HEWRAT v2.0 Help Guide

Contents

1. Overview of the Tool

1.1 Purpose

The purpose of the Highways England Water Risk Assessment Tool (HEWRAT)[1] is to help highway designers decide whether or not pollution mitigation measures are needed in specific circumstances.

1.2 Core Features

The tool has certain core features:

- It requires relatively little site specific data to make an assessment;
- It incorporates a tiered consequential approach to assessment whereby unnecessary work is avoided if the impact can be shown to be low;
- It uses a 'traffic light' reporting method whereby:
  - **Red** indicates an unacceptable impact, or signals the need for a more detailed assessment using the guidance given in DMRB 11.3.10 (Highways England, 2016);
  - **Green** indicates no marked impact with no need for any further investigation; and
  - **Amber** indicates no marked sediment impact, but the proximity of a conservation site or downstream structure may cause a problem and requires further investigation, or that the sediment result is close to the threshold for failure.
- The underlying algorithms for assessing pollutant impacts are based on the latest detailed research and data collection carried out by the Highways Agency on runoff quality from non-urban highways under a wide range of traffic and weather conditions (Dempsey *et al*, 2007, Crabtree *et al*, 2007).
- Similarly, the tool uses ecological research to evaluate whether predicted impacts are acceptable or not (Johnson *et al*, 2007, Gaskell *et al*, 2007).

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[1] Previously the Highways Agency Water Risk Assessment Tool (HAWRAT). HEWRAT v2.0 replaces HAWRAT v1.0 for general release.

1.3 Pollutants

The assessment tool deals with the following pollutants:

Soluble pollutants associated with acute pollution impacts: Expressed as Event Mean Concentrations (EMCs in µg/l) for dissolved copper and zinc;

Soluble pollutants associated with Environmental Quality Standards (EQS): Expressed as Annual Average Concentrations (AACs in µg/l) for dissolved copper and zinc; and

Sediment related pollutants associated with chronic pollution impacts: Expressed as Event Mean Sediment Concentrations (EMSCs in mg/kg) for total copper, zinc, cadmium, and (in µg/kg) for pyrene, fluoranthene, anthracene, phenanthrene and total PAH (Polycyclic Aromatic Hydrocarbons).

1.4 Runoff pollution models

The assessment tool uses statistically-based models for predicting the runoff quality for each pollutant. These models were developed by WRc (Crabtree *et al*, 2007) based on data collected during the "Improved Determination of Pollutants in Highway Runoff Phase 2 project" (Dempsey *et al*, 2007) and the "Long term monitoring of pollution from highway runoff" (Moy *et al*, 2002).

The models use traffic density, climatic region and event rainfall characteristics to predict runoff quality in terms of EMCs and EMSCs. Using long term rainfall event data the models generate distributions of runoff quality that reflect the likely distributions of runoff quality that could be observed in practice.

1.5 Impact models

The assessment tool also incorporates models for predicting the impact of the runoff on receiving rivers and streams. For the soluble pollutants that cause acute impact this involves a simple mass balance approach taking account of river flows.

For the sediment related pollutants that cause chronic impact, the impact models consider both the likelihood and extent of sediment accumulation based broadly on the chronic impact assessment procedure developed by University of Sheffield (Gaskell *et al*, 2007).

1.6 Threshold analysis

The assessment tool incorporates a number of ecologically-based pollutant thresholds. The tool compares the predicted impacts with these thresholds to evaluate toxicity risks (Johnson *et al*, 2007, Gaskell *et al*, 2007).

For the sediment related pollutants that cause chronic impact, the impact models include additional thresholds to judge the likelihood of sediment accumulation and whether the extent of accumulation is excessive.

For Annual Average Pollution Concentrations, the threshold limits used are the EQS limits set by the Environment Agency.

1.7 Limitations

The runoff pollution model incorporated in the tool was developed based on a sample dataset of 24 rural highway sites across England with traffic density ranges from 11,000 – 159,000 vehicles/day (vpd) (Moy *et al*, 2002, Crabtree *et al*, 2007). For the impact models, non–tidal flow is simulated by the tool for the receiving watercourses for each rainfall event. Consequently, the tool may not be applicable in the following scenarios:

- urban highways;
- highways with traffic densities outside the 11,000 - 159,000 vpd range; and
- highways discharging to receiving watercourse that are tidal and/or saline.

The tool can be used for highways with traffic density less than 11,000 vpd but the result may be over conservative.

The tool can be applied in Wales, Scotland and Northern Ireland, but it should be remembered that the basic data was generated in England.

The tool is also limited in its ability to assess the impact on streams where the flow is intermittent or seasonal. Advice for these situations is given in DMRB 11.3.10.

1.8 Software

The assessment tool is an Excel application originally developed in Microsoft Excel 2003 under Windows XP. It has been updated for compatibility with Excel 2007 and 2010, this development having been under Windows 7. The tool incorporates Visual Basic code to manage the user interface, perform a prediction and execute the other commands of the HEWRAT menu, popup menus and command buttons. In order to allow the code to perform, macros must be enabled when the tool is opened.

2. First Time User

A first time user needs to note the following points and bear these in mind in the subsequent use of the tool.

- The macros in the tool must be enabled when the tool is first opened up to allow the code to perform. For more help on how to enable macros, please click here.
- The user should choose an appropriate accessibility level when logging into the tool to pick up the associated rights in using the tool.
- Once the tool is opened up, ALL Excel workbooks that are already open will NOT automatically recalculate, click here for more information and what to do.
- Saving the workbook using Excel's File→Save DOES NOT save the current results, because the workbook is reset to default values on being opened. To save results the user must use the Save Results & Parameters option on the HEWRAT menu or popup menu, or the <Save Results & Parameters> button on the Interface worksheet.
- To exit the tool the user must use either the 'Exit Tool' option on the HEWRAT menu or popup menu, or the <Exit Tool> button on the Interface worksheet.

3. Structure of the Tool

The Excel workbook comprises a number of worksheets and associated code.

3.1 Worksheets

A brief description of the worksheets is given below:

Sheet Name	Purpose	Accessibility
Interface	The Interface worksheet is the main 'window' to the tool where the User can enter data, request a prediction and see the 'headline' results.	User
Detailed Results	The Detailed Results worksheet provides more detail about the predictions for a given simulation.	User
User Parameters	The User parameters worksheet records all the User-entered parameters for a particular outfall/site.	User
Assessment Parameters	The Assessment Parameters worksheet holds the various fixed parameters used in the risk assessment models – such as the thresholds. The sheet also holds the default values and allowable ranges for the User parameters.	User (View only) Administrator (Edit)
Spillage Risk	The Spillage Risk assessment worksheet allows the user to input information on road type, location, traffic flow and various other factors in order to assess the amount of risk from accidental spillage.	User
Groundwater Assessment	The Groundwater Assessment worksheet allows the user to undertake a high-level assessment of the risk of run-off to groundwater.	User
Rain Table	The Rain Table worksheet provides a summary of the location and statistics for each of the rainfall series available within the tool.	Administrator
Rain1, Rain2, etc.	There is a separate worksheet for each of the rainfall series. Each series is a chronological list of rainfall events together with associated river flows for a unit area of river catchment.	Administrator
ModelSheet and other calculation sheets	The ModelSheet worksheet contains the **core models** for predicting concentrations in highway runoff. Predictions are made for each rainfall event. Other worksheets are used to support the model calculations and to process the results for comparison with the thresholds.	Developer

3.2 Code

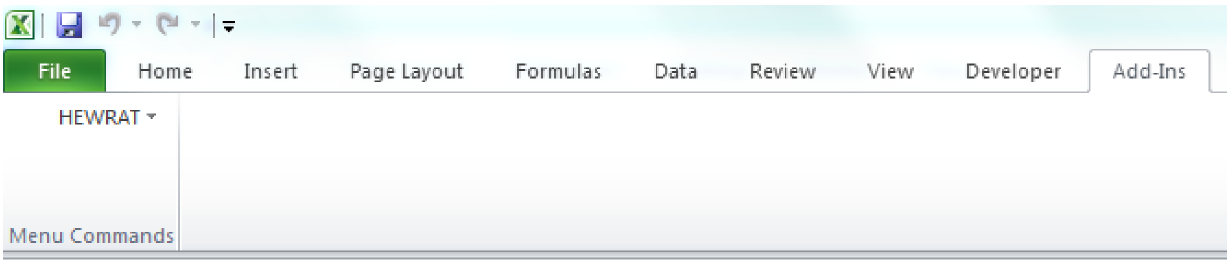
The Visual Basic code incorporated in the tool is used to run a prediction, manage the user interface and execute the commands of the HEWRAT menu, popup menus and command buttons. The code is only visible to developers.

3.3 Accessing worksheets and functionality

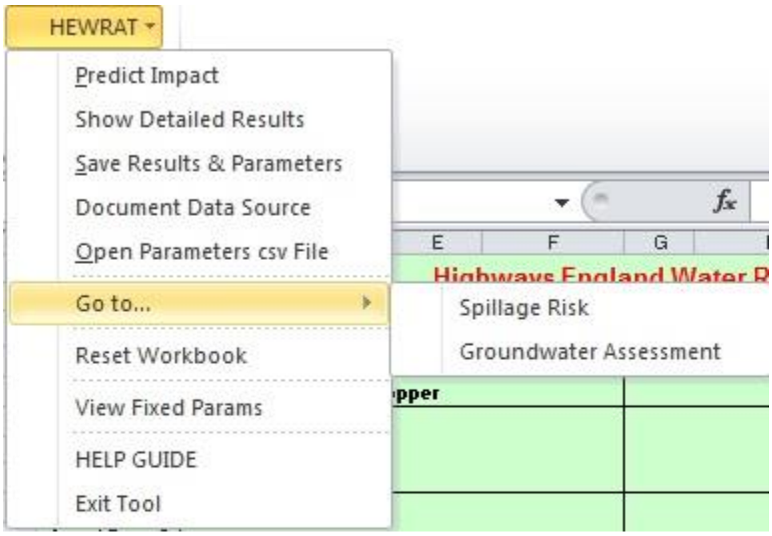
The tool opens with the Interface worksheet displayed. During use, only the active worksheet is visible. Moving between worksheets and accessing other functionality is enabled by the HEWRAT Menu, located on the Excel 'Add-Ins' ribbon (Excel 2007-2010); popup menus on individual worksheets; and command buttons on individual worksheets.

3.4 HEWRAT Menu

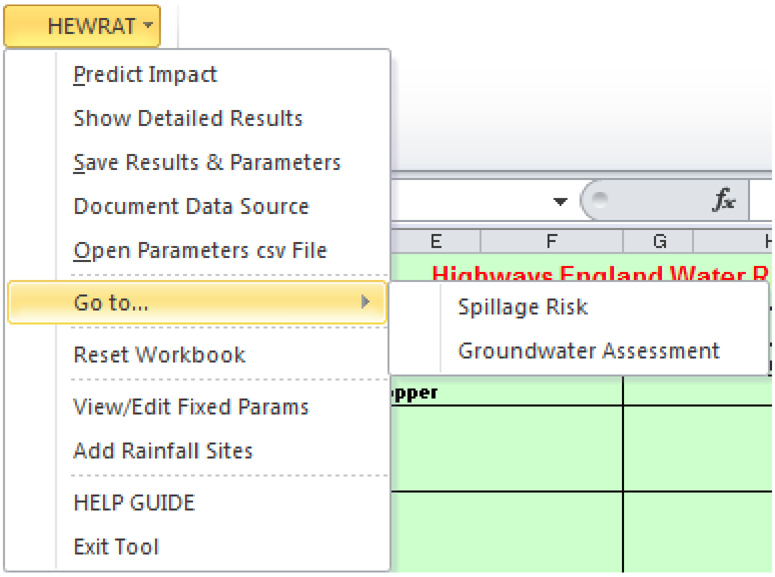
Once the tool is opened up, a new menu called 'HEWRAT' is added to the Excel 'Add-Ins' ribbon (Excel 2007-2010). It provides access to most of the functionality of the tool.



If logged in as a User the menu items are:



If logged in as an Administrator the menu items are:



The menu items under the HEWRAT menu are briefly described in the table below. More details are given in FILE MANAGEMENT and MAINTAINING THE TOOL.

Menu item	Purpose
Predict Impact	To initiate a prediction
Show Detailed Results	To inspect detailed results (Detailed Results worksheet)
Save Results & Parameters	To save the parameters used (in .csv format) and detailed results (in .xlsx format) of a prediction to a user defined location
Document Data Source	To inspect the current user parameter values and to provide notes to explain/justify data entries (User Parameters worksheet)
Open Parameters csv File	To populate the tool with saved user parameters from a .csv file (created previously using Save Results and Parameters)
Go to… Interface	To assess the risk from runoff (Interface worksheet)[1]
Go to… Spillage Risk	To assess the risk level from accidental spillage according to Highways England's Spillage Risk assessment tool (Spillage Risk worksheet)[1]
Go to… Groundwater Assessment	To assess risk to groundwater from run-off (Groundwater Assessment worksheet)[1]
Reset Workbook	To reset all user-entry worksheets (Interface, Spillage Risk, Groundwater Assessment, User Parameters) to default values
View/Edit Fixed Params	To view (for user) or edit (for administrator) assessment parameters (Assessment Parameters worksheet)
Add Rainfall Sites	To add rainfall sites other than those in the current version to the tool (Template worksheet)
HELP GUIDE	To access the help guide[2]
Exit Tool	To exit tool

1 Which Go to… submenu options are visible depends on the current worksheet.
2 To function, the PDF Help guide must be stored in the same folder as the HEWRAT tool.

3.5 Popup menus

On the principal worksheets, the menu items available on the HEWRAT menu, together (where applicable) with items specific to the current worksheet, are also available from a popup menu displayed by right-clicking on the worksheet. Worksheet-specific popup menu items are summarised below.

Worksheet	Popup menu item specific to worksheet	Purpose
Interface	Reset Interface	To reset Interface worksheet to default values
Spillage Risk	Reset Spillage Risk	To reset Spillage Risk worksheet to default values
Groundwater Assessment	Reset GW Assessment	To reset Groundwater Assessment worksheet to default values
Assessment Parameters	Save Changes	To save any changed parameter values on the Assessment Parameters worksheet
User Parameters	Clear All Notes	To clear any notes entered by the user on the User Parameters worksheet
Template[1]	Add data series to tool	To save new series of rainfall data that has been entered on the Template worksheet
Template[1]	Cancel adding data	To clear any data entered on the Template worksheet and return to Interface worksheet
Template[1]	Save data to csv	To save data entered on Template worksheet to .csv file

1 These are the only popup menu options available on the Template worksheet.

The user-entry sections of the Interface worksheet are constructed using textbox and other controls which do not support the right-click event. Thus on this worksheet the cursor must be in the green areas to display the popup menu by right-clicking.

3.6 Command buttons

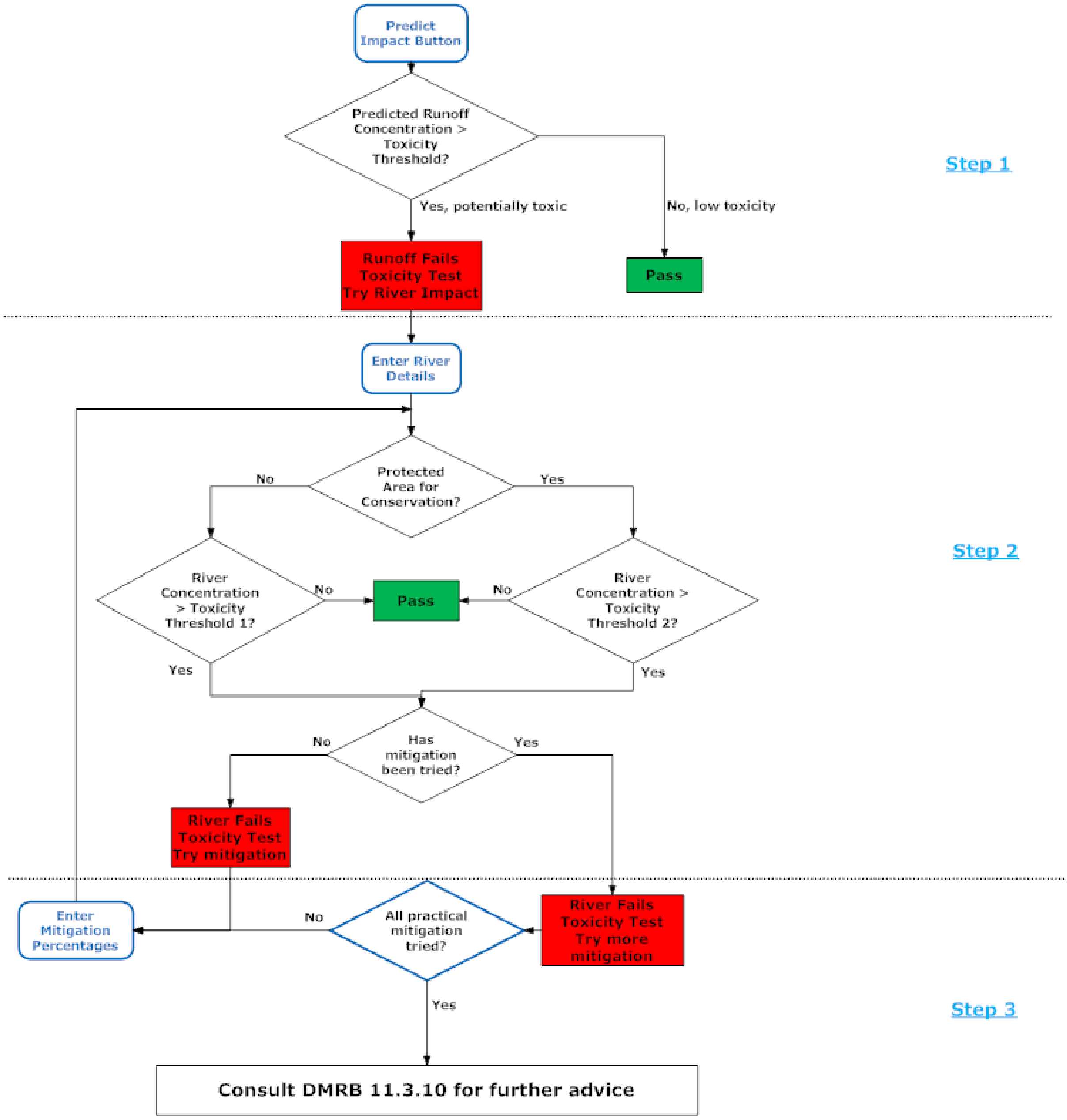
There are command buttons on the worksheets to access some of the functionality of the menus and, where applicable, simple navigation within the worksheet. The most comprehensive set of command buttons is on the Interface worksheet, essentially reproducing all the HEWRAT and local popup menu options applicable to that worksheet.

On other worksheets, the command buttons provided are limited to navigation and worksheet-specific functionality. The buttons are in a fixed pane so remain visible when scrolling down worksheets. The <Back to Top> button provided on some worksheets returns the user to the top of the worksheet.

4. Logic Flow Charts

The logic flow charts used by the tool are shown here. These charts illustrate how the assessment is carried out leading to the Traffic light assessment on the Interface worksheet.

4.1 Solubles - Acute Impacts Logic Flow Chart



a) User action

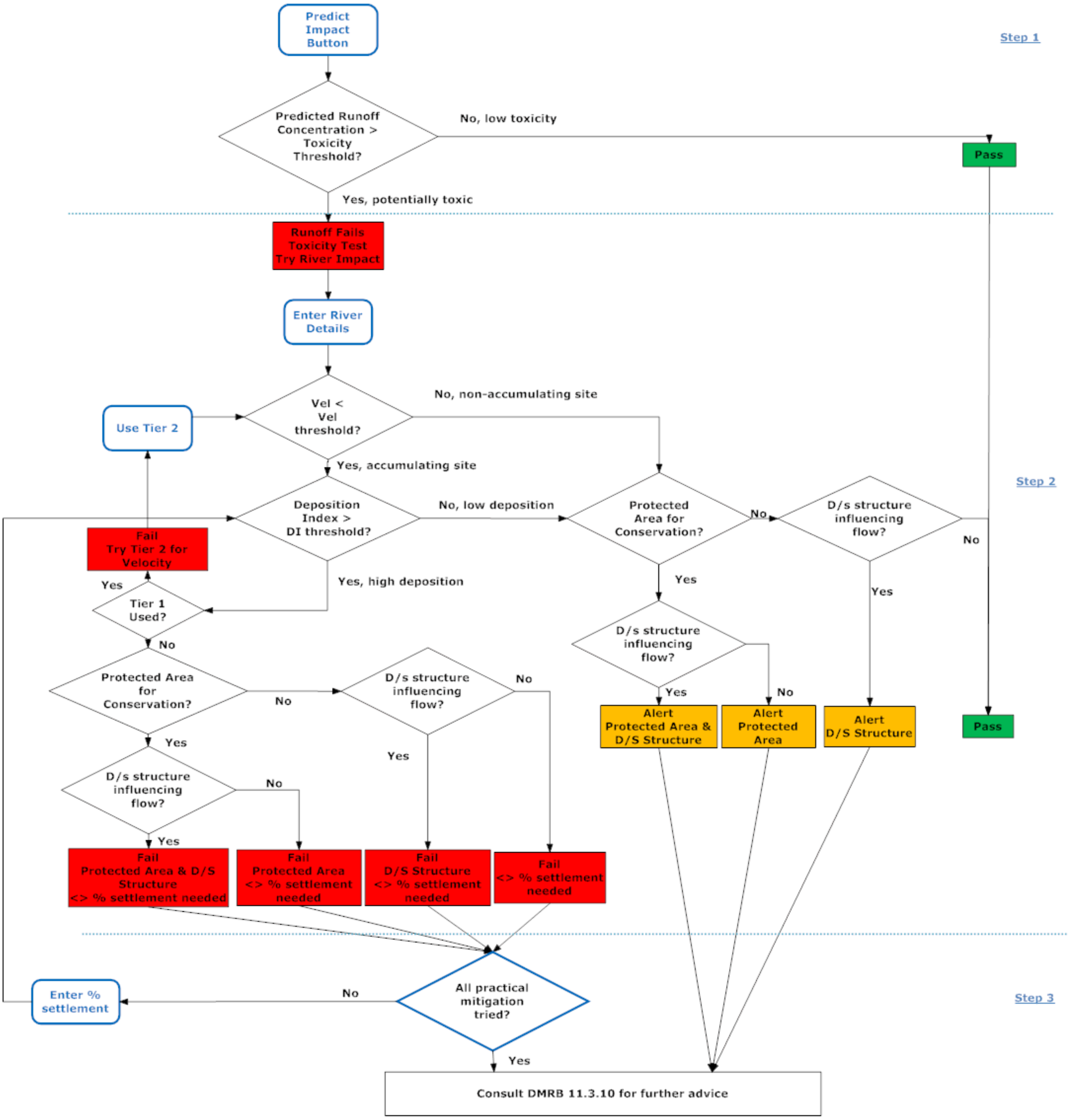
b) Step 1 if River Flow = 0 m^3/s

Step 2 if River flow > 0 m^3/s and mitigation percentage = 0

Step 3 if River Flow > 0 m^3/s and mitigation percentage > 0

These are used to determine which red fail box to display

4.2 Sediments – Chronic Impacts Logic Flow Chart



a) User action

b) Step 1 if River Flow = 0 m^3/s

Step 2 if River flow > 0 m^3/s

These are used to determine which red fail box to display

5. Assessment Thresholds

5.1 Soluble - acute impacts

Look-up tables (see below) are included to define the Runoff Specific Thresholds (RSTs) for dissolved copper and zinc and the allowable number of exceedances of these thresholds. The derivation of the RSTs is described in WRc Report UC7486 (Johnson *et al*, 2007). Different criteria (toxicity thresholds) are applied depending on which step in the procedure and whether or not the discharge is likely to impact on a protected site for conservation. The current toxicity thresholds used in v2.0 are shown below.

