the natural conditions pertaining at the particular site. This should include information on such matters as climate, topography, geology, hydrology, soils, biota and the existing radiation environment. This information would then be considered in conjunction with the proposed project particulars - the mining method to be employed, the milling process to be adopted, wastes expected to be generated, etc. - thereby enabling the evaluation of various systems for the management of the wastes. This evaluation should lead to the selection of the optimal waste management system for the project. The waste management system would then be incorporated into the waste management program together with the proposed monitoring programs, contingency plans to deal with unplanned events and the plans for decommissioning and rehabilitation.

41 The four major factors that need to be considered in developing a waste management program for the particular project are:

- the environmental characteristics of the project area and its surroundings;
- wastes expected to be generated by the proposed uranium mining and milling operation;
- the waste disposal sites available; and
- the pathways of exposure of human and other biota to radioactive and non-radioactive contaminants from the proposed project.

These factors, which are in the main site specific, are inter-dependent and require consideration of their inter-relationships from the outset in order that the optimal waste management program can be developed.

42 A brief description of these four factors is given below together with an initial check-list of the information required to be submitted to the appropriate authority in order to permit a realistic assessment of the waste management program. It is recognised that many of the items will have been addressed to some extent in the environmental impact statement (EIS) the preparation of which is normally required for any proposal to mine or mill uranium. Therefore much of the data collected for the preparation of the EIS would provide a useful basis for the development of the waste management program. However, some of the items addressed in the EIS would require more detailed consideration in the development of the waste management program, either because more detailed information is necessary, or further

investigation and development has taken place since the ELS stage.

Environmental Characteristics of the Project Area and its Surroundings

43 For any proposed mining or milling operation, the development of a successful waste management program will require the collection and analysis of data on the existing physical environment at the site and its surroundings. The site characteristics requiring consideration are:

- Geography and Land-use
- Climate
- Demography
- Biota
- Hydrology
- Geology
- Mineralogy
- Hydrogeology
- Soils
- Existing Radiation Environment
- Archaeological, Anthropological, Historical and Aesthetic Aspects.

In the following sections, where distances are given in relation to the collection of data, these should be taken as a guide only as they will vary from site to site.

Geography and Land Use

44 This factor has a large influence on the selection of a waste management strategy for a particular project. For instance, topographical features of the site and its surroundings such as swamps, rivers, hills, etc. may not allow the construction of large tailings embankments, while permanent rivers may not be available to accept effluent discharges. The proximity of agricultural lands, grazing lands and townships may impose additional constraints. In turn, the present and potential terrestial and aquatic food production in the area would be influenced by the anticipated dose commitment from the discharge of radioactive material. Cognisance must also be taken of the possible adverse effects of the wastes on other known and potential resources of the region; including mineral and water resources.

45 **Information required** - A description of the site location and layout should be provided with maps showing the site and its location in relation to State, Territory and local

government boundaries. Detailed map(s) should be provided depicting the following :

- the topography of the project area and environs;
- the proposed project area and associated lease boundaries;
- the plant perimeter and the area to be occupied or modified by the mine or mill;
- adjacent mining/milling projects;
- nearby settlements, industrial plants and agricultural holdings;
- recreational and other public facilities (parks, etc.); and
- transportation links (railways, highways, waterways).

46 The nature and extent of present and projected land use, within a radius of, for example, 10 kilometres should be discussed.

47 Data on annual production and distribution of meat and farming produce within, for example, a 100 kilometre radius from the project area should be provided.

48 Where applicable data should be provided on the annual recreational and commercial aquatic food catch from waters within, for example, a 10 kilometre radius of the site. The catch data should be recorded in terms of principal species, location of catch and amount for human consumption noting, in particular, that consumed locally.

49 With regard to present and projected surface and groundwater resources within, for example, a 20 kilometre radius of the project site, information should be provided to the appropriate authority indicating:

- location of each significant water resource noting the distance of each from the mill and the population size dependent upon each resource - provide maps and map co-ordinates if appropriate;
- type of water use - noting, for example, whether the use is municipal, industrial, irrigation, stock watering, recreational or transport;
- for groundwater resources indicate the depths of wells, groundwater elevation and drawdown, and characterise the use by aquifer; and

- the withdrawal rates, both present and projected, for each water use.

Demography

50 The radiological impact on members of the public as a result of the operation of the mine and mill is evaluated in terms of the impact on specific groups of this wider population. These groups - the critical groups - are representative of those persons expected to receive the maximum radiological impact. For a given project and site there may be one or more critical groups. Each critical group should be small enough to be relatively homogeneous with respect to age, diet and aspects of behaviour that would affect the radiological impact. Accordingly, information on the population density and distribution, and the age, diet, recreational and working habits of residents in areas potentially affected by the mine and mill enables identification of the relevant critical group(s). The latest census statistics should be checked and, where necessary, special studies carried out to determine dietary and other behavioural patterns.

51 **Information required** - Current and projected population for the area within, for example, a 100 kilometre radius of the project area should be tabulated together with maps (of suitable scale) which depict the location of each significant population group.

52 The above census data should be accompanied by a description of the significant population and visitor statistics associated with schools, hospitals, recreational facilities, residential areas, etc. within, for example, a 10 kilometre radius of the project area.

53 With regard to dietary and other behavioural characteristics, the critical group(s) should be identified and their rationale for selection presented to the appropriate authority. For further comment on the selection of critical groups, reference should be made to the guideline: <u>Determination of Limits for Radioactive Discharges and Releases</u>, and to the following guidelines to the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1980):

- Background to Radiation Protection Criteria Embodied in the Radiation Protection (Mining and Milling) Code 1980;

- Radiation Monitoring Programs; and

- Record Requirements.

Climate

54 The climate of a region will have significant effects on the design, operation and rehabilitation strategies for the waste

management system. For example, precipitation, especially when considered with the annual evaporation at a site, is a major factor in determining whether all the liquid wastes can be retained in the waste management system, or whether liquid waste will have to be discharged to the environment. If the average annual evaporation exceeds the annual precipitation, and if seepage levels are known or estimated, it is relatively simple to calculate the area of the waste retention system required to evaporate all the effluent. Consideration must then be given to the distribution of the rainfall, both throughout the year and from year to year, to ensure that adequate freeboard in the waste retention systems is available at all times. For such systems it is essential to consider the catchment area draining to the waste management system and groundwater in-flow rates to mine pits, etc. This topic is discussed in more detail in the guideline : Design and Operation of a Water Management System for a Uranium Mining and Milling Operation.

55 In areas where annual evaporation is less than precipitation, or where evaporation of waste water is not a viable option, liquid waste may have to be discharged to the environment. In this case segregation of waters by water quality within the waste management system and/or treatment before discharge may be required to allow achievement of the appropriate effluent discharge limits (see the guideline: Determination of Limits for Radioactive Discharges and Releases). Variability of rainfall can be such that rivers or streams may cease to flow during certain times of the year, so that effluents cannot be discharged at those times. Therefore, discharge, if approved, may be limited to certain periods throughout the year to ensure sufficient dilution is achieved.

56 The diurnal and seasonal fluctuations in surface ground temperatures also influence waste management. In warmer climates, the diurnal temperature cycle can be a significant mechanism for the transport of oxygen into tailings and waste rock material with a resultant increase in bacterial leaching.

57 The atmospheric inversion characteristics of the mine and mill sites are an important factor. A knowledge of the frequency, duration, strength and break-up interval for atmospheric inversions is required for the calculation of the concentration at the plant and town site of airborne contaminants arising from mining and milling operations.

58 Wind direction, strength and frequency will influence the concentration of particulate and gaseous airborne contaminants. It will also determine, together with the rate of rainfall and storm intensity, the rate of erosion of waste rock heaps, ore stockpiles, exposed tailings and rehabilitated tailings disposal sites.

59 **Information required** - Sufficient meteorological data, obtained from the site itself and from nearby weather stations

should be included to justify the proposals submitted. This data is required for use in conjunction with an appropriate air dispersion model so that the points of maximum ground level concentration of radon, radon daughters and fugitive dust can be defined. The data should include the following:

- quarterly and annual wind rose presentation for the 16 principal compass directions;
- quarterly and annual wind speed, wind direction and atmospheric stability data in joint frequency form. The data should be presented for each of the 16 compass directions and the stability categories should be established to conform as closely as possible with those of Pasquill;
- monthly and annual precipitation and evaporation rates and pan coefficients (include comparison of lake and pan coefficients);
- frequency, duration and intensity of storms and/or tropical cyclones including rainfall intensity/duration curves for periods of 1 to 6 hours;
- monthly and annual temperature, relative humidity and barometric pressure averages;
- temperature inversion characteristics of the site including frequency and duration of inversion conditions, inversion and mixing heights, noting the diurnal and seasonal variation of these parameters; and
- background air quality both during normal and inversion conditions.

60 For a detailed discussion of this topic refer to the guidelines: Design and Operation of a Water Management System for a Uranium Mining and Milling Operation and Management of Airborne Emissions.

Biota

61 The nature of the aquatic, atmospheric and terrestrial ecosystem influences the degree of environmental degradation that would result from inappropriate waste management. In this context it is recognised that even minor waste discharges could upset the local ecosystem and produce substantial changes in the abundance and diversity of species present. To monitor and hence provide one form of assessment of the effectiveness of the waste management program certain species or habitats may be identified as suitable ecological indicators. For example, fish-breeding grounds and egg viability are two aspects of aquatic life which may be sensitive to siltation, changes in acidity, presence of heavy metals and other mill process chemicals.

62 An inventory of the environment in and around the project area should therefore be able to identify those species and habitats most sensitive to environmental degradation. Such an inventory does not necessarily provide a full and comprehensive assessment of all species and habitats in the project impact area. However, the inventory should comprise important species, where "important" implies that the species may be:

- commercially or recreationally valuable;
- threatened or endangered;
- critical to the viability of the above species or to the structure and function of the aquatic or terrestrial ecosystem; or
- a vector within a food chain that may potentially enable the transfer of radioactive and non-radioactive nuclides from the proposed mine/mill to critical groups of members of the public.

