CEFAS
The Centre for Environment, Fisheries & Aquaculture Science

User Guide for Radiological Assessments PC Version 1.1

for the

Food Standards Agency

CEFAS Contract RB101
Environment Report RL6/04

Environment Report RL 6/04

User Guide for Radiological Assessments

PC VERSION 1.1

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September 2003

The work in this report was completed under contract to
the Food Standards Agency.
FSA Service Level Agreement
CEFAS Contract RB101

Summary

This document instructs the new user in the installation and running of the WAT and ADO (PC Version 1.1) models for regular assessments of radionuclide discharges into the marine environment.

Two specific models are considered:

- WAT - to calculate the radionuclide concentrations in the water column. This is split into two modules for different situations. The advection-diffusion model is generally used for open coastlines, and the single compartment model for estuarine systems.
- ADO - to calculate the doses to members of the critical group due to the aforementioned discharges. This can be conducted for 5 age groups:
  - Adults
  - 15 years old
  - Children – 10 years old
  - Infants – 1 year old
  - Fetus – based on mother's consumption

The construction of input text files is described and a template is provided for the user to become familiar with the required format. Additionally, examples of output files are given to ensure that the installation has been performed successfully.

The purpose of **this update** is to increase the ease of using the text-based input system, as well as the incorporation of fetal doses. Methods for displaying outputs using Microsoft Excel are also discussed. Furthermore, it is intended that future versions of this modelling suite will include further additions to the scope of the model as well as the development of a graphical user interface for ease of use (Version 2.0).

Contents

1. Introduction

The WAT and ADO models have been used at CEFAS for regular assessments of doses to the public from radiological discharges into the aquatic environment. A scientific description of these models, including the assumptions made and mathematical techniques incorporated, is given by Round (1998a and 1998b).

In order to model the effects of discharges, we follow two steps:

- Calculation of the concentration of radionuclides in the water column, undertaken by the WAT model.
- Calculation of doses to the critical group, which is undertaken by the ADO model but uses the values obtained through the use of the WAT model.

A number of factors must be taken into account in order to calculate the concentration of radionuclides in the water column. Involved in this is the choice of either the *Advection-Diffusion* or *Single Compartment* versions of the WAT model. This depends on the placement of the discharge point and the shape of the regional coastline. Further choices of parameter values must be made in order to take into account the environmental conditions in the local region. These decisions must often be made with limited available measurements, which increases the value of expert experience in the use of these models.

The newly obtained radionuclide concentrations may then be applied to the ADO model. Also used are data obtained from surveys of the habits of the people that are deemed to be most at risk from the discharges (known as the 'Critical Group'). Choices of other parameter values are also required before the overall dose to the critical group can be obtained.

It is the intention of this User Guide that the application of WAT and ADO to regular assessments is simplified. In particular, it is hoped that the new user is able to more quickly gain knowledge of the parameters involved to use these models accurately and realistically. This guide should be used at specific sites in conjunction with the report of Allison and Grzechnik (2003), which provides ‘initial estimates’ of parameter values.

2. Program Installation and File Handling

The WAT and ADO models must be installed from the available CD ROM to a fixed disk on an IBM compatible PC in order to be used effectively. Additionally, a number of data files incorporating concentration factors and specific radionuclide data must also be installed.

The steps that must be followed are:

1) Create a directory for the assessment to be undertaken.
2) Copy the *Wat PC V1.1.exe* and *Ado PC V1.1.exe* files to this directory.
3) Create a directory within the assessment directory called *nucdat*. Copy the files of the form *nuc*.dat* and *cfac.dat* to the *nucdat* directory (where * includes numbers in the range *47-55*).
4) The WAT input file must be created. This can be most easily achieved by copying the commented template files, *Single-Comp_template.txt* (single compartment model) and *Adv-Diff_template.txt* (advection-diffusion model), to the assessment directory. These can then be renamed and various parameter values can be edited as described in Section 3.
5) To run the WAT model, double-click on the *Wat PC V1.1.exe* icon and follow the onscreen instructions to produce relevant output files. This is described further in Section 3.3.
6) The ADO input and pathways files must be created to perform the dose assessment. This can be most easily achieved by copying the commented template files, *ADO_input.txt* and *pathways.txt*, to the assessment directory. These may be edited as described in Section 4, specific to the requirements of the current dose assessment.
7) After successfully completing steps 5) and 6) and producing the water concentration output file (Section 3.4), the ADO model can be run by double clicking on *Ado PC V1.1.exe*.

If the input files have been properly constructed, the specified output files should be produced listing the calculated doses. If there is a problem with the running of the model, the user should consider:

- Does the input file follow the format of the template?
- Are all support files installed into the correct directory?
- Is the problem occurring with the application of WAT, or is ADO the source of difficulties? To determine this, the user should consult the output of the WAT model, discussed in Section 3.4, to ensure that the model is reading parameters in the correct manner.

Note that all output files will be constructed in the assessments directory previously created.

To make certain that the programs will run on the installation PC an attempt should be made to activate the model with the unchanged template files used as input. The output can then be compared to the expected output file, as shown in Section 3.4.

3. Using the WAT Model

The WAT model incorporates various conditions of the local marine environment to predict the concentration of discharged radionuclides. There are two types of model available which perform this task. Their use depends on the type of coastline situation being considered as different assumptions are made for each method.

In general, the following guidelines should be followed:

- The **advection-diffusion** model is intended for use on open coastlines, and the assumptions involved in its derivation indicate this (Round 1998a). Examples of this situation include Sellafield and Sizewell.
- The **single compartment** model may be used in situations where the advection-diffusion model is not appropriate, such as where the discharge is located in an enclosed or estuarine environment (Hunt, 1982). Some examples of this include Rosyth and Berkeley.

3.1 The Advection-Diffusion Model

The line-by-line format of the input file for the advection-diffusion model (provided as a template file, *Adv-Diff_template.txt*) is shown in this section. The user should edit the template file according to the parameter values for the particular region/situation being studied.

3.1.1 Title

The title for the input file is included as a single line of up to 80 characters in length. It's content is relatively unimportant, but should be informative and descriptive of the assessment that is being conducted.

3.1.2 Output file name

The output file is given a name of up to 20 characters in length. This is generally recommended to take the form **.out* and can include spaces. In the template this is *Adv-Diff.out*.

3.1.3 Mode

The mode is an integer that can take one of two possible values. These are:

- 1 - In the case of the advection-diffusion model,
- 2 - in the case of the single compartment model.

In the case considered here the mode should be set to 1.

3.1.4 Suspended sediment load (mg l^{-1})

This parameter is a real number. It refers to the amount of sediment that can be carried in the water column, and differs regionally. In the UK it usually takes a value between 0.0 and 200.0 mg L^{-1} (Brownless et al., 2001).

3.1.5 Sedimentation rate (kg m^{-2} y^{-1})

The sedimentation rate is real number, and refers to a measure of the effective rate of loss of sediments from the water column. 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^{-1} (Brownless et al., 2001).

3.1.6 Mean depth (m)

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

3.1.7 Residual Velocity (m s^{-1})

The residual velocity, input as a real number, is actually 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 hydrographic charts of the region of interest. Residual velocities are typically in the range of 0.02 to 0.04m s^{-1} near UK coastal nuclear installations (Round 1998a).

3.1.8 Diffusion coefficient (m^2 s^{-1})

This variable is often used to 'tune' the model, and is input as a real number. It refers to the eddy diffusion coefficient 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 further away from the source. In the UK use of diffusion coefficients has varied over a number of orders of magnitude, for example 0.1 to 100m^2 s^{-1} (Talbot, 1976). However, in the use of the WAT model Brownless et al. (2001) found that the there is less sensitivity to changes in this parameter for values above 10m^2 s^{-1}.

3.1.9 Tidal excursion at pipe (m)

This parameter refers to the mean of spring and neap (full) tidal excursions at the point of discharge. It is input as a real value. Determination of this value can be from either the vector calculation of the tidal ellipse (where the tidal excursion is twice the major axis), or by local observations. The spreadsheet *tidal diamond revised.xls* is designed to calculate this value and the residual velocity (Section 3.1.7) from tidal diamonds. It should be noted also that in the report of parameters for WAT/ADO, Allison & Grzechnik (2003), the values listed are in fact for the full tidal excursion and not the half excursion (as is incorrectly indicated).

3.1.10 Tidal excursion at critical group (m)

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

3.1.11 Discharge start time

This is the time point in the tidal cycle when the discharge begins. It is assumed that discharges occur regularly, and are timed according to the tidal flow. The input is a real number between 0.0 and 1.0, which represents the fraction of time through the tidal cycle. These extremes correspond to:

- high water – if the residual velocity is parallel to the tidal velocity from high tide to low tide, or
- low water – if the residual velocity is anti-parallel to tidal velocity.

For example if the high-to-low tidal currents in a region are found to move towards the north (sources such as Nautical Almanacs can provide this information) and the residual velocity is towards the south, then 0.0 and 1.0 correspond to times of low water. If there is a timed discharge at a nuclear facility it will usually correspond to the high-to-low phase (where water is ebbing), so you would expect starting time to be between 0.5 (high water) and 1.0 (low water).

3.1.12 Discharge end time

This is calculated in a similar way to the discharge start time, and will be a value between 0.0 and 1.0 that is higher than that of the discharge start time.

3.1.13 Initial spreading radius (m)

This is a real parameter that 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 value 50m, as the model output is not very sensitive to this parameter (Brownless et al., 2001).

3.1.14 Distance to critical group (m)

This is 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. Note that the model assumes all concentrations that are more than half a tidal excursion ‘upstream’ (in opposite direction of residual velocity) from the pipe are zero, and will return an error if the critical group is placed in this position.

3.1.15 Number of Nuclides

An integer value that represents the number of radionuclides released in the discharge.

3.1.16 Nuclides used and rates of discharge (TBq y^{-1})

The radionuclides used are specified here, with each line representing a new nuclide. The input takes the following format, with allowed space for characters shown in brackets:
Nuclide name (2), *mass number* (4), *daughters* (2), *discharge rate* (12)

Note that no extra spaces should be added, and the inclusion of daughters is indicated by the character + and a space, with two spaces used otherwise. The discharge rate (TBq y^{-1}) has a maximum of 6 decimal places, and should be double-checked in the output file to ensure the correct value has been input to the model (see Section 3.4).

