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User guide for Prame v2.0

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User Guide for Prame v2.0

(Probabilistic Radiological Assessments of the Marine Environment)

PC Version 2.0.3

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Summary

This document instructs the new user in the installation and running of the 'Probabilistic Radiological Assessments of the Marine Environment' model (Prame, version 2.0). This model can be used for assessing the effective dose of radiation to critical groups through a number of pathways due to radionuclide discharges into the marine environment.

Version 2.0 of Prame includes both deterministic and probabilistic modelling capabilities. In deterministic mode, the model replicates the WAT and ADO models (Round 1998*a*, *b*), with an enhanced graphical user environment. The probabilistic mode adds a sampling routine to the mathematical model to enable the variability of input parameters to be modelled and propagated. The concentration distribution of radionuclides in the water is calculated using the WATP model and these results are then used to calculate the distribution of effective dose via the ADOP model. Details of these models can be found in Grzechnik *et al.* (2002), Round (1998*a*, *b*), with correlations and sensitivities investigated in Grzechnik (2003) and (2005) respectively.

This User Guide is intended as a complete guide to running the model in both deterministic and probabilistic modes. Experience with Prame v1.0 and WAT/ADO is beneficial but not essential. A step-by-step guide to the use of Prame is provided, covering installation of the program to the user's PC, choice of model type, input of all required parameters, execution of the model, and the generation and analysis of output statistics and charts.

In addition to the deterministic mode, Prame v2.0 also incorporates:

- Improved parameter validation to prevent run-time errors
- Additional subroutines to handle parameter values sampled outside their allowable range during run-time
- Generation of input distribution charts for each pathway selected in probabilistic mode
- An additional output option in probabilistic mode – choose to display overall effective dose, or dose broken down by nuclide and pathway

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1 Introduction

Grzechnik *et al.* (2002) developed a two-part probabilistic modelling suite (known as WATP and ADOP) to predict the distribution of effective dose due to the discharge of radionuclides to the marine environment. This suite was an extension of the deterministic models (WAT and ADO) developed by Round (1998*a*, *b*). The probabilistic approach specifies a range and distribution for each input parameter such that, over a number of runs, the model gives an output distribution that reflects the uncertainty and variability of the input. The distribution of input parameters is randomly sampled using the Latin Hypercube Sampling (LHS) routine (see Grzechnik *et al.*, 2002).

Values for a number of the parameters are typically variable both by region and over time. Difficulty in obtaining precise measurements also makes them open to a degree of uncertainty. For this reason, the probabilistic approach to radiological assessments provides a realistic and valuable tool for recognising instances in which critical groups[1] could be exposed to a high effective dose due to radionuclide discharge.

The Prame model was originally developed to combine WATP and ADOP, and provide a simplified method of parameter input to these models. Due to the continued use of the deterministic WAT and ADO models, it was decided to incorporate these into version 2.0 of Prame, whilst enhancing the probabilistic modelling and user environment.

In order to model the effects of discharges, the Prame model uses three sub-models:

1) Random sampling of parameter distributions, which is undertaken by the application of the Latin Hypercube Sampling (LHS) routine (probabilistic mode only).

2) Calculation of the concentration of radionuclides in the water column, undertaken by utilising the WAT/WATP model.

3) Calculation of effective dose to the critical group, undertaken by utilising the ADO/ADOP model. This model incorporates the output from the WAT/WATP model.

The output from each of these steps can be displayed and saved for future reference, with probabilistic output loaded into an Excel spreadsheet and displayed in a distribution chart.

This User Guide leads the client through the installation and use of version 2.0 of the Prame model. In particular, it is hoped that the new user is able to gain knowledge of the parameters involved to enable use of this tool accurately

[1] The 'critical group' is generally defined as those persons whose consumption or occupancy rate falls within a factor of three of the highest individual consumption or occupancy rate (Hunt *et al.*, 1982).

and efficiently. Computation time can vary widely, dependent on the number of samples required, the model type chosen, and the number of radionuclides being considered in the discharge scenario. It is therefore recommended that the user reads and understands each Section of this Guide before executing the Prame model.

The guide is divided into a number of Sections. Section 2 describes the installation of the necessary program files to the user's hard drive. In Section 3 the user is guided through each stage of the parameter input process. Where appropriate, typical parameter values and distribution types are given, along with references to enable clarification if necessary. The dimensions in which each parameter should be input are also specified. After all relevant parameters have been successfully entered the program can be executed. Section 4 explains how to initialise the execution and progress through the three stages of the Prame model. Section 5 explains how to utilise the model output to make radiological assessments. The generation of Excel charts when in probabilistic mode, and the data contained in them, is described.

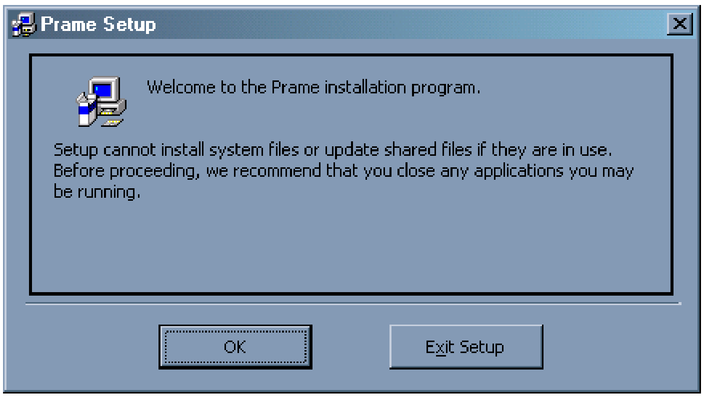
Prame is supplied with a sample input file. This can be loaded and executed to check that the program has been correctly installed and is compatible with the user's PC. Details of how to access this file, and how to save user-input selections for subsequent use, are included in Appendix A.

