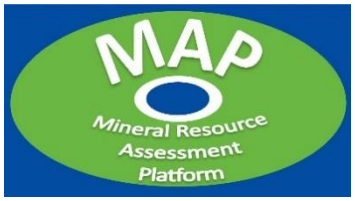
MapWizard User Manual

December 2020



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Content

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1. Introduction

This User manual describes the tools and functionalities of MapWizard software. MapWizard consists of a graphical user interface (UI) main window and separate tools to carry out various tasks during an assessment. The main window and each tool are described in a separate chapter of this manual.

1.1. Installation and requirements

MapWizard is installed simply by running the Windows installer. Please see the separate installation guide included in the MapWizard distribution package. MapWizard tools are coded using the R, Python and C# programming languages. MapWizard comes with its own internal R (version 3.6.3). The user does not have to install R in order to be able to run MapWizard. However, the internal R cannot be run outside of MapWizard.

Although MapWizard reads and writes spatial data files, it cannot be used to view such files. Separate GIS software is needed to view and process spatial data files.

The MapWizard distribution package contains a dataset that can be used to test the MapWizard tools. In addition to this, a larger data package is available for testing MapWizard MPM tools at https://github.com/gtkfi/demodata.

1.2. Naming conventions

The following conventions are used throughout this User Manual.

<ProjectRoot>:	The root folder for the assessment project, selected when the project is created.
<DepositModels>:	The root folder for deposit models permanently saved by MapWizard. These models can be read by MapWizard and reused in various assessment projects.
<ID>:	Identification code for a permissive tract, given by the user in the Tract delineation tool.
<GivenName>:	Folder with a name given by the user
InputParameter:	Names of input parameters and radio buttons the user can interact with are shown in bold font

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2. General functionality

- An assessment project is always related to a mineral deposit type
- Descriptive model tool and Grade-Tonnage model tool can be used to generate several models, but eventually one descriptive model and one grade-tonnage model have to be selected using the Result window. The selected models will be used in the Monte Carlo simulations and they can be included reports generated by the Reporting tool.
- The results produced by each tool (excluding the assessment report tool) can be used by other tools. As one tool can produce several alternative results depending on the input parameter values, it is important that the user eventually selects one result to be used in the assessment. This is done by selecting the required result using the Result window.
- An assessment project can contain several permissive tracts. Each tract must be defined using the Tract delineation tool. This can be done either by just giving the tract boundaries to the tool as a shapefile, or by creating the tract using the Tract delineation tool. The tool creates a subfolder for each tract in folder <ProjectRoot>/TractDelineation/Tracts/.
- A Dummy tract is created automatically by MapWizard on startup. This temporary tract can be used in various tests that are not necessarily meant to be saved.
- The Undiscovered deposits tool, Monte Carlo simulation tool and Economic filter tool work on one permissive tract at the time. The Aggregate results tool works on several tracts and the Reporting tool can work on one or several tracts. All these tools must be given the name(s) of the tract(s) for which data will be processed. This is done by selecting from a drop-down menu, which is based on the subfolders under <ProjectRoot>/TractDelineation/Tracts/.
- In the Result window, double-clicking on a graph will open it in Windows default graphics viewing program. However, if the figure is left open in the viewing software, MapWizard might not be able to process it later in the process. It is advisable to close the graphics viewing program before continuing the MapWizard run.

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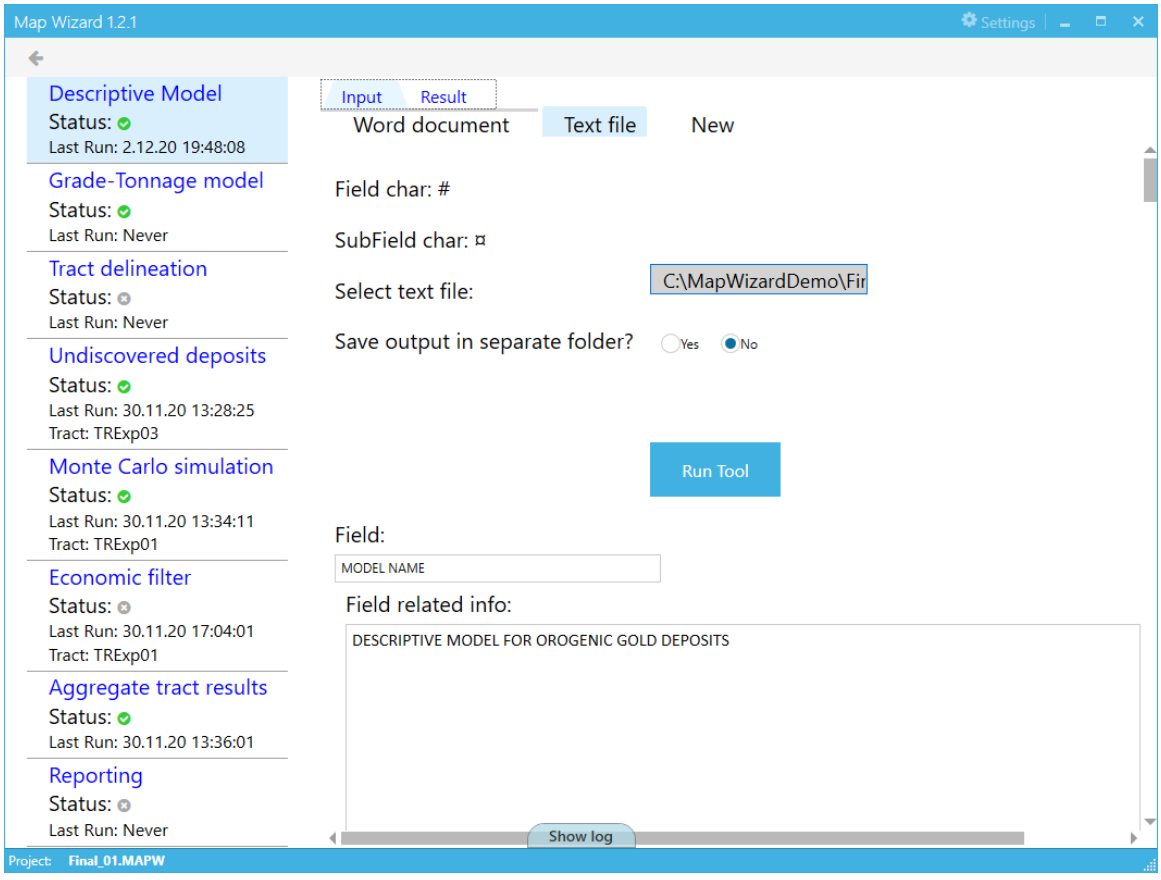
3. MapWizard main window

MapWizard software consists of a set of tools to perform an assessment of undiscovered mineral resources. The user interface displays the tools along the left margin of the window in an intuitive order to support the flow of the assessment process. When MapWizard is started, it opens the main window where the user can set some parameters in the Settings menu, open an existing MapWizard project or create a new project. A project covers the whole assessment process from the selection of deposit models to the reporting of results. MapWizard requires that a project is active when running the tools.



3.1. Settings

File paths

R path: During MapWizard installation, R software (version 3.6.3) is installed in a subfolder of the MapWizard program root folder. The R path shows the location.

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Deposit models

Root path for DepositModels: Deposit models created by MapWizard tools can be stored permanently for use in subsequent assessments. The user can define the location where the folder "DepositModels" will be created. MapWizard will save individual models in subfolders under this folder.

Deposit type

Name of deposit type: MapWizard requires that each assessment project is associated with a certain deposit type, which is usually given when the project is created. The user can change the deposit type associated with the active project using this setting.

3.2. Open project

Open an existing MapWizard project file (*.MAPW). The user can browse to the location of the project folder.

3.3. New project

Create a new assessment project. "Project location" indicates the folder in which the new project folder will be created, and "Project name" is the name of the folder to be created. MapWizard tools will place their results into subfolders in the project folder. "Deposit type" indicates the mineral deposit type that is being assessed in the project.

3.4. Show log

The Show log tab at the bottom of the screen can be clicked to reveal and hide a log file containing information of the status of the software.

3.5. Output

MapWizard output is placed in two locations. A new project is created in folder <ProjectRoot>, which is located in the folder given by the user when creating the project ("Project location"). Deposit models created by MapWizard tools can be stored permanently in folder <DepositModels>, which is created in the location given by the user in Settings/Deposit models.

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The following output is created by MapWizard main window:

- <Project>.MAPW
    - Project setting file, where <Project> is the name given to the project by the user.

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4. Descriptive model tool

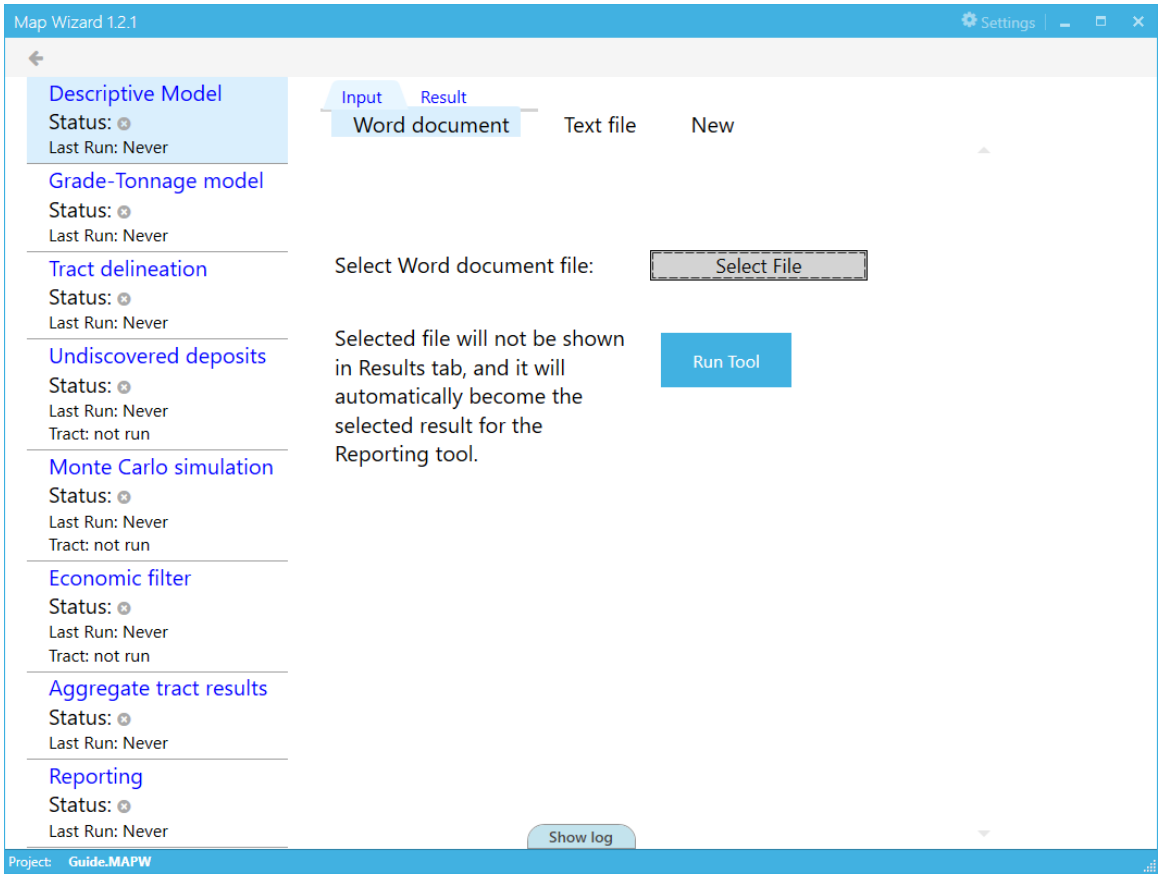
The Descriptive model tool reads in or creates a summary descriptive model for a mineral deposit type and allows the user to edit and save the modified model.

4.1. Input window

Word document tab

Select Word document file

Allows the user to give the path to a complete descriptive model in Microsoft Word file format (.docx). When the tool is run and the "Word document" input option is selected, the tool will copy the selected file to the <ProjectRoot>\DescModel\SelectedResult folder and select the model for further use.



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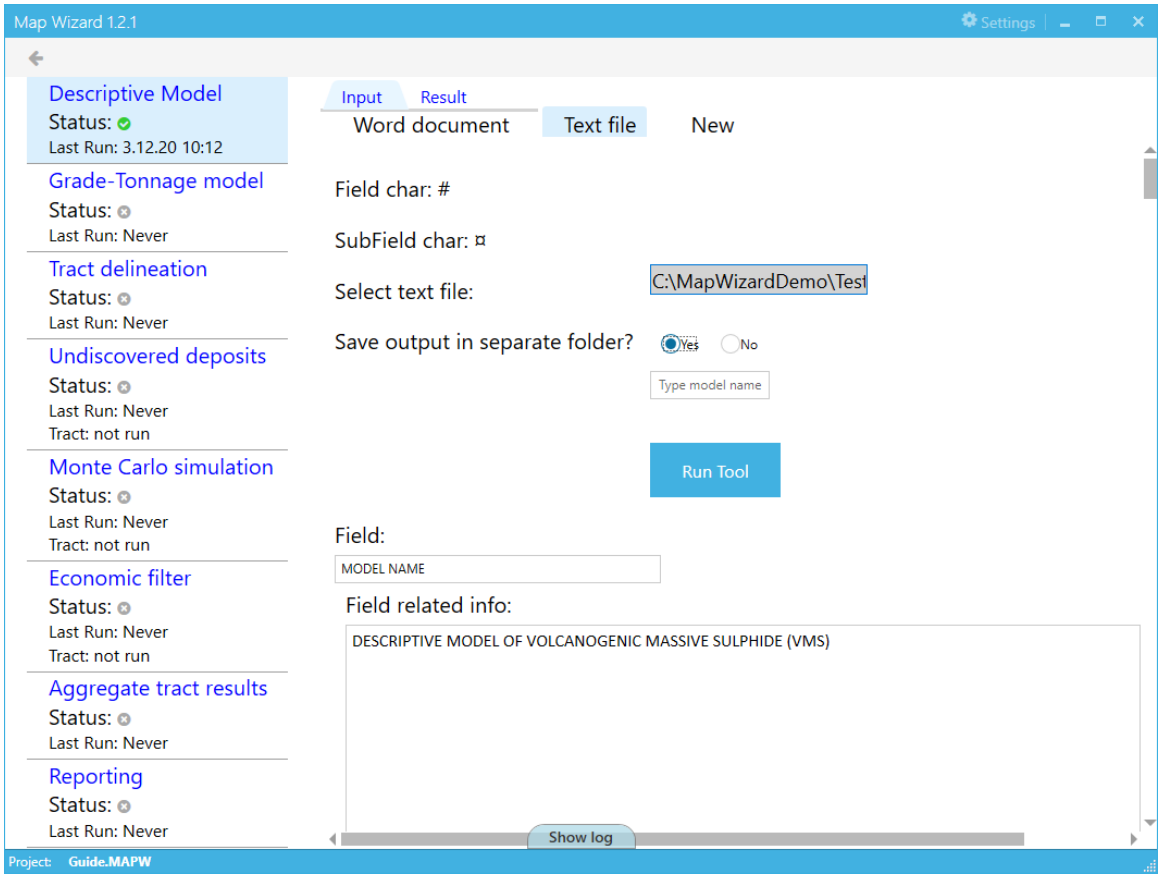
Text file tab

Select text file

Allows the user to give the path to a text file containing the descriptive model. Each heading in the file must begin and end with the character "#". Each subheading in the file must begin and end with the character "¤". After the file is selected, the tool reads it and displays its contents in separate fields, the contents of which can be edited interactively.



Save output in separate folder?

If "Yes", the tool saves the descriptive model file in a specified subfolder when the **Run tool** button is clicked.

Run tool

Saves the (possibly modified) model in Microsoft Word (.docx) and text format.

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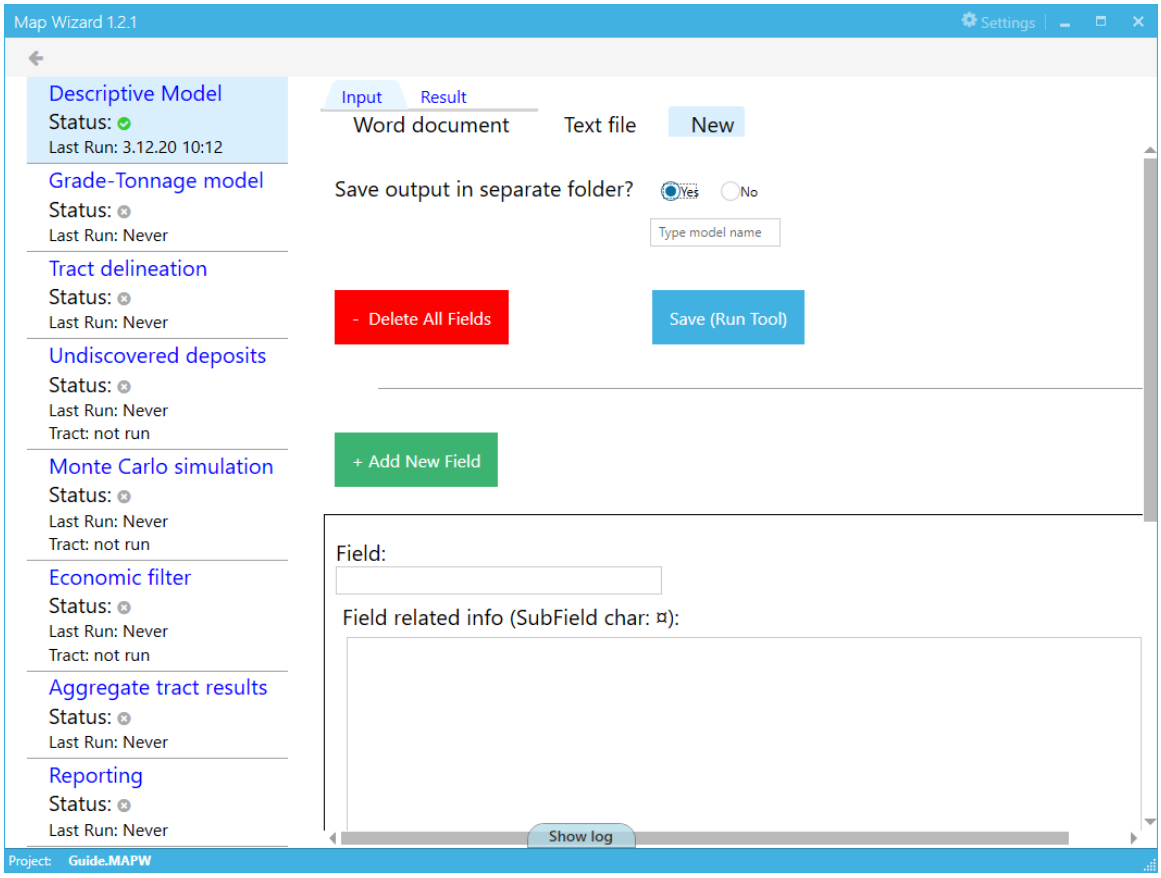
New tab

+ Add new field

Adds text boxes for a new title field and corresponding text. Text can be entered interactively in these text boxes.