The format of this input file, specifically the nuclides included in discharges, is shown in Figure 1.

```
Adv-Diff_template - Notepad
File  Edit  Search  Help
Advection-Diffusion model template example
Adv-Diff.out
1         ! Mode (1 for ad-diff, 2 for single comp)
50.       ! Suspended Sediment Load (mg/L)
0.15      ! Sedimentation Rate (kg.m^2/y)
5.0       ! Mean Depth (m)
0.026     ! Residual Velocity (m/s)
1.0       ! Diffusion Coefficient (m^2/s)
8600      ! Tidal Excursion (Pipe) (m)
8600      ! Tidal Excursion (Critical Group) (m)
0.08      ! Start time
0.33      ! End time
50.0      ! Initial Spreading Radius (m)
12000.0   ! Distance to Critical Group (m)
12        ! Number of Nuclides
H 3     2.75E+2       ! Nuclide (a2), Mass no. (a4), Daughters (a2), Discharge (g12.6) (TBq/y)
S 35    2.30E+0
CA45    2.71E-1
MN54    9.68E-3
FE55    3.23E-3
CO58    3.20E-4
ZN65    3.23E-3
ZR95    6.50E-4
CO60    3.00E-2
SB124   3.23E-3
CS134   6.45E-3
CS137 + 3.06E-1
```

Figure 1 An example of the format used in the input file for the Advection-Diffusion model.

3.2 The Single Compartment Model

The line-by-line format of the input file for the single compartment model (provided as a template file, *Single-comp_template.txt*) is shown in this section. The user should edit the template file according to the parameter values for the particular region/situation being studied.

3.2.1 Title

As in the advection-diffusion model, see Section 3.1.1.

3.2.2 Output file name

As in the advection-diffusion model, see Section 3.1.2.

3.2.3 Mode

The mode is an integer that can take one of two possible values. These are:

- 1 - In the case of the advection-diffusion model,
- 2 - in the case of the single compartment model.

In the case considered here the mode should be set to 2.

3.2.4 Suspended sediment load (mg l^{-1})

As in the advection-diffusion model, see Section 3.1.4.

3.2.5 Sedimentation rate (kg m^{-2} y^{-1})

As in the advection-diffusion model, see Section 3.1.5.

3.2.6 Mean depth (m)

As in the advection-diffusion model, see Section 3.1.6.

3.2.7 Dispersion factor (fraction per day)

The (real) daily fractional turnover of the exchange volume (see next section) with respect to the surrounding water. The dispersion factor can be calculated by:

D = (Residual velocity) $\times$ *(No. seconds per day) / (Tidal Excursion),*

where the residual velocity is in m s^{-1}, the number of seconds in a day is 86400 s d^{-1}, and the tidal excursion is in s. Subsequently, D has units d^{-1}. It should be noted that other processes influence the value of this factor, such as diffusion effects. These can be taken into account by refining this parameter from its original calculated value in order to 'tune' specific model applications to better match observations in biota and the environment.

3.2.8 Exchange volume (km^3)

The (real) volume into which the radionuclides are discharged and assumed to be uniformly mixed. The exchange volume may be calculated (quantities in km) by:

V = (Mean depth) $\times$ *(Tidal excursion)* $\times$ *(Assumed offshore extent)*,

where the offshore extent often refers to either the width of an estuary, or the minor axis length of the tidal ellipse used to calculate the tidal excursion. The exchange volume can also be calculated by multiplying the area of the tidal ellipse by the mean depth.

3.2.9 Number of nuclides

The (integer) number of radionuclides discharged.

3.2.10 Nuclides used and rates of discharge (TBq y^{-1})

As in the advection-diffusion model, see Section 3.1.16.

Single-Comp_template - Notepad

File Edit Search Help

```
Single Compartment Model example template
Single_site.out
2      ! Mode (1 for ad-diff, 2 for single comp)
50     ! Sediment Load (mg/L)
0.2    ! Sedimentation Rate (kg/m^2.y)
20     ! Average Depth (m)
0.045  ! Dispersion Factor
0.9    ! Volume Exchange (km^3)
3      ! Number of Nuclides
H 3     3.95E-02        ! Nuclide (a2), Mass no. (a4), Daughters (a2), Discharge (g12.6)
CO60    2.5E-03
C 14    4.8E-04
```

Figure 2 An example of the format used in the input file for the WAT Single Compartment model.

3.3 *Running WAT*

The following steps should be used to run the WAT model:

1) Construct the input text file by editing a renamed copy of the template, as described in Sections 3.1 and 3.2.
2) Double-click on the *Wat PC V1.1.exe* icon.
3) When prompted, type in the name of the input file. This should include the file extension, e.g. *filename.txt*

The program should then run in either the advection-diffusion or single compartment modes. The user can tell if the program has run effectively after an onscreen prompt (see Figure 3 for advection-diffusion example). Investigation of the (specified) output file, which is constructed after the model run, can be used to confirm that input parameters have been correctly recognised. If there is no output file there has been an error, and the format of the input file should be reviewed. The process of running the model can then be repeated.

Note that the user should make an intelligent choice of output filename. If the output file is the same as another file in the assessment directory there may be cause for error. Output files will be overwritten during new runs of the model, so it is advisable to take copies of these.

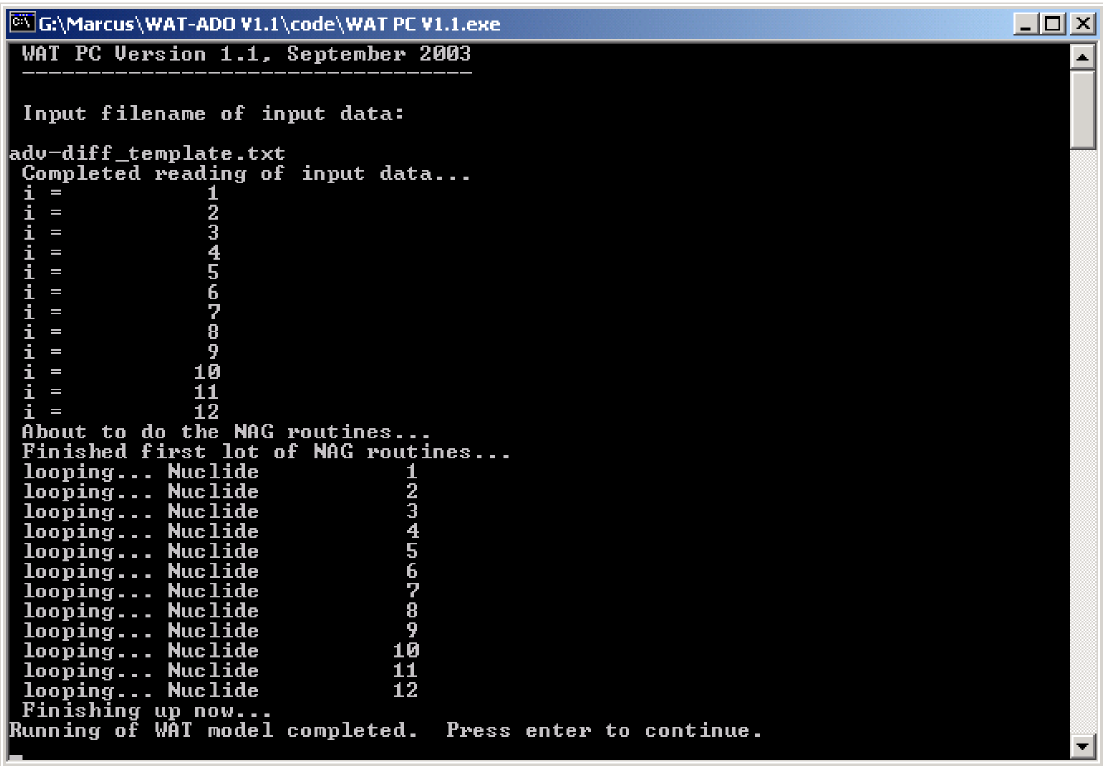
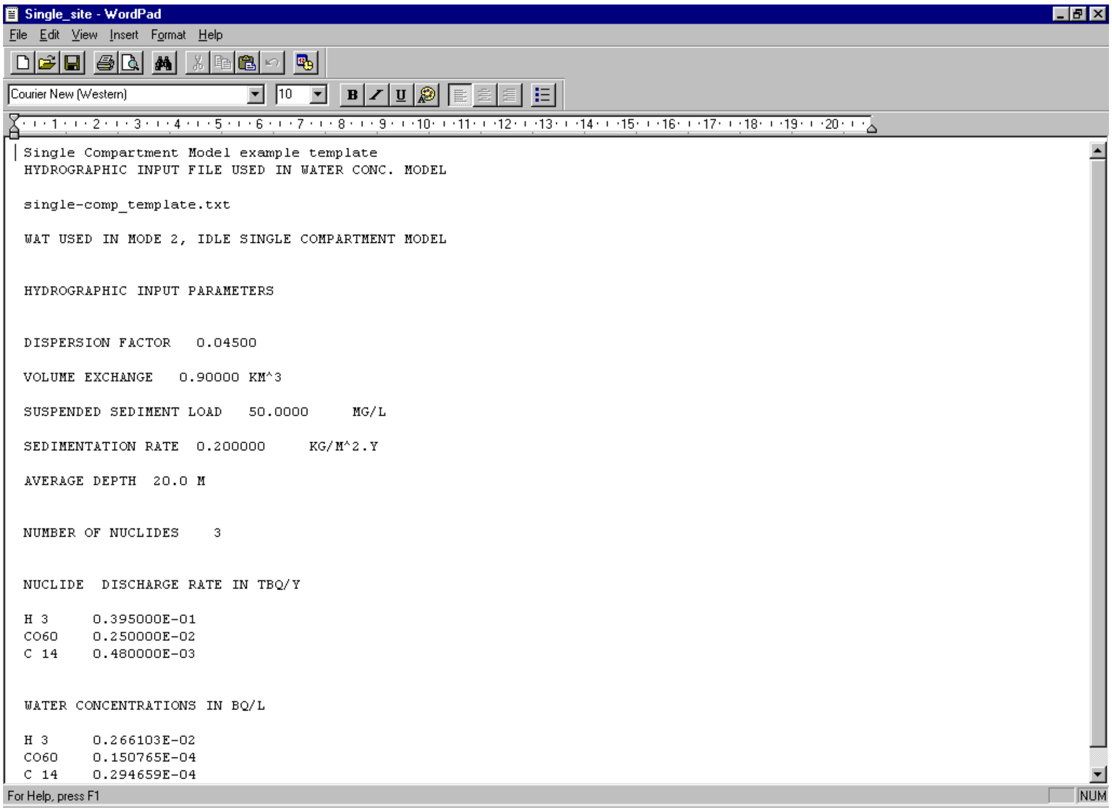


Figure 3 An example of the screen output from the running of the WAT advection-diffusion model.