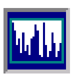
2 Program Installation

Prame must be installed to a hard drive on a PC running a Windows Operating System (95 and above). Program files and folders must be installed to the directory specified below, and it is recommended that the hard drive has at least 20 MB of free space to enable installation and effective operation of the program. Microsoft Excel must also be installed to enable probabilistic output charts to be automatically generated.

If Prame has been supplied on a CD-ROM, insert the disk and follow the instructions below. If Prame has been supplied electronically (via email or download), access the folder to which the program was saved on your PC and follow instructions 2) – 6) below.

1) Access the CD drive, via the 'Start' menu or the 'My Computer' icon on the desktop.
2) Double-click on the 'setup' file to run the installation program.
3) The user will be presented with the window below. Close any open applications and then click 'OK' to begin installing Prame.



4) The Install Wizard will guide users through the installation process. If the user is unsure about any of the options offered during installation, it is recommended that the default setting be accepted. (***Note that the program files and folders* must *be installed to the default 'C:\Prame\' directory in order for the application to run correctly***).
5) To run the program, click Start > Programs and locate the 'Prame' sub-menu.
6) Click on the  icon to start the program.

Prame

3 Parameter Input in Prame

The Prame program is divided into eight pages - this section of the guide will take the user through pages 1 - 6. These pages are used to build an input file consisting of the user-definable parameters required to run Prame.

3.1 Model Type

The first page of the Prame suite allows the user to select the number of model runs, the type of model that will be used and whether the deterministic or probabilistic mode is desired. A larger number of runs will increase computation time, but improve the resolution of the output solution. To change the default value of 500 runs, simply **click the box and enter the desired number.**

The user can then choose one of two models; this choice determines which radionuclide dispersion equation will be used in the calculation of water concentrations. Each of these is suited to a particular hydrographical situation, and the user should choose that which best represents the location to which the model is being applied. In general, the following guidelines apply:

- The **Advection-Diffusion**[2] model is intended for use on open coastlines, where the main transport processes are the underlying tidal drift and eddy diffusion (Round, 1998*a*). Installations such as Sizewell and Torness discharge radionuclides into this environment.

- The **Single Compartment** model is intended for use where the radionuclides are discharged in an enclosed or estuarine environment (Hunt, 1982). Examples of such installations include Berkeley and Rosyth.

The relevant model type can be selected via the 'Model' drop-down menu.

The mode in which you wish to operate the chosen model type is then selected by clicking one of the 'Mode' buttons. As the deterministic mode is analogous to running the probabilistic mode once, when this mode is chosen the 'Number of runs' will automatically be set to 1. If probabilistic mode is chosen, the number of runs will remain as selected. The choice of mode affects the method of parameter input, and so in the rest of this section we distinguish between parameter entry in either mode.

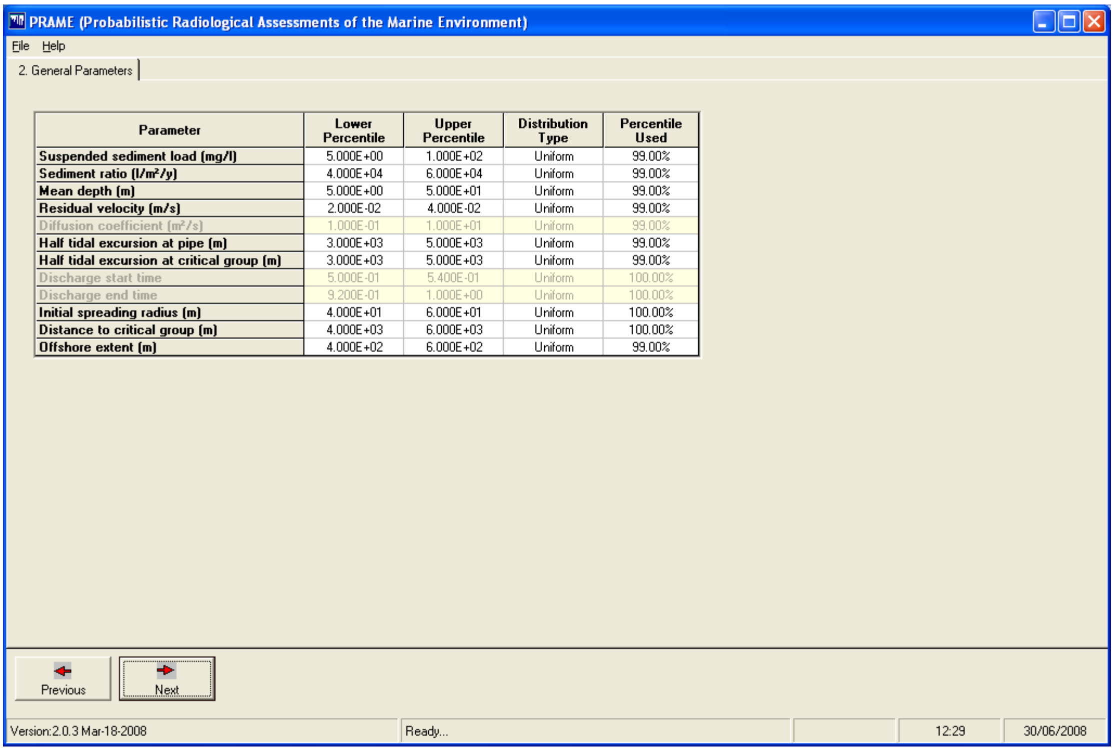
[2] The advection-diffusion model requires significantly more computation time than the single compartment model due to the increased complexity of the underlying mathematics.

3.2 General Parameters

The second page allows the user to adjust a number of general hydrographic parameters used by the model.

Probabilistic mode

Parameter values are input as distributions of real numbers. These are randomly sampled by the LHS routine, and are defined by means of a **Lower Percentile**, **Upper Percentile**, **Distribution Type**, and **Percentile Used**. It is thus possible to reflect the uncertain and variable nature of many of the input parameters.