Save output in separate folder?

If “Yes”, the tool saves the descriptive model file in a specified subfolder when the “Run tool” button is clicked.

Run tool

Saves the created model in Microsoft Word (.docx) and text format.

4.2. Result window

The saved descriptive models can be viewed in the Result window.

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Select model

Select the model to be used in this assessment from a list of models created by or input in the tool. The model must be selected to make its inclusion in the Tract report possible. A descriptive name must be given to the selected model.

Save model for further use?

If yes, the selected model is saved permanently for use in other assessment projects using the name given.

4.3. Output

The tool saves the created descriptive model in Microsoft Word (.docx) and text format in <ProjectRoot>\DescModel folder, or if a separate folder was selected, in <ProjectRoot>\DescModel\<GivenName>.

The model selected for use in the assessment is copied to folder <ProjectRoot>\DescModel\SelectedResult.

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If a model is saved permanently for use in other assessments, it is placed in <DepositModels>\Descriptive\<GivenName>, where <DepositModels> is the name of the root folder in which permanently saved deposit models are placed, given by the user in MapWizard settings.

The following output is produced by the tool:

- descriptive_input_params.json
    - Input parameters used in running the tool
- DescriptiveModel(Chars).txt
    - The model as a text file, containing the field and subfield control characters
- DescriptiveModel.txt
    - The model as a text file
- DescriptiveModel(docx).docx
    - The model in Microsoft Word format

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5. Grade-Tonnage model tool

The Grade-Tonnage model tool estimates probability density functions (pdf) for ore tonnage and metal grade data or metal tonnage data of well-known deposits input by the user. The tool provides summary statistics and plots of the data and estimated probability distributions and saves the distribution probability density function(s) for use in Monte Carlo simulation. Several probability density functions can be created in consequent runs using different combinations of input parameters, and the final model to be used can be selected among these and saved permanently for further use in other assessments. The tool is based on and uses the R functions of the USGS software MapMark4 (Ellefsen 2017a,b, Shapiro 2018).

5.1. Functioning of the tool

If a data file is given to the tool, it will estimate independent probability distributions of the ore tonnage and metal grade values, a joint probability distribution of the ore tonnage and metal grade values, or a probability distribution of metal tonnage values in the data file. If a path to an existing grade-tonnage model or a metal tonnage model created previously by the Grade-Tonnage tool is given, the tool displays the model summary tables and graphs and stores the model for further use in the active project by the Monte Carlo simulation tool.

Ore and metal tonnages in the input data file are first transformed with the natural logarithm, and the pdf is developed for the transformed tonnages. There are two choices for the pdf, a normal distribution and a kernel density estimate. For the normal distribution, the mean and standard deviation are estimated with the sample mean and sample standard deviation. For the kernel density estimate, the kernel is Gaussian. For both choices, random samples are drawn and then transformed with exponentiation, yielding random samples of tonnage. These random samples implicitly define the pdf for the tonnage.

Metal grades in the input data file are first transformed using the isometric log-ratio transformation to avoid problems involved in calculations using compositional data. A standard pdf is developed for the transformed grades. There are two choices for the pdf. One choice is the multivariate normal distribution, for which the mean vector and covariance matrix are estimated with the sample mean vector and sample covariance matrix. The other choice is a multivariate kernel density estimate, for which the kernel is Gaussian. For both choices, random samples are drawn and then transformed with the inverse isometric log-ratio transformation, yielding random samples of mineral resource and gangue grades. These random samples implicitly define the probability distribution for the mineral resource and gangue grades.

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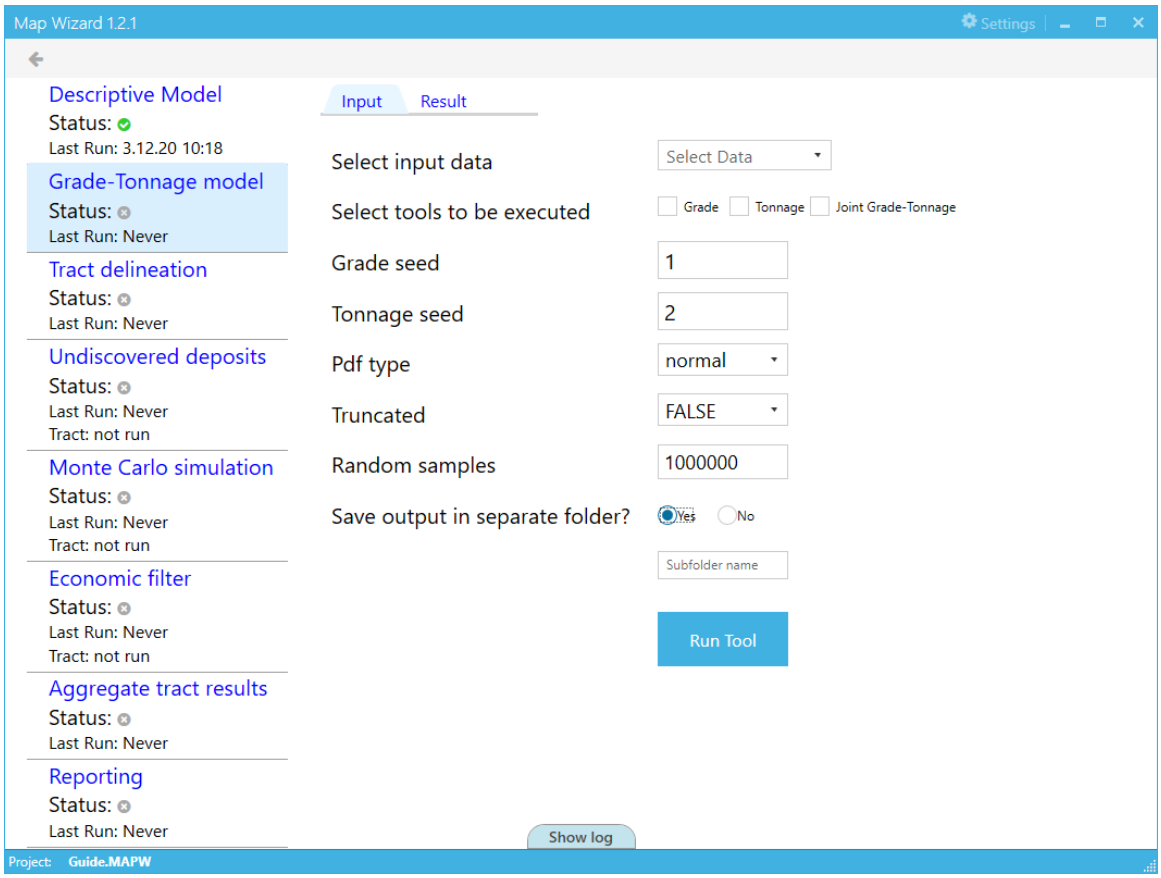
The tool outputs the summary results and plots of the estimation and stores these results as well as the estimated pdfs as R objects. The user can store several estimated models. This makes it easier to compare the effects of various options on the estimated pdfs. After the trials, the final model is selected and saved for use by the Monte Carlo simulation tool. The model can also be saved permanently for further use in subsequent assessment projects.

5.2. Input window

Select input data

Select the nature of the input data. The alternatives are “Grade-Tonnage”, “Metal tonnage” and “Existing Model”.



Grade-Tonnage or Metal tonnage

Selecting one of these options lets the user to browse to the location of the file containing ore tonnage and metal grade data or contained metal tonnage data for well-known deposits. These data will be used in the construction of the grade-tonnage or metal tonnage model. The tool supports files in CSV format. The structure of the data files is described below.

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A *grade-tonnage data file* contains information of ore tonnage and grades of one or more metals in well-known mineral deposits of a certain type. The first six lines of a grade-tonnage data file are given below as an example. The file is in CSV format, but here the columns are separated by spaces for clarity.

ID	Name	Ore	Cu	Au
DepID1	DepName1	10000000	0.45	0.000055
DepID2	DepName2	27000000	0.38	0.000047
DepID3	DepName3	1178000	0.77	0.000089
DepID4	DepName4	12340000	0.52	0.000061
DepID5	DepName5	7560000	0.85	0.000034

The first two columns are unique identifiers for the individual deposits in the data set. These identifiers are not used by the Grade-Tonnage model tool. The first two columns can be given any name. In the example above, the first column is each deposit's ID, and the second column is each deposit's name. The next columns provide the deposit data. The third column should be named "Ore", and it must list the ore tonnage in metric tons. All tonnages must be positive, no zero or negative values are permitted. The remaining columns contain the commodity grades in percent units. The column headings for these columns should be the commodity abbreviations without percentage signs. Missing grades are not permitted, and all grades must be between 0 and 100; they cannot equal 0 or 100.

A *metal tonnage data file* contains information of contained tonnage of one metal in well-known mineral deposits of a certain type. The first six lines of a metal tonnage data file are given below as an example. The file is in CSV format, but here the columns are separated by spaces for clarity.

ID	Name	U
DepID1	DepName1	15.85
DepID2	DepName2	27.05
DepID3	DepName3	34.55
DepID4	DepName4	20.91
DepID5	DepName5	29.10

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The first two columns are similar as those in a grade-tonnage data file (see above). The third column lists the amount of contained metal in the deposit in metric tons. The column heading for the third column should be the commodity abbreviation. All values must be positive, missing or zero values are not permitted. Further columns after column three are ignored.

Existing model
Selecting this option lets the user to browse to the folder containing a grade-tonnage or metal tonnage model previously created by MapWizard Grade-Tonnage model tool.

Select tools to be executed
Select whether a probability density function (pdf) should be estimated for only ore tonnage or metal grade(s), or both. In these cases, the generated grade and tonnage probability distributions are independent of each other. For metal tonnage data, only the "Tonnage" option can be selected. Selecting "Joint Grade-Tonnage" causes a joint probability distribution of tonnage and grades to be generated, which takes into consideration the correlation between ore tonnage and metal grades in the input data.

Grade seed
Seed value to be used in random number generation when estimating the grade pdf.

- Default: 1

Tonnage seed
Seed value to be used in random number generation when estimating the tonnage pdf.

- Default: 2

Pdf type
Type of the probability density function (pdf) to be estimated for the grade and/or tonnage data. The alternatives are normal and kde. The default alternative is normal, which is a normal pdf. The alternative is a kernel density estimate (Hastie et al. 2009, Shalizi 2016), for which the kernel is Gaussian. As a guideline, when there are less than roughly 50 well-known deposits in the grade-tonnage or metal tonnage data file, the normal pdf should be selected. With more than roughly 50 well-known deposits in the data file, the kernel density estimate pdf could be selected. It is advisable to check the pdfs generated with both methods.

- Default: normal

Truncated
This parameter specifies whether the estimated pdf is truncated at the lowest and highest data values in the grade-tonnage or metal tonnage data file.

- Default: FALSE

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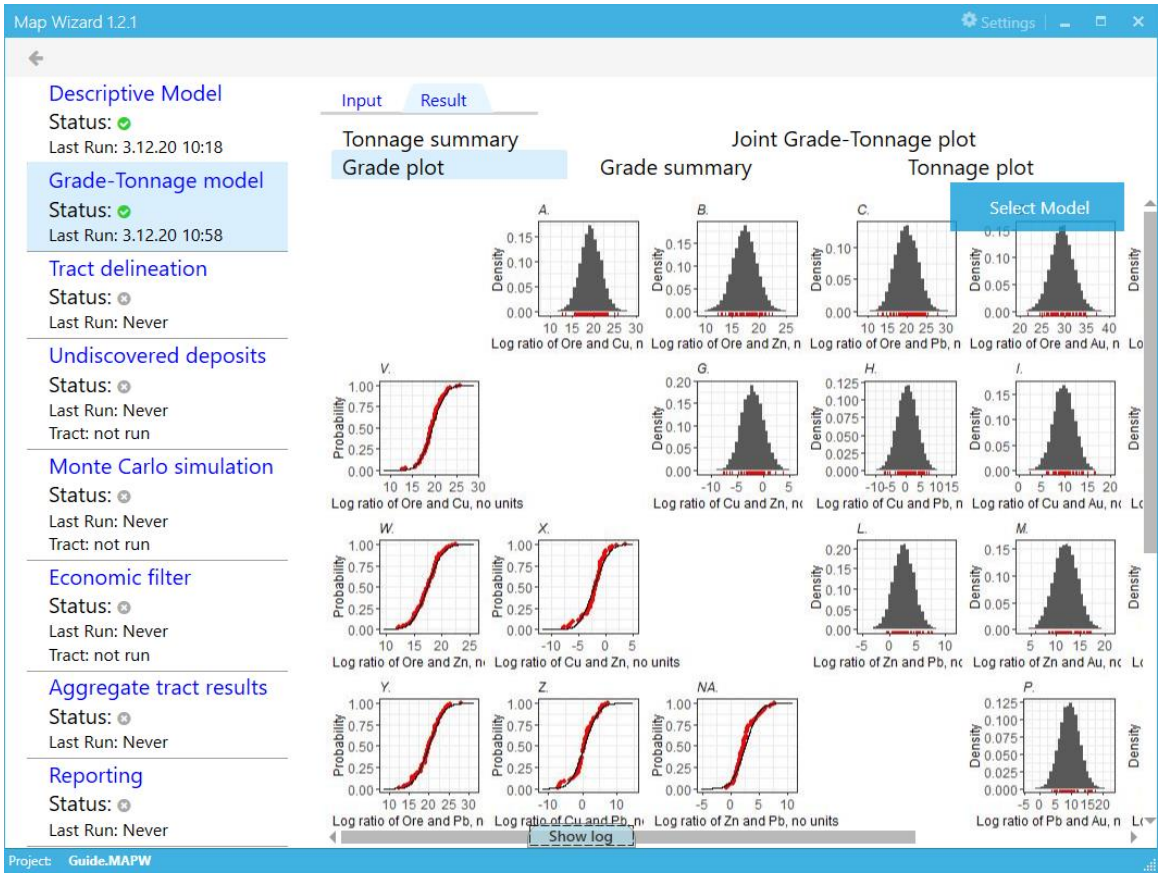
Random samples
Number of random samples generated when estimating summary statistics for the pdfs. This should be a large number to ensure precise summary statistics.

- Default: 1,000,000

Save output in separate folder?
If "Yes", the generated model will be stored in a separate folder. This is useful when the user wants to compare the effects of the various input options on the produced model.

5.3. Result window

The summary results and plots of the most recent estimation run are shown in the "Result" window.



Select model
Select the model to be used in the Monte Carlo simulation from a list of models created by the tool.

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Save model for further use?
This allows the user to save the selected model permanently for further use in other assessments. A saved model can be read by the Grade-Tonnage model tool in another project.

Grade plot tab

Displays histograms and cumulative distribution functions that are calculated from the probability density function representing the grades.

Grade summary tab

Displays summary statistics for the grades and a comparison of the pdfs representing the grades and the actual grades in the model dataset.

Tonnage plot tab

Displays the probability density function that represents the ore tonnage in an undiscovered deposit and the corresponding cumulative distribution function.

Tonnage summary tab

Displays summary statistics for the tonnage and a comparison of the pdf representing the tonnage and the actual tonnages in the model dataset.

Joint Grade-Tonnage plot

Displays a matrix of scatterplots of simulated grade and tonnage values on which the estimated joint probability density functions are based. The simulated values are displayed in red and the actual input data values are displayed in black.

5.4. Output

The tool saves the created grade-tonnage model in <ProjectRoot>\GTModel folder, or if a separate folder was selected, in <ProjectRoot>\GTModel\<GivenName>.

The model selected for use in the assessment is copied to folder <ProjectRoot>\GTModel\SelectedResult.

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If a model is saved permanently for use in other assessments, it is placed in <DepositModels>\GradeTonnage\<GivenName>, where <DepositModels> is the name of the root folder in which permanently saved deposit models are placed, given by the user in MapWizard settings.

The following output is produced by the tool:

- GradeTonnage_input_params.json
    - Input parameters used in running the tool
- GT_InputFile.csv
    - A CSV file containing the ore tonnage and metal grade data or metal tonnage data used as input in the estimation of the probability density functions
- tonnage_summary.txt
    - A text file containing summary statistics for the ore tonnage or metal tonnage data and the estimated probability density function
- tonnage_plot.jpeg
    - A jpeg file containing a plot of the estimated ore tonnage or metal tonnage pdf and data
- tonnage_plot.tiff
    - A high-resolution tiff file containing a plot of the estimated ore tonnage or metal tonnage pdf and data
- tonnage_plot.eps
    - An eps file containing a plot of the estimated ore tonnage or metal tonnage pdf and data
- tonnage.rds
    - An R object file containing the estimated ore tonnage or metal tonnage pdf
- grade_summary.txt
    - Text file containing summary statistics for the metal grade data and the estimated probability density functions
- grade_plot.jpeg
    - A jpeg file containing a plot of the estimated metal grade pdfs and data
- grade_plot.tiff
    - A high-resolution tiff file containing a plot of the estimated metal grade pdfs and data

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- grade_plot.eps
    - An encapsulated postscript file containing a plot of the estimated metal grade pdfs and data
- grade.rds
    - An R object file containing the estimated metal grade pdfs
- tongrade_plot.jpeg
    - A jpeg file containing a scatterplot matrix of the estimated joint tonnage-grade pdfs and data
- tongrade_plot.tiff
    - A high-resolution tiff file containing a scatterplot matrix of the estimated joint tonnage-grade pdfs and data
- tongrade_plot.eps
    - An encapsulated postscript file containing a scatterplot matrix of the estimated joint tonnage-grade pdfs and data
- tongrade.rds

    An R object file containing the estimated joint grade-tonnage pdfs

5.5. References

Ellefsen, K.J. 2017a. User's guide for MapMark4—An R package for the probability calculations in three-part mineral resource assessments. U.S. Geological Survey Techniques and Methods, book 7, chap. C14. 23 p. https://doi.org/10.3133/tm7C14.

