Final Report **Project UKRSR03**

Development of a Framework for Assessing the Suitability of Controlled Landfills to Accept Disposals of Solid Low-Level Radioactive Waste: User Manual

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EXECUTIVE SUMMARY

This report forms part of a research project aimed at establishing a framework for assessing the suitability of controlled landfills to accept disposals of solid low-level radioactive waste. The disposal of radioactive waste alongside other wastes at landfill sites is a disposal route aimed at small users rather than at the nuclear industry, and it is restricted to relatively low activity wastes.

The framework comprises the overall process for determining the suitability of landfill sites for accepting certain types of low-level radioactive waste. The framework comprises four principal stages:

- Initial screening for potentially suitable sites.
- Development of the assessment context and methodology.
- Calculation of specific doses and radiological capacity.
- Authorisation decision and conditions.

The framework is aimed at assessing new sites, or sites that have not previously accepted radioactive waste. For the purpose of this project, it has been assumed that all SPB disposals will be made to non-hazardous landfill sites. The framework therefore may not be applicable to inert and hazardous landfill sites.

Assessments of landfill sites in terms of their environmental impacts require the identification of the sources, pathways and receptors through which environmental harm could arise. A generic set of these that encompasses the activities and environmental setting of landfill sites has been identified and conceptual models have been developed. In addition to the generic elements of the assessment context, there are elements of the assessment context that must be established on a site-specific basis.

An Assessment Model implementing the framework for calculating specific doses and radiological capacities has been developed from mathematical models that describe the source-pathway-receptor linkages.

The Assessment Model has been implemented as an Excel spreadsheet, designed to guide the user through the process of dose assessment and calculation of radiological capacity. This report describes the installation and use of this spreadsheet.

In addition to describing use of the spreadsheet, this report describes the parameters required to conduct the dose assessments. The report provides guidance on sources of information for site-specific parameter values and describes the basis for the reference values used for generic data.

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Development of a Framework for Assessing the Suitability of Controlled Landfills to Accept Disposals of Solid Low-Level Radioactive Waste: User Manual

1 Introduction

1. The Environment Agency for England and Wales (EA), the Scottish Environment Protection Agency (SEPA), and the Environment and Heritage Service, Northern Ireland (EHS) are responsible for the regulation of radioactive waste disposal in the UK. The Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) has commissioned research on behalf of these UK regulatory agencies to establish a framework for assessing the suitability of controlled landfills to accept disposals of solid low-level radioactive waste (LLW) from small users.

2. The key principles on which the framework is based are described in more detail in the Principles Document: Development of a Framework for Assessing the Suitability of Controlled Landfills to Accept Disposals of Solid Low-Level Radioactive Waste: Principles Document (SNIFFER 2005). Details of the models that underpin the dose calculations, and hence the calculation of the potential radiological capacity, are presented in: Development of a Framework for Assessing the Suitability of Controlled Landfills to Accept Disposals of Solid Low-Level Radioactive Waste: Technical Reference Manual (SNIFFER 2006a). A Case Study, aimed at an initial assessment for a generic site and as a means of understanding model behaviour and sensitivities, has also been reported (SNIFFER 2006b).

3. This document describes the use of the model, which is provided in the form of an Excel spreadsheet, and includes information on potential sources for the information required to run the model for a specific site.

1.1 Model Overview

4. The model developed for assessing the suitability of landfill sites for controlled burial of LLW comprises two key elements:

- A dose assessment model, used to calculate doses to a variety of exposed groups from unit disposals (1 MBq) of different radionuclides.

- A radiological capacity model, used to calculate the amount of each radionuclide that could be consigned to the site within an overall dose constraint of 20 $\mu Sv\ y^{-1}$.

5. The information required by the dose assessment model is described in detail in a companion report (SNIFFER 2006a). Broadly, there are four types of information required:

- Site-specific. Data describing the site and its setting.

- Scenario-dependent. Data describing the types of release scenarios being considered.

- Reference values. Data describing typical material properties and habits of exposed groups.

- Established values. Constants and literature data for radionuclide-dependent parameters.

6. The dose assessment model described in this User Manual requires specification of values for the first two groups by the user. Default values are provided for some scenario-dependent parameters that can be reviewed and changed by the user as required for a particular assessment. Default values are also provided for the reference values. These can be changed to investigate model sensitivities and to account for particular features of a specific site. The normal user interface does not provide a means for changing the final group of parameter values, but manual editing of the underlying data dictionary can be done by experienced users if required.

7. The radiological capacity calculation is based on the results from the dose assessment. The overall Assessment Methodology described in the Principles Document (SNIFFER 2005) is based on the assumption that there is a linear relationship between the disposed inventory and dose. The potential radiological capacity of a site can therefore be calculated through the ratio between the dose from a 1 MBq disposal and the 20 μSv/yr constraint proposed for this type of disposal.

8. The radiological capacity model calculates a potential capacity for each individual radionuclide considered. In practise, however, a disposal site will receive wastes with different radionuclide fingerprints from different consignors. To optimise disposals within the available capacity, the user must provide an overall fingerprint in terms of ratios between radionuclides.

9. Both the dose assessment and radiological capacity calculations are implemented in an Excel spreadsheet. This spreadsheet also allows for a record to be kept of disposals to a site. By updating these records on an annual or other basis, the radiological capacity remaining at any time can be determined and authorisation conditions modified as appropriate.

1.2 Report Structure

10. The report is structured as follows:

- Section 2 describes the installation requirements for the model.

- Section 3 describes the dose assessment part of the model, including information on potential sources of data.

- Section 4 describes the radiological capacity part of the model.

11. Figures 1.1 and 1.2 illustrate the main stages of the dose assessment and radiological capacity calculations. Paragraph references to this User Manual are given to allow the user to quickly locate descriptions of each stage.

1.3 Conventions

12. In this User Guide, the following conventions are used in descriptions of the user interface:

- Buttons are identified by “quotation” marks.

- Text boxes and list boxes are identified by *italics.*

- Option buttons (only one selection can be made) and check boxes (multiple selections can be made) are identified by <u>underline</u>.

- Key points regarding the use of the Assessment Model are highlighted with a blue border.

Figure 1.1 Key stages in the dose assessment process, with references to paragraphs in this User Manual where further details can be found.