Parameter	Lower Percentile	Upper Percentile	Distribution Type	Percentile Used
Suspended sediment load (mg/l)	5.000E+00	1.000E+02	Uniform	99.00%
Sediment ratio ($l/m^2/y$)	4.000E+04	6.000E+04	Uniform	99.00%
Mean depth (m)	5.000E+00	5.000E+01	Uniform	99.00%
Residual velocity (m/s)	2.000E-02	4.000E-02	Uniform	99.00%
Diffusion coefficient (m^2/s)	1.000E-01	1.000E+01	Uniform	99.00%
Half tidal excursion at pipe (m)	3.000E+03	5.000E+03	Uniform	99.00%
Half tidal excursion at critical group (m)	3.000E+03	5.000E+03	Uniform	99.00%
Discharge start time	5.000E-01	5.400E-01	Uniform	100.00%
Discharge end time	9.200E-01	1.000E+00	Uniform	100.00%
Initial spreading radius (m)	4.000E+01	6.000E+01	Uniform	100.00%
Distance to critical group (m)	4.000E+03	6.000E+03	Uniform	100.00%
Offshore extent (m)	4.000E+02	6.000E+02	Uniform	99.00%

Figure 1: *The General Parameter input page in probabilistic mode*

The lower and upper percentiles are the bounds within which a specified percentage of normal and log-normal parameter distributions will lie. The percentile used relates to this percentage, with a higher value decreasing the incidence of parameter values outside the lower and upper bounds. For example, a 'percentile used' of 95% implies that 95% of the distribution will be above the lower percentile value and 95% will be below the upper percentile value. These specific lower and upper values may also be referred to as 5th and 95th percentiles. To fix absolute parameter bounds, the percentile used should be set to 100%. Further, a parameter value can be assigned a constant value in probabilistic mode by setting both the lower and upper percentiles to this constant.

The distribution type describes the shape of the parameter distribution. This can be set to one of four distributions that have been shown (Grzechnik *et al*., 2002) to describe the variation and uncertainty of each parameter.

Absolute bounds should be used cautiously with normal and log-normal distributions, as these distributions are based on the assumption that the parameter value is not bounded. Inspection of the sampled input parameter distributions in the relevant excel worksheet after execution may help decide if this distribution choice is suitable for the parameter being described.

Uniform and triangular distributions should only be used with the absolute bounds.

To change the range and distribution of the parameters described below, **double-click on the row to be altered and update values as required in the popup window. Click 'OK' to register changes or 'Cancel' to return to the main window and discard changes.** If an invalid parameter range has been selected, a popup box will notify you of the nature of the problem. Click 'OK' in the popup box to return to the parameter entry box and enter a valid parameter range.

Deterministic mode

Parameter values for each of the parameters described below are input in the 'Value' column by simply **clicking in the relevant cell** and entering a valid parameter value. Pressing **'Enter'** or clicking away from the cell will confirm the input value. To **confirm and move to the next cell**, press the 'Tab' key, or to **exit the cell and discard changes**, press the 'Escape' key. If an invalid parameter value has been entered a popup box will open as you leave the cell and notify you of the nature of the problem. Click 'OK' in the popup box to edit the invalid parameter.

A description of each of the general parameters is given below. A brief description is also displayed on the screen when the mouse pointer runs over a parameter name. Parameters that are not applicable to the model type chosen on the previous page are shaded out (see Figure 1), and these entries cannot be accessed or altered.

3.2.1 Suspended sediment load (input dimensions: milligrams per litre)

This refers to the mass of sediment that can be carried in suspension per unit volume of the water column. This value varies regionally. In the UK it usually takes a value between 0.0 and 200.0 mg/l (Brownless *et al*., 2001). The distribution of suspended sediment load around a number of nuclear sites has been calculated based on available experimental data (Jenkinson, 2006).

3.2.2 Sediment ratio (litres per square metre per year)

The sediment ratio is defined as the sedimentation rate divided by the suspended sediment load and takes account of the direct correlation between these two parameters (see Grzechnik, 2003). The sedimentation rate is the amount of suspended sediment that settles on the ocean/river bed per unit area per unit time – it is specific to the region being assessed, and in the UK usually takes a value between 0.0 and 10.0 kg/m^2/y (Brownless *et al*., 2001). To calculate this ratio, measurements of mass should be in kg; thus, the (constant) default sediment ratio of $5x10^4$ is equivalent to a sedimentation rate of 5kg/m^2/y for each 100mg/l of suspended sediment. This parameter may also be input as a distribution to take account of variability in the sedimentation rate with respect to the suspended sediment load.

3.2.3 Mean depth (metres)

This is the mean depth below mean sea level over the local area. This may be obtained from depth soundings of the local region, which are recorded in bathymetric charts.

3.2.4 Residual Velocity (metres per second)

The residual velocity is calculated as the mean of the residual velocities over spring and neap tides parallel to the coast. This value represents the mean drift of a particle in the sea over larger time scales, and can be estimated through the vector addition of tidal diamonds available in hydrographical charts or current observations in the region of interest. Residual velocities are typically in the range of 0.02 to 0.05m/s near UK coastal nuclear installations (Round, 1998*a*).

3.2.5 Diffusion coefficient (square metres per second)

(Advection-diffusion model only)

This variable is often used to 'tune' the deterministic advection-diffusion model, and refers to the eddy diffusion perpendicular to the coast. Physically it can be regarded as the rate of increase in width (and hence area) of the pollutant plume as it drifts farther away from the source. Diffusion coefficients vary over a number of orders of magnitude, for example 0.1 to 100m^2/s (Talbot, 1976). However, in the use of the WAT model Brownless *et al*. (2001) found that there is little sensitivity to changes in this parameter above 10m^2/s.

