SOUTH AFRICAN WATER QUALITY GUIDELINES FOR FRESHWATER ECOSYSTEMS – VERSION 2
Volume 2: Implementation Manual

ON Odume, NJ Griffin, PK Mensah, D Forsyth, L Ncube and HJ van Niekerk

WATER RESEARCH COMMISSION

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South African Water Quality Guidelines for Freshwater Ecosystems – Version 2

Volume 2: Implementation Manual

Report to the
Water Research Commission

by

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This report forms part of a set of two reports. the other report is *South African Water Quality Guidelines for Freshwater Ecosystems – Version 2. Volume 1: Technical Report.* (WRC Report No. TT 936/1/23)

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS & ABBREVIATIONS

ACWUA	Assessment of Consideration for Water Use Application
AEV	Acute Effect Value
AQUIRE	Aquatic toxicity information retrieval database
CAS	Chemical Abstracts Service
CCME	Canadian Council of Ministers of the Environment
CEV	Chronic Effect Value
CSV	Comma Separated Values file format
DSS	Decision Support System
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
ECx	Effect concentrations where x% effect was observed
EPA	Environmental Protection Agency
HTML	Hypertext Mark-up Language
IUA	Integrated Units of Analysis
LCx	Lethal concentrations where x% mortality was observed
LOEC	Lowest Observed Effect Concentration
MIRAI	Macroinvertebrate Rapid Assessment Index
NOEC	No Observed Effect Concentration
NWA	National Water Act
NWRS	National Water Resource Strategy
QSAR	Quantitative Structure Activity Relationships
RDM	Resource-Directed Measures
RQO	Resource Quality Objective
RU	Resource Units
SACNASP	South African Council for Natural Scientific Professions
SASS	South African Scoring System
SAWQG	South African Water Quality Guidelines
SDC	Source-Directed Controls
SSD	Species Sensitivity Distribution
TPC	Threshold of Potential Concern
TWQR	Target Water Quality Range
USEPA	United States Environmental Protection Agency
WMS	Water Management System
WQG	Water Quality Guideline
WRC	Water Research Commission

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CHAPTER 1: INTRODUCTION

1.1 NOTE TO USERS

This implementation manual must be read with the technical report: South African Water Quality Guidelines for Freshwater Ecosystems – Version 2; Volume 1: Technical Report. Download the DSS from here: https://www.ru.ac.za/iwr/resources/software/wqgdss/

1.2 1996 GUIDELINES

In 1995 and 1996, the Department of Water Affairs and Forestry (DWAF) published a series of water quality guidelines. The guidelines covered water quality in marine and fresh waters, and produced different guidelines for different end users depending on their priorities and/or needs. One user for which a water quality guideline was compiled was freshwater ecosystems (DWAF 1996).

The 1996 freshwater ecosystem guidelines contained guideline values for water quality parameters understood to be of importance to freshwater ecosystems. In general, two boundary values were used to derive three potential classes that water might be in with respect to the concentration of one particular water quality parameter. The classes were defined in terms of acute and chronic toxicological response, which are defined as follows:

- The Chronic Effect Value (CEV), is defined as that concentration or level of a constituent at which there is expected to be a significant probability of measurable chronic effects to up to 5% of the species in the aquatic community.

- The Acute Effect Value (AEV) is defined as that concentration or level of a constituent above which there is expected to be a significant probability of acute toxic effects to up to 5% of the species in the aquatic community. Acute effects here would be mortality.

Knowledge of these criteria allows the definition of a management objective, the Target Water Quality Range (TWQR), which is the range of concentrations of a particular compound that are ideal for aquatic ecosystems, and that will not lead to measurable adverse effects given life-long exposure (DWAF 1996). As both the AEV and CEV are adverse effects, the TWQR is lower than these. As the concentration of the water quality parameter increases, one can anticipate that chronic effects would occur, followed by acute impacts.

Guidelines were produced for 16 toxic inorganic compounds, 3 toxic organic compounds, 4 system variables, 1 non-toxic inorganic constituents, and 2 nutrients (25 compounds in total). The majority of toxic inorganic compounds were metals, making these compounds well represented in the final guidelines.

CEV and AEV were calculated following methods derived from EPA (Environmental Protection Agency) methods, and gave guidelines that were methodologically aligned with those of the United States, Netherlands, and Canada (Roux et al., 1996, DWAF 1996). Basically, deriving an aquatic ecosystem water quality guideline for the 1996 guidelines involved toxicity data from the EPA AQUIRE database (more recently absorbed into the Ecotox database which we used for the current project), or a toxicity estimate using EPA's implementation of Quantitative Structure Activity Relationships, or QSAR (DWAF 1996, EPA 2023a, 2023b). Thereafter, a series of calculations followed, the structure of which depended on data availability (Roux et al., 1996, DWAF 1996). The 1996 aquatic ecosystem water quality guidelines relied more on data from particular animal taxa.

Plant or algal toxicity only contributed to the CEV, but not the AEV (DWAF 1996). Owing to the limited set of toxicity data available, boundary values produced were then adjusted using a safety factor depending on specific data factors. Finally, again depending on certain criteria, one might to adjust the final values to account for site-specific factors (DWAF 1996).

The 1996 aquatic ecosystem guidelines therefore reflect the response of taxa to a toxin, or possibly the predicted response to a toxin. The response is a simple physiological one to a single stressor. This is unlike what might be found in nature, where other stressors and other factors mediate the success of a taxon in a particular location. This makes these guidelines widely appropriate across a range of environments and locations, but with little consideration of how natural variation between sites may occur.

1.3 CRITICISM

The criticism of the 1996 Guidelines are fully described in Volume 1 of this series. Briefly, the guidelines have been criticise for four fundamental reasons. First, they have been criticised for not being risk-based. Second, they have been criticized for not aligning with important strategies and approach for managing freshwater resources as envisaged in the National Water Act. The reason for this is that the guidelines were developed prior to the promulgation of the National Water Act in 1998. The third reason is that with the exception of a few system variables, the guidelines are not site-specific, and thus prescribe a single target water quality range (TWQR) for the entire country, implying that spatial contexts have not been taken into account. Fourth, the guidelines have also been criticised for being limited in the number of compounds for which guidelines exist, implying that recent research in the field of contaminants of emerging concerns such as pharmaceutical compounds are not reflected in the guidelines. In addition to these criticisms, the guidelines are hard-copy paper based, and have thus been criticize for not being easily updatable and not facilitating rapid decision making process. In this regard, a software-based decision support system (DSS) was recommended in revising the guidelines.

1.4 REVISION

Since the 1996 guidelines were published, much research has been undertaken locally and internationally in terms of derivation approaches, use of technologies in guideline application, effects of critical pollutants such as pesticides, persistent organic pollutants, endocrine disruptive compounds, pharmaceuticals, acid mine drainage, and emerging toxicants of concern. The majority of these pollutants are not in the current SAWQGs for freshwater ecosystem. Thus, a revision is imperative to reflect new knowledge and research in the field of guideline development. Risk-based guideline implies that there must be a shift from the effects of pollutants on single species to the effect on ecosystems as a whole.

This project largely adopted the Boyd et al. (2015) proposed framework for the revision of risk-based water quality guidelines in South Africa. Thus, the revised South African Water Quality Guideline (SAWQG) for aquatic ecosystems is a three-tiered approach packaged into a Decision Support System (DSS), which is ultimately used to derive the risk-based water quality guidelines.

Tier 1, which represents the scientific domain, is generic and the most conservative guideline, with minimum user input requirement and a simple output provided by a Decision Support System (DSS). This level of guidelines is largely what the 1996 SAWQG details, but has been updated by adding new variables that have become imperatives, as well as updating to current science. The Tier 1 guideline is conservative and precautionary in nature as it gives protection to the most sensitive receptor in the aquatic ecosystem. It is also generic due to its applicability to all water resources.

Tier 2 is at ecoregional levels, which largely relies on predefined water use scenarios and limited site characterisation choices. However, it requires some user skill as it is precedent on common field observation as well as measurement input for scenarios manipulation. In this sense, the in-stream water quality due to site location and the actual water quality profile are used to rate possible occurrence of risk. The water quality guideline (WQG) at this level may also be derived using the DSS.

The Tier 3 guideline is site-specific guidance and may be employed as a risk assessment protocol. As such, it requires highly skilled input and output interpretation. The Tier 3 risk category is based on site-specific risk assessments and objectives setting. The DSS allows for derivation of Tier 3 water quality guidelines.

These water quality guidelines are for freshwater ecosystems, and as such it is appropriate to align the classes derived to correspond with ecological categories derived as part of the ecoclassification process as described by Kleynhans and Louw (2007). Although methodologies differ between various Tier levels, all produce guidelines correspond to ecological categories A to F, or from natural water quality to critically impacted.

CHAPTER 2: TIER 1

2.1 INTRODUCTION

Tier 1 guidelines are conceptually linked to the previous 1996 guidelines in that there is no spatial component and that Tier 1 guidelines are conservative and are derived from toxicological response data (DWAF 1996, Roux et al., 1996). The guidelines are therefore based on taxa responses to the toxin in question, unmediated by local ecologies and other factors that might alter the toxicological response.

The use of toxicological results in setting of guidelines has wide application worldwide (Posthuma et al., 2019). Conceptually, knowing the response of a taxon to a compound allows one to make recommendations about acceptable levels of that compound for protection of that taxon. Knowing the response of a range of taxa to a compound allows one to make rough estimations of how a community or an ecosystem might respond. This is the concept that underlies the use of multiple toxicological results in a species sensitivity distribution (SSD) to produce sensible ecosystem water quality guidelines. These methods underlie the derivation of ecologically-based guidelines around the globe, including Australia/New Zealand (Warne et al., 2015, 2018), the European Union (EU) , United States (US) (USEPA 1992, 1998, 2023) and Canada (CCME 2007, Posthuma et al., 2019).

The Tier1 methods that were finally selected broadly follow those described in Posthuma et al. (2019). Toxicological data from a number of sources were compiled into a database, where they were standardized, and identified flawed records were filtered out These data were queried to produce an SSD, from which an appropriate protective concentration suitable for guideline production were extracted.

2.2 METHODS

2.3 TOXICOLOGICAL RESPONSE DATA

Toxicological data was downloaded from the USEPA Ecotox database (Olker et al., 2022) in May 2021. Text files with received data were uploaded to a PostgreSQL database, and compiled to a single data table. Data were simplified as required, and filtered such that only valid freshwater ecotoxicological records were used, giving a final data set of 165 320 valid freshwater toxicology records on 907 compounds.

The other primary source of data was MistraPharma's WikiPharma database (Molander et al., 2009), downloaded in January 2022. This data source contains the results of toxicological testing for environmental effects of pharmaceuticals in fresh water. WikiPharma contains 7 999 toxicological endpoint records of 341 compounds.

Guidelines are generated for 24 inorganic compounds, 45 organic compounds and 26 pharmaceuticals. Where compounds are present in an ionized state in freshwater, toxicological results from their salts are used to generate SSDs and extract guidelines. Where the compound existed in water as a cation, the chloride, sulphate, hydroxide and carbonate salt results were used. Where it was an anion, the hydrogen, sodium, potassium, and magnesium salts were used. All hydration states of the salt were used, and a conversion factor was used to get the mass fraction of the test compound in the salt.

All data were coded using a CAS number to provide an unambiguous unique reference for each compound. The CAS Registry Number provides a unique identification number from the Chemical Abstracts Service (CAS) to every chemical substance described in the open scientific literature (CAS 2023). All data were filtered to

ensure that only freshwater toxicological data from records with suitable numeric results and adequate controls were loaded to the DSS. Within the DSS the units of the endpoints were converted to the units used with the DSS where possible. Where this was not possible, toxicological records were not used in guideline derivation.

2.4 TOXICOLOGICAL DATA TO GUIDELINES

2.4.1 Overview

For any given compound, data can be queried from underlying freshwater toxicology database to conform to a number of criteria (see below for details), and used to create an SSD analysis, from which a protective guideline can be generated such that one can define what proportion of taxa are protected from exceeding the selected endpoint (e.g. see Figure 2-1) (Posthuma et al., 2002 and references therein). This point defines the guideline value, and, depending on one's requirements, can be highly protective, or less. It will be affected by the toxicological endpoint selected for SSD analysis, and by underlying data availability. Clearly, if a suitable guideline for water quality for aquatic ecosystems is desired, it will best be achieved by basing the guideline of an SSD based on toxicological data from an adequately large and diverse dataset. When this is the case, confidence in a derived guideline can be high, and it can be taken as representative of an ecosystem with all its diversity. Where the dataset is limited, and/or skewed in favour of particular taxa, risk is higher that the derived guideline is inappropriate. In the case of some potential toxins, large datasets of results are available (e.g. see Figure 2-1). However, some toxins have received less attention, and as a result, guideline boundary values are less reliable.

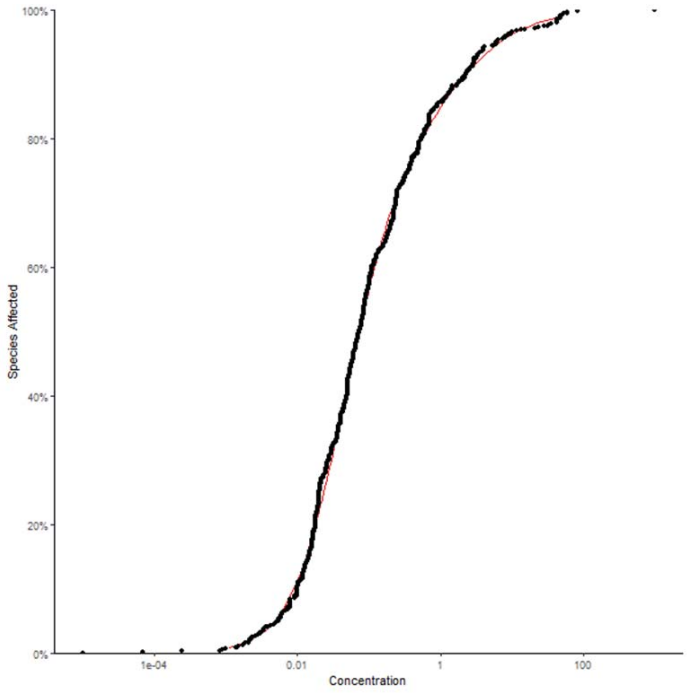


Figure 2-1 Example of a Species Sensitivity Distribution (SSD) plot, produced using 722 records of LC_{50} data from 86 different taxa exposed to copper chloride ($CuCl_2$).

2.4.2 Endpoints

Generally, toxicity can either be classified as acute or chronic. Here, these follow general conventions (e.g. Batley et al., 2018; EPA 2023) and in the context of this guideline are defined as:

- Acute: Acute tests are short-term exposure tests to a potential toxicant. They commonly have lethality as an endpoint. For this guideline, data selected are those from tests that assess mortality and that return valid numeric endpoints that assess impacts on 40-60% of the population (the great majority of these data were labelled as EC_{50} or LC_{50}).

- Chronic: Chronic tests are longer term exposures to potential toxicants. They generally use a sublethal endpoint that assesses a criterion relevant to the test population. Here, data selected are those from tests that affect growth, development, reproduction, physiology, genetics, and behaviour and feeding of the test taxa and that returned valid numeric data for NOEC, LOEC and other endpoints returning data for effects that impact 10% or less of a population.

Given that enough data are available for each compound, a chronic and an acute SSD analysis is undertaken for each compound. The chronic endpoint data are used to derive the natural or A class, while acute data are used to define the remainder of the classes.

For most organic compounds and pharmaceuticals, using toxicological data to derive a guideline is fairly straightforward, as toxicological tests are run on the dissolved compounds directly. Inorganic compounds, which are usually tested in the form of one or another salt, are more complex, as the toxicological results reflect the combined impact of ions on the test organism(s). However, management systems utilize measures of the active compound, and not its salt, and so guidelines for individual compounds or elements are required.

In order that guidelines on inorganic ions could be included, salts were identified where the compound being tested was assessed using several of its salts. These were selected in order that the toxicological impact of the associated ion would not be high and therefore that the toxicological response would indicate to a great extent the compounds or elements being tested. What this in effect meant was that, for any given cation, the chloride, sulphate, hydroxide and carbonate salt results were used together to determine the SSD. For anions, the hydrogen, sodium, potassium, and magnesium salts would be considered. Different hydration states of the salts were also combined.