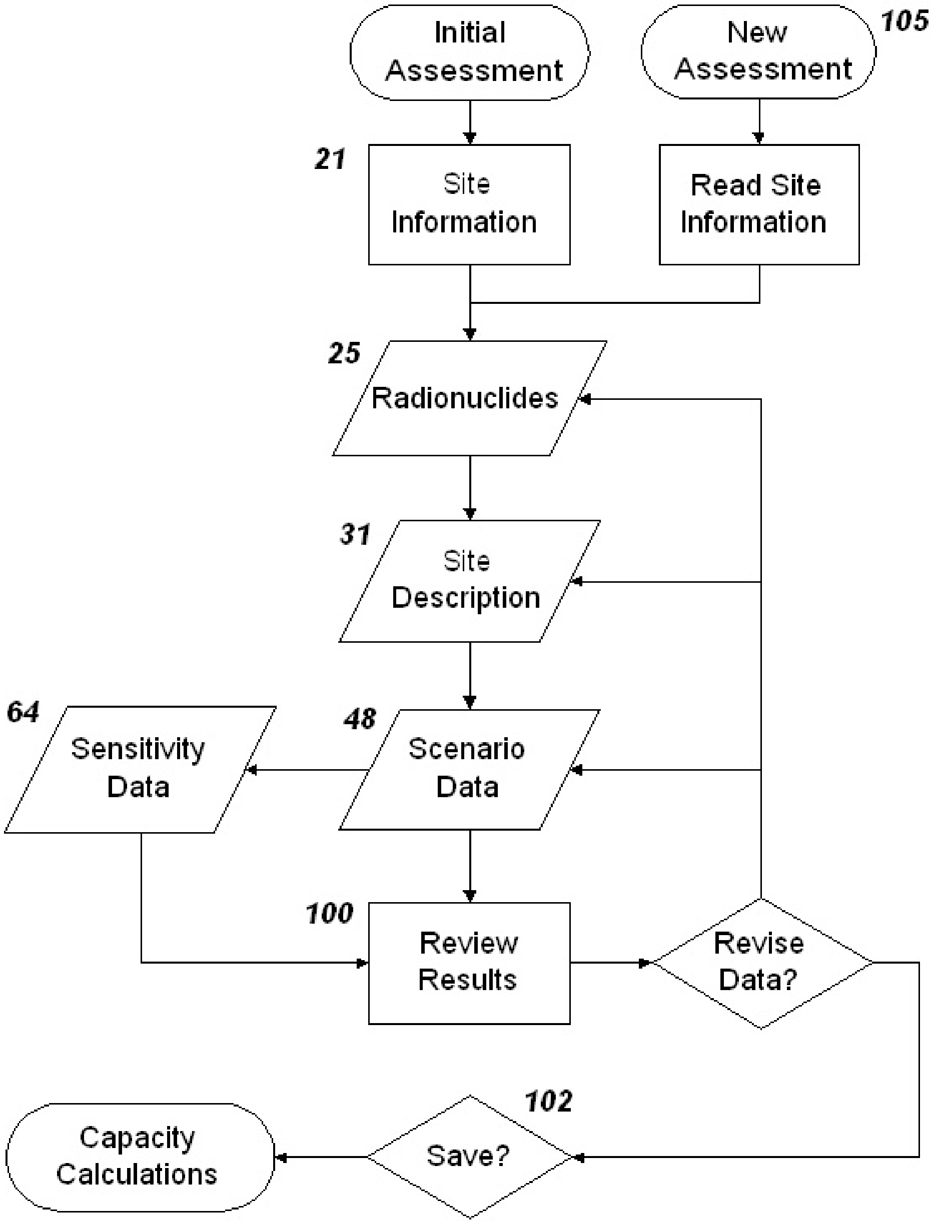
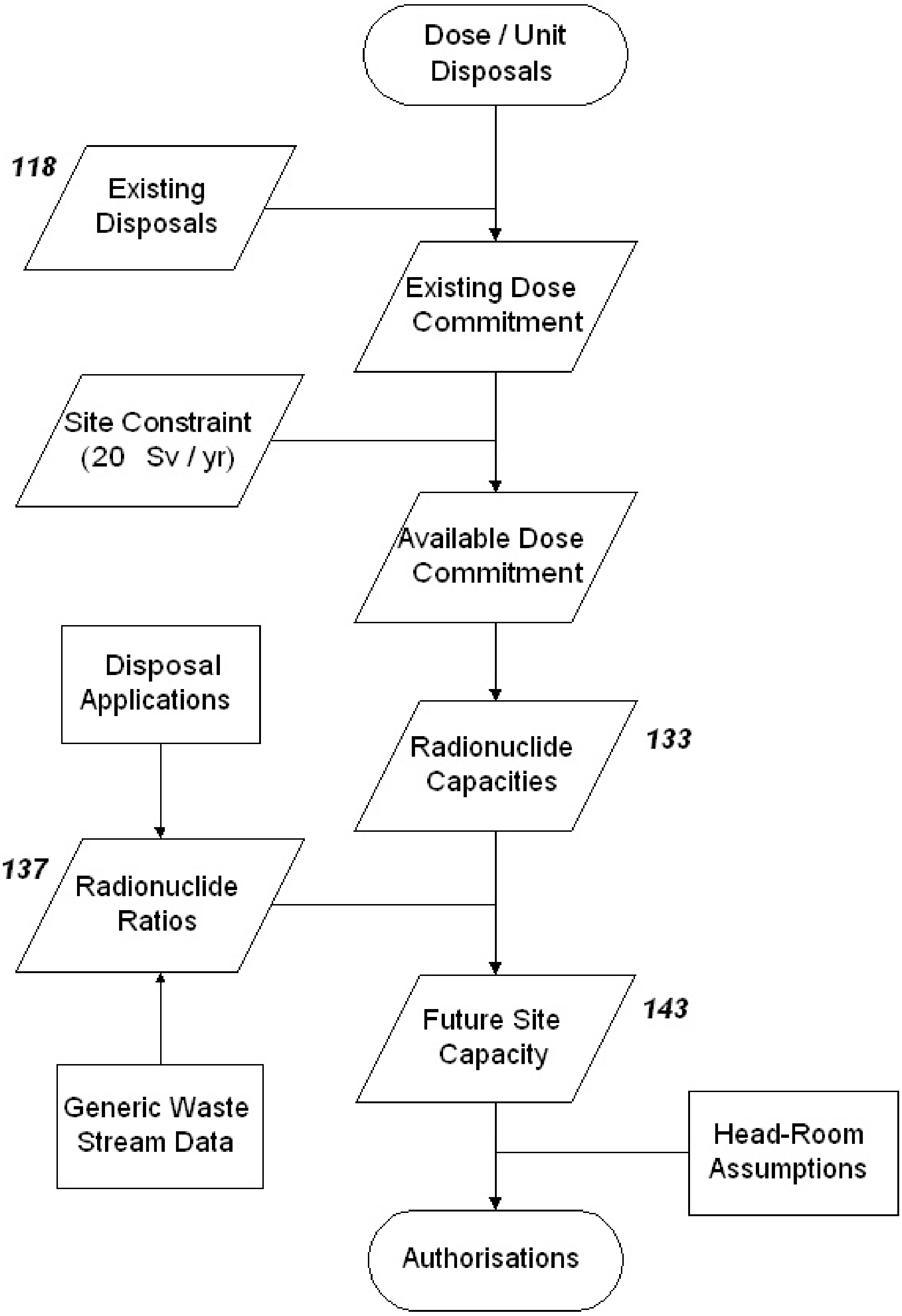


Figure 1.2 Key stages in the calculation of radiological capacity, with references to paragraphs in this User Manual where further details can be found.



2 Installation

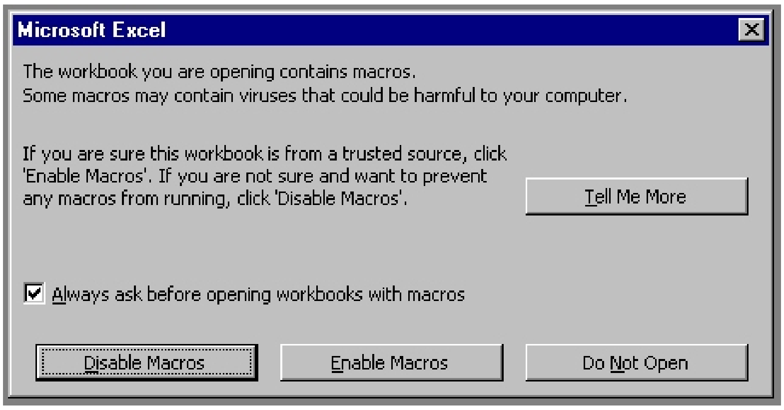
13. The model is provided as an Excel spreadsheet. The file, SPB_Capacity.xls, should be copied into a convenient folder. It is suggested that a new folder is made specifically for the model and assessments (e.g., “C:\Program Files\SPB_Assessments”). Users with constraints on installing new software should seek advice from their system administrator. The model is not designed to run over a network.

14. Although a new file name is requested when results are first saved, it is recommended that the file SPB_Capacity.xls is made **read-only** to prevent inadvertent over-writing.

15. The model has been developed and tested using Excel 2000 and Excel 2003. The model also works with Excel 97, although there are circumstances with this version when an error message is displayed when dose assessments are repeated. For Excel 97 users, this situation can be avoided by saving and re-starting the spreadsheet after each dose assessment. The model is not compatible with older versions of Excel (Excel 95).

16. By default, Excel warns users when opening spreadsheets with macros. Users may see a dialog box similar to Figure 2.1, and must select “Enable Macros” to run the model. Users with constraints on running macros should seek advice from their system administrator.

Figure 2.1 Warning dialog seen when opening spreadsheet. Select “Enable Macros”.



17. For the initial dose assessment / capacity calculation for a particular site, the model is started by opening the file SPB_Capacity.xls. Once assessment results have been calculated, the user saves the results in a new, site-specific file. Subsequent assessments and radiological capacity calculations are then all undertaken using this new file. Assessments of additional sites can be undertaken using the original file.