3.2.6 Half tidal excursion at pipe (metres)

This parameter refers to the mean of spring and neap half-tidal excursions at the point of discharge. Determination of this distribution can be from either the vector calculation of the tidal ellipse (where the full tidal excursion is twice the major axis), or by local observation.

3.2.7 Half tidal excursion at critical group (metres)

Measured in the same way as at the pipe, this value refers to the mean half-tidal excursion at the location of the critical group.

3.2.8 Discharge start time

(Advection-diffusion model only)

This is the fraction of time through a complete tidal cycle that discharge begins. It is assumed that discharges occur regularly, and are timed according to the tidal flow. The input may range between 0.0 and 1.0 (both extremes correspond to low water), subject to the constraint that the discharge start time must be before the discharge end time. If there is a discharge beginning at high water then the start time will take the value 0.5. As the program is relatively insensitive to this parameter it is reasonable to assume a constant value, even though it may be input as a distribution.

3.2.9 Discharge end time

(Advection-diffusion model only)

This is calculated in a similar way to the discharge start time, and will be a range of values between 0.0 and 1.0. The discharge end time must take a greater value than the start time, and to avoid the possibility of the start and end times overlapping these parameter distributions are given absolute bounds when probabilistic mode is selected. However, as with the start time it is reasonable to assume a constant value.

3.2.10 Initial spreading radius (metres)

This refers to the distance perpendicular to the coast in which 95% of the discharge is contained at the point of release. It is often given the constant value 50m, as the model output is relatively insensitive to this parameter (Brownless *et al.*, 2001).

3.2.11 Distance to critical group (metres)

A distribution may be input to represent the distance between the discharge pipe and the location of the critical group or the area of fishing which supplies them, as determined during habits surveys[3].

3.2.12 Offshore extent (metres)

(Single compartment model only)

The offshore extent describes the distance offshore that the discharged radionuclides are able to disperse due to transverse diffusion. This is often dictated by the size of the estuary being considered for the single compartment model. This may also be determined as being twice the minor axis of the tidal current ellipse.

After all parameter values and/or distribution types have been entered as required click ‘Next’ in the main window to continue to the next page.

3.3 Nuclides

The user can now specify which nuclides are to be included in the model and their individual discharge rates in dimensions of terabecquerels per year (TBq/y). Data for this parameter is site-specific and can be obtained from individual site operators.

[3] Radiological Habits Surveys of the consumption of foodstuffs potentially exposed to radionuclides and occupancy of intertidal areas in the vicinity of radionuclide discharge points are regularly undertaken by Cefas, Lowestoft.

To add the desired nuclide(s) to the model, click 'Add' in the menu above the table. A popup window allows you to choose a nuclide and enter the discharge rate. **Click 'OK' to insert the nuclide data into the Nuclides table.** The user may enter more nuclides by selecting the required nuclide code from the drop-down menu and entering the discharge rate; repeat this procedure until all desired nuclides have been input. **Click 'Done' to return to the main window.**

To **delete** a nuclide, select the nuclide to be deleted by **clicking the relevant row, then selecting 'Delete' from the menu above the table.**

When the user has input all desired nuclides and discharge rates, click 'Next' at the bottom of the main window to continue to the next page.

3.4 Sediment Distribution Coefficient

On this page the sediment distribution coefficient for each nuclide can be adjusted. This parameter, often called the K_d value, is input in a similar way to the general parameters described in Section 3.2.

The K_d value describes the partition of sediments in the water column between dissolved and adsorbed phases. Recommended values for the sediment distribution coefficient can be found in IAEA Technical Report 422 (IAEA, 2004). Grzechnik *et al*. (2002) suggest that a log-normal distribution would give a reasonable representation of the uncertainty associated with this parameter.

Probabilistic mode

To alter the distribution of this coefficient for a particular nuclide, **double-click on the relevant row** and alter values in the popup window as desired. **Click 'OK' to update the values, or click 'Done' to return to the main page.**

Deterministic mode

Click on the distribution coefficient you wish to alter and **enter the required value**. Press 'Enter' to register this change, or press 'Escape' to discard any changes.

After all changes have been made, click 'Next' at the bottom of the main window to continue to the next page.

3.5 Estuarine Sedimentation Rate

The estuarine (or shoreline) sedimentation rate refers to the depth, in metres, of sediment that settles in a particular estuary per year. Grzechnik *et al*. (2002) suggest a log-normal distribution would adequately represent the variation in this parameter.

Probabilistic mode

To alter the distribution of this parameter, **double-click on this row** and change values in the popup window as desired. **Click 'OK' to save changes and return to the main window, or click 'Done' to return to the main page.**

Deterministic mode

Click on the box containing the current parameter value and **input the required estuarine sedimentation rate**. Press 'Enter' to register the change, or press 'Escape' to discard changes

After all changes have been made, click 'Next' at the bottom of the main window to continue to the next page.

3.6 Pathways

The user is now required to specify one or more pathways through which the critical group are exposed to radionuclides.

Probabilistic mode

Each pathway is again assigned a distribution according to lower and upper percentiles, distribution type and the percentile used. This represents the consumption or occupancy of a pathway. Data for consumption and occupancy are site-specific and can be obtained from habits surveys of the area under consideration.

In addition there is a 'pathway modifier', which is used to model any shielding factors that may be present along a particular pathway (see Round, 1998*b*). Where this is not relevant the pathway modifier should be set to 1.

To include the desired pathway(s), click 'Add' in the menu above the table. A popup window allows you to choose a pathway and alter the distribution type and pathway modifier. **Click 'OK' to insert the pathway distribution into the Pathways table.** The user may add more pathways by selecting a different pathway name from the drop down menu and entering the desired distribution data; repeat this procedure until all required pathways have been input. **Click 'Done' to return to the main window.**

To **delete** a pathway, select the pathway to be deleted by **clicking the relevant row, then selecting 'Delete' from the menu above the table.**

Deterministic mode

Each pathway is assigned a consumption or occupancy rate. Habit surveys of the site being considered contain data on the average and high-level rates for all pathways observed.