Runoff Specific Thresholds for soluble pollution from highway runoff

Threshold Name	Cu µg/l	Zn µg/l Hardness		
		Low	Medium	High
RST24hr	21	60	92	385
RST6hr	42	120	184	770

Low = < 50mg $CaCO_3$ l^{-1}
Medium = 50-200mg $CaCO_3$ l^{-1}
High = >200mg $CaCO_3$ l^{-1}

Toxicity thresholds for acute impacts – Step 1

Max number of RST24hr exceedances allowed per year	Traffic light assessment	
	Criteria met	Criteria failed
1	Green	Red

Toxicity thresholds for acute impacts – Steps 2 and 3

Is the discharge in, or within 1km upstream of, a protected site for conservation?		Max number of exceedances allowed per year[1]		Traffic light assessment	
	Reference on logic flow chart	Exceedance of RST24hr	Exceedance of RST6hr	Both criteria met	Either criterion failed
No	Toxicity threshold 1	2	1	Green	Red
Yes	Toxicity threshold 2	1	0.5	Green	Red

1 Based on a 10-year average.

5.2 Soluble - EQS

The annual average concentrations of dissolved copper and zinc calculated in Steps 2 and 3 are compared against the current Environmental Quality Standards (EQS) set by the Environment Agency. Current (December 2015) EQS values are included in the tool but can be changed if subsequently revised by the EA.

Freshwater EQS standards for bioavailable dissolved copper and zinc (December 2015) – Steps 2 and 3

	EQS (µg/l)
Copper (Cu)	1.0
Zinc (Zn)	10.9

Is the annual average concentration > EQS?	Traffic light assessment
No	Green
Yes	Red

5.3 Sediment - chronic impacts

The procedure for sediments is broadly based on the risk assessment procedure derived by Gaskell *et al*, 2007. The assessment thresholds are used differently depending on whether the highway discharge could reach a protected conservation site where sediment could accumulate.

A Look-up table (see below) is included to define the Threshold Effect Levels (TELs) and Probable Effect Levels (PELs) used for the sediment (chronic) impact assessment. The derivation of the TELs and PELs is described in Gaskell *et al*, 2007.

TELS and PELS

Metal	Copper mg/kg	Zinc mg/kg	Cadmium mg/kg
TEL	35.7	123	0.6
PEL	197	315	3.5

PAHs	Total PAH µg/kg	Pyrene µg/kg	Fluoranthene µg/kg	Anthracene µg/kg	Phenanthrene µg/kg
TEL	1684	53	111	46.9	41.9
PEL	16770	875	2355	245	515

The current toxicity thresholds used in Step 1 in v2.0 are shown below.

Max number of PEL exceedences allowed per year	Traffic light assessment	
	Criteria met	Criteria failed
1	**Green**	**Red**

A key part of the sediments procedure is a judgement about whether or not sediment will accumulate in the stream/river downstream of the outfall. This judgement is based on estimating the stream velocity under low flow conditions and comparing this with a threshold velocity. Different methods are available for estimating the stream velocity. The outcomes are judged using the table below.

N.B. *The derivation of 0.1 m/s threshold velocity is described in Gaskell et al, 2007. As with other thresholds, the value used in the model can be amended if necessary. See Editing the Assessment Parameters.*

Velocity thresholds for sediment (chronic) impacts – Step 2

Estimated stream velocity at low flow conditions	Type of site	Traffic light assessment
≤0.1 m/s	Accumulating	Depends on DI and other factors – see logic chart
>0.1 m/s	Dispersing	Green unless other factors apply – see logic chart

A further aspect of the sediments procedure is a judgement about whether or not, for an accumulating site, the amount, or extent, of sediment deposition is likely to be high. A Deposition Index (DI) is calculated for this purpose. The DI is then compared with a DI threshold. The current DI threshold is set at 100 based on preliminary testing carried out in 2008. This threshold may be revised in the future as further experience is gained. The outcome is judged using the table below

Deposition Index thresholds for sediment (chronic) impacts – Step 2

Estimated Deposition index	Type of site	Traffic light assessment
<100	Low extent of deposition	Green unless other factors apply – see logic chart
≥100	High extent of deposition	Red

6. Rainfall Series

6.1 Series included in the tool

Twenty-one rainfall series are included in the tool to represent different rainfall patterns for England, Scotland, Wales and Northern Ireland. For each rainfall site, the Standard Annual Average Rain (SAAR), distance from coast, altitude and the location (NGR) were identified. These parameters were then fed into the WRc StormPac software to stochastically generate 10 years of hourly rainfall data for each site.

StormPac was then used to identify all rainfall events for each site and to characterise these events in terms of date, rainfall total, rainfall duration, maximum hourly intensity and antecedent conditions i.e. the Antecedent Dry Weather Period (ADWP), the rainfall in the preceding 10 days and 20 days. All events greater than 0.1 mm were included. Typically, there are about 1000 events/site in the 10 year period.

The rainfall event data are incorporated in the tool as separate worksheets that can be accessed by the model if the site is selected on the Interface worksheet.

Rainfall series built into the tool (Rainfall sites maps)

Rainfall site	Altitude (MOD)	Easting	Northing	Distance from coast (km)	SAAR (mm)	Climatic Region	Average rainfall events per year
Ashford	50	6012	1427	15	710	Warm Dry	78
Ipswich	35	6164	2448	17	550	Warm Dry	68
London	20	5301	1795	45	600	Warm Dry	109
Huntingdon	15	5237	2716	100	600	Warm Dry	108
Lincoln	40	4976	3718	55	600	Colder Dry	111
Newcastle upon Tyne	75	4248	5648	18	680	Colder Dry	129
Penrith	200	3514	5304	45	900	Colder Wet	136
Keighley	200	4060	4410	70	1000	Colder Wet	97
Warrington	20	3610	3885	15	830	Colder Wet	91
Birmingham	120	4073	2872	120	750	Warm Dry	122
Bristol	70	3561	1754	10	850	Warm Wet	130
Southampton	25	3561	1754	10	820	Warm Wet	131
Exeter	70	2918	1924	15	1000	Warm Wet	141

Rainfall site	Altitude (MOD)	Easting	Northing	Distance from coast (km)	SAAR (mm)	Climatic Region	Average rainfall events per year
Bodmin	110	2072	1670	20	1200	Warm Wet	151
Edinburgh	57	3254	6733	3	676	Colder Dry	81
Cardiff	9	3176	1773	4	1112	Warm Wet	95
Paisley	32	2478	6642	28	1205	Colder Wet	105
Aldergrove	63	1263	5358	22	862	Colder Wet	93
Carmoney	73	669	5822	6	993	Colder Wet	95
Colwyn Bay	36	2830	3796	1	788	Colder Wet	83
Ardtalnaig	130	2703	7389	58	1344	Colder Wet	103

6.2 River flows

A range of unit river flows for different BFIs (Base Flow Index) were calculated and assigned to each rainfall event. The calculation procedure was as follows:

The rainfall series were processed into hydrologically effective rainfall (HER) taking account of evaporation and soil moisture deficit. HER series were then fed through a soil store and a groundwater store to attenuate flows and create river flow series. This was repeated for different BFIs. Flows at this stage were based on a unit catchment area and the Q_{95} of each unit flow series was calculated. The river flow assigned to a particular rainfall event (and thus used for the pollution assessment calculation) is taken as the river flow just before the start of the event factored by:

$$\frac{Actual\ Q_{95}\ river\ flow\ (provided\ by\ the\ user)}{Q_{95}\ of\ the\ unit\ flow\ series}$$

6.3 Additional rainfall series

Additional rainfall series can be incorporated in the tool if required. StormPac software was used to create the rainfall series for the first release but historical rainfall series or rainfall series generated by other methods or tools can be used. The important thing is that the series created provides an adequate expression of the long term variability of rainfall close to a particular highway site being investigated.

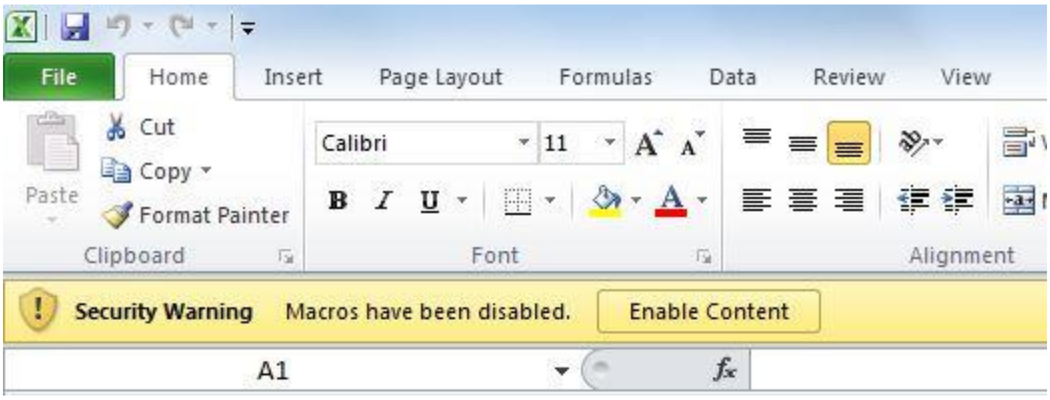
Additional rainfall series can only be added by an Administrator. Please see Adding rainfall sites for guidance.

7. Using the Tool

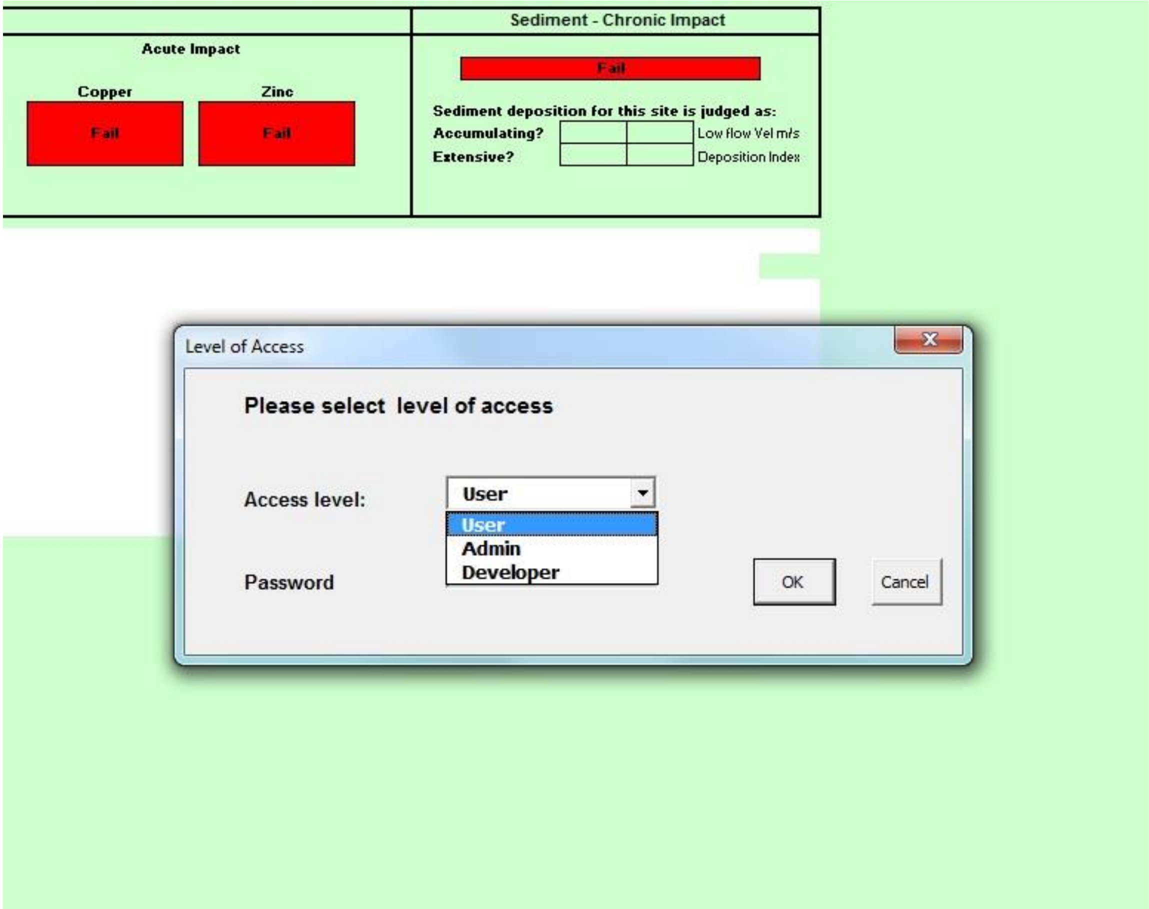
7.1 Getting started

7.1.1 Opening

The opening of the tool can be initialised in the same way as other Excel applications e.g. double click the tool workbook. In order to allow the tool to perform, the macros in the tool workbook must be enabled. For more help on how to enable macros, please click here.



During the starting up process, a form will automatically come up to facilitate access to the tool with different level of authority. Passwords will be required if the user accesses the tool as Administrator or Developer. The three levels of accessibility and the associated rights are set out in detail in ACCESSIBILITY.

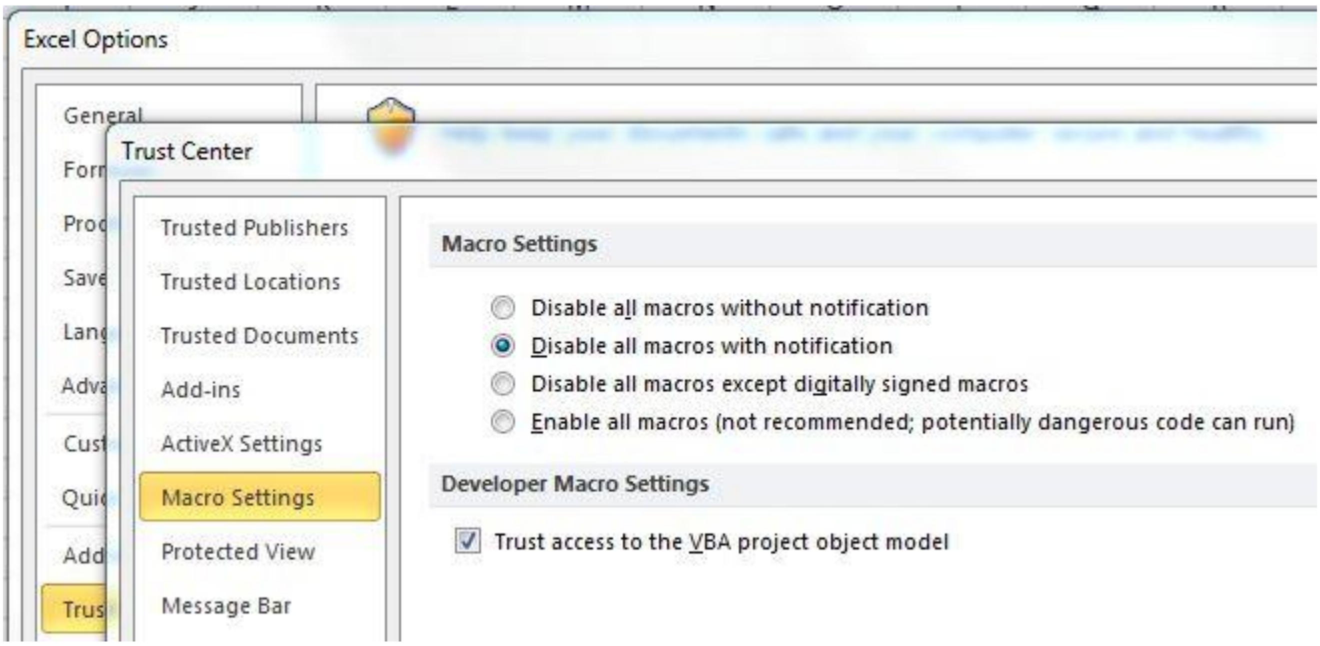


Once the tool is opened up, a new menu called '[HEWRAT]' is added to the Excel 'Add ins' ribbon (Excel 2007-2010).

N.B. *Once the tool is opened up, the calculation option of all the Excel workbooks currently open on the user's computer will be switched to and kept at 'Manual', i.e. opened workbooks only calculate and update results when the <F9> key is pressed. This prevents automatic updating of calculations– and thus may create unexpected results in other opened workbooks. The calculation option will be automatically switched back to 'Automatic' once the tool is exited.*

N.B. *The Macro Settings for the local Excel application determine whether macros are automatically enabled. For Excel 2010, the Macro Settings are reached via the File tab:*

File → Options → Trust Center → Trust Center Settings… → Macro Settings

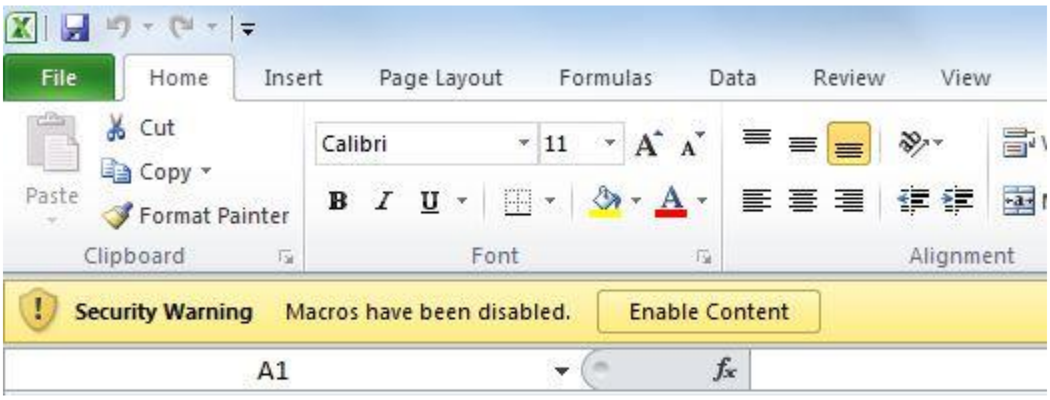


The options are:

- ***Disable all macros without notification*** *– This option disables macros without displaying any warning, unless the file is in a Trusted Location. Trusted Locations are managed via the File tab:*

  File → Options → Trust Center → Trust Center Settings… → Trusted Locations

- ***Disable all macros with notification*** *– This is the Excel default option, which will display a warning if a file containing macros is opened:*



If this warning message is displayed when opening a file, the file can be identified as a 'Trusted Document' to allow it to be subsequently opened with automatic enabling of the macros. This is set via the File tab:

- *File → Info*

- ***Disable all macros except digitally signed macros*** *- The HEWRAT tool does not have a digital signature so will not work if this option is selected.*

- ***Enable all macros (not*** *recommended****; potentially dangerous code can run)***

The default setting for a given user may be determined by company IT policy.

7.1.2 Interface Worksheet

Once the tool is fully opened, the user will be presented with the Interface worksheet with all user parameters required for a prediction set at their default values and location details cleared. The Interface worksheet is divided into three sections as shown.

Inputs section

The user parameters are categorised by assessment steps and are in the form of text box entries and combo box entries. For some parameters, next to the input box there is a default identifier which has 'D' shown if the entry is at its default value.

The tool includes code to validate the parameter inputs entered on the interface against valid ranges set out in the Assessment Parameters. A warning message will come up if an invalid value is entered by the user and the parameter will be automatically set back to its default value.