63 A range of biota and habitats also requires evaluation in terms of the interrelationships between various components of the ecosystem; in particular, those involved in transfer mechanisms. The capacity and rate of transfer of radionuclides for the soil-pasture-stock system should be one example considered, as should the effects of waste management practices on the bioaccumulation factors for the relevant radionuclides and non-radioactive chemical pollutants.

64 **Information required** - For the purposes of identifying the range of ecological indicators to be monitored during the life of the operation, a catalogue of the diversity and interrelationships (where applicable) of flora and fauna in and around the project site should be submitted to the appropriate authority. This submission would include:

- information on the abundance, distribution and type of habitat(s) for the various species;
- a map of the region depicting the principal plant communities;
- information on migratory species, especially where they use the project area or environs for breeding grounds;
- an inventory of "important" species (refer para. 62), in particular, domestic livestock (cattle, sheep, goats, etc.) because of their importance in the human food chain; and

- information on the current and potential resource importance of the project area biota in relation to the overall regional area resources.

65 From this catalogue, a list of the important species and of the proposed ecological indicators (be they species or habitats) would be provided to the appropriate authority. This list would be accompanied by supporting evidence which justifies the selection of these species and habitats in terms of enabling an assessment of the effectiveness of the waste management program. This evidence would include a discussion on the species to species and species to environment relationships. In particular the information would include:

- life histories, normal seasonal population fluctuations and habitat (e.g breeding-ground) requirements for the various species (particularly aquatic and terrestrial); and

- data on food-chains and species-to-species and species-to-environment relationships for determination of potental transfer mechanisms (e.g. soil-pasture-stock-human).

66 Part of the pre-operational studies conducted in and around the proposed project site, should be directed at the identification of any definable environmental stresses from already existing sources such as pollutants, as well as identifying the pertinent ecological conditions indicative of such stresses. The status of ecological succession should be described for the site and its environs. The histories of any infestations, epidemics, natural catastrophes should be discussed where they have had a significant impact on regional biota profile.

67 It is important that all sources of information should be identified wherever data from those sources are used in justifying the proposals for waste management such as selection of the ecological indicators. A list of published material dealing with the ecology of the region should be referenced in addition to any such studies currently in progress.

Hydrology

68 The local and regional hydrology determines the design and capacity of the water management and erosion control component of the waste management system. The magnitude and frequency of floods, seasonal flow patterns, water quality and surface run-off coefficients under varying storm conditions, dictate the quantity of, and rate at which, liquid wastes can be stored, evaporated or discharged. The magnitude and frequency of floods must also be considered as it is generally unwise to site a waste disposal system where there may be periodical flooding.

69 **Information required** - Information provided should include the following:

- Seasonal flow patterns and rates as well as estimates of frequency distribution of floods for water courses or water bodies in the project area and surrounding areas.

- Estimation of probable maximum precipitation and the resulting probable maximum flood.

- Water quality of all surface waters in the project area including analyses for the following constituents:

pH	chlorides as Cl
total solids	gross alpha-radioactivity
suspended solids	gross beta-radioactivity
dissolved solids	iron as Fe^{++} and Fe^{+++}
sulphates as SO_4^{--}	managanese as Mn
uranium as U	sodium as Na
thorium - 228, 230, 232	
lead - 210	potassium as K
radium - 224, 226, 228	calcium as Ca
total Kjeldahl nitrogen (expressed as N)	copper as Cu
nitrates (expressed as N)	lead as Pb
B.O.D. (Biological Oxygen Demand)	C.O.D. (Chemical Oxygen Demand)
	zinc as Zn
ammonia (expressed as N)	nickel as Ni
acidity as $CaCO_3$	barium as Ba
alkalinity as $CaCO_3$	vanadium as V
phosphorous as P	molybdenum as Mo
	selenium as Se
	chromium as Cr

- Annual run-off records.

- Run-off coefficients and their variability for sub-catchments within the project area.

- Information on the soil depth, vegetative cover and surface infiltration characteristics.

- Scale plans which should indicate the following:

  - Watercourses or water bodies that could receive effluent from the waste management system.

  - Any existing water system which will or might flow into any part of the waste management system.

  - Any water courses or waterbodies that could receive runoff from the mine-mill site.

- Catchment areas within the project area.

- Plan(s) indicating extent and depth of flooding for the probable maximum flood.

Geology

70 The geology of the orebody generally dictates the choice of mining method which in turn will determine the range of waste management strategies that can be considered.

71 The selection of the most suitable disposal site(s) will be based, to a large extent, on a detailed interpretation of the geology of the area. For example, in instances where the geological, mineralogical and hydrogeological characteristics of an open pit site are suitable, the open pit itself could be used for disposal of part, or all, of the mill tailings and other solid radioactive wastes. Some underground mines located in weak ground may require back-filling for stabilisation. Backfilling of voids left by mining may also be necessary to maximise recovery of an orebody.

72 The seismicity of the area must also be considered. For example, when siting and designing embankments, since earthquake deformation and possible consequent liquefaction due to earthquake shocks can have serious consequences such as failure of the dam and hence release of the tailings.

73 **Information required** - The geological aspects of the site and its environs should be discussed including the stratigraphy, structure, and tectonic history together with comments on regional continuity, faulting, and the dip and strike of water-bearing formations that will be affected. An inventory of economically important minerals and energy-related deposits, in addition to the uranium ore, should be included. Any effect that planned operations might have on the future availability of other mineral resources should be noted.

74 Detailed geological data at building sites and in the vicinity of tailings or other effluent impoundments and disposal areas, sanitary landfills, waste rock disposal areas, and sewage disposal facilities should be provided. This data should include:

- strike and dip and lateral and vertical distribution of permeable and impermeable layers;

- geochemical and engineering properties of soils and surficial weathered rocks including their chemical exchange capabilities;

- existence of faults, fractures and joint patterns; and

- detailed geological maps of the site and appropriate geological cross-sections of the tailings impoundment and the mine and mill sites.

75 A discussion of the seismicity (including history) of the region should be included. Where possible, seismic events should be associated with tectonic features identified in the geology discussion. A regional earthquake epicentre map should be provided showing site location and a seismic probability analysis may be required in active areas.

Mineralogy

76 The mineralogy of the ore, host and waste rock influence the nature and complexity of the waste management problem. The choice of an acid or alkaline leach uranium extraction process, is largely determined by the characteristics of the gangue minerals present in the ore. The mineralogy of the ore and the milling process determine the pH of the tailings, their salinity, heavy metal content, particle size and water retention characteristics. The pH of the tailings influences the solubility of the radionuclides, heavy metals and other chemical elements in the tailings. In this regard the presence and abundance of sulphides in the ore is important since the presence of sulphides (particularly pyrite) can lead to the production of sulphuric acid in the tailings. Any acid produced has the potential for leaching heavy metals and radioactive contaminants from the tailings.

77 Due to the relatively low hardness of uranium-bearing minerals, the uranium, vanadium, radium and other elements of interest tend to concentrate in the fine slimes fraction during the crushing and grinding processes. Thus, the handling of the slimes portion of the tailings is of special importance in consideration of the waste management procedures to be adopted.

78 **Information required** - The percentage composition of economically important minerals and the percentage composition of gangue minerals should be listed. The list should include the pyrite (marcasite), pyrrhotite and other base metal sulphide content. The estimated sulphide, uranium and radium content of waste rock and over-burden should also be tabulated.

Hydrogeology

79 The location and characteristics of confined and unconfined aquifers and points of groundwater recharge and discharge influence the quantity of water infiltrating into the workings (and in some cases into the waste management systems) and controls the length of time that the water is in contact with the ore. This in turn controls the composition of the mine drainage and tailings seepage and affects their disposal.

80 Seasonal variations in the water table level will have a large bearing on whether a below grade waste disposal system is a viable option for particular sites.

81 Groundwater quality and the existing and potential users of groundwater in the area will determine the extent of seepage control required as well as determining the amount and quality of controlled surface liquid effluent discharged to the environment. Where suitable hydrogeological conditions can be demonstrated it may be satisfactory to dispose of effluent by injecting it into a confined underground aquifer containing water of poor quality.

82 The area encompassed by the groundwater studies during site characterisation will vary, depending upon the types of aquifers underlying the proposed mining and waste management sites. Shallow, (unconfined) aquifers may require a study area radius of the order of several kilometres to encompass the groundwater flow system and off-site groundwater users while confined (artesian) aquifers may require a study area radius of the order of several tens of kilometres.

83 This topic is also discussed in the guidelines: Design and Operation of a Water Management System for a Uranium Mining and Milling Operation and Mining of Uranium by In Situ Leaching.

84 **Information required** - Sufficient site-specific groundwater data should be furnished to enable an evaluation of the effects of construction, operation of the project and disposal of wastes on confined and unconfined aquifers and water usage. Subsurface geological information including the groundwater conditions should define a hydrogeological model of the project area which should provide the basis for the water management plan proposed. The data should describe the occurrence and movements of water in both the unsaturated and saturated zones.

85 The parameters which govern the rate, direction and velocity of soil moisture movement and groundwater flow should be discussed. These parameters should include:

- range of vertical and horizontal hydraulic conductivities/permeabilities of soils, aquifers and confining beds of the natural and modified terrain including the waste management sites;
- hydraulic gradient, head distribution;
- transmissivity of aquifers;
- saturated thickness of aquifers and confining beds;
- storage coefficients of confined aquifers and specific storage of unconfined aquifers;

- total and effective porosities of aquifers;
- dispersion and distribution (sorption) coefficient of aquifers and soils;
- cation exchange capacity of soils and aquifers;
- depth to water tables (including perched water tables);
- natural fluctuation of water table; and
- groundwater quality including analyses for the constituents as listed for surface waters in paragraph 69.

Potentiometric surface and/or water table contour maps should be provided.

86 The investigation and description of significant hydrogeological units overlap with geologic studies and data described in an earlier section. Together they should identify the lithology, thickness, lateral extent, continuity, inclination, areas and modes of recharge and discharge, hydraulic properties, head, hydraulic communication and adjacent hydrogeological units and interrelationships with surface water bodies for the significant water-bearing units underlying the mine/mill and waste management sites. The presence of secondary permeability, such as solution features, or other preferential pathways, such as fault or zones joint systems would also be included in such a description.