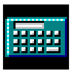
To include the desired pathway(s), click 'Add' in the menu above the table. A popup window allows you to choose a pathway and the habit rate associated with it. The pathway modifier is used to account for shielding factors, as explained in Round (1998*b*). **Click 'OK' to insert the pathway and rate into the Pathways table.** The user may add more pathways by selecting a different pathway name from the drop down menu and entering the desired rate; repeat this procedure until all required pathways have been input. **Click 'Done' to return to the main window.**

To **delete** a pathway, select the pathway to be deleted by **clicking the relevant row, then selecting 'Delete' from the menu above the table.**

When the user has input all desired pathways and their respective distributions or parameter values, click 'Next' at the bottom of the main window to continue to the next page.

4 Execution

The parameters required to run the Prame model have now been input. Before executing the program, the user may wish to check the input data by using the 'Previous' button at the bottom of the window to return to each of the parameter input screens. It is not possible to check or alter the input data whilst the program is executing.

To run the Prame model, click the  **button on the main page.**

A window will open listing the nuclides included in the current model run (see Figure 2). If running the model in probabilistic mode, details of the LHS sampling routine are also displayed. Press 'Return' to continue to the next stage of execution. A second window will open displaying the progress of the water concentration model (WAT or WATP depending on mode of operation). Upon completion, you will be asked to press 'Return' to continue to the final stage of the model. The progress of ADO/ADOP is then displayed in a third window. When this has completed its run, press 'Return' to finish execution of the model and return to the Prame screen.

The overall result of the execution process and its individual models is displayed in red. If the result is 'Success', **click 'Next' at the bottom of the main window to continue to the final page.** If execution of any component of the model is unsuccessful, the application will halt and the user will be required to return to the parameter input stage of the program.

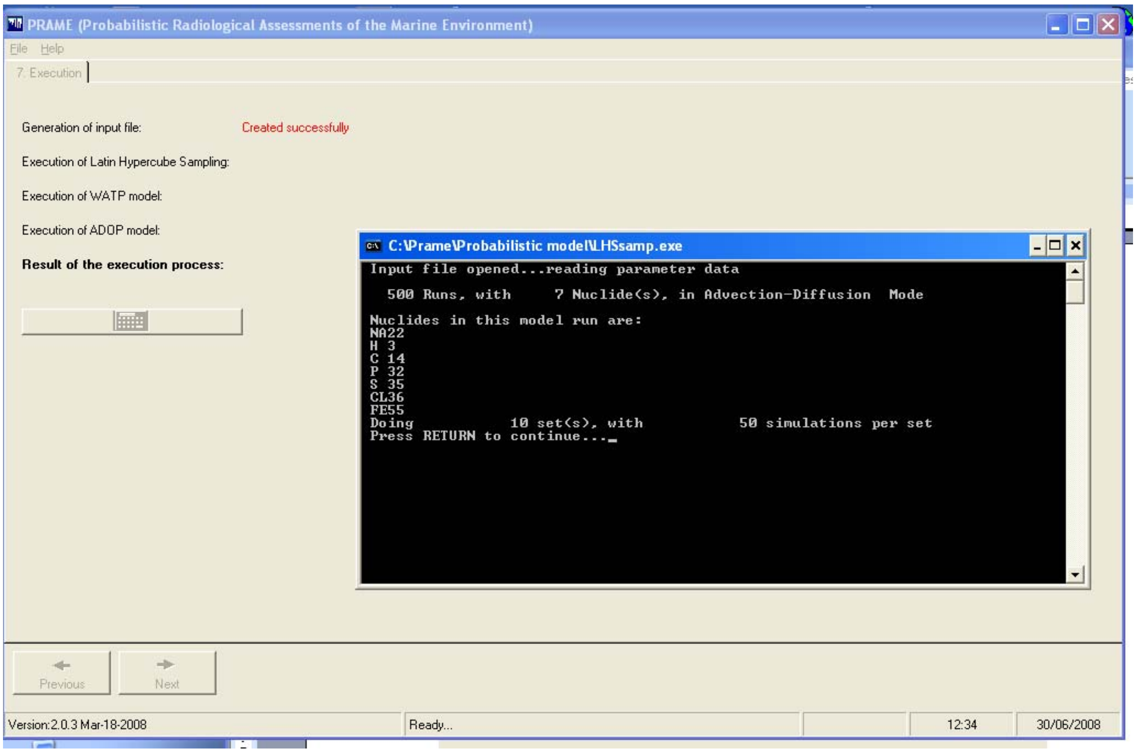


Figure 2: *The command window, showing the progress of the LHS routine during the execution stage*

5 Model output

After execution of the Prame model has been completed successfully, the user is able to display the model output and save these results for future reference. If the model has been run in probabilistic mode, results are viewed in spreadsheet form with charts generated for input and output distributions. The individual parameter values used for each model run are also presented. If the model has been run in deterministic mode, the output results from WAT and ADO are displayed on the Prame screen.