18. On opening the spreadsheet, the user will be presented with a series of dialog boxes requiring information about a site and the assessment. These dialog boxes are supported by a series of worksheets that are not normally visible to the user. Some of the underlying worksheets are used to enter information and display results, but access to these is available only after completion of the appropriate dialog boxes. **Accessing the underlying spreadsheet in any other way may lead to corruption of the database and should be avoided**.

If a dialog box is accidentally closed during the course of the dose assessment / capacity calculation, the user can click on the “RE-START” button on the “User” worksheet. This will reopen the initial dialog box, and allow the user to start over without needing to close and reopen the spreadsheet.

3 Dose Assessment Calculations

19. The methodology adopted for determining radiological capacity of landfill sites for SPB disposal is based on dose assessments for unit disposals (1 MBq) of each radionuclide of interest. With the assumption that dose is proportional to inventory, the capacity for each nuclide can then be calculated by scaling the doses to the overall dose constraint of 20 μSv y^{-1}. The overall approach to dose assessment that is implemented in the model is illustrated in Figure 1.1.

20. A dose assessment is required before any radiological capacity calculations can be performed. When the model is used for the first time for a particular site, the opening (Assessment Type) screen therefore allows only the "New Assessment" option to be selected. The following section describes use of the model for such an initial assessment. Section 3.2 describes the different options available for subsequent assessments. Section 3.3 describes how results from previous dose assessments can be reviewed.

3.1 Initial Dose Assessment

Assessment Type

21. The Assessment Type screen requires information about the site and the assessment. The *Site Name* and *Site Location* are used to identify the site throughout the assessment life-cycle and cannot be edited later. *Site Operator* is an optional descriptor and can be edited later if required.

22. The *Assessment* field must be completed, as this description is used to distinguish between the multiple assessments that can be performed for each site. Assessment descriptions should therefore be brief but descriptive (e.g., 2005 Initial Assessment, 2006 Update, etc.).

23. The *Assessor* and *Date* fields are completed automatically from the computer being used. These fields can, if necessary, be edited manually.

24. Completing the site / assessment details and clicking "Next -->" opens the radionuclide selection screen.

Select Radionuclides

25. Radionuclides to be considered in the assessment are selected from the *Available Nuclides* list by clicking on the nuclide name. More than one radionuclide can be selected by holding down the "Ctrl" key and clicking on each radionuclide.

> New assessments with additional radionuclides can be made in the future, and specific assessments can be made to examine model behaviour for key radionuclides. For deriving site radiological capacities, however, it would be prudent to select all the radionuclides that are likely to be consigned to the site for the initial assessment.

26. The set of radionuclides selected in *Available Nuclides* becomes the *Current List* once the "Confirm" button is clicked. The list of radionuclides can be modified in the left-hand window and the new list re-confirmed. The *Current List* can be cleared by clicking "Cancel/Re-select" and a new list selected.

27. Once the list of radionuclides has been finalised, clicking "Next -->" opens the Site & Scenario Data screen.

Site & Scenario Data

28. The parameters on the five tabbed pages on this screen describe the overall characteristics of the site and the principal scenarios that are assessed. Each page of parameters on the data entry screen is described below. Information relating to some parameters is also provided when the mouse pointer is over the item.

29. Default values are provided for the majority of the parameters describing the site and scenarios (see SNIFFER 2006a), but these values can be varied to take account of specific site characteristics or particular assessment requirements. Additional information about the scenarios, pathways and exposed groups considered in the assessment can be found in the Principles Document (SNIFFER 2005).

30. Clicking the "Default" button restores the default values for **all** scenario parameters, overwriting any edits that have been made on the data entry screens. Values for parameters describing the site for which default values are not provided (volume, area and operational period) are not overwritten.

Site characteristics

31. *Volume of the landfill* (cubic metres). The overall volume of the landfill available for disposal of waste.

> The Assessment Model makes various assumptions regarding the distribution of SPB disposals within the landfill site. For pathways involving the release of leachate, the model assumes that disposals, and activity, are distributed throughout the site. The volume entered here should be the volume of the part of the site receiving SPB disposal and that forms a hydrogeologically distinct unit. For example, where disposals are in two or more parts of the overall site, the entire site volume should be entered. Where SPB disposals are restricted to a particular cell or phase that is hydrogeologically isolated from the rest of the site, the value entered should be the volume of the cell or phase concerned.
>
> The site Licence Application, Environmental Statement and similar documentation from the operator will include information on site volume.

32. *Surface area of the landfill* (square metres). The overall surface area of the disposal footprint.

> The surface area of the landfill is a key control on how much water enters the site and hence on the dilution of activity in leachate and in the groundwater and other pathways. All water falling on the cap within the landfill footprint is assumed to contribute to leachate. For sites in which there is complete hydrogeological isolation of the cell or phase used for SPB disposal, the surface area should be that of the cell or region used.
>
> The site Licence Application, Environmental Statement and similar documentation from the operator will include information on site areas.

33. *Duration of landfill operation* (years). The scheduled period during which the landfill is open to accept waste following the initial emplacement of SPB radioactive wastes.

This parameter determines the period considered for operational pathways. This parameter also affects doses calculated for non-operational pathways (groundwater, gas and intrusion) because the model assumes that a site cap will only be installed at the end of site operations. This may be a conservative assumption if disposal cells used for SPB disposals are completed and capped early. If such cells are hydrogeologically isolated, and no SPB disposals are expected in other parts of the site, then the assessment could be limited to a portion of the site. Sensitivity studies are recommended to evaluate the effect of early capping on the non-operational pathways.

The site Licence Application, and similar documentation from the operator will include information on the scheduled period of operations.

34. *Cap lifetime* (years). The anticipated lifetime of the cap in terms of controlling infiltration.

The efficiency of the cap is a key control on the amount of infiltration and hence on the groundwater pathway. This parameter represents the period over which the cap becomes ineffective in terms of controlling infiltration rather than the time at which a sudden failure occurs. The model assumes a linear degradation between an impermeable cap at closure and an ineffective cap after the cap lifetime.

Degradation of the cap will depend on the design and construction of the cap, and also on the thickness and nature of the underlying waste, which will affect settlement and the formation of cracks. Detailed information on cap behaviour is unlikely to be available for a specific site and generic assumptions about long-term effectiveness will be required. A simple cap over a site with a large amount of compactable waste may be ineffective after 30-50 years. A more highly engineered cap, with geomembranes and geotextile reinforcement, over a site with well compacted waste may be at least partially effective for over 100 years. In the absence of any further information, the default cap lifetime of 30 years is a useful starting point for sensitivity studies.

35. *Area of holes in liner* (square metres). The overall size of defects in the geomembrane or clay liner used to prevent leachate migration from the base of the landfill.

The liner may have defects at the time of installation or may be damaged during operations. Documentation from the operator and inspections by staff from the Agencies should ensure appropriate levels of CQA (construction quality assurance) during installation but is unlikely to provide site-specific estimates of the extent of defects. The default value of 3.75×10^{-4} m^2 is based on generic estimates of the extent of such defects (Hall and Marshall 1991) for a unit hectare (10,000 m^2) site and good CQA. The value should be changed proportionately for larger or smaller sites or if there is reason to assume that the number or type of defects differs from the default assumptions of:

- 5 pinholes (0.1 – 5 mm^2) per hectare
- 2 small holes (5 – 100 mm^2) per hectare and
- 0.15 large hole (100 – 10,000 mm^2) per hectare.

For example, a 2 hectare site with poor CQA leading to 0.5 large holes per hectare could have around 2.15×10^{-3} m^2 of holes in the liner.

Composite liners are increasingly used and there is growing interest in the use of asphaltic liners. Both of these systems should reduce the effective size of imperfections and would therefore warrant use of values at the low end of the above ranges. More precise data for these liner systems may become available in the future.

Water Usage

36. The assessment methodology assumes that leachate from the site may flow through holes in the liner and the geological barrier beneath the site into an aquifer. Exposed groups may use groundwater directly through a borehole, or the aquifer may discharge into a lake, river, sea or estuary. Contaminated water may be used for a variety of purposes. Parameters on this page determine which pathways by which doses might be received are considered in the assessment.