2.4.3 Ecological categories

The boundary values that define ecological categories A to F are presented in Table 2-1 below. The guidelines produce a means of classifying water into 6 classes that correspond to the ecological categories from the Ecoclassification process as described in Kleynhans and Louw (2007).

The result of using chronic results for class A is that the Natural or A class is very conservative, and, for the toxins is assessed at Tier 1, many but not all of which are not found naturally, class A should represent the natural state. The other taxa allow for an increasing level of mortality, until, at class F, half the individuals of 30% or more of the taxa present or expected to die in the relatively short term.

Table 2-1 Guideline derivation for application to SSD consensus model fits. Corresponding to generic ecological categories of Kleynhans and Louw (2007).

Category	Title	Description
A	Natural	Chronic impacts in 1% or fewer of test taxa.
B	Largely natural	Acute impacts in 5% or fewer of test taxa.
C	Moderate impact	Acute impacts in 10% or fewer of test taxa.
D	Large impact	Acute impacts in 20% or fewer of test taxa.
E	Serious impact	Acute impacts in 30% or fewer of test taxa.
F	Critical impact	Acute impacts in more than 30% of test taxa.

2.5 USE OF TIER 1 GUIDELINES

When a user starts the DSS, they are offered the choice of undertaking a Tier 1, 2, or 3 analysis (see Figure 2-2). Pressing the Tier 1 button takes one to the page for Tier 1 analysis (see Figure 2-3).

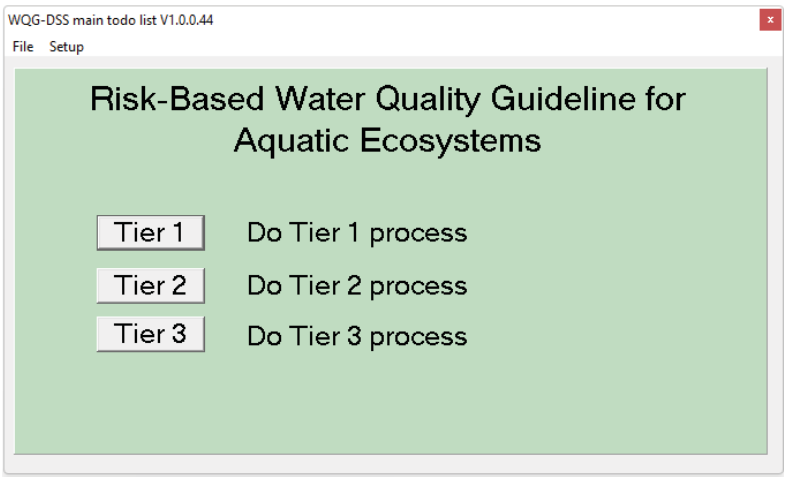


Figure 2-2 Water quality guidelines DSS opening page.

Once on that page, the first thing that a user should do is select a variable for which guidelines are sought. Pressing this option presents a list of variables in a drop-down list (see Figure 2-4). These consist of elements or ions, organic compounds (including a number of biocides) and selected pharmaceuticals, here shown by name and CAS number. The CAS number is a unique identification number assigned by the Chemical Abstracts Service (CAS) to every chemical substance described in the open scientific literature. Then the user has a choice as to whether to simply produce a guideline, or to supply one's own data for comparison against the generated guideline.

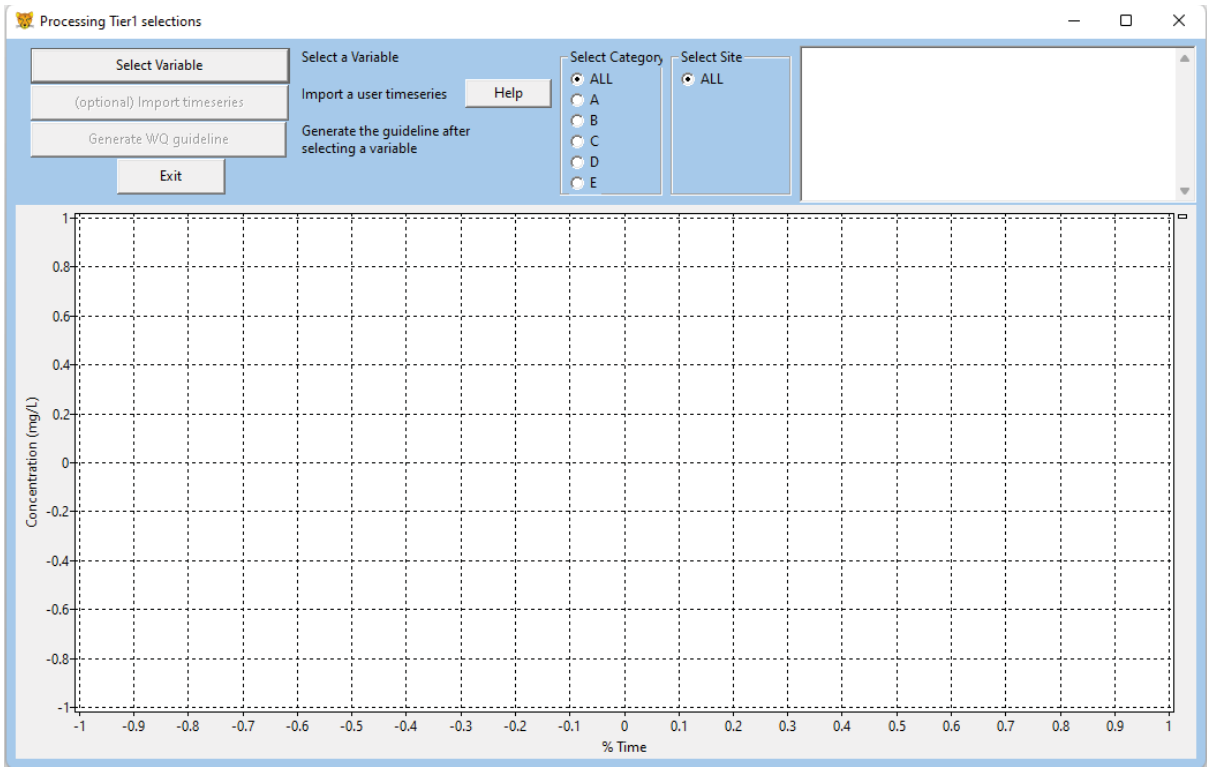


Figure 2-3 Water quality guidelines DSS Tier 1 data entry page.

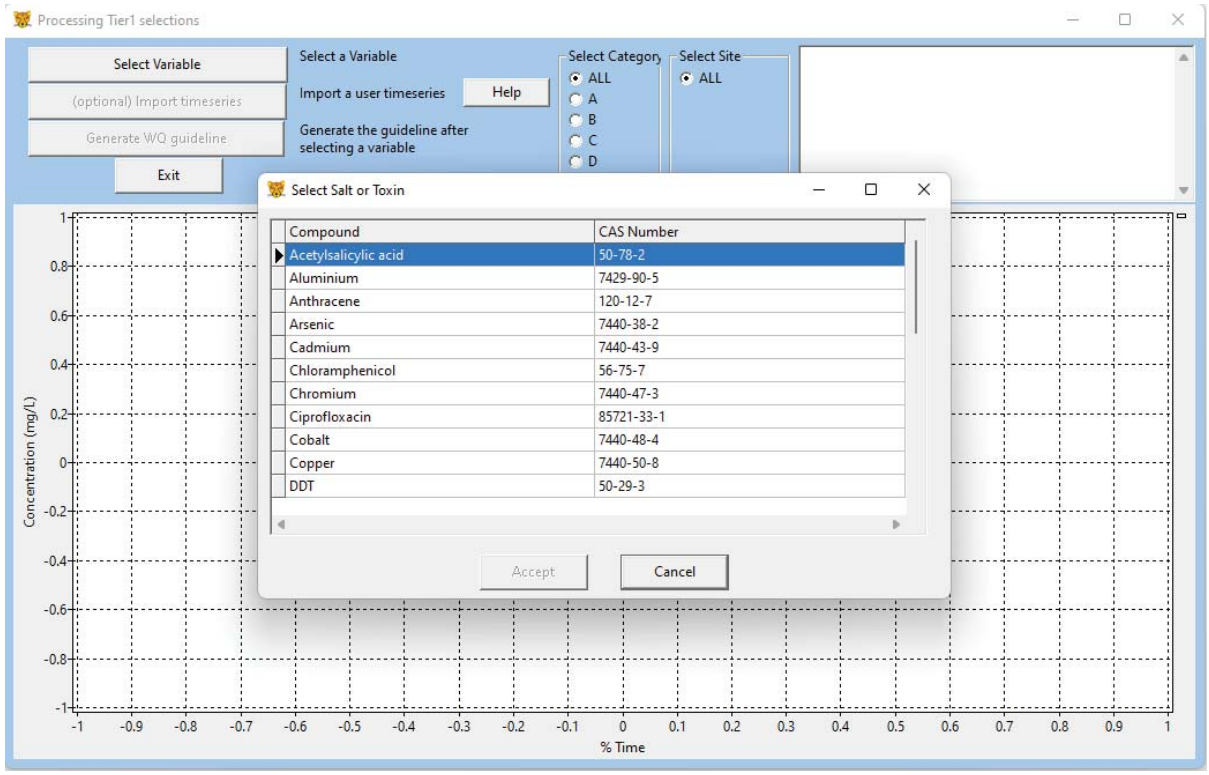


Figure 2-4 Water quality guideline DSS at Tier 1 level, showing the selection process of compounds for which a guideline can be generated.

If a simple guideline is required, one can click on the button to generate a guideline. On clicking this button, the DSS undertakes an acute and a chronic SSD analysis, and outputs ecological category boundaries (with error estimates). For Ecological Categories A-E, the boundary conditions are the upper boundary of the particular class in concentrations of the compound. Ecological category F consists of all concentrations greater

than that given for Ecological Category E (see Table 2-1 for details, and Figure 2-7 and Figure 2-8 for examples). Output of this process is an HTML file that is transmitted to the user's default browser for visualization (see Figure 2-7). Within the output is a table, with information on Ecological Category names (A-F), a brief description of the Category, the class upper (or, for F, lower) boundary value, and description of the risk posed, based on the SSD analysis. This thus provides a simple tabulation of the guideline values and the implication of guideline levels for the environment.

Another option that is open at Tier 1 is to upload one's own data for comparison with the guidelines. When multiple values are uploaded, the DSS generates a concentration duration plot, that can give an estimate of risk at any particular site. Here, one can import a simple .csv file, with data on the compound requested (in mg/ℓ), and a column with site of sample identifiers (sitename). An example of data file structure is presented in Table 2-2. The interface for file upload is shown in Figure 2-5. Pressing on "Get timeseries" opens a file browser window that allows a user to select a file with their own data.

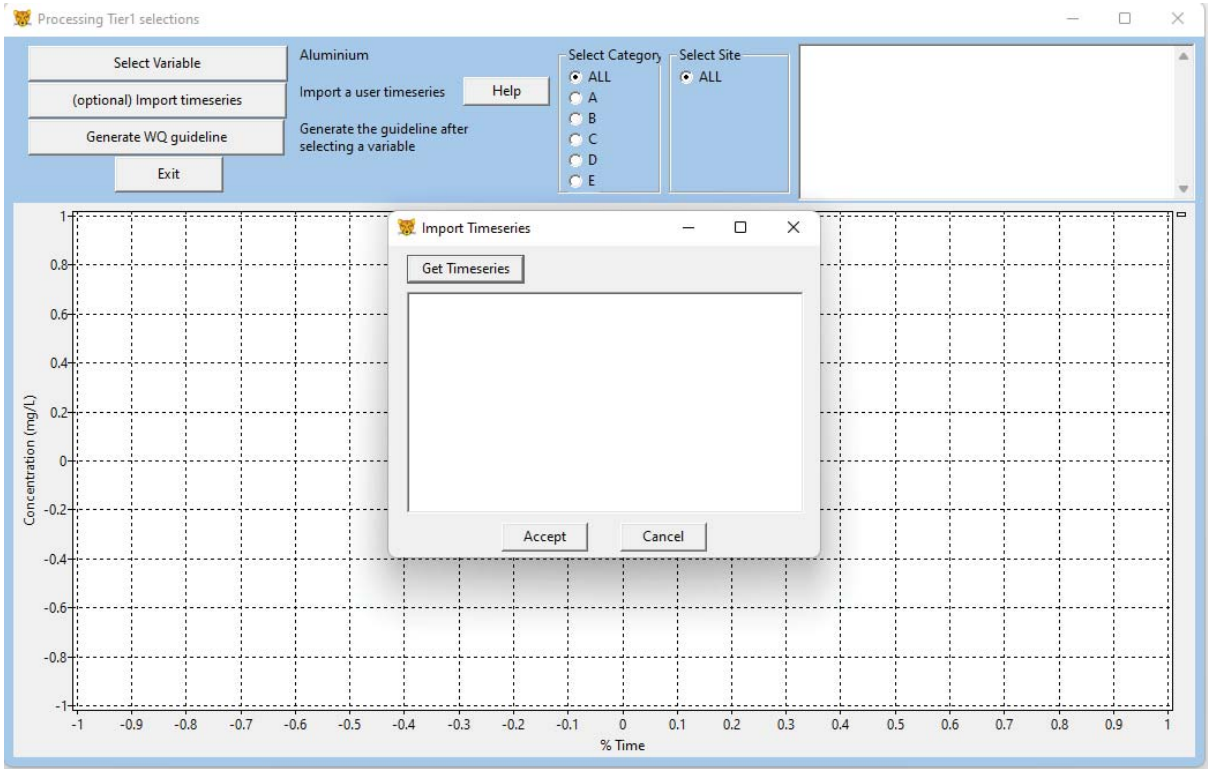


Figure 2-5 Water quality guidelines DSS Tier 1 interface for user file upload.

The data input format is a standard CSV text file containing columns as follows: sitename, ecoregion, data1[,data2,data3]. Column sitename is required, and column data1 is required. Column ecoregion is optional, as are further data columns. The data column names can be any single word, like: Al or Aluminium, or Ca or Calcium. Each row begins with the sitename, and where there are multiple sitenames, they must be grouped together. The number of sites is limited to 10.

Table 2-2 File format for upload of own data in csv format for analysis under the guideline DSS. The example here is for aluminium data collected at two different sites.

sitename	Al
A12A	0.01
A12A	0.2
A12A	0.001
B12B	0.07
B12B	0.09
B12B	0.1
B12B	0.11

Now, when a guideline is generated, the DSS generates an html file that contains the same guideline boundary value table as is generated when a guideline without sample input data is produced from SSD analysis of toxicological data (see Figure 2-8). It also produces summary statistics on the submitted data (5th, 50th and 95th percentiles, as well as sample mean) for each of the samples defined under column “sitename” in the input file. The output also contains a concentration duration curve that shows the percentage of uploaded samples that are likely to equal or exceed a particular concentration of the compound for which a guideline is required, again grouped by site or sample identifier (for an example, see Figure 2-6). If the input samples were collected regularly, they would represent a time series, and, if they were collected over a long enough time frame, might be valuable as a tool for predictions of future water quality at the site samples were collected at. Plotting these data against concentration allows the user to easily identify concentrations that are either always, or never, exceeded. By plotting the guideline ecological category values on the y-axis, the plot allows the user to directly read what proportion of submitted samples are in which ecological category.