5.1 Probabilistic mode

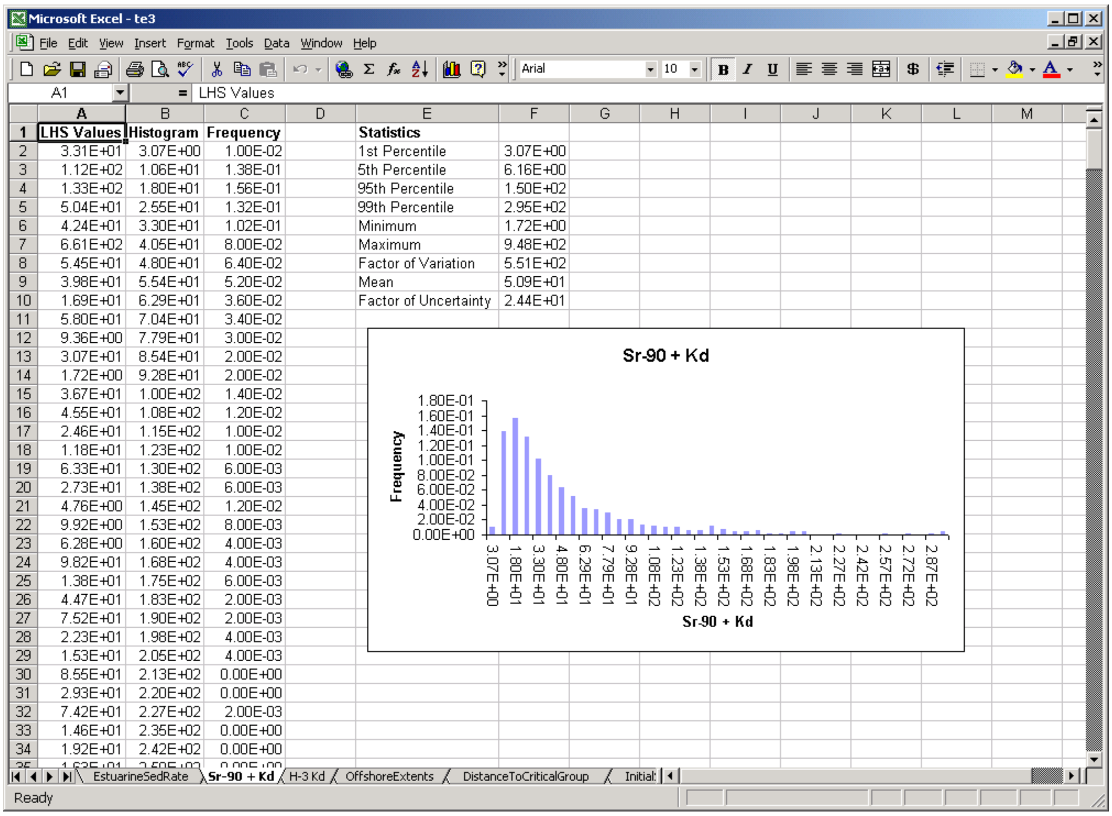
In probabilistic mode, four buttons are displayed enabling generation of different model outputs. Data for each of the input parameters can be automatically presented in an Excel spreadsheet by clicking the **'Generate LHS Charts'** button. The user will be asked to select a spreadsheet in which to display these results. Navigate to the folder in which you wish to save results, and type an appropriate filename. Click 'Open' to begin loading data to the spreadsheet. To view the spreadsheet, right-click on the minimised Excel window in the taskbar and select 'Restore'.

Results of the LHS routine for each of the input parameters are now displayed on individual sheets (see Figure 3). The user may view a different parameter by selecting from the tabs at the bottom of the spreadsheet.

The format of each sheet is the same. Column A consists of the randomly selected values chosen by the LHS routine. These are the parameter values that have been used in individual model runs. Columns B and C provide the data for the histogram; that is, the frequency (column C) with which each interval (column B) of the parameter space was selected by the LHS routine. Some statistical data about the distribution, including the mean and the uncertainty, is given in columns E and F.

To display the water concentration distributions for each radionuclide in an Excel spreadsheet click **'Generate WAT Charts'.** As for the LHS charts, the user will be asked to select a spreadsheet in which to display these results. Selecting the same file as the LHS charts will not erase those results; a new tab, marked '**Water conc**', will appear for each nuclide.

Column A in each WAT chart displays the output from each run of the WAT model – the water concentration of the relevant nuclide at the location of the critical group. Columns B and C again relate to the histogram, the concentration intervals and frequencies respectively. Statistical data pertaining to the water concentration of each nuclide is displayed in columns E and F.



	LHS Values	Histogram	Frequency		Statistics	
2	3.31E+01	3.07E+00	1.00E-02		1st Percentile	3.07E+00
3	1.12E+02	1.06E+01	1.38E-01		5th Percentile	6.16E+00
4	1.33E+02	1.80E+01	1.56E-01		95th Percentile	1.50E+02
5	5.04E+01	2.55E+01	1.32E-01		99th Percentile	2.95E+02
6	4.24E+01	3.30E+01	1.02E-01		Minimum	1.72E+00
7	6.61E+02	4.05E+01	8.00E-02		Maximum	9.48E+02
8	5.45E+01	4.80E+01	6.40E-02		Factor of Variation	5.51E+02
9	3.98E+01	5.54E+01	5.20E-02		Mean	5.09E+01
10	1.69E+01	6.29E+01	3.60E-02		Factor of Uncertainty	2.44E+01
11	5.80E+01	7.04E+01	3.40E-02			
12	9.36E+00	7.79E+01	3.00E-02			
13	3.07E+01	8.54E+01	2.00E-02			
14	1.72E+00	9.28E+01	2.00E-02			
15	3.67E+01	1.00E+02	1.40E-02			
16	4.55E+01	1.08E+02	1.20E-02			
17	2.46E+01	1.15E+02	1.00E-02			
18	1.18E+01	1.23E+02	1.00E-02			
19	6.33E+01	1.30E+02	6.00E-03			
20	2.73E+01	1.38E+02	6.00E-03			
21	4.76E+00	1.45E+02	1.20E-02			
22	9.92E+00	1.53E+02	8.00E-03			
23	6.28E+00	1.60E+02	4.00E-03			
24	9.82E+01	1.68E+02	4.00E-03			
25	1.38E+01	1.75E+02	6.00E-03			
26	4.47E+01	1.83E+02	2.00E-03			
27	7.52E+01	1.90E+02	2.00E-03			
28	2.23E+01	1.98E+02	4.00E-03			
29	1.53E+01	2.05E+02	4.00E-03			
30	8.55E+01	2.13E+02	0.00E+00			
31	2.93E+01	2.20E+02	0.00E+00			
32	7.42E+01	2.27E+02	2.00E-03			
33	1.46E+01	2.35E+02	0.00E+00			
34	1.92E+01	2.42E+02	0.00E+00			

***Figure 3:** Excel sheet displaying results of the LHS routine*

The user has two options for displaying the distribution of effective dose – **'Generate ADO Charts'**, which generates a series of charts containing the dose broken down by nuclide and pathway, or **'Generate ADO Totals'**, which generates one summary chart displaying the distribution of dose due to all nuclides and pathways. The user may again choose to display these results in the same file as the LHS and WAT charts.