37. *Distance to abstraction point* (metres). The effective length of the groundwater pathway.

If the groundwater pathway is not considered important (e.g., no underlying aquifer), setting this parameter to zero will disregard the whole pathway.

If boreholes are in use for abstracting potentially contaminated groundwater, this parameter represents the distance from the site boundary to the nearest borehole down-gradient of the site.

If there are no boreholes in use, this parameter is the distance from the site to the nearest spring or other groundwater discharge point.

The hydrogeological risk assessment or the environmental impact assessment will include the location of boreholes around the site, and should similarly identify springs and discharge points. In general, a borehole providing drinking water will constitute the most vulnerable groundwater pathway. For sites at which boreholes are used for other purposes, sensitivity studies involving distance to the discharge point and water use (see below) may be required.

A default value of 250 m is set for the distance to the abstraction point. This value should generally only be used for preliminary or illustrative assessments as there should be a detailed hydrogeological assessment for any site that has been assessed for a licence under PPC.

38. *Water contaminated* and *Water usage*. The type of water body into which potentially contaminated groundwater discharges, and types of water usage that could lead to doses. Discharge into an estuary should generally be treated as a discharge to the sea.

The type of water body selected controls the types of water usage that can be considered and the assumptions made about dilution. Only one type of water body can be selected, but multiple water uses can be assessed.

The default water usage for an Aquifer/borehole is Drinking water. Use of a borehole for supplying water for Livestock or for Irrigation is also possible.

The default water usage for a River/lake is Fishing. Use of a river/lake for supplying Drinking water, water for Livestock or for Irrigation is also possible.

The default water usage for the Sea is Fishing. No other uses are possible.

Information on potentially contaminated water bodies and water usage should be available in the hydrogeological risk assessment or the environmental impact assessment for the site. If there are doubts as to the most significant type of abstraction for a particular site, alternative assessments should be undertaken to establish the highest potential doses (lowest radiological capacity). In general, the highest doses are likely to arise through use of a borehole for drinking water.

39. *River cross-section* (square metres). Contaminated groundwater discharged into a river or lake will be diluted according to the size of the water body, determined by its length and cross-sectional area.

For discharge into a river or lake, the assessment model assumes a compartment length of 2,000 m and the volume is calculated by multiplying this length by the value entered for the river cross section. The default value of 10 m^2 is intended to represent a small to medium-sized, meandering river. A smaller value (e.g., 1 m^2) should be set for sites where discharge is into a small stream, and a larger value (e.g., 100 m^2) should be set for sites where discharge is to a large river or lake.

The hydrogeological risk assessment or the environmental impact assessment for the site should provide information on the type and size of water bodies receiving groundwater discharge.

40. *Turnover in river / sea* (number per year). Ratio between annual flow and volume of contaminated water body.

Discharge of groundwater into a river, lake, estuary or the sea will dilute activity, both because of mixing into a larger volume of non-contaminated water and because of flow transferring contaminated water to adjacent water bodies. The ratio between the annual flow through the compartment into which discharge occurs and the volume of this compartment is the turnover. The default value of turnover for discharges to a river, estuary or the sea is 500 y^{-1}. This value is intended to represent a small to medium-sized, meandering river or discharge into a sheltered bay. If discharge is to a lake, the value for turnover should be lowered, and for a high energy regime (e.g., fast-flowing river or exposed coastline) the value should be increased.

The hydrogeological risk assessment or the environmental impact assessment for the site should provide information on the type and size of water bodies receiving groundwater discharge.

41. *Drinking water consumption* (cubic metres per year). The annual volume of water consumed by an individual from a potentially contaminated source.

The default value of 0.73 m^3 yr^{-1} is the recommended value from IAEA (2003) for the overall annual consumption by an adult. Changes to this value may be appropriate for other age groups or if not all drinking water is obtained from the potentially contaminated source.

Groundwater

42. If the groundwater pathway is considered (i.e., if *Distance to abstraction point* is set to a value greater than zero), the Assessment Model uses a simplified groundwater flow model to calculate rates of discharge. Parameters on this page describe the hydrogeological characteristics of the flow path. Parameters under “Pathway length” describe the flow path between the waste and the aquifer. “Hydraulic gradient” and the parameters under “Rock properties” describe the leachate pathway between the waste and the aquifer.

43. *Thickness of geological barrier* (metres). Thickness of the geological barrier or artificial equivalent.

Current landfill regulations require the use of a geological barrier or artificial equivalent to protect groundwater in addition to barriers such as geomembranes. The performance of the barrier must be equivalent to a layer with a hydraulic conductivity ≤ 1.0×10^{-9} m s^{-1} and a thickness ≥ 1 m.

The Assessment Model assumes a hydraulic conductivity of 1.0×10^{-9} m s^{-1} for the geological barrier and the default thickness is 1 metre. The thickness can be changed to reflect site-specific construction or geological conditions.

The hydrogeological risk assessment and the site Licence Application should include information on the characteristics of the geological barrier.

44. *Thickness of unsaturated zone* (metres). Thickness of any unsaturated zone between the base of the geological barrier and the aquifer discharging or exploited for groundwater.

Particularly in the case of a landfill with an artificial equivalent for the geological barrier, there may be an unsaturated zone above the aquifer unit modelled for groundwater flow and transport. Flow through this zone is assumed to be vertical, and the Assessment Model also assumes that there is no dispersion in this unit.

The default value for this parameter is 0.5 m, based on a generic landfill site. Information from the hydrogeological risk assessment should be used to determine an appropriate value for this parameter on a site by site basis.

45. *Thickness of groundwater zone* (metres). The thickness of the aquifer unit modelled in terms of groundwater flow to a borehole or other discharge point.

The Assessment Model includes a one-dimensional compartment model for groundwater transport, based on assumptions that advective transport in the groundwater underlying a landfill obeys Darcy's Law, and that flow occurs horizontally, with longitudinal and transverse dispersion. This parameter determines the thickness of the modelled compartments.

The default value for this parameter is 30 m, based on a generic landfill site. Information from the hydrogeological risk assessment should be used to determine an appropriate value for this parameter on a site by site basis.

46. Hydraulic gradient (unitless). The average hydraulic gradient of the modelled aquifer unit between the landfill and a borehole or other groundwater discharge point.

The Assessment Model includes a one-dimensional compartment model for groundwater transport, based on assumptions that advective transport in the groundwater underlying a landfill obeys Darcy's Law, and that flow occurs horizontally, with longitudinal and transverse dispersion. This parameter determines the hydraulic gradient of the modelled transport pathway.

The default value for this parameter is 0.05, based on a generic landfill site. Information from the hydrogeological risk assessment should be used to determine an appropriate value for this parameter on a site by site basis.

47. *Rock properties*. A variety of physical properties for the modelled aquifer unit are used in the assessment of groundwater flow.

Default values for *Conductivity*, *Porosity*, *Density* and *Saturation* are provided for several different *Rock types*, and selecting a rock type from the drop-down list will set the respective values:

Rock type	Conductivity (m s^{-1})	Porosity	Density (kg m^{-3})	Saturation
Clay	1 x 10^{-9}	0.5	2000	1
Granite	1 x 10^{-5}	0.4	2300	1
Silt	1 x 10^{-9}	0.3	2000	1
Sand	1 x 10^{-7}	0.2	2100	1
Limestone / Chalk	1 x 10^{-6}	0.1	2200	1

Selecting *Specific* as the rock type allows site-specific values to be entered for each of these rock properties.

The hydrogeological risk assessment or the environmental impact assessment for the site should provide information on the geology around the site from which a typical rock type can be determined. Where possible, the default properties should be reviewed against detailed hydrogeological information, and site-specific data used if any significant differences are noted.

Spillage

48. The spillage scenario assesses the consequences of failure of the leachate management system and subsequent contamination of surface water used for drinking water or other purposes. If this is not a potential scenario for a particular site (i.e., if nearby water bodies are not exploited) it can be disregarded by unchecking the Consider Spillage check box.

49. *Spillage volume*. The volume of leachate discharged into surface water.

There are uncertainties regarding the potential size of a spillage to surface water, relating to the types of leachate management systems in place at a particular site. The volume of spillage to be considered is therefore presented in qualitative terms: Large, Medium, and Small, corresponding to spills of about 100 m^3, 10 m^3, and 1 m^3 respectively.