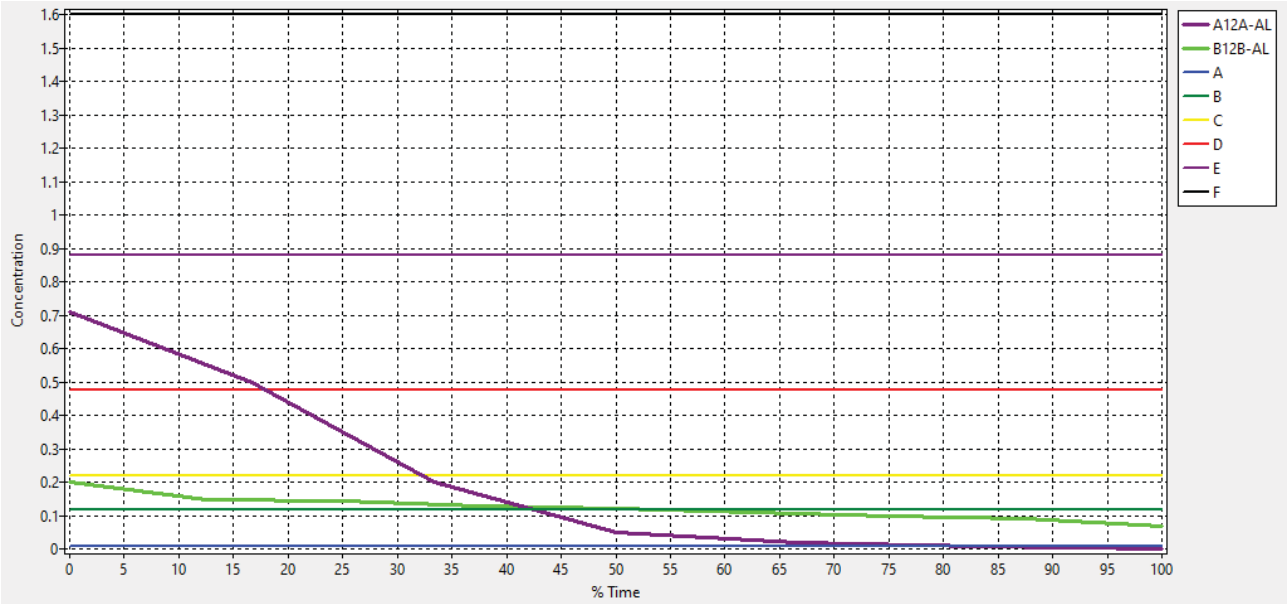


Figure 2-6 Example of a concentration duration curve as produced by the Tier 1 guideline DSS. These data were entered in a similar format to the data in Table 2-2.

In the example presented in Figure 2-66, aluminium data from two hypothetical sites (A12A and B12B) are used to generate a pair of concentration duration curves. The guideline boundaries are also shown, and these allow the water quality implications of the concentration duration plot to be read from the figure. In this example, inspection of the two sets of data shows two different sets of behaviour. Site A12A, which shows varying water quality with approximately 20% of samples in ecological category A, 38% in category B, about 10% in category C, 14% in category D, and the remaining 18% in category E. Site B12B varies far less, with about 48% of samples in category B, and the remaining 52% of samples in category C.

Unless the number of individual samples in each user-defined group is large, the percentages as reported above from graphical inspection may be somewhat ambiguous, as they are based on intersections between concentration duration curves and guideline category boundaries. When few samples are present, these intersections will be at interpolations of the flow duration curve. When few data are available may be wiser to rely on a simple count of data points in each category.

Output: Tier 1

Generated: 2023/11/02 15:47:00

This is Tier 1 output from the Water Quality Guidelines Decision Support System (WQGDSS).

Selected chemical **Aluminium**

Timeseries info

Sitenames

None Imported

Chemicals

None Imported

Filename:

None Imported

Sitename	Chemical	5th	50th	95th	Mean
No chemicals imported					

Info for selected chemical

Ecological Category	Description of Category	Water quality guideline value	Risk Description
A	Natural	<= 0.0070 mg/L (0.0054-0.0086 95% CI)	<=1% chronic guideline Concentration of a water quality constituent most likely suitable for 99% or more of species. The risk of more than 1% of species being affected is low. Extremely sensitive species may still be affected.
B	Largely Natural	<= 0.119 mg/L (0.0754-0.162 95% CI)	<=5% acute guideline Concentration of a water quality constituent most likely non-lethal for 95% or more of species. The risk of more than 5% of species being affected is low. Highly sensitive species may still be affected.
C	Moderate impact	<= 0.218 mg/L (0.150-0.286 95% CI)	<=10% acute guideline Concentration of a water quality constituent may cause mortality in a number of species. The risk of 10% or fewer of the species dying is high, with moderate impact on biodiversity and ecosystem functionality.
D	Large impact	<= 0.475 mg/L (0.303-0.647 95% CI)	<=20% acute guideline Concentration of a water quality constituent may cause mortality in a large number of species. The risk of 20% or less of the species

Ecological Category	Description of Category	Water quality guideline value	Risk Description
			dying is high, with large impact on biodiversity and ecosystem functionality.
E	Serious impact	<= 0.880 mg/L (0.517-1.2 95% CI)	<=30% acute guideline Concentration of a water quality constituent may cause mortality in a very large number of species. The risk of 30% or less of the species dying is high, with serious impact on biodiversity and ecosystem functionality. Water quality is unacceptable.
F	Critical impact	>0.880 mg/L	>30% acute guideline Concentration of a water quality constituent may cause mortality in a very large number of species. The risk of 30% or more of the species dying is high. Water quality is unacceptable.

To see a distribution curve graph you must import a timeseries.

Figure 2-7 Example of a simple guideline report produced when no data are supplied at Tier 1 level of the water quality guideline DSS. See text for full explanation.

For each of the ecological categories A-E, the generated guideline report gives the upper boundary value, and the 95% confidence interval (CI) around the derived boundary value (Figure 2-7). The confidence interval indicates the level of statistical support for the boundary estimation based on the available toxicological data. Category F is defined as having a greater concentration of the compound for which guidelines are requested than the other combined ecological categories.

In contrast to the simple guideline report shown in Figure 2-7, when a user uploads their own data, analysis of these data in light of the generated guideline is also presented in the output report (Figure 2-8). When the “Generate Guideline” button is pressed after loading user data, the basic guidelines from Figure 2-7 are produced together with summary statistics from user data, and a concentration duration curve with overlaid guidelines (Figure 2-8). The summary statistics include the 5th, 50th and 95th percentiles, as well as sample mean. The concentration duration plot is the same as Figure 2-6 above, and is interpreted in the same way.

Output: Tier 1

Generated: 2023/11/01 12:05:25

This is Tier 1 output from the Water Quality Guidelines Decision Support System (WQGDSS).

Selected chemical **Aluminium**

Timeseries info

Sitenames

- A12A
- B12B

Chemicals

- AL

Filename:
H:\WQGDSS\data\timeSereisAL.csv

Sitename	Chemical	5th	50th	95th	Mean
A12A	AL	0.010	0.050	0.710	0.213
B12B	AL	0.090	0.120	0.200	0.124

Info for selected chemical

Ecological Category	Description of Category	Water quality guideline value	Risk Description
A	Natural	<= 0.0070 mg/L (0.0054-0.0086 95% CI)	<=1% chronic guideline Concentration of a water quality constituent most likely suitable for 99% or more of species. The risk of more than 1% of species being affected is low. Extremely sensitive species may still be affected.
B	Largely Natural	<= 0.119 mg/L (0.0754-0.162 95% CI)	<=5% acute guideline Concentration of a water quality constituent most likely non-lethal for 95% or more of species. The risk of more than 5% of species being affected is low. Highly sensitive species may still be affected.
C	Moderate impact	<= 0.218 mg/L (0.150-0.286 95% CI)	<=10% acute guideline Concentration of a water quality constituent may cause mortality in a number of species. The risk of 10% or fewer of the species dying is high, with moderate impact on biodiversity and ecosystem functionality.
D	Large impact	<= 0.475 mg/L (0.303-0.647 95% CI)	<=20% acute guideline Concentration of a water quality constituent may cause mortality in a large number of species. The risk of 20% or less of the species dying is high, with large impact on biodiversity and ecosystem functionality.
E	Serious impact	<= 0.880 mg/L (0.517-1.2 95% CI)	<=30% acute guideline Concentration of a water quality constituent may cause mortality in a very large number of species. The risk of 30% or less of the species dying is high, with serious impact on biodiversity and ecosystem functionality. Water quality is unacceptable.

Ecological Category	Description of Category	Water quality guideline value	Risk Description
F	Critical impact	>0.880 mg/L	>30% acute guideline Concentration of a water quality constituent may cause mortality in a very large number of species. The risk of 30% or more of the species dying is high. Water quality is unacceptable.

Figure 2-8 Example of a simple guideline report produced when no data are supplied at Tier 1 level of the water quality guideline DSS. See text for full explanation.

CHAPTER 3: TIER 2

3.1 INTRODUCTION

South Africa rivers are spatially variable and heterogenous. This spatial variability is driven by several factors such as climate, physiography, geology and soils as well as attitude. As a result, rivers in South Africa have been typed hierarchically into ecoregion levels I and II. The underlying assumption is that rivers within the same ecoregion are ecologically more similar than rivers in distinct ecoregions. One of the criticisms of the 1996 Guidelines is that they were prescriptive without taking spatial variability into account in the sense that the same guideline values were applied throughout the country. A key short-coming of this approach is that in some parts of the country, certain water quality variables are naturally elevated due to underlying natural factors, e.g. some coastal rivers in the Eastern Cape such as Swartkops River that has elevated salt levels due to the underlying geology. The revised guidelines accounted for spatial variability within the country by deriving guidelines at ecoregion level II.

3.2 METHODS

Tier 2 Guidelines were derived using the DWS data in the WMS database. WMS maintains a good set of data on major salts and other commonly measured physico-chemical variables such as nutrients, pH and dissolved oxygen, but has very little data on organic contaminants including herbicide and pesticide levels (guidelines for organic chemicals were derived at Tier 1 using toxicological data). WMS contains data from 333 routinely monitored points, which were relied upon as the primary source of data for the derivation of Tier 2 Guidelines. These data cover the period 1970s-2020 but this varies by ecoregion. The DWS data covers all seasons in South Africa, and by using these spatially and seasonally variable dataset, the revised guidelines thus account for both spatial and seasonal variability. Given the general rarity of data on metals in WMS, and the near absence of data on organic toxins, guidelines for these variables were derived only at Tier 1 based on ecotoxicological data, and may be regarded as conservatives.

Tier 2 physico-chemical guidelines were derived at ecoregion level 2. The DWS data were processed and regionalised. The derivation of the guidelines follows mainly the water quality methods for the Reserve (DWAF 2008), with some modifications. The Reserve method places emphasis on the use of data from over earliest three-year period, but an exploration of the data per ecoregion level II suggest data paucity in many of the ecoregions. Therefore, the guidelines were developed based on all data reported for an ecoregion. For nutrients and common inorganic salts, the guidelines were developed as per using DWS data.

In addition to physico-chemical constituents, Tier 2 guidelines also uses macroinvertebrate biomonitoring data. The expected assemblage per ecoregion level 2 were derived from the Macroinvertebrate Response Assessment Index (MIRAI) model version 2 (Thirion, 2007). The rationale is that under reference conditions, the expected assemblage should be similar to those observed. To derive macroinvertebrate-based guidelines at Tier 2, a macroinvertebrate risk model was developed and implemented. The macroinvertebrate risk model relies on three metrics: ecoregion level 2 presence and associated confidence, geozone presence and associated confidence and water quality sensitivity for each macroinvertebrate taxon.

An estimate of the amount of risk associated with changes in the macroinvertebrate community in any particular ecoregion level 2 and geozone location can be generated using the macroinvertebrate risk model. If the macroinvertebrate reference community perfectly matches those observed at a site, the site risk score would be zero, and the site would be classified an ecological category A. As the community accumulates differences from the reference community, either through omission of taxa or insertion of new taxa, the risk score would accumulate. The boundary levels outlining the different categories is presented below in Table

3-1. Different methods were used to derive guidelines for dissolved oxygen (DO), and pH as described in Volume 1. Temperature guidelines method default to Dallas and Rivers-Moore (2019a, 2019b, 2022). A summary of this is also described in Volume 1.

Table 3-1 Guideline derivation for Ecoregion level 2 and geozone macroinvertebrate risk estimates, corresponding to generic ecological categories of Kleynhans and Louw (2007).

Ecological category	Name	Upper boundary for rescaled risk	Description
A	Unmodified, natural	0.05	Unmodified and natural, expected and observed taxa are the same or extremely similar. Risk is very low.
B	Largely natural	0.2	A small change between the expected and observed taxa have taken place. Risk is low.
C	Moderately impacted	0.4	Moderate change has taken place between expected and observed taxa. Risk is moderate.
D	Largely impacted	0.6	Large change has taken place between expected and observed taxa. Risk is high
E	Seriously impacted	0.8	Serious change has taken place between expected and observed taxa, resulting in the loss of many taxa. The risk is very high and unacceptable.
F	Critically impacted	1	The macroinvertebrate assemblage has been critically modified, many taxa have been lost; the risk is extreme and unacceptable.

3.3 USE OF TIER 2 GUIDELINES

Upon starting the DSS, the user should click on the Tier 2 button to open the Tier 2 screen of the DSS as shown in Figure 3-1 below. Within Tier 2, the user is able to generate guidelines for both macroinvertebrates and physico-chemistry at ecoregion level 2. The user may decide to use both, i.e. macroinvertebrate data and physico-chemistry or either, depending on the availability of data and the user interest. To proceed, the user must enter the ecoregion level 2 either be selecting the number corresponding to the ecoregion (on the top left side of the DSS screen), or by entering the longitude and latitude information for the site and then clicking on the “Find” button. If the longitude and latitude information is entered and the Find button is pressed, the DSS immediately recover the corresponding ecoregion level 2. Upon entering the Ecoregion level 2 information, the DSS return a screen with the list of chemicals for which guidelines exist at that particular ecoregion level 2 (Figure 3-2).