Ellefsen, K.J. 2017b. Probability calculations for three-part mineral resource assessments. U.S. Geological Survey Techniques and Methods, book 7, chap. C15. 14 p. https://doi.org/10.3133/tm7C15.

Hastie, T., Tibshirani, R. and Friedman, J. 2009. The elements of statistical learning—Data mining, inference, and prediction (2d ed.). New York, Springer Science + Business Media, LLC. 745 p.

Shalizi, C.R. 2016. Advanced data analysis from an elementary point of view. Cambridge, United Kingdom, Cambridge University Press. http://www.stat.cmu.edu/~cshalizi/ADAfaEPoV/.

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Shapiro, J. 2018. User's guide for MapMark4GUI—A graphical user interface for the MapMark4 R package. U.S. Geological Survey Techniques and Methods, book 7, chap. C18. 19 p. https://doi.org/10.3133/tm7c18.

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6. Tract delineation tool

Tract delineation tool creates permissive tracts using mineral prospectivity modelling methods. The tracts are saved as GIS shapefiles.

6.1. Functioning of the tool

There are two processes in the tool: Tract delineation and tract classification. In the first, the user can either input the tract as a shapefile, or create it interactively using either Fuzzy logic of Weights of evidence method. In both methods, a delineation raster is first created using selected evidence rasters. After this, the tract boundaries are defined in the 'Delineate tract' process based on the score values of the created delineation raster. The delineated tract is saved in <ProjectRoot>\TractDelineation\Tracts\TR<ID>. Other tools read the tract names from this folder structure. The following tools depend on the existence of the tracts created by the Tract delineation tool: Undiscovered deposits tool, Monte Carlo simulation tool, Economic filter tool, Reporting tool and Aggregate tract results tool.

In the classification process, the user can classify the tract based on prospectivity (or some other criterion). The user first selects the tract, and the tool reads the tract boundary from the tract folder. The user can then either input the path to a raster to be used in the classification process, or create the raster using either Fuzzy logic or Weights of evidence.

6.2. GIS file formats and requirements

All input GIS raster files should be in Erdas Imagine (.img), GeoTIFF or Esri grid format and all GIS vector files should be in shapefile (.shp) format. In additions to these formats, the Create/Fuzzy process also accepts Jpeg2000 (.jp2) format.

It is very important that all the GIS data layers input to the tool have the same coordinate system and exactly the same dimensions.

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6.3. Input window

Delineation tab

Input tract polygon subtab

Path to tract polygon
Path to a polygon containing tract boundaries.

Explanation for the tract:
Explanation of the tract being input as a shapefile.

ID for the tract
ID for the tract that is being input as a shapefile.

Save
Creates a folder for the tract and saves the shapefile in it.

Create / Fuzzy subtab

Input evidence rasters
All evidence layer rasters to be combined in one or more rounds using fuzzy logic operators. The rasters have to be fuzzified, i.e., the fuzzy membership functions must have been determined before importing the rasters in MapWizard.

Rasters to be combined
Select the rasters to be combined in the present combination round. The evidence rasters can be combined in one or several rounds or steps.

Fuzzy overlay type
The fuzzy operator to be used in combining the evidence rasters.

Gamma value
Value of the gamma operator, if Gamma is selected as the operator.

Split number N
Allows to split the raster in N parts that are processed separately. This can save time for large rasters (more that 500 MB).

Output file name
Name of the resulting combination raster.

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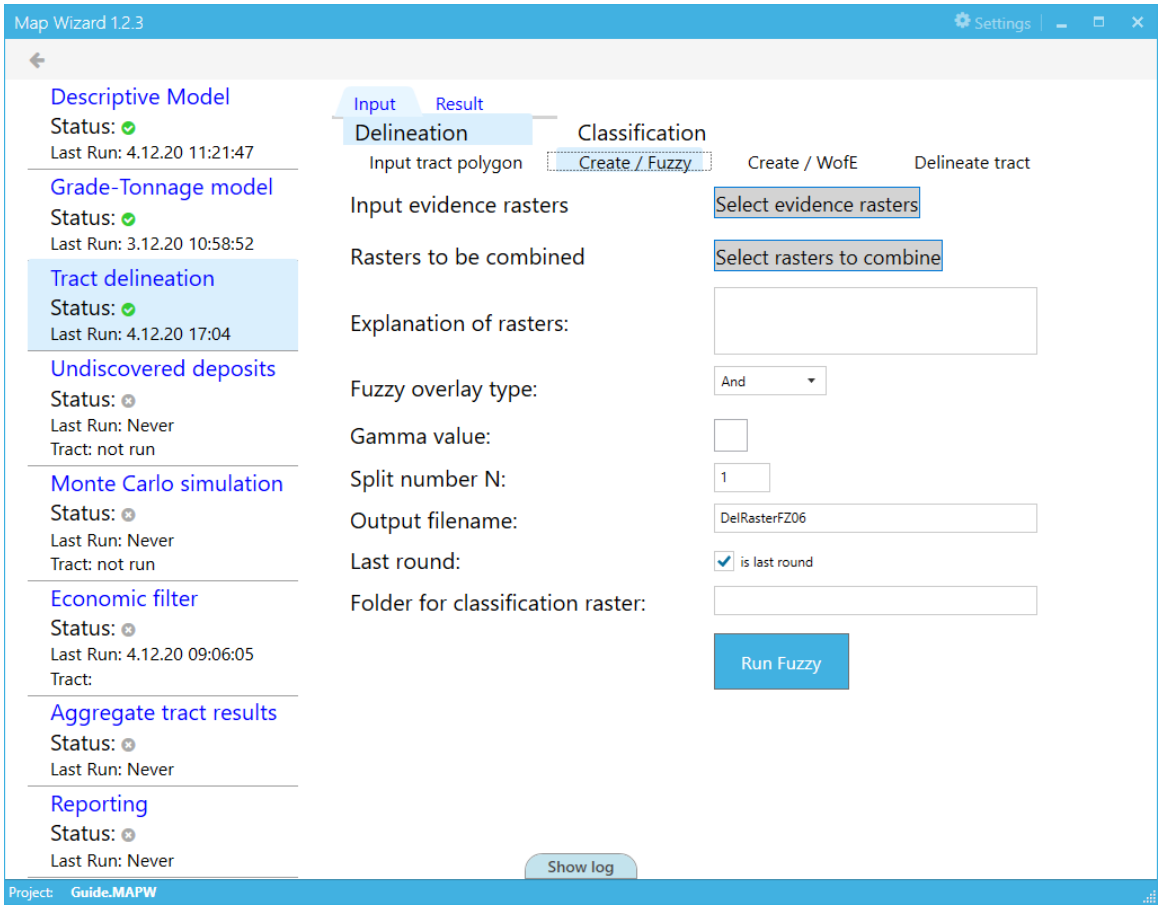

Last round

Indicates the last round of combining evidence layer rasters. This produces the final prospectivity raster.

Folder for saving delineation raster

Name of the folder in which the final delineation raster will be saved.

Create / WofE subtab

Evidence rasters

Rasters to be used as evidence layers. The rasters must be discretised, i.e., they can only contain a limited number of discrete values.

Explanation of evidence rasters

Explanations for the rasters.

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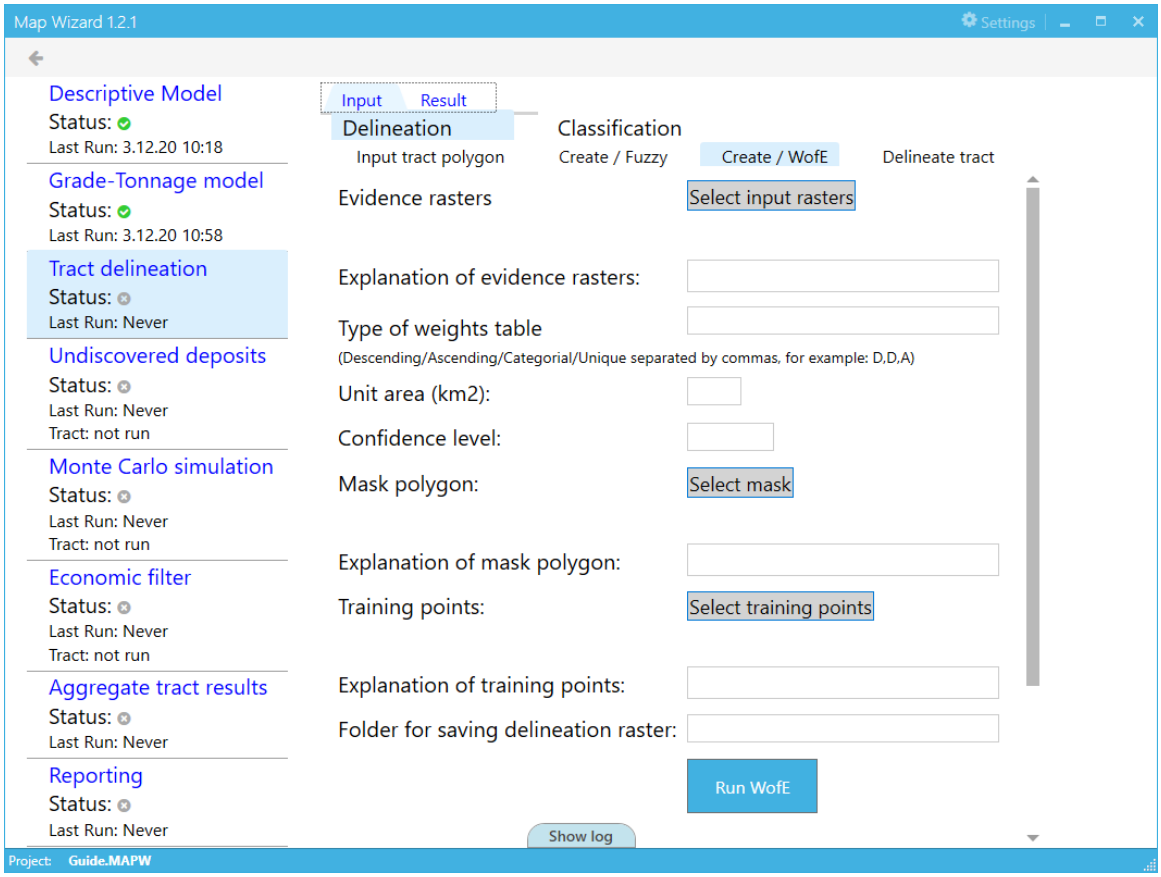
Type of weights table

The types of weights table for each input raster separated by commas. Possible values are descending, ascending, categorical and unique, and they can be abbreviated as D, A, C and U, respectively.



Unit area

The unit area is given in square kilometres and it is used as the counting unit for area measurements. It cannot be smaller than the cell size of the evidence rasters.

Confidence level

Confidence level of the studentized contrast. The contrast is the difference between the weights, and it is an overall measure of spatial association between the training points and the evidence layer. Value 2 is suggested as a default.

Mask

A polygon or raster layer defining the limits of the area for which the weights of evidence analysis is performed.

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Training points
Training points used to calculate the weights and associated statistics. These should be given as a shape file.

Explanation of training points
Training points used to calculate the weights and associated statistics. These should be given as a shape file.

Folder for saving delineation raster
Name of the folder in which the final delineation raster will be saved.

Delineate tract subtab

Delineation raster
The path to the raster to be used as the starting point in the delineation of the permissive tract. This can be the delineation raster created in the Fuzzy logic or Weights of evidence process described above, but it can also be a raster created by other means.

Tract boundary values
Up to 5 prospectivity score values separated by commas, to be tested as tract boundary values. The values should be between 0 and 1.

ID for this permissive tract
Identification code for the delineated tract is given here. This ID identifies the tract throughout the rest of the assessment process.

Select evidence raster file
Select a raster on which the tested tract boundaries will be plotted for viewing. This can be any of the evidence layers used in the generation of the prospectivity raster, or it can be some other raster. For example, it might be useful to plot the generated tract boundaries on a lithological map.

Generate boundaries
Generates a masked prospectivity raster corresponding to each given boundary value. Only prospectivity score values higher than the given boundary values are shown. Plots of the generated tract candidates are listed below the Generate boundaries button. Double-clicking on a PDF file name on the list opens the file in the operating system default PDF viewer. The masked prospectivity raster plotted on the selected evidence layer raster is produced as a PDF file in folder <ProjectRoot\TractDelineation\Delineation\temp. If none of the tested value produces an acceptable result, the user can give another set of boundary values and click on the Generate boundaries button again.

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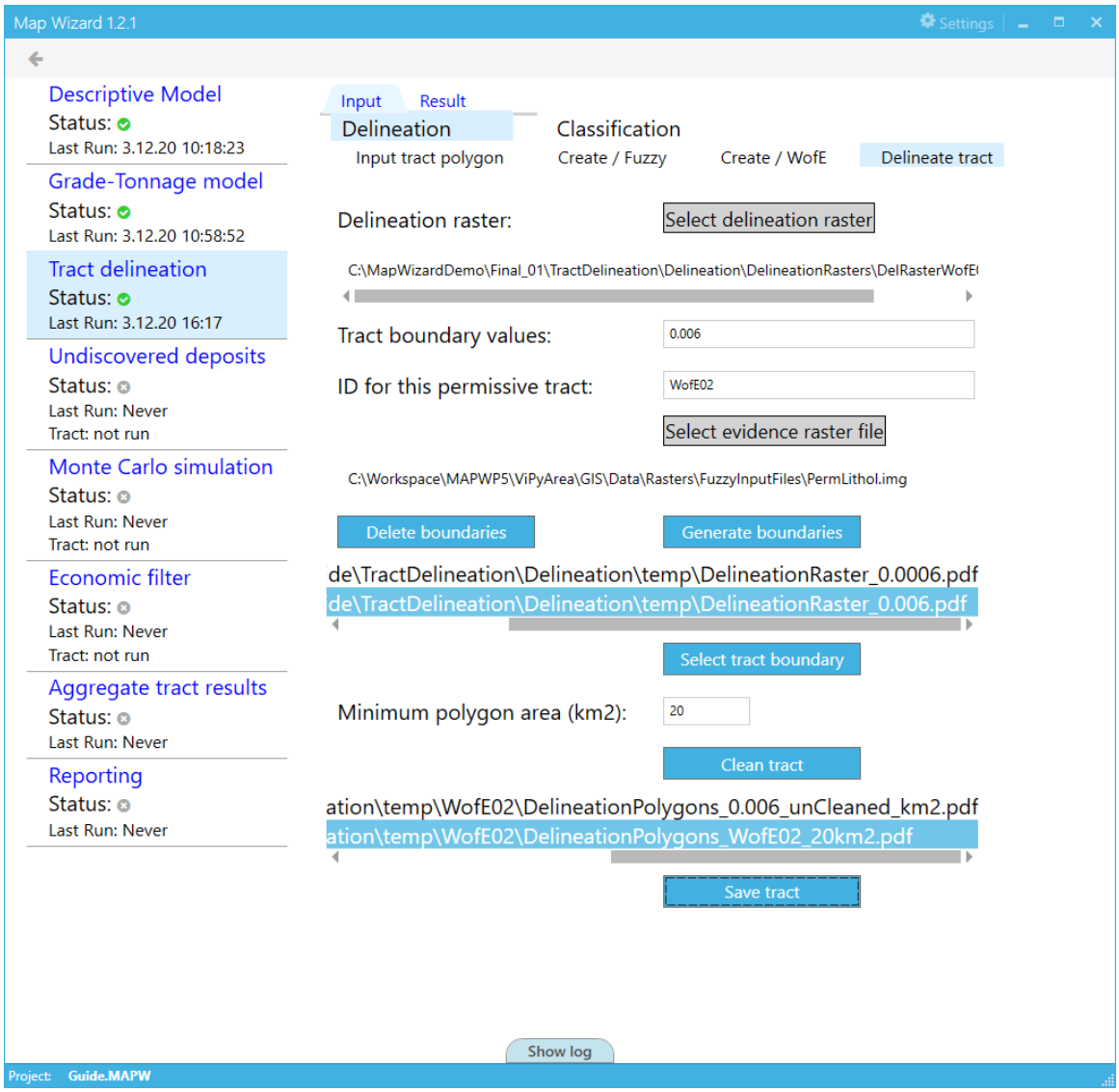
Delete boundaries

Clear the list of previously generated tract boundary files by deleting the files.



Select tract boundary

This button only appears after the **Generate boundaries** button has been clicked. The user can click on one of the listed tract boundary files and then select it by clicking on the **Select tract boundary** button. The selected raster is polygonised along the borders, i.e., a polygon shape file is created where the polygons represent tract boundaries. A frequency distribution of polygon areas in the generated polygon layer is generated as well as summary statistics for the polygon areas.

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Minimum polygon area (km^2)

This only appears after the Select tract boundary button has been pressed. The generated polygon set representing the permissive tract often contains a large number of small isolated polygons. The user can clean the tract to some extent by erasing polygons smaller than a limiting area given in the “Minimum polygon area (km2)” input field.

Clean tract

Erases the polygons smaller than the given limit. The produced cleaned tract is listed as a PDF file below the Clean tract button. Bouble-clicking on it opens the PDF file in operating system default PDF viewer. Several rounds of cleaning can be run by giving consequently larger areas in the “Minimum polygon area (km2)” field and clicking the Clean tract button.

Save tract

The final permissive tract is saved by selecting the corresponding PDF file from the list of cleaned files and clicking on the Save tract button. Output file locations are given in chapter 6.4. Output.

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Classification process tab

Classification main subtab

Tract ID

ID of the tract to be classified. The ID is selected from the drop-down list.

Raster to classify

This can be the raster produced by the delineation process described above, but it can also be any other raster. There are three alternatives:

Select raster

Browse to the location of the raster file to be classified

Create / Fuzzy

Run the Fuzzy process to create a raster to be classified. This will open the Create classification fuzzy subtab. The Fuzzy process is identical to the Delineation Create / Fuzzy process. When the process is completed the created raster is automatically selected as the raster to be classified.