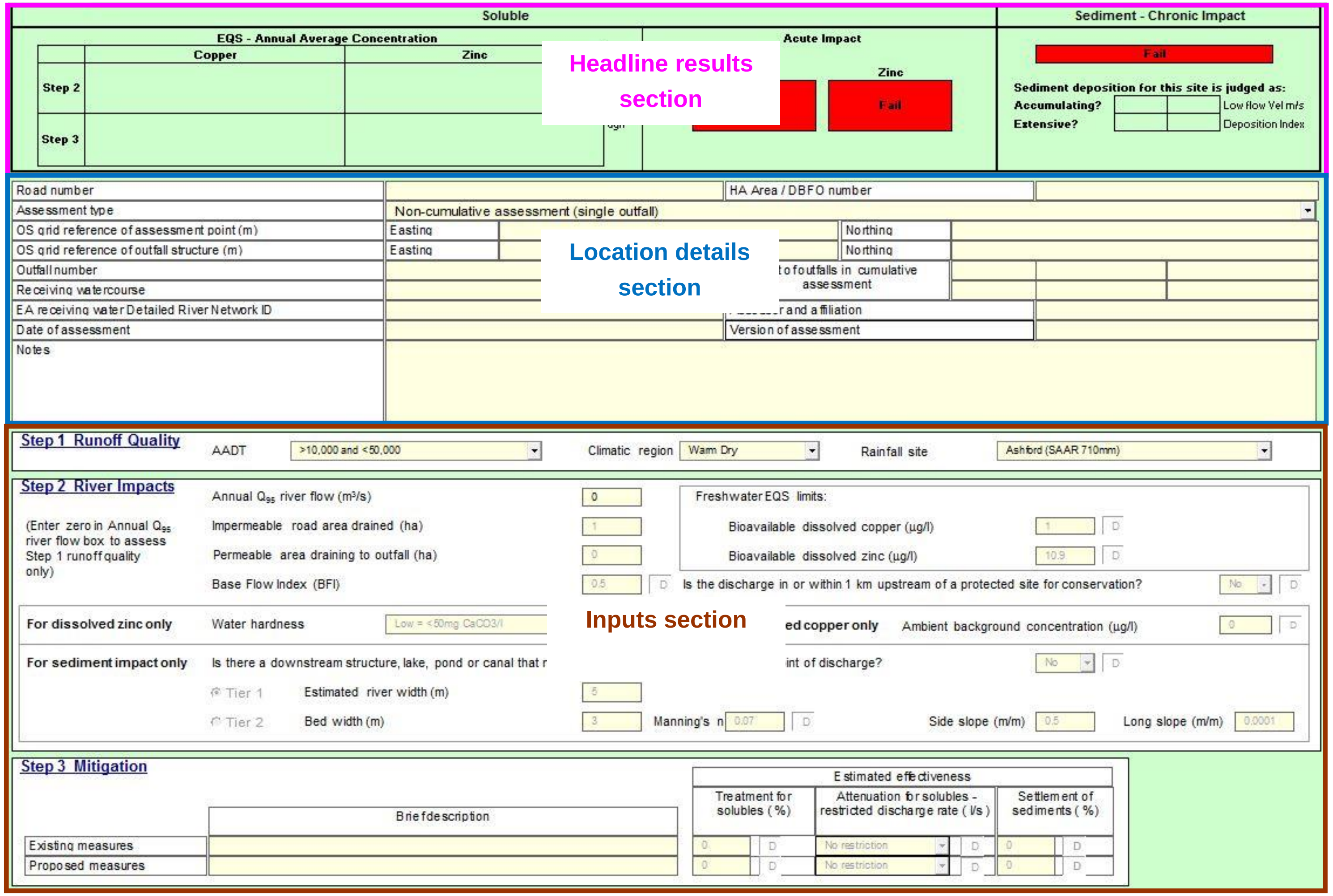
For more details on the user inputs on each step and their valid input ranges, refer to the individual steps Step1, Step2, Step3 and Assessment Parameters.

Headline results section

The headline results section presents the traffic light assessment results regarding the acceptability of the impacts. Also presented on the interface are values in relation to whether the site is judged likely to accumulate sediment and how extensive this accumulation will be. For more details on all the results given by the tool, refer to 'INSPECTING THE DETAILED RESULTS'.

Location details section

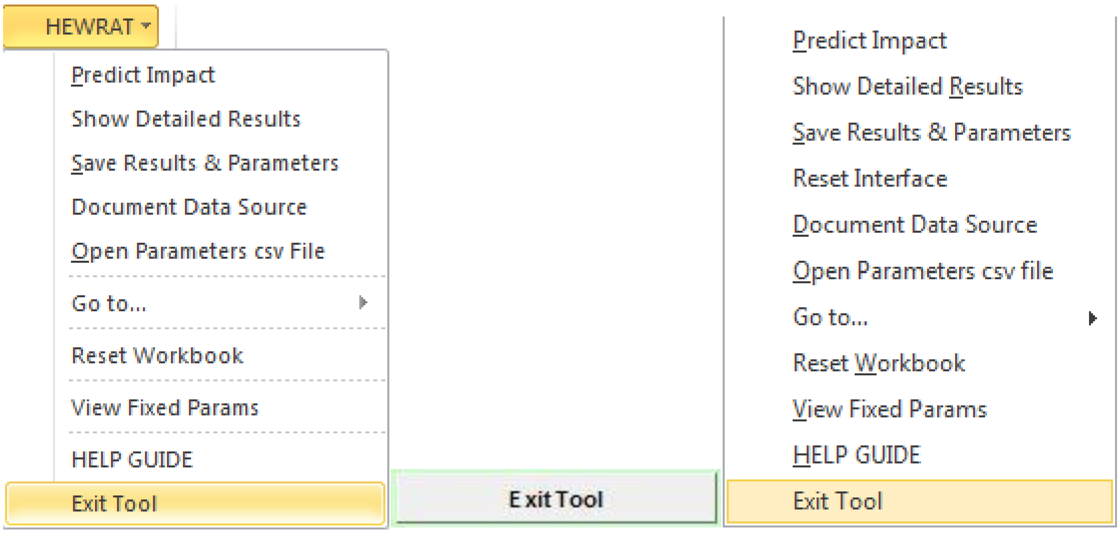
This section allows a user to specify details of the outfall location. These details are not used in the calculations. See Location details.



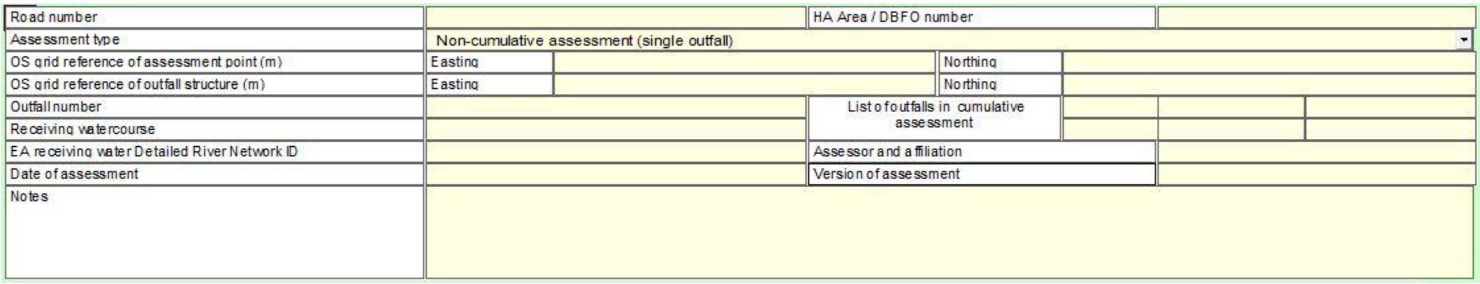
Headline results section
Location details section
Inputs section
Soluble
Sediment - Chronic Impact
EQS - Annual Average Concentration
Acute Impact
Copper
Zinc
Step 2
Step 3
Fail
Sediment deposition for this site is judged as:
Accumulating?
Extensive?
Low flow Vel m/s
Deposition Index
Road number
HA Area / DBFO number
Assessment type
Non-cumulative assessment (single outfall)
OS grid reference of assessment point (m)
OS grid reference of outfall structure (m)
Easting
Northing
Outfall number
Receiving watercourse
EA receiving water Detailed River Network ID
Date of assessment
Version of assessment
Notes
Step 1 Runoff Quality
AADT
>10,000 and <50,000
Climatic region
Warm Dry
Rainfall site
Ashford (SAAR 710mm)
Step 2 River Impacts
Annual Q95 river flow (m³/s)
Impermeable road area drained (ha)
Permeable area draining to outfall (ha)
Base Flow Index (BFI)
(Enter zero in Annual Q95 river flow box to assess Step 1 runoff quality only)
Freshwater EQS limits:
Bioavailable dissolved copper (µg/l)
Bioavailable dissolved zinc (µg/l)
Is the discharge in or within 1 km upstream of a protected site for conservation?
For dissolved zinc only
Water hardness
Ambient background concentration (µg/l)
For sediment impact only
Tier 1
Estimated river width (m)
Tier 2
Bed width (m)
Manning's n
Side slope (m/m)
Long slope (m/m)
Step 3 Mitigation
Brief description
Estimated effectiveness
Treatment for solubles (%)
Attenuation for solubles - restricted discharge rate (l/s)
Settlement of sediments (%)
Existing measures
Proposed measures
No restriction

7.1.3 Exiting the tool

The tool can only be exited via the ‘Exit Tool’ option in the HEWRAT menu, <Exit Tool> button on the Interface worksheet, or ‘Exit Tool’ option on a popup menu.



7.1.4 Location details



This section allows the entry of details required to identify the point of assessment, receiving watercourse and further information needed to provide an audit trail. To ensure consistency between users and between assessments, each field should be completed according to the following rules.

1. Road number

For HE users the road number should be in HAPMS format, i.e. A or M followed by the number, no brackets or ‘T’ etc., e.g. A1(M) would be A1M, A66T would be A66. For non-HA users, the format used should be as agreed with the overseeing organisation.

2. HE Area/DBFO number

This field need only be completed by HE users. Enter the HE Area or DBFO (Design Build Finance Operate) number. This must be numeric.

3. Assessment type

Select from three options:

- Non-cumulative assessment (single outfall)
- Cumulative assessment including sediments (outfalls within 100m)
- Cumulative assessment for solubles only (outfalls between 100m and 1km apart)

4. OS grid reference of assessment point

The Ordnance Survey grid coordinates of the assessment point should be defined to the nearest metre using a six figure easting and a six figure northing (in metres). The entries must be numeric.

For an assessment of a single outfall discharging directly into a natural watercourse, this will be the same grid reference as the outfall structure (below). Where outfalls do not discharge directly into a natural watercourse this will be the point on the river network that is being assessed. For a cumulative assessment this will be the grid reference of the assessment point that is furthest downstream.

5. OS grid reference of outfall structure

The Ordnance Survey grid coordinates of the outfall structure should be defined to the nearest metre using a six figure easting and a six figure northing (in metres). The entries must be numeric.

For an assessment of a single outfall discharging directly into a natural watercourse, this will be the same grid reference as the assessment point (above). For a cumulative assessment this will be the grid reference of the outfall structure that is furthest downstream.

6. Outfall number

For HE users if the outfall is in the existing HADDMS register then the 'HADDMS outfall asset reference number' should be used. The HADDMS asset reference number must be in HD 43/04 format.

For non-HE users (or if the outfall is not in the HADDMS register) then the outfall number should be defined by the user and should be unique to that outfall. This self-generated reference number may be in any format that the user defines, but it is recommended that the numbering format detailed in HD 43/04 (Drainage Data Management System for Highways) is avoided so it is not mistaken for a registered 'HADDMS outfall asset reference number'.

For cumulative assessments, the number of the outfall furthest downstream should be given.

7. List of outfalls in cumulative assessment

This field need only be completed for cumulative assessments. Each outfall in the assessment should be listed.

8. Receiving watercourse

This is the name of the watercourse that the outfall discharges into.

HE users should obtain the receiving watercourse name from the Environment Agency's Detailed River Network (EA DRN) which can be obtained from HADDMS. The 'RIVERNAME' attribute should be used (if this is not defined then use the 'WCRS_NAME' attribute).

For non-HE users, the EA DRN should be used where available but if not, an alternative equivalent can be used.

If the watercourse is not named then it should be recorded as 'Undefined' and text should be added in the 'Notes' field to assist in later identification.

9. EA receiving water Detailed River Network ID

This field need only be completed by HE users. Each watercourse in the EA DRN has a unique reference number and this should be recorded for the watercourse at the point of assessment. The 'DRN_ID' attribute can be obtained from HADDMS. If the assessment is made at a river confluence the 'DRN_ID' attribute of the junction node at the confluence should be recorded.

10. Assessor and affiliation

Enter the name or initials of the assessor and the affiliation.

11. Date of assessment

Enter the date of the assessment in dd/mm/yyyy format.

12. Version of assessment

Enter the version of the assessment. This should be a sequential number starting at 1 that is incremented each time the assessment is revised.

13. Notes

Additional notes which serve to clarify other inputs or locate the point of assessment should be entered here.

N.B. Predictions can be carried out without entering any information in these boxes.

7.1.5 Step 1 – Runoff quality only

Step 1 allows an initial quick check to assess the quality of the direct highway runoff against the thresholds. This step requires minimal information. It is assumed that there is no stream dilution and no treatment/attenuation – the test is simply on the toxicity of the direct runoff against the thresholds. If the test shows that the toxicity is acceptable, then no further assessment is required.

To obtain a Step 1 result, the Q_{95} river flow must be set to zero.

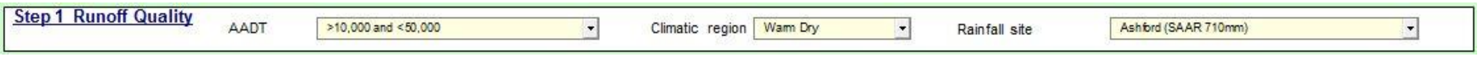
Overview of calculations

The runoff quality for each rainfall event and each pollutant is predicted using the statistical models developed during the project 'Improved determination of pollutants in highway runoff' (Dempsey *et al*, 2007). These models predict the EMCs and EMSCs for all the events from a chosen rainfall series applied to a highway of a specified AADT in a specified climatic region. Rainfall characteristics (maximum hourly intensity, preceding 10 days' rain, preceding 20 days' rain, and antecedent dry weather period), AADT and climatic region were the factors that were found to offer some explanation for the wide variability in the runoff concentrations measured in the project.

For soluble (acute) impacts the number of events for which the EMCs exceed the toxicity thresholds are calculated and compared with the exceedance frequency thresholds.

For sediment (chronic) impacts, the number of events for which the EMSCs exceed the toxicity thresholds are calculated and compared with exceedance frequency thresholds.

Data entry



Explanations of parameters required:

- AADT
- Climatic Region
- Rainfall Site

Using the drop down boxes, select the most appropriate AADT, climatic region and rainfall site for the highway site under investigation.

N.B. *The 'headline results' reported are always in line with the current results of an assessment. The 'headline results' will be the Step 1 results if zero is entered for Annual* Q_{95} *river flow.*

For the selected rainfall site, the details – SAAR, altitude, easting, northing, coastal distance - are displayed in a box on the detailed results page to give more information about the rainfall and to facilitate the user in selecting the most appropriate rainfall site.

7.1.6 Step 2 – River impacts, without mitigation

Step 2 is a refinement of Step 1. For assessing acute impacts, account is taken of the nature and diluting capacity of the stream/river that receives the outfall(s) discharge.

For sediment (chronic) impacts, Step 2 is based on the risk assessment procedure developed by Sheffield University (Gaskell *et al*, 2007). The procedure takes account of the likelihood of sediment deposition and the extent of deposition.

Step 2 also involves consideration of the proximity to a protected site for conservation.

Step 2 assumes no mitigation (i.e. all mitigation percentages set to 0).

Overview of calculations – Acute impacts

The tool incorporates a hydrological model that generates river flows in response to the chosen rainfall series. The selected BFI is used in these calculations and the generated stream flow series is adjusted to match the Annual Q_{95} River Flow figure entered by the user. See River Flows.

Each rainfall event is characterised by (among other things) a rainfall depth total (mm) and a duration (hrs). The event runoff volume is calculated as:

Runoff volume generated from impermeable area + Runoff volume generated from permeable area

where

Runoff volume generated from impermeable area (m³)
*= (rainfall depth total (mm) - rainfall initial loss (mm)) *Impermeable area (ha)* runoff coefficient for impermeable area *10*

Runoff volume generated from permeable area (m³)
*= (rainfall depth total (mm) - rainfall initial loss (mm)) * permeable area (ha)* runoff coefficient for permeable area *10*

N.B. *If justified, the runoff factors and rainfall initial losses can be amended by an Administrator. The current factors being used are viewable by the 'View/Edit Fixed Params' option of the HEWRAT menu or popup menus, or the <View/Edit Fixed Params> button on the Interface worksheet.*

This volume, with its associated runoff EMC from the Step 1 calculations, is assumed to be discharged at a uniform rate over the event duration.

The mixed river concentration is then calculated by a simple mass balance of river flow and runoff flow for each event:

*(pollutant concentration in highway runoff (µg/l) * runoff flow rate (m^3/s) + pollutant concentration in upstream river (µg/l) * river flow rate (m^3/s)) / (runoff flow rate (m^3/s) + river flow rate (m^3/s))*

***N.B.** The river flow is the flow rate calculated by the hydrological model at the start of the rainfall event – i.e. it is assumed that the event itself will not elevate river flows quickly enough to provide extra dilution during the event itself.*

Finally, the number of events for which the mixed river concentrations exceed the toxicity thresholds are calculated and compared with the exceedance frequency thresholds to give the traffic light assessment.

Overview of calculations – EQS

The annual average concentrations of dissolved copper and zinc are calculated and compared against the EQS values to give the traffic light assessment.

Overview of calculations – Sediment (chronic) impacts

Is sediment accumulation likely?

The first stage in the risk assessment procedure for sediments is to gauge whether sediment accumulation is likely or not. This can be carried out at different levels (tiers) of sophistication. The following is a summary of the calculation procedure – for details about the rationale and assumptions see report "Accumulation and dispersal of suspended solids in watercourses: Stage 3 Task 1 Report: Risk assessment tool development HA3/368 (Gaskell *et al*, 2007).

Tier 1

Using the estimated river width (provided by the user), the river flow area is calculated from the following equation:

$$\log_{10}(\text{River flow area}) = -0.93 + 1.66\log_{10}(\text{width})$$

The corresponding velocity (m/s) under low flow conditions is then calculated as:

$$\text{Annual } Q_{95} \text{ river flow } (m^3/s) \,/\, \text{River flow area } (m^2)$$

Tier 2

This uses channel dimensions (including the longitudinal slope – see notes on site measurements for tier 2 user inputs), measured during a site visit, to iteratively estimate the velocity (and surface width for use in the extent calculations) at the Q_{90} river flow.

The equations that are solved iteratively are:

$$V = \frac{R^{2/3} s^{1/2}}{n}$$

$$Q = VA$$

where: R – hydraulic radius (m)

s – longitudinal slope (m/m)

n - Manning's roughness coefficient

V – velocity (m/s)

Q – annual Q_{90} river flow estimated from Q_{95} river flow (m^3/s)

A – cross sectional flow area (m^2)

Whichever tier is used, the calculated velocity is then compared with the threshold mean velocity to judge whether the site is likely to accumulate or disperse sediment.

Is the sediment deposition extensive?

If the site is accumulating, the next stage is to gauge how extensive sediment deposition is likely to be. The following is a summary of the calculation procedure.

a. Deposition Index

A Deposition Index is calculated as follows:

The DI is 100 times the ratio of the estimated annual volume of sediment in the highway runoff to a volume represented by a layer of 0.01 m thick over a 10 m length of river assuming the layer extends to the full river width, *w*.

Thus:

$$Deposition\ Index\ (DI) = \frac{Annual\ sediment\ volume\ (m^3)}{0.01 * 10 * w} * 100$$

where *w* = surface width of the river at low flow (m).

b. Annual Sediment Volume

The annual average sediment load generated from the highway runoff which is used in the DI calculation, is calculated using either of the following two approaches:

Type	Method used for Annual Runoff Volume
1	Including all the rainfall events in the calculation
2	Only including the rainfall events during which the receiving water velocity is less than threshold mean velocity

N.B. *The model can be switched between the above two approaches by switching the 'Event Selection Type' parameter through the 'View/Edit Fixed Params' option of the HEWRAT menu* *or [popup menus](), or the <View/Edit Fixed Params> button on the Interface worksheet, by an [Administrator](). The default approach is Type 2.*

The calculation uses a suspended solids (SS) concentration of 139 mg/l with the annual runoff volume estimated by one of these two methods. The median SS concentration of 139 mg/l is derived from Phase 2 of the Improved determination of pollutants in highway runoff project (Crabtree *et al*, 2007).

Thus:

$$Annual\ Sediment\ Volume = \frac{SS\ conc\ (mg/l) * Annual\ Runoff\ Volume\ (m^3)}{Sediment\ Density\ (kg/m^3) * 1000}$$

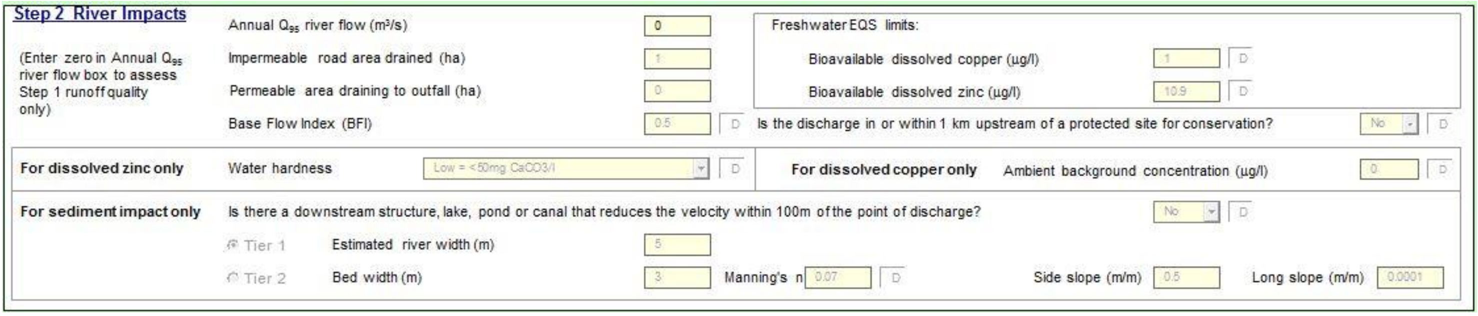
The stream width is as entered by the user, if tier 1 is used, or iteratively calculated from flow and channel dimensions if tier 2 is used.

c. DI Threshold

The calculated DI is then compared with the DI Threshold to judge whether sediment deposition is extensive or not.

N.B. *The median SS concentration of 139 mg/l, the assumptions on sediment density and the DI threshold in the model can be changed by an Administrator if the changes can be justified. See Editing the Assessment Parameters for more details for how to make a change.*

Data entry



Explanation of parameters required:

- Annual Q_{95} river flow m^3/s (see also)
- Base Flow Index (BFI)
- Impermeable road area drained
- Permeable area draining to outfall
- Is the discharge in, or within 1 km upstream of, a protected site for conservation?