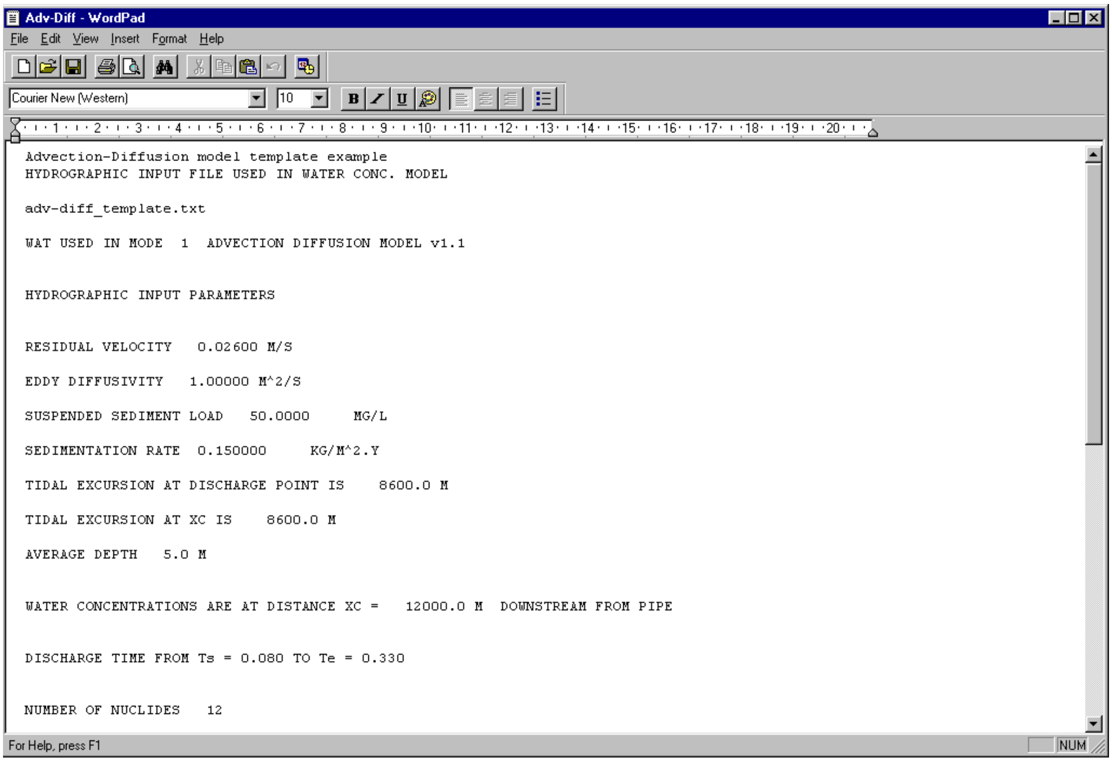
3.3 The Output From WAT

The output of the WAT program is a text file, the name of which is specified by the user in the second line of the input file (see Sections 3.1.2 and 3.2.2). This file should be opened with a text editor, such as *Notepad* or *Wordpad*, and an example is shown in Figures 4 and 5 for the single compartment and advection-diffusion models. In the output file each parameter input into the model is re-stated, as well as the calculated concentrations of each of the radionuclides discharged into the marine environment.

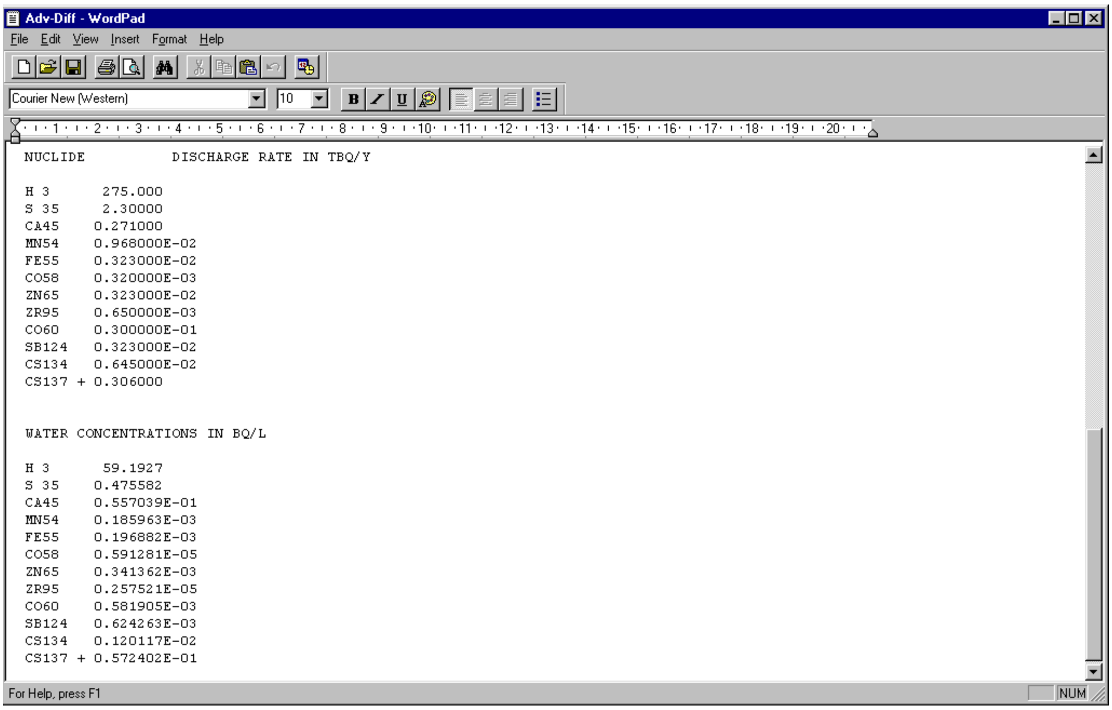



```
Single Compartment Model example template
HYDROGRAPHIC INPUT FILE USED IN WATER CONC. MODEL

single-comp_template.txt

WAT USED IN MODE 2, IDLE SINGLE COMPARTMENT MODEL


HYDROGRAPHIC INPUT PARAMETERS


DISPERSION FACTOR   0.04500

VOLUME EXCHANGE   0.90000 KM^3

SUSPENDED SEDIMENT LOAD   50.0000     MG/L

SEDIMENTATION RATE  0.200000     KG/M^2.Y

AVERAGE DEPTH   20.0 M


NUMBER OF NUCLIDES    3


NUCLIDE  DISCHARGE RATE  IN TBQ/Y

H 3      0.395000E-01
CO60     0.250000E-02
C 14     0.480000E-03


WATER CONCENTRATIONS  IN BQ/L

H 3      0.266103E-02
CO60     0.150765E-04
C 14     0.294659E-04
```

Figure 4 An example of the output file from the single compartment model.



```
Advection-Diffusion model template example
HYDROGRAPHIC INPUT FILE USED IN WATER CONC. MODEL

adv-diff_template.txt

WAT USED IN MODE  1  ADVECTION DIFFUSION MODEL v1.1


HYDROGRAPHIC INPUT PARAMETERS


RESIDUAL VELOCITY   0.02600 M/S

EDDY DIFFUSIVITY   1.00000 M^2/S

SUSPENDED SEDIMENT LOAD   50.0000     MG/L

SEDIMENTATION RATE  0.150000     KG/M^2.Y

TIDAL EXCURSION AT DISCHARGE POINT IS    8600.0 M

TIDAL EXCURSION AT XC IS    8600.0 M

AVERAGE DEPTH   5.0 M


WATER CONCENTRATIONS ARE AT DISTANCE XC =   12000.0 M  DOWNSTREAM FROM PIPE


DISCHARGE TIME FROM Ts = 0.080 TO Te = 0.330


NUMBER OF NUCLIDES   12
```



```
NUCLIDE          DISCHARGE RATE IN TBQ/Y

H 3       275.000
S 35       2.30000
CA45      0.271000
MN54      0.968000E-02
FE55      0.323000E-02
CO58      0.320000E-03
ZN65      0.323000E-02
ZR95      0.650000E-03
CO60      0.300000E-01
SB124     0.323000E-02
CS134     0.645000E-02
CS137 + 0.306000


WATER CONCENTRATIONS IN BQ/L

H 3       59.1927
S 35      0.475582
CA45      0.557039E-01
MN54      0.185963E-03
FE55      0.196882E-03
CO58      0.591281E-05
ZN65      0.341362E-03
ZR95      0.257521E-05
CO60      0.581905E-03
SB124     0.624263E-03
CS134     0.120117E-02
CS137 + 0.572402E-01
```

Figure 5 An example of the output file from the WAT advection-diffusion model.

4. Using the ADO Model

Important detailed information about the workings of the ADO model for dose assessment is given by Round (1998b). This model uses habits of critical group members to calculate a probable dose to the group. This is presented as an output file of doses (see Section 4.4). Various pathways are taken into account, including those due to radionuclide ingestion and exposure.

4.1 Habits Data

Data on consumption and occupancy of critical group members, as determined in habits surveys, are incorporated into the construction of this file. This is an important input into the ADO model.

The file containing information about these habits is assigned a name by the user. One example is the file *pathways.txt*, which is shown in Figure 6.

```
pathways - Notepad
File  Edit  Search  Help
Example Template - Adult Pathways File
8
FISH      20.6 1.0
CRUS       6.6 1.0
MOLL       5.6 1.0
EXMU    1137.0 1.0
BTMD    1137.0 1.0
DREB    1440.0 1.0
BOAT    1137.0 1.0
GEAR    1312.0 10.0
[End of file]
```

Figure 6 The file of pathways constructed from habits surveys.