Create / WofE

Run the WofE process to create a raster to be classified. This will open the Create classification wofe subtab. The WofE process is identical to the Delineation Create / WofE process. When the process is completed the created raster is automatically selected as the raster to be classified.

Number of classes

The number of classes to generate. The number should be between 1 and 10.

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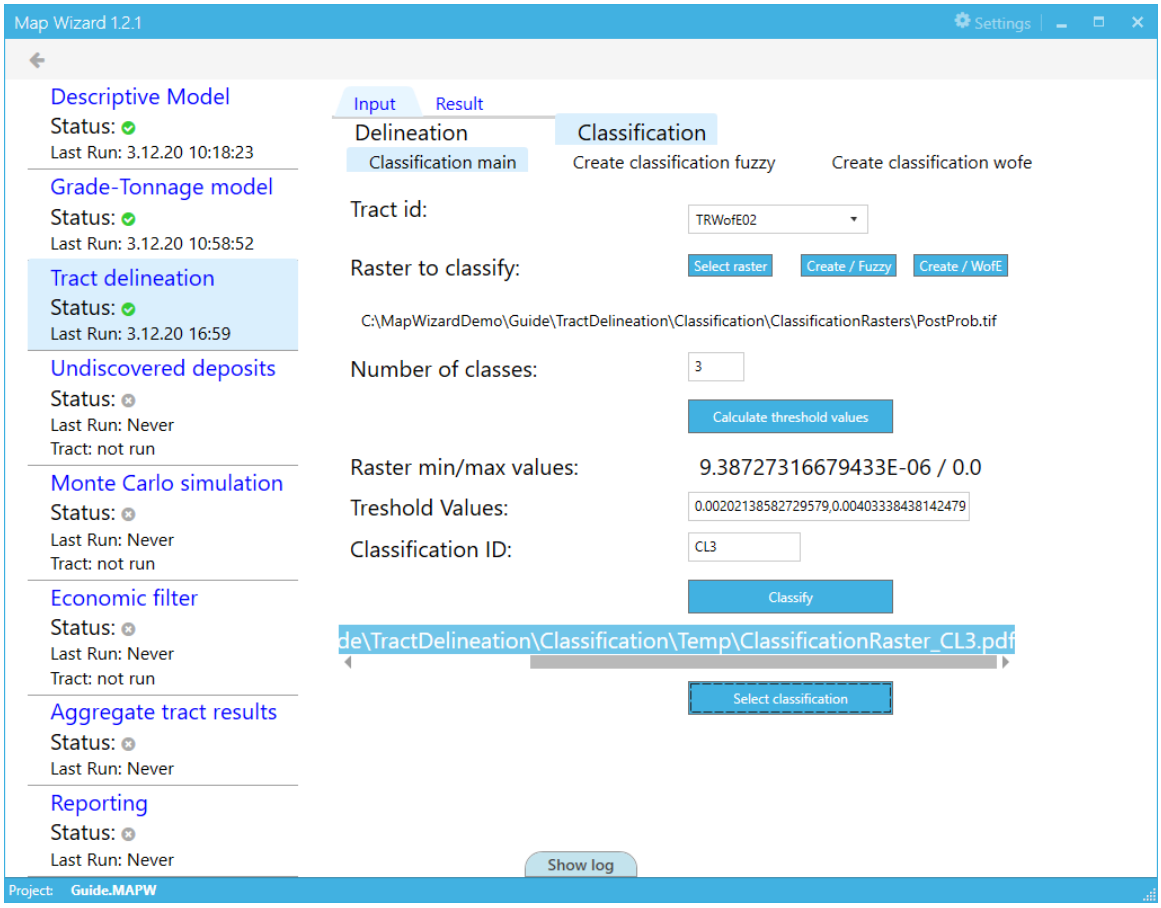

Calculate threshold values

This produces equally spaced threshold values that divide the input raster values into the number of classes given above. The threshold values are displayed in the “Threshold values” text box. Minimum and maximum values of the input raster are also displayed.

Threshold values

The threshold values in the text box can be modified before running the classification process.

Classification ID

Identification for the classification run.

Classify

Produces a raster consisting of the required number of classes, coded from one to the required number of classes. The classified raster is listed on screen. A new classification run can be initiated by giving a new number of classes and/or new threshold values.

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Select classification
The result of the classification can be accepted by selecting it from the list and clicking on this button.

6.4. Result window

Show results in filesystem
Opens file explorer in the folder where the files produced by the selected Tract delineation tool process have been placed. Some of the produced results are saved in pdf format, but to view all the produced raster and polygon files, GIS software is required.

6.5. Output

The tool parameter file is placed in <ProjectRoot>\TractDelineation.

- permissive_tract_input_params.json
    - Input parameters used in running the tool

Output of the Tract delineation tool processes is placed in corresponding subfolders of <ProjectRoot>\TractDelineation.

Delineation Create / Fuzzy process

The following files are produced by the Fuzzy process.
In folder <ProjectRoot>\TractDelineation\Delineation\Fuzzy\EvidenceData:

- Input evidence rasters and intermediate combinations of evidence rasters
- FuzzyParameter.json
    - Parameters for the Fuzzy process

In folder <ProjectRoot>\TractDelineation\Delineation\DelineationRasters\<GivenName>, where <GivenName> is folder name given by the user

- Final delineation raster
- FuzzyRasterExplanation.txt
    - Explanation of the Fuzzy process parameters
- logfile.txt
    - A log of the Fuzzy process

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All raster files produced by the Fuzzy process are of type .tif and follow the naming convention <GivenName>.tif, where <GivenName> is the file name given by the user.

Delineation Create / WofE process

The following files are produced by the WofE process.
In folder <ProjectRoot>\TractDelineation\Delineation\WofE\EvidenceData:

- Input evidence rasters
- WofeParameterWeights.json
    - Parameters for the calculate weights process
- WofeParameterResponse.json
    - Parametersfor the calculate response process

In folder <ProjectRoot>TractDelineation\Delineation\DelineationRasters\<GivenName>, where <GivenName> is folder name given by the user:

- PostProb.tif
    - The posterior probability raster
- Confidence.tif
    - A raster showing the confidence that the reported posterior probability is not zero. This is the posterior probability divided by the total standard deviation, an approximate Student T test.
- StdDev.tif
    - A raster with the standard deviation due to the weights. If there is no missing data, this is also the total standard deviation for the response raster.
- Ndv.tif
    - A raster containing the no data value mask
- <LayerName>_weight_table.json files, one for each evidence layer used, where <LayerName> is the name of the input evidence layer in question
    - Weights tables for the input evidence layers
- WofERasterExplanation.txt
    - Explanation for the wofe process parameters
- logfile.log
    - A log of the WofE process

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Delineation process

The delineation process produces a set of files for each given delineation raster boundary value <val>. The files are stored in <ProjectRoot>\TractDelineation\Delineation\temp. Among the files are:

- DelineationRaster_<val>.img
    - Prospectivity raster where values smaller than <val> are masked
- DelineationRaster_<val>.img.aux.xml
    - Statistics for the DelineationRaster_<val>.img values
- DelineationRaster_<val>.pdf
    - The raster as a pdf file
- BoundariesOnEvidence_<val>.pdf
    - DelineationRaster_<val>.img plotted on the selected evidence raster layer for viewing

When a tract boundary value is selected, the delineation process produces a set of files for the selected delineation raster boundary value <val>. The files are stored in <ProjectRoot>\TractDelineation\Delineation\temp. Among the files are:

- DelineationPolygons_<val>.shp
    - DelineationRaster_<val>.img polygonised into a polygon layer
- DelineationPolygons_<val>.shp_dist.pdf
    - Frequency distribution of polygon areas in the polygon layer
- DelineationPolygons_<val>.shp_stats.txt
    - Summary statistics for the polygon areas in the polygon layer

After the final delineation raster has been cleaned, the resulting tract is saved in folder <ProjectRoot>\TractDelineation\Tracts\<ID>, where <ID> is the identification code given by the user for the delineated tract. The files include:

- DelineationExplanation.txt
    - Explanation of the whole delineation process
- DelineationRaster.img
    - The original delineation raster
- DelineationRasterExplanation.txt

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    - Explanation of data and parameters used in the construction of the delineation raster
- DelineationRaster_<val>.img
    - The delineation raster where values smaller than the selected threshold value <val> are masked
- DelineationRaster_<val>.img.aux.xml
    - Statistics for the DelineationRaster_<val>.img values
- DelineationPolygons_<val>_stats.txt
    - A text file containing summary statistics for the polygon areas in the Delineation polygon layer
- DelineationPolygons_<val>_cdf.pdf
    - A pdf file containing a cumulative frequency distribution of polygon areas in the Delineation polygon layer
- TR<ID>.shp and associated files
    - A shapefile containing the delineated tract based on the cleaned delineation polygon layer
- TR<ID>.pdf
    - A pdf file showing the delineated tract
- TR<ID>_stats.txt
    - A text file containing summary statistics for the polygon areas in the Delineation polygon layer
- TR<ID>_cdf.pdf
    - A pdf file containing a cumulative frequency distribution of polygon areas in the tract polygon layer

Classification process

The classification process produces a classified prospectivity raster in folder <ProjectRoot>\TractDelineation\Classification\Temp:

- MaskedRaster<ID>.img, where <ID> is the Tract ID
    - Selected classification raster masked by the tract boundaries
- MaskedRaster<ID>.img.aux.xml
    - Statistics for the MaskedRaster<ID>.img raster values

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- MaskedRaster<ID>.pdf
    - MaskedRaster<ID>.img raster as a pdf file
- ClassificationRaster_<CLID>.img, where <CLID> is the ID for the classification run given by the user
    - Raster classified into chosen number of classes
- ClassificationRaster_<CLID>.img.aux.xml
    - Statistics for the ClassificationRaster_<CLID>.img raster values
- ClassificationRaster_<CLID>.pdf
    - ClassificationRaster_<CLID>.img raster as a pdf file

The selected final classified raster is saved in folder <ProjectRoot>\TractDelineation\Tracts\<ID>, where <ID> is the identification code given by the user for the delineated tract:

- TR<ID>_<CLID>.img, where <CLID> is the classification ID given by the user
    - The classified raster masked by the tract boundary
- TR<ID>_<CLID>.img.aux.xml
    - Statistics for the TR<ID>_<CLID>.img raster values
- TR<ID>_<CLID>.pdf
    - TR<ID>_<CLID>.img raster as a pdf file

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7. Undiscovered deposits tool

The Undiscovered deposits tool estimates a probability mass function (pmf) for the number of undiscovered deposits that might exist within a permissive tract. The tool provides summary statistics and plots of the input data and estimated probability distribution, and saves the distribution probability mass function for use in Monte Carlo simulation. The tool is based on and uses the R functions of USGS MapMark4 (Ellefsen 2017a,b, Shapiro 2018) and Eminers (Root et al. 1992, Duval 2012) software. The algorithm used by the MARK3 process is given in Appendix 2 of Singer and Menzie (2010).

7.1. Functioning of the tool

The tool supports the expert estimation method of assessing the number of undiscovered deposits. It uses the expert estimates of the number of deposits at several levels of confidence as the starting point of the probability mass function estimation. The tool has the option to use an existing deposit density model as a guideline in the expert estimation of the number of undiscovered deposits.

Three different types of probability mass functions (pmf) can be estimated: Negative binomial, non-parametric (MARK3) and custom. For negative binomial pmf calculation, the estimated numbers of each expert are used as input. The MARK3 option estimates an empirical probability mass function using a non-parametric method. For this option, only one set of estimated numbers of deposits at various confidence levels is used. The custom option can be used to input a custom probability mass function. This is represented by a list of deposit numbers and corresponding probabilities.

An estimate of the number of undiscovered deposits is always connected to a permissive tract. The tool requires that a tract is selected before it can be run.

7.2. Input window

Deposit density tab

The Deposit density tool estimates the number of deposits that might exist at 90, 50 and 10 per cent confidence within a permissive tract having a specific geographic area. The tool uses published global deposit density models in the estimation: General model (Singer 2018), porphyry copper (Singer 2018), VMS (Mosier et al. 2007), podiform chromite (Singer & Kouda 2011). The global models are based on the number of existing deposits in well-known and

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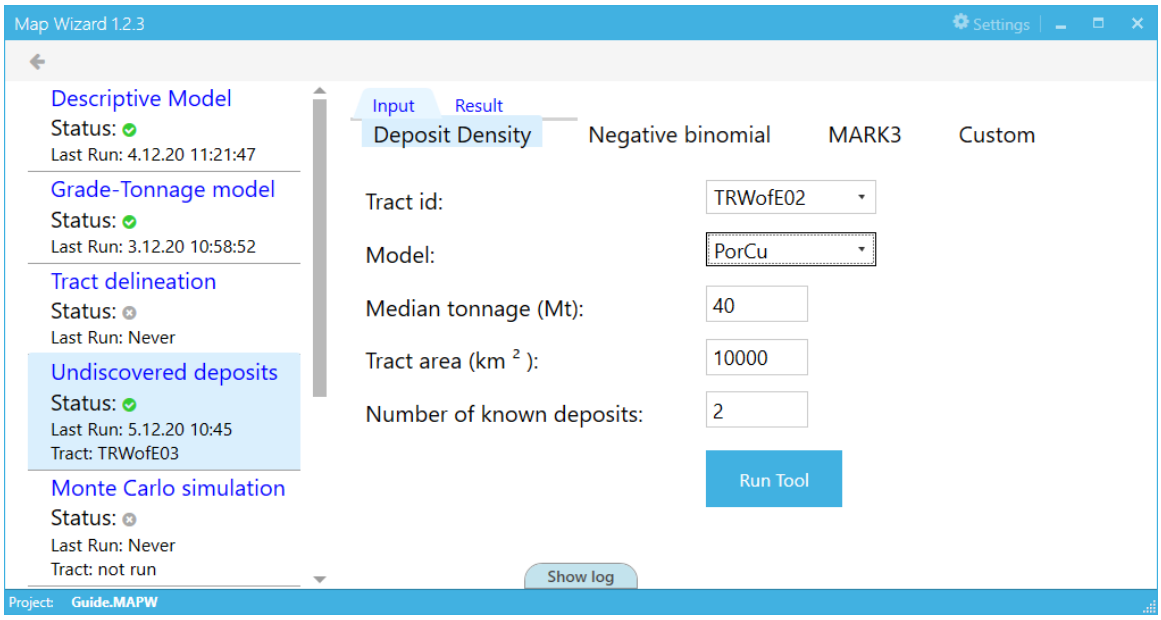
explored permissive tracts. The deposit specific density models are basically linear regression equations of the number of deposits against the area of the permissive tract, using logarithmic values. The general density model relates the number of deposits to the area of the tract and the median tonnage of the deposit type.

The tool takes as input the model type, the median tonnage of the deposit type being estimated, the area of the permissive tract and the number of known deposits in the tract. It calculates the median estimate of the number of undiscovered deposits and the 90 and 10 percent prediction limits for the estimate. The results are shown on the output window and stored in a text file. A graph displaying the global data, the regression line (median estimate) and the prediction boundaries is also shown and stored.



Tract ID

ID of the permissive tract for which the number of deposits is estimated is selected from a drop-down list.

Model

Selects the deposit density model to use. Models for four deposit types are available: Volcanogenic massive sulphide deposits (VMS), porphyry copper deposits (PorCu), podiform chromite (PodiformCr) and a general model (General).

Median tonnage (Mt)

Median tonnage of the deposit type in million metric tons. This is only relevant for the General model.

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Tract area
Surface area of the permissive tract in square kilometres.

Number of known deposits
The number of well-known deposits of the assessed deposit type within the permissive tract. This should be the number of deposits that occur within the boundaries of the tract and are included in the grade-tonnage model.

Negative binomial tab

The Negative binomial option estimates a negative binomial probability mass function for the number-of-deposits estimates.

Tract ID
ID of the permissive tract for which the estimate is carried out. This variable is selected using the drop-down list.

Estimator ID
Identifier for the assessment team member producing the number-of-deposits estimate.

Weight for estimator's estimates
Weight associated with the estimate. The weight controls the extent to which the estimates of a specific team member affect the calculated probability mass function. The weight must be positive. Negative or zero values are prohibited. For most assessment team members, the weight should be 1, which is the standard value. For an expert, the weight could be greater than 1, and for a novice, a weight less than 1 could be used.

N90, N50, N10
The N90 value represents the estimated number of undiscovered deposits at a probability of 0.90. This probability is often called an "elicitation percentile of 90" among assessment geoscientists. The N50 and N10 values are analogous and represent the estimated number of undiscovered deposits at elicitation percentiles of 50 and 10.