- Freshwater EQS limits for dissolved copper and zinc

For dissolved zinc only

- Water Hardness

For dissolved copper only

- Ambient background concentration

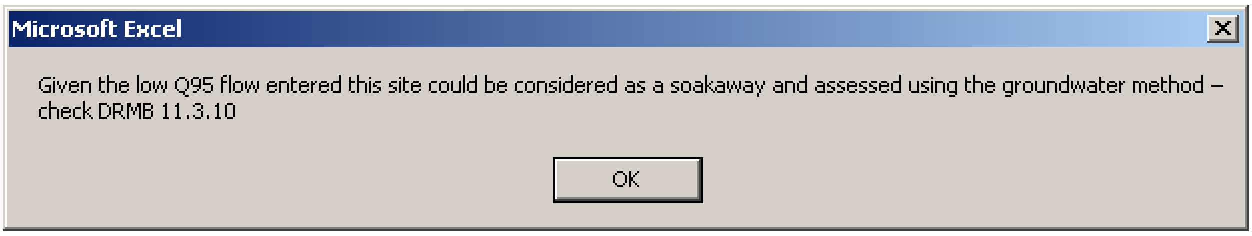
For sediment impact only

- Is there a downstream structure that reduces the velocity within 100m of the point of discharge?
- Estimated river width
- Bed width (for further guidance, see here)
- Side slope (for further guidance, see here)
- Long slope (for further guidance, see here)
- Manning's n (for further guidance, see here)

N.B. *Annual Q_{95} river flow:*

1) If the user wants a Step 1 (runoff) only simulation, this can be achieved by entering a flow of 0 to the Annual Q_{95} river flow entry box. A message box will pop up and all Step 2/3 parameters will be reset to defaults and disable if the user chooses to proceed.

2) If the entry for the Annual Q_{95} river flow is less than or equal to $0.001m^3/s$, the below message will pop up to remind the user that the site should be considered as a soakaway. However, the user can still proceed to use the tool.



7.1.7 Step 3 – River impacts, with mitigation

Step 3 is a further refinement of Step 2. Step 3 allows an assessment of the effects of (i) restriction on the maximum outfall discharge rate to attenuate road runoff, (ii) treatment of road runoff to reduce pollutant concentrations and (iii) settlement of sediments in the road runoff to reduce annual sediment volume. The refined estimates following these mitigation measures may lead to a change of impact status.

Overview of calculations – acute impacts

If (Discharge rate calculated in Step 2 ≤ Restricted discharge rate) Then

Attenuated discharge rate = Discharge rate calculated in Step 2

Else If (Discharge rate calculated in Step 2 > Restricted discharge rate) Then

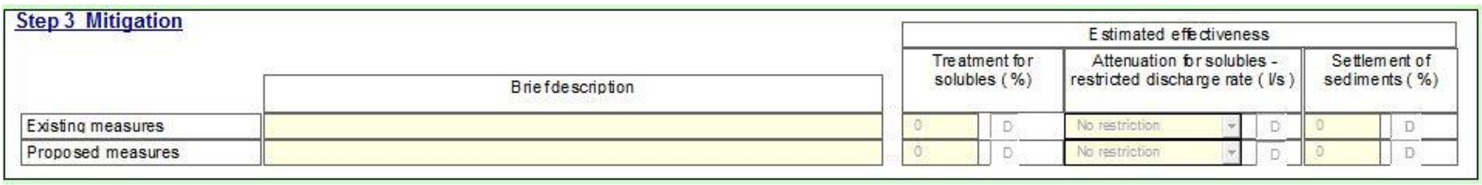
Attenuated discharge rate = Restricted discharge rate

Together with the treatment measures (*%Treatment*), the mitigated pollutant concentration in the receiving watercourse is then calculated.

Overview of calculations – Sediment (chronic) impacts

The Deposition Index is recalculated using the annual sediment volume after settlement measures (% Settlement) and the sediment risk impact is then re estimated using the same procedure as in Step 2.

Data entry



Explanation of parameters required:

- Treatment for solubles (Existing measures)
- Treatment for solubles (Proposed measures)
- Attenuation for solubles – restricted discharge rate (Existing measures)

- Attenuation for solubles – restricted discharge rate (Proposed measures)
- Settlement of sediments (Existing measures)
- Settlement of sediments (Proposed measures)

N.B. *The tool ONLY uses the input data for the proposed mitigation measures in calculating the Stage 3 results. The existing measures values are for information only and are not used in the calculations.*

The extent of mitigation by the proposed measures should always be greater than or equal to the existing measures. The tool will automatically update the proposed measures if this isn't the case, e.g. if the new entries for the existing treatment measures/settlement of sediments are 25% and the last entries for the proposed measures were 15%, the proposed measures will automatically be changed to 25% to match the existing measures; similarly, if the new entry for existing attenuation is 3 l/s and the last entry for proposed attenuation is 5 l/s, the proposed attenuation will automatically be changed to 3l/s to match the level of attenuation in the existing measures.

After a Step 2 prediction, if the traffic light assessment indicates a Fail for Sediment – Chronic Impact, the % settlement required to achieve a Pass is shown. This provides the minimum value for proposed Settlement of sediments (%) for the Step 3 prediction.

Initiating a prediction

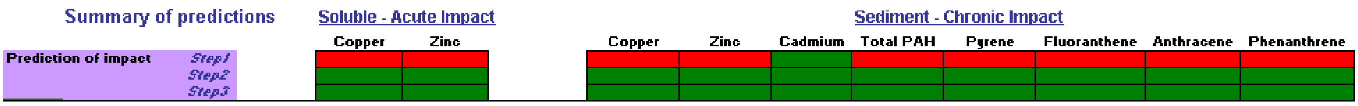
A prediction is initiated using either the <Predict Impact> button on the Interface worksheet or the 'Predict Impact' options of the HEWRAT menu or popup menus.

8. Inspecting the Detailed Results

The Detailed Results sheet provides a summary of the results from each step of the assessment. It also provides additional statistical information about the predicted frequency and severity of the pollutant concentrations. This information may be useful in judging the significance of marginal failures and in gauging the amount of mitigation required. In addition the results will be useful if the assessment needs to be referred for more specialist judgement.

The Detailed Results view can be activated by ‘Show Detailed Results’ option of the HEWRAT menu or popup menus, or by clicking the <Show Detailed Results> button on the Interface worksheet.

8.1 Summary of results



This section of the detailed result sheet provides an overview of the predicted impacts at each step for the concerned pollutants. It uses a ‘traffic light’ reporting method described earlier:

N.B. *The headline results for the latest step are reported on Interface worksheet, e.g. if all three steps are used in an assessment, the Step 3 result will be reported.*

N.B. *The tool carries out the runoff toxicity test for each sediment pollutant and reports the results in the detailed results sheet separately. When using the logic chart to assess sediment risk, if any of the sediment pollutants fail, it is regarded that the untreated highway runoff fails the toxicity test.*

8.2 Detailed results for each step

Step 1

In this step, the model checks whether the untreated pollutant concentrations in the highway runoff, at the point of discharge prior to any dilution from receiving waters, are acceptable or not. This is a conservative emission standard test. If acceptable at this step, then no further assessment is required.

In Runoff

Step 1

		Copper	Zinc
		RST24	
Allowable Exceedances/year		1	1
No. of exceedances/year		**34.80**	**23.70**
No. of exceedances/worst year		46	32
		RST6	
Allowable Exceedances/year		1	1
No. of exceedances/year		**11.10**	**7.40**
No. of exceedances/worst year		14	13
		(ug/l)	(ug/l)
Thresholds	RST24	21	60
Thresholds	RST6	42	120
Event Statistics Mean		24.08	56.04
90%ile		45.69	116.92
95%ile		59.78	164.50
99%ile		88.19	273.08

Step 1

	Copper	Zinc	Cadmium	Total PAH	Pyrene	Fluoranthene	Anthracene	Phenanthrene
	Toxicity Threshold							
Allowable Exceedances/year	1	1	1	1	1	1	1	1
No. of exceedances/year	**46.80**	**58.80**	**0.40**	**9.80**	**32.40**	**9.80**	**8.10**	**17.70**
No. of exceedances/worst year	59	72	2	16	43	16	14	23
	(mg/kg)	(mg/kg)	(mg/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)
Toxicity	197	315	3.5	16770	875	2355	245	515
Event Statistics Mean	366	1212	1	10191	1763	1692	108	477
90%ile	807	2739	1	28184	4876	4679	299	1319
95%ile	1024	3736	2	56234	9729	9335	596	2632
99%ile	1436	6510	3	112202	19411	18626	1189	5251

Detailed results for this step include:

- the predicted frequency of threshold exceedances
- the statistics of predicted pollutant concentrations
- threshold values used in the assessment of runoff quality

N.B. *Not all the results presented are used in determining the acceptance of the impact. See* *Results used in assessing risks* *for more detail.*

Step 2

In this step, the model checks whether the impacts of the pollutants (with no mitigation) on the receiving watercourse are acceptable or not. If acceptable at this step, then no further assessment is required.

In River (no mitigation)

Step 2

		Copper	Zinc
		RST24	
Allowable Exceedances/year		2	2
No. of exceedances/year		**0**	**0**
No. of exceedances/worst year		0	0
No. of exceedances/summer		0	0
No. of exceedances/worst summer		0	0
		RST6	
Allowable Exceedances/year		1	1
No. of exceedances/year		**0**	**0**
No. of exceedances/worst year		0	0
No. of exceedances/summer		0	0
No. of exceedances/worst summer		0	0
Annual average concentration (ug/l)		0.01	0.03
		(ug/l)	(ug/l)
Thresholds	RST24	21	60
Thresholds	RST6	42	120
Event Statistics Mean		0.09	0.23
90%ile		0.24	0.58
95%ile		0.36	0.84
99%ile		0.80	2.22

Step 2

Velocity	**0.03**	m/s
DI	**18.70**	
% settlement needed	0	%

Tier 1 is used for the calculation

For the acute impacts, the type of results presented in the detailed results are similar to those in step 1 but are for the pollutants in the receiving river/stream. By comparing these results to the step 1 results, the user can gauge the reduction in soluble concentrations and in threshold exceedances achieved by dilution in the receiving watercourse.

An annual average concentration calculation (for dissolved copper and zinc) is also carried out at this step and reported here.

For the chronic impacts, the flow velocity of the receiving stream and the Deposition Index (DI) (which are used in sediment risk assessment) are reported. See the logic chart for how they are used. Also reported is the percentage settlement needed for the runoff to meet the low deposition criteria. For documentation, the Tier used in estimating stream flow velocity is recorded in the detailed results section of Step 2.

N.B. *Not all the results presented are used in determining the acceptance of the impact. See Results used in assessing risks for more detail.*

Step 3

In this step, the model checks the change in impacts as a result of mitigation.

In River (with mitigation)	Step 3				
		Copper	Zinc		
		RST24			
Allowable Exceedances/year		2	2		
No. of exceedances/year		**0.00**	**0.00**		
No. of exceedances/worst year		0	0		
No. of exceedances/summer		0	0	DI	9.35
No. of exceedances/worst summer		0	0		
		RST6			
Allowable Exceedances/year		1	1		
No. of exceedances/year		**0.00**	**0.00**		
No. of exceedances/worst year		0	0		
No. of exceedances/summer		0	0		
No. of exceedances/worst summer		0	0		
Annual average concentration (ug/l)		0.01	0.02		
		(ug/l)	*(ug/l)*		
Thresholds resholds	*RST24*	21	60		
Thresholds	*RST6*	42	120		
Event Statistics Mean		0.05	0.12		
90%ile		0.12	0.29		
95%ile		0.18	0.42		
99%ile		0.40	1.11		

The type of results presented for this step are similar to those of step 1 and 2 but are only for the soluble pollutants in the receiving river course after mitigation. By comparing these results to the step 2 results, the user can gauge the extent of in-stream concentration reduction caused by the mitigation applied.

The annual average concentration calculation (for dissolved copper and zinc) is repeated at this step and reported here.

For sediment-bound pollutants, the reduced DI following settlement is reported.

N.B. *Not all the results presented are used in determining the acceptance of the impact. See* *Results used in assessing risks* *for more detail.*

8.3 Details of chosen rainfall site

The details of chosen rainfall site used for the assessment are recorded in the detailed results sheet for reference only. For example, if rainfall site Ashford is chosen, the following details will be given in the detailed results sheet.

Details of the chosen rainfall site	
SAAR (mm)	710
Altitude (m)	50
Easting	6012
Northing	1427
Coastal distance (km)	15

8.4 Results used in assessing risks

Not all the model estimations shown in the Detailed Results are used in the assessment process presented on the Interface worksheet. The figures used are:

- the number of exceedances per year for judging threshold breaches (for acute and chronic impact assessment)
- stream flow velocity for assessing sediment accumulation (for chronic impact assessment)
- the deposition index for estimating the extent of sediment deposition (for chronic impact assessment)
- the annual average concentration for judging compliance with the EQS.

These figures are key assessment results and are bolded and yellow highlighted. Other figures given by the tool are for information only and will be useful in gauging the reduction of pollutant impact when compared to other steps or if the assessment needs to be referred for more specialist judgement.

The risk for each pollutant is determined by comparing these key assessment results to the thresholds. Refer to Assessment Thresholds for more details.

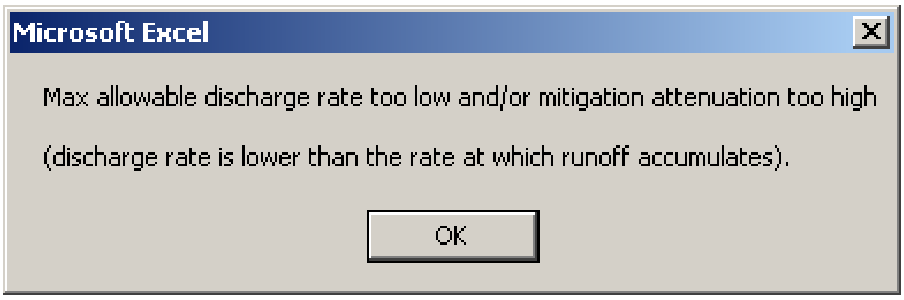
8.5 Annual average concentrations

The tool calculates the annual average concentration for dissolved copper and dissolved zinc only. This calculation assumes that the whole simulation period is divided into (a) the event periods when the river concentration is as calculated earlier (mixed in-river concentrations) and (b) the intervening non-event periods when the river concentration is equal to the upstream river concentration. The annual average concentration is calculated as a time-weighted average of the river concentration during individual discharging event periods and non–event periods:

$$\begin{aligned}&Annual\ average\ concentration =\\ &\left[\sum\left(Mixed\ in\text{-}River\ Concentration * Event\ Runoff\ Discharge\ Duration\right) +\right.\\ &\left.Upstream\ River\ Concentration * \sum Non\text{-}event\ Duration\right] / \left[Total\ Hours\right]\end{aligned}$$

The total non–event duration is calculated by subtracting the total event runoff discharge duration from the total number of hours in the simulation period.

N.B. *The total non-event duration cannot be less than zero, i.e. the total attenuated discharge duration cannot be greater than the total number of hours in the simulation period. As such for a given site with a specific set of rainfall events, there is a maximum degree of attenuation that can be practically achieved. If the user enters values that cause this to happen, the following message will pop up.*



9. Other Utilities

The tool has the following additional utilities:

- Spillage Risk Assessment methodology
- Groundwater Assessment methodology

9.1 Assessing risk levels from accidental spillage

The HE Spillage risk assessment tool is incorporated within HEWRAT. When a run is saved, the sheet below is saved in the results spreadsheet, and associated user inputs are saved in a .csv document.

highways england | View Parameters | Reset Spillage Risk | Go To Interface

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

			Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type								
D2	Length of road draining to outfall *(m)*								
D3	Road Type *(A-road or Motorway)*								
D4	If A road, is site urban or rural?								
D5	Junction type								
D6	Location (response time for emergency services)								
D7	Traffic flow (AADT two way)								
D8	% HGV								
D8	Spillage factor *(no/10⁹ HGVkm/year)*								
D9	Risk of accidental spillage	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000		
D10	Probability factor								
D11	Risk of pollution incident	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000		
D12	Is risk greater than 0.01?								
D13	Return period without pollution reduction measures	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0000	#DIV/0!
D14	Existing measures factor								
D15	Return period with existing pollution reduction measures	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0000	#DIV/0!
D16	Proposed measures factor								
D17	Residual with proposed Pollution reduction measures	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0000	#DIV/0!

Justification for choice of existing measures factors:

Justification for choice of proposed measures factors:

For further details on how to use this function in the tool, please refer to the Highways England Design Manual for Roads and Bridges, Volume 11, Section 3, Part 10, 'Road Drainage and the Water Environment' (Highways England, 2016).

9.2 Assessing risk levels to groundwater

The HE Groundwater assessment tool is incorporated within HEWRAT. When a run is saved, the sheet below is saved in the results spreadsheet, and associated user inputs are saved in a .csv file.

highways england

Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	15	Traffic density		#N/A	#N/A
2		15	Rainfall volume (annual averages)		#N/A	#N/A
3	PATH WAY	15	Soakaway geometry		#N/A	#N/A
4		20	Unsaturated zone		#N/A	#N/A
5		20	Flow type		#N/A	#N/A
6		5	Clay Content of Unsaturated Zone		#N/A	#N/A
7		5	Organic Carbon		#N/A	#N/A
8		5	Soil pH		#N/A	#N/A

TOTAL SCORE	#N/A
RISK SCREENING LEVEL	#N/A

10. File Management

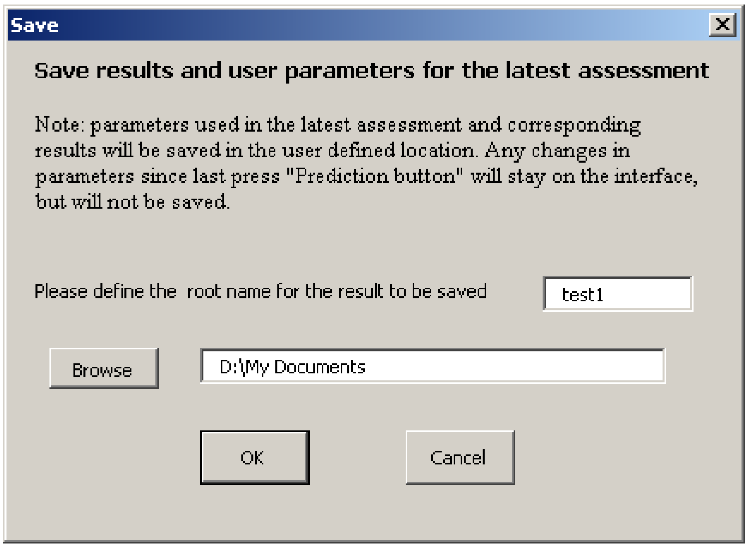
The tool has been developed with facilities for file management of results and input parameters.

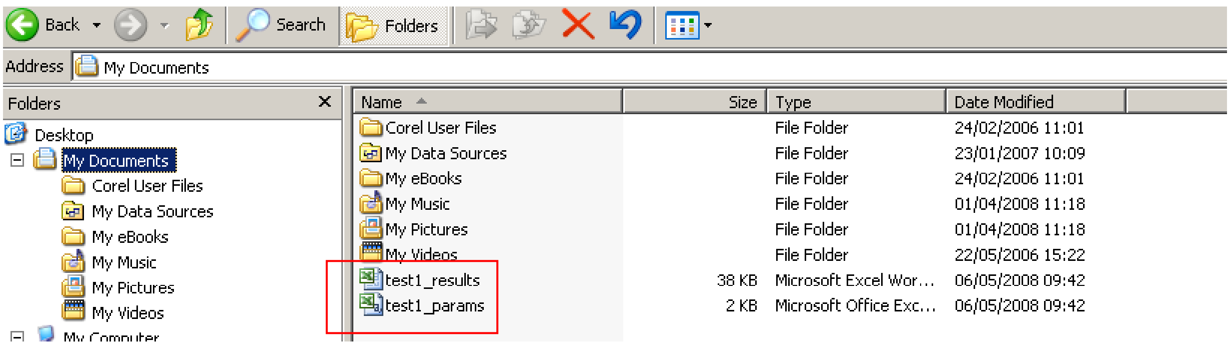
The file management options accessible from the HEWRAT menu, popup menus and command buttons on the Interface worksheet are set out below.

10.1 Save Results & Parameters

The tool allows the user to save the detailed results along with the user parameters as .csv files in a user defined location.

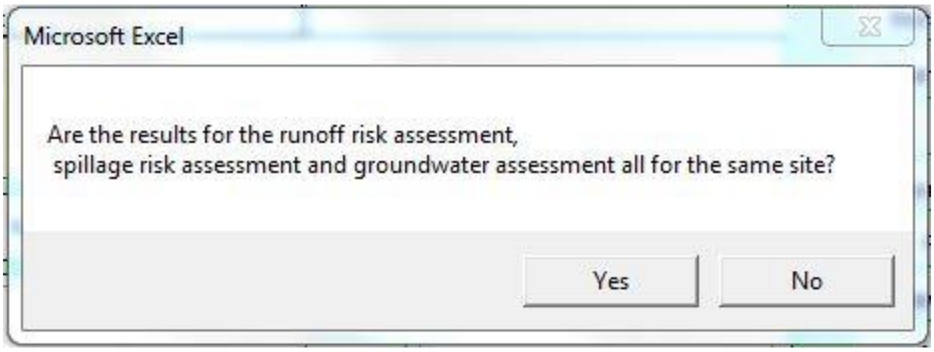
Selecting ‘Save Results & Parameters’ opens the ‘Save’ dialog, on which the user defines the root name and location for the results files to be saved.





An Excel workbook (.xlsx file) and a .csv file are saved in the user defined location after confirming the save using <OK>. The Excel workbook is named in the form of ‘root name_results’ and comprises a copy of the detailed results and user parameters of the saved run. The .csv file named in the form of ‘root name_params’ comprises the user parameters as currently displayed in the tool. This .csv file can be used to repopulate the tool (by the ‘Open Parameters csv File’ option) if a user wants to revisit a previous assessment.

N.B. *If runoff risk assessment, spillage risk assessment and groundwater assessment are carried out for the run to be saved, the following message box will pop up before showing the ‘Save’ dialog. A <Yes> response is needed for the results saving to proceed. This is to avoid any later confusion when the results are inspected at a later stage.*



N.B. To save results, the HEWRAT ‘Save Results & Parameters’ option should always be used. Saving the workbook using the Excel application File → Save ***DOES NOT preserve current results or parameters, because the workbook is reset to default values on being opened.*** If, however, the user selects File → Save a warning message will be displayed which will prompt the user to use the HEWRAT ‘Save Results & Parameters’ option if that was intended.

10.2 Document data source

This option allows a user to both inspect the current user parameter values and to provide notes to explain/justify any of the data entries. This is likely to be needed at a final stage in assessment to provide an audit trail. These notes will get saved when the ‘Save Results & Parameters’ option is used. ‘Document data source’ opens the User Parameters worksheet, which is illustrated below.