Soils

87 The mineralogy and characteristics of the subsurface soils of the areas under consideration for mill sites and waste storage and disposal sites require special attention for reasons of structural stability and seepage control. For example, an area with high limestone or dolomite content near the surface may prove unsatisfactory for a waste retention system if the wastes contain sulphides that could generate acids. Acidic solutions from the wastes can percolate into and dissolve alkaline rocks thereby opening channels for seepage loss from the site and also possibly affecting the stability of the waste retention and disposal systems. On the other hand, the presence of some calcium carbonate in the soils increases the ability of the soils to raise the pH of the seepages.

88 Areas with high clay content may be more suitable as sites for waste storage and disposal. The rate of seepage will be reduced due to the lower permeability of clay soils and also the interaction between seepage solution and the clay particles can result in the adsorption, exchange or removal of toxic elements from solutions. Moreover, the suitability of the soils

available for construction or lining of tailings dams is an important consideration.

89 Rehabilitation of the waste disposal and other areas of the project site may also be affected by the availability of suitable cover materials which will effectively reduce the radon flux to acceptable levels, withstand erosion forces and support revegetation of the tailings surface.

90 **Information required** - A detailed surface soils map of the project area should be provided together with a profile of the surface structure. Given that the surface soils represent the upper few metres and the surface structure extends down to 50-100 metres, a substantial data base may be available from the geological, hydrological and hydrogeological studies of the project area. Additional data collected on surface and sub-surface materials should be related to the potential use of such materials, for example, the sub-surface structure should be assessed in terms of its capability to support surface waste storage and disposal facilities. Surface and sub-surface material may provide an effective resource for the construction and lining of such facilities. Finally surface soils should be examined in terms of their ability to support vegetation as may be required in rehabilitation of the project sites, including waste disposal sites.

91 A detailed analysis of the attributes of the surface and sub-surface materials is essential to the appropriate location and rehabilitation of waste management structures. The physical and chemical attributes to be determined include:

- the identification of soil types and their parent materials;
- moisture content, conductivity, infiltration and permeability rates, bulk density, degree of aeration, exchange capacity, strength and plasticity; and
- composition of soluble materials, potential nutrients and possible toxic antagonists in terms of ability to support vegetation.

Existing Radiation Environment

92 The radiological impact on the environment as a result of disturbance of the project area can only be accurately assessed if the radiation levels in and around that area were measured prior to that disturbance. Such measurements would encompass the types, levels and distribution of radiation and radionuclides. It is the radionuclides of the uranium and thorium decay series which would form a significant part of the operational monitoring program, as they are the radionuclides potentially released by the mining/milling operation. With the pre-operational profile as a base line or reference point, the

effectiveness of the waste management system in minimising the radiological impact of the operation on the environment should be more readily demonstrable.

93 Knowledge of the pre-operational environment is also required in assessment of the radiation exposure of the critical groups of members of the public (see paragraph 50). To determine the dose received by these groups as a consequence of the mining/milling operation, the pre-operational dose must be known and subtracted from the overall dose calculated during the operational period. For further information on this point reference should be made to the guideline to the Radiation Protection (Mining and Milling) Code 1980 entitled Radiation Monitoring Programs.

94 A further purpose for the measurement of the pre-operational radiation environment is to provide an adequate reference data base for evaluation of the effectiveness of rehabilitation of the project area in the long term - an important element of the waste management program. Its evaluation will involve determination of the ambient levels of radiation and a number of radionuclides in the post-operational period and comparison of these levels with those determined prior to disturbance of the project area by the mining and milling operation.

95 **Information required** - The pre-operational survey should include data on the overall radiation levels (eg. gross alpha- and gamma-radiation levels at a number of locations in and around the project area) as well as the measurement of specific radionuclides in air, water, soils and those species identified as "important" or as ecological indicators. For example, the levels of radon daughters and thoron daughters at various locations and times should be reported in addition to the levels and locations of radon and thoron emanations. Because of their potential for adverse health effects, members of the uranium and thorium decay series should be measured and reported to the appropriate authority; for example, U-238, U-234, Th-232, Th-228, Ra-228, Ra-226, Po-210, Pb-210. In reporting the above data it is important that the variations of the levels of radiation and specific radionuclides be noted and discussed.

96 In undertaking these radiation surveys cognisance should be taken of the low levels anticipated for a number of the radionuclides in the pre-operational environment. Consequently, equipment specifications should be reported, in particular in respect of the lower limits of detection, and the precision, accuracy and specificity of such equipment. A description of the methods should be described for each type of radiation data reported to the authority. Where data from other or previous studies are included in the report, adequate reference should be made as to the author, methodology, date, etc.

Archaeological, Anthropological, Historical and Aesthetic Aspects

97 The location and significance of sacred, archaeological and historical sites will have a bearing on the siting and design of a waste management system. If such sites exist and are deemed in need of preservation, measures to ensure their preservation need to be incorporated into the waste management strategy from the outset.

98 Areas with special aesthetic value may require protection from the visual intrusion of waste management earth works and structures. The siting and design of the waste management system as well as the rehabilitation of the site may need to be specially planned with this visual aspect in mind.

99 **Information required** - Areas valued for their cultural, archaeological, scenic or historical significance may be affected by the project. A discussion of such areas, if any, (e.g. Aboriginal sacred sites, paintings or engravings or areas of early settlement, historic roads,etc.) should be provided together with a detailed map showing the location of all such areas or sites. As the exact location of certain Aboriginal sacred sites should not be made public, the information provided to the appropriate authority should include a statement to the effect that such sites are or are not within the project area. The statement would include a supporting attestation from an appropriate body such as a State/Territory Museum, Land Council, Traditional owners, etc.

100 Evidence of contact with the appropriate State/Commonwealth Authorities and/or Aboriginal groups and/or groups representing local interests and a copy of comments by these bodies concerning the possible effects of the proposed project on these significant areas should be provided. Reference may also need to be made to groups such as National, State or Territory Parks and Wildlife Services, Heritage Commissions, State Museums, etc.

101 New roads, pipelines, and utilities connected with the proposed mine and mill that will pass through or near any area or location of known historical, scenic, cultural, natural or archaeological significance should be identified.

Wastes Generated by the Uranium Mining and Milling Operation

102 To properly utilise the environmental information outlined in the previous section, and to decide on the best practicable technology to be used in the management of these wastes, the volumes and characteristics of wastes expected to be generated by the project must be delineated.

103 Wastes produced during mining of radioactive ores are mainly site-specific; they depend on the size of the orebody, nature and composition of the ore and its host rock and the method of mining employed. Mine wastes will include waste rock,

ore dust, mine drainage and seepage as well as liquid and airborne effluents.

104 The two processes used in uranium milling at present are: the acid leach process coupled with either solvent extraction or ion exchange; and the alkaline leach process coupled with caustic precipitation. The acid leach process is the most widely used technology. Alkaline leaching is applied when the host rock contains minerals that would consume excessive quantities of acid. Whether an acid or alkaline leach is adopted, essentially similar wastes are produced and will include tailings, process liquids, tailings seepage and liquid and airborne effluents.

105 Wastes expected to be generated from the mining/milling operation can therefore be categorised in terms of solid, liquid and airborne and would include:

<u>MINE WASTES</u>

- Solid:
  - waste rock, below ore grade uranium material (bogum)
  - miscellaneous waste

- Liquid:
  - run-off from the RRZ
  - mine drainage
  - seepage
  - waste rock pile run-off
  - miscellaneous waste

- Airborne:
  - radon and radon daughters
  - ore dust
  - waste rock dust

<u>MILL WASTES</u>:

- Solid:
  - tailings
  - precipitates, concentrates
  - miscellaneous waste

- Liquid:
  - run-off from the RRZ
  - process liquids (solvents, etc.)
  - tailings liquid
  - tailings seepage
  - ore stockpile run-off and seepage
  - miscellaneous waste

- Airborne:
  - radon and radon daughters
  - dusts (yellowcake, tailings, ore)
  - other gaseous emissions

Mine Wastes

106 **Solid waste** - The major waste produced from the mining phase of the operation is the waste rock. The quantity will vary with the type of mining method employed, the shape and size of the orebody, depth below surface and the cut-off limits set for the extraction of uranium. The characteristics of the waste rock are frequently more variable than the orebody itself since the material may originate in the surrounding or overlying rock with little or markedly different mineralisation, or it may be a portion of the orebody itself.

107 If of suitable engineering property waste rock may be used for various construction projects on the site such as:

- for construction of embankments on the mine site;
- for construction of diversionary structures to divert run-off and water-course streams away from waste storage and disposal systems; and
- for construction of roads and similar projects on the mine site requiring fill.

However the mineralogy, radioactivity and chemical reactivity of the waste rock should be assessed before a decision is taken on any of these uses. For example, the mineralogy of the waste rock may not allow its use for construction of diversionary structures.

108 Because it isolates the material from the external environment, disposal of waste rock back into the mine may be preferable if the hydrogeological, engineering, radiological and economic aspects are favourable.

109 Where there is no alternative to the disposal of waste rock in dumps constructed above ground, the dumps should be located to minimise environmental impact and to ensure mechanical stability. They should be constructed using good engineering practice. Consideration must also be given at the planning stage to the requirements to be met for the rehabilitation of the waste rock dumps following the cessation of mining. The environmental impact that could result from waste rock dumps depends on the mineralogy of the materials, the climatic conditions of the area, the construction of the dump and the site where the dump is formed.

110 For a detailed discussion of this topic refer to the guideline: <u>Waste Rock and Ore Stockpile Management</u>

111 **Liquid waste** - With regard to mine drainage, this mainly consists of surface water or groundwater which has entered the workings through subterranean channels or fissures, or rainwater which has fallen or drained into open pit operations. Other

sources may be drainage from back fill operations, drill water, drinking and washing water.

112 It may be possible to reduce or minimise the volume of mine drainage by:

- reduction of groundwater seepage by grouting or diversion of surface waters;
- transporting tailings fill underground at the highest practical solids content;
- using recirculated water for transporting tailings fill underground; and
- treatment of water within the mine for re-use.