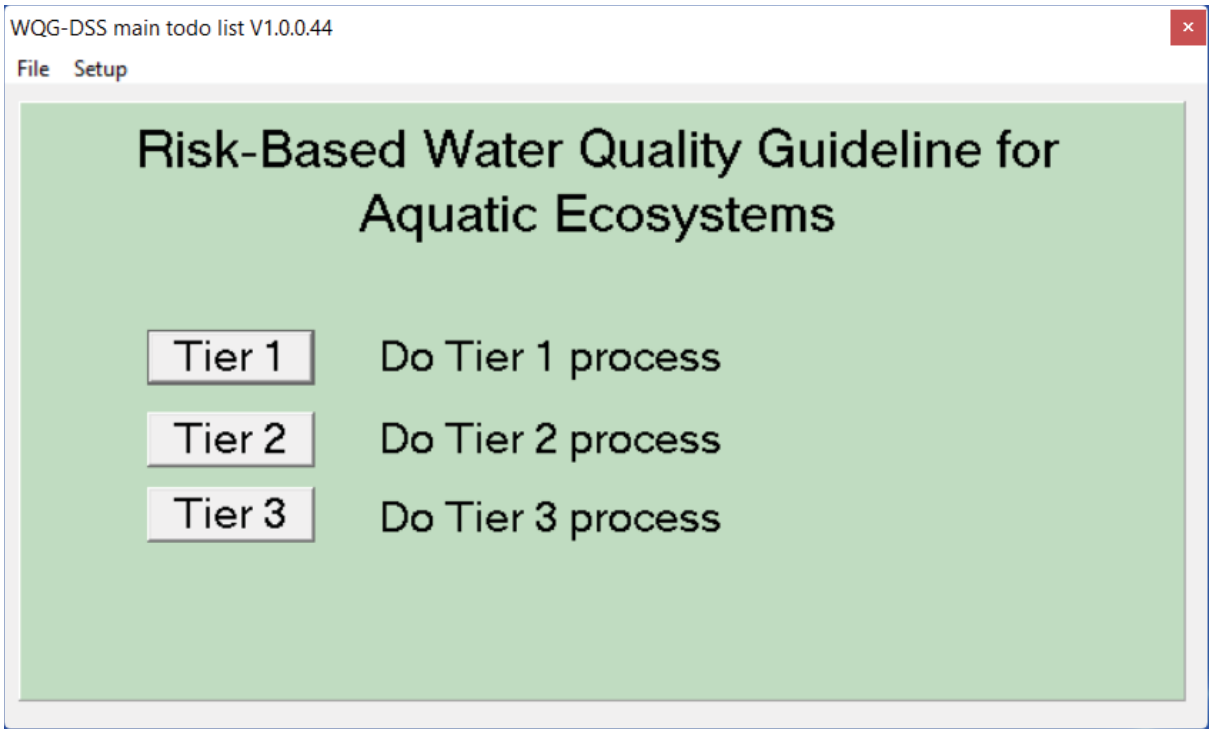


Figure 3-1 DSS screen showing the interface for Tiers 1-3

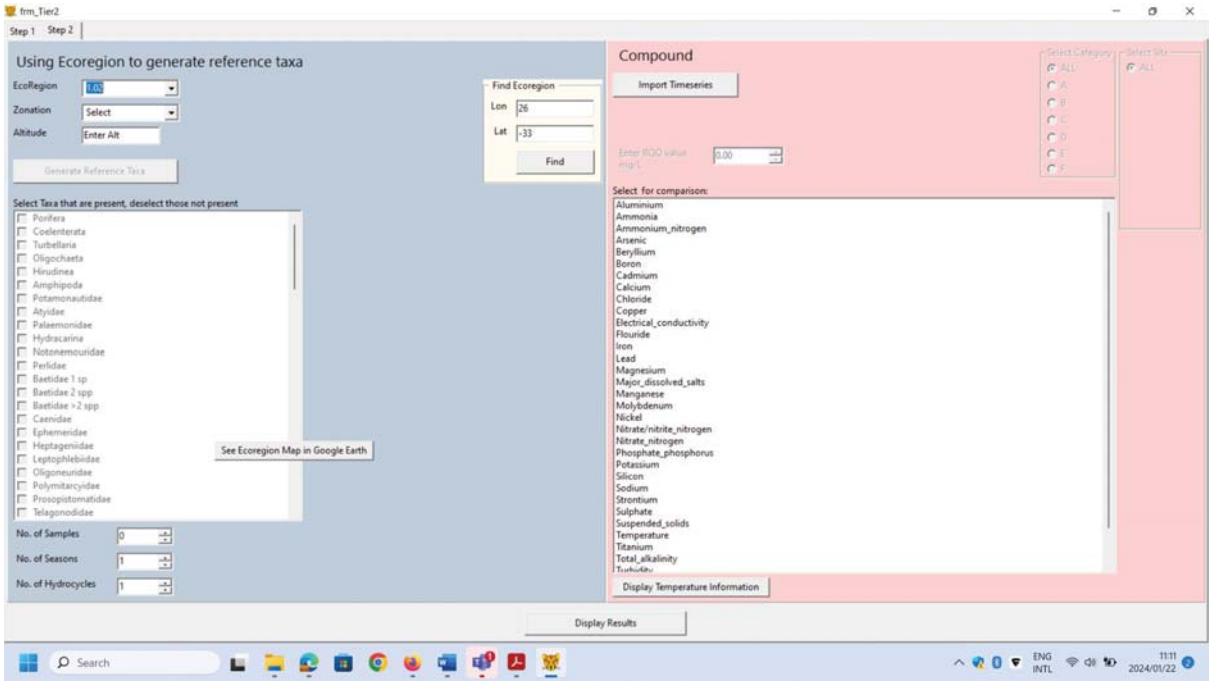


Figure 3-2 DSS screen showing names of chemical constituents for which guidelines exist for ecoregion level 2 (ecoregion 1.02).

Once the screen with the names of chemicals have been returned, the user has the option to generate the guidelines for a particular chemical for that ecoregion level 2 by simply clicking on the chemical and displaying results, or by importing own data, and comparing these data with the guidelines. To import own data, click on the Timeseries button, and then the Get timeseries button, and then click on the Accept button (Figure 3-3).

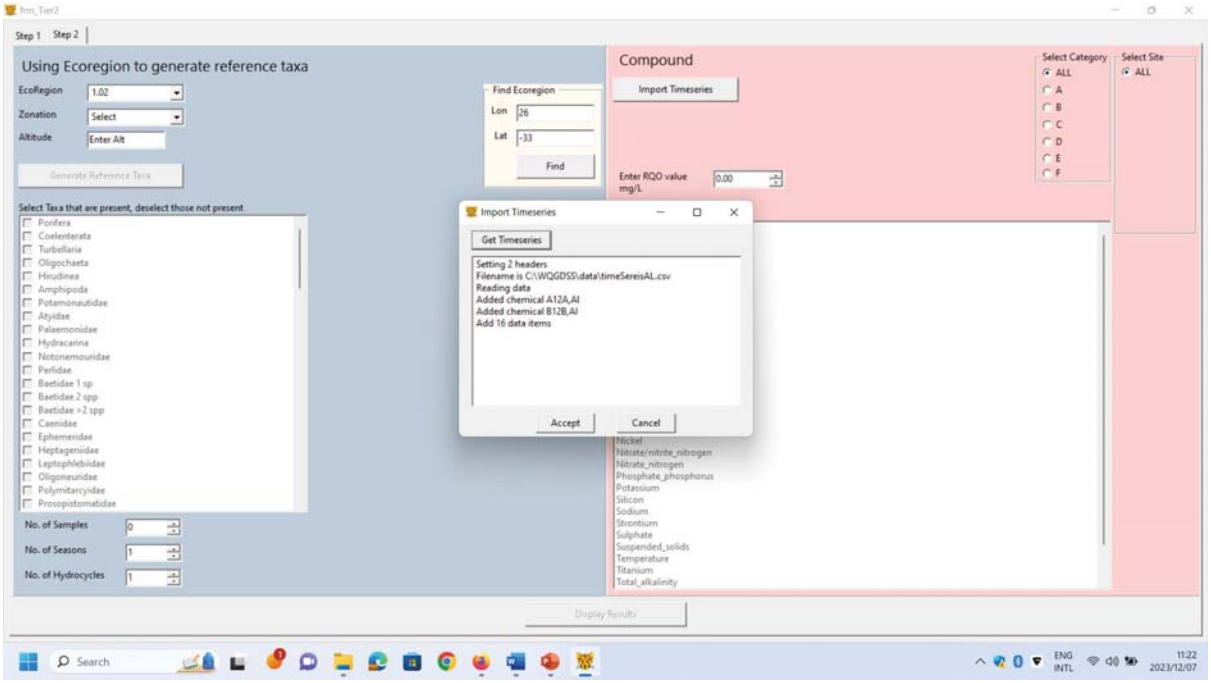


Figure 3-3 DSS screenshot showing Get Timeseries button for importing own data for comparison with guidelines.

The data input format is a standard CSV text file containing columns as follows: sitename, ecoregion, data1[,data2,data3] (Table 3-2). Column sitename is required, and column data1 is required. Column ecoregion is optional, as are further data columns. The data column names can be any single word, like: Al or Aluminium, or Ca or Calcium. Each row begins with the sitename, and where there are multiple sitenames, they must be grouped together. The number of sites is limited to 10.

Table 3-2 File format for upload of own data in csv format for analysis in the DSS. The example here is for aluminium data collected at two different sites (A12A and B12B).

sitename	Al
A12A	0.01
A12A	0.2
A12A	0.001
A12A	0.5
A12A	0.71
A12A	0.02
A12A	0.05
B12B	0.07
B12B	0.09
B12B	0.1
B12B	0.11
B12B	0.12
B12B	0.13
B12B	0.15
B12B	0.15
B12B	0.2

Once the data has been imported, the user has the option of returning guidelines for all the ecological categories by selecting the ALL button at the top right conner under “Select Category or selecting only the ecological category of interest, from category A to F. The User can also compare guidelines for all the sites by selecting the All button under “Select Site” or by selecting only the site of interest. Still the user also has the

option of comparing the water quality data with an RQO (Resource quality objective) value in case where an RQO exist. In such a situation, the user can just enter the RQO number, under “Enter RQO value” on the right side of the screen (Figure 3-4).

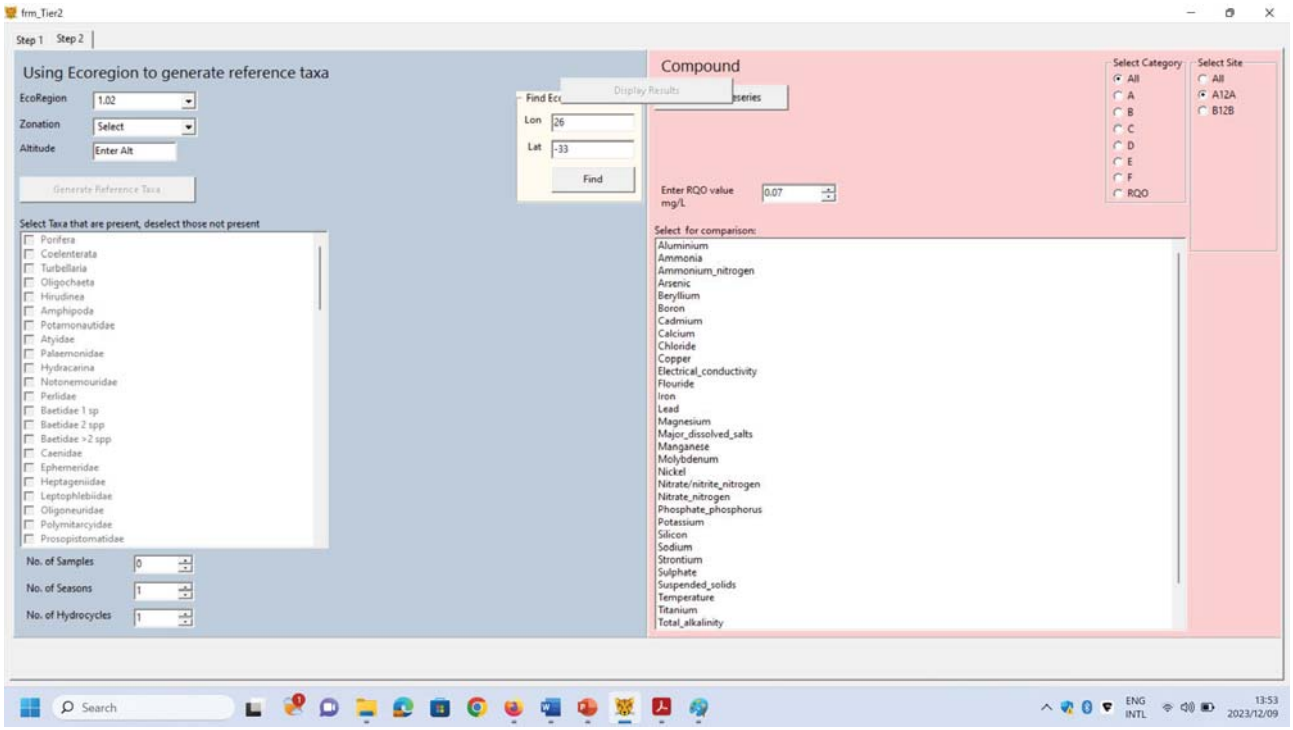


Figure 3-4 DSS screenshot showing the selection of All for all the ecological categories including the RQO and the selection of Site A12A. An hypothetical RQOs value of 0.07 mg/l for aluminium.

Now, the user can then click on the display results button to output the results. In the case of the example of the output displayed in Figure 3.4 above, the water quality data for aluminium are from site A12A and are compared with guidelines for ecological categories A-F, and for an RQO value of 0.07 mg/l. The DSS generates an html file that contains the guideline boundary value (Figure 3.5). It also produces summary statistics on the submitted data (5th, 50th and 95th percentiles, as well as sample mean) for each of the samples defined under column “sitename” in the input file. The output also contains a concentration duration curve that shows the percentage of uploaded samples that are likely to equal or exceed a particular concentration of the compound for which a guideline is required, again grouped by site or sample identifier (Figure 3.6). If the input samples were collected regularly, they would represent a time series, and, if they were collected over a long enough time frame, might be valuable as a tool for predictions of future water quality at the site samples were collected at.

Plotting these data against concentration allows the user to easily identify concentrations that are either always, or never, exceeded. By plotting the guideline ecological category values on the y-axis, the time equal or exceedance on the x-axis, the plot allows the user to directly read what proportion of submitted samples are in which ecological category, or proportion that are equal or exceeding that particular ecological category or the RQO. The DSS also produces a table that provides a confidence measure for the Tier 2 guideline values for that particular ecoregion. The measure of confidence simply reflect the number of samples used to generate the guideline value for that particular ecoregion. Care should thus be taken when interpreting guidelines with low confidence level (Figure 3-5).

Guideline values for Aluminium

Ecological Category	Title	Water Quality Guideline Value	Description
A	Unmodified, natural	<=0.0020	Unmodified, natural
B	Largely Natural	<=0.0050	Largely natural with very minmal or negligible effect
C	Moderately impacted	<=0.0080	Moderately impacted, some noticeable effect have occured but do not translate into significant effect on basic ecosystem function and processes
D	Largely impacted	<=0.0140	Effect is significant and has impacted considerably on basic ecosystem function and processes
E	Seriously impacted	<=0.0230	Effect is serious and unacceptable, management action must be taken to remedy the situation
F	Critically impacted	> 0.0320	Effect is critical and unacceptable, management action must be taken to remedy the situation

Confidence rating	Description
Moderate	Guideline values have been generated with at least 25 samples.

Figure 3-5 A typical DSS output table showing the guidelines for Al for ecoregion level 1.02 and the associated confidence rating.

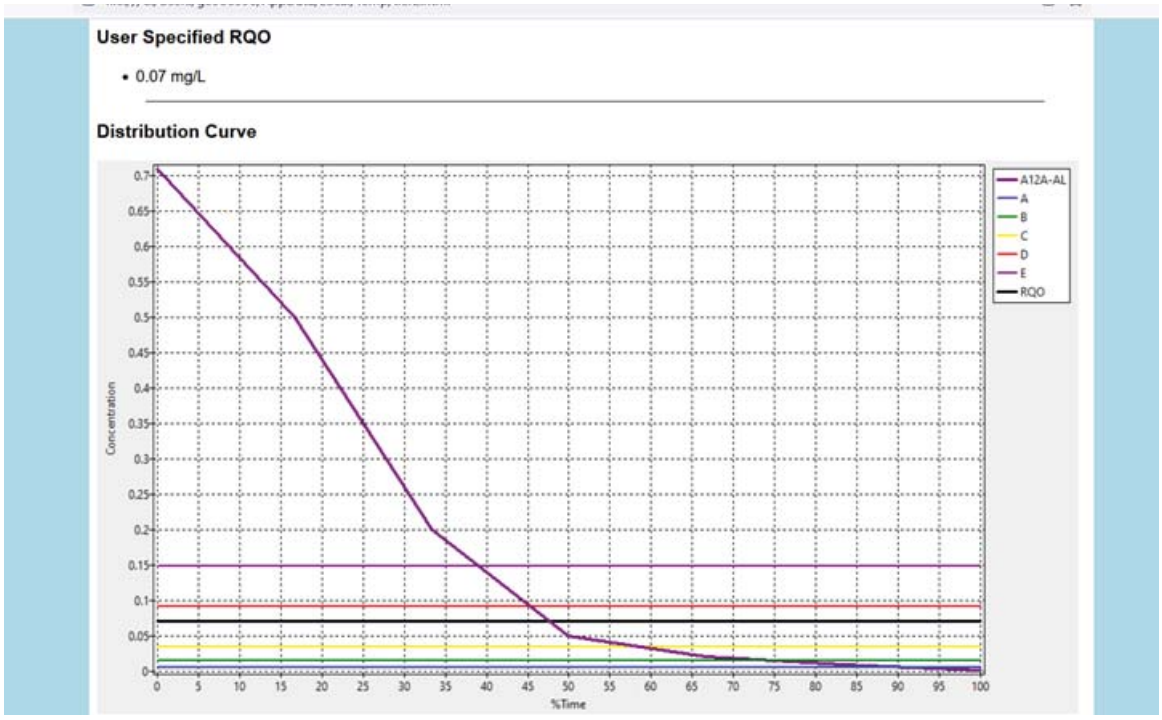


Figure 3-6 A typical DSS concentration duration curve. (Note that this example is not produced based on the data in Figure 3-5 above).

3.4 INTERPRETATION OF THE CONCENTRATION DURATION CURVE

The concentration duration curve is interpreted in terms of the proportion of samples that are within or exceed a particular water quality guideline value for the specified ecological category. In the case of the plot shown in Figure 3-6, 38% of the samples exceeds guideline values for ecological category E, meaning that 62% of the samples are within this ecological category. For ecological category D, 45% of the samples exceed the guideline value for this ecological category, implying that 55% of the samples were within this ecological category. Regarding ecological category C, 58% of the samples exceed its guideline value, and only 42% were within the guideline value. 70% of the samples exceed guideline value for ecological category B, and 85% of

the samples exceed guideline values for ecological category A. Regarding the RQO, 47% of the samples exceed the RQO value and only 53% of the samples were within the example RQO value.

As already stated in Tier 1, unless the number of individual samples in each user-defined group is large, the percentages as reported above from graphical inspection may be somewhat ambiguous, as they are based on intersections between concentration duration curves and guideline category boundaries. When few samples are present, these intersections will be at interpolations of the flow duration curve. When few data are available it may be wiser to rely on a simple count of data points in each category.