If 'Generate ADO Charts' is selected, worksheets labelled **'Eff Dose – [nuclide code] Chart [pathway code]'** display statistical data and a chart relating to the effective dose distribution due to that particular combination of nuclide and pathway. The distribution of total effective dose due to individual nuclides is shown in a similar form in the **'Eff Dose – [nuclide code] Chart TOTAL'** worksheet. Finally, the raw output data from the ADO model are listed in the **'Eff Dose – [nuclide code]'** sheet. The effective dose, in µSv/y, received through each pathway in each model run is shown, as well as the intervals and frequencies used in generating the effective dose charts.

If 'Generate ADO Totals' is selected, a worksheet titled 'Eff Dose – Totals' displays a chart showing the total effective dose distribution. Statistical data and the results from individual model runs is also loaded into the worksheet.

This information allows the user to assess the probability of the total effective dose to the critical group exceeding prescribed levels, and also enables the user to elicit the combinations of parameter values that give rise to such doses. In doing so, the user should note that data in row *n* of the LHS and WAT charts corresponds to that in row *n+1* of the ADO data sheets.

5.2 Deterministic mode

The output from the Prame deterministic mode can be loaded to the results grid by clicking the '[model name] Results' button. The concentration in water of each nuclide included in the model run can be viewed in the Prame window by clicking **'WAT Results'**, and the breakdown of dose by nuclide and pathway, as well as the total dose, can be viewed by clicking **'ADO Results'** (see Figure 4).

The user can save these results to a text file by clicking the 'Save [model name] Results' button below the results display area. This will open a 'Save' dialog box enabling the user to select the desired save location and filename. Note that it is only possible to save the data that is currently being displayed in the results grid.

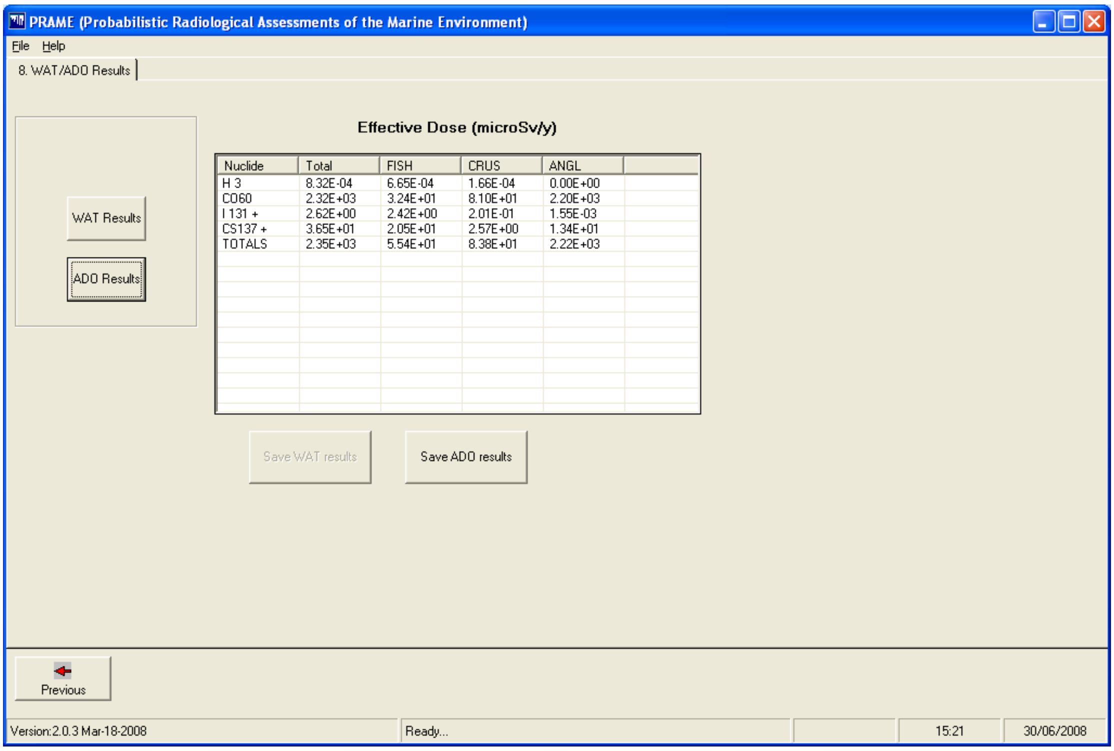


Figure 4: *Deterministic mode output displayed in the results grid*

6 Concluding Remarks

The Prame (PC Version 2.0) program for calculating single values and distributions of effective dose to critical groups has been tested and is available for use in probabilistic radiological dose assessments. Installation is possible on PCs running a Windows OS (95 and above); Microsoft Excel must also be installed to enable generation of output charts from the probabilistic mode.