113 Mine water may have been in contact with the orebody for substantial periods of time, and thus may contain dissolved uranium, radium, thorium, radon, thoron, non-radioactive heavy metals, and be quite acidic (or basic). Table 2 lists some potential contaminants in liquid wastes. It is not intended to be comprehensive but simply to provide an indication of the source and extent of the radioactive and non-radioactive nuclides that may be encountered.

114 In underground mines, mine water may contribute appreciably to radon levels in mine air. It is preferable to use this effluent as make-up water in the mill if this is feasible, as in this way the number of effluent streams is reduced and any uranium in the water can be recovered.

115 If more drainage is available than can be utilised in the mill, then it may be discharged to the water retention system without treatment if the latter is a no release system and it has the capacity to evaporate the additional volume. However, where the water retention system cannot accept the excess drainage, then it may be possible, in some cases, to discharge it under controlled conditions to surface waters, after treatment if necessary. Specific treatment and disposal of a mine drainage waste stream is dependent on local conditions such as the mineralogy of the orebody, climate, topography and the proximity to an operating mill. Treatment may include separation of uranium, radium, and other heavy metals before release by utilising such processes as sedimentation, lime neutralisation, ion exchange and precipitation with barium salts.

116 This topic is also discussed in the guideline: <u>Design and Operation of a Water Mangement System for a Uranium Mining and Milling Operation</u>.

117 The effects of any seepage from waste rock dumps must be assessed and provision for collection and treatment of this seepage made if required. For example, dumps formed by road

haulage of rock will normally be steepsided with flat top surfaces except for the approach road and usually exhibit a low run-off coefficient. Thus a large part of the precipitation will ultimately appear as groundwater or surface seepage. If the waste rock contains active sulphide material, this seepage will have a low pH, high total dissolved solids and, if the mineralogy is complex, may contain high concentrations of some heavy metals (e.g. Cu, Zn, Co, Ni and As), as well as radionuclides. Consequently, dumps that are a potential source of pollution could be centrally drained and the waste stream treated during the operational phase. The problem may be exacerbated in areas that have a marked seasonal or heavy rainfall. Rehabilitation of the dumps would then need to render unnecessary the need for such active drainage and treatment measures. For a detailed discussion of this topic refer to the guideline: Waste Rock and Ore Stockpile Management.

118 **Airborne waste** - Ore dust represents a radiological hazard (for example, from radionuclides radium-226, polonium-218 and thorium-230) to on-site personnel and to the environment. The significance of the impact will vary according to the contained radionuclides and the particular operation generating the ore dust, for example, drilling and blasting operations and ore stockpiling. Management of the ore dust should commence at the source.

119 Besides containing radon (thoron) and its daughter products, exhaust ventilation from underground mines may be contaminated to some extent with ore dust, rock dust, and fumes from blasting and diesel engines and some control of the discharge of the non-radioactive components may be necessary. In many cases, rapid atmospheric dispersal of the discharges will dilute the concentrations of radioactive contaminants to levels below those appropriate for members of the public, as specified in the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1980). However, these discharges may, under special conditions (inversions, mine conditions or proximity to large population centres), require some additional action or treatment to prevent the discharge of airborne radionuclides in concentrations which might result in the levels specified for employees and for members of the public being exceeded. Thus it may be necessary, for example, to discharge through a stack of sufficient height to restrict ground-level concentrations to acceptable values, or to position the exhausts down-wind from the public and to avoid recirculation of the discharge into the mine.

120 It should be noted that occupational control of dusts does not necessarily provide for environmental control unless the dust is physically collected and prevented from contaminating the environment.

121 For a detailed discussion of this topic refer to the guidelines: The Management of Airborne Emissions and Waste Rock and Ore Stockpile Management.

122 **Miscellaneous waste** - Contaminated miscellaneous waste, such as scrapped drilling, digging, loading, transport and other equipment should not be disposed of with the normal (uncontaminated) scrap and waste. In addition, disposal of items such as air and oil filters and engine oil should be carefully considered.

123 **Information required** - All types of waste and effluent likely to be produced as a result of the proposed mining operation should be identified together with the sources of such wastes. The estimated quantities, concentrations, physical and chemical characteristics should be specified along with the average and maximum rates of production. All models and assumptions underpinning these estimates should also be made available to the appropriate authority.

124 The above detailed inventory of mining wastes and effluents should be set down in the context of a general description of the proposed mining operation. This description would include:

- the total quantities (mass and volume) of ore, waste rock and overburden to be mined over the life of the operation;
- the average grade of ore, and an indication of the range of ore grades expected;
- the mineralogy of the waste rock, particularly, the sulphide mineral content;
- the estimated quantities (mass and volume) of ore, waste rock and overburden to be mined, stockpiled and treated on a monthly and yearly basis;
- the method(s) for managing the mine wastes and, in particular, any dewatering activities, and ventilation facilities for underground mines; and
- topographical maps showing locations and areas to be mined, areas to be used for bulk storage of ore, bogum, waste rock, overburden and low grade ore, and the position of haulage and access roads.

Mill Wastes

125 **Solid waste** - The major wastes resulting from the milling process are the tailings. Radiological protection problems arise in the management of uranium mill tailings because of the presence of the long lived thorium - 230 (half life 80,000 years) and its daughter radium - 226 which remain in the tailings following conventional extraction processes. Though the radioactive content of the tailings is essentially the same as

the original ore body the various radionuclides (and the heavy metals), after the milling process, are more mobile and potentially more accessible to the environment and man than they were in the mineralised state, underground. The tailings are generally readily accessible, stored in large impoundment structures sometimes above ground level and subject to the vagaries of nature. Thus, the potential environmental and radiological impact of the contained radium (and its daughter product radon) has been significantly increased as a result of the uranium extraction operation. It is the function of the waste management system to ensure that all reasonable steps are taken to minimise the detrimental impact of the tailings on man and the environment, both now and in the future.

126 The tailings are a potential source of airborne radioactive material in the form of radon gas and airborne particulates and of waterborne contaminants as well as radionuclides contained in seepage, surface run-off, and the waste solutions. Sufficient radioactivity is in the tailings to create a weak field of gamma radiation in their immediate vicinity. Chemical pollutants, including various heavy metals, sulphates and acid, may also be leached from the tailings and pollute surface or sub-surface waters. Measures to reduce or control these pollutants (both radioactive and non-radioactive) require consideration.

127 The design, construction and size of an impoundment for disposal of tailings will vary significantly from one milling location to another. The characteristics of the impoundments will depend on such diverse factors as the capacity of the mill, type of ore processed, amount of waste produced, type of milling process, topography of the area, amount of land available, climatological parameters, permeability of soil in the area and of the materials with which these impoundments are constructed.

128 Because it provides a convenient disposal site, backfilling of all or part of the tailings into worked out portions of an underground mine may offer considerable promise, if the whole operation is planned on this basis. However, matters which should be specifically addressed when considering this disposal option are:

- the tailings consist of a graded mixture which can consist of sand and slimes; normally only the former are satisfactory as backfill for underground mines; the structural properties of desanded tailings are not as good as those of the original tailings, giving rise to more difficult dewatering and revegetation problems;

- most of the radium and other daughter products are contained in the slimes fraction, which, after separation of the sand fraction, are still subject to approved waste disposal requirements; and

- tailings backfilled into underground mines, even under adequate engineering control, may alter the contaminant level in mine drainage. Those backfilled into open cut mines may cause contamination of groundwater or surface water with radionuclides, heavy metals and other significant environmental pollutants.

129 Tailings deposited in properly engineered, properly located waste impoundment systems may not present a significant hazard while the mill is operational, provided that they are properly managed. However after the mill has been decommissioned, control, surveillance and maintenance of the waste management systems may present problems which will last into the future unless adequate rehabilitation measures are undertaken. Some of the potential problems are:

- The slimes portion aided by rainfall on, and drainage into, the waste management system may stay fluid for a very long period, exerting a continuous hydrostatic pressure on an impoundment wall. This may, especially if weakened by erosion and seepage, eventually fail, leading to widespread release of tailings before the defect is observed.

- Revegetation of unrehabilitated tailings disposal sites is difficult to initiate and even more difficult to sustain. If a vegetative cover is not established, then wind and water erosion over the centuries (or even a few decades) could lead to widespread contamination of the surrounding area.

- Seepage from the impoundment containing a significant concentration of radionuclides may eventually reach underground or surface waters that are a potential resource.

- Some uranium mill tailings present a different type of problem. Owing to the sulphide content of the ore, acid production occurs in the tailings. The sulphides in the tailings are oxidised by a complex series of reactions which may be generally summarised by the following general equation:

  $$4FeS_2 + 2H_2O + 15O_2 = 2Fe_2(SO_4)_3 + 2H_2SO_4$$

  The process of oxidation may be both chemical and bacterial. Different forms of sulphide react at different rates but require water and oxygen as seen in the above equation. Light, temperature, acidity and bacteria will also influence the rate of reaction. While chemical oxidation is slow, more rapid oxidation by bacteria (e.g. *Thiobacillus ferroxidans*) occurs below pH 3.5-4.0 with optimum conditions between pH 1.5 and pH 3.5.

For a detailed discussion of strategies for the disposal of tailings refer to the guideline : Tailings Impoundment for Uranium Mines.

130 Other solid wastes subject to approved disposal requirements include waste concentrates formed as a result of the treatment process carried out to remove and concentrate hazardous material from a product or effluent stream. Although such concentrates are generally fluid sludges or wet filter cakes, they may be considered as solid wastes because the hazardous materials are concentrated in the solid phase. The most common wastes which fall into this category are sludges containing a mixed precipitate of $(BaRa)SO_4$ produced during the treatment of decant liquor.

131 Other solid wastes that may require consideration are the areas previously occupied by an ore stockpile. The foundation material of these stockpiles may have become contaminated by seepage through the stockpile. This material may require disposal with the tailings. For a more detailed discussion of this topic refer to the guideline: Waste Rock and Ore Stockpile Management.

132 Other miscellaneous solid waste may include such items as plant and machinery, ventilation ducting and filters; their final disposal requires consideration and approval by the appropriate authority.

133 **Liquid waste** - The main liquid wastes requiring consideration are the mill process solutions, the tailings seepage, run-off from restricted release zone(s) and seepage from ore stockpiles.