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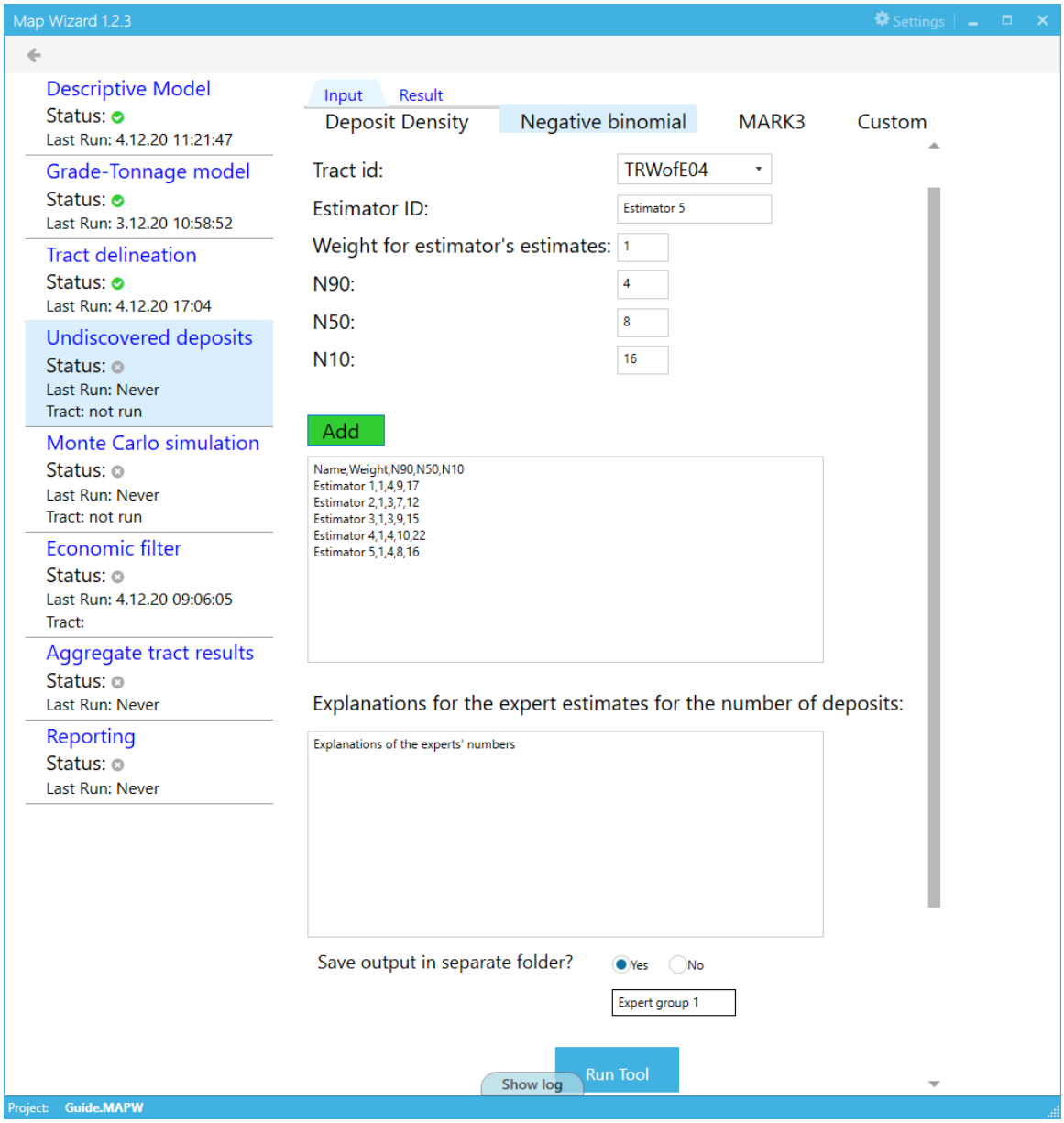

Add

Adds the values in the interactively filled input fields above it in the summary input field below. The values for the parameters Estimator ID, Weight, N90, N50 and N10 can be added interactively for each expert one at the time using the corresponding input fields, or they can be typed or pasted directly in the summary input text field below the **Add** button. In the latter case, each row must contain all the five variables listed in the header row at the top of the summary input text field, separated by commas.

Explanations for the expert estimates for the number of deposits

The rationale and explanations for the numbers given by each expert can be input in the text box.

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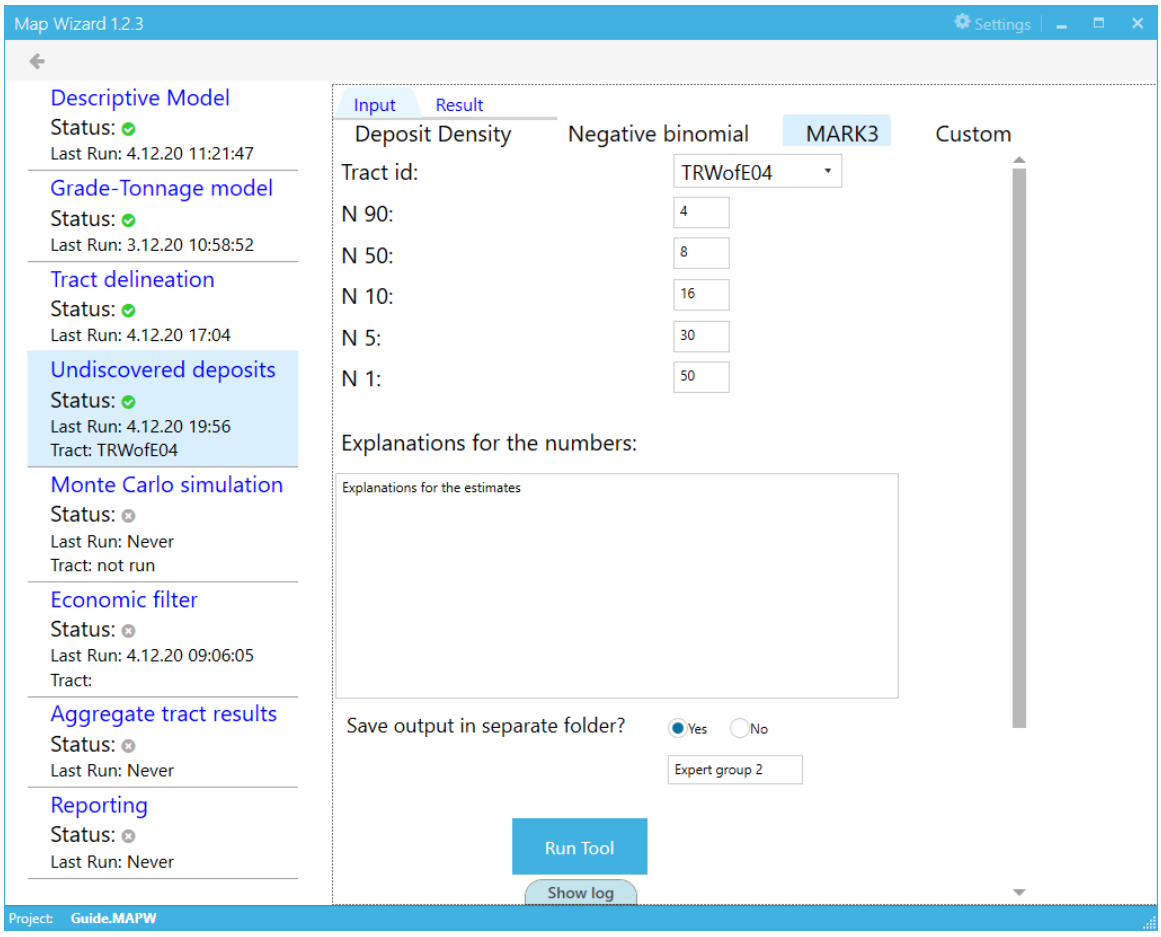
Save output in separate folder?
If “Yes”, the output of the probability mass function estimation will be saved in a separate folder. If several rounds of estimates are carried out it is advisable to save each estimate in its own folder.

MARK3 tab

The MARK3 option estimates an empirical probability mass function using a non-parametric method previously used in USGS Eminers software. The algorithm is given in appendix 2 of Singer and Menzie (2010).



Tract ID
ID of the permissive tract for which the estimate is carried out. This variable is selected using the drop-down list.

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N90, N50, N10, N5, N1
The N90 value represents the estimated number of undiscovered deposits at a probability of 0.90. This probability is often called an "elicitation percentile of 90" among assessment geoscientists. The N50, N10, N5 and N1 values are analogous and represent the estimated number of undiscovered deposits at elicitation percentiles of 50, 10, 5 and 1.

Explanations for the numbers
The rationale and explanations for the numbers can be input in the text box.

Save output in separate folder?
If "Yes", the output of the probability mass function estimation will be saved in a separate folder.

Custom tab

The Custom option can be used to input a custom probability mass function. This is represented by a list of deposit numbers and corresponding probabilities.

Tract ID
ID of the permissive tract for which the estimate is carried out. This variable is selected using the drop-down list.

Number of deposits
Number of undiscovered deposits.

Probability
Probability corresponding to the given number of deposits.

Add
Add the given number of deposits – probability pair in the summary text box below. All number-probability pairs can be typed or pasted directly in the summary text box. The list should begin with zero deposits and the number of deposits should increase downwards.

Explanations for the numbers
The rationale and explanations for the numbers can be input in the text box.

Save output in separate folder?
If "Yes", the output of the probability mass function estimation will be saved in a separate folder.

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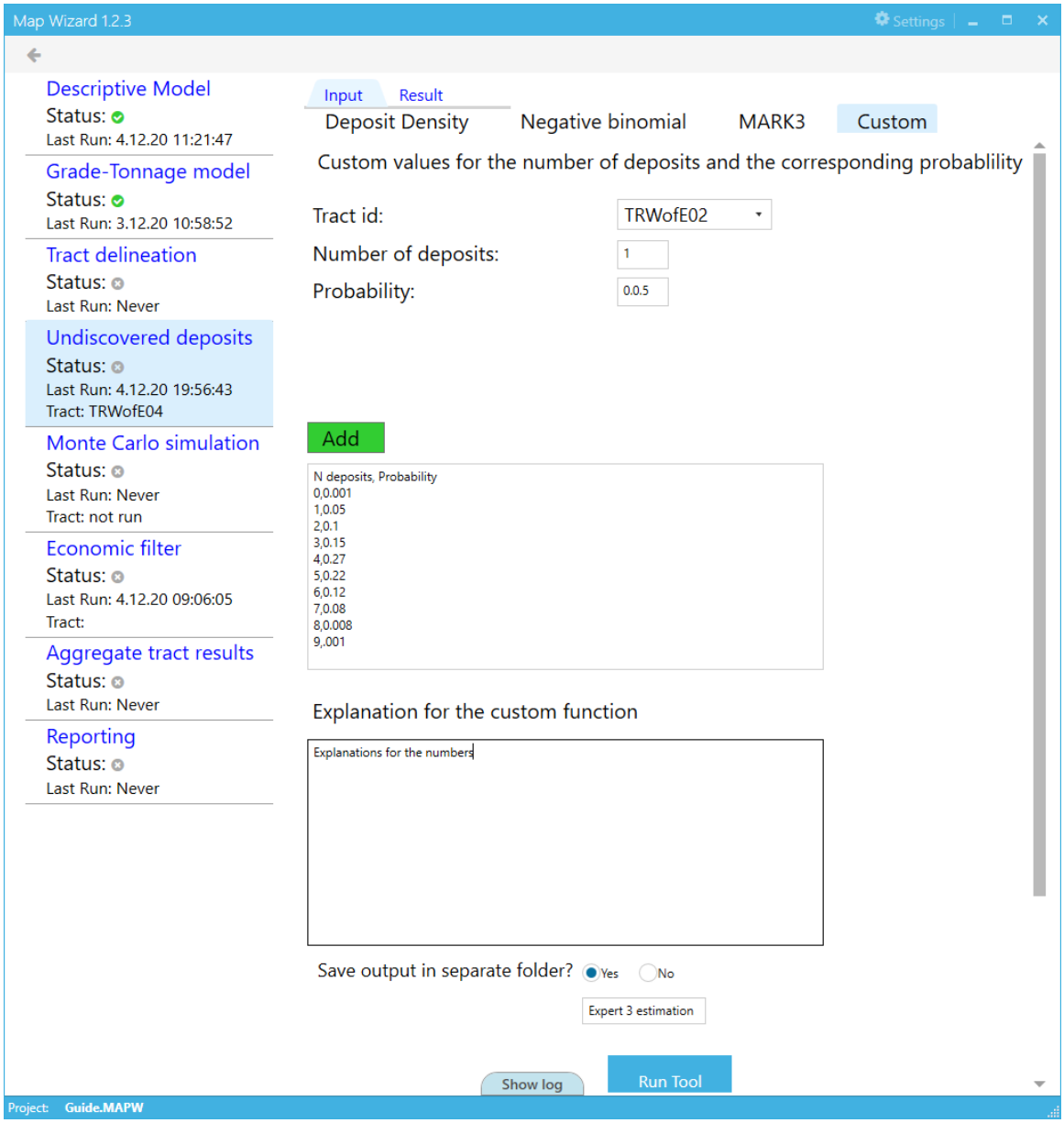

7.3. Result window

Select result

Select a specific probability mass function for the number of undiscovered deposits to be used in the Monte Carlo simulation. The function must be selected even if only one method was used.

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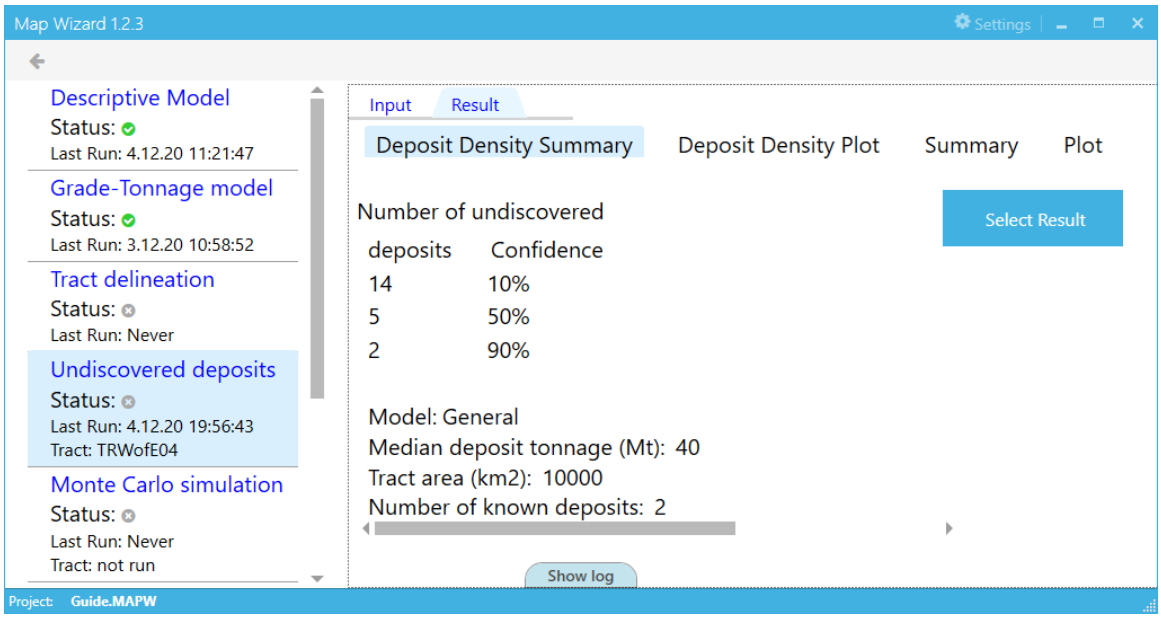
Deposit Density Summary tab

The tab contains the results of the estimation using the selected deposit density model: Number of deposits at 10%, 50% and 90% confidence level. Input parameters are also listed.



Deposit Density Plot tab

The plot displays the data from well-known permissive tracts used in the deposit density model. In case of specific deposit types, number of deposits within a permissive tract is plotted against area of the tract. For the general model number of deposits is plotted against a function of tract area and median tonnage of the deposit type. A regression line and 10% and 90% prediction limits are plotted on the data.

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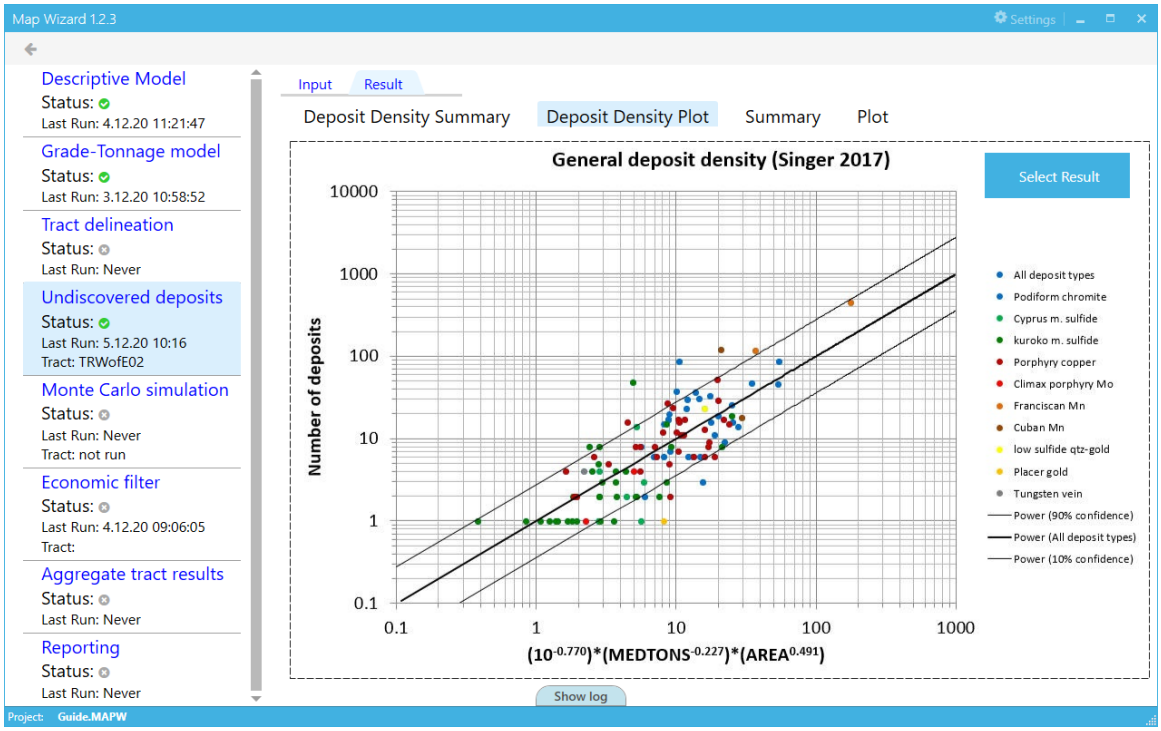
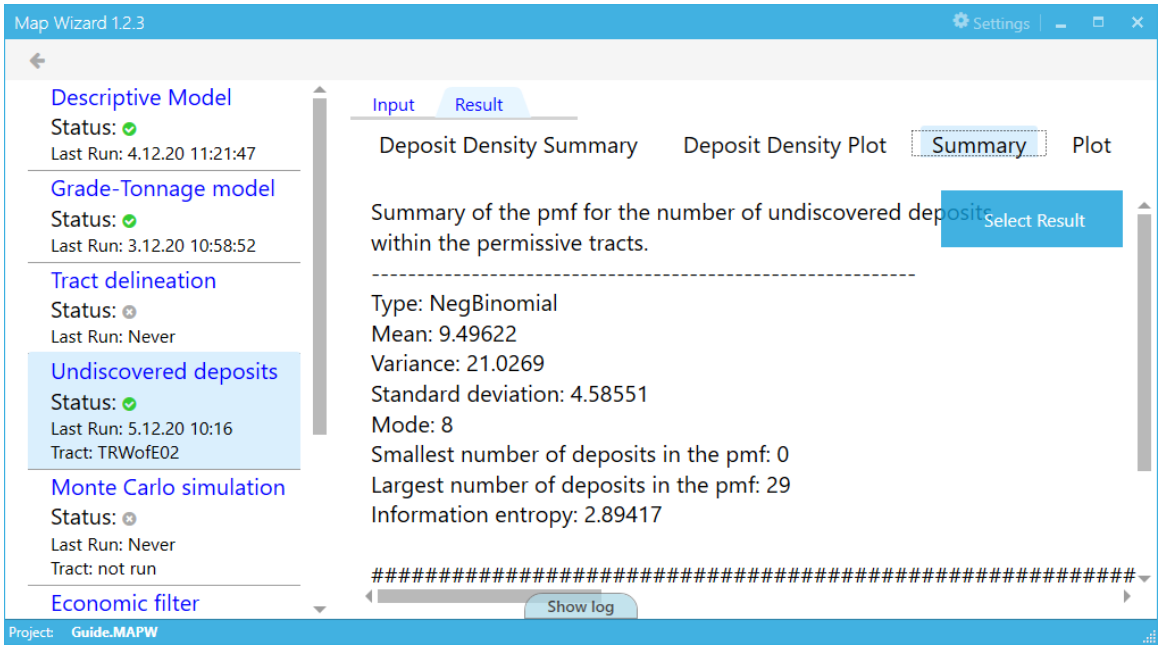


Summary tab

The summary tab displays summary statistics for the probability mass functions estimated for the number of undiscovered deposits using the negative binomial, MARK3 or custom option.