User parameters	Back To Top	Go To Interface	Go To Spillage Risk	Go To GW Assessment	Clear All Notes

Location Details

Road Number			**Assessment type**	Non-cumulative assessment (single outfall)
HA Area/DBFO number				
OS grid reference of assessment point (m)	**Easting**		**Receiving watercourse**	
	Northing		**EA receiving water Detailed River Network ID**	
OS grid reference of outfall structure (m)	**Easting**		**Assessor and affiliation**	
	Northing		**Date of assessment**	
Outfall number			**Version of assessment**	
List of outfalls in cumulative assessment				
Notes				

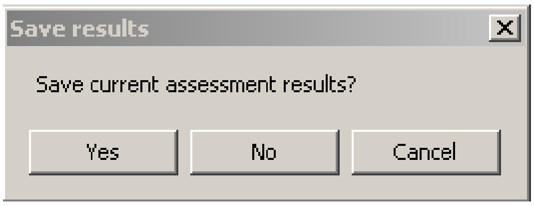
Parameter	Units	Default Value	Value used	Notes	
Runoff Risk Assessments					
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***		
Climatic Region	-	Warm Dry	***Warm Dry***		
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***		
Q95 River flow	m3/s	0	***0***		
Baseflow Index	-	0.5	***0.5***		
Impermeable road area drained	ha	1	***1***		
Permeable area draining to outfall	ha	0	***0***		
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***		
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***		
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***		
Use Tier 1	-	TRUE	***TRUE***		
Use Tier 2	-	FALSE	***FALSE***		
Tier 1 Estimated river width at Q95	0	5	***5***		
Tier2 Bed width	m	3	***3***		
Tier2 Side slope	m/m	0.5	***0.5***		
Tier2 Long slope	m/m	0.0001	***0.0001***		
Tier2 Mannings' n	-	0.07	***0.07***		
Existing treatment for solubles	%	0	***0***	***Description for existing measures***	
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Existing settlement of sediments	%	0	***0***		
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***	
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Proposed settlement of sediments	%	0	***0***		
EQS, bio avail dissolved Cu	ug/l	1	***1***		
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***		
Spillage Risk Assessments					
A MainRoad					
Water body type	-	-			
Length of road draining to outfall	m	-			
Road Type (A-road or Motorway)	-	-			
If A road, is site urban or rural?	-	-			
Junction type	-	-			
Location	-	-			
Traffic flow (AADT two way)	-	-			
% HGV	-	-			
Spillage factor	no/109HGVkm/year	-			
Existing measures factor	-	-			
Proposed measures factor	-	-			
B					
Water body type	-	-			
Length of road draining to outfall	m	-			
Road Type (A-road or Motorway)	-	-			
If A road, is site urban or rural?	-	-			
Junction type	-	-			
Location	-	-			
Traffic flow (AADT two way)	-	-			
% HGV	-	-			
Spillage factor	no/109HGVkm/year	-			
Existing measures factor	-	-			
Proposed measures factor	-	-			

C				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
D				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
E				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
F				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
Justification for choice of existing measures factors				
Justification for choice of proposed measures factors				
Groundwater Assessments				
Traffic density	-	-		
Rainfall volume (annual averages)	-	-		
Soakaway geometry	-	-		
Unsaturated zone	-	-		
Flow type	-	-		
Clay Content	-	-		
Organic Carbon	-	-		
Soil pH	-	-		
Runoff Risk Assessments (continued)				
Ambient background concentration, dissolved copper	ug/l	0	***0***	

N.B. *The 'value used' column on the User Parameters worksheet will only automatically update after 'Predict Impact' has been performed.*

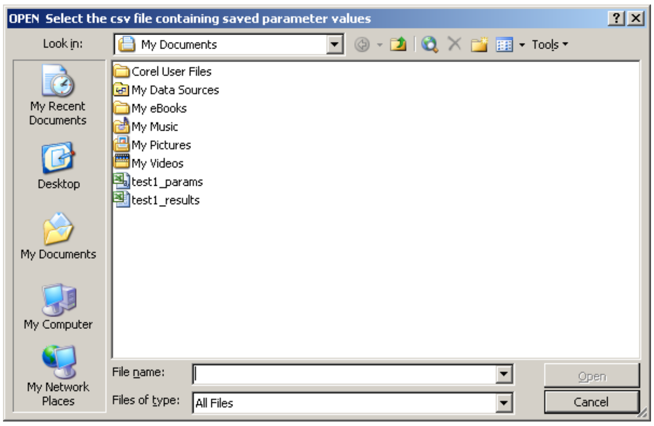
10.3 Open Parameters csv File

This option allows a user to identify an existing .csv file that has been previously saved, and to populate the tool with the previous saved user parameters. When selected, the user is first asked if the current assessment results need saving:



If 'Yes', the 'Save' dialog is displayed as in 'Save Results & Parameters' option.

If 'No', a browse window comes up to allow the user to select the .csv file containing the previously saved user parameter values and the tool is then populated with these. The data source notes in the selected .csv file are also written to the User Parameters worksheet.



10.4 Compatibility with earlier versions

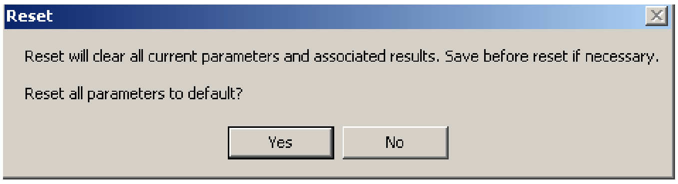
In v1.0, the default 'Attenuation for solubles' under Step 3 Mitigation was 'Unlimited'. This was changed to 'No restriction' in v2.0. The tool automatically substitutes 'No restriction' for 'Unlimited' if necessary when opening a .csv file saved from an earlier version.

In v1.0, EQS values for dissolved copper and zinc were not part of the tool. V2.0 automatically imposes the default EQS values if necessary when opening a .csv file saved from an earlier version.

In v1.0, results and parameters were saved in Excel 97-2003 format .xls files. V2.0 saves files in .xlsx format files compatible with Excel 2007 onwards. Saved results files from v2.0 are not compatible with Excel 2003.

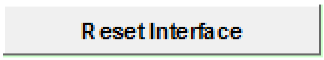
10.5 Reset Workbook

This option clears existing entered values on all user-entry worksheets (Interface, Spillage Risk, Groundwater Assessment and User Parameters) and resets the tool to the default values (as if the tool has just been opened). A warning message is given as below.

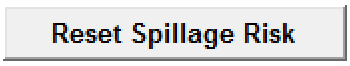


Each user-entry worksheet can be individually reset using the appropriate button on the worksheet or equivalent popup menu item:

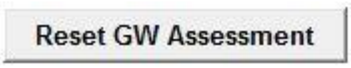
On the Interface worksheet (this will also reset the User Parameters worksheet):



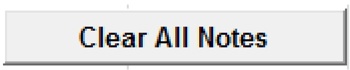
On the Spillage Risk worksheet:



On the Groundwater Assessment worksheet:



On the User Parameters worksheet:



11. Maintaining the Tool

The Assessment Parameters and rainfall data series can all be reviewed or extended.

11.1 View/Editing the Assessment Parameters

The tool includes a range of fixed values which are used each time an assessment is carried out. These 'Assessment Parameters' can be reviewed on the Assessment Parameters worksheet by all users and amended by an Administrator if further experience and/or research justifies this.

The Assessment Parameters in the tool can be grouped into three categories:

11.1.1 User parameters – defaults and ranges

Default, minimum and maximum values are defined for most user parameters. The default value is applied when the tool is first opened or Reset, and the minimum and maximum values are used to validate user-entry values to prevent unrealistic values being entered. An Administrator can change the default, minimum and maximum values.

N.B. *The default for the Annual Q_{95} river flow and for the mitigation options should be left at 0; this ensures that the tool defaults to Step 1 when first opened.*

The default values and validation ranges in the tool are as follows:

User Parameters – Defaults and Ranges

Params	Unit	Default	Min	Max
AADT	vpd	>10,000 and <50,000	-	-
Climatic Region	-	Warm Dry	-	-
Rainfall Site	-	**Ashford (SAAR 710mm)**	-	-
95%ile River flow	m^3/s	0	0	50
Baseflow Index	-	0.5	0	1
Impermeable road area drained	ha	1	0	1000
Permeable area draining to outfall	ha	1	0	1000
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	-	-
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	-	-
Hardness	-	Low = <50mg $CaCO_3$/l		
Use Tier 1	-	TRUE	-	-
Use Tier 2	-	FALSE	-	-
Tier 1 Estimated river width at Q_{95}	0	5	0	500
Tier2 Bed width	m	3	0	500
Tier2 Side slope	m/m	0.5	0.1	10
Tier2 Long slope	m/m	0.0001	0.000001	0.1
Tier2 Mannings' n	-	0.07	0.01	1
Existing treatment for solubles	%	**0**	0	100
Proposed treatment for solubles	%	**0**	0	100
Existing attenuation -restricted discharge rate	l/s	**Unlimited**	0	1E+12
Proposed attenuation -restricted discharge rate	l/s	**Unlimited**	0	1E+12
Existing settlement of sediments	%	**0**	0	100
Proposed settlement of sediments	%	**0**	0	100
Water body type	-	-	-	-
Length of road draining to outfall	m	-	0	10000000
Road Type (A-road or Motorway)	-	-	-	-
If A road, is site urban or rural?	-	-	-	-
Junction type	-	-	-	-
Location	-	-	-	-
Traffic flow (AADT two way)	-	-	0	100000000
% HGV	-	-	0	100
Spillage factor	no/10^9HGVkm/year	-	0	5.35
Existing measures factor	-	-	0	1
Proposed measures factor	-	-	0	1

***N.B.** When adjusting the default rainfall site, the administrator must ensure that the new rainfall site is within the current default climatic region.*

11.1.2 Thresholds

The toxicity thresholds are related to the RSTs, TELs and PELs. They also include the allowable exceedance frequencies used with these concentration thresholds to determine the traffic light assessment. These thresholds may need to be reviewed in future in light of further experience and research on the ecological impacts at monitored sites.

Acute Impact Thresholds

Concentration thresholds

Threshold Name	Cu ug/l	Zn ug/l Hardness		
		Low = <50mg CaCO3/l	Medium = 50-200 CaCO3/l	High = >200mg CaCO3/l
RST24hr	21	60	92	385
RST6hr	42	120	184	770

Allowable frequence of exceedances for Step 1

Thresholds	Max number of exceedances allowed per year
>RST24hr	1

Allowable frequence of exceedances for Step 2

	Max number of exceedances allowed per		Traffic light assessment	
	>RST24hr	>RST6hr	Both criteria met	Either criteria failed
Non-SAC	2	1	**Green**	**Red**
SAC/SPA	1	0.5	**Green**	**Red**

Chronic Impact Thresholds

Toxicity thresholds

Substance	Copper	Zinc	Cadmium	Total PAH	Pyrene	Fluoranthene	Anthracene	P
Unit	(mg/kg)	(mg/kg)	(mg/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	
Threshold value	*197*	*315*	*3.5*	*16770*	*875*	*2355*	*245*	

Allowable frequence of exceedances for toxicity threshold (for Step 1)

Max number of exceedances allowed in 1 year	Copper	Zinc	Cadmium	Total PAH	Pyrene	Fluoranthene	Anthracene	P
	1	1	1	1	1	1	1	

Threshold mean velocity Vt	0.1	m/s
Deposition Index (DI) threshold	100	

Threshold mean velocity – if the low flow velocity at a site is less than this threshold, the site is assumed to be an accumulating site; if it is greater than this threshold, the site is assumed to be dispersive. When calculating velocities, 'Low flow' is taken as either the Q_{90} flow (Tier 2) or the Q_{95} flow (Tier 1).

Deposition Index Threshold – used to assess whether the amount of sediment deposition is high.

The thresholds defined in the first release of the tool are described in the Assessment Thresholds section.

11.1.3 Other parameters

Other parameters include:

The start and end months of summer period

These parameters define the 'summer' as used in the 'No. of exceedances per summer' in the detailed results.

N.B. *If the assessor is interested in threshold exceedances for a particular period of the year, he/she can obtain such information by setting the 'summer' period to his/her interested period and check results displayed for 'summer' in the detailed results view.*

Assumptions used in runoff calculation

- Rainfall initial loss – the initial depth of rainfall that is retained by the road surface and would not generate any runoff; and
- Runoff coefficients – the percentage of precipitation after initial loss that appears as runoff for impermeable and permeable areas respectively.

Dissolved copper and dissolved zinc concentration in upstream river

- For runoff impact assessment - the 'natural background' concentration in the receiving watercourse exclusive of any road runoff. The natural background assumes no other upstream anthropogenic inputs of dissolved copper or dissolved zinc; and
- For annual average concentration calculation – the upstream dissolved copper and dissolved zinc concentration of the receiving watercourse exclusive of any road runoff from the site being assessed.

N.B. As agreed with the Environment Agency during development of the tool, the background and upstream concentrations are set to zero. This enables an assessment of the added risk rather than total risk, i.e. the additional risk to organisms in the receiving water when they are exposed to road runoff. An administrator can set different upstream concentration values for the runoff impact assessment and annual average concentration calculation. If different values are set, the tool will pick up the associated values for the corresponding calculation. In version v2.0 of the tool, users are able to enter a value of the upstream dissolved copper concentration, which impacts the annual average concentration calculation for copper, on the Interface worksheet.

Factors used in the sediment calculations and results display

- Median EMC for SS – the assumed suspended solid concentration in the highway runoff which is used in the estimation of annual average sediment load;
- Event Selection Type – defines the method used by the model to calculate the annual average sediment load;
- Density of the sediment – the assumed density of the sediment in highway runoff; and
- The marginal range within which the 'Accumulation' and 'Extensiveness' related results are displayed with an Amber background on the Interface worksheet (N.B. This is for results display only, and does not affect the results calculation).

Spillage Risk Parameters

- Probability of a Serious Pollution Incident occurring as a result of a serious accidental spillage – depending on the size and remoteness of the watercourse.

These parameters may need changing if the risk assessment procedures are updated.

The parameters are defined in v2.0 of the tool as follows:

Other Parameters

Summer period (inclusive)

Summer Start Month	4	Summer End Month	9

Runoff calculation assumptions

Rainfall Initial Loss	1	mm

Concentrations in upstream river (for runoff impact assessments)

Dissolved copper	0	ug/l
Dissolved zinc	0	ug/l

Concentrations in upstream river (for annual average concentration calculation)

Dissolved copper	0	ug/l
Dissolved zinc	0	ug/l

Runoff coefficients

Impermeable areas	Permeable areas
0.5	0.1

Sediment calculation factors

Median EMC for SS	139	mg/l		
Event Selection Type	2		***1 - All***	***2- Below Threshold mean velocity***
Density of the sediment	2000	kg/m3		

Display the "Accumulation" and "Extensive" cells on the interface in Amber if the velocity/percentage coverage is within ± | 10 | % of the threshold value

Spillage Risk Parameters

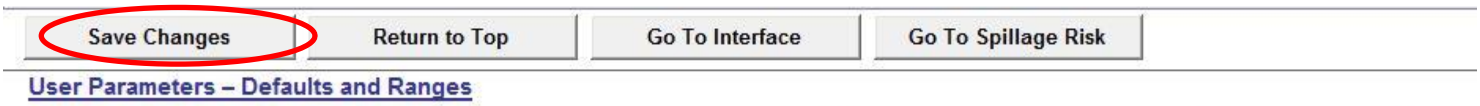
Probability of a Serious Pollution Incident occurring as a result of a serious accidental spillage

Receiving Water	Urban (response time to site < 20 min)	Rural (response time to site < 1 hour)	Remote (response time to site > 1 hour)
Surface watercourse	0.45	0.60	0.75
Groundwater	0.45	0.60	0.75

11.2 How to view or edit assessment parameters

The Assessment Parameters can be viewed by a User and altered by an Administrator through 'View/Edit Fixed Params' option of the HEWRAT menu, popup menus, or <View/Edit Fixed Params> button on the Interface worksheet.

To alter the fixed parameters, the user needs to log into the tool as an Administrator and confirm the changes using the <Save Changes> button (or equivalent option on the popup menu) for the adjustments to take effect.



Params	Unit		Default	Min	Max
AADT	vpd		>10,000 and <50,000	-	-
Climatic Region	-		Warm Dry	-	-
Rainfall Site	-		Ashford (SAAR 710mm)	-	-

N.B. *The changes to the assessment factors confirmed by <Save Changes> button take effect immediately, therefore the tool doesn't need closing and reopening to pick up the change. If the tool is being used by a User, the <Save Changes> button will be greyed out.*

11.3 Adding rainfall sites

11.3.1 Authority and data required

There are 21 rainfall sites in v2.0 of the tool. However, the number of sites can be increased by an Administrator if the necessary data are available.

To add an additional rainfall site to the tool, the following data series are required:

- Site information
  i.e. site name, altitude, grid reference, distance to the coast, SAAR, and climatic region. This information will be shown on the Interface worksheet when the site is selected.

- Data series of rainfall events and associated unit river flow rates for receiving watercourse
  i.e. date of the event, total rain, rain duration, mean intensity, maximum hourly intensity, preceding 10 days' rain, preceding 20 days' rain, antecedent dry weather period, unit river flow with BFI at 0.1, 0.2 …0.9. The total period of the event data and the number of events are also needed.

- Low river flow rates at different BFIs
  i.e. Q_{90} and Q_{95} at BFI 0.1, 0.2 … 0.9 based on the above series.

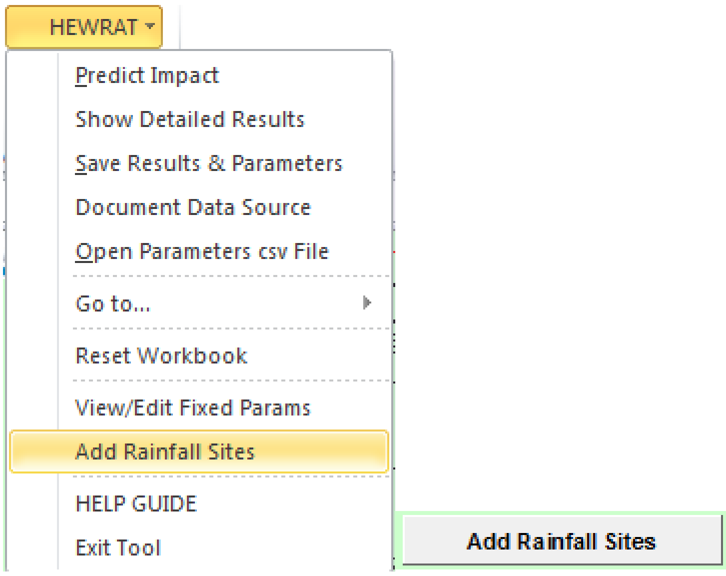
The river flow estimates must all be based on some assumed unit catchment size, say 10 ha. The actual size does not matter because the flows will be factored using the annual Q_{95} river flow entered by the user.

N.B. *It should be noted that although the StormPac software was used to create the rainfall series for the first release, there is no reason why historical series or rainfall series generated by other methods or tools could not be used. The important thing is that the series created provides an adequate expression of the long term variability of rainfall close to a particular highway site being investigated*

11.3.2 How to add an additional site

N.B. *Once a new rainfall site has been added to the tool it can only be deleted by a Developer. If it is required to preserve an unaltered copy, make a copy of the file before opening it or, if already open, use Excel's File → Save As command before entering the new site data.*

- **Log in as an Administrator**
  'Add Rainfall Sites' option is visible on the HEWRAT menu and popup menus, and the <Add Rainfall Sites> command button is visible on the Interface worksheet, if logged in as an Administrator.



N.B. *'Add Rainfall Sites' option does not appear on the HEWRAT menu or popup menus if logged in as a User.*

- **Access template**

After the ‘Add Rainfall Sites’ option is selected, the Template worksheet becomes the active view. The Template worksheet sets out the information needed to add an additional rainfall site to the tool and presents the layout of the data.

Add data series to the tool | Cancel adding and return to interface | Save data on the template to csv

Site information for the additional site

Site Name	Altitude (m)	GR	Easting	Northing	Coastal Distance (km)	SAAR (mm)	Climatic Region

- **Fill the template**
  The data needed can either be entered to the template by direct input or by pasting from other sources. The following is part of the completed template for the Ashford site for illustration.