134 With regard to the mill process solutions in the alkaline leaching process, the barren liquor is recovered and re-used, and does not become a waste stream. The leached, washed tailings are transported to the waste retention system in a water slurry. The water slurry is slightly alkaline and may be contaminated with radioactive nuclides and chemicals, as indicated in Table 2, and may need treatment before disposal. After the acid leaching process, however, the solution that is normally used to transport the tailings may contain greater concentrations of contaminants including sulphuric acid, heavy metals, nitrates, sulphates, organic solvents and amines (both from solvent extraction), chlorides and the radionuclides of which the most critical is radium-226 as well as other contaminants as shown in Table 2.

135 The most effective method for minimizing contamination of the environment by effluents from uranium milling operations is to avoid, or limit as far as possible, the discharge of effluents. In some instances this objective may be achieved through complete recycle of the decant solution to the milling

process if the metallurgy is not detrimentally affected. The amount of new water required should be reduced by optimizing water usage and practising water reclamation where possible. A detailed water balance should be made and periodically reviewed so as to ensure the optimum use of water throughout the operation. The mill process effluent is the waste component most likely to influence the treatability of waste streams and to affect the degree to which they can be recycled to the mill. Processes and reagents used in the mill should therefore be selected so as to reduce as far as possible any adverse effects on treatability and recycle capability.

136 All working areas which may be sources of contaminated waste streams should be consolidated to the greatest degree feasible (i.e. all RRZ's should be kept as small as possible). For example, from the standpoint of drainage control, it is usually preferable to locate the mill, mine head, maintenance shops and materials handling facilities in one controlled area. The relative advantages of segregating waste streams for treatment should be assessed.

137 The main process for the treatment of acidic mill effluents is neutralisation with lime or a combination of limestone and lime. During this step the following purification processes occur:

- sulphuric acid is neutralised;
- some sulphate is precipitated;
- some heavy metals are precipitated;
- thorium-230, thorium-232, and lead-210 are reduced to a low concentration; and
- amine is removed by adsorption on precipitated solids.

138 It is possible to reduce the radium 226 concentration quite considerably by co-precipitation with barium sulphate. This is achieved by addition of barium chloride to the solution in the presence of excess sulphates at pH 8-9.

139 Where discharge of all or part of the mill process waste stream is considered, specific discharge limits will need to be approved by the appropriate authority. For a discussion of this subject refer to the guideline: Determination of Limits for Radioactive Discharges and Releases.

140 With regard to tailings seepage this can change in character with time as the tailings accumulate, and the seepage may present quite different problems at different stages. Initially the seepage corresponds quite closely in composition with the decant solution and contains appreciable quantities of radium, so seepage should be minimised to reduce the discharge of

radium. As the depth of tailings increases and the impoundment rises, the pond may retreat from it, depending on the method of distributing tailings, and the seepage may consist more of rain-water which has infiltrated through the tailings and less of decant solution. Thus, the radium levels may drop and there may also be marked changes in pH and the concentration of sulphate and metallic ions. These changes may continue long after operations cease.

141 For a detailed discussion of this topic refer to the guideline: Tailings Impoundment for Uranium Mines.

142 **Airborne waste** - Airborne wastes in the mill may be generated during stockpiling operations, crushing, grinding and screening processes as well as in the packaging area. Dusts are a potential source of radioactive decay products such as radium-226, polonium-218 and thorium-230. In addition, the finely divided state of the material increases the probability of radon-222 escaping to the air.

143 For a detailed discussion of this topic refer to the guideline: Management of Airborne Emissions.

144 **Information required** - The entire mill process and/or circuit should be quantitatively and qualitatively described in sufficient detail to permit assessment of the quantities and constituents of all gaseous, liquid, and solid wastes and effluents generated in the process. The following information should be included:

- a flow diagram of the process and/or circuit;
- a material balance diagram;
- a description of any water recycle systems;
- a water balance diagram for the entire project; and
- scale plans showing all structures for settling, decanting, retaining, treating and for controlling the movement of wastes and effluents.

145 All solid, liquid and airborne wastes and effluents likely to be produced as a result of the milling operation should be quantified including the sources of such wastes. The expected quantities, concentrations, physical and chemical characteristics of the wastes and effluents should be specified. Average and maximum production rates should be included along with all pertinent, supporting information such as assumptions, computational methods and models.

146 A discussion of the tailings produced should include:

- the estimated total tonnage and volume of tailings to be produced during the life of the operation and the monthly and yearly production rates;
- the estimated concentrations of radioactive and non-radioactive contaminants in the slimes and sands tailings fractions as well as in the liquid phases in the tailings management system;
- the pH of the tailings pile and changes in pH that may be expected to develop during and after the life of the operation;
- the estimated percentage of the slimes, sands and liquid fractions of the tailings pile during and after the life of the operation;
- the estimated bulk density, permeability, shear strength, moisture content, porosity and dry density of the tailings mass during operation and at the time of decommissioning;
- estimates of the average and maximum radon release rates from the tailings impoundment during the operational stage;
- the amount of seepage, the seepage release rate and the contaminants release rates expected from the tailings management system;
- the estimated depth and area of tailings in the tailings management system at the end of the mining and milling operations; and
- the final surface shape(s) of the tailings impoundment(s) after rehabilitation.

The Waste Disposal Sites Available

147 The wastes produced by mining/milling operations, and in particular the large volume of tailings and waste rock which are generated, dictate disposal in close proximity to the mine/mill. The principal implication of such circumscribed options is that disposal facilities must cope with the circumstances pertaining at the nearest suitable site. The environmental characteristics of the site, together with the mineralogy of the ore and the mining/milling method adopted, will largely determine the type of waste disposal system employed.

148 The most essential characteristic of a waste disposal system is that its elements be located in a naturally stable environment and designed in such a way that the contaminants

(both radiological and non-radiological) will not pose problems for present or future generations (as far as can be predicted). The characteristics and location of the site, the design of the system and the characteristics of the wastes therefore all enter into determining the requirements of an effective waste management system.

149 The site selection process should seek to optimise the advantages of site features while placing primary emphasis on long-term factors. The attractiveness of possible savings in the short term, through minimisation of transport or land acquisition, for example, should be kept in perspective.

150 In deciding on a particular location from several alternatives the following site features should be considered:

- remoteness from populated areas;
- hydrological and other natural conditions, as they contribute to continued immobilization and isolation of contaminants from usable surface and groundwater resources; and
- potential for minimising erosion, disruption and dispersion by natural forces over the long term.

151 The major wastes produced from most uranium mining and milling operations are the mill tailings, waste rock and waste waters. For a detailed consideration of these topics refer to the guidelines: Tailings Impoundment for Uranium Mines, Waste Rock and Ore Stockpile Management, and Design and Operation of a Water Management System for a Uranium Mining and Milling Operation.

152 **Information required** - Information should be provided to the appropriate authority which details the range of sites considered for the disposal of mine and mill wastes. These options should be discussed in the context of the specific wastes being considered including the rationale for selecting a specific site.

Pathways of Exposure of Human and other Biota to Radioactive and Non-Radioactive Contaminants from a Particular Project

153 Pathways in the environment by which radionuclides released from radioactive wastes can give rise to human exposures are schematically outlined in Figure 1.

154 Exposure pathways may be generalised as follows:

- Atmospheric Pathways
  - inhalation (of radon and its daughters and of airborne radioactive particulates).

- external radiation (from airborne radioactive material).
- ingestion (of foodstuffs contaminated by deposition of radioactive material).
- external radiation (from deposited radioactive material).

. Aquatic Pathways
  - ingestion (of contaminated water).
  - ingestion (of fish and other aquatic biota).
  - ingestion (of irrigated foodstuffs).
  - external radiation (from waterborne radioactivity).

155 In principle, the individual and collective doses for each radionuclide released or discharged to the environment from the project taking into account all of these pathways, need to be evaluated in order to determine whether compliance with the dose limits and with the "as low as reasonably achievable" criterion is being met. In practice, a few radionuclides and pathways usually contribute the major fraction of individual or collective doses. The evaluation of the relationship between discharges and doses can therefore be focussed on these few radionuclides and pathways, often referred to as critical radionuclides and critical pathways. Identification of the critical nuclides and pathways for a specific site, however, will require a thorough survey of local conditions.

156 The analysis of the relationships between discharges to the environment and doses to population groups may be used to set discharge limits to be met by the particular operation. In general, discharge limits are determined by the doses received by members of the public outside the Restricted Release Zone(s) determined for the project. In the case of discharges to the atmosphere, exposure of individuals on the project site, and therefore likely to be within the Restricted Release Zone, should also be considered and may require point source discharge limits. For a detailed discussion on this topic refer to the guideline on Determination of Limits for Radioactive Discharges and Releases.

157 The Code provides for protection of people and the environment from possible harmful effects associated with radioactive wastes. However, it is recognised (Clause 4(3)) that non-radioactive contaminants will also need to be controlled as, in many cases, they would be discharged from the same sources and through the same pathways to the environment and to people.

158 Another factor to be taken into account is that pre-operational base line environmental parameters will sometimes be significantly changed by the discharge of chemicals and as a result radionuclides already in the environment could be transported in ways different from those predicted were chemical discharge not taken into account.

159 **Information required on the radiological impact on humans** - The major pathways for radiation exposure of humans from the mining, milling and waste management operations should be identified and described in textual and flow-chart format.

160 For aquatic pathways, where the sources of contamination are liquid effluents the following information should be provided:

- Estimates of the expected annual average concentrations (and of significant short-term variations to this average) in ground and surface receiving waters at locations where water is consumed or otherwise used by human beings or where it is inhabited by biota of significance to human food chains. Dilution factors used in preparing the estimates and the location where the dilution factors are applicable should be specified.

- The expected radionuclide concentrations in aquatic and terrestrial organisms significant to human food chains. The bio-accumulation factors used in the calculation of the estimates should be specified.

- A calculation of the whole body dose equivalent (sieverts/year) to the critical group(s) of members of the public from the major exposure pathways related to receiving waters, i.e. both external and internal exposure, should be provided. Details of the models and assumptions used in the calculations should be included.