Temperature guidelines

As the DSS defers to Dallas and Rivers-Moore (2019b) for temperature guidelines, to return methods for setting targets for temperature, the user should click on the button “Display Temperature information” at the bottom of the DSS as shown below (Figure 3-7).

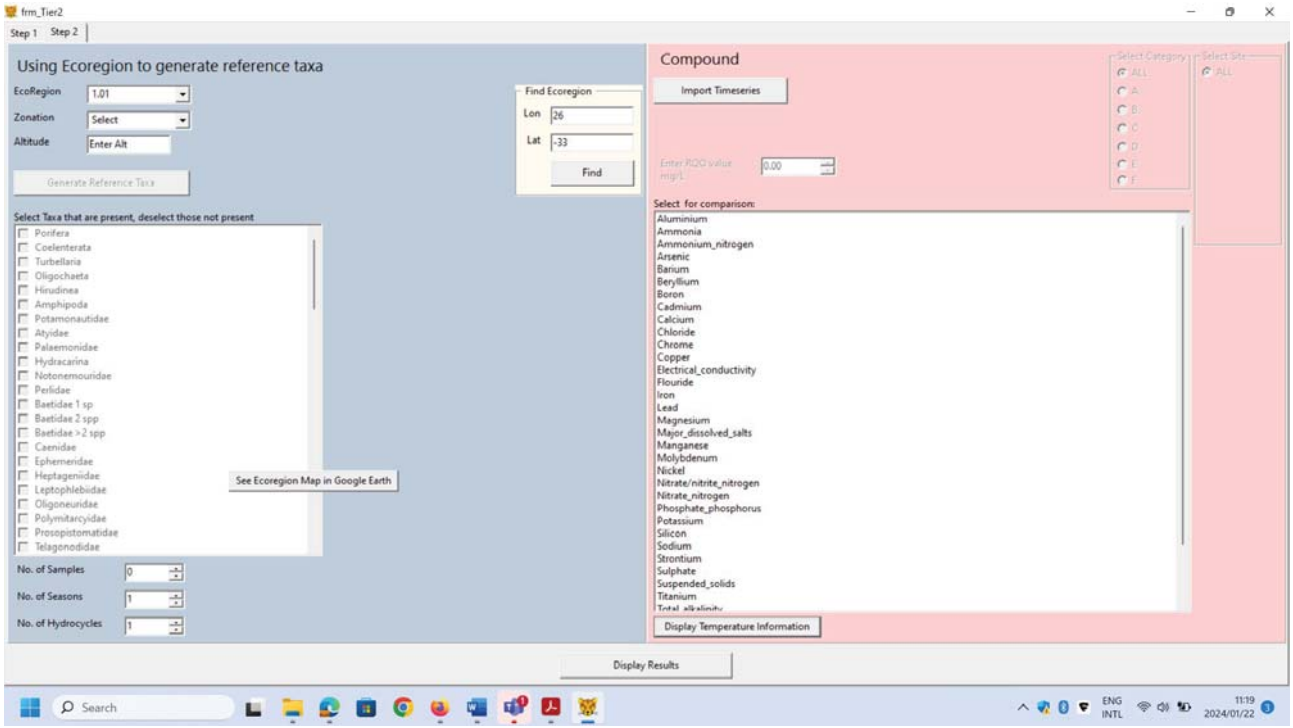


Figure 3-7 DSS interface showing display temperature information near the bottom of the screen.

3.5 MACROINVERTEBRATES

As stated earlier, at Tier 2, the DSS allows one to either work with macroinvertebrate or chemical data, or a combination of both. The principle underpinning the use of macroinvertebrate for guideline is different from that for chemistry, and users are refer to the technical report. Once the user has open the Tier 2 DSS screen as per earlier instruction, to generate macroinvertebrate guidelines, the user must click on the Ecoregion button to select the appropriate ecoregion level 2. The user must also click on the Zonation button to select the appropriate zone (A-F; S). And then enter the appropriate value for the site altitude (Figure 3-8). Once these have been completed, the user then clicks on the Generate Reference taxa button for the DSS to predict the macroinvertebrate taxa likely to occur in that region, within the specified longitudinal zone. The predicted macroinvertebrate taxa are selected automatically by the DSS as shown in the Figure 3-8 below.

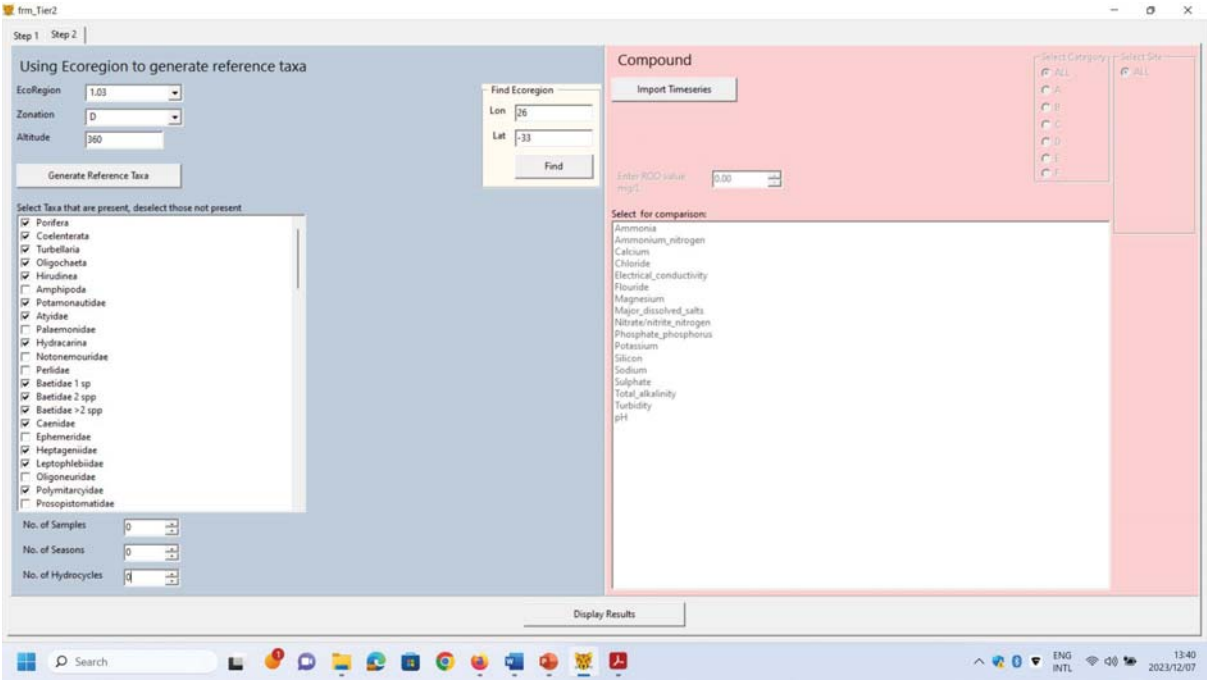


Figure 3-8 DSS screenshot showing predicted macroinvertebrate taxa for ecoregion level 2 (level 2 ecoregion 1.03).

The macroinvertebrates guidelines are generated only by comparing the predicted taxa versus the observed data. To compare the predicted and observed data, the user can either deselect taxa that are not observed, by clicking the appropriate taxa, or adding taxa that were observed but not predicted by clicking the appropriate taxa as shown below (Figure 3-9). The number of macroinvertebrate samples, the number of sampling seasons and the number of hydrological cycles the samples cover should also be entered at the left bottom of the screen. In this particular example (see DSS screen below), there were three samples, covering two seasons and one hydrological cycle (Figure 3-9). These allow an estimation of confidence of the results. Once these have been entered, the user should then click on the Display Results button for an output.

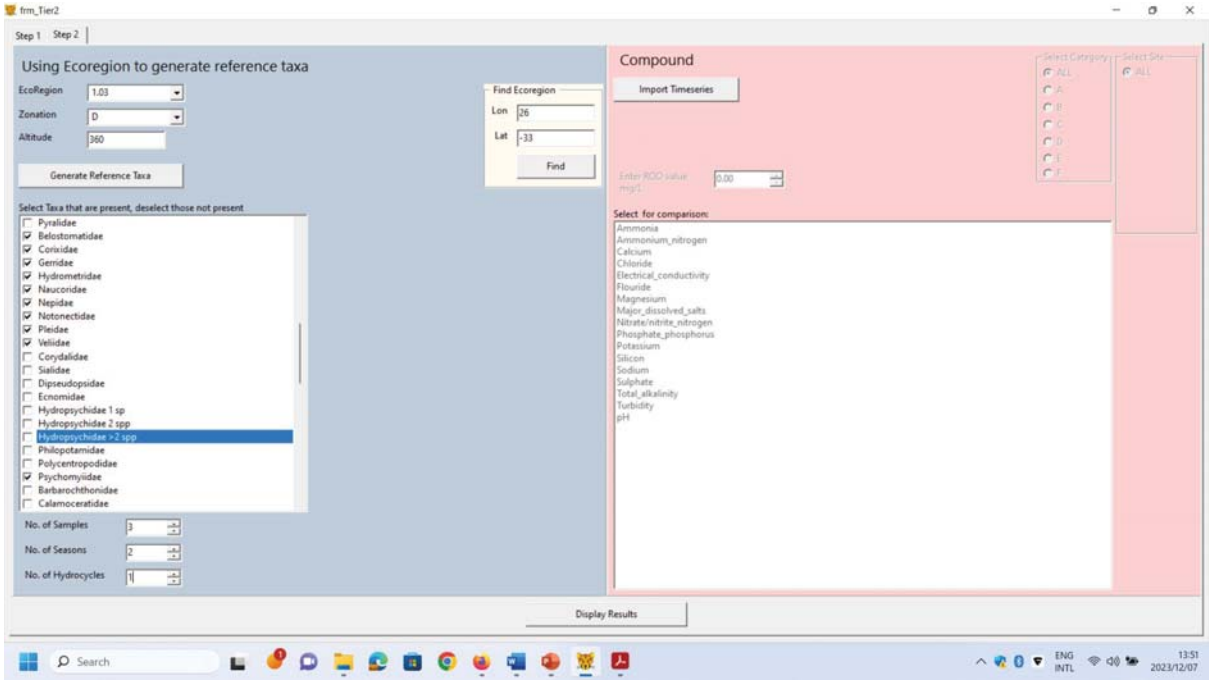
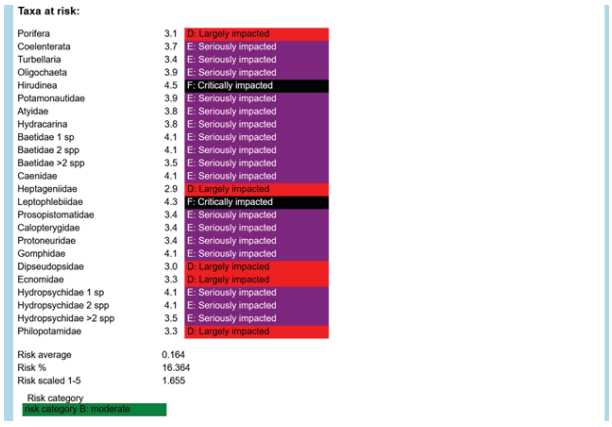


Figure 3-9 DSS screenshot showing addition and/or removal of taxa based on the difference between predicted and observed communities, as well as the entering of the number of samples, no. of seasons and no. of hydrological cycles.

The DSS output an HTML file format (Figure 3-10). The output contains an ecological category and management class (if already known and selected) as well as the ecoregion, zonation and altitude. The number of expected taxa and those observed are also returned by the DSS output. The DSS also return a list of taxa with their indicative risk profile relative to their absence from the resource. Therefore, the risk profile does not indicate the degree of risk of the particular taxon, instead it indicates the risk to the resource should that taxon be absent when it was predicted to be present and vice versa. For example, the risk to the resource is higher for highly tolerant taxa compare to very sensitive taxa. That is, when a highly tolerant taxa is absent when it has been predicted to be present, then the risk to the resource is higher compare to when a very sensitive taxon was expected but not observed. The DSS also return the ecological category based on the difference between the observed and expected taxa. In the case of the example shown below, the DSS has returned an ecological category B. The final output is the confidence rating. The DSS takes the information entered regarding the number of samples, seasons and hydro cycle to return a confidence rating table (Figure). This allows for the interpretation of the results within context.



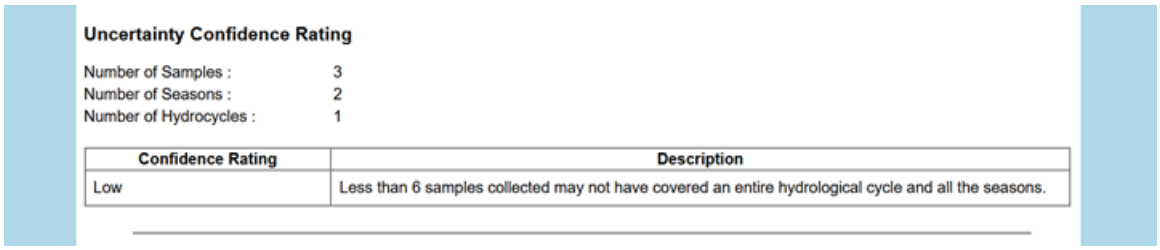
Taxa at risk:

Porifera	3.1	D: Largely impacted
Coelenterata	3.7	E: Seriously impacted
Turbellaria	3.4	E: Seriously impacted
Oligochaeta	3.9	E: Seriously impacted
Hirudinea	4.5	F: Critically impacted
Potamonautidae	3.9	E: Seriously impacted
Atyidae	3.8	E: Seriously impacted
Hydracarina	3.8	E: Seriously impacted
Baetidae 1 sp	4.1	E: Seriously impacted
Baetidae 2 spp	4.1	E: Seriously impacted
Baetidae >2 spp	3.5	E: Seriously impacted
Caenidae	4.1	E: Seriously impacted
Heptageniidae	2.9	D: Largely impacted
Leptophlebiidae	4.3	F: Critically impacted
Prosopistomatidae	3.4	E: Seriously impacted
Calopterygidae	3.4	E: Seriously impacted
Protoneuridae	3.4	E: Seriously impacted
Gomphidae	4.1	E: Seriously impacted
Dipseudopsidae	3.0	D: Largely impacted
Ecnomidae	3.3	D: Largely impacted
Hydropsychidae 1 sp	4.1	E: Seriously impacted
Hydropsychidae 2 spp	4.1	E: Seriously impacted
Hydropsychidae >2 spp	3.5	E: Seriously impacted
Philopotamidae	3.3	D: Largely impacted

Risk average	0.164
Risk %	16.364
Risk scaled 1-5	1.655

Risk category
Risk category B: moderate

Figure 3-10 DSS output for Tier 2 using macroinvertebrate data for guidelines.



Uncertainty Confidence Rating

Number of Samples : 3
Number of Seasons : 2
Number of Hydrocycles : 1

Confidence Rating	Description
Low	Less than 6 samples collected may not have covered an entire hydrological cycle and all the seasons.

Figure 3-11 DSS output showing the confidence rating for the macroinvertebrate guideline.

CHAPTER 4: TIER 3

4.1 INTRODUCTION

Tier 3 assessment is triggered when risk is suspected based on the results of Tiers 1 and/or 2. Tier 3 provides a means for a site-specific water quality risk assessment and the associated confidence level. A key feature of Tier 3 assessments is that they are event/scenario-based. The reasoning behind this approach is that improving water quality implies a focus on the event/scenario driving water quality change rather than on the symptoms. The guidelines at Tier 3 are based on site-specific risk assessment and should be performed only by experts or a trained practitioner.

4.2 METHODS

The risk assessment model has three sub-models: 1) the consequence sub-model, 2) the likelihood sub-model and 3) the uncertainty sub-model. In the consequence sub-model, consequence is conceptualized as the sum of severity, duration and spatial scale (magnitude). Severity is determined as the effect on the water physico-chemistry and macroinvertebrate response. The physico-chemical severity is extrapolated from the percent Time Equal or Exceeded curve relative to the water quality guideline value for a predetermined ecological category A-F (read from either Tier 1 or Tier 2 Guidelines). Based on the percent Time Equal or Exceeded curve, the water physico-chemical severity is rated. The sub-model uses the average of the ratings for all physio-chemical variable to determine the overall severity rating for physico-chemistry.