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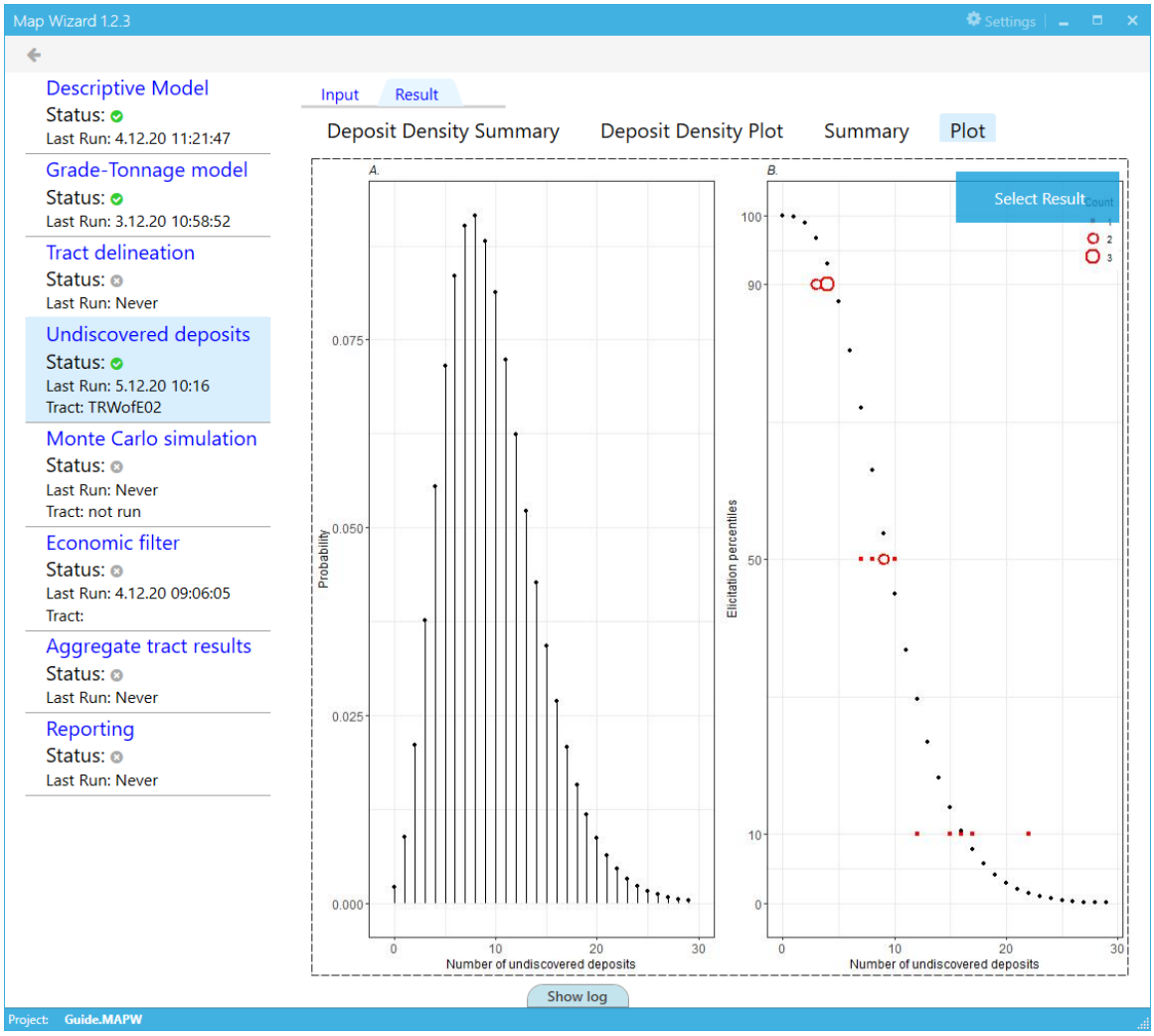
Plot tab

The plot tab displays a plot of the probability mass function estimated using the negative binomial, MARK3 or custom option. In case of the negative binomial option, also a corresponding cumulative distribution is plotted.



7.4. Output

Output of the tool is in subfolders under <ProjectRoot>\UndiscDep\TR<ID>, where <ID> is the ID of the permissive tract for which the number of deposits is estimated.

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Deposit Density output

Output of the Deposit Density option is stored in folder <ProjectRoot>\UndiscDep\TR<ID>\Densmodel, where

The following output is produced:

- <Model>_results.txt
    - A text file containing summary results of the density model estimate. <Model> is one of General, PorphyryCu, VMS or PodiformCr.
- Plot_<Model>.jpeg
    - A jpeg file containing a plot of the global model used; data points and regression and prediction lines.

Negative binomial, MARK3 and Custom output

Output of these options is stored in folder <ProjectRoot>\UndiscDep\TR<ID>\<Method> or in folder <ProjectRoot>\UndiscDep\TR<ID>\<Method>\<GivenName>, where <Method> is one of NegativeBinomial, MARK3 or Custom and <GivenName> is the optional folder name given by the user. Once the user has selected the probability mass function (pmf) to be used in Monte Carlo simulation, the selected result for the tract is copied to <ProjectRoot>\UndiscDep\TR<ID>\SelectedResult

The following output is produced by the tool:

- undiscovered_deposits_input_params.json
    - Parameters used to run the tool
- Summary.txt
    - A text file containing summary results of the run
- Plot.jpeg
    - A jpeg file containing a plot of the estimated pmf. For the negative binomial option, the corresponding cumulative distribution function is also plotted together with the expert estimates.
- Plot.tiff
    - A high-resolution tiff file containing the same plot as the jpeg file.
- Plot.eps
    - An encapsulated postscript file containing the same plot as the jpeg file.

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- oPMF.rds
    - An R object containing the estimated pmf for further use by the Monte Carlo simulation tool.
- TractPmf.csv
    - A csv file containing a list of undiscovered deposit estimates and corresponding probabilities, based on the estimated pmf. This file can be used be the Aggregate results tool.
- nDepEst.csv, nDepEstMiddle.csv, nDepEstCustom.csv
    - A csv file containing the input to the tool
- EstRationale.txt
    - A text file containing the explanations for the input numbers

7.5. References

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This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

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8. Monte Carlo simulation tool

The Monte Carlo simulation tool produces a set of simulated undiscovered deposits and a probabilistic estimate of the amount of undiscovered mineral resources contained by these deposits. The tool provides summary statistics and plots of the estimated metal endowments. The tool is based on and uses the R functions of the USGS software MapMark4 (Ellefsen 2017a,b, Shapiro 2018).

8.1. Functioning of the tool

The tool uses the probability mass function estimated for the number of undiscovered deposits within a permissive tract by the Undiscovered deposits tool together with the probability density functions estimated for ore tonnage and metal grades, or for metal tonnage, by the Grade-Tonnage model tool. It creates a large number (default 20,000 simulation rounds) of simulated undiscovered deposits and calculates their metal contents. It produces summary statistics and plots of the results, as well as a csv file containing all the simulated deposits.

If a probability density function (pdf) was created separately for ore tonnage and metal grades by the Grade-Tonnage model tool, then both pdfs must be input to the Monte Carlo simulation tool. If a joint grade-tonnage pdf was created, then only it is used as input to the Monte Carlo simulation tool. If a metal tonnage pdf was created, then only it is used as input to the tool.

8.2. Input window

Tract ID
ID of the permissive tract for which the simulation is run. The ID is selected from a drop-down list of tract IDs.

Grade probability density function
Location of the R object (grade.rds) produced by the Grade-Tonnage model tool. The object contains the estimated probability density functions of metal grades.

Tonnage probability density function
Location of the R object (tonnage.rds) produced by the Grade-Tonnage model tool. The object contains the estimated probability density function of ore or metal tonnage.

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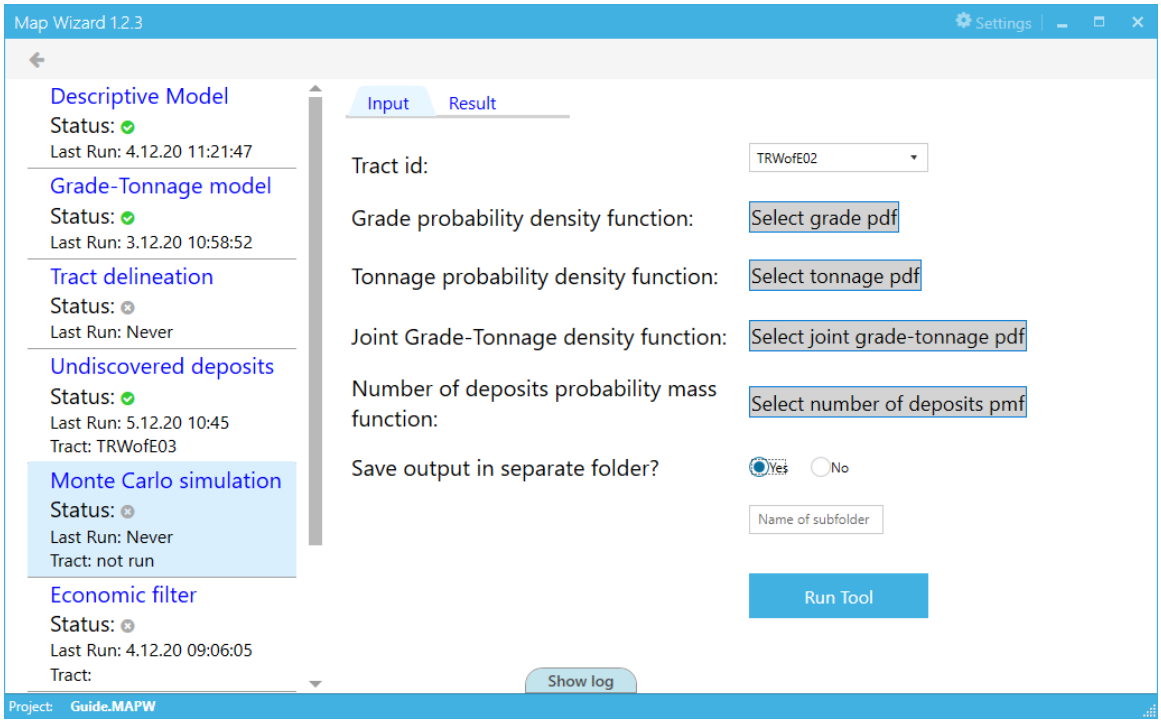

Joint Grade-Tonnage probability density function

Location of the R object (tongrade.rds) produced by the Grade-Tonnage model tool. The object contains the estimated joint probability density function of ore grade(s) and metal tonnage.

Number of deposits probability mass function

Location of the R object (oPmf.rds) produced by the Undiscovered deposits tool. The object contains the estimated probability mass function of the number of undiscovered deposits.

Save output in a separate folder?

If “Yes”, the output of the Monte Carlo simulation run is saved in a given folder. This makes it possible to save and compare the results of several runs.

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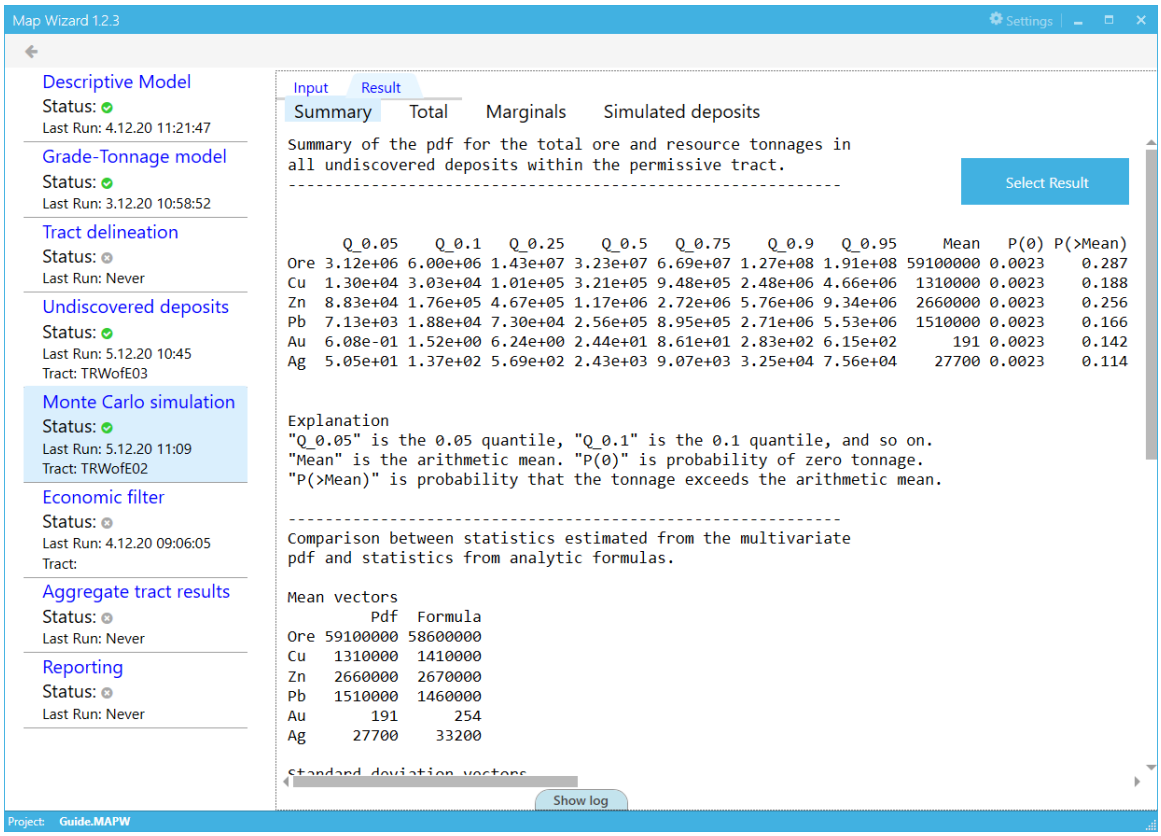
8.3. Result window

Summary tab

The summary tab contains a summary table of the Monte Carlo simulation results. The table lists the estimated undiscovered resources at several levels of probability. It also contains a comparison between statistics estimated from the multivariate pdf and statistics from analytic formulas.