4.1.1 Title

As with the WAT input file, a short text description of the file can be useful for future applications.

4.1.2 Number of pathways

This is an integer value referring to the number of exposure pathways that are to be considered. This will usually depend on the region being assessed and the relevant survey, and can have any value from 1 to 26.

4.1.3 Pathway and consumption/occupancy rate

The pathways and consumption rates are input here, with one line for each pathway considered. The list of possible pathways and their identifiers is shown in Table 1. The input takes the following format, with allowed number of spaces for characters shown in brackets:
Pathway identifier (4), *Habit rate* (10), *Modifying factor* (10)

Note that no extra spaces should be added, and the habit rate and modifying factor are real numbers of up to three decimal places.

Table 1 ADO pathway codes and brief descriptions.

Pathway	*Habits Units*	*Description of Pathway*	*Modifying Factor (=1 if not specified)*
FISH	kg y^{-1}	Generic fish consumption.	
CRUS	kg y^{-1}	Generic crustacean consumption.	
MOLL	kg y^{-1}	Generic mollusc consumption.	
WEED	kg y^{-1}	Consumption of generic seaweed.	
PLAK	kg y^{-1}	Consumption of plankton (zooplankton).	
SALT	kg y^{-1}	Consumption of sea salt.	
DESL	l y^{-1}	Consumption of desalinated water.	
PART	h y^{-1}	Inhalation of airborne fine coastal sedment due to coastal occupancy. Airborne sediment load is 100 µg m^{-3}.	
EVAP	h y^{-1}	Inhalation of seaspray. Vapour concentration 10 g m^{-3}.	
EXBE	h y^{-1}	External exposure over semi-infinite plane of beach sediments. Includes (beta) contribution from unclothed skin and gonads assuming even split of genders.	May be used if not semi-infinite plane. E.g. value of 0.1 appropriate for narrow strip or river bank.
EXBG	h y^{-1}	As EXBE but gamma exposure only, beta assumed to be shielded.	As for EXBE. Value of 0.4 recommended for houseboat hull shielding.
ISND	h y^{-1}	Inadvertent ingestion of beach sand for use with EXBE and EXBG.	Modifying factor is inadvertent ingestion rate (kg h^{-1}). 4.2E10^{-5} kg h^{-1} may be used as default (double for infants).
EXMU	h y^{-1}	External exposure over semi-infinite plane of fine sediments. Includes beta contribution from unclothed skin and gonads.	As for EXBE.
EXMG	h y^{-1}	As EXMU but only gamma exposure. Beta assumed shielded	As for EXMU & EXBG.
IMUD	h y^{-1}	Inadvertent ingestion of fine sediments for use with EXMU & EXMG.	As for ISND.
SWME	h y^{-1}	External exposure due to swimming. Includes beta contribution.	
SWMI	h y^{-1}	Inadvertent ingestion of seawater whilst swimming.	Modifying factor is inadvertent ingestion rate (l h^{-1}). Use rate of 0.01 l per swim as a guide.
BOAT	h y^{-1}	External exposure to gammas whilst on a boat. Hull shields beta.	
DREB	h y^{-1}	External exposure from operating a dredger. Includes beta contribution from clothed skin and gonads (male workers).	
DREG	h y^{-1}	As DREB for gamma only. Beta assumed shielded.	
WILD	h y^{-1}	External exposure to wildfowlers. Includes beta contribution from clothed skin and gonads (predominantly male critical group).	
ANGL	h y^{-1}	External exposure to sitting anglers in muddy estuaries. Includes beta contribution from clothed skin and gonads (male group).	
BTMD	h y^{-1}	External exposure to baitdiggers over mud. Includes beta from clothed skin and gonads (male group).	
BTSN	h y^{-1}	As BTMD but over sand.	
GEAR	h y^{-1}	External exposure from handling fishing gear. Contribution due to beta emitters included (male group).	For handling mud directly use modifying factor of 10. For handling sand directly use modifying factor of 1.
EXWD	h y^{-1}	External exposure from seaweed collection from sandy beaches. Includes beta contribution from clothed skin and gonads (assumes even split of genders).	

The Habit rate is measured in kg y^{-1} (or l y^{-1}) for consumption and h y^{-1} for occupancy. The dimensionless modifying factor allows for shielding of gamma radiation, modified geometry and inadvertent ingestion rates where appropriate. For more information, see Round (1998b).

4.2 ADO Input File Format

The ADO input file must be constructed to run the dose assessment. This includes filenames, parameter values and the answers to a number of questions. An example of the input file (*ADO-template*.txt) is shown in Figure 7. Each prompt and input file answer will show on the screen to enable further checking.

```
ADO-template - Notepad
File  Edit  Format  Help
1                         ! which group to target (1-9)
Adv-Diff.out              ! Enter the name of the water conc file (allow 40 char.)
pathways.txt              ! Pathways file (40 char.)
0.02                      ! Estuarine Sedimentation rate
n                         ! Change mud wet/dry ratio?
n                         ! Change sand wet/dry ratio?
doses.out                 ! Text output filename (40 char.)
y                         ! Excel dose output required?
doses_excel.txt           ! Name of excel dose output (40 char.)
y                         ! Excel nucdat file?
nucdat_excel.txt          ! Name (40 char.)
y                         ! Confac excel file?
confac_excel.txt          ! Name (40 char.)
```

Figure 7 The template for ADO input, *ADO-template.txt*.

4.2.1 Specification of target group

- **Which nuclear doses datafile is required (1-9)?**

This determines which file specific nuclear data is obtained from, and thus which members of the critical group are to be considered. For normal use, the dose to adults is considered, and so this option is answered with 1 for the example considered here. Otherwise, the user may select the appropriate number, as listed in the screen output of Figure 8.

4.2.2 Water concentration filename (40 characters or less)

- **Enter the water concentration filename.**

This is the output file from the WAT model. Either the advection-diffusion and single compartment models may be used, but in this case the example will follow the advection-diffusion example. Thus, the user types in *Adv-Diff.out*

4.2.3 Pathways data filename

- **Enter the pathways data filename.**

As described in Section 4.1, the pathways data file must be incorporated. Thus, the user could answer *pathways.txt* in the example case considered here.

4.2.4 Shoreline sedimentation rate (m y^{-1})

- **Enter the shoreline sedimentation rate.**

The shoreline (or estuarine) sedimentation rate must be entered as a real number in units of m y^{-1}. It refers to the rate that sediment settles in a particular estuary. In the case considered here it is assigned a value of *0.02*

4.2.5 Alteration of defaults for mud

- **Do you want to change the default values of the mud from dry to wet ratio of 0.6 and wet density of 1.66 (t m^{-3})?**

Answer *n* for 'no', to leave the default values. Otherwise, the user is given the option of changing these ratios by answering *y* for 'yes' and is required to input new values for mud wet/dry ratio and wet density on the next two input lines. Generally the default values are used for these parameters.

4.2.6 Alteration of defaults for sand

- **Do you want to change the default values of the sand from dry to wet ratio of 1.0 and wet density of 1.66 (t m^{-3})?**

As in the previous case, the possible answers are *n* (for 'no') and *y* (for 'yes'), and the user is required to enter new values in the case of the latter.

4.2.7 Output data file name

- **Enter OUTPUT data file name.**

Any filename can be chosen. For example, *doses.out*

4.2.8 Output for use in Microsoft Excel

- **Would you like the output as an Excel file (y or n)?**

If the answer is *y* the user is required to enter the Excel filename (format **.xls*), otherwise (*n*) the program continues. See Section 5 for instructions on opening Excel files created by the ADO model.

- **Would you like the nucdat data to be output as an Excel file (y or n)?**

See the previous question.

- **Would you like the confac data to be output as an Excel file (y or n)?**

See the previous question.

4.3 Running ADO

The following steps should be followed in the use of the ADO model:

1) The WAT model should have been previously run, and the output file produced. Construct the consumption/occupancy habits and ADO input text files by editing a renamed copy of the templates, as described in Sections 4.1 and 4.2.
2) Double click the *Ado PC V1.1.exe* icon.
4) When prompted, type in the name of the input file. This should include the file extension, e.g. *filename.txt*

The program should run (see Figure 8) and produce the specified output file (*doses.out* in the case of the template). A prompt should indicate successful running of the program. If further runs are conducted, the output file will be overwritten if the same name is still specified.