The default value for spillage volume is medium (10 m^3), based on a generic landfill site. The site licence application and site working plan should provide information on leachate management systems from which the potential for larger or smaller spills may be assessed.

50. *Water contaminated* and *Water usage*. The type of water body into which leachate may be spilt, and types of water usage that could lead to doses.

The type of water body selected controls the types of water usage that can be considered. Only one type of water body can be selected, but multiple water uses can be assessed.

The default water usage for a River/lake is Fishing. Use of a river/lake for supplying Drinking water, water for Livestock or for Irrigation is also possible.

The default water usage for the Sea is Fishing. No other uses are possible.

Information on potentially contaminated water bodies and water usage should be available in the hydrogeological risk assessment or the environmental impact assessment for the site. If there are doubts as to the most significant type of abstraction for a particular site, alternative assessments should be undertaken to establish the highest potential doses (lowest radiological capacity). In general, the highest doses are likely to arise through use of surface water for drinking.

51. *Volume contaminated* (cubic metres). The effective volume of the water body into which a leachate spillage occurs.

This volume determines the extent to which a leachate spillage is diluted before the water is used or contaminates resources.

The default value for the volume contaminated is 1,000 m^3 based on a generic landfill. Taken together with the default size of spillage, this represents a conservative assumption of 1:1 dilution of leachate before use of the contaminated water.

The environmental impact assessment for the site should provide information on size of potentially contaminated water resources.

Other Scenarios

52. In addition to the groundwater and leachate spillage scenarios described above, there are several other scenarios that can be included in a dose assessment:

- Fire
- Leachate spraying
- Intrusion
- Bathtubbing

53. **Fire**. Fires in a landfill used for SPB disposal can lead to doses to both workers and members of the public through inhalation and ingestion of radionuclides released in particles and smoke. Hotspots within the waste mass may persist for much longer than fires and give rise to gaseous releases rather than particles and smoke. The decision on whether the fire scenario is considered should be based on the operational history of the site and knowledge of similar sites and those operated by the same company. The potential consequences of hotspots can be explored through sensitivity studies of the fire and gas pathways.

54. *Fires per year*. The number of fires to be considered in an assessment.

The fire scenario can be switched-off by setting the number of fires to zero. The default number of fires is 2, based on a generic landfill site.

55. *Size of fire*. The amount of waste consumed in each fire.

The size of the fire controls the amount of material released into the atmosphere and the concentration of radionuclides in dust and air breathed by workers and the public.

The size of fires to be considered is presented in qualitative terms: large, medium, and small, corresponding to fires of about 1,000 m^3, 100 m^3, and 10 m^3 respectively.

The default size of fire is large (1,000 m^3), based on a generic landfill site.

56. **Leachate spraying.** Some methods used for leachate management may lead to the generation of aerosols that may be breathed by workers or members of the public. Spraying of leachate back on to the landfill is one such method, although this is now less commonly used for leachate management. The leachate spraying scenario is based on brief exposures (1 hour) to aerosols at very high concentrations (1 x 10^{-3} kg m^{-3} - sufficient to reduce visibility to less than 10 m) and is intended to represent exposures to accidental releases. Because calculated doses are directly proportional to the number of events and inversely proportional to aerosol concentration, each event can also be regarded as a prolonged exposure (approximately 1 month for members of the public, 6 months for workers) to aerosols at a lower concentration (0.2 mg m^{-3}) more typical of routine releases.

57. *Sprayings per year*. The number of times that leachate management leads to the accidental release of aerosols at high concentrations.

The leachate spraying scenario can be switched-off by setting the number of sprayings to zero. The default number of leachate sprayings is 1, based on a generic landfill. The site licence application and site working plan should provide information on leachate management systems from which the aerosol generation may be assessed.

58. **Intrusion.** The Assessment Model assumes that, at some time after site capping and closure, knowledge of the former use of the site is lost. Activities on the site after this time (e.g., building works) could result in contaminated material being excavated. For calculating potential doses to intruders, the Assessment Model assumes that the material excavated includes all of the SPB disposals.

59. *Excavated volume* (cubic metres). The volume of waste excavated by an intrusion.

The excavated volume should typically be set to a value slightly greater than the volume of the SPB disposals. Setting a value less than the volume of the disposals will lead to higher activity concentrations, and hence dose, than would be encountered in practise. Setting a larger excavated volume would implicitly include uncontaminated material and hence lead to lower activity concentrations and doses. This may be appropriate for sites where SPB disposals are widely dispersed rather than being concentrated in one part of the site. The default value of 10 m^3 represents a fairly small intrusion, and is conservative except for sites receiving only small amounts of SPB disposals.

60. *Time of intrusion* (years). The time after closure of the site before intrusion is assumed to occur.

Although consequences would be highest if intrusion occurred immediately after closure, it can be assumed that planning and similar controls would prevent unsuitable use of the site for some period after closure.

The default value for time of intrusion is 20 years after closure. The site licence application may provide information on proposed closure and after use, but any assumptions about long-term maintenance of controls should be carefully assessed.

61. **Bathtubbing**. Although the cap is assumed to prevent infiltration of rainfall into the landfill for some time after closure, the cap will become less efficient with time. If the rate of infiltration exceeds the rate at which leachate flows from the base of the site, the landfill will eventually fill with leachate and then overflow (bathtubbing). Under this scenario, contaminated leachate will contaminate soil directly, without a period of flow and transport in the groundwater or dilution within a surface water body.

62. *Bathtubbing volume* (cubic metres). The annual volume of leachate overflowing from the landfill and contaminating soil.

> The bathtubbing scenario can be switched-off by setting the bathtubbing volume to zero. The default volume is 1000 m^3, based on a generic landfill site. The maximum bathtubbing volume would be the volume of rainfall falling on the site, but the effective volume of contaminated leachate overflowing would normally be significantly less than this.

63. Once data entry for site and scenario data is complete, clicking "Next -->" will open a further screen for reviewing modelling data. Clicking "<-- Back" will allow revisions to the list of radionuclides. As noted above, clicking "Default Values" will restore default values for **all** data, overwriting any edits made to the site and scenario data, except for volume, area and duration of operation).

Sensitivity Studies

64. The next screen "Sensitivity Studies" allows the user to change some of the reference values used in the Assessment Model. These values may be changed when there is site-specific information available that differs from the reference values, or when the user wishes to understand the effect of different pathways on the calculated dose and radiological pathways.

65. Sensitivity studies are most easily undertaken by performing a baseline assessment with the default reference values, and then performing additional assessments (as described in Section 3.2) varying one or more of the reference values.

66. The "Sensitivity Studies" screen opens displaying the reference values for sorption coefficients. Reference values for other parameters can be viewed and edited by clicking "Sensitivity Values". The other parameters are categorised into five sections:

- Exposure
- Aerosol / Fire
- Gas
- Groundwater
- Other scenarios

67. Each of the parameters available for editing is described briefly in the following sections, along with the basis for the reference value included in the Assessment Model. Further information on how the parameters are used in the Assessment Model can be found in SNIFFER (2006a).

Sorption coefficients (K_ds)

68. Sorption coefficients (K_ds) are key parameters in any model of radionuclide transport, since they determine the extent to which radionuclides are retained in different parts of the system and thus the extent to which activity can decay before workers or the public are exposed. Because of the variety of pathways by which doses could be received, there is no single set of

conservative assumptions that can be made about sorption – ignoring sorption in one part of the system might lower exposure through one pathway but increase it through another. One conservative assumption that is made in the Assessment Model, however, is that there is no sorption within the waste itself (K_d = 0), so that radionuclide concentrations in leachate are maximised.

69. The Assessment Model includes a default set of K_ds for different parts of the disposal system and different rock types. The default values for the selected radionuclides can be reviewed on this page, and edited either because there is additional information about sorption in a particular environment or for sensitivity studies.

70. To edit K_ds, highlight the appropriate line in the list and click "Edit". This will display an additional set of text boxes displaying the current K_ds for *Waste*, *Barrier*, *Soil* and *Rock*. New values for any of the K_ds (in m^3 / kg) can be entered and confirmed by clicking on "✓". Clicking on "✗" will discard any edits to the K_ds for the currently selected radionuclide.