N.B. *Event data must be in chronological order to get a correct prediction*

Site information for the additionall site

Site Name	Altitude (m)	GR	Easting	Northing	Costal Distance(k	SAAR (mm)	Climatic Region
Ashford	50	TR012427	6012	1427	15	710	Warm Dry

Flow rates of receiving water course for the additional site

Baseflow Index	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
95%ile low flow (m3/s) at different BFIs	0.003024251	0.005438396	0.00770133	0.009854936	0.01195748	0.013983357	0.015943086	0.017823227	0.019532789
90%ile low flow (m3/s) at different BFIs	0.004150466	0.007311265	0.010260522	0.012973469	0.015518258	0.017955216	0.020258686	0.022384029	0.024238331

Event data series for the additonal site

Event data period (yrs)	10	No. of events	779

Date	Total Rain (mm)	Rain Duration (hrs)	Mean Intensity (mm/hr)	Max Hourly Intensity (mm/hr)	Preceding 10 days' rain (mm)	Preceding 20 days' rain (mm)	Antecedent Dry Weather Period (hrs)
01/01/2020	19.2	24	0.8	3.3	5	5	15
03/01/2020	4.6	3	1.5	2	19.2	19.2	12
04/01/2020	8.7	31	0.3	3.6	23.8	23.8	22
13/01/2020	9.3	54	0.2	1.3	13.3	32.5	70
19/01/2020	1.3	2	0.7	0.8	9.3	41.8	104
21/01/2020	25.6	27	0.9	4	10.6	43.1	42
29/01/2020	2.2	9	0.2	0.8	26.9	36.2	15
03/02/2020	7	36	0.2	1.7	2.2	29.1	15
07/02/2020	2.3	3	0.8	1.3	9.2	36.1	65
14/02/2020	2.3	9	0.3	1.6	2.3	11.5	153
17/02/2020	8.8	23	0.4	2.7	4.6	13.8	72
20/02/2020	16.7	52	0.3	1.7	11.1	20.4	49
25/02/2020	5.7	8	0.7	1.8	25.5	30.1	64
28/02/2020	1.9	7	0.3	0.8	22.4	33.5	67
07/03/2020	2.4	15	0.2	1.2	1.9	33.1	58
10/03/2020	9.4	7	1.3	2.4	60	26.7	59

Date	River Flow with BFI at 0.1 m3/s	River Flow with BFI at 0.2 m3/s	River Flow with BFI at 0.3 m3/s	River Flow with BFI at 0.4 m3/s	River Flow with BFI at 0.5 m3/s	River Flow with BFI at 0.6 m3/s	River Flow with BFI at 0.7 m3/s	River Flow with BFI at 0.8	River Flow with BFI at 0.9
01/01/2020	0.136359141	0.155998362	0.175725467	0.195470455	0.215289765	0.235167875	0.255078131	0.275012	0.294964
03/01/2020	0.87271926	0.81640895	0.75725077	0.701438806	0.64553467	0.588512681	0.53051163	0.474341	0.41777
04/01/2020	0.524102304	0.508840511	0.494518203	0.479149997	0.462641318	0.447127624	0.432367816	0.415882	0.400168
13/01/2020	0.03138599	0.061253861	0.091130037	0.121007	0.150883278	0.180758526	0.210632955	0.240506	0.270379
19/01/2020	0.03107658	0.055238515	0.079464953	0.10371764	0.127984325	0.15225939	0.176540144	0.200824	0.225112
21/01/2020	0.030612023	0.052557004	0.074583796	0.09664483	0.118723702	0.14081749	0.162917075	0.185018	0.207122
29/01/2020	0.038931993	0.062077951	0.085268974	0.108488513	0.131728907	0.15498831	0.178262713	0.201562	0.224907
03/02/2020	0.032463851	0.051230006	0.070143079	0.089110757	0.108105135	0.12711012	0.146118572	0.165131	0.184144
07/02/2020	0.039305704	0.055102814	0.070990524	0.086931781	0.10290852	0.118910596	0.134931662	0.150968	0.167016
14/02/2020	0.013741748	0.027289154	0.040831651	0.054370845	0.067907672	0.081442709	0.094976439	0.108509	0.12204
17/02/2020	0.014392629	0.025761638	0.037167714	0.048588546	0.060017003	0.071450013	0.082886133	0.094324	0.105764
20/02/2020	0.03219794	0.040902355	0.049664747	0.058466384	0.06729635	0.076147996	0.08501656	0.093897	0.10279
25/02/2020	0.050811407	0.061770478	0.072788342	0.083848858	0.0949417	0.106059535	0.117198619	0.128355	0.139525
28/02/2020	0.034470259	0.046450193	0.058505534	0.070608004	0.082742684	0.094899603	0.107075608	0.119266	0.131467
07/03/2020	0.01048764	0.020093052	0.029709517	0.039328936	0.048949349	0.058570024	0.068190729	0.077811	0.087432
10/03/2020	0.012886597	0.02091068	0.028984304	0.037081193	0.045191349	0.05331006	0.061434666	0.069564	0.077696

- **Add additional data to the tool**
  When the template has been filled, click the <Add data series to the tool> button at the top of the worksheet, or the ‘Add data series to the tool’ option of the popup menu.

  The data to be incorporated in the tool will be validated first. If data entered are all valid then the process will proceed and the following message will be given upon completion.

If some data are not valid, a new data series will not be created and a message with information about the invalid data will be given, e.g.

- **Cancel adding an additional rainfall site**
  If for whatever reason an Administrator wants to stop the adding process after accessing the template, he/she can achieve this by clicking the <Cancel adding and return to interface> button (or equivalent popup menu option). A message (shown below) will appear asking for confirmation in order to prevent accidental cancellation. If cancellation is confirmed, all the data an Administrator has entered will be cleared and the view will be switched to the Interface worksheet.

N.B. *Cancellation can only be done before the <Add data series to the tool> button (or equivalent popup menu option) is clicked. Once this button is clicked and no validation message comes up, the data series for the new site will be incorporated into the currently-open copy of the tool and the site can only be deleted by a Developer. If it is required to preserve an unaltered copy, use the Excel's File → Save As command before entering the new site data.*

The <Save data on the template to csv> command button (or popup menu option) enables the data on the Template worksheet to be saved to a csv file.

12. Accessibility

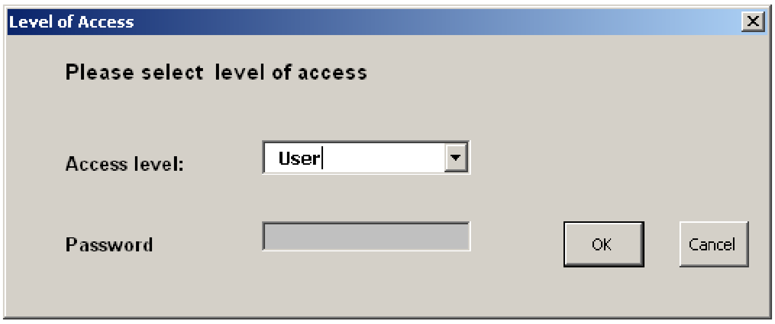
The assessment tool is password protected with 3 levels of accessibility – User, Administrator, Developer.

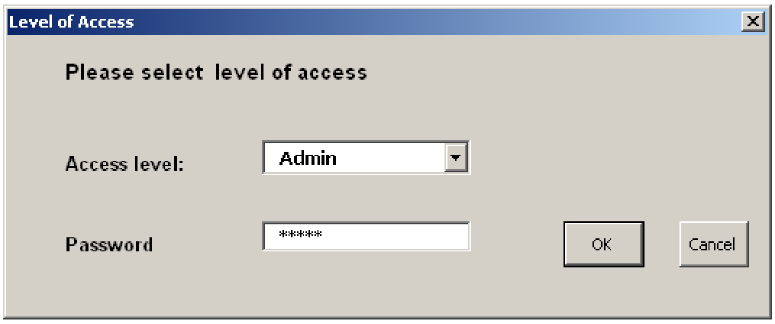
- The **User** is able to use the tool to make assessments and manage input data and results, as described here. A User has access to the Interface, Spillage Risk and Groundwater Assessment and User Parameter worksheets for data entry. The User does not have the authority to adjust any of the standards/thresholds or other default parameter settings but is able to view these.

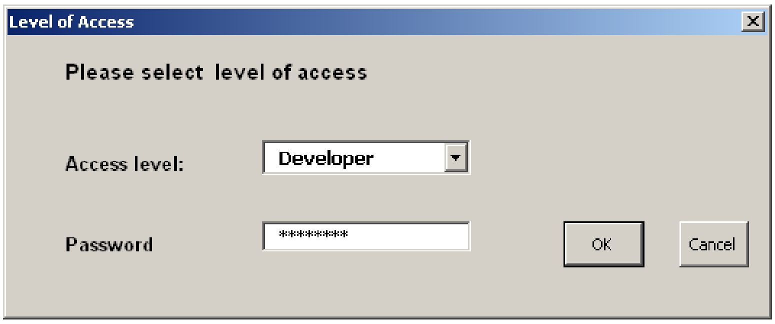
- The **Administrator** can view and change the Assessment Parameter worksheet that holds the default values for the standards/thresholds and other parameters. An Administrator can also add worksheets for additional rainfall sites.

- The **Developer** has full access of the assessment tool including the code and hidden worksheets used in the calculation of runoff quality.

On opening the application, a box will pop up asking for the user type. If ‘User’ is chosen from the dropdown list, no password is required. If ‘Admin’ or ‘Developer’ is chosen, passwords are needed.






Level of Access
Please select level of access
Access level:
Developer
Password
****
OK
Cancel

13. User Parameters

13.1 Water Risk Assessment Tool User Parameters

Name *(ShortName)*	Units	Default	Allowable Range	Notes
Step 1				
Annual Average Daily Traffic *(AADT)*	vpd	>10000 to <50000	>10000 to <50000; >= 50000 and <100000; >=100000	Annual Average Daily Traffic. This is used by the core model equations to generate the predicted pollutant concentrations. **N.B.** *The model was developed based on a sample dataset with AADT ranges from 11000 to 159000 vpd. Therefore, the model may be less applicable for sites outside this range. The results maybe over conservative if the tool is used for less trafficked roads.*
Climatic region *(CR)*	-	Colder Wet	ColderWet ColderDry WarmWet WarmDry	This is used by the core model equations to generate the predicted pollutant concentrations. (maps showing climatic regions)
Rainfall site *(RainSite)*		Ashford	As currently available	The characteristics of the rainfall and unit area river flow data for each rainfall event for the selected site are used by the model in predicting pollutant concentrations in the highway runoff and in the mass balance calculation in the receiving river.
Step 2				
Annual Q_{95} river flow *(95RiverFlow)*	m^3/s	0	0 - 50	The low flow value that is exceeded 95% of the time. This is used by the core model in generating river flow for each rainfall event and is also used in estimating the flow velocity and width for the sediment assessment.
Base Flow Index *(BFI)*	-	0.5	0 - 1	The proportion of river flow from groundwater. This is used by the core model in simulating the river flow for each rainfall event.

Name (ShortName)	Units	Default	Allowable Range	Notes
Impermeable road area drained *(HDA_Imp)*	ha	1	0 - 1000	The impermeable area of the highway draining to the outfall. This is used by the model in calculating the runoff volume for rainfall events.
Permeable area draining to outfall *(HDA_Per)*	ha	1	0 - 1000	The permeable area that contributes runoff to the outfall. This is used by the model in calculating the runoff volume for rainfall events.
Is the discharge in or within 1 km upstream of a protected site for conservation? *(ProtectedSite)*	-	No	Yes No	Is it considered likely that a protected site for nature conservation could be affected by the pollutant concentration or the accumulation of the sediment from highway outfalls? This is used by the core model river impact assessments. See logic flow charts for how this is used.
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100 m of the point of discharge? *(Downstream_Struc)*	-	No	Yes No	Whether there is a downstream flow structure that alters the natural flow velocities and depths at the point of discharge. This factor only affects the sediment (chronic) impact assessment. See logic flow charts for how this is used.
Water hardness *(Hardness)*	-	Low	Low Medium High	The hardness of receiving water body. This parameter only affects the acute impact assessment of dissolved zinc. Depending on the hardness selected, appropriate threshold values are used for the dissolved zinc assessment.
Tier 1 Estimated river width *(RiverWidth)*	m	5	0 - 500	The surface flow width of the stream at the annual Q_{95} river flow, estimated by desk study. This is used by the model in estimating if the sediment from the highway runoff will accumulate in the receiving watercourse and the extent of sediment deposition for the tier 1 assessment of sediment (chronic) impact.

Name *(ShortName)*	Units	Default	Allowable Range	Notes
Tier 2 Bed width *(BedWidth)*	m	3	0 - 500	The bed width of the receiving water stream derived from the measurements during site visit. The channel is assumed to be trapezoidal. This is used by the model in estimating the flow velocity and surface flow width of the stream which are used to estimate if the sediment from the highway runoff will accumulate in the receiving watercourse and the extent of sediment deposition for tier 2 assessment of sediment (chronic) impact.
Tier 2 Side slope *(SideSlope)*	m/m	0.5	0.1 - 10	The side slope of the receiving watercourse derived from measurements made during the site visit. This is used by the model in the same calculation processes as Tier 2 Bed width is used. **N.B.** *For the required site measurements and formulas to derive side slope, please refer to Step 2 data entry notes.*
Tier 2 Long slope *(LongSlope)*	m/m	0.0001	0.000001 – 0.1	The longitudinal slope of the receiving watercourse. This is used by the model in the same calculation processes as Tier 2 Bed width is used. For advice on measuring the long slope, see *Step 2 data entry notes.*
Tier 2 Manning's n *(Mannings_n)*	-	0.07	0.01 - 1	The Manning's roughness coefficient appropriate to the receiving watercourse. This is used by the model in the same calculation processes as Tier 2 Bed width is used. *Please see Notes on Finding Manning's n for guidance on where to look up this coefficient.*

Name *(ShortName)*	Units	Default	Allowable Range	Notes
Freshwater EQS for bioavailable dissolved copper	µg/l	1.0	0.1 - 100	Environmental Quality Standards (EQS) are set by the Environment Agency (EA). This value should not be changed unless the EA have changed the EQS.
Freshwater EQS for bioavailable dissolved zinc	µg/l	10.9	0.1 - 100	Environmental Quality Standards (EQS) are set by the Environment Agency (EA). This value should not be changed unless the EA have changed the EQS.
Ambient background concentration, dissolved copper *(UpRivCu)*	µg/l	0	0 - 50	The upstream dissolved copper concentration. Impacts the annual average concentration calculation if >0.
Step3				
(Existing measures) Treatment for solubles	-	0	0 - 100	The percent reduction in soluble concentrations of the highway runoff by the existing treatment measures. It is expressed as percentage - the larger this value, the more existing treatment measures applied to the discharge. 10% treatment for soluble means that the concentrations are reduced to 90% of the untreated concentration. Existing Treatment for Soluble is not directly used in calculating the acute impact assessment results. However, it has effect on the Proposed Treatment for Solubles which gets used in the result calculations. If the latest entry for the Existing Treatment for Soluble is GREATER than the Proposed Treatment for Solubles, the tool will automatically update the Proposed Treatment for Solubles to the latest entry of the Existing Treatment for Soluble, i.e. the proposed measures should always impose more or equal extent of treatment compared to the existing measures.
(Proposed measures)	-	0	0 - 100	The percent reduction in soluble

Name (ShortName)	Units	Default	Allowable Range	Notes
Treatment for solubles *(%Treatment)*				concentrations of the highway runoff by the proposed treatment measures (which may include all or part of the existing measures). It is expressed as percentage - the larger this value, the more existing treatment measures applied to the discharge. 10% treatment for soluble means that the concentrations are reduced to 90% of the untreated concentration. This user parameter only affects the acute impact assessment. For use of this factor, see Step 3 acute impact calculations.
(Existing measures) Attenuation for solubles – restricted discharge rate	l/s	No restriction	0 - 1E+12	The restricted maximum runoff discharge rate for the outfall by the existing mitigation measures. Existing Attenuation for Solubles is not directly used in calculating the acute impact assessment results. However, it has effect on the Proposed Attenuation for Solubles which gets used in the result calculations. If the latest entry for the Existing Attenuation for Solubles is LESS than the Proposed Attenuation for Solubles, the tool will automatically update the Proposed Attenuation for Solubles to the latest entry of the Existing Attenuation for Solubles, i.e. the proposed measures should always impose more or equal extent of attenuation compared to the existing measures.
(Proposed measures) Attenuation for solubles – restricted discharge rate (Restricted discharge rate)	l/s	No restriction	0 - 1E+12	The restricted maximum runoff discharge rate for the outfall by the proposed mitigation measures (which may include all or part of the existing measures). This user parameter only affects the acute impact assessment. In the model, if the discharge rate exceeds this restricted

Name (ShortName)	Units	Default	Allowable Range	Notes
				discharge rate, the discharge will be capped at the restricted rate and the runoff will occur over a longer period. For use of this factor, see Step 3 acute impact calculations.
(Existing measures) Settlement for sediments	-	0	0 - 100	The percent reduction in the volume of annual sediment discharge from the highway runoff by the existing treatment measures. Existing Settlement for Sediments is not directly used in calculating the chronic impact assessment results. However, it has effect on the Proposed Settlement for Sediments which gets used in the result calculations. If the latest entry for the Existing Settlement for Sediments is GREATER than the Proposed Settlement for Sediments ,the tool will automatically update the Proposed Settlement for Sediments to the latest entry of the Existing Settlement for Sediments, i.e. the proposed measures should always impose more or equal extent of settlement compared to the existing measures.
(Proposed measures) Settlement for sediments *(%Settlement)*	-	0	0 - 100	The percent reduction in the volume of annual sediment discharge from the highway runoff by the existing treatment measures (which may include all or part of the existing measures). It is expressed as percentage - the larger this value, the more proposed settlement applied to the sediment introduced by highway runoff. 10% settlement for sediments means that the amount of annual discharged mass of sediment is reduced to 90% of the untreated amount.

Name (ShortName)	Units	Default	Allowable Range	Notes
				This user parameter only affects the chronic impact assessment. For use of this factor, see Step 3 acute impact calculations.

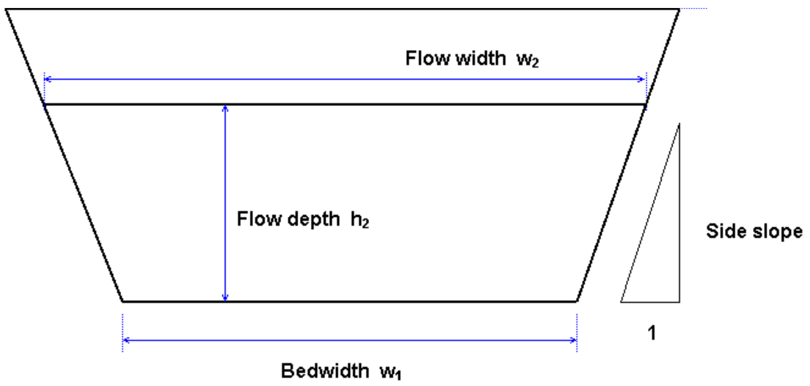
13.2 Spillage Risk Assessment Tool User Parameters

Name	Units	Default	Allowable Range
Water body type	-	-	Surface watercourse Groundwater
Length of road draining to outfall	m	-	0-10,000,000
Road Type (A-road or Motorway)	-	-	M(otorway) A(-road)
If A-road, is site urban or rural?	-	-	Rural Urban
Junction type	-	-	No junction Slip road Roundabout Cross road Side road
Location (response time for emergency services)	-	-	< 20 minutes < 1 hour > 1 hour
Traffic flow (AADT two way)	-	-	0-1,000,000
% HGV	-	-	0-100
Spillage factor	10^9HGVkm/year	-	0-1
Existing measures factor	-	-	0-1
Proposed measures factor	-	-	0-1

14. Notes on Site Measurements for Tier 2 User Inputs

14.1 Bedwidth and side slope

Tier 2 requires bedwidth and side slope estimates to define the trapezoidal channel section. Making a direct estimate of the bedwidth can be done during a site visit. The side slope can then be estimated by also taking measurements of the flow width and flow depth, as shown in the diagram below.



Assuming the stream channel is a trapezoid (with base angles being equal) the following equation can be used to derive the side slope:

$$Side\ slope = \frac{2 * h_2}{w_2 - w_1}$$

Please refer to BS 3680-2 and BS 3680-3J for more details on taking stream measurements.

14.2 Calculating long slope

This can be estimated by taking a water surface level in the stream at the outfall location and at a second location downstream. The downstream location should be as far downstream as practical but within 200m. Levels should be measured to an accuracy of at least 5mm, preferably greater. The distance between the outfall location and the downstream location should be measured along the river, not in a direct line. As the gradient may be slight in many rivers, the measurements should be repeated three times and the average gradient calculated. If the gradient is so slight that no fall is measurable, a default value of 0.0001m/m should be used.

15. Notes on Finding Manning's n

Manning's n is used to describe the effective channel roughness and its effect upon water velocities and depths. In addition to surface roughness, there are several other factors which can influence the value of Manning's n. Vegetation can have a major influence and may account for marked seasonal variation in n. Channel irregularity may also increase n, as will sharp curvature in a channel.

When tier 2 is used for sediment risk assessment, the appropriate Manning's n for the receiving stream can be estimated from the Chow Table based on its type and characteristics.

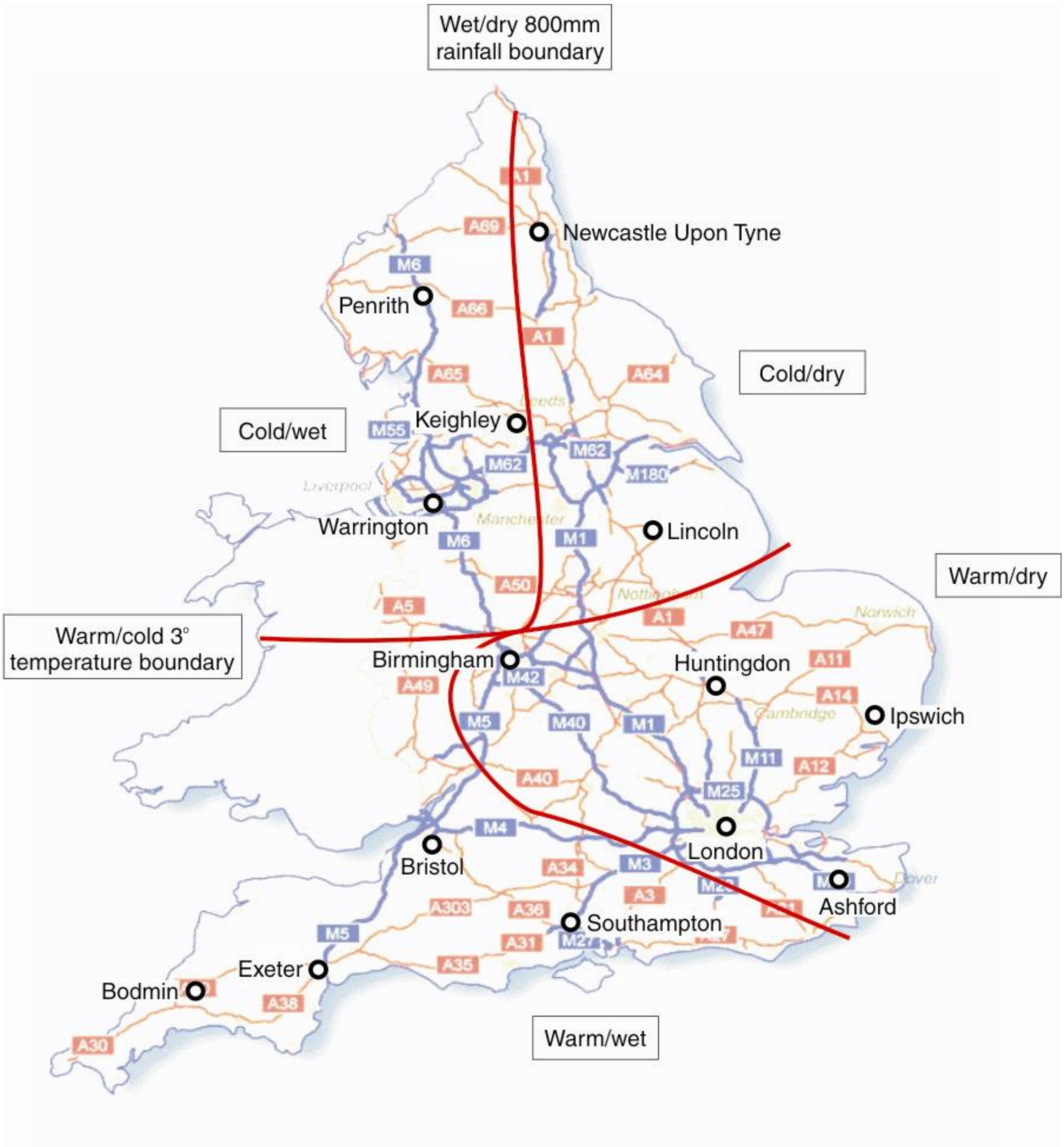
Values of Manning's n for various stream types (from Chow, 1973)