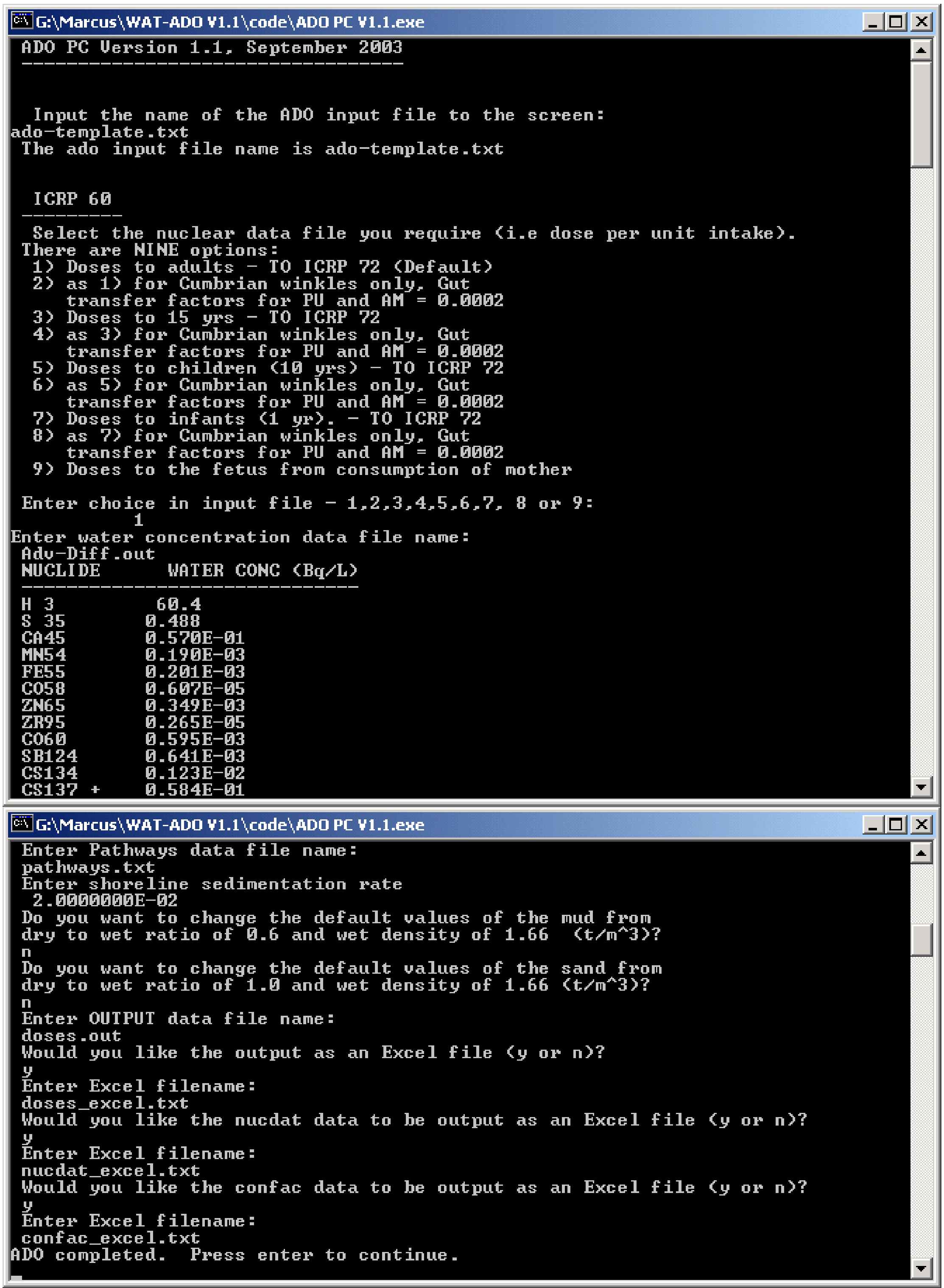
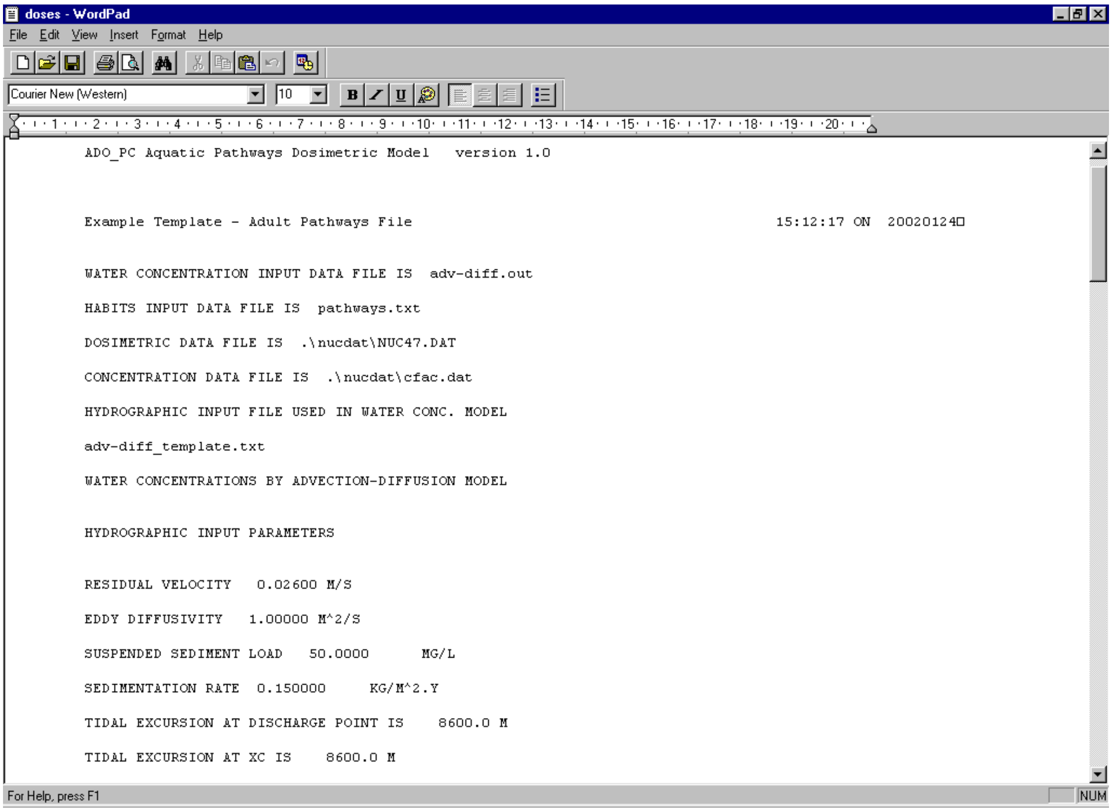


Figure 8 The screen output from running the ADO model.

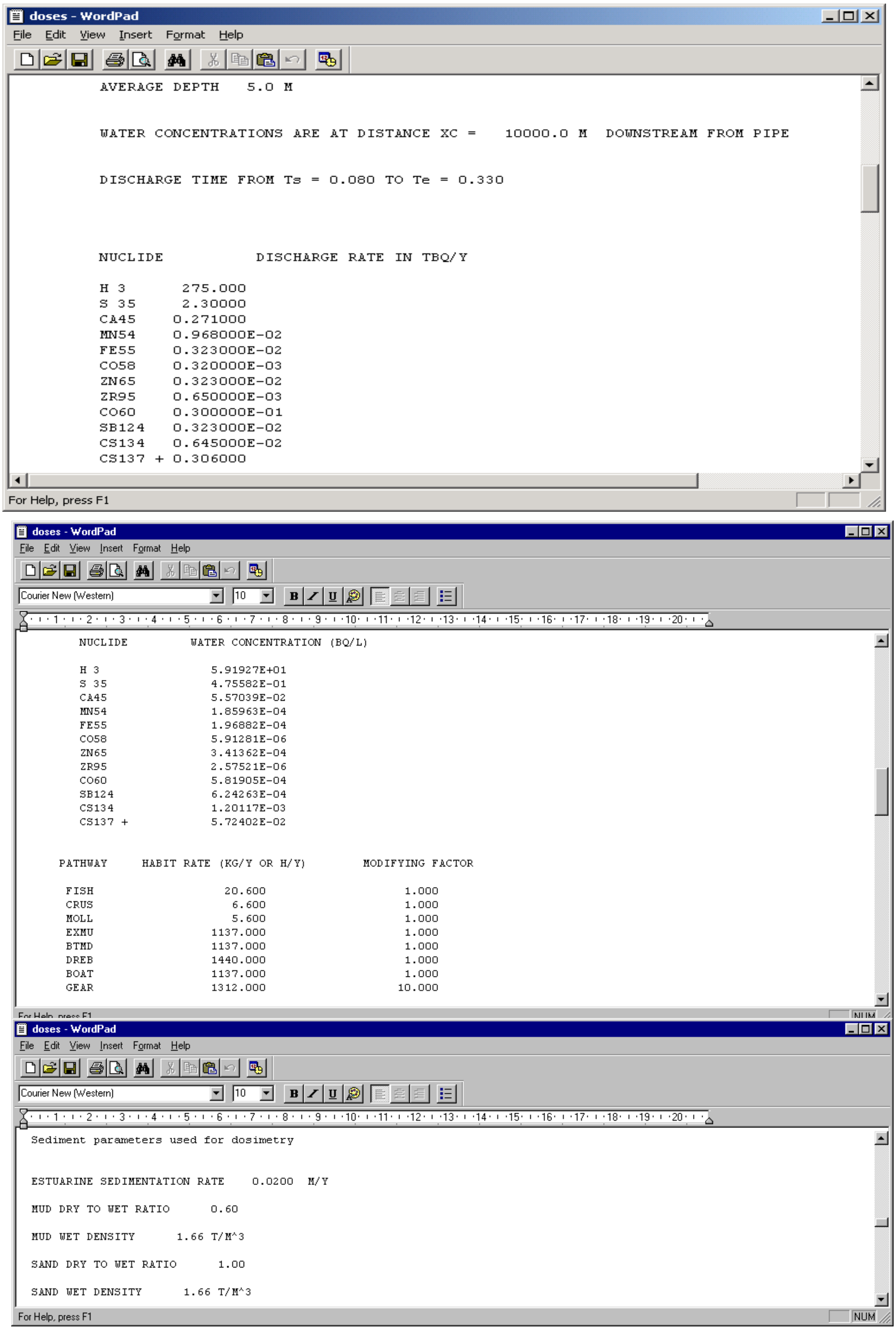
4.4 The ADO Output File

The running of the program produces a file of doses as shown in Figures 9, 10 and 11. For the example considered, this file has been called *doses.out*, and has been constructed using the advection-diffusion form of the WAT model. It is important that the ADO output file is thoroughly consulted by the user, as it shows if the input parameters have been read into the model in the intended manner. Also, if there are problems with running ADO the output file can help to pinpoint where the error may be occurring. As with the WAT output files, these files can be opened with *Wordpad* or *Notepad* text editors.



```
ADO_PC Aquatic Pathways Dosimetric Model   version 1.0


Example Template - Adult Pathways File                                     15:12:17 ON  20020124

WATER CONCENTRATION INPUT DATA FILE IS  adv-diff.out

HABITS INPUT DATA FILE IS  pathways.txt

DOSIMETRIC DATA FILE IS  .\nucdat\NUC47.DAT

CONCENTRATION DATA FILE IS  .\nucdat\cfac.dat

HYDROGRAPHIC INPUT FILE USED IN WATER CONC. MODEL

adv-diff_template.txt

WATER CONCENTRATIONS BY ADVECTION-DIFFUSION MODEL


HYDROGRAPHIC INPUT PARAMETERS


RESIDUAL VELOCITY   0.02600 M/S

EDDY DIFFUSIVITY   1.00000 M^2/S

SUSPENDED SEDIMENT LOAD   50.0000      MG/L

SEDIMENTATION RATE  0.150000     KG/M^2.Y

TIDAL EXCURSION AT DISCHARGE POINT IS    8600.0 M

TIDAL EXCURSION AT XC IS    8600.0 M
```