71. The K_d values for *Rock* are for the rock type selected on the Groundwater data page. If *Specific* was selected as the rock type, all the K_ds for *Rock* will be set to zero and will require editing. The reference values for the other rock types that can be used as a guide are listed in SNIFFER (2006a).

Exposure

72. Doses to workers and members of the public are a function not only of radionuclide concentrations in various media and resources but also on the level of exposure. The Assessment Model includes default values for consumption rates of various foodstuffs and for the amount of time spent at various locations. These values can be edited for sensitivity studies aimed at understanding which are the most important pathways and the robustness of the assessment.

73. The reference values for consumption rates of *Fish, Green Vegetables, Root Vegetables, Grain, Cow Meat* and *Cow Milk* represent the average annual consumption of these foodstuffs by an individual. The conservative assumption in the Assessment Model is that this entire annual consumption comes from the area of land or volume of water contaminated. In practice, it is unlikely that a sufficiently large area or volume would become contaminated to support this rate even for a single person. A more likely scenario is that only part of an individual's annual food intake would come from contaminated resources. Reducing the values for consumption rates in order to take account of this consumption pattern would decrease the calculated specific doses and increase the potential radiological capacity.

74. Excavating material from a closed landfill or remediating an operating site may lead to contaminated dust being inhaled or ingested by workers. Reference values for *Dust load inhaled by excavator* and *Rate of dust ingestion by excavator* are based on the dust loads assumed for during large-scale excavations (IAEA 2003).

75. Contaminated dust may also be present where there is contaminated soil used for agriculture. The reference value for *Dust concentration in air* represents a relatively high dust concentration for normal air. Higher concentrations would be reached during ploughing, but exposure to these higher levels would be brief.

76. Contaminated groundwater or river water may be used for irrigation and thereby transfer radionuclides to the soil and to crops. The reference value for *Irrigation rate* is typical for temperate conditions where there is no irrigation of pasture (IAEA 2003). Under more arid conditions, where pasture is irrigated, a higher irrigation rate would be appropriate. For the

assessment of sites in regions where irrigation is not practised, this pathway can be omitted by unchecking Irrigation as a water use (see para. 38).

77. The extent to which soil is contaminated and plant uptake of radionuclides takes place is a function of the *Soil thickness* assumed. The reference value for this parameter is typical for agricultural soils. The Assessment Model assumes that thinner soils would have greater radionuclide concentrations, leading to higher calculated specific doses. Thinner soils may not, however, support the level of agriculture necessary to support the other assumptions regarding consumption.

78. Doses to members of the public from radioactively contaminated ground, including inhalation of dust and radioactive gases, are controlled in part by the amount of time spent indoors and outdoors. The reference value for *Outdoor occupancy by public* is typical for a resident spending an average of 6 hrs per day outdoors (e.g., in the garden). Some agricultural workers could spend longer outdoors, but the overall exposure of such a group would only be higher if they were also resident above the site.

79. Doses from external exposure (irradiation) are less indoors than outdoors. The Assessment Model uses a *Shielding factor* to calculate the difference in dose, with the reference value typical of similar assessments (IAEA 2003).

Aerosol / Fire

80. Doses from aerosol and fire releases are a function of the radionuclide concentrations in leachate and material consumed in a fire. They are also a function of atmospheric conditions, which control the rate of dispersion in the atmosphere, and the nature of the material on which wind-borne contaminants settle.

81. The reference value for the *Concentration* of aerosols represents a typical concentration of an aerosol plume that might travel beyond the site boundary. Higher concentrations could be found close to the point of release.

82. The *Plume height* for aerosols is the height which the aerosol release reaches. The reference value is conservatively set to the same value as the plume height for the fire. In practice, aerosol releases are likely to reach a lower height, which will lead to lower concentrations on the ground and hence lower calculated doses.

83. Because the radiological criterion for determining radiological capacity is an annual dose, the Assessment Model uses reference values of 1 year for both the *Time since deposition* and the *Time following release over which vegetables are consumed*. In practice, surface contamination of vegetables by aerosols is likely to be washed off within days of deposition and so these values are conservative.

84. The reference value for *Plume height* for releases from a fire is typical of the types of fire at waste disposal sites (IAEA 2003).

85. The dose pathways assessed for releases through fires include inhalation of smoke and dust. The reference value for the *Breathing rate of general public* is an average breathing rate for normal activities (IAEA 2003). The reference value for *Breathing rate of worker* assumes that a worker is working to control the fire and therefore has a higher breathing rate than a member of the public.

86. The Assessment Model uses reference values of 1 year for the *Time since deposition* and 0.25 years for the *Time following fire over which vegetables are consumed*. In practice, surface

contamination of vegetables by dust from fires is likely to be washed off within days of deposition and so these values are conservative.

Gas

87. The gas pathway includes the exposure of workers to gases generated during the operational period, exposure of members of the public to dispersed gases from the landfill and exposure of members of the public living in houses constructed on the landfill after closure.

88. Reference values for *Horizontal area of dwelling* and *Volume of dwelling* represent a single storey, small to medium-sized house. An increase in volume (i.e., assuming a two-storey property) would decrease calculated gas concentrations and hence specific doses.

89. The reference value for *Height for vertical mixing* is based on the approximate height for breathing. A lower height for mixing would yield higher concentrations, but air near the ground is not breathed in by workers. Landfill gas releases may reach much greater heights, particularly if flared, and for these gases the reference value is conservative.

90. The reference value for *Width of source perpendicular to wind direction* assumes that gas release takes place across a relatively small part of the site, consistent with the assumption of SPB disposals being confined to part of the site.

91. The reference value for *Time spent in gas plume by worker* is based on the assumption of working 8 hrs per day, 5 days per week, 44 weeks per year.

92. The *Cover thickness* is important in determining concentrations of radon in houses and hence calculated doses. The Assessment Model assumes that the site will be occupied immediately after closure. Although, in practice, some time may elapse before occupation, allowing some erosion and thinning of the cap to take place, the reference value is conservative in that it effectively discounts the material used to cover the waste after emplacement.

Groundwater

93. Key controls on the groundwater pathway are the amount of water entering the site and the rate of leakage through the liner.

94. Leakage through the liner is a function of the size of the holes in the liner (see para. 34) and also the extent to which there is contact between the liner and the underlying formation. The reference value for *Contact liner/material* is an average value for landfills (DOE 1996).

95. The Assessment Model assumes that the effectiveness of the cap, in terms of preventing infiltration, decreases over time. The reference value for *Initial cap efficiency* conservatively assumes that the cap will not be entirely effective even when first constructed.

96. In addition to the effectiveness of the cap, the rate of infiltration into the landfill is controlled by the amount of rainfall and losses such as evapotranspiration and runoff. The Assessment Model does not explicitly calculate a water budget for the cap, and the reference value for *Water infiltration rate* is based on an annual rainfall of the order of 1.1 m, evapotranspiration of the order of 0.45 m, and runoff at 45%.

Other Scenarios

97. Doses to members of the public living on the site after an excavation are determined by the concentration of radionuclides in the soil, which depends in turn on the extent to which

excavated waste is diluted by the incorporation on non-contaminated excavated material, such as the cap, and mixing with other materials. The reference value for *Dilution factor* is based on excavation of waste from a 3 m deep trench type disposal site (IAEA 2003). To assess the effects of dilution, this parameter value can be varied between 1 (no dilution) and 0 (no waste in soil).

98. As noted above, the reference values for the consumption rates of crops assume that the entire annual consumption for an exposed individual is derived from contaminated ground. The Assessment Model assumes that leachate overflowing from the site (bathtubbing) contaminates an area that can provide this much crop. The reference value for *Area of soil for crops/livestock* corresponds to a farm or small-holding providing food to a group of about 25 people. Dispersing radionuclides over this entire area may not be realistic, and the concentration of radionuclides in the ground actually contaminated may be somewhat greater than calculated. However, a smaller contaminated area could not support the annual food consumption and so changes to this parameter value should be accompanied by corresponding changes to consumption rates.