Stream type	Min	Normal	Max
Natural Stream - Lowland Streams			
1. Clean, straight, full stage, no rifts or pools	0.025	0.030	0.033
2. As above with more stones and weeds	0.030	0.035	0.400
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. As above with some weeds and stones	0.035	0.045	0.050
5. As above, lower stages, more ineffective slopes & sections	0.040	0.048	0.055
6. As 4 above with more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools & heavy timber stand	0.075	0.100	0.150
Natural Stream - Mountain Streams			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
Excavated Channel			
1. Gravel, straight uniform, clean	0.022	0.030	0.033
2. Straight, uniform, short grass and weeds	0.022	0.027	0.033
3. Winding and sluggish, grass some weeds	0.025	0.030	0.033
4. Winding, sluggish, dense weeds or plants in deep channels	0.030	0.035	0.040
5. Winding, sluggish, earth bottom, rubble sides	0.028	0.030	0.035
6. Winding, sluggish, stony bottom, weedy banks	0.025	0.035	0.040
7. Winding, sluggish, cobble bottom, clean sides	0.030	0.040	0.050

Stream type	Min	Normal	Max
8. Dredged light brush on banks	0.035	0.050	0.060
9. Rock smooth and uniform	0.025	0.035	0.040
10. Rock jagged and irregular	0.035	0.040	0.050
Unmaintained excavated channel, weeds/brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on both sides	0.040	0.050	0.080
3. As 2, highest stages of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140

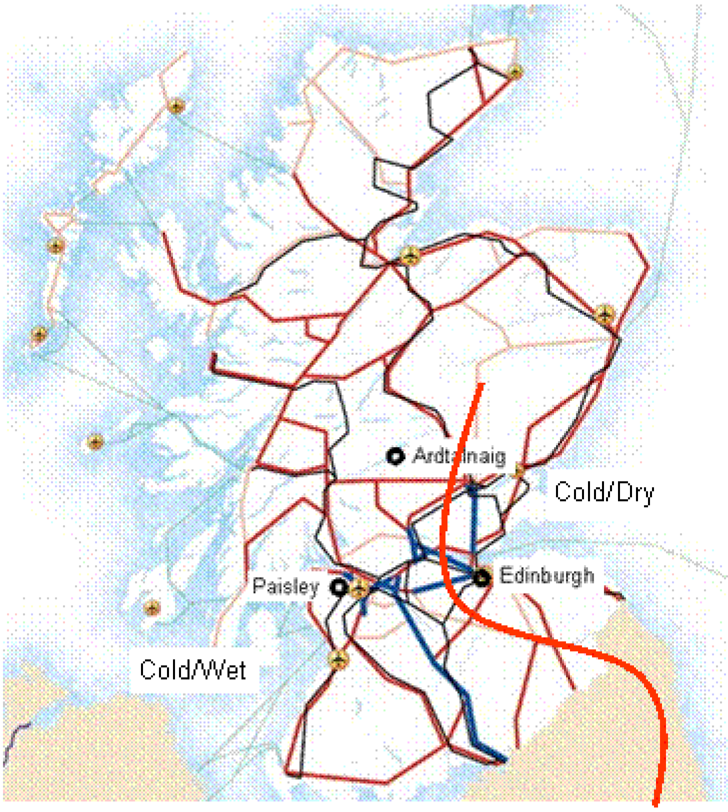
16. Maps showing climatic regions and rainfall sites

England

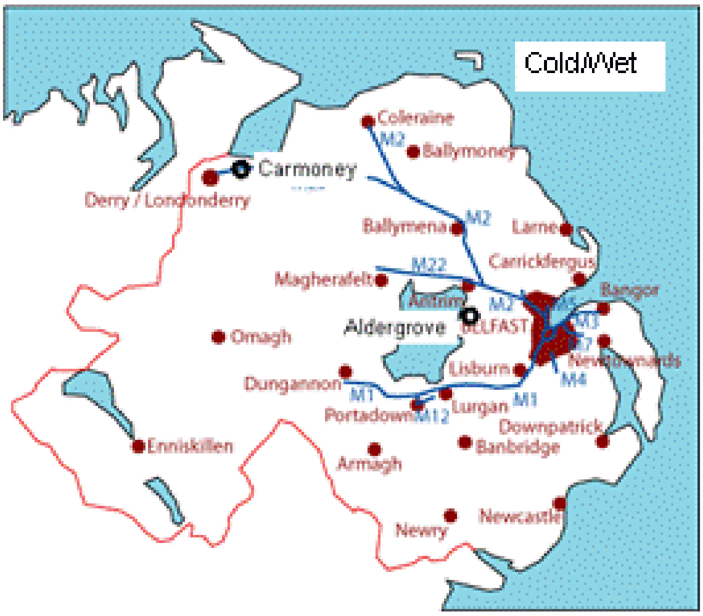


Wales

Scotland



Northern Ireland



17. Troubleshooting

This section provides advice on possible problems that a user may encounter.

17.1 Effects on other Excel workbooks

Once the tool is opened up, the calculation option of all the Excel workbooks currently open on the user's computer will be switched to and kept at 'Manual', i.e. opened workbooks only calculate and update results when the <F9> key is pressed. This prevents automatic updating of calculations and thus may create unexpected results in other opened workbooks. The calculation option will be automatically switched back to 'Automatic' once the tool is exited. To ensure this happens, the tool can only be exited using the 'Exit Tool' option in the HEWRAT menu, <Exit Tool> button on the Interface worksheet, or 'Exit Tool' option on a popup menu.

18. References

Chow, V.T. (1973). Open Channel Hydraulics.

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Dempsey, P. and Song, M. (2007a). Improved determination of pollutants in highway runoff phase 2 stage 4 report. WRc Report UC7405.

Gaskell, P.N., Guymer, I., Maltby, L. (2007). "Accumulation and dispersal of suspended solids in watercourses: Stage 3 Task 1 Report: Risk assessment tool development HA3/368," ECUS Ltd. & The University of Sheffield.

Highways England (2016). *Design Manual for Roads and Bridges*, 'Road Drainage and the Water Environment', Volume 11, Section 3, Part 10. *Publication due 2016, updating 2009 version*.

Johnson, I., Harman, M. and Crabtree, R. (2007c). Effects of Soluble Pollutants on the Ecology of Receiving Waters. WRc Report UC7486

Moy, F., Crabtree, R. and Simms, T. (2002). Long Term Monitoring of Pollution from Highway Runoff: Final Report. WRc Report UC6037.

Appendix A HEWRAT Technical Guide

The purpose of this Technical Guide is to document the equations and calculation process used in HEWRAT, to show how the HEWRAT results are produced.

The methodologies used for the Spillage Risk Assessment and Groundwater Assessment are not described here. For further details on the technical aspect of the Spillage Risk Assessment and Groundwater Assessment functions of the tool, please refer to the Highways England *Design Manual for Roads and Bridges*, 'Road Drainage and the Water Environment', Volume 11, Section 3, Part 10 (Highways England, 2016).

A1 Overview

In broad terms HEWRAT works as follows:

1. The specific values for a number of Calculated Parameters are determined.

2. Given the defined river channel geometry and annual Q_{95} river flow it decides if the site is an accumulating or dispersing site for sediments.

3. For each rainfall event, it calculates:
   - the event mean runoff concentrations for each pollutant (Step 1);
   - the event mean runoff flow from impermeable and permeable highway surfaces (Step 2);
   - the event mean river flow (Step 2);
   - the mixed in-river concentrations (soluble pollutants) (Step 2); and
   - the mixed in-river concentrations after any treatment and attenuation (soluble pollutants) (Step 3).

4. It then takes the individual event estimates and calculates:
   - The number of events (per year and per summer) when concentrations exceed defined toxicity thresholds;
   - A range of concentration statistics (mean, 90%ile etc.); and
   - the annual sediment volume.

5. It then compares these results with the assessment thresholds and reports on pass/fail. If a site fails because the sediment load is extensive, it calculates the amount of settlement needed to pass.

In describing the equations used for these calculations it is helpful to define various terms. These can be grouped as follows:

A1.1 Parameters

Parameters refer to specific factors, coefficients and site details that are not event dependent and that are taken as fixed for any specific impact assessment. Parameters can be divided into four categories:

User Parameters	These are the parameter values that the User enters on the Interface worksheet. The definition of these and their Short names are set out in the User Parameters table.
Toxicity Thresholds and Other parameters	These are parameters with built-in default values. These can be viewed by the User but cannot be changed by the User. They are described in Toxicity Thresholds and Other parameters.
Rain Table Parameters	These are parameters related to the different rainfall sites. See Rainfall Series.
Calculated parameters	These are parameters that are calculated from other parameters and are not event related.

Further details on parameters are given below.

A1.2 Other Parameters

The Short names used in equations for the Other Parameters are shown below:

Use in Tool Calculations	Parameters	Short Name	Units	Default	Notes
Exceedance calculations	Summer Start Month	*SummStart*	-	4	See Start and end months for summer
	Summer End Month	*SummEnd*	-	9	
Runoff	Rainfall Initial Loss	*Rain_InitialLoss*	mm	1	See Assumptions used in runoff calculation
	Runoff Coefficient Impermeable Areas	*RunoffFactor_Imp*	-	0.5	
	Runoff Coefficient Permeable Areas	*RunoffFactor_per*	-	0.1	
Sediment calculation factors	Threshold Mean Velocity	*ThresholdVelocity*	m/s	0.1	See Factors used in the sediment calculations
	Median EMC for SS	*EMC_SS_Med*	mg/l	139	
	Event Selection Type	*Event_Type*	-	1	

Use in Tool Calculations	Parameters	Short Name	Units	Default	Notes
	Density of the sediment	*Sed_Density*	kg/m^3	2000	
	Deposition Index Threshold	*DI_Thres*	-	100	
Average annual concentration calculation	Background concentration in upstream river for dissolved copper	*UpRivCu*	µg/l	0	See Concentrations in upstream river
	Background concentration in upstream river for dissolved zinc	*UpRivZn*	µg/l	0	
Runoff concentration calculation	Concentration in upstream river for dissolved copper	*UpRivCu_Event*	µg/l	0	See Concentrations in upstream river
	Concentration in upstream river for dissolved zinc	*UpRivZn_Event*	µg/l	0	

A1.3 Rainfall Table Parameters

These are parameters that relate to a particular rainfall series and BFI that have been selected.

Rainfall Table Parameter	Short Name	Units	Where used?
Number of events	*Number_Events*	-	
Number of years	*Number_Years*	-	
Q_{95} Low River Flow for this site and the chosen BFI (based on a unit area)	*RS_95RiverFlow*	m^3/s	To factor up river flows for each event
Ratio of Q_{90} to Q_{95} river flow for this site and the chosen BFI	*Ratio_lowflow*	-	

A1.4 Calculated Parameters

The Short names used in equations for the Calculated Parameters are shown below:

Calculated Parameter	Short Name	Units	Where used?
Tier 1 cross sectional area of river	*XSecArea*	m^2	Tier 1 sediment accumulation
Tier 1 threshold river flow	*T1_Threshold_RivFlow*	m/s	Tier 1 sediment accumulation
Tier 2 velocity alpha & beta constants	*Alpha_VelW, Beta_VelW*	-	Tier 2 sediment accumulation
Tier 2 depth alpha & beta constants	*Alpha_Dep, Beta_Dep*	-	Tier 2 sediment accumulation
Tier 2 threshold river flow	*T2_Threshold_RivFlow*	m^3/s	Tier 2 sediment accumulation
Q_{90} river flow	*90RiverFlow*	m^3/s	Tier 2 sediment accumulation
Channel width at Q_{90} low flow	*Channel_Width*	m	Tier 2 sediment accumulation
River flow factor	*RiverFlowFactor*	-	To calculate River Flow

A1.5 Variables

Variables are event dependent and not fixed. Variables can be divided into 3 categories:

Event variables – input	These are the rainfall and unit river flow details for each event. These depend on the rainfall site that is selected by the User.
Event variables – calculated	These are the flows, concentrations and loads that are calculated for each pollutant for each event.
Summary statistics	These are the statistics that are calculated from the event variables

Event Variable - input	Short Name	Units	Where used?
Month	*MonthNumber*		
Event total rainfall	*TotalRain*	mm	To calculate Runoff
Rainfall duration	*RainDur*	hrs	
Maximum hourly intensity	*MaxHourIntensity*	mm/hr	
Antecedent dry period	*ADWP*	hours	
Unit river flow	*UnitRiverFlow*	m^3/s	

Event Variable - calculated	Short Name	Units	Where used?
Loss deducted event total rainfall	*Rain_LossDeducted*	mm	To calculate Runoff
EMC[1] (for Cu, Zn)	*EMC_Cu, EMC_Zn*	µg/l	Step 2
EMSC[2] (for Cu, Zn, Cd, PAH)	*EMSC_Cu, EMSC_Zn, EMSC_Cd, EMSC_PAH*	g/kg	Step 2
Runoff volume (Impermeable)	*Runoff_Imp*	l	Step 2
Runoff rate (Impermeable, permeable, total)	*RunoffRate_Imp, RunoffRate_Per, TotalRunoffRate*	m^3/s	Step 2
Discharge duration to watercourse without attenuation	*DischDur_UnAttenuated*	hrs	Steps 2
Discharge duration to watercourse with attenuation	*DischDur_Attenuated*	hrs	Steps 3
Total Runoff Volume	*TotalRunoff*	m^3	
River flow	*River_Flow*	m^3/s	Step 2
Dissolved Cu/Zn river concentration	*DissCu_RiverConc, DissZn_RiverConc*	µg/l	Step 2
Attenuated discharge	*Discharge_Attenuated*	m^3/s	Step 3
Dissolved Cu/Zn after mitigation	*DissCu_Mit dissZn_Mit*	µg/l	Step 3

1 EMC = Event Mean Concentration (for soluble pollutants)

2 EMSC = Event Mean Sediment Concentration (for sediment attached pollutants).

See Pollutants.

Summary statistics	Short Name	Units	Where used?
Annual average runoff volume	*Ave_AnnualRunoff*	l	Calculation for final assessment
Annual volume of sediment	*Annual_Sed_Vol*	m^3	Calculation for final assessment
Deposition Index	*DI*	-	Assessment outputs
Number of threshold exceedances (for all water quality indicators used in tool)	*Exceedances_RST24_Cu*	-	Assessment outputs
Percentage settlement needed	*PercSettlementNeeded*	%	Assessment outputs

A2 Determine specific values for Calculated Parameters

If **Tier 2** is selected, the tool carries out a series of calculations to generate the parameter values for specific velocity/flow and depth/flow equations. These equations are of the form:

$$Flow\_Velocity = Alpha\_VelW * RiverFlow^{Beta\_VelW}$$

$$WaterDepth = Alpha\_Dep * RiverFlow^{Beta\_Dep}$$

Where the alpha and beta parameters are site specific and determined as follows.

The flow velocity at the annual Q_{95} river flow entered by the user (95RiverFlow) is calculated by iteration. A water depth is guessed and the following equations are used to calculate the corresponding flow. If the flow is not equal to the Q_{95} flow, the water depth is adjusted and the process repeated. When the estimated flow is within 1% of the Q_{95} flow, the iteration stops.

Hydraulic Radius (m):

$$Hydraulic\_Radius = \frac{WaterDepth * (BedWidth + WaterDepth)/SideSlope}{BedWidth + 2 * WaterDepth * \left(1 + (1/(SideSlope)^2)\right)^{0.5}}$$

Flow Velocity (m/s):

$$Flow\_Velocity = \frac{Hydraulic\_Radius^{0.667} * LongSlope^{0.5}}{Mannings\_n}$$

Estimated Flow (m^3/s):

$$Estimated\_Flow = Flow\_Velocity * WaterDepth * \frac{BedWidth + WaterDepth}{SideSlope}$$

Where *BedWidth, SideSlope, LongSlope* and *Mannings_n* are all User Parameters.

The iteration is then repeated for 2 * Q_{95} River Flow, 3 * Q_{95} River Flow… etc. up to 10 * Q_{95} River Flow. This generates a set of values for River Depth and for Flow Velocity for a range of flows. The tool calculates the best fit power equation for each relationship thus giving the required alpha and beta parameters.

The velocity equation is then used to calculate the river flow that corresponds to the Threshold Mean Velocity (for judging sediment accumulation risk see Factors used in the sediment calculations).

Threshold River Flow (m^3/s):

$$T2\_Threshold\_RivFlow = \left(\frac{ThresholdVelocity}{Alpha\_VelW}\right)^{\frac{1}{Beta\_VelW}}$$

In addition, for Tier 2, the Q_{90} low river flow is calculated using the Q_{95} river flow entered by the user and the *Ratio_lowflow* from the Rainfall Table Parameters. This ratio is the ratio of the Q_{90} to Q_{95} river flow for this site and selected BFI.

Q_{90} River Flow (m^3/s):

$$90RiverFlow = 95RiverFlow * Ratio\_LowFlow$$

A final Calculated Parameter for Tier 2 is the channel width at this estimated Q_{90} low flow. The previously calculated velocity/flow and depth/flow equations are used first to calculate the water velocity and depth at this flow:

$$Flow\_Velocity = Alpha\_VelW * 90RiverFlow^{Beta\_VelW}$$

$$WaterDepth = Alpha\_Dep * 90RiverFlow^{Beta\_Dep}$$

The flow cross-sectional area (m^2) is then calculated in two different ways:

$$FlowArea = 90RiverFlow/Flow\_Velocity$$

$$FlowArea = (Channel\_Width + BedWidth) * WaterDepth/2$$

based on a trapezoidal section

By equating these two equations, gives the solution for Channel Width.

Channel Width at Q_{90} Low Flow (m):

$$Channel_{Width} = \left(\frac{2 * 90RiverFlow}{Flow_{Velocity} * WaterDepth}\right) - BedWidth$$

If **Tier 1** is used, the calculations are simpler. A single estimate of the low flow cross sectional area of the stream is estimated from the River Width using equations from Gaskell *et al* (2007).

Cross Sectional Area (m^2):

$$Log_{10}(XSecArea) = -0.93 + 1.66log_{10}(RiverWidth)$$

This is then used to give the threshold river flow.

Threshold River Flow (m^3/s):

$$T1\_Threshold\_RivFlow = XSecArea * ThresholdVelocity$$

A3 Calculation to determine if the site is an accumulating or dispersing site for sediments

This step involves calculating the river velocity at low flow and comparing this velocity with the threshold mean velocity. The estimated low flow velocity is displayed on the Interface worksheet. If this is below the threshold mean velocity, the Interface worksheet will display the fact that the stream is accumulating. If it is above, then the site is deemed dispersive. The calculation depends on whether Tier 1 or Tier 2 has been selected.

Tier 1

For Tier 1, the flow velocity at the Q_{95} low flow is calculated as follows:

Low Flow Velocity (m/s):

$$LowFlowVelocity = \frac{95RiverFlow}{XSecArea}$$

where *95RiverFlow* is entered by the User.

Tier 2

For Tier 2, the flow velocity at the Q_{90} low river flow is used:

$$LowFlowVelocity = Alpha\_VelW * 90RiverFlow^{Beta\_VelW}$$

A4 Event calculations

The following section describes the calculations that are carried out for each rainfall event.

A4.1 Month

Each event is tagged with a season as follows:

$$Season = IF(AND(MonthNumber \geq SummerStart,\ MonthNumber \leq SummerEnd),\ "Summer",\ "Winter")$$

This is used later at the Aggregation stage.

A4.2 Runoff concentrations (Step 1)

The runoff concentrations are calculated using the statistical models developed in Stage 4 of the Improved Determination of Pollutants in Highway Runoff Phase 2 project. The basis for, and justification for, these models are given in the Stage 4 report (Dempsey et al, 2007) and are not repeated here. In summary, the following models are used:

a) Multiple Linear Regression (MLR) equations for:
Dissolved copper and zinc EMCs, after a log10 transformation, and;

Total copper and zinc EMSCs, after a fourth root transformation.

b) Non-parametric distributions for:
Total cadmium and total PAH EMSCs.

c) Linear relationships for Pyrene, Anthracene, Fluoranthene and Phenanthrene EMSCs as functions of total PAH EMSC.

The EMSCs produced from these statistical models refer to **total** pollutant concentrations (based upon WRc's unfiltered samples). These concentrations are an overestimate of the **sediment attached** fraction. Data from the Stage 3 report (Crabtree *et al*, 2007) was examined to correct for this. In Table 4.5 of that report there are EMC statistics for Total and Dissolved (Filtered) fractions of all pollutants.

The results for the pollutants included in HEWRAT are given in **Table A.1** below. For each, the dissolved to total ratio for the mean, median and maximum concentrations has been calculated. The table suggests that about 30-40% of the total metal loads are dissolved. For

PAHs the dissolved component is generally less at around 5-10% of the total: when the maximum PAH concentrations are considered the ratio is much less, at around 1-3%. The maximum concentrations are important because the standards are related to the extremes (1 year return period)

Based on this analysis, and still maintaining a degree of conservatism, the sediment attached to total ratios used in HEWRAT are as follows:

For copper and zinc, 70% of the total concentration

For cadmium, 60% of the total concentration

For PAHs, 100% of the total (i.e. treat PAHs as all attached to sediment)

Table A.1 EMC concentration statistics from the Stage 3 report and associated dissolved:total ratios

Determinand	Average EMC	Median EMC	Largest EMC	Diss:Tot ratio at Mean	Diss:Tot ratio at Median	Diss:Tot ratio at Max
Total Cu	**91.22**	**42.99**	**876.8**	**0.34**	**0.54**	**0.35**
Dissolved Cu	**31.31**	**23.3**	**304**			
Total Zn	**352.63**	**140**	**3510**	**0.32**	**0.42**	**0.39**
Dissolved Zn	**111.09**	**58.27**	**1360**			
Total Cd	**0.63**	**0.29**	**5.4**	**0.41**	**0.45**	**0.58**
Dissolved Cd	0.26	0.13	3.12			
Total Phenanthrene	0.35	0.13	3.63	0.06	0.08	0.03
Dissolved Phenanthrene	0.02	0.01	0.11			
Total Anthracene	0.08	0.03	0.81	0.13	0.33	0.02
Dissolved Anthracene	0.01	0.01	0.02			
Total Fluoranthene	**1.02**	**0.3**	**12.5**	**0.04**	**0.10**	**0.01**
Dissolved Fluoranthene	0.04	0.03	0.09			
Total Pyrene	**1.03**	**0.31**	**12.5**	**0.04**	**0.10**	**0.01**
Dissolved Pyrene	0.04	0.03	0.09			
Total PAHs (Total)	**7.52**	**3.33**	**62.18**	**0.04**	**0.08**	**0.01**

Determinand	Average EMC	Median EMC	Largest EMC	Diss:Tot ratio at Mean	Diss:Tot ratio at Median	Diss:Tot ratio at Max
Total PAHs (Dissolved)	0.27	0.25	0.54			

a) MLR models

The results for the final MLR models are summarised in the two tables below. The first table identifies the factors that were significant for each pollutant, the level of significance and the percentage variance explained overall. The second table lists the values of the constants, coefficients and overall standard error for each model. For the category variables, the category used as the Reference category (with constant = 0) is indicated in the first table by 'REF'.