This program builds on the Prame v1.0 probabilistic model by incorporating a deterministic mode into the original Prame GUI, simplifying the parameter input stage of the program and ensuring that the input files are correctly formatted. It also enables straightforward execution of each stage of the model. Model output from the probabilistic mode can be automatically entered into an Excel spreadsheet to allow statistical manipulation and graphical illustration of probability densities. Output from the deterministic mode is displayed in a results grid within Prame, and can be easily saved to file for future use.

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8 Appendix A – Saved input files

Frequently used sets of parameters can be saved in a suitable format for reloading directly into the GUI, allowing for quicker navigation through the parameter input stage of Prame. In case of problems with the parameter input, execution or spreadsheet generation stages of the Prame model, the user is also able to load a sample file from the 'Saved Input Files' folder of the 'Prame' directory. Once this file is loaded into Prame the program should execute quickly, and produce output files that can be used to generate sample Excel spreadsheets as explained in Section 5.

To save a particular set of parameters, the user should first navigate through pages 1 – 6 of the Prame program, as described in Section 3. Once the desired parameter set has been input, click 'File' > 'Save Inputs' and enter a suitable name in the 'File name' field. This will then be saved in the 'C:\Prame\SavedInputFiles' folder. To subsequently retrieve this parameter set, click 'File' > 'Open Input File' and select the desired file.

To load the test file, select 'File' from the GUI, and then click 'Open Input File'. Highlight 'Test.pra' and click 'Open'. Each necessary input field will now be completed, and the user can move through each page of the GUI by clicking 'Next' at the bottom of the main page. Follow the execution instructions in Section 4. If the program does not execute successfully, then Prame is incorrectly installed or the user's PC is not compatible with this version of Prame.

9 Appendix B – Verification of deterministic mode

We now present a brief comparison of the output from Prame in deterministic mode with the output from the WAT and ADO models in order to verify the consistency of results. Comparison of both Single Compartment and Advection-Diffusion models is undertaken. Input parameters are given in Tables B1 – B3, with the output from the Advection – Diffusion model compared in Tables B4 and B5 and the output from the Single Compartment model compared in Tables B6 and B7. Note that the original WAT model requires the full tidal excursion, thus the values for the half tidal excursion given in Table B1 were doubled for WAT model runs. The WAT Single Compartment model also requires an exchange volume and a dispersion factor to be included in the input file. Prame calculates these parameters internally, but for the purpose of this exercise they were manually calculated as:

$$V_{ex} = \frac{d \cdot T_{exc} \cdot O}{10^9}$$

$$D = \frac{v_{res} \cdot (60 \cdot 60 \cdot 24)}{T_{exc}}$$

where *d* is depth, T_{exc} is the full tidal excursion at the pipe, *O* is the offshore extent and v_{res} is the residual velocity. The factor 10^9 converts the exchange volume to units of cubic kilometres and 60x60x24 is the number of seconds in a day. Using these formulae, the exchange volume was found to be 0.032 km^3 and the dispersion factor was 0.216 d^{-1}.

As expected, the results from Prame in deterministic mode and the output from WAT/ADO provide a good match (Tables B4 – B7). Results from WAT and ADO have been rounded to three significant figures for comparison with the Prame default. This default is the reason for the discrepancies between effective dose in Table B7 – by rounding the WAT output to three significant figures before running the ADO model, we can exactly obtain the effective dose as predicted by Prame.

Table B1: *General parameters used for model verification*

Parameter	Value
Suspended sediment load (mg/l)	25
Sediment ratio (l/m^2/y)	4 x 10^4
Mean depth (m)	10
Residual velocity (m/s)	0.02
Diffusion coefficient (m^2/s)	1
Half tidal excursion at pipe	4 x 10^3
Half tidal excursion at critical group	5 x 10^3
Discharge start time	0.5
Discharge end time	0.85
Initial spreading radius (m)	50
Distance to critical group (m)	7 x 10^3
Offshore extent (m)	400
Estuarine sedimentation rate (m/y)	0.05

Table B2: *Nuclides, discharge rates and* K_d *values used for model verification*

Nuclide	Discharge rate (TBq/y)	K_d value
Tritium	1	1
Cobalt-60	1	3 x 10^5
Ruthenium-106+	1	4 x 10^4
Caesium-137+	1	4 x 10^3
Americium-241	1	2 x 10^6

Table B3: *Pathways and consumption/occupancy rates*

Pathway	Rate (kg/y or h/y)	Pathway modifier
Fish consumption	50	1
Mollusc consumption	45	1
Bait digging over mud	150	1
Inhalation of sea spray	150	1
Angling	300	0.3

Table B4: *Comparison of water concentrations using Advection-Diffusion model*

Nuclide	Water concentration (Bq/l)	
	Prame	WAT
Tritium	0.187	0.187
Cobalt-60	0.0214	0.0214
Ruthenium-106+	0.0917	0.0917
Caesium-137+	0.170	0.170
Americium-241	0.00356	0.00356

***Table B5:** Comparison of effective dose using Advection-Diffusion model*

Pathway	**Effective dose (μSv/y)**	
	Prame	**ADO**
Fish	17.2	17.2
Molluscs	118	118
Bait digging over mud	260	260
Inhalation of sea spray	2.39×10^{-4}	2.39×10^{-4}
Angling	156	156
Total	551	551

***Table B6**: Comparison of water concentration using Single Compartment model*

Nuclide	**Water concentration (Bq/l)**	
	Prame	**WAT**
Tritium	0.396	0.396
Cobalt-60	0.0445	0.0445
Ruthenium-106+	0.192	0.192
Caesium-137+	0.358	0.358
Americium-241	0.00740	0.00740

***Table B7:** Comparison of effective dose using Single Compartment model*

Pathway	**Effective dose (μSv/y)**	
	Prame	**ADO**
Fish	36.1	36.1
Molluscs	246	246
Bait digging over mud	540	541
Inhalation of sea spray	5.01×10^{-4}	5.00×10^{-4}
Angling	325	325
Total	1150	1150

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