Default values

99. The sensitivity studies data entry screen does not include a default values button, but the reference values can be re-set by clicking “<-- Back” to return to the Site and Scenario Data screen and clicking “Default Values”. This will reset **all** edited values to their default values (data entered for parameters with no default value will not be changed).

Dose Assessment Results

100. Once data entry is complete, clicking “Run model” will start the calculation. A progress bar on the Dose Assessment Results screen will indicate progress. On completion of the calculation, the dose assessment results are displayed in a series of tabbed pages for each of the exposed groups considered:

- Workers 1. This group comprises workers operating the site during the normal operations phase. The site operators will have the highest occupancy (i.e., period of time spent on the site), and so will receive the highest doses from the exposure pathways associated with the surface of the landfill. For the normal operations scenario, the pathways are external irradiation from the landfill surface, inhalation of aerosols from leachate and potentially inhalation of radioactive gases and dust or particles from fires.

- Workers 2. This group comprises workers engaged in site operations that may lead to the exposure of waste. Pathways include external irradiation from exposed waste and inhalation or ingestion of dust from contaminated material. At sites where there is landfill gas abstraction, this group may be exposed during normal site operations. At all sites exposure may occur during remediation or re-engineering. A group with similar habits may also be involved in inadvertent intrusion of the landfill after closure.

- Public 1. This group comprises members of the public living sufficiently close to the site to be affected directly by site operations. Members of this group may inhale aerosols from leachate treatment and gas from landfill gas utilisation. Spillage of leachate during treatment or handling may contaminate surface water and lead to exposure through ingestion of water or foodstuffs. Fires on the site may lead to exposure of this group through inhalation of dust or particles, ingestion of dust deposited on foodstuffs or irradiation from dust deposited on the ground.

- Public 2. This group comprises members of the public living at the point of groundwater discharge or surface water consumption where they will receive the highest dose associated with contaminated groundwater. Potential exposure pathways include drinking contaminated water, consumption of crops irrigated by contaminated water, consumption of fish and inhalation of dust from soil contaminated by groundwater discharge. The same groundwater pathways and exposed public apply for the normal post-closure scenario and to the failure of barrier and spillage of leachate scenarios.

- Public 3. This group comprises members of the public living on or in close proximity to the site after capping and closure. There are three sets of exposure pathways that could affect this group. The first relates to the continued, normal evolution of the site and comprises inhalation of radioactive gases. The second comprises the ingestion of soil and food contaminated during a bathtubbing incident. These two pathways could potentially occur at any time after closure. The third set of pathways could occur only after loss of control over site use and relates to contamination after an intrusion. It is assumed that the land will be levelled, and that the new soil layer may contain a component of the radioactive waste. Doses are calculated for a member of the public residing on this land and farming it for crops and livestock.

101. Results are displayed both as total specific doses from all of the pathways (normal evolution and potential exposure scenarios), and as specific doses for individual pathways.

102. The dose assessment results can be saved by clicking “Save”. This will write the results and the associated parameter values to a new worksheet to allow for future review of the results, and also save the spreadsheet. If the spreadsheet has not previously been saved, the user will be prompted for a file name (a file name based on the site name will be suggested). If previous dose assessment results have been saved, the existing file will be over-written with the new version to include the new results in addition to the previous results. Once dose assessment results are saved, there is no means of deleting them through the user interface.

103. If the dose assessment results just calculated have not been saved, the “<-- Restart Assessment” button can be used on this screen to return to the Select Radionuclides screen and restart the assessment with a new list of radionuclides. This action will discard the unsaved assessment results and a warning message will appear requiring the user to confirm. Clicking “OK” will return the user to the data entry screens and discard the results. Clicking “Cancel” will return the user to the results screen and allow the results to be saved. If the dose assessment results are saved, the “<-- New Assessment” button can be used to return to the Assessment Type screen.

104. Clicking “Capacity Calculations” on the Dose Assessment Results screen will open the Radiological Capacity screen (see Section 4). If the results of a dose assessment have not been saved, a warning message will appear requiring the user to confirm. Clicking “OK” will allow radiological capacity calculations to be undertaken using the most recent dose assessment results, but these results will **not** be saved when the capacity results are saved, and they will **not** be available for later review or use in subsequent capacity calculations. Clicking “Cancel” will return the user to the results screen and allow the results to be saved.

3.2 Subsequent Dose Assessments

105. If one or more dose assessments have already been undertaken and the results saved, the opening screen allows the user to select between performing a further dose assessment, reviewing an existing assessment or conducting radiological capacity calculations.

106. Selecting New Dose Assessment at this stage requires completion of the *Assessment* details, as with the initial assessment. The *Site Operator*, *Assessor* and *Date* details can be edited if required. Clicking "Next -->" then allows selection of radionuclides.

107. Other than in the initial assessment, the "Load Previous" button is enabled on the Select Radionuclides screen. Clicking this button selects the list of radionuclides used in the previous (i.e., last saved) assessment. Alternatively, the user can select a new list of radionuclides in the same manner as for the initial assessment.

108. Clicking "Next -->" from the radionuclide selection screen opens the Site and Scenario Data screen. Again, for assessments other than the initial assessment, the "Load Previous" button is enabled on this screen. Clicking this button loads the parameter values used in the previous (i.e., last saved) assessment. These values can be edited as for the initial assessment and the default values can be re-loaded by clicking "Default Values".

109. The other stages of conducting subsequent dose assessments are the same as for the initial dose assessment. Saving the results of a subsequent dose assessment will generate a further internal worksheet and over-write the existing file. The list of radionuclides and other parameter values from this dose assessment will become the "Previous" results if a further assessment is undertaken.

3.3 Reviewing Dose Assessments

110. If one or more dose assessments have been performed and the results saved, the opening screen allows the user to select between performing a further dose assessment, reviewing an existing assessment or conducting radiological capacity calculations.

111. Selecting Review Dose Assessment at this stage and clicking "Next -->" will display a list of saved dose assessments. Selecting an assessment from this list and clicking "Next" will display the results as described above (para. 100 *et seq.*). If only one dose assessment has been undertaken, the results will be displayed without an intermediate selection menu.

112. From the Dose Assessment Results screen, the user may select "Back" to return to the opening screen or "Capacity Calculations" to undertake radiological capacity calculations (Section 4).

4 Radiological Capacity Calculations

113. The calculation of radiological capacity is a step-wise process requiring information on existing and anticipated disposals and waste stream characteristics in addition to the results of dose assessments (Figure 1.2). The Assessment Model guides the user through the process using a series of dialog boxes for the following stages:

- Enter / edit existing disposals
- Select basis for capacity calculations
- Review individual radiological capacities
- Enter / edit radionuclide ratios
- Review site radiological capacity

114. For an initial capacity calculation, these stages should be conducted in this order. Once each stage is complete, clicking the “Next” button will take the user to the next stage. To re-visit a stage, clicking the “Cancel” button will return to the initial radiological capacity screen on which command buttons for stages that are available will be enabled.

115. Capacity calculations can be saved at any stage by clicking the “Save” button. If the spreadsheet has not previously been saved, the user will be prompted for a file name (a file name based on the site name will be suggested). If previous results have been saved, this will over-write the existing file, including any previously saved capacity calculations, and the user is advised to complete the capacity calculation process and review the results prior to saving.

116. The user may at any stage use the “<-- New Assessment” button to return to the initial Assessment Type screen to access different dose assessment results or undertake a new assessment. If changes have been made but not saved (capacity calculations or dose assessments), the user will be prompted to confirm. Clicking “Yes” will save the changes. If the spreadsheet has not previously been saved, the user will be prompted for a file name (a file name based on the site name will be suggested). Otherwise, the existing file will be over-written with any changes made to the dose assessment results or radiological capacity calculations. Clicking “No” will take the user to the Assessment Type screen without saving the capacity calculations, and clicking “Cancel” will return the user to the radiological capacity calculations screen to allow the results to be saved or more changes to be made prior to saving.

117. Clicking the “Exit” button on either the Radiological Capacity or Assessment Type screen will close the spreadsheet. If changes have been made but not saved (capacity calculations or dose assessments), the user will be prompted to confirm. Clicking “Yes” will save the changes and clicking “No” will close the spreadsheet without saving. If the spreadsheet has not previously been saved, the user will be prompted for a file name (a file name based on the site name will be suggested). Otherwise, the existing file will be over-written with any changes made to the dose assessment results or radiological capacity calculations. Clicking “Cancel” closes the prompt without any action.