Table A.2 Significant factors in the MLR equations and percentage variance explained

		EMCs		EMSCs	
		Dissolved Cu	Dissolved Zn	Total Cu	Total Zn
Site Factors	ClimaticRegion ColderDry	REF	REF	REF	REF
	ClimaticRegion ColderWet	**		*	*
	ClimaticRegion WarmDry	**		**	*
	ClimaticRegion WarmWet	**	*	*	*
	AADT <50000	REF	REF	REF	REF
	50000=<AADT<100000				*
	AADT >=100000	**	**	**	**
Event Factors	January				
	February	*	*		
	March				*
	April	*			*
	May	*		*	**
	June				
	July	**	*	*	**
	August				
	September			*	
	October	REF	REF	REF	REF
	November	*			
	December			*	
	MaxHourlyIntensity	**		**	**
	PrecedingRain10day				
	PrecedingRain20day				
	ADWP	**			
	% variance accounted for	37.8	24.9	35.9	31.2

* denotes significant difference at 95% confidence level

** denotes significant difference at 99% confidence level

Table A.3 Constants and coefficients in the MLR equations

		EMCs		EMSCs	
		Dissolved Cu	Dissolved Zn	Total Cu	Total Zn
	Constant	1.0078	1.4220	0.6878	0.8555
Site Factors	ClimaticRegion ColderDry	0.0000	0.0000	0.0000	0.0000
	ClimaticRegion ColderWet	0.2177	0.0986	0.0914	0.1154
	ClimaticRegion WarmDry	0.2453	0.0233	0.1361	0.1442
	ClimaticRegion WarmWet	0.2635	0.1937	0.0959	0.1081
	AADT <50000	0.0000	0.0000	0.0000	0.0000
	50000=<AADT<100000	0.0847	0.0994	0.0423	0.1117
	AADT >=100000	0.3233	0.4946	0.1949	0.2820
Event Factors	January	-0.0780	0.1970	-0.0428	0.1430
	February	0.2650	0.3940	0.0727	0.1798
	March	0.1694	0.1770	0.0630	0.1965
	April	0.2028	0.1370	0.0968	0.2231
	May	0.2345	0.2170	0.1024	0.2535
	June	0.0640	0.0730	0.0844	0.0976
	July	0.3160	0.3510	0.1368	0.2681
	August	0.1657	0.0300	0.0406	0.0059
	September	0.0930	0.0730	0.1006	0.0581
	October	0.0000	0.0000	0.0000	0.0000
	November	-0.2610	0.0400	-0.0368	0.0445
	December	-0.1350	0.0980	-0.1494	-0.1160
	MaxHourlyIntensity	-0.0341	0.0000	-0.0281	-0.0270
	PrecedingRain10day				
	PrecedingRain20day				
	ADWP	0.0005			
	Standard error	*0.265*	*0.368*	*0.18*	*0.262*

The overall form of the MLR models for a normally distributed variable is:

$$Mean = Constant$$
$$+ Constant\ for\ Climatic\ Region\ (CR)$$
$$+ Constant\ for\ AADT$$
$$+ Constant\ for\ Month$$
$$+ Factor * Max\ hourly\ intensity$$
$$+ Factor * ADWP$$

For example, for dissolved copper EMC where a log_{10} transformation was used to get normality, the equation can be further illustrated by the example below - in the WarmDry climate region in June, with medium daily traffic (>50,000 and <100,000):

$$Mean\ log_{10}(EMC\_Cu) = 1.008$$
$$+ 0.245\ (CR\ constant)$$
$$+ 0.085\ (AADT\ constant)$$
$$+ 0.064\ (Month\ constant)$$
$$- 0.034 * Max\ Hourly\ Intensity\ (mm/hr)$$
$$+ 0.005 * Antecedent\ Dry\ Weather\ Period\ (hours)$$

For total copper EMSC, where the fourth root transformation was used, the equation can be illustrated for the same conditions as:

$$Mean\ (EMSC\_Cu)^{\wedge 0.25} = 0.688$$
$$+ 0.136\ (CR\ constant)$$
$$+ 0.042\ (AADT\ constant)$$
$$+ 0.084\ (Month\ constant)$$
$$- 0.028 * Max\ Hourly\ Intensity\ (mm/hr)$$

These equations give the mean EMC or EMSC predicted for a given event. The standard error from the MLR analysis was then used as the standard deviation (SD) to express the unexplained variability. The Excel NORMINV and RAND functions were used to pick random values from these distributions and the inverse transformation was then used to get back to the predicted EMC or EMSC. So:

$$EMC\_\ Cu\ or\ EMC\_Zn = 10^{(NORMINV(Rand(),\ Mean,\ SD))}$$

$$EMSC\_Cu\ or\ EMSC\_Zn = (NORMINV(Rand(),\ Mean,\ SD))^{4}$$

As a final step the EMSC values for Cu and Zn were multiplied by 0.7 to give the sediment attached fraction only (as described earlier)

b) Non-parametric distributions

Non-parametric distributions were created for total Cadmium and total PAH EMSCs, grouping the data according to the main explanatory factors.

For Total Cd, AADT was divided into three categories (as used for the MLR analysis) and the year was divided into two seasons (Jan–June and July-Dec) giving 6 categories in total. For each of these, the distributions of logged data were separately calculated and look-up tables created to represent the cumulative distributions.

Table A.4 Lookup Tables for log10(EMSC_Cd) by season and traffic density categories

Summer_AADT High		Winter_AADT High		Summer_AADT Med		Winter_AADT Med		Summer_AADT Low		Winter_AADT Low	
Cumulative No (CN)	Mid point	CN	Mid point	CN	Mid point	CN	Mid point	CN	Mid point	CN	Mid point
0	-4.7	0	-4.7	0	-4.7	0	-4.8	0	-4.7	0	-4.7
0	-4.6	0	-4.6	0	-4.6	1	-4.7	0	-4.6	0	-4.6
0	-4.5	0	-4.5	1	-4.5	1	-4.6	0	-4.5	0	-4.5
0	-4.4	0	-4.4	2	-4.4	1	-4.5	1	-4.4	0	-4.4
1	-4.3	0	-4.3	2	-4.3	1	-4.4	3	-4.3	0	-4.3
1	-4.2	0	-4.2	2	-4.2	1	-4.3	3	-4.2	0	-4.2
1	-4.1	0	-4.1	3	-4.1	1	-4.2	6	-4.1	0	-4.1
2	-4	0	-4	5	-4	1	-4.1	10	-4	0	-4
2	-3.9	0	-3.9	6	-3.9	2	-4	12	-3.9	0	-3.9
2	-3.8	0	-3.8	9	-3.8	2	-3.9	15	-3.8	1	-3.8
2	-3.7	0	-3.7	10	-3.7	2	-3.8	15	-3.7	1	-3.7
4	-3.6	0	-3.6	13	-3.6	2	-3.7	16	-3.6	1	-3.6
4	-3.5	0	-3.5	15	-3.5	2	-3.6	23	-3.5	1	-3.5
5	-3.4	0	-3.4	18	-3.4	2	-3.5	28	-3.4	1	-3.4
6	-3.3	0	-3.3	20	-3.3	2	-3.4	32	-3.3	2	-3.3
7	-3.2	2	-3.2	24	-3.2	2	-3.3	36	-3.2	5	-3.2
8	-3.1	3	-3.1	29	-3.1	4	-3.2	39	-3.1	7	-3.1
9	-3	7	-3	34	-3	6	-3.1	43	-3	8	-3
12	-2.9	15	-2.9	37	-2.9	8	-3	50	-2.9	12	-2.9
13	-2.8	22	-2.8	40	-2.8	10	-2.9	52	-2.8	16	-2.8
20	-2.7	25	-2.7	42	-2.7	10	-2.8	55	-2.7	18	-2.7
22	-2.6	33	-2.6	43	-2.6	14	-2.7	61	-2.6	21	-2.6

Summer_AADT High		Winter_AADT High		Summer_AADT Med		Winter_AADT Med		Summer_AADT Low		Winter_AADT Low	
Cumulative No (CN)	Mid point	CN	Mid point	CN	Mid point	CN	Mid point	CN	Mid point	CN	Mid point
26	-2.5	36	-2.5	51	-2.5	15	-2.6	64	-2.5	25	-2.5
33	-2.4	38	-2.4	53	-2.4	16	-2.5	64	-2.4	26	-2.4
36	-2.3	38	-2.3	55	-2.3	21	-2.4	64	-2.3	28	-2.3
38	-2.2	39	-2.2	58	-2.2	27	-2.3	66	-2.2	29	-2.2
39	-2.1					30	-2.2				
						33	-2.1				

The values in the table can be explained by example: 7 out of 39 values for $\log_{10}$(EMSC_Cd) in the Summer_High AADT category are less than or equal to -3.2.

The tool uses the Excel Rand() function to pick a value from the appropriate season/AADT category and then transform the value back, as follows:

$$EMSC\_Cd = 10^{m}$$

where m = randomly selected *Mid Point* value based on season and traffic category.

As a final step the EMSC values for Cd were multiplied by 0.6 to give the sediment attached fraction only (as described earlier).

For the Total PAH EMSCs, the climatic regions were divided into warm or colder and the year into two seasons (June-September; the rest) thus giving four overall categories. Again, the distributions of logged data in each of these four categories were calculated and prepared as look-up tables (see below). Values for specific events were generated in the same way as for Cadmium to give the required *EMSC_TotalPAH*.

As described earlier these EMSC values for Total PAH were taken as equal to the sediment attached fraction.

Table A.5 Lookup Table for log10(EMSC_TotalPAH) by season and climate region categories

Winter_Cold region		Summer_Cold region		Winter_Warm region		Summer_Warm region	
Cumulative No	Mid point	Cumulative No	Mid point	Cumulative No	Mid point	Cumulative No	Mid point
0	-4.75	0	-4.85	0	-4.75	0	-4.75
0	-4.65	1	-4.75	0	-4.65	0	-4.65
0	-4.55	1	-4.65	0	-4.55	0	-4.55
0	-4.45	1	-4.55	1	-4.45	0	-4.45
1	-4.35	1	-4.45	2	-4.35	0	-4.35
1	-4.25	1	-4.35	4	-4.25	0	-4.25
1	-4.15	3	-4.25	5	-4.15	1	-4.15
1	-4.05	3	-4.15	5	-4.05	2	-4.05
1	-3.95	4	-4.05	5	-3.95	3	-3.95
1	-3.85	5	-3.95	6	-3.85	4	-3.85
2	-3.75	5	-3.85	8	-3.75	4	-3.75
2	-3.65	5	-3.75	9	-3.65	4	-3.65
2	-3.55	5	-3.65	9	-3.55	4	-3.55
3	-3.45	5	-3.55	9	-3.45	6	-3.45
3	-3.35	5	-3.45	9	-3.35	8	-3.35
3	-3.25	5	-3.35	9	-3.25	9	-3.25
3	-3.15	5	-3.25	11	-3.15	9	-3.15
3	-3.05	6	-3.15	11	-3.05	12	-3.05
3	-2.95	6	-3.05	11	-2.95	14	-2.95
5	-2.85	6	-2.95	12	-2.85	16	-2.85
6	-2.75	6	-2.85	14	-2.75	17	-2.75
7	-2.65	7	-2.75	14	-2.65	20	-2.65
8	-2.55	8	-2.65	15	-2.55	23	-2.55
8	-2.45	8	-2.55	16	-2.45	24	-2.45
8	-2.35	9	-2.45	19	-2.35	26	-2.35
9	-2.25	9	-2.35	23	-2.25	32	-2.25
12	-2.15	11	-2.25	26	-2.15	32	-2.15
14	-2.05	12	-2.15	31	-2.05	38	-2.05

Winter_Cold region		Summer_Cold region		Winter_Warm region		Summer_Warm region	
Cumulative No	Mid point	Cumulative No	Mid point	Cumulative No	Mid point	Cumulative No	Mid point
17	-1.95	14	-2.05	35	-1.95	43	-1.95
18	-1.85	16	-1.95	37	-1.85	48	-1.85
26	-1.75	21	-1.85	46	-1.75	49	-1.75
37	-1.65	29	-1.75	53	-1.65	49	-1.65
49	-1.55	33	-1.65	61	-1.55	50	-1.55
58	-1.45	36	-1.55	69	-1.45	52	-1.45
71	-1.35	38	-1.45	70	-1.35	53	-1.35
81	-1.25	40	-1.35	72	-1.25	53	-1.25
90	-1.15	40	-1.25	75	-1.15	54	-1.15
91	-1.05	40	-1.15	75	-1.05	54	-1.05
92	-0.95	41	-1.05	76	-0.95	55	-0.95
93	-0.85			77	-0.85		
95	-0.75						
96	-0.65						

c) Linear models

The linear relationships between individual PAHs and total PAH were taken as:

$$EMSC\_Pyrene = 0.173 * EMSC\_total\ PAH$$

$$EMSC\_Fluoranthene = 0.166 * EMSC\_total\ PAH$$

$$EMSC\_Anthracene = 0.0106 * EMSC\_total\ PAH$$

$$EMSC\_Phenanthrene = 0.0468 * EMSC\_total\ PAH$$

A4.3 Event mean runoff flow from highway surfaces (Step 2)

Total Rainfall (Loss Deducted) (mm):

$$Rain\_LossDeducted = TotalRain - RainInitialLoss$$

This takes the event total rainfall and subtracts the initial loss value due to evaporation. For outcomes less than 0 mm, *Rainfall_LossDeducted* is recorded as 0 mm.

Runoff Volume from Impermeable Area (litres):

$$Runoff\_Imp = \frac{Rain_{LossDeducted}}{1000} * HDA\_Imp * RunoffFactor\_Imp * 10000 * 1000$$

Rain_LossDeducted is given in mm, while HDA_Imp is expressed in hectares, therefore conversions are needed to calculate runoff in litres.

Runoff Rate from Impermeable Surface (m^3/s):

$$RunoffRate\_Imp = \left(\frac{Rain\_LossDeducted * RunoffFactor\_Imp * HDA\_Imp * 10}{RainDur}\right)/3600$$

This equation requires conversion factors since rain duration is expressed in hours, area in hectares, and rainfall in millimetres.

Runoff Rate from Permeable Surface (m^3/s):

$$RunoffRate\_Per = \left(\frac{Rain\_LossDeducted * RunoffFactor\_Per * HDA\_Per * 10}{RainDur}\right)/3600$$

The above two results may then be summed to give the total runoff rate and volume.

Total Runoff Rate (m^3/s):

$$TotalRunoffRate = RunoffRate\_Imp + RunoffRate\_Per$$

Total Runoff Volume (m^3):

$$TotalRunoff = (RunoffRate\_Imp + RunoffRate\_Per) * RainDur * 3600$$

A4.4 Event mean river flow (Step 2)

The river flow estimates (*UnitRiverFlow*) for each rainfall event, provided as an input Event Variable, are based on an arbitrary catchment area. The Q_{95} of all the river flows upon which these event estimates are based is the *RS_95RiverFlow* (a Rainfall Table Parameter). The User provides the actual Q_{95} river flow for the site (*95RiverFlow*). The ratio of these two values provides the factor to scale all the river flows estimates as follows:

$$RiverFlowFactor = \frac{95RiverFlow}{RS\_95RiverFlow}$$

$$RiverFlow = UnitRiverFlow * RiverFlowFactor$$

A4.5 Mixed in-river concentrations (soluble pollutants) (Step 2)

These are basic mass balance calculations, assuming the pollutant mass comes from the impermeable runoff only.

Discharge Duration to the watercourse (hours):

$$DischDur\_Unattenuated = RainDur$$

Dissolved Copper River Concentration (µg/l):

$$DissCu\_RiverConc = \frac{(RunoffRate\_Imp * EMC\_Cu) + (UpRivCu\_Event * RiverFlow)}{TotalRunoff + RiverFlow}$$

An equivalent calculation is carried out for zinc giving the *DissZn_RiverConc*.

A4.6 Mixed in-river concentrations after treatment and attenuation (soluble pollutants) (Step 3)

Solubles impacts may be mitigated by attenuation and/or treatment. The calculations are:

Attenuated discharge rate (m^3/s):

$$If \left(TotalRunoffRate \geq \frac{ProposedRestrictedDischargeRate}{1000}\right) Then$$

$$Discharge\_Attenuated = \frac{ProposedRestrictedDischargeRate}{1000}$$

$$Else\ If \left(TotalRunoffRate < \frac{ProposedRestrictedDischargeRate}{1000}\right) Then$$

$$Discharge\_Attenuated = TotalRunoffRate$$

Discharge Duration to the watercourse (hours):

$$DischDur\_Attenuated = \left(\frac{TotalRunoff}{Discharge\_Attenuated}\right)/3600$$

Dissolved copper in river after mitigation measures (µg/l):

$$DissCuMit = \frac{\left(\left(\frac{RainDur}{DischDur\_Attenuated}\right) * RunoffRate\_Imp * EMC\_Cu\right) * \left(1 - \frac{\%Treatment}{100}\right) + (UpRivCu\_Event * RiverFlow)}{Discharge\_Attenuated + RiverFlow}$$

An equivalent calculation is carried out for zinc giving the *DissZn_Mit*.

A5 Aggregation of Event estimates

Standard Excel functions (e.g. COUNTIF) are used for these following calculations, together with code to help manipulate the numbers.

A5.1 Toxicity threshold exceedances

For all the EMC estimates of dissolved copper and zinc (in runoff, in river and in-river after mitigation) the tool counts the number of exceedances of the RST6 and RST24 thresholds – for all months and for summer months only. These counts are then normalised to numbers per year and per summer and reported on the Detailed Results sheet.

Similarly, for all the EMSC estimates for cadmium, total PAH and the individual PAHs in the highway runoff, the tool counts the number of exceedances of the sediment toxicity thresholds – for all months and for summer months only. These counts are then normalised to numbers per year and per summer and reported on the Detailed Results sheet.

A5.2 Statistics

Using all the EMC estimates of dissolved copper and zinc (in runoff, in river and in-river after mitigation) the tool calculates the mean, 90%ile, 95%ile and 99%ile. These statistics are reported on the Detailed Results sheet.

Using all the EMSC estimates for cadmium, total PAH and the individual PAHs in the highway runoff the tool calculates the mean, 90%ile, 95%ile and 99%ile. These statistics are reported on the Detailed Results sheet.

A5.3 Annual sediment volume

The annual sediment volume used depends on which event selection method has been specified:

Event_Type	Method used for Annual_Sed_Vol
1	Including all the rainfall events in the calculation
2	Only including the rainfall events during which the receiving water velocity is less than threshold mean velocity

Type 1 – All events

Average annual runoff volume from impermeable area (l):

$Ave\_AnnualRunoff = \frac{\sum(Runoff\_Imp)}{Number\_years}$ summed over all events

From the above equation, the annual volume of sediment can then be calculated, using the Median EMC for SS (mg/l) and the sediment density (kg/m^3).

Annual discharged volume of sediment (m^3):

$$Annual\_Sed\_Vol = \frac{Ave\_AnnualRunoff * EMC\_SS\_Med}{Sed\_Density * 1{,}000{,}000}$$

Type 2 – Events when river velocity is less than the velocity threshold

This is essentially the same calculation except that the summation is for those events where:

$RiverFlow < T1\_Threshold\_RivFlow$ (Tier 1), or;

$RiverFlow < T2\_Threshold\_RivFlow$ (Tier 2)

A5.4 Annual average river concentrations (solubles)

This calculation assumes that the whole simulation period is divided into the event periods when the river concentration is as calculated earlier (mixed in-river concentrations) and the intervening non-event periods when the river concentration is equal to the upstream river concentration.

The calculation for dissolved copper in Step 2 is as follows:

$$AnnAve\_DissCu = \frac{\sum(DissCu\_RiverConc * DischDur\_Unattenuated) + (TotalHours - \sum DischDur\_Unattenuated) * UpRivCu}{TotalHours}$$

Where *TotalHours* is the total number of hours in the simulation period – for 10 years this is about 87672 hours.

The calculation is repeated for dissolved zinc (using *DissZn_RiverConc* and *UpRivZn*). Then both calculations are repeated for Step 3 using *DischDur_Attenuated, DissCu_Mit* and *DissZn_Mit*.

A6 Compare results with assessment thresholds

A6.1 Solubles Toxicity test

The calculated number of exceedances of the RST24 and RST6 thresholds per year is compared to the allowable numbers for both copper and zinc. If the calculated number is greater than the allowable number, the test is failed. The outcome is reported in line with the logic diagram

A6.2 Sediment Toxicity test

The calculated number of exceedances of the sediment toxicity thresholds per year is compared to the allowable numbers for all the sediment attached pollutants. If the calculated number is greater than the allowable number, the test is failed. The outcome is reported in line with the logic diagram. On the Interface worksheet, the outcome for the most critical pollutant is reported.

A6.3 Sediment Extensiveness test

For this test, the Deposition Index (DI) is calculated:

$$Deposition\ Index\ (DI) = \frac{Annual\_sed\_vol * 100}{0.01 * 10 * w}$$

where *w* = surface width of the river at low flow (m). This is taken as either *RiverWidth* (Tier 1) or *Channel_Width* (Tier 2).

The calculated DI is then compared with the DI Threshold to judge whether the sediment deposition quantity is high or low.

A calculation is also carried out to find the amount of settlement needed to pass the DI threshold:

$$PercSettlementNeeded = (DI - DI\_thresh)/DI * 100\ \%$$