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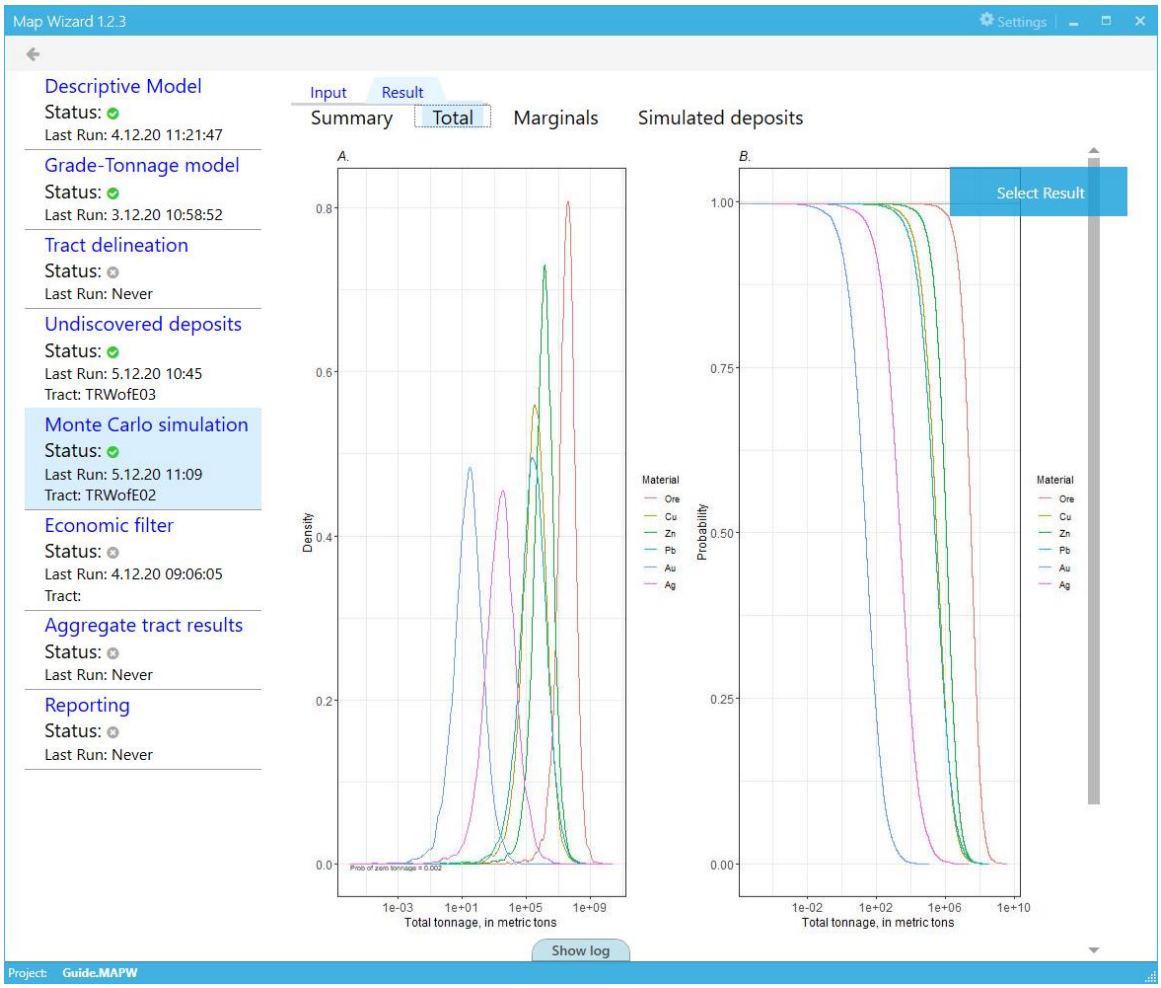
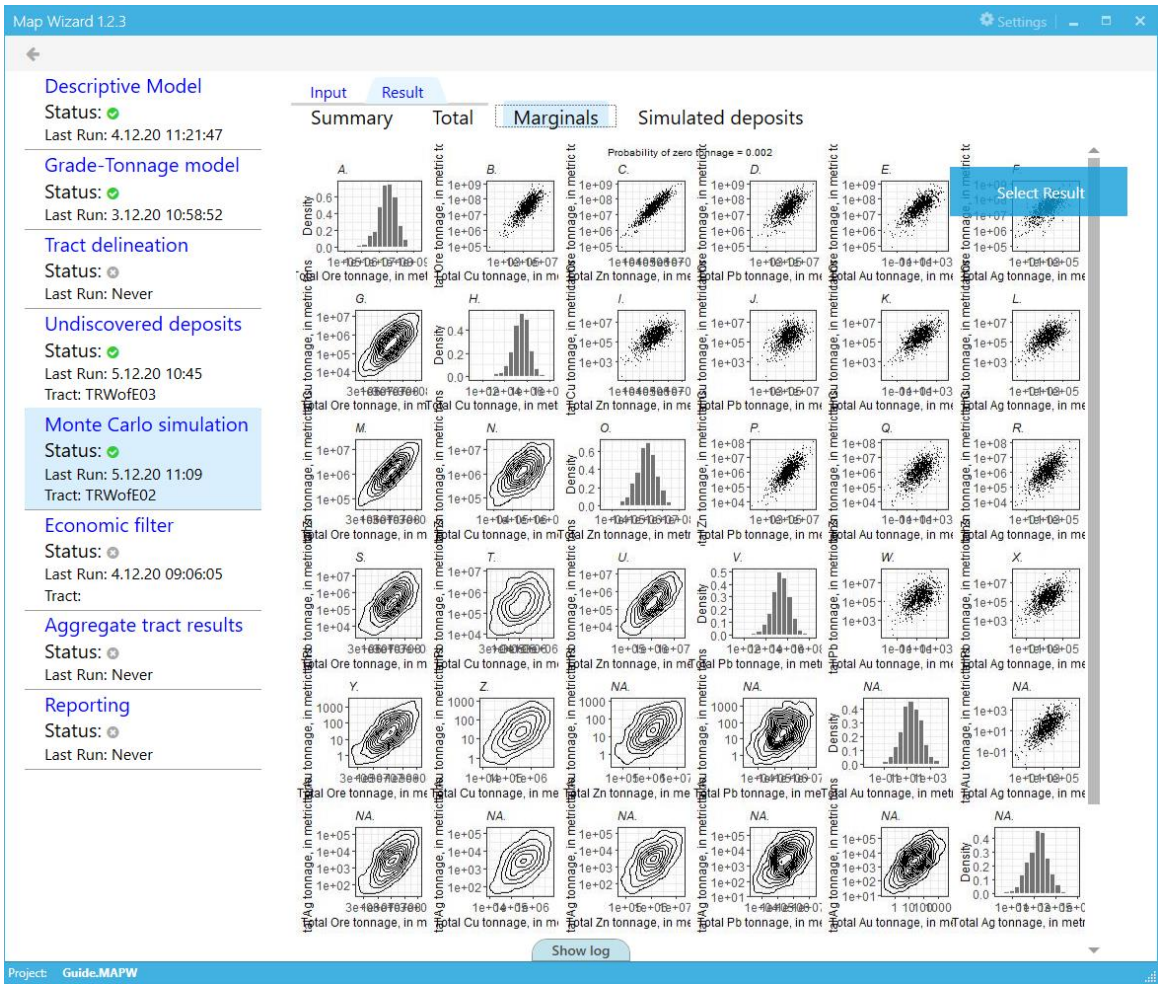
Total tab

The tab shows a plot of estimated probability density functions for the ore and metal tonnages in the undiscovered deposits, and corresponding cumulative distribution functions.



Marginals tab

The tab shows a plot of univariate and bivariate marginal distributions for the ore and metal tonnages in the undiscovered deposits.



Simulated deposits tab

The tab contains a link to open the csv file containing all the simulated deposits.

8.4. Output

Output of the tool is stored in folder <ProjectRoot>\MCSim\TR<ID> or in <ProjectRoot>\MCSim\TR<ID>\<GivenName>, if the user selected to save the result in a separate

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folder. Once the user has selected the simulation run result, the selected result for the tract is copied to <ProjectRoot>\MCSim\TR<ID>\SelectedResult.

The following output is produced by the tool:

- monte_carlo_simulation_input_params.json
    - Input parameters used in running the tool
- Summary.txt
    - A text file containing summary statistics for the estimated ore and metal endowment in the undiscovered deposits
- Plot.jpeg
    - A jpeg file containing plots of univariate marginal probability density functions and cumulative distribution functions for total ore and metal tonnages in the undiscovered deposits
- Plot.tiff
    - A high-resolution tiff file containing the same plots as file plot.jpeg
- Plot.eps
    - An encapsulated postscript file containing the same plots as file plot.jpeg
- plotMarginals.jpeg
    - A jpeg file containing plots of univariate and bivariate marginal distributions for total ore and metal tonnages in the undiscovered deposits
- plotMarginals.tiff
    - A high-resolution tiff file containing the same plots as file plotMarginals.jpeg
- plotMarginals.eps
    - An encapsulated postscript file containing the same plots as file plotMarginals.jpeg
- TR<ID>_Datafile.csv
    - A csv file containing the simulated undiscovered deposits
- TR<ID>_05_SIM_EF.csv
    - A csv file containing the simulated undiscovered deposits and their calculated metal contents, for use as input to the Economic filter tool
- TR<ID>_06_SIM_EF_stats.csv
    - A csv file containing statistics for the simulated deposits

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- TR<ID>_07_SIM_Contained_Totals.csv
    - A csv file containing total ore and metal contents of the tract for each simulation round
- TR<ID>_08_SIM_EF.csv
    - A csv file containing statistics of the simulated ore and metal content of the tract. The file contains more detailed statistics than the Summary.txt file.

8.5. References

Ellefsen, K.J. 2017a. User's guide for MapMark4—An R package for the probability calculations in three-part mineral resource assessments. U.S. Geological Survey Techniques and Methods, book 7, chap. C14. 23 p. https://doi.org/10.3133/tm7C14.

Ellefsen, K.J. 2017b. Probability calculations for three-part mineral resource assessments. U.S. Geological Survey Techniques and Methods, book 7, chap. C15. 14 p. https://doi.org/10.3133/tm7C15.

Shapiro, J. 2018. User's guide for MapMark4GUI—A graphical user interface for the MapMark4 R package. U.S. Geological Survey Techniques and Methods, book 7, chap. C18. 19 p. https://doi.org/10.3133/tm7c18.

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9. Economic filter tool

The Economic filter tool estimates the proportion of the total estimated undiscovered resource that can be considered to be economically viable for mining. The tool applies simple engineering cost models to estimate the economic resource and it is a slightly simplified version of USGS RAEF software (Shapiro & Robinson 2019).

A Screener process is implemented to provide insight into the distribution of the metal content in the simulated undiscovered deposits. The process enables calculation of the resource contained in a selected fraction of the largest deposits, or in the selected fraction of the total resource contained by the undiscovered deposits.

9.1. Functioning of the tool

The RAEF process of the Economic filter tool performs a series of simple engineering mine model calculations using as input information on mine and beneficiation methods, mineral deposit type characteristics, simulated ore tonnage and grade estimates, undiscovered deposit depth profiles, and regional cost features. The calculations estimate the fraction of simulated deposits, which have tonnage and grade characteristics that provide a positive return on investment on the basis of the engineering cost model analysis. This analysis produces an estimate of economic recoverable resources in the study area and an assessment of the risk of failure, defined by the fraction of simulated deposits that are not economic. RAEF provides a simple engineering economic analysis for each simulation deposit input and creates a series of supplementary statistical tables and graphics to summarize the results.

The Economic filter tool RAEF process allows the same run options as USGS RAEF software: Batch run using a parameter file, interactive run using GUI input of parameters and empirical mode run.

As the RAEF process is quite versatile and complicated, the user is encouraged to read the RAEF manual, which is provided with MapWizard documentation. Running the MapWizard RAEF process interactively is recommended as a first step. The interactive run produces a parameter file, which can be modified and used in consecutive batch runs. This enables testing the effect of various parameter value changes on the output.

Depending on the Monte Carlo simulation results, running RAEF might take a long time, from less than 20 minutes to over an hour.

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The Screener process in MapWizard reads the file containing the simulated deposits. The process ranks the deposits into decreasing order from largest to smallest based the content (amount) of the selected commodity. It plots the fraction of the commodity contained against the fraction of deposits containing the amount. Depending on user input, the Screener then selects either the given N per cent of the deposits starting from the largest one, or the deposits (starting from the largest one) containing cumulatively N per cent of the total amount of the commodity in all the deposits. It recodes the contained commodities in the remaining (smaller) deposits to zero, aggregates over simulation rounds, and produces the summary statistics.

9.2. Input window

RAEF tab

Tract ID
ID of the permissive tract for which the economic analysis is run. The ID is selected from a drop-down list of tract IDs.

Select simulated deposits file
Location of the csv file (TR<ID>_05_SIM_EF.csv) produced by the Monte Carlo simulation tool and containing the simulated undiscovered deposits.

Run type
Select whether to run RAEF in batch mode, interactive mode or empirical mode. Each mode has different input parameters.

Batch run subtab

Select batch run parameter file
The file containing the batch run parameters for the RAEF process. A sample file is provided with the MapWizard test data, but it is advisable to install RAEF and run it interactively to produce a parameter file for the deposit type required.

Save output in separate folder?
If “Yes”, the output of the RAEF run is saved in a separate folder.

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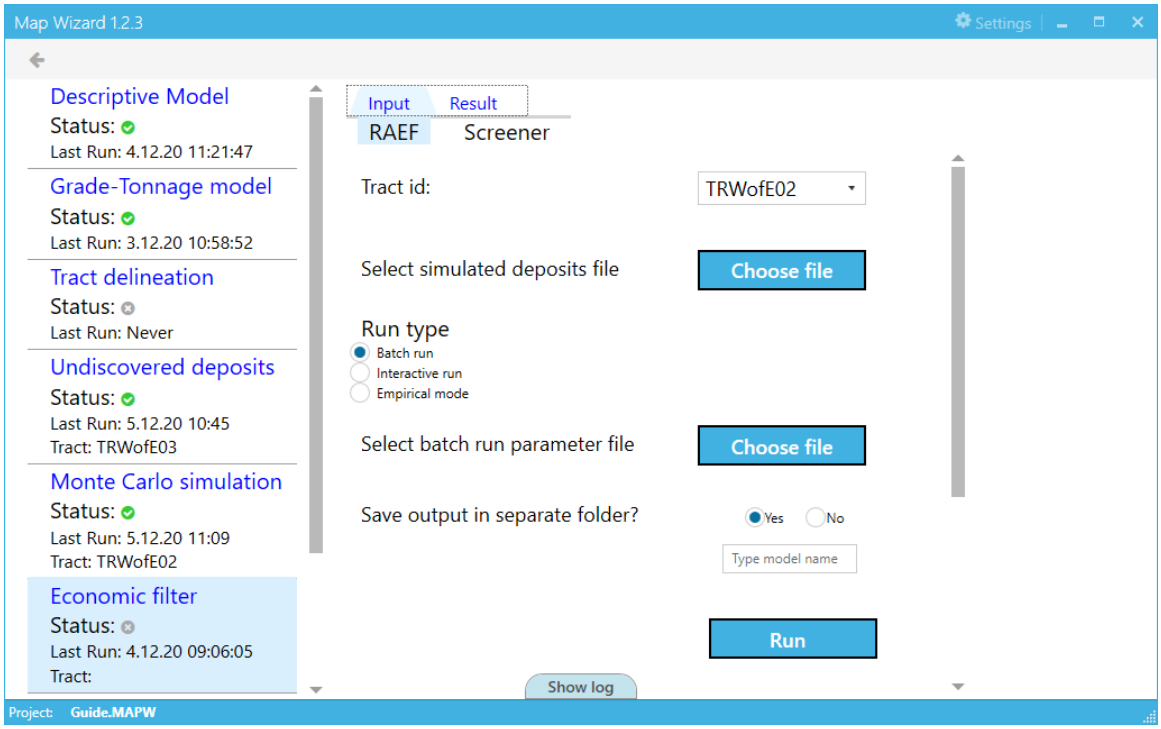

Interactive run subtab

Run name

Name of the interactive run

Tract area (km²)

Area of the permissive tract

Number of depth intervals of undiscovered deposits

Select one to four depth intervals to describe the distribution of undiscovered deposits by depth.

Minimum and maximum depth of each interval and fraction of deposits within the interval

Min1

Minimum depth of interval 1

Max1

Maximum depth of interval 1

Fract1

Fraction of undiscovered deposits that exists within the interval between Min1 and Max1

If more than one depth interval was selected, fill the corresponding Min, Max and Fract fields.

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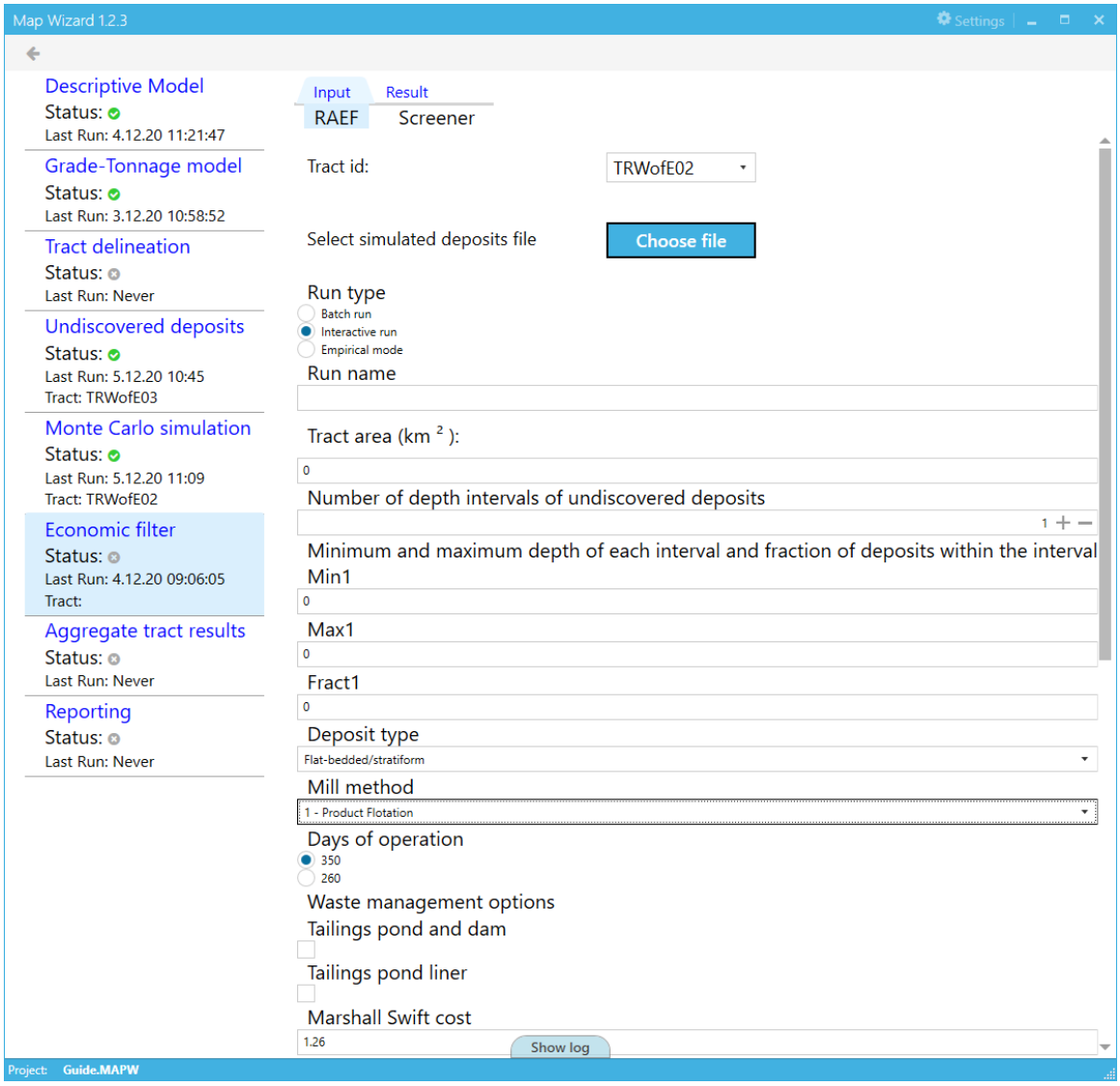

Deposit type

Select the suitable deposit type from the drop-down list

Mill method

Select the mill method from the drop-down list

Days of operation

Select between 350 and 260

Waste management options

Tailings pond and dam

Select if tailings pond and dam costs should be included in the analysis

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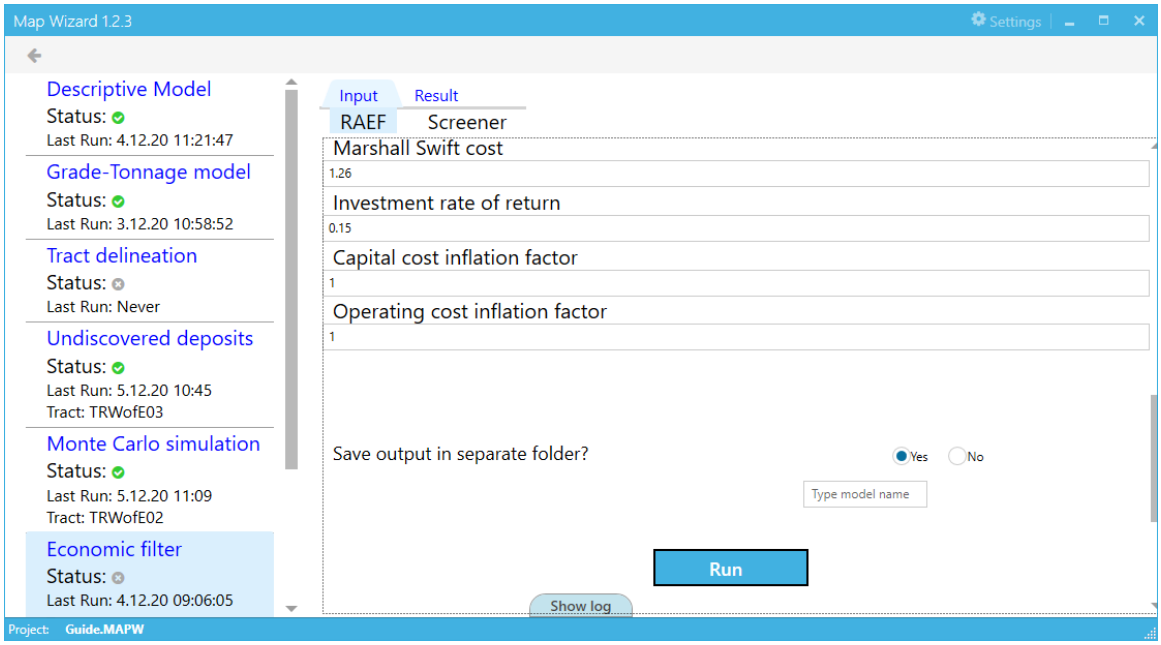
Tailings pond liner
Select if tailings pond liner costs should be included in the analysis

Marshall Swift cost
The default value (1.26) is given here. It can be changed by typing in a new figure.