Macroinvertebrate response data are used in the consequence sub-model to determine the biological dimension of the severity. The deviation of the observed data from the expected calculated based on the macroinvertebrate risk model (Tier 2) provides the basis for the rating of macroinvertebrate severity. Where the macroinvertebrate risk model returns a deviation, corresponding to ecological category F, then the severity rating of 5 is awarded, whereas a deviation between the expected and observed assemblage corresponding to an ecological category B, corresponds to a severity rating of 1. An ecological category A has no severity rating, implying that the expected and observed assemblages are either the same or extremely similar. The overall severity in the consequence sub-model is calculated as the average of the physico-chemical severity rating and that for the macroinvertebrate response.

The second dimension of the consequence sub-model is the duration. The duration relates to the temporality of the event/scenario or compound that trigger the risk. The duration is rated. Event that occurs within a short period say one day to one month with no discernible impact on the water quality are rated lower compared to those occurring over a prolong period say one year with noticeable impact on the water quality status.

The third dimension of the consequence sub-model is the spatial scale, which quantify the spatial magnitude of the risk-triggering event. The spatial scale is rated in the consequence sub-model as well. Events that occur within a confined/localized area are rated lower compared to those occurring over and affecting several catchments or resource units.

The likelihood sub-model calculates the probability of the event occurrence, its impact and its detection. In the sub-model, likelihood is calculated as the sum of the frequency of occurrence of the risk-triggering event, frequency of the impact of the event and its detection, following DWS (2023).

The frequency of the risk triggering event refers to how often the event occurs. Events that occur rarely are rated lower compared to those that occur frequently or daily.

The frequency of impact relates to how often the occurrence of the event impact on the receiving water resource. This aspect is critical as the mere occurrence of an event does not necessarily translate to an impact. The frequency of impact is also rated in the likelihood sub-model.

The early detection of a water quality risk-triggering event is critical for water resource protection. Events that are detected early enough may trigger the necessary management action or mitigation measures unlike those that are difficult to detect yet may have serious impact on water quality. The detection aspect of the likelihood-sub model allows for the rating of the ease with which the event or its impact may be detected.

The site-specific water quality risk assessment model returns an overall risk rating for a site by integrating the consequence and likelihood sub-models as per Table 4-1 below.

Table 4-1 Overall site-specific risk rating based on the consequence and likelihood sub-models.

Rating	Risk category	Description
1-20	Very low	Risk is acceptable.
21-40	Low	Risk is acceptable, water quality impact is minimal and easily managed/mitigated.
41-120	Moderate	Water quality risk are notable and require mitigation measures.
121-180	High	Water quality risk are very notable, may be long term and may require specialist mitigation measures.
181-225	Very High	Water quality risk is unacceptable and mitigation measures must be implemented to lower the risk.

The levels of uncertainty/or confidence associated the risk rating is assessed and rated. The rating is done based on i) the reliability and reasonability of the assumptions made about the various metrics or component of the risk; ii) the adequacy of the relevant, reliable data and information upon which the risk judgement is based; iii) the degree of agreement among experts and/or literature support for the various components of the risk being described; iv) the degree to which the phenomenon in question is well-understood and whether it can accurately be modelled; v) knowledge or otherwise of the site-specific risk modifying factors. These are integrated to produce an uncertainty/confidence rating as shown in Table 4-2 below.

Table 4-2 Overall uncertainty rating associated with the site-specific water quality risk assessment.

Rating	Confidence level	Description
1-5	Very high	The uncertainty associated with the risk assessment is acceptable.
6-10	High	The uncertainty associated with the risk assessment is minimal and acceptable.
11-15	Moderate	The uncertainty associated with the risk assessment is notable.
16-20	Low	The uncertainty associated with the risk assessment is high. Steps should be taken to reduce the uncertainty and improve the confidence level.
21-25	Very low	The uncertainty associated with the risk assessment is very high. Steps should be taken to reduce the uncertainty and improve the confidence level.

4.3 USE OF TIER 3 FOR SITE-SPECIFIC WATER QUALITY RISK ASSESSMENT

Upon starting the DSS, the user should click on the Tier 3 button to open the Tier 3 screen of the DSS as shown in Figures 4.1 below. In Tier 3, there are three sub-models the user must complete. These are the consequence, likelihood and uncertainty sub-models. The user starts by clicking on the consequence sub-model. On the consequence sub-model, the user enters the water quality issue(s) for which risk assessment is sought. Please note that this should ideally be the risk triggering event/or scenario rather than the water

quality stressor or symptoms. In the case of the example shown in Figure 4-1 below, the risk-triggering event is an agricultural farmland. Within the consequence sub-model, the DSS allows the user to undertake the severity rating for both or either physico-chemistry and macroinvertebrates.

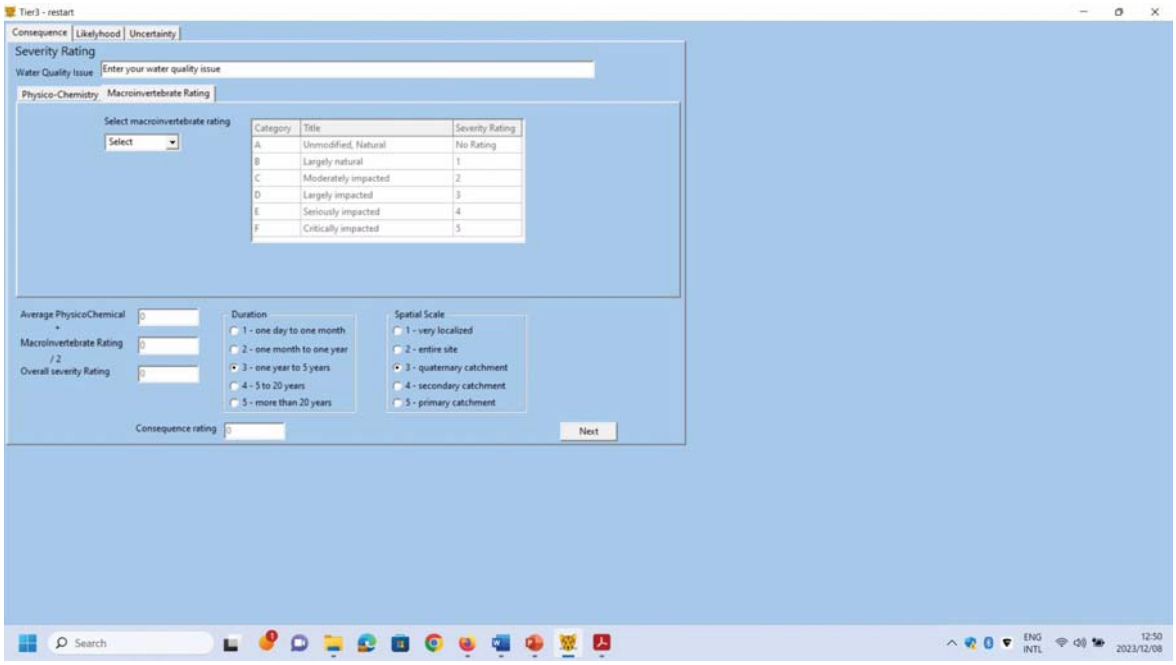


Figure 4-1 Screenshot of the DSS interface for Tier 3.

To undertake the severity rating for the physico-chemistry, click on the physico-chemistry button to return a DSS screen shown in Figure 4-2. Click on the Add Row button to enter the name of the chemical variables and undertake the rating for each variable. Once the Add Row button is activated, type in the name of the chemical variable(s), and enter the % time equal or exceedance, read from the Tier 1 or Tier 2 duration curve for that variable. The time equal or exceedance refers to the percentage of samples that are outside the range of the water quality guideline values for the particular ecological category (please refers to the interpretation of Tier 1 or Tier 2 frequency duration curve). For example, in the DSS screen below (Figure 4.2), the time equal or exceedance for nitrite-nitrogen is 50% (meaning 50% of the samples fall outside of the water quality guideline value for the particular ecological category of interest, e.g. A-D). That for Nitrate-nitrogen is 70% meaning only 30% of the samples fall within the water quality guideline value for the particular ecological category of interest, and in the case of ammonia-nitrogen only 10% samples are within the water quality guideline value for the particular ecological category of interest. Once these values have been entered the DSS automatically calculates the average physico-chemical rating by integrating the rating for all the physico-chemical variables. Variables can be removed by clicking on the Remove last button, or added by Clicking on the Add Row button.

The duration of the risk triggering event/scenario is rated by clicking on the appropriate duration rating. This function allows the user to assess the temporal dimension of the risk triggering event as shown in Table 4-3. In the particular example displayed on the DSS screen (Figure 4-2) the duration is rated 4, meaning the risk triggering event has been occurring between 5-20 years, and is considered a long event in which the water quality status may be permanently degraded, and improvement is almost impossible.

Table 4-3 Rating for the duration aspect of the consequence sub-model.

Duration of event/scenario	Rating	Description
One day to one month	1	An event occurring over a very short period, and has no noticeable effect on the water quality status.
One month to one year	2	An event occurring over a short period, the water quality status may be impacted but the status remains the same. The impact is not enough to change the water quality status.
One year to 5 years	3	An event occurring over a relatively long period, the water quality status may be impacted, there is a degradation of the water quality status. Mitigation/management action may improve the status.
5 years to 20 years	4	A long event in which the water quality status may be permanently degraded, and improvement is almost impossible.
More than 20 years	5	A very long event resulting in an extremely impacted water quality status, resulting in an F category, and no management action may result in any noticeable improvement.

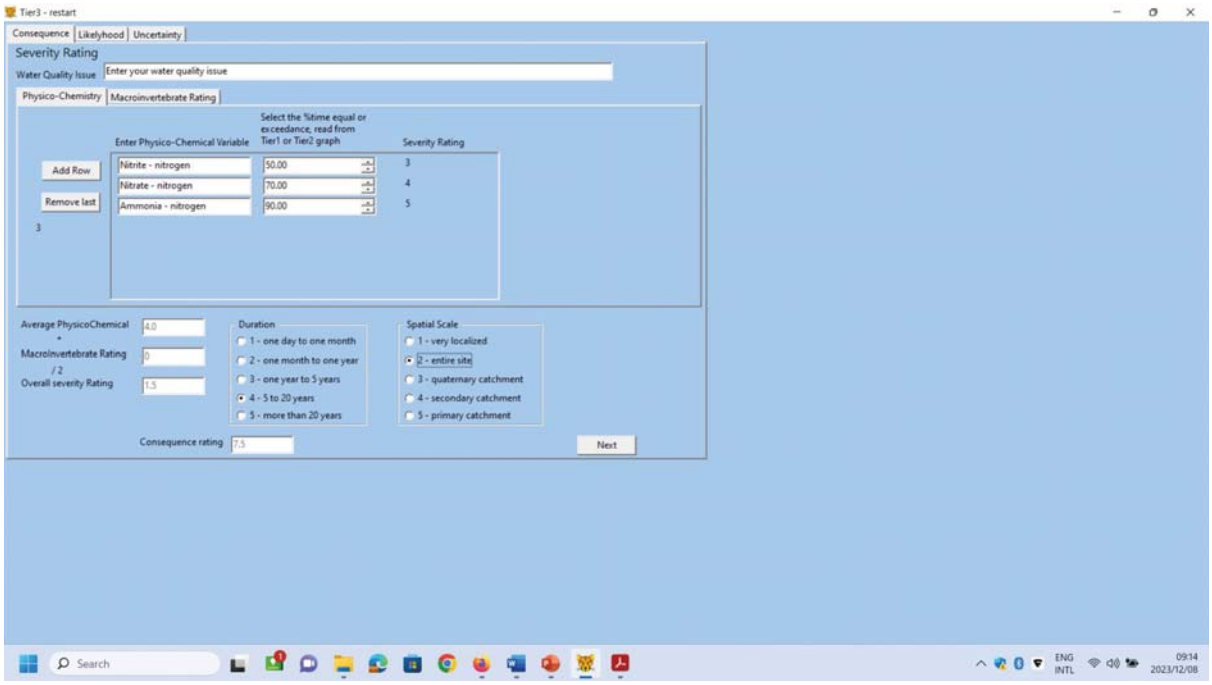


Figure 4-2 Screenshot of the physico-chemical severity rating for the risk-triggering event.

Once the duration is rated, the spatial scale should also be rated. The spatial relates to the extent of geographical coverage of the risk triggering event, and is rated as per Table 4-4 below: In the case of the example provided (Figure 4-2) on the DSS screen, the spatial scale is rated 2 meaning the risk-triggering event, i.e. the agricultural farmland affects an entire site.

Table 4-4 Rating for the spatial scale dimension of the consequence sub-model.

Duration of event/scenario	Severity rating	Description
Very localized	1	A confined and highly localized event.
Entire site	2	An event affecting an entire site.
Quaternary catchment	3	An event affecting and entire sites, extending down streams and affecting downstream resource, potentially more than one resource units.
Secondary catchment	4	A large event affecting an entire secondary catchment. Resources within the secondary catchment are affected. May affect multiple provinces.
Primary catchment and beyond	5	An event with large spatial scale, affecting the entire country and potentially beyond.

If macroinvertebrate data exist, then severity rating can also be undertaken for the macroinvertebrate component. Click on the macroinvertebrate rating to return the DSS screen shown in Figure 4-3 below. Then select the macroinvertebrate rating, from A to F. These rating are based on the macroinvertebrate risk model results for macroinvertebrate-based ecological categories returned at Tier 2 assessment (refers to the interpretation of the macroinvertebrate risk model results in Tier 2). These rating are as described in Table 4-5Table 4-5 Macroinvertebrates severity rating as a function of the extent of deviation between the expected and observed taxa returned by the macroinvertebrate risk model in Tier 2. below: In the case of the DSS screen shown below, the severity rating for the macroinvertebrate is a “C” meaning that a moderate change has taken place between expected and observed taxa.

Upon completion of the consequence model either by rating the severity for physico-chemistry and/or macroinvertebrates, the DSS automatically calculates the overall consequence rating. In the case of the example on the DSS screen, the overall consequence rating is 9.0.

Table 4-5 Macroinvertebrates severity rating as a function of the extent of deviation between the expected and observed taxa returned by the macroinvertebrate risk model in Tier 2.

Ecological category	Title	Upper boundary for rescaled risk	Description	Severity rating
A	Unmodified, natural	0.05	Unmodified and natural, expected and observed taxa are perfectly the same.	No rating
B	Largely natural	0.2	A small change between the expected and observed taxa have taken place. Risk is low.	1
C	Moderately impacted	0.4	Moderate change has taken place between expected and observed taxa. Risk is moderate.	2
D	Largely impacted	0.6	Large change has taken place between expected and observed taxa. Risk is high.	3
E	Seriously impacted	0.8	Serious change has taken place between expected and observed taxa, resulting in the loss of many biotas. The risk is very high and unacceptable.	4
F	Critically impacted	1	The macroinvertebrate assemblage has been critically modified, many biota have been lost; the risk is extreme and unacceptable.	5

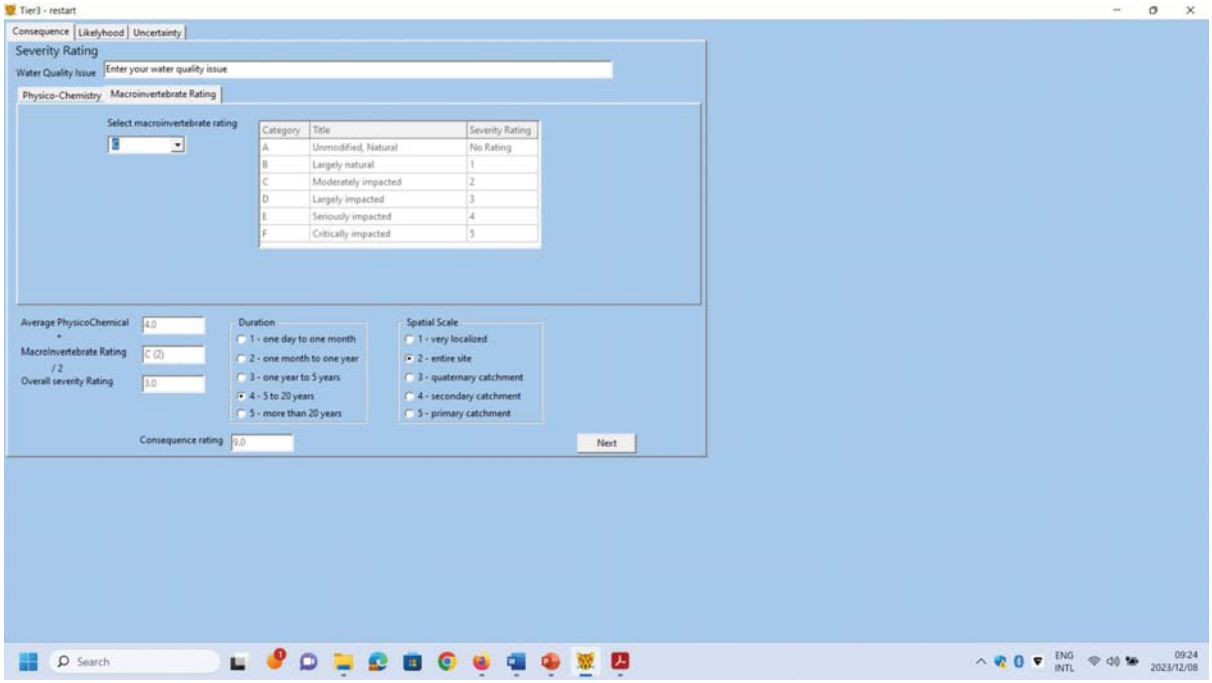


Figure 4-3 Screenshot of the DSS showing the macroinvertebrate risk rating.