161 For atmospheric pathways, where the sources of contamination are airborne effluents, the following information should be provided:

- From the release rates of radioactive gases and meteorological data give estimates of whole body dose equivalent (sieverts/year) to the critical group(s) of members of the public exposed at the point of maximum ground-level concentrations off-site, the population exposed at the site boundary nearest to the sources of emissions and the population exposed at the residence expected to receive the highest dose commitment.

- Estimates of the amounts of deposited radioactive materials on food crops and pastures. Estimates of whole body dose equivalents (sieverts/year) from the major airborne potential pathways. A description of the models and assumptions used in the calculation should also be included.

162 **Direct radiation** - An estimate of the maximum annual external dose equivalent that would be received by an individual at the nearest site boundary from direct radiation should be provided along with models and assumptions used in the calculations.

163 **Information required on the non-radiological impacts on humans** - The specific concentrations of non-radioactive wastes in effluents at the points of discharge should be compared with natural ambient concentrations without the discharge and with applicable standards. The projected effects of the effluents for both acute and chronic exposure of human beings (including those resulting from any long-term build-up in soils, sediments and biota) should be identified and discussed. Dilution and mixing of discharges into the receiving environs should be discussed in detail, and estimates of concentrations at various relevant distances from the points of discharge should be provided that relate to factors such as dilution, habitations, wells, and water intakes. The effects on humans from changes in terrestrial and aquatic environments resulting from chemicals that contaminate ground water should be included.

164 **Information required on the radiological and non-radiological impact on non-human biota** - The various possible pathways for radiation exposure of the important local flora and local and migratory fauna should be identified and described in textual and flow-chart format. The pathways should include the important routes of radionuclide and non-radionuclide translocations to organisms in and around the project site.

165 From considerations of the exposure pathways and the distribution of radioactive and non-radioactive wastes released into the environs, estimates should be provided on the maximum radioactive and non-radioactive contaminant concentrations (e.g. heavy metals) that may be present in important local flora and local and migratory fauna. Values of bio-accumulation factors used in the estimates should be based on site specific data if available or on values from the literature, citing appropriate references.

PART III - THE WASTE MANAGEMENT PROGRAM

166 The waste management program for a particular mining and milling project comprises the waste management system together with relevant elements of the monitoring programs; the contingency plans to deal with unplanned events; and the decommissioning and rehabilitation plans. Figure 2 depicts schematically the sequence of events associated with the development of an approved waste management program.

167 The program document should describe each of these components and, in particular, address the proposals for the long-term disposal of the wastes and for regular review and update of the program (and, as necessary, approval by the appropriate authority). This latter aspect of the program would allow for details of the program to be modified throughout the life of the operation in the light of operating experience and changes in technology.

168 A summary of the project characteristics should introduce the waste management program. This summary would include:

- objective of the project;
- location and lease arrangements;
- a brief description of the existing environment;
- a description of the proposed mining and milling operation (including schedules for mining and milling and anticipated workforce for the construction, operation, decommissioning and rehabilitation phases); and
- a brief assessment of the environmental impacts of the project.

Waste Management System

169 The description of the waste management system for the project would include a discussion of:

- the restricted release zone(s);
- the water management plan;
- the management of mine wastes; and
- the management of mill wastes.

170 Restricted release zone(s) - The proposed restricted release zone(s) for the project should be delineated on a plan of appropriate scale. The plan should include topographical

contours; catchment areas; and the location of the various components of the mining and milling operation. In keeping with the requirement that the restricted release zone be kept to the minimum area possible, the plan should be accompanied by a description of the restricted release zone(s) which would demonstrate that this requirement had been complied with. This discussion should also indicate any proposed future amendments to the zone(s) in relation to the schedule of mining and milling.

171 **Water management plan** - The plan of management for handling all waters which come into contact with or are generated by the mining and milling operation should be described and discussed in detail. This description should include:

- a clear statement of the type of water management strategy adopted, that is, Absolute No Release, No Release, Contingency No Release, Controlled Release or Uncontrolled Release Systems. (These strategies are defined in the guideline : Design and Operation of a Water Management System for a Uranium Mining and Milling Operation.);

- a statement of the methods for operation and maintenance of the water management system;

- a clear diagramatic presentation of the water flows in the system and as necessary, a "Start of Operations" mathematical model;

- a water-balance calculation for the project, identifying the site parameters and project design parameters on which the calculation is based together with sensitivity modelling and simulation of operation of the system to variations in the governing parameters;

- the management systems and procedures for controlling mine waters from underground and open pit mines, runoff from ore stockpiles, waste rock heaps and access roads and seepage from ore stockpiles and waste rock heaps;

- an outline of contingency procedures for disruptions that may occur to the operation and maintenance of the water management system; and

- details of the surface water and groundwater monitoring program.

172 Proposals for the release, if any, of liquid effluents from the restricted release zone(s) should be specified in the program including:

- expected discharge rates and quantities (in terms of liquid volume and contaminant load);

- physical and chemical characteristics of the expected discharge effluent;

- discharge procedures;

- average and maximum discharge rates;

- hydrological conditions of the receiving waters; and

- the quality of the receiving waters.

173 More detailed information on development and contents of water management system is set out in the guideline: Design and Operation of a Water Management System for a Uranium Mining and Milling Operation. Detailed information on erosion control to reduce radiological impact is given in the guideline : Decommissioning and Rehabilitation of Uranium Mine, Mill and Waste Disposal Sites.

174 **Management of mine wastes -** In relation to solid and liquid mine wastes, the program should specify:

- the strategy for managing ore stockpiles, including proposals for preparation of the foundation for such stockpiles and for dust suppression;

- the strategy for managing and disposing of waste rock, including information on expected quantities and types of waste rock, with the annual rates of production, geological description, mineral content, contaminant potential and the expected usage in various construction projects; and

- the methods for disposal of obsolete, damaged or worn-out mining plant and equipment.

175 In relation to gases and airborne particulate emissions, details of the management systems and procedures for their control should be included in the program specifications. These specifications should detail:

- the potential sources of gaseous and other airborne emissions, such as ore stockpiles, waste rock heaps, haulage and access roads, underground mine workings and open pits; and

- the estimates of the average and maximum expected radon exhalation rates, radon/radon daughter and dust concentrations from and around these potential sources.

176 For more detailed information on the above items reference should be made to the guidelines: Management of Airborne Emissions; Waste Rock and Ore Stockpile Management, and Determination of Limits for Radioactive Discharges and Releases.

177 **Management of mill wastes** - The program should detail the specifications for the proposed mill waste management system including all relevant plans and diagrams. The system should encompass the management of tailings, contaminated process liquids, airborne discharges and contaminated plant and equipment.

178 **Tailings** - the strategy for the management of the tailings should be described in detail including:

- the characteristics of the orebody, and the processes and treatment to be used in the production and handling of tailings;

- the type of impoundment proposed, its design and expected behaviour;

- a detailed description of the physical characteristics of the proposed impoundment site;

- the type of tailings management to be utilised;

- measures for controlling (as far as possible by the use of best practicable technology minimising):

  - seepage from the impoundment;
  - radon/radon daughter exhalation from the tailings; and
  - dust arising from the tailings;

- the long-term rehabilitation proposals for the tailings impoundment;

- scenario for behaviour during the long term; and

- the assessed environmental impact of the impoundment during operations and for the long term.

179 For further comment on the siting, constructing, operating, decommissioning and rehabilitation of uranium tailings impoundments refer to the guideline: <u>Tailings Impoundment for Uranium Mines</u>.

180 **Other solid and liquid wastes and effluents** - The program should identify the procedures for disposing of radioactive precipitates and concentrates resulting from the treatment of tailings liquids discharges with, e.g. barium chloride. Details should be included on expected quantities, concentrations of radioactive wastes and other physical and chemical properties of such precipitates and concentrates.

181 Procedures for disposal of other process liquids (e.g. solvents) and other miscellaneous liquid wastes should be provided to the appropriate authority.

182 A description of the methods for disposing of contaminated plant and equipment used in the milling process, such as filters, filter presses and obsolete or worn-out equipment should also be provided to the appropriate authority.

183 **Airborne wastes and effluents** - The program should include specifications on the ventilation, filtration and dust collection systems to be used to control airborne radioactive materials such as radon/radon daughters, ore and yellowcake dusts. The type of equipment used, minimum performance specification, its location and an analysis of the efficiency as designed and operated should be included in order to show that the best practicable technology will be utilised to minimise the release of radioactive material. A description of the mill discharge stacks, including stack heights and methods for minimising releases (e.g. scrubbers, filters) should be provided together with a description of the proposed sampling regime and sampling equipment.

Monitoring Programs

184 The waste management program should document the mine and mill effluent and environmental monitoring programs for assessing the radiological impacts of the mining and milling wastes. In particular, the program should summarise the scope, schedule and resources (personnel and equipment) for the monitoring of radiation levels and chemical concentrations of radionuclides in the discharges in the effluent streams and in the environment (air, water, soils and biota). As required by the appropriate authority similar details should be given for the monitoring of significant non-radionuclides.

185 Specific details included in the waste management program should include the proposed observation sites, sample collection and analysis procedures (including frequency), instrumentation and the methods of assessing and reporting data. The program should be explicit with respect to minimum sensitivities and the parametric limits that are not to be exceeded by the operation - these limits should be related to the pre-operational background environmental and radiological measurements and proposed discharge levels. With regard to presonnel and equipment resources: the program should note the number, qualifications and experience of the proposed staff and the purpose, specifications, operating limits and performance efficiency of the instrumentation.

186 **Radiation and chemical monitoring** - In the context of the above information provided to the appropriate authority, the waste management program should document the levels, concentrations and rates of discharge and accumulation (as appropriate) of radiation, radionuclides and significant non-radioactive contaminants expected in the effluent streams and in the environment. These estimates - in terms of the average,

maximum, minimum and routine - should be compared with the sensitivity limits for detection and with the relevant prescribed limits set by the appropriate authorities, citing the applicable legislative instrument(s). Where particular monitoring procedures are prescribed by the appropriate authority, these should be incorporated into the program unless agreement on alternative procedures has been reached with the appropriate authority. The program should clearly identify the effluent streams and environmental components, if any, that will not be monitored, documenting (with supporting evidence appended if necessary) the reasons for the absence of monitoring. Finally, the program should define the levels at which corrective measures will be initiated when these levels are exceeded and indicate the range of measures available (ranging from investigation and assessment to amendment of the waste management program).