Figure 9 The first part of the *doses.out* output file from running the ADO model.



```
AVERAGE DEPTH   5.0 M

WATER CONCENTRATIONS ARE AT DISTANCE XC =   10000.0 M  DOWNSTREAM FROM PIPE

DISCHARGE TIME FROM Ts = 0.080 TO Te = 0.330


NUCLIDE           DISCHARGE RATE IN TBQ/Y

H 3        275.000
S 35       2.30000
CA45      0.271000
MN54      0.968000E-02
FE55      0.323000E-02
CO58      0.320000E-03
ZN65      0.323000E-02
ZR95      0.650000E-03
CO60      0.300000E-01
SB124     0.323000E-02
CS134     0.645000E-02
CS137 +   0.306000
```

```
NUCLIDE           WATER CONCENTRATION (BQ/L)

H 3                  5.91927E+01
S 35                 4.75582E-01
CA45                 5.57039E-02
MN54                 1.85963E-04
FE55                 1.96882E-04
CO58                 5.91281E-06
ZN65                 3.41362E-04
ZR95                 2.57521E-06
CO60                 5.81905E-04
SB124                6.24263E-04
CS134                1.20117E-03
CS137 +              5.72402E-02


PATHWAY      HABIT RATE (KG/Y OR H/Y)        MODIFYING FACTOR

FISH                  20.600                    1.000
CRUS                   6.600                    1.000
MOLL                   5.600                    1.000
EXMU                1137.000                    1.000
BTMD                1137.000                    1.000
DREB                1440.000                    1.000
BOAT                1137.000                    1.000
GEAR                1312.000                   10.000
```

```
Sediment parameters used for dosimetry


ESTUARINE SEDIMENTATION RATE    0.0200  M/Y

MUD DRY TO WET RATIO       0.60

MUD WET DENSITY       1.66 T/M^3

SAND DRY TO WET RATIO       1.00

SAND WET DENSITY       1.66 T/M^3
```

Figure 10 The second part of the *doses.out* output file from running the ADO model.

Nuclear data used in run

NUCLIDE	INGESTION SKIN	INGESTION EFFECTIVE	INHALATION SKIN	INHALATION EFFECTIVE	HALF LIFE	MEAN BETA	MEAN GAMMA
H 3	4.10E-11	4.20E-11	2.10E-12	4.50E-11	4.511E+03	5.683E-03	0.000E+00
S 35	7.60E-10	7.70E-10	0.00E+00	1.40E-09	8.744E+01	4.884E-02	0.000E+00
CA45	0.00E+00	7.10E-10	1.20E-11	2.70E-09	1.630E+02	7.720E-02	0.000E+00
MN54	0.00E+00	7.10E-10	0.00E+00	1.50E-09	3.125E+02	4.220E-03	8.364E-01
FE55	8.60E-11	3.30E-10	9.50E-11	3.80E-10	9.862E+02	4.201E-03	1.691E-03
CO58	1.30E-10	7.40E-10	2.50E-10	1.60E-09	7.079E+01	3.413E-02	9.976E-01
ZN65	2.40E-09	3.90E-09	6.30E-10	1.60E-09	2.435E+02	6.870E-03	5.845E-01
ZR95	6.30E-11	9.50E-10	3.90E-10	4.80E-09	6.399E+01	1.117E-01	7.390E-01
CO60	1.30E-09	3.40E-09	2.40E-09	1.00E-08	1.925E+03	9.656E-02	2.500E+00
SB124	2.20E-10	2.50E-09	3.90E-10	6.40E-09	6.020E+01	3.867E-01	1.819E+00
CS134	1.30E-08	1.90E-08	4.40E-09	6.60E-09	7.531E+02	1.634E-01	1.550E+00
CS137+	1.10E-08	1.30E-08	3.60E-09	4.60E-09	1.096E+04	2.486E-01	5.651E-01

Concentration factors used in run

EL.	FISH	CRUS	MOLL	WEED	PLAK	SALT	DESL	EVAP	SAND	MUD
H	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E-01	1.0E+00
S	2.0E+00	1.0E+00	4.0E+00	4.0E+00	1.0E+00	3.0E+01	1.0E-03	0.0E+00	5.0E-02	5.0E-01
CA	2.0E+00	5.0E+00	1.0E+00	6.0E+00	1.0E+01	3.0E+01	1.0E-03	0.0E+00	5.0E+01	5.0E+02
MN	4.0E+02	5.0E+02	5.0E+03	6.0E+03	1.0E+03	3.0E+01	1.0E-03	0.0E+00	2.0E+04	2.0E+05
FE	3.0E+03	5.0E+03	3.0E+04	3.0E+04	1.0E+04	3.0E+01	1.0E-03	0.0E+00	5.0E+03	5.0E+04
CO	1.0E+03	5.0E+03	5.0E+03	1.0E+04	2.0E+03	3.0E+01	1.0E-03	3.0E-02	2.0E+04	2.0E+05
ZN	1.0E+03	5.0E+04	3.0E+04	2.0E+04	2.0E+04	3.0E+01	1.0E-03	0.0E+00	2.0E+03	2.0E+04
ZR	2.0E+01	2.0E+02	5.0E+03	3.0E+03	2.0E+04	3.0E+01	1.0E-03	3.0E-02	1.0E+05	1.0E+06
CO	1.0E+03	5.0E+03	5.0E+03	1.0E+04	2.0E+03	3.0E+01	1.0E-03	3.0E-02	2.0E+04	2.0E+05
SB	4.0E+02	4.0E+02	2.0E+02	4.0E+02	6.0E+01	3.0E+01	1.0E-03	0.0E+00	1.0E+02	1.0E+03
CS	1.0E+02	3.0E+01	3.0E+01	5.0E+01	3.0E+01	3.0E+01	1.0E-03	3.0E-02	3.0E+02	3.0E+03

Effective Dose (uSv/y)

	TOTAL	FISH	CRUS	MOLL	EXMU	BTMD	DREB	BOAT	GEAR
H 3	8.15E-02	5.12E-02	1.64E-02	1.39E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S 35	2.57E-02	1.51E-02	2.42E-03	8.20E-03	1.60E-06	8.01E-07	1.01E-06	0.00E+00	3.95E-06
CA45	6.63E-03	1.63E-03	1.31E-03	2.21E-04	1.25E-03	6.46E-04	8.18E-04	0.00E+00	7.54E-04
MN54	6.41E+00	1.09E-03	4.36E-04	3.70E-03	1.43E+00	1.43E+00	3.00E+00	4.76E-04	5.47E-01
FE55	2.18E-02	4.02E-03	2.14E-03	1.09E-02	1.41E-03	1.41E-03	1.61E-03	3.24E-07	2.93E-04
CO58	1.73E-01	9.01E-05	1.44E-04	1.23E-04	1.88E-02	1.88E-02	1.14E-01	1.81E-05	2.08E-02
ZN65	1.46E+00	2.74E-02	4.39E-01	2.24E-01	1.55E-01	1.55E-01	3.85E-01	1.11E-04	7.02E-02
ZR95	2.74E-01	1.01E-06	3.23E-06	6.85E-05	2.84E-02	2.83E-02	1.84E-01	2.70E-05	3.36E-02
CO60	9.85E+01	4.08E-02	6.53E-02	5.54E-02	3.26E+01	3.26E+01	2.81E+01	4.45E-03	5.12E+00
SB124	1.82E-01	1.29E-02	4.12E-03	1.75E-03	1.64E-02	1.64E-02	1.10E-01	3.32E-04	2.00E-02
CS134	1.54E+00	4.70E-02	4.52E-03	3.83E-03	4.22E-01	4.22E-01	5.40E-01	5.96E-04	9.85E-02
CS137 +	4.47E+01	1.53E+00	1.47E-01	1.25E-01	1.59E+01	1.59E+01	9.44E+00	1.04E-02	1.73E+00
TOTALS	1.53E+02	1.73E+00	6.83E-01	4.47E-01	5.05E+01	5.05E+01	4.19E+01	1.64E-02	7.64E+00

Maximum Dose to 1cm**2 of Skin(uSv/y)

	TOTAL	FISH	CRUS	MOLL	EXMU	BTMD	DREB	BOAT	GEAR
H 3	7.96E-02	5.00E-02	1.60E-02	1.36E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S 35	2.67E-02	1.49E-02	2.39E-03	8.10E-03	1.60E-04	1.60E-04	2.03E-04	0.00E+00	7.90E-04
CA45	5.55E-01	0.00E+00	0.00E+00	0.00E+00	1.25E-01	1.25E-01	1.59E-01	0.00E+00	1.46E-01
MN54	6.78E+00	0.00E+00	0.00E+00	0.00E+00	1.51E+00	1.51E+00	3.18E+00	5.04E-04	5.80E-01
FE55	9.45E-03	1.05E-03	5.59E-04	2.84E-03	1.49E-03	1.49E-03	1.70E-03	3.43E-07	3.10E-04
CO58	1.85E-01	1.58E-05	2.54E-05	2.15E-05	2.00E-02	2.00E-02	1.21E-01	1.91E-05	2.47E-02
ZN65	1.24E+00	1.69E-02	2.70E-01	1.38E-01	1.65E-01	1.65E-01	4.08E-01	1.18E-04	7.43E-02
ZR95	4.03E-01	6.68E-08	2.14E-07	4.54E-06	5.84E-02	5.84E-02	2.31E-01	2.86E-05	5.50E-02
CO60	1.08E+02	1.56E-02	2.50E-02	2.12E-02	3.54E+01	3.54E+01	3.09E+01	4.72E-03	6.18E+00
SB124	3.17E-01	1.13E-03	3.63E-04	1.54E-04	5.94E-02	5.94E-02	1.70E-01	3.51E-04	2.66E-02
CS134	1.90E+00	3.22E-02	3.09E-03	2.62E-03	5.25E-01	5.25E-01	6.71E-01	6.31E-04	1.44E-01
CS137 +	7.19E+01	1.30E+00	1.25E-01	1.06E-01	2.36E+01	2.36E+01	1.85E+01	1.10E-02	4.71E+00
TOTALS	1.91E+02	1.43E+00	4.42E-01	2.92E-01	6.14E+01	6.14E+01	5.44E+01	1.73E-02	1.19E+01

Dose to Lens of Eye(uSv/y)