Enter / edit existing disposals

118. The radiological capacity of a new disposal site can be calculated and used to establish authorisations for waste consignors. It is likely, however, that actual disposals will differ from authorised disposals, and other changes, such as changes in waste stream composition, may occur over the lifetime of the site. One objective of the Assessment Model is therefore to allow for periodic re-calculation of the radiological capacity of a site.

119. The radiological capacity of a disposal site is, in part, a function of the mix of radionuclides in the waste stream(s) that will be consigned. To calculate radiological capacity, it is necessary for all the radionuclides of interest to be included in the dose assessment. After the initial dose assessment, subsequent dose assessments can be undertaken to include any additional radionuclides that are identified as important during the operation of the facility (e.g., if a new waste stream is proposed for consignment to the site).

120. The Assessment Model does not automatically update the list of radionuclides in the radiological capacity calculations if the radionuclides included in subsequent assessments differ from those included in the initial dose assessment. The user must check the list of radionuclides for capacity calculations against the list for the current dose assessment and update it manually. The former list is displayed on the Existing Disposals page as the *Current list* and radionuclides can be added to the list by clicking "Add Nuclide", selecting the additional radionuclide(s) from the *Available Nuclides* list and clicking "Add". Failure to update the list at this stage will prevent the calculation of a comprehensive radiological capacity.

121. Conversely, the user must ensure that all radionuclides for which there are existing or planned disposals (see below) are included in the current dose assessment. Failure to ensure this will generate a warning message when the capacity calculations are performed.

122. Once the list of radionuclides has been updated, clicking "Edit Inventory" on the Existing Disposals page opens a worksheet on which details of existing disposals can be entered. Data can be entered on an annual basis or any other interval. For example, an overall estimate of radioactive material other than SPB disposals that might be consigned over the lifetime of the site waste could be made as one entry.

123. All values entered on the Existing Disposals worksheet must be in MBq.

124. Data must only be entered on the white part of the worksheet. Coloured areas of the worksheet must not be edited.

125. To ensure that the data on existing disposals is correctly summed, each new line of data must include an entry in the description field (column C) in the first blank row beneath existing values (any blank lines will result in incorrect totals). If there are no disposals of a particular radionuclide in the period concerned, the corresponding cell can be left blank. The date field is also optional but is useful to keep track of the data entered.

126. After the initial data entry, the data rows that contribute to the *Authorised Disposals to Date* total are highlighted. Data in this area should **not** be edited. If there is a need to correct data already entered, this should be done using a new entry, contiguous with the previous entries, comprising the differences between old and new data (negative values can be entered to reduce the total for existing disposals).

127. Once data on existing disposals have been updated, clicking the "Done" button on the worksheet will re-open the Radiological Capacity screen. Clicking the second "Next" button on this screen will open the Dose Basis page.

128. If there is no information on existing disposals to add or review, clicking "Next -->" on the Existing Disposals page will open the Dose Basis page.

Select basis for capacity calculations

129. The dose assessments evaluate potential doses to members of 5 exposed groups via a number of pathways. Some of the scenarios that result in exposure pathways are expected to

occur as part of normal site evolution. Other scenarios have a lower probability of occurring. The lower probability scenarios may lead to higher calculated specific doses and hence to lower radiological capacities. Regulatory judgement is therefore required as to whether doses that are not certain to occur should be used in determining radiological capacities.

130. The exposed groups considered include both workers and members of the public. Workers are included because not all workers at a landfill site used for SPB disposals will necessarily be aware of the presence of radioactive material. It is likely, however, that precautions would be taken during any remediation work on an SPB site to prevent or reduce workers' exposure to radioactive materials. Excavation of material from the site after the end of institutional controls, and the subsequent exposure of members of the public to excavated material, will not be subject to the same precautions.

131. To determine the radiological capacity based on the maximum calculated dose to any exposed group, whatever the probability of the exposure scenario, select Maximum Dose. To exclude the exposures that are not certain to occur, select Maximum Dose – Pathways certain to occur. Other selections can be made in order to understand the behaviour of the system and the relative contributions of different exposure pathways. In particular, comparing results from Maximum Worker Dose – Pathways certain to occur and Maximum Worker Dose – All Pathways will allow the importance of the uncertain (and potentially very low probability) scenarios to be assessed. Similarly, selecting Maximum Public Dose – All Pathways will demonstrate whether potential exposures occurring after loss of control have a significant effect on radiological capacities.

132. Once a basis for the capacity calculations has been selected, clicking "Next -->" will open the Radiological Capacity page.

Review individual radiological capacities

133. The dose criterion and specific doses (μSv y^{-1} MBq^{-1}) for each radionuclide can be used to determine the potential radiological capacity for individual radionuclides. These individual capacities are displayed on the Radiological Capacity page.

134. The information on the Radiological Capacity page is of limited use for setting disposal authorisations because there will be few occasions when a single radionuclide is being considered in isolation. This information does show which radionuclides potentially pose little hazard (high capacity) and those that are likely to control the amount of waste disposed of through SPB (low capacity).

135. This page also shows the extent to which existing disposals contribute to the potential doses from the site, and hence a broad indication of how close to capacity the site is (i.e., if the sum of the doses from existing disposals is 10 μSv y^{-1} the site is about "half-full").

136. After reviewing the individual radiological capacities, clicking "Next -->" will open the Radionuclide Ratios page.

Enter / edit radionuclide ratios

137. As noted above, individual radiological capacities are of limited use in determining authorisation conditions. Except in rare cases where only one radionuclide is being consigned, site radiological capacity is determined by the relative amounts of different radionuclides. The Radionuclide Ratios page allows for the ratio between radionuclides to be entered.

138. By default all of the radionuclides are assumed to be present in the same relative proportions (i.e., every MBq of radionuclide A is accompanied by 1 MBq of radionuclide B). These ratios are also expressed such that the sum of the ratios is 1 (i.e., for *N* radionuclides, the ratio is 1/*N*).

139. If only a single waste stream is intended for consignment to a particular SPB site, determining the radionuclide ratios is a case of determining the relative amounts (by activity) of all the radionuclides in the waste stream. These relative amounts are most readily expressed in the form 10:1:3:1… but can also be normalised.

140. If multiple waste streams are to be consigned to the site, then the relative amounts of different waste streams must be taken into account in determining the overall radionuclide ratios.

141. To edit the ratios, select each radionuclide in turn and edit the ratio displayed (initially 1 for every radionuclide). Click on "✓" to confirm the new value or on "X" to cancel.

142. When all the radionuclide ratios have been edited, click on "Next -->" to review the site radiological capacity.

Review site radiological capacity

143. The calculated site radiological capacity is displayed on a worksheet along with other key information and results.

- The name of the dose assessment used to determine capacity
- Which calculated dose is used to determine capacity
- The calculated dose for radionuclides already consigned to the site (both total and by radionuclide)
- The nuclide-specific radiological capacity for each radionuclide (how much of each radionuclide could be consigned in isolation)
- The ratios between radionuclides in the waste stream(s) to be consigned
- The site radiological capacity – the amount of each radionuclide that can be consigned to the site (over and above the existing disposals).

144. The radiological capacity worksheet can be printed or copied to another application using the normal Excel controls. To return to the Assessment Model, click "Done".

145. Alternative assumptions, such as the dose basis or radionuclide ratios, can be entered and the radiological capacity re-calculated. This will over-write any previous capacity calculations but, if the dose assessment results have been saved, the radiological capacity can be re-calculated for any set of assumptions. Nevertheless, the user is advised to print or copy key results.

146. Click on "Exit" to close the application. If there have been changes to the spreadsheet since the last save, the user will be prompted. Clicking "Yes" will save the changes and clicking "No" will close the spreadsheet without saving. If the spreadsheet has not previously been saved, the user will be prompted for a file name (a file name based on the site name will be suggested). Otherwise, the existing file will be over-written with any changes made to the dose assessment results or radiological capacity calculations.

5 References

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