187 **Related environmental monitoring** - Because of their particular relevance to the control and regulation of airborne discharges, the meteorological parameters to be monitored in and around the project area should be specified.

188 Where the project area lies within a region for which environmental assessments are carried out by public agencies or agencies not directly supported by the proponent, such assessments should be identified together with their author(s), purpose and relevance to the waste management program. Plans for exchange of information with the organisations responsible and, to the extent possible, the procedures, methodologies and types of data being collated should also be summarised.

189 **Development of monitoring programs** - For further details on the development and implementation of monitoring programs refer to the guideline: Determination of Limits for Radioactive Discharges and Releases and the guideline to the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1980): Radiation Monitoring Programs.

Contingency Plans to deal with Unplanned Events

190 Unplanned events may occur that involve release of contaminants, either radioactive or non-radioactive, to the environment. These possible unplanned events should be identified, associated effects evaluated and contingency plans for dealing with such events outlined. The plan should include details of monitoring procedures specifically designed for each of the events identified.

191 **Release of radioactivity** - The proponent should provide analyses for a spectrum of unplanned events that might occur ranging from minor (essentially no release of radioactivity to the environment) to very large releases. Each class within the spectrum should be characterised by an occurrence rate or probability and its potential consequences, if any. Examples of unplanned events resulting in large releases would be a cyclone

striking the mill or the failure of a waste management system. Examples of unplanned events resulting in small releases would be a fire or explosion in a solvent extraction circuit or failure of the air cleaning system servicing the yellowcake packaging area during operation. An example of a minor unplanned event would be the malfunction of mill process equipment or the rupture of a vessel containing mill solutions resulting in a spill of liquids into a bunded area.

192 **Other releases** - In addition to unplanned events which can release radioactivity to the environment, there may be events that, although not involving the release of radioactive materials, do have consequences that affect the environment. Such unplanned events as chemical explosions or fires, steam boiler failures and leakage or rupture of vessels containing toxic materials can have significant environmental impacts.

193 **Accidents during the transport of radioactive and other hazardous materials** - The potential environmental effects from accidents involving radioactive and other hazardous materials should be summarised in the program even though the probability of such an accident may be low and its consequences small. Adequate documentation should be appended to the program to provide assurance that all safety requirements will be met prior to and during the transport of hazardous materials (e.g. spillage of hazardous chemicals, ores, fuels, yellowcake, sulphuric acid).

194 The transport of radioactive materials should comply with the provisions of the Code of Practice for the Safe Transport of Radioactive Substances (1982). The transport of other hazardous materials should comply with the Australian Code for the Transport of Dangerous Goods by Road and Rail (1982).

Decommissioning and Rehabilitation

195 The broad strategy for a decommissioning and rehabilitation program including schedules and plans for the progressive rehabilitation of the mine, mill and waste disposal sites at the termination of mining and milling activities, should be outlined, together with proposed surety arrangements to allow completion of the decommissioning and rehabilitation program.

196 The waste management program should include reference to any requirements prescribed by the appropriate authority, concerning clean-up of contaminated surfaces and land.

197 A rehabilitation program for any site where radioactive wastes arising from exploration, mining, milling and decommissioning operations have been deposited should be provided. Information to be contained in the rehabilitation plan should include:

- plans for progressive rehabilitation of radioactive waste disposal sites;

- measures for control of radon flux from the surface of the waste disposal systems. The estimated radon flux from the rehabilitation disposal sites should be provided together with a discussion of the method used to calculate the radon flux. The expected radon flux at the rehabilitated disposal site(s) should be compared with the natural background (pre-mining) radon flux of the disposal sites or with the relevant levels set by the appropriate authority;

- measures to reduce the external gamma-radiation exposure at the surface of the rehabilitated disposal site(s);

- measures to control water and wind erosion of the rahabilitated waste disposal site(s);

- measures to revegetate the waste disposal site(s), if applicable;

- measures for restricting the access of humans and fauna to the rehabilitated waste disposal site(s); and

- post-operational monitoring and surveillance to establish the performance and success or otherwise of the rehabilitation program prior to the termination of the owner/operator/manager's responsibility for the site.

198 For a detailed consideration of these matters refer to the guideline: <u>Decommissioning and Rehabilitation of Uranium Mine, Mill and Waste Disposal Sites</u>.

PART IV OPERATION AND MAINTENANCE MANUAL

199 The waste management program, as noted previously, is the essential element in planning for the safe disposal of wastes from mining and milling operations. However, implementation of the program could be jeopardised by failure to operate the component systems of the program effectively through, for example poor staff training, lack of maintenance of equipment, or lack of planning for emergency situations. Therefore, once the waste management program has been approved by the appropriate authority, steps should be taken to ensure that the program is implemented as intended and kept updated throughout the life of the operation. This will require management and staff commitment to the waste management program and to a high standard of operation of the elements of the program.

200 A vital element in this process is the development of an Operation and Maintenance Manual (O and M Manual) pertaining specifically to the elements of the waste management program. The O and M Manual is therefore the means by which the waste management program is implemented. Responsibility for the O and M Manual should rest with the person who is responsible for the overall operation of the waste management program.

201 Ideally, the O and M Manual should be written and presented in such a way that it becomes a well regarded, readily referenced document for use by any person responsible for any of the operations it covers. The format adopted should be such that material pertaining to individual systems is self-contained and easily extracted for use as a separate document rather than having relevant material dispersed throughout the whole Manual.

202 The Manual should be reviewed and updated as appropriate to ensure it reflects the actual operation of the waste management program, and incorporates any changes necessary resulting from modifications to the program approved by the appropriate authority.

<u>Components of an O and M Manual</u>

203 The O and M Manual should include the following :

- a statement of the objectives of the waste management program;
- a statement of the interrelated nature of the waste management system and the production systems (noting where there are interrelated components);
- a list of the managerial units and/or management positions responsible for the operation of the waste management program or of its component systems or of any portion of these systems. Units or positions to which the responsible parties report should also be listed;

- a detailed description, including plans, of the component parts of the waste management program including the various elements of the waste management system. Included would be relevant drawings of a system and its component parts such as an overall layout of the system, installation or as-built drawings showing actual location of parts of a system, flow diagrams, etc;

- lists of equipment, materials and plant comprising each system or used in the management or operation of each system (e.g. pumps, pipelines, liners, treatment facilities, trucks, loaders and monitoring equipment) together with specifications and performance criteria (e.g. pipe types and thicknesses, ability to withstand chemical or abrasive action, pumping capacity, detection limits of monitoring and analytical equipment and pollution control standards to be met by bag house treatment facilities), special requirements for installation or use (e.g. not to be used in water, installation in shock proof mounts and protection from weather);

- a list of all material in the company's possession relevant to the waste management program and its systems and instructions as to where this material can be found if required. This material could include design data, monitoring data, performance data, equipment operation manuals, and consultants' reports;

- details of all operating procedures including short and long term control and back up procedures and procedures for handover of responsibility at changes of shift;

- a description of the inspection and maintenance program which should embrace all components of the waste management program. In particular the inspection and maintenance program should include a list of items and issues critical to the establishment of an equipment maintenance program including maintenance schedules for all equipment. The list should take into account such matters as the periods during which reliable function is most critical, delay times which might be reasonably expected in obtaining spare parts, number of back-up units available, records of frequency of repairs, necessity to send units off-site for repairs, program for the stocking of spare parts, program for the replacement of items with a high repair frequency, peculiarities in operation or maintenance of equipment, necessity to ensure adequate back-up equipment is available and operational, qualifications required of personnel carrying out various maintenance and calibration work, policy regarding on-site repair of various types of equipment, schedules for visual inspection and various other operational performance checks, and warning signs for various items of equipment;

- a list of those items or incidents which are considered to be infringements or breaches of the approved waste management program and therefore reportable to the management, and by the management ultimately to the appropriate authority. Procedures for reporting such matters should be described;

- a list of "flag points" relevant to the waste management program or its component systems. "Flag points" would be conditions indicating that changes may have occurred with a system or its components and that a close watch will have to be instituted. Such situations may warn of a possible need to shut down units, perform unscheduled maintenance, undertake alternative actions or institute investigations. These "flag points" may be reportable items as noted above or include non-critical items which if attended to at the earliest opportunity might only require routine handling and hence avoid their development into reportable items;

- a description of contingency procedures for dealing with disruptions in the operation of the waste management program;

- details of the program relating to induction procedures, training, retraining and staff development for all staff to enable the efficient implementation and operation of the waste management program; and

- a clear statement of procedures for modifying any aspect of the O and M Manual including:

  - definition of what constitutes a change;

  - preparation of a proposal for program modification;

  - approval mechanism for changes; and

  - implementation of change.

When changes to the O and M Manual are proposed, consideration should be given to the implications of such proposed changes for the waste management program.

204 Reference should be made to other guidelines to the Code in relation to specific aspects to be included in the O and M Manual for particular parts of the mining/milling operation. In relation to water management reference should be made to the guideline: Design and Operation of a Water Management System for a Uranium Mining and Milling Operation.

SELECTED REFERENCES

205 These references have been selected to provide a broad overview of current radioactive waste management strategies and practices. Also included are examples of environmental impact statements relating to current or proposed uranium mining and milling operations in Australia.