	TOTAL	FISH	CRUS	MOLL	EXMU	BTMD	DREB	BOAT	GEAR
H 3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S 35	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CA45	8.65E-23	0.00E+00	0.00E+00	0.00E+00	1.96E-23	1.96E-23	2.48E-23	0.00E+00	2.26E-23
MN54	9.80E+00	0.00E+00	0.00E+00	0.00E+00	2.18E+00	2.18E+00	4.59E+00	7.28E-04	8.37E-01
FE55	7.22E-03	0.00E+00	0.00E+00	0.00E+00	2.16E-03	2.16E-03	2.46E-03	4.96E-07	4.48E-04
CO58	2.64E-01	0.00E+00	0.00E+00	0.00E+00	2.88E-02	2.88E-02	1.74E-01	2.76E-05	3.17E-02
ZN65	1.17E+00	0.00E+00	0.00E+00	0.00E+00	2.38E-01	2.38E-01	5.89E-01	1.70E-04	1.07E-01
ZR95	4.18E-01	0.00E+00	0.00E+00	0.00E+00	4.30E-02	4.30E-02	2.81E-01	4.13E-05	5.12E-02
CO60	1.50E+02	0.00E+00	0.00E+00	0.00E+00	4.98E+01	4.98E+01	4.30E+01	6.81E-03	7.83E+00
SB124	2.50E-01	0.00E+00	0.00E+00	0.00E+00	2.49E-02	2.49E-02	1.68E-01	5.08E-04	3.11E-02
CS134	2.27E+00	0.00E+00	0.00E+00	0.00E+00	6.45E-01	6.45E-01	8.25E-01	9.11E-04	1.50E-01
CS137 +	6.53E+01	0.00E+00	0.00E+00	0.00E+00	2.42E+01	2.42E+01	1.43E+01	1.58E-02	2.61E+00
TOTALS	2.30E+02	0.00E+00	0.00E+00	0.00E+00	7.71E+01	7.71E+01	6.39E+01	2.50E-02	1.17E+01

END OF RUN

Figure 11 The final part of the *doses.out* file for output from the ADO model.

5. Excel Outputs

The ADO model has the capacity to output various files that may be opened using Microsoft Excel. These have been formatted so that they may be opened following the procedure set out in this section.

5.1 Creation of the Files

The Excel files are created by answering *y* to any of the three questions of Section 4.2.8. In the template file all three are created, with the names:

- *doses_excel.txt* – The doses file
- *nucdat_excel.txt* – The nuclear data file
- *confac_excel.txt* – The concentration factors file

Note that each of these is actually a text file, but will be copied into an Excel file in the following sections. The procedure for opening each of these three files is identical, so only the first of these (*doses_excel.txt*) will be described here.

5.2 Opening ADO Excel Files

A step-by-step description of the file opening and handling now follows:

1) Open a new (blank) sheet in Microsoft Excel.

2) Click on the “Open” tab to open a new file. Navigate to the directory containing the assessment and change the “Files of type:” tab so that it reads “All Files”. Select *doses_excel.txt* and click “Open” (see Figure 12).

3) The Text Import Wizard should then present the screen shown in Figure 13. This enables the user to specify the format of the input text file. In this case the data is “Delimited”. Check this box and press “Next”.

4) In Step 2 of the Text Import Wizard only two boxes should be ticked. These are marked “Comma” (the delimiter type) and “Treat consecutive delimiters as one” (see Figure 14). Press “Next” to continue.

5) No changes need to be made at Step 3 of the Import Wizard, so the “Finish” button should be pressed (Figure 15).

6) The Excel file shown in Figure 16 is the result of the previous 5 steps. This should be saved to a new Excel filename (rather than a text file) for future use.

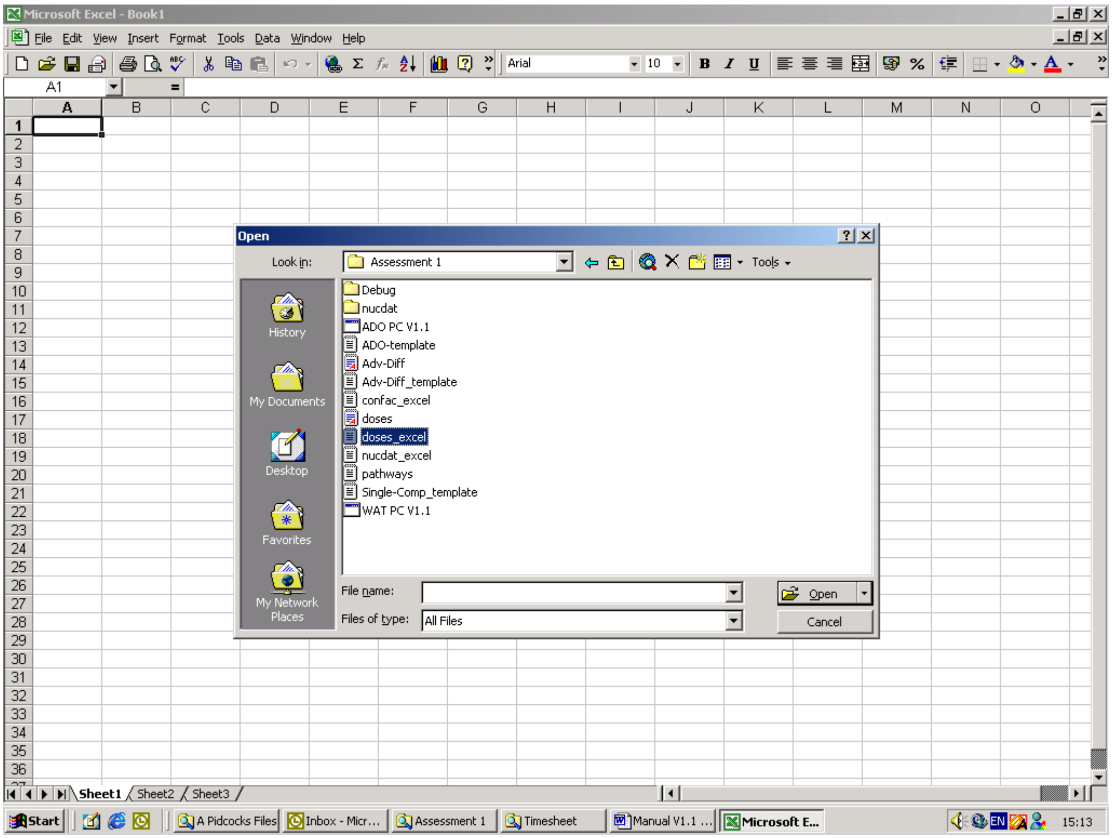


Figure 12 Opening the file *doses_excel.txt* in Excel (Step 2).

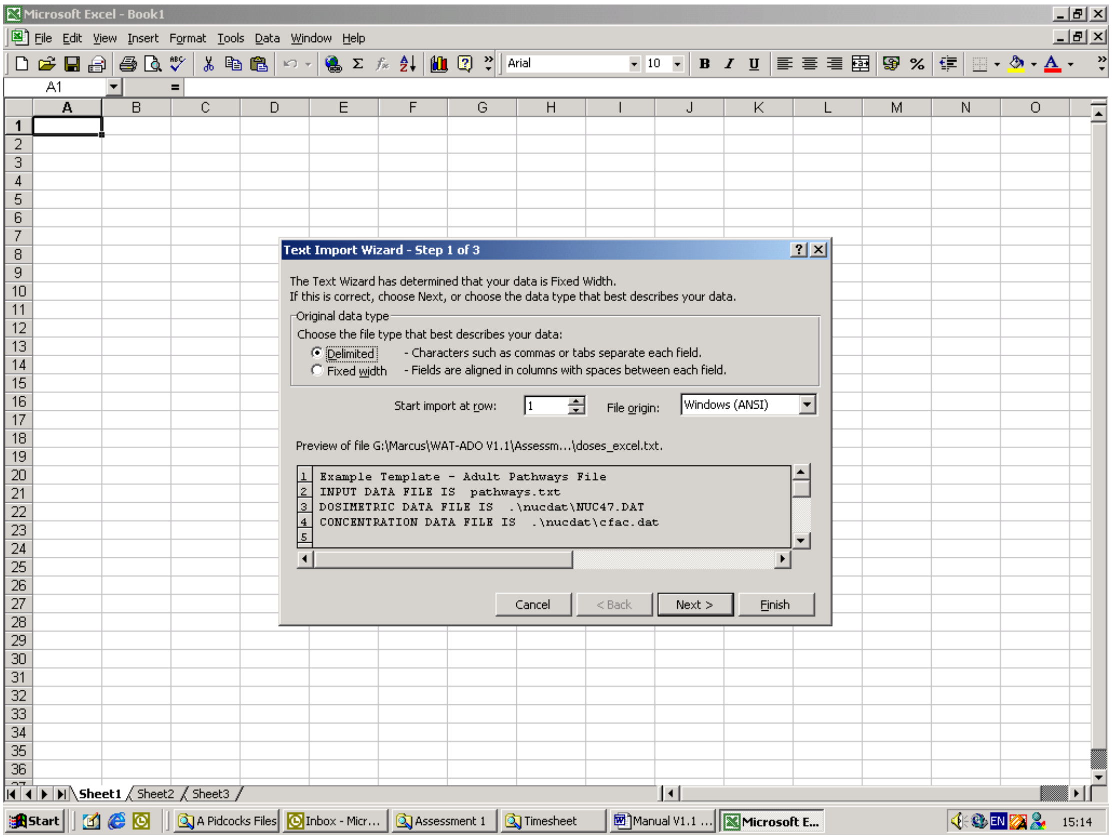


Figure 13 Specifying the format of the input text file (Step 3).