To proceed to the likelihood sub model, click on the Next button at the bottom of the screen. This takes you to the likelihood sub-model. Within the Likelihood sub-model, rating is done for the risk triggering event/scenario based on 1) the frequency of occurrence, 2) frequency of impact and 3) detection. These ratings are done as per Table 4-6 to Table 4-8 below: In the case of the example shown in Figure 4-4 below on the DSS screen, the frequency of occurrence has been rated as monthly, the impact as > 40% meaning that it is an event that very seldom impacts the water quality or it is highly unlikely that it impacts on the water quality. The detection is rated as difficult to detect.

Table 4-6 Rating for frequency of occurrence of the risk-triggering event.

Frequency of occurrence	Rating	Description
Annually or more	1	An event that rarely occurs, mainly annually or more
Biannual	2	An event that occurs occasionally, mainly six monthly or more, but less than annually.
Monthly	3	An event that occurs monthly but less than six monthly.
Weekly	4	An event that occurs frequently, mainly weekly.
Daily or less	5	A highly frequent event, occurring daily or even hourly, creating a condition of persistence.

Table 4-7 Rating for frequency of impact of the risk-triggering event.

Frequency of impact (how often does the event impact on the receiving water resource?)	Rating	Description
>20%	1	An event/concern/scenario whose frequency of impact on the water quality is negligible.
>40%	2	An event that very seldom impacts the water quality or it is highly unlikely that it impacts on the water quality.
>60%	3	An event that occasionally impacts on the water quality
>80%	4	An event that often/regularly impacts on the water quality
>100%	5	An event that definitely impacts on the water quality

Table 4-8 Rating for the detection of the risk-triggering event or its impact on the water quality component of the resource.

Detection	Rating	Description
Immediately	1	The effect on the water quality is immediate and can be detected easily
Without much effort	2	The effect on water quality may not be immediate but can be detected easily.
Require some effort to detect	3	The effect on water quality may not be easily observable and some effort is required to detect it.
Difficult to detect	4	The effect on water quality is difficult to observe and detect
Unnoticed	5	The effect on water quality may go unnoticed and is very difficult to detect.

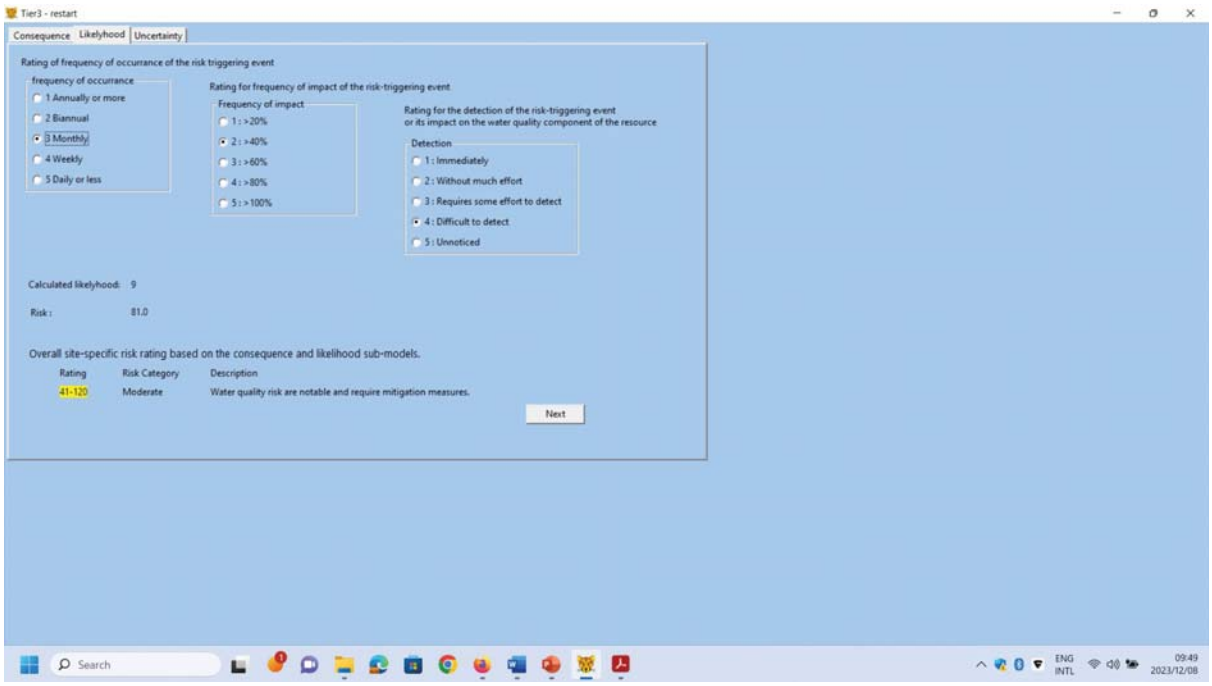


Figure 4-4 Screenshot showing the likelihood rating for frequency of occurrence, frequency of impact and detection for the risk triggering event (an agricultural farmland).

Upon completion of the likelihood sub-model, click on Next button to commence the uncertainty assessment. The uncertainty sub-model has five components (Figure 4-5)

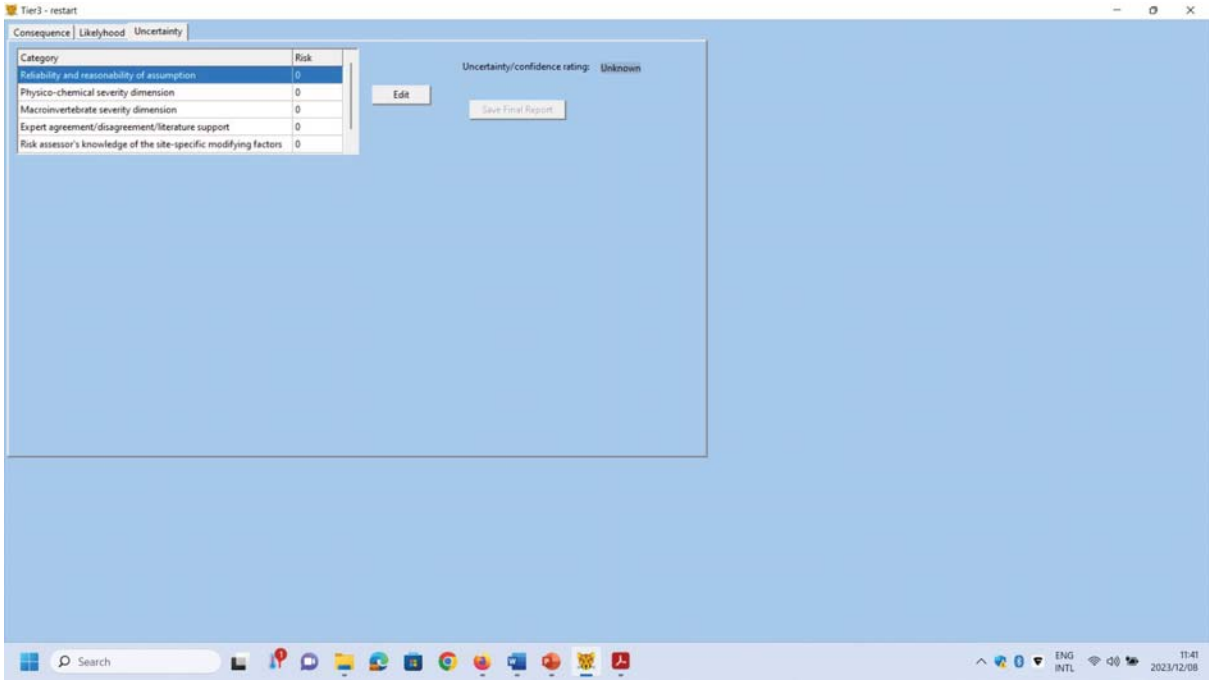


Figure 4-5 Screenshot of the DSS showing the sub-component for which assessment is needed regarding the uncertainty sub-model.

To start, click on the first component: the reliability and reasonability of assumption, and the click on the Edit button to open the DSS screen as shown in Figure 4-5. From the options provided, select the most appropriate regarding the assumption and reasonability of the risk-triggering event. In this particular example (Figure 4-6), option 1 has been selected, indicating very low uncertainty/very high confidence, suggesting that the risk is definitely attributable to the risk-triggering event being assessed. Once done, click the Save button and continue.

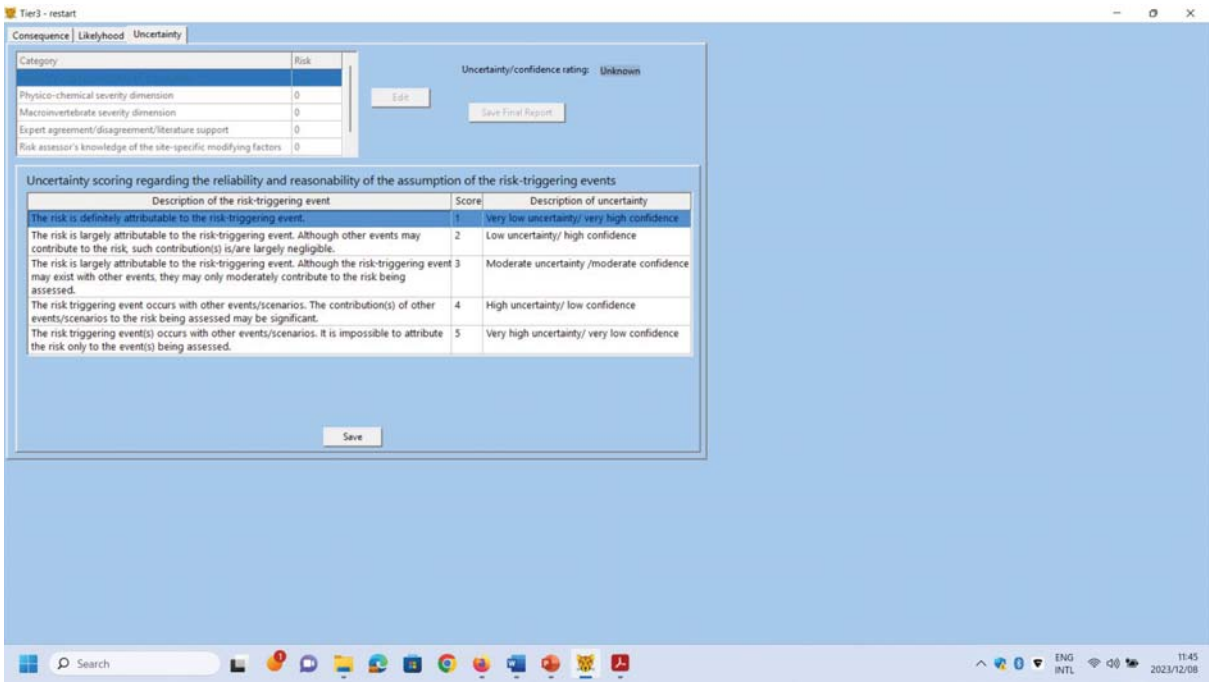


Figure 4-6 Screenshot of the DSS showing the uncertainty rating about the reliability and reasonability of the assumptions regarding the risk-triggering events.

The uncertainty regarding the physico-chemical severity rating is also assessed. Click on the physico-chemical severity dimension and then click on the Edit Button to take you to the screen display in Figure 4-7. Select the appropriate option from those provided in the DSS. As shown in the figure, a rating of 3 has been activated/awarded, meaning the uncertainty is moderate. Once done, click on the Save button and continue.

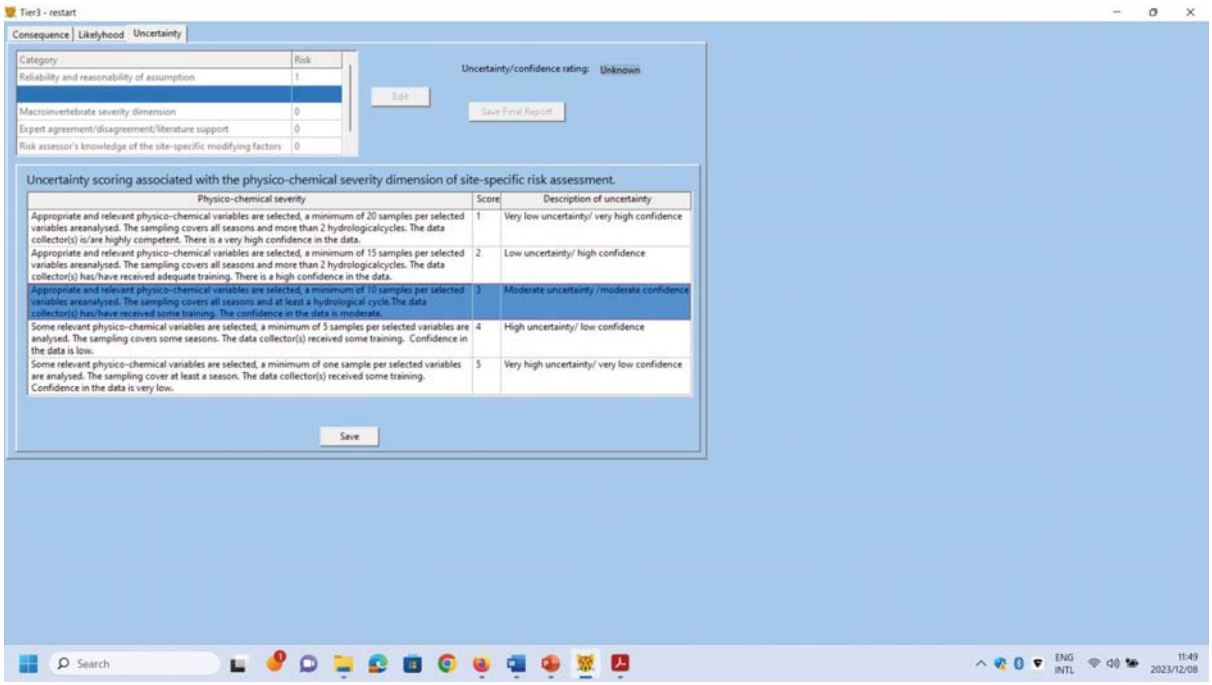


Figure 4-7 Screenshot of the DSS showing the uncertainty rating about the physico-chemical severity rating.

The uncertainty regarding the macroinvertebrate severity rating is also assessed. Click on the macroinvertebrate severity dimension, and then click on the Edit Button. This takes you to the DSS screen shown in Figure 4-8. Click on the option most relevant for the macroinvertebrate data used in undertaking the severity rating. In the particular example shown in Figure 4-8 below on the DSS screen, the uncertainty is rated as 4 meaning there is a low confidence or high uncertainty regarding the macroinvertebrate data used in undertaking the macroinvertebrate severity rating, read from Tier 2. Once done, click on the save button and continue.