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Table 1 - Uranium and Thorium Radioactive Decay Series

Isotope	Radiation	Half Life	Isotope	Radiation	Half Life
$^{238}_{92}U$	a	$4.5x10^{9}yr$	$^{232}_{90}Th$	a	$1.4x10^{10}yr$
$^{234}_{90}Th$	B, Y	24.1d	$^{228}_{88}Ra$	B	5.1 hr
$^{234}_{91}Pa$	B, Y	1.17 min	$^{228}_{89}Ac$	B, Y	5.1 hr
^{234}U	a, Y	$2.5x10^{5}yr$	^{228}Th	a, Y	1.9 yr
$^{230}_{90}Th$	a, Y	$8x10^{4}yr$	$^{224}_{88}Ra$	a, Y	3.65d
$^{226}_{88}Ra$	a, Y	1620 yr	$^{220}_{86}Rn$	a	55 s
$^{222}_{86}Rn$	a	3.83 d	$^{216}_{84}Po$	a	0.15 s
$^{218}_{84}Po$	a	3.05 min	$^{212}_{82}Pb$	B, Y	10.64 hr
$^{214}_{83}Bi$			$^{212}_{83}Bi$	a, B, Y	60.6 min
$^{214}_{83}Bi$	B, Y	19.7 min	$^{212}_{84}Po$	a	$0.3x10^{-6}$ sec
$^{214}_{84}Po$	a	$1.64x10^{-4}s$	$^{208}_{83}Tl$	B, Y	3.1 min
$^{210}_{82}Pb$	B, Y	22 yr	$^{208}_{82}Pb$	-	-
$^{210}_{83}Bi$	B	5 d			
$^{210}_{84}Po$	a	140 d			
$^{206}_{82}Pb$	-	-			

Table 2 - Some Potential Contaminants in Liquid Wastes

Contaminant	Mine Drainage		Decant Solution and Tailings Seepage		Decomissioned Mine Drainage	
	Acid	Basic	Acid Leach	Alkaline Leach	Acid	Basic
Radioactive						
^{226}Ra	+	+	+	+	+	+
^{222}Rn	+	+	+	+	+	+
^{210}Pb	+		+	+	+	
$^{230-232}Th$	+		+	+	+	
^{210}Po	+		+		+	
U	+	+	+	+	+	+
Non-Radioactive						
H_2SO_4	+	+			+	
HCO_3		+	+	+		
CO_3		+	+	+		+
NH_3	+	+	+			
Cl		+	+	+		+
SO_4	+	+	+	+	+	+
PO_4	+		+		+	
F	+		+	+	+	
NO_3	+	+	+	+		
Na	+	+	+	+	+	+
Fe	+		+		+	
Mn	+		+			
Co	+		+		+	
Ni	+		+		+	
Zn	+		+		+	
Cu	+		+		+	
Pb		+				
V	+		+	+	+	
Cr	+	+	+			
As	+		+		+	
Mo	+	+	+	+	+	+
Se	+	+	+	+	+	+
Ba			+			
Ca	+	+	+	+	+	+
Mg	+	+	+	+	+	+
Kerosene) alcohol) amine - TBP)			+			
Oil (lubrication or fuel)	+	+				

+ = potential contaminant

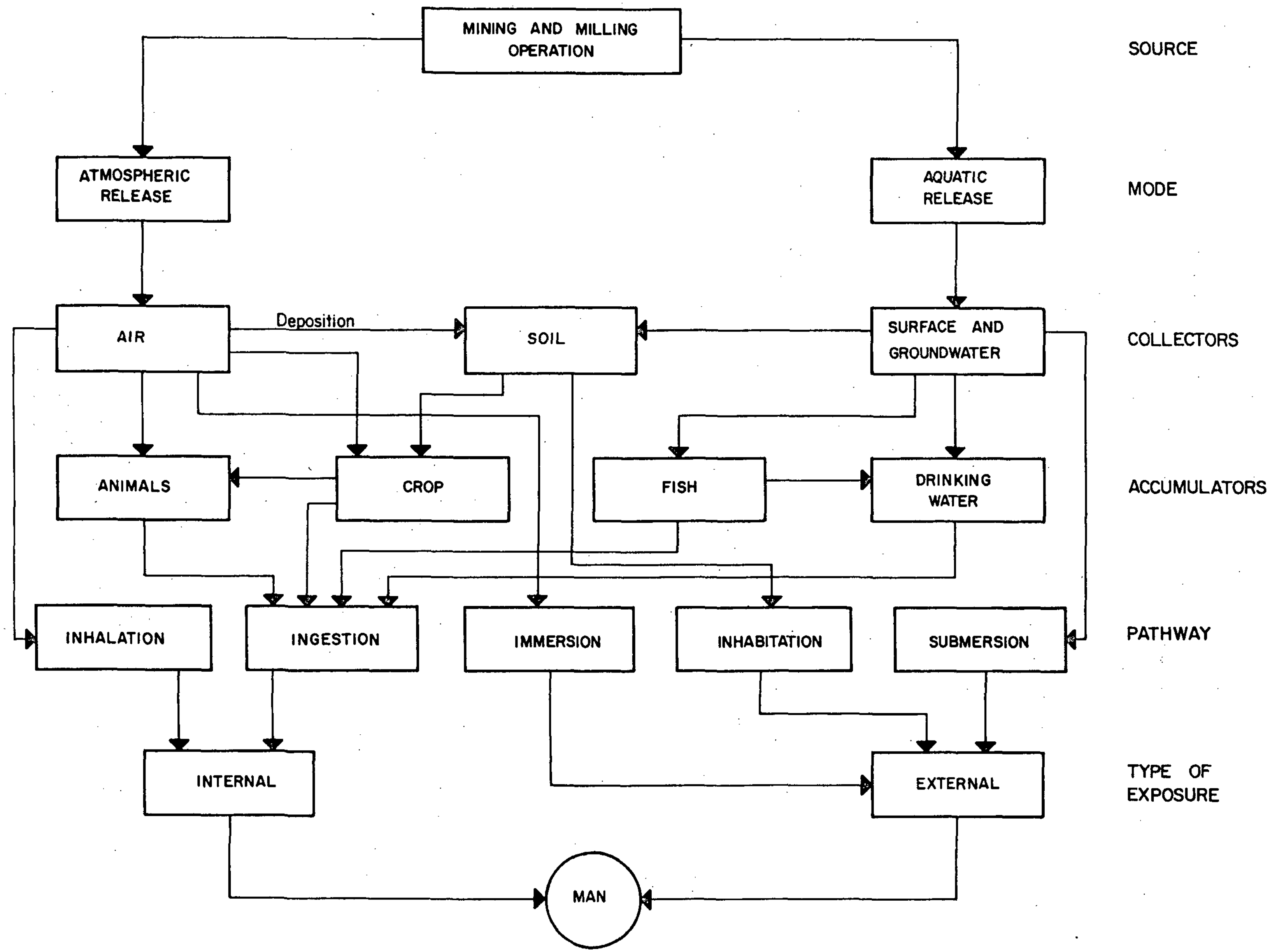

FIGURE 1 EXPOSURE PATHWAYS

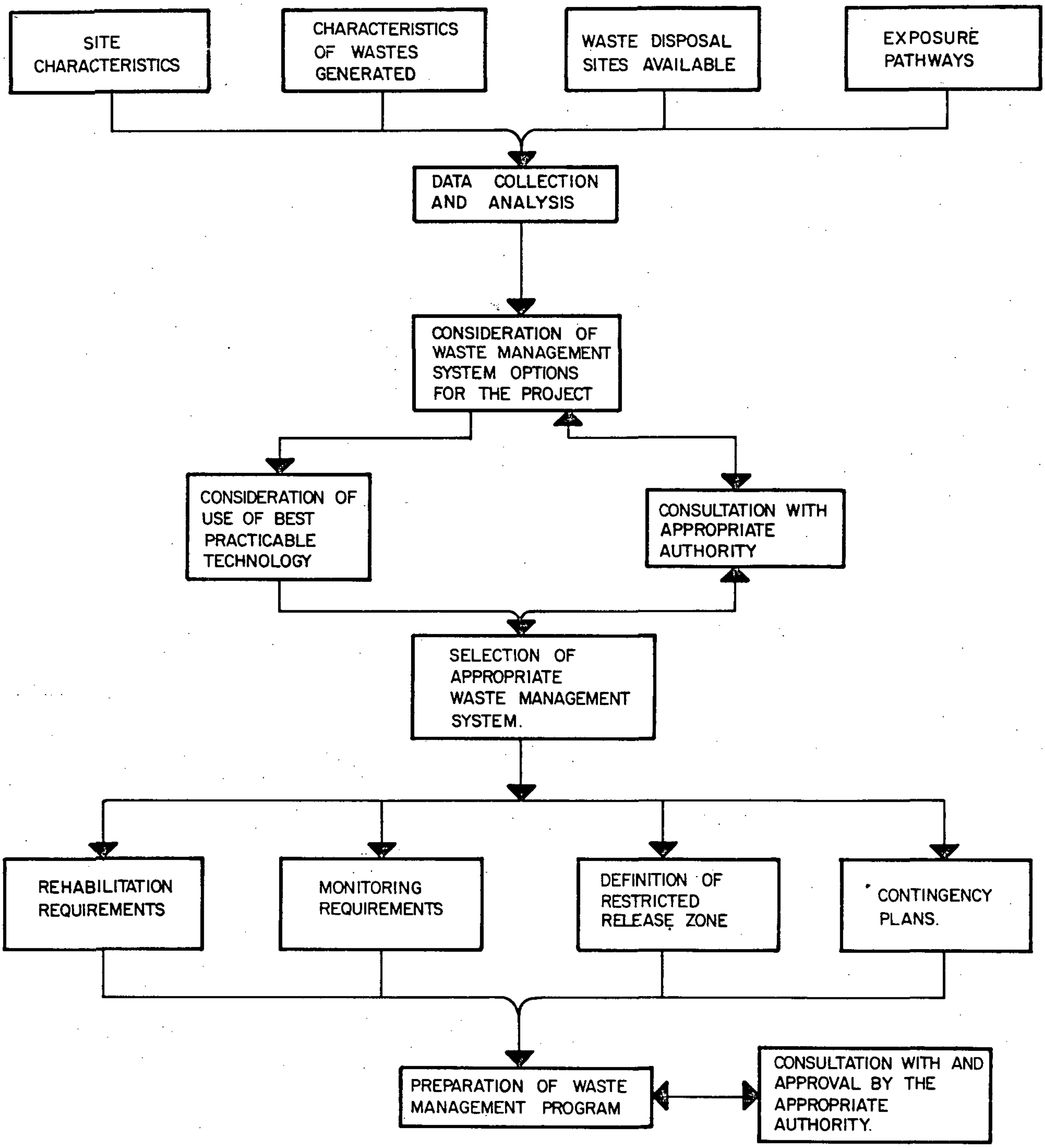

FIGURE 2. DEVELOPMENT OF AN APPROVED WASTE MANAGEMENT PROGRAM.