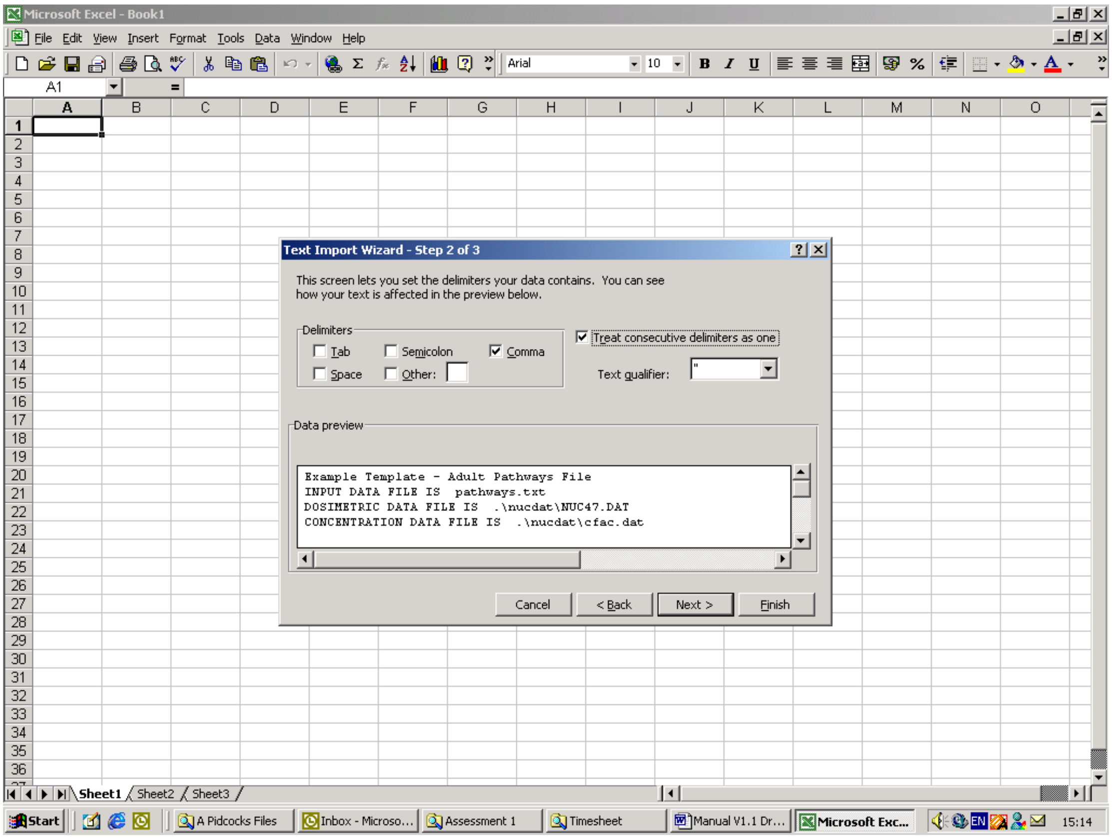


Figure 14 Further specification of the text file using the Text import Wizard (Step 4).

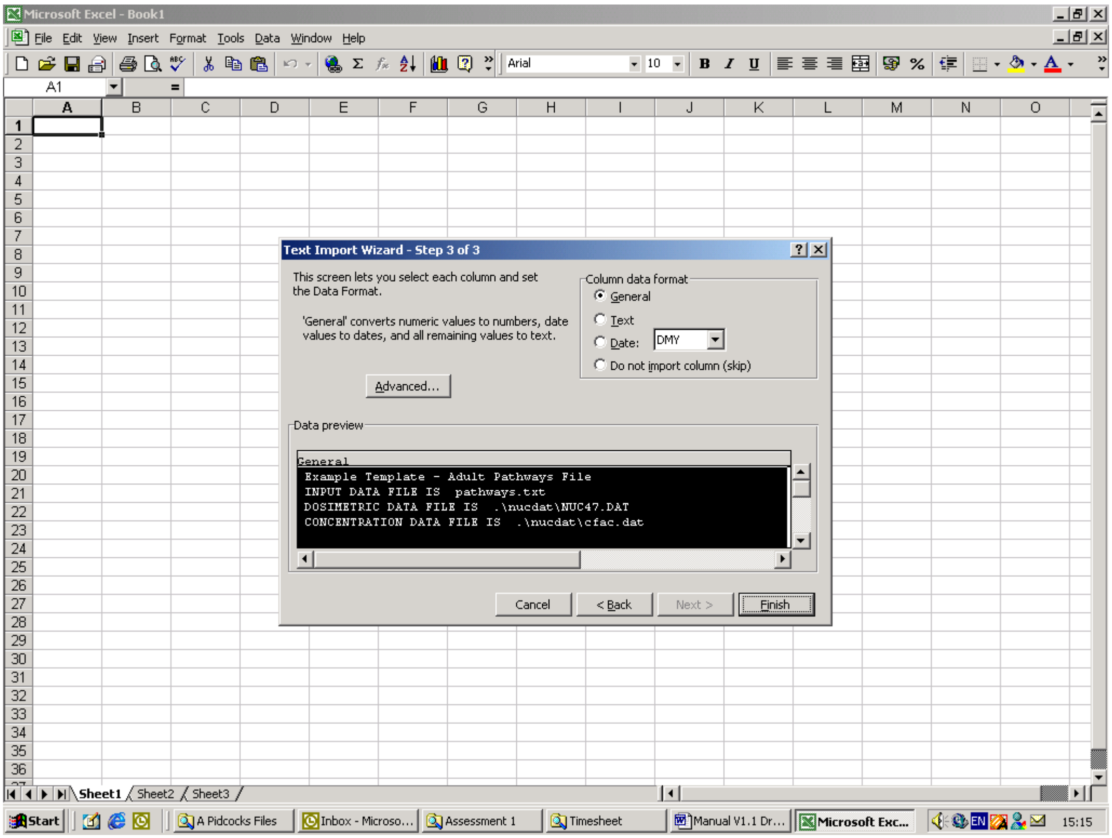
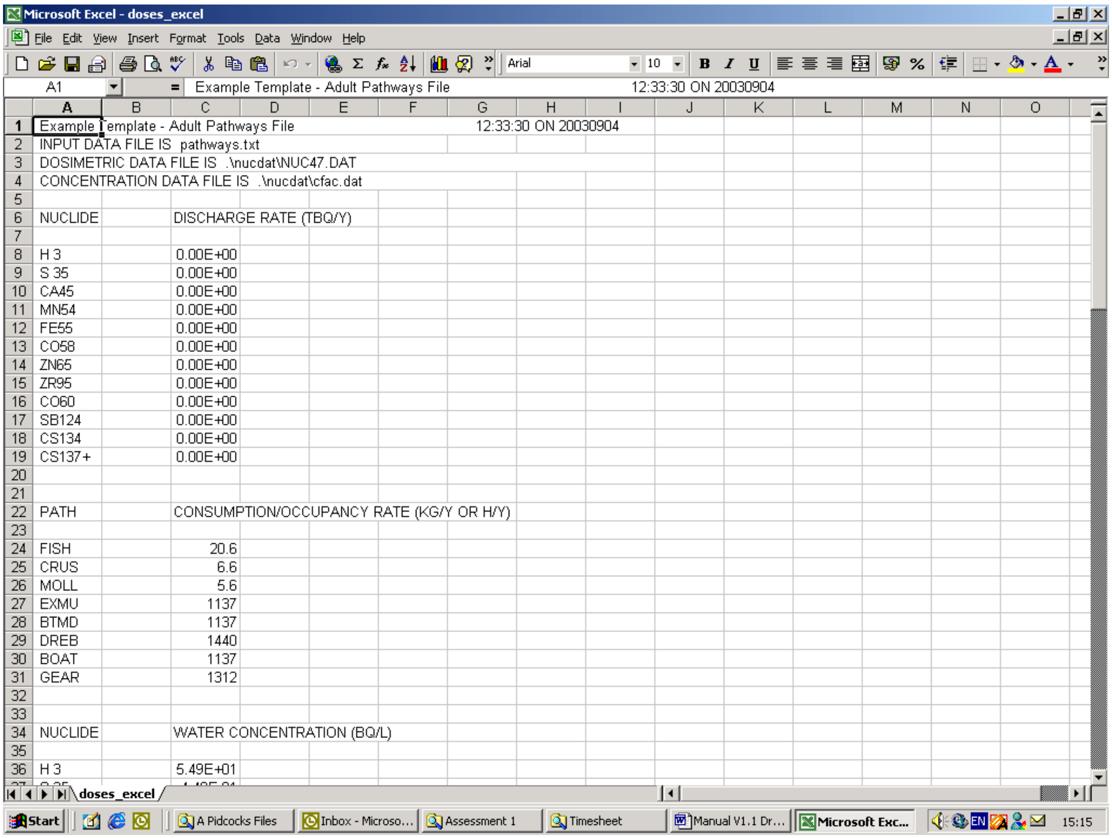


Figure 15 The third and final step of the Text Import Wizard (Step 5).



	A	B	C	G
1	Example Template - Adult Pathways File			12:33:30 ON 20030904
2	INPUT DATA FILE IS pathways.txt			
3	DOSIMETRIC DATA FILE IS .\nucdat\NUC47.DAT			
4	CONCENTRATION DATA FILE IS .\nucdat\cfac.dat			
5				
6	NUCLIDE		DISCHARGE RATE (TBQ/Y)	
7				
8	H 3		0.00E+00	
9	S 35		0.00E+00	
10	CA45		0.00E+00	
11	MN54		0.00E+00	
12	FE55		0.00E+00	
13	CO58		0.00E+00	
14	ZN65		0.00E+00	
15	ZR95		0.00E+00	
16	CO60		0.00E+00	
17	SB124		0.00E+00	
18	CS134		0.00E+00	
19	CS137+		0.00E+00	
20				
21				
22	PATH		CONSUMPTION/OCCUPANCY RATE (KG/Y OR H/Y)	
23				
24	FISH		20.6	
25	CRUS		6.6	
26	MOLL		5.6	
27	EXMU		1137	
28	BTMD		1137	
29	DREB		1440	
30	BOAT		1137	
31	GEAR		1312	
32				
33				
34	NUCLIDE		WATER CONCENTRATION (BQ/L)	
35				
36	H 3		5.49E+01	

Figure 16 The file *doses_excel.txt* after it has been imported into Excel. This should be saved as a **.xls* file (Step 6).

6. Conclusions

The PC version 1.1 of the WAT and ADO models has been tested and is available for use in regular assessments. Installation is expected to be possible on a range of computers and it is hoped, with the help of this manual and further training, these versions may be put to use immediately.

It is intended that the WAT and ADO programs and manual will be continually updated as new developments in the modelling system are produced. As a part of this the inclusion of river models and a graphical user interface are high on the list of priorities for use in the regular assessment of radiological discharges into the marine environment.

7. References

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