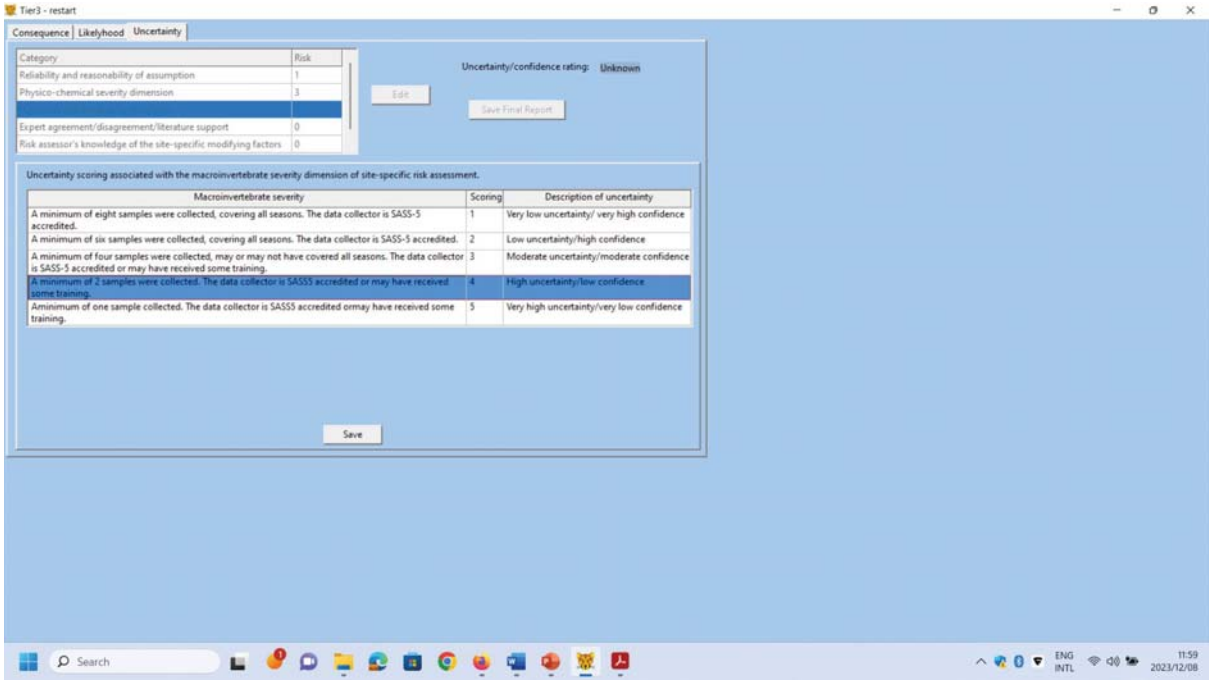


Figure 4-8 Screenshot of the DSS showing the uncertainty rating about the physico-chemical severity rating.

The uncertainty regarding the experts agreement/disagreement/literature support as well as that for the risk assessor's knowledge of the site-specific modifying factors are assessed following the same procedures already described. In the case of the example provided in Figure 4-9, expert agreement is rated as 1 meaning the agreement between experts or literature support for the rating of the likelihood metrics and the duration of the risk triggering event is very high. The site-specifying modifying factors is rated 2 (Figure 4-10), meaning that the knowledge of site-specific risk modifying factors is high, and thus the confidence level is high.

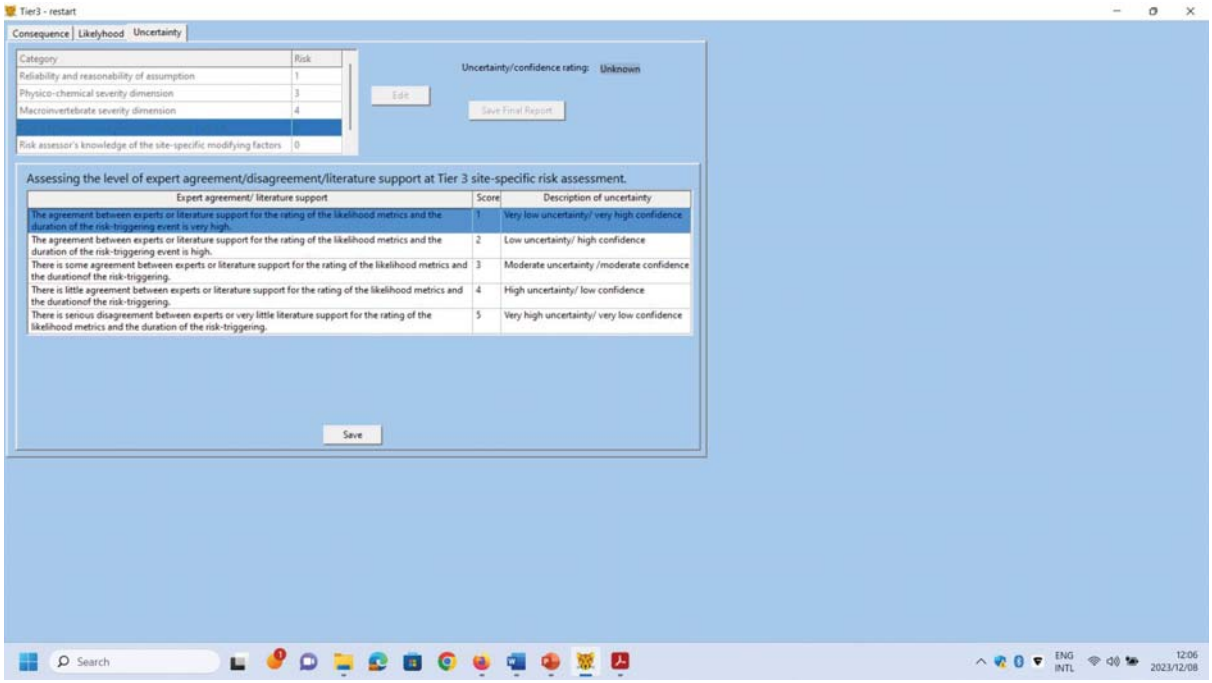


Figure 4-9 Screenshot of the DSS showing the uncertainty rating about the expert agreement/disagreement and literature support.

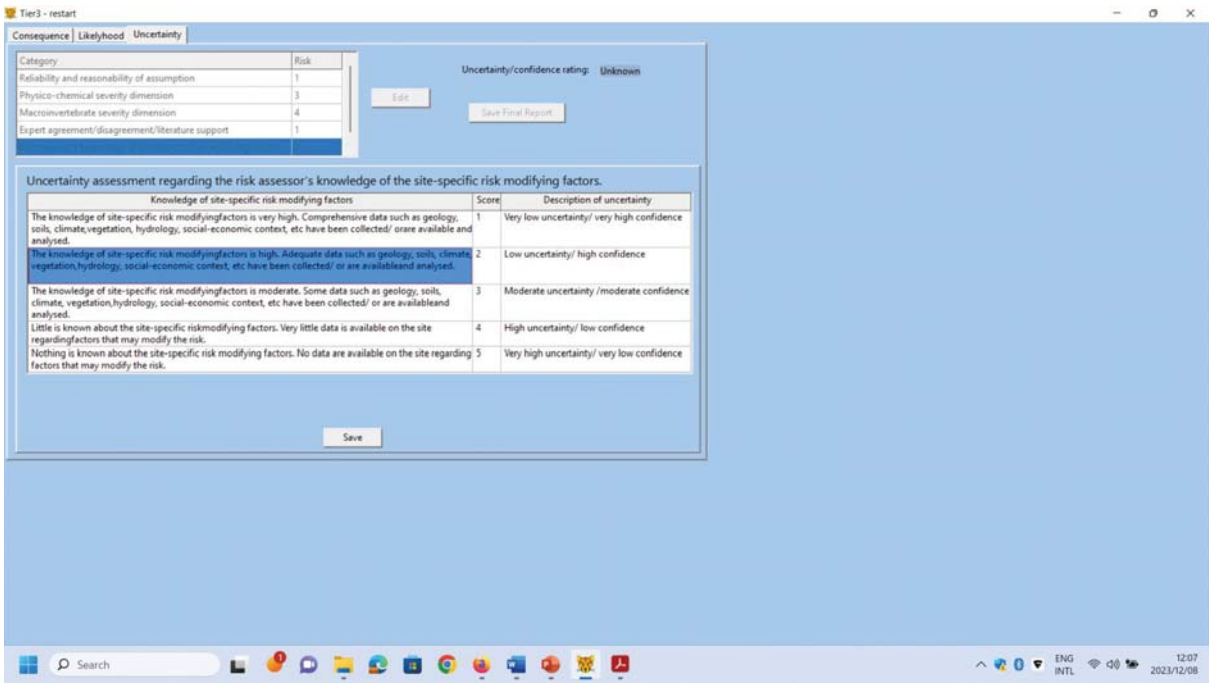
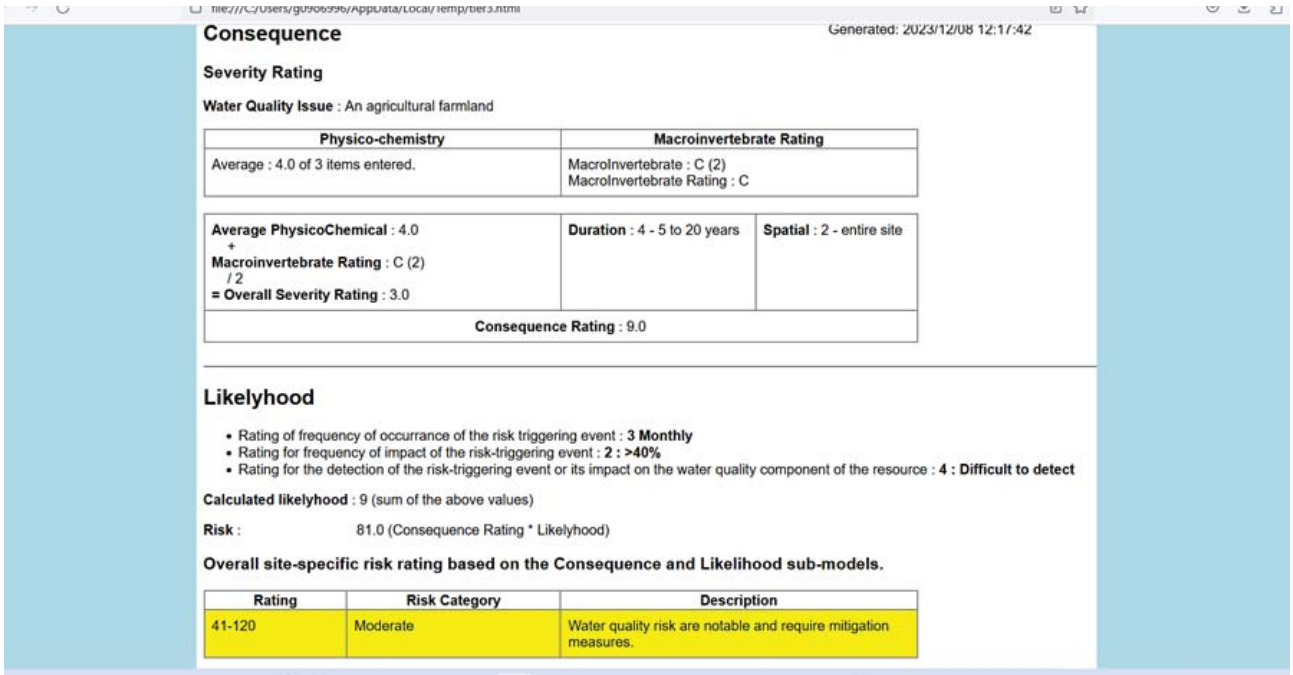


Figure 4-10 Screenshot of the DSS showing the uncertainty rating the knowledge of site-specific risk modifying factors.

Once the risk rating and associated confidence level/uncertainty has been done, click on the Save Final Report button. This should generate the final report as shown in Figure 4-11 and Figure 4-12 below. As can be seen, the report is broken into two main sections. The risk rating for the site based on the consequence and likelihood sub-models as well as the uncertainty accompanying the risk.



Consequence

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Severity Rating

Water Quality Issue : An agricultural farmland

Physico-chemistry	Macroinvertebrate Rating
Average : 4.0 of 3 items entered.	MacroInvertebrate : C (2) MacroInvertebrate Rating : C

Average PhysicoChemical : 4.0 + **Macroinvertebrate Rating** : C (2) / 2 **= Overall Severity Rating** : 3.0	**Duration** : 4 - 5 to 20 years	**Spatial** : 2 - entire site
Consequence Rating : 9.0		

Likelyhood

- Rating of frequency of occurrance of the risk triggering event : **3 Monthly**
- Rating for frequency of impact of the risk-triggering event : **2 : >40%**
- Rating for the detection of the risk-triggering event or its impact on the water quality component of the resource : **4 : Difficult to detect**

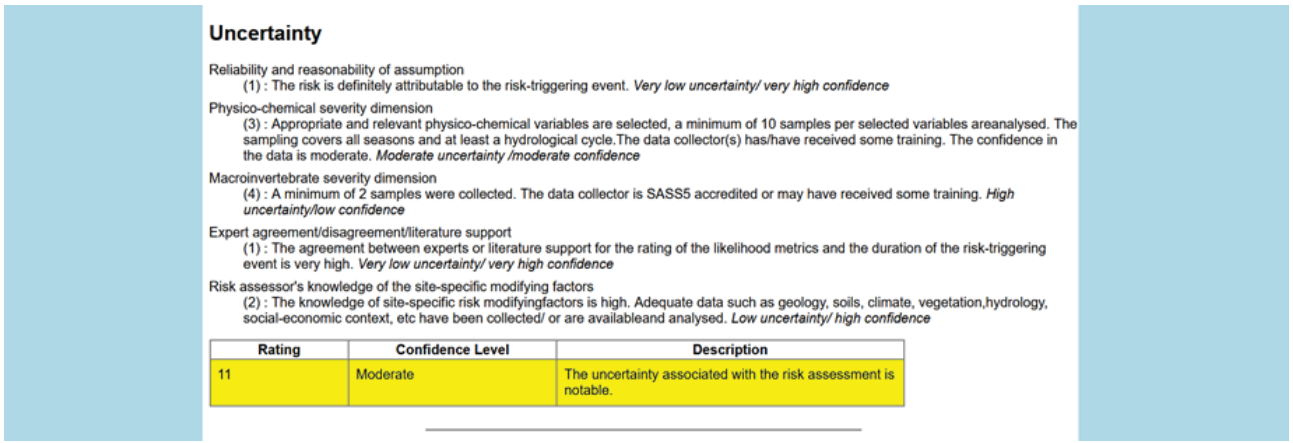
Calculated likelyhood : 9 (sum of the above values)

Risk : 81.0 (Consequence Rating * Likelyhood)

Overall site-specific risk rating based on the Consequence and Likelihood sub-models.

Rating	Risk Category	Description
41-120	Moderate	Water quality risk are notable and require mitigation measures.

Figure 4-11 DSS screenshot showing the final output of the site-specific water quality risk assessment rating for the risk triggering event.



Uncertainty

Reliability and reasonability of assumption
(1) : The risk is definitely attributable to the risk-triggering event. *Very low uncertainty/ very high confidence*

Physico-chemical severity dimension
(3) : Appropriate and relevant physico-chemical variables are selected, a minimum of 10 samples per selected variables areanalysed. The sampling covers all seasons and at least a hydrological cycle.The data collector(s) has/have received some training. The confidence in the data is moderate. *Moderate uncertainty /moderate confidence*

Macroinvertebrate severity dimension
(4) : A minimum of 2 samples were collected. The data collector is SASS5 accredited or may have received some training. *High uncertainty/low confidence*

Expert agreement/disagreement/literature support
(1) : The agreement between experts or literature support for the rating of the likelihood metrics and the duration of the risk-triggering event is very high. *Very low uncertainty/ very high confidence*

Risk assessor's knowledge of the site-specific modifying factors
(2) : The knowledge of site-specific risk modifyingfactors is high. Adequate data such as geology, soils, climate, vegetation,hydrology, social-economic context, etc have been collected/ or are availableand analysed. *Low uncertainty/ high confidence*

Rating	Confidence Level	Description
11	Moderate	The uncertainty associated with the risk assessment is notable.

Figure 4-12 DSS screenshot showing the final output of the accompanying uncertainty/confidence rating for the site-specific water quality risk assessment rating.

CHAPTER 5: References

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