Investment rate of return
The default value (0.15) is given here. It can be changed by typing in a new figure.

Capital cost inflation factor
The default value (1) is given here. It can be changed by typing in a new figure.

Operating cost inflation factor
The default value (1) is given here. It can be changed by typing in a new figure.

Save output in separate folder?
If "Yes", the output of the RAEF run is saved in a given folder. This makes it possible to save and compare the results of several runs.

Empirical mode subtab

Select grade-tonnage data file
Location of the data file containing the ore tonnage and metal grade data. This is the input file for the Grade-Tonnage model tool that is described in Chapter 5.

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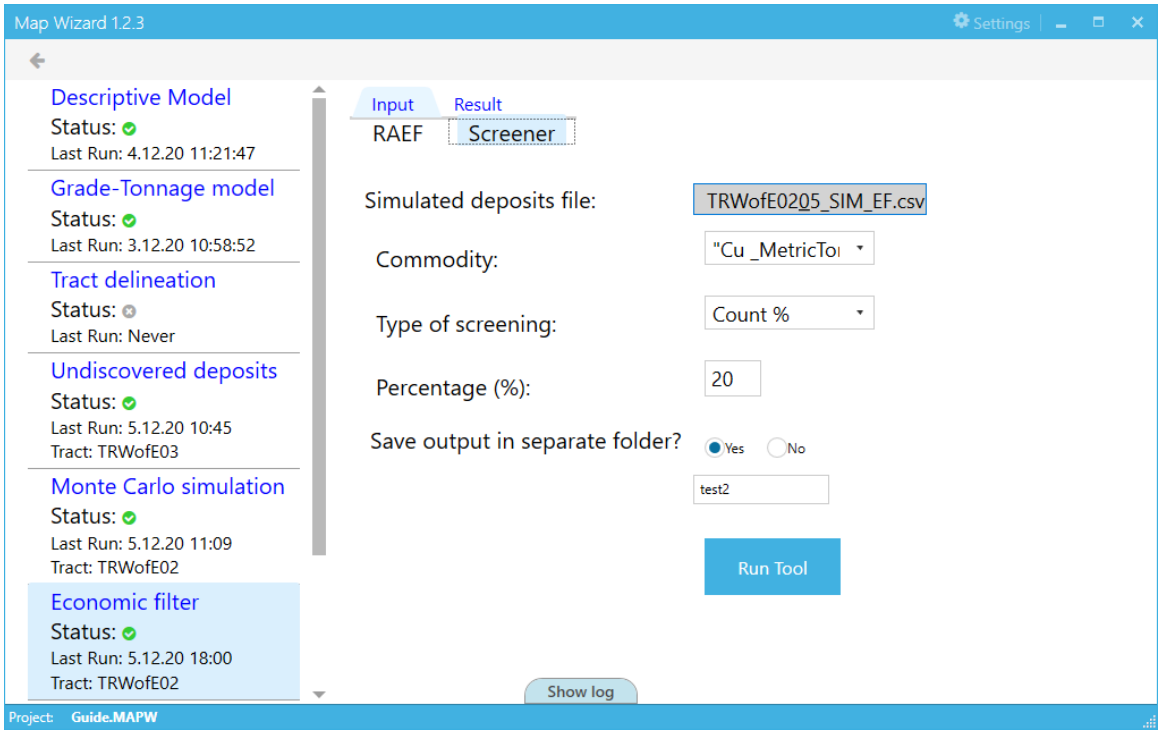
Run name
Name of the empirical mode run

Save output in separate folder?
If "Yes", the output of the RAEF run is saved in a given folder.

Screener tab

Simulated deposits file
The csv file (TR<ID>_05_SIM_EF.csv) produced by the Monte Carlo simulation tool and containing the simulated undiscovered deposits.



Commodity
The commodity on which the calculations will be based. The drop box shows the commodities present in the simulated deposits file.

Type of screening
The cumulative resource in the largest deposits can be calculated based on either the N percent of largest deposits ranked by the contained amount of the commodity selected above (count %), or the Nth percentile of the cumulative amount of the commodity contained in the largest deposits (metal %).

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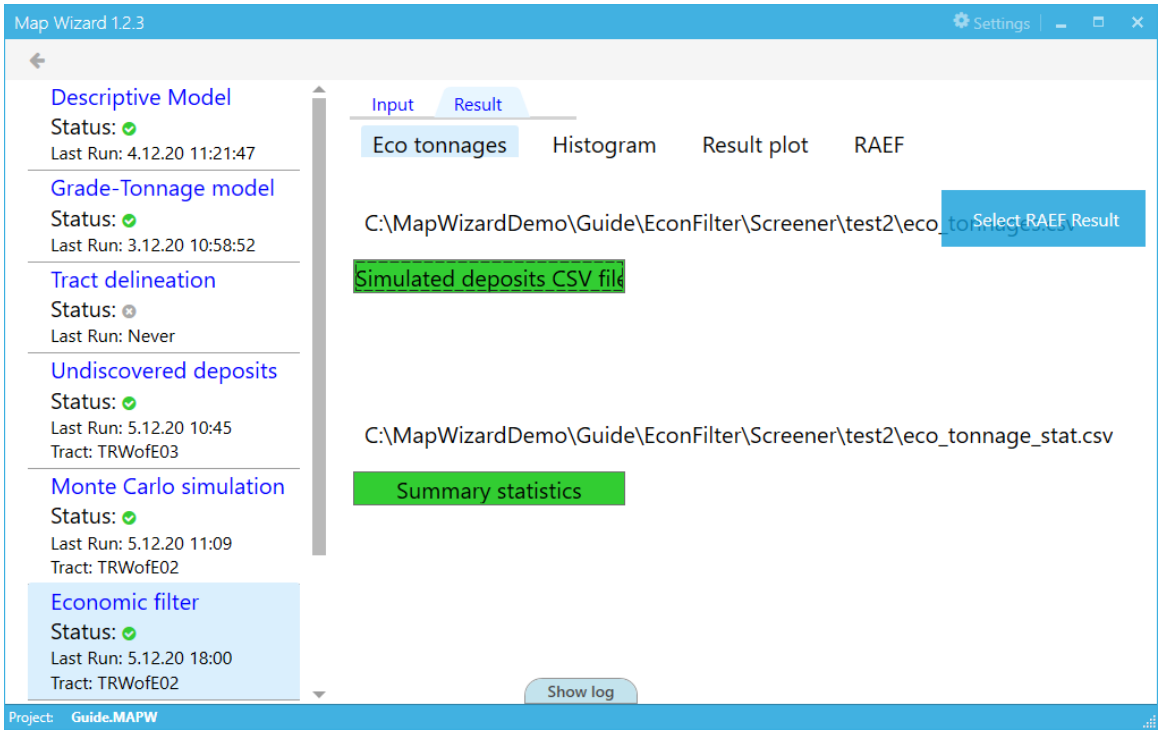
Percentage (%)
The value to use as the threshold in per cent units (0-100).

Save output in separate folder?
If "Yes", the output of the Screener run is saved in the given folder

9.3. Result window

Eco tonnages tab

This tab contains results of the Screener process.



Simulated deposits CSV file
Open the simulated deposits file using the program associated with csv files by the operating system. This file is otherwise identical to the file of simulated undiscovered deposits produced by the Monte Carlo simulation tool (TR<ID>_05_SIM_EF.csv), but the metal contents of deposits that are smaller than the selected threshold value have been recoded to zero.

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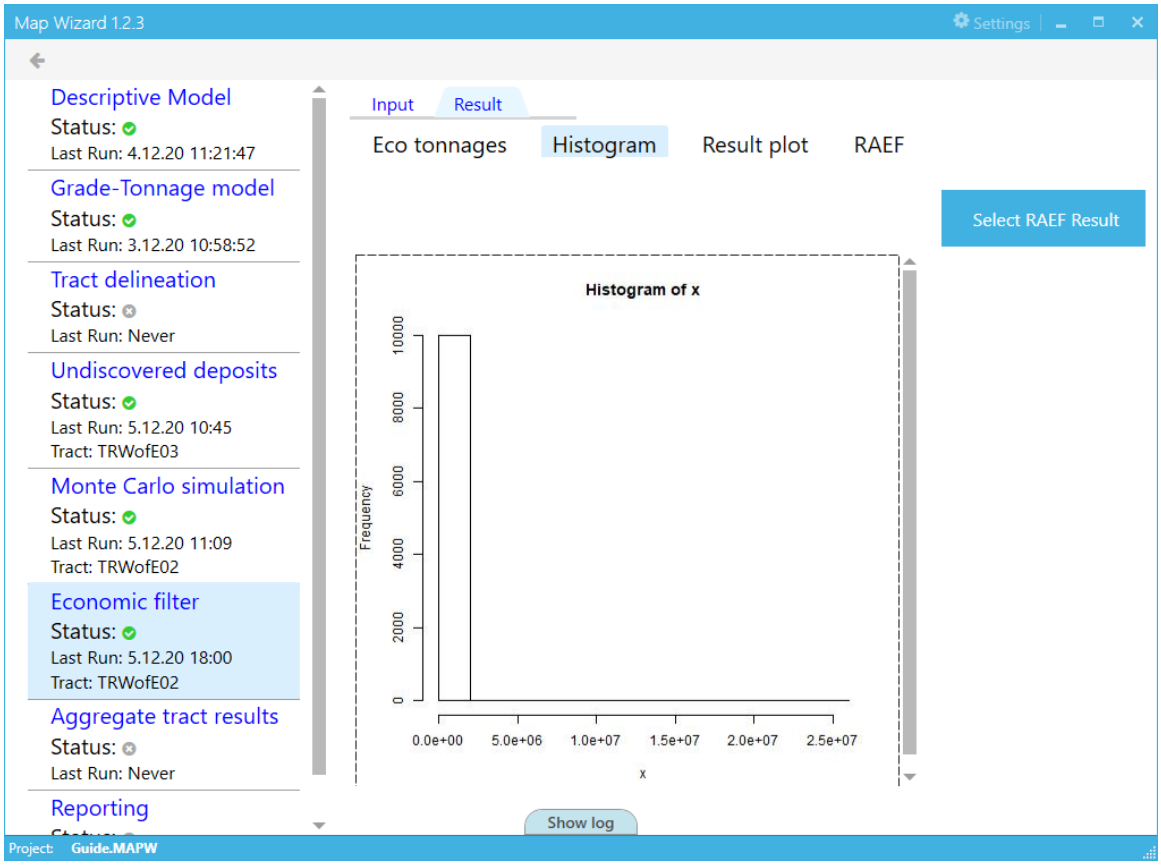
Summary statistics

Open the summary statistics csv file. This file contains summary statistics calculated using the screened file of simulated deposits. In other words, summary statistics when all simulated deposits smaller than the selected threshold criterion are considered to contain zero resources.

Histogram tab

This tab contains results of the Screener process. The tab displays a frequency distribution of the values of the selected commodity in the screened simulated deposits.



Result plot tab

This tab contains results of the Screener process. The tab displays a plot of the cumulative fraction of the commodity contained in the simulated deposits against the cumulative fraction of simulated deposits.

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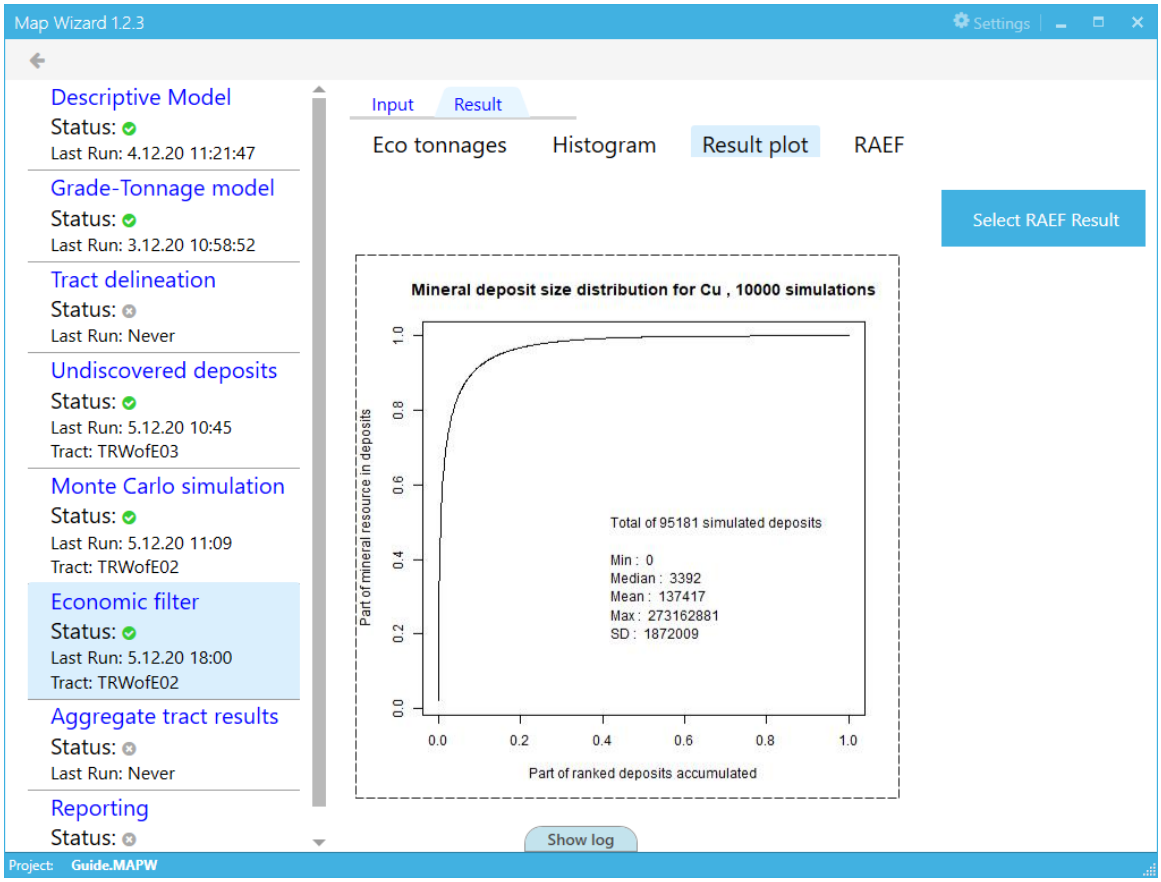

RAEF tab

This tab contains results of the RAEF process.

Show results in file system
Open the folder containing the output of the RAEF run.

9.4. Output

Output of the Screener process is stored in folder <ProjectRoot>\EconFilter\Screener, or if the user has selected to save the results in a separate folder, in <ProjectRoot>\EconFilter\Screener\<GivenName> where <GivenName> is the folder name given by the user.

The following output is produced by the Screener process:

- economic_filter_input_params.json

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- Input parameters used in running the tool

- eco_tonnages.csv
    - A screened csv file of the ore and metal contents of each simulated deposit, in which the contents of deposits that are smaller than the selected threshold value have been recoded to zero
- eco_tonnage_stat.csv
    - A csv file containing summary statistics calculated using the screened file of simulated deposits
- result_plot.jpeg
    - A jpeg file containing a plot of the cumulative fraction of commodity contained against the cumulative fraction of deposits
- result_plot.tiff
    - A high-resolution tiff file containing the same plot as result_plot.jpeg
- result_plot.eps
    - An encapsulated postscript file containing the same plot as result_plot.jpeg
- result_plot.pdf
    - A pdf file containing the same plot as result_plot.jpeg.
- eco_ton_histogram.jpeg
    - A jpeg file containing a plot of the frequency distribution of the values of the selected commodity in the screened simulated deposits
- eco_ton_histogram.tiff
    - A high-resolution tiff file containing the same plot as eco_ton_histogram.jpeg
- eco_ton_histogram.eps
    - An encapsulated postscript file containing the same plot as eco_ton_histogram.jpeg
- eco_ton_histogram.pdf
    - A pdf file containing the same plot as eco_ton_histogram.jpeg

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Output of the RAEF process is stored in folder <ProjectRoot>\EconFilter\RAEF\TR<ID>, or in <ProjectRoot>\EconFilter\RAEF\TR<ID><GivenName>, if the user has selected to save the results in a separate folder.

The following output is produced by the RAEF process:

- economic_filter_input_params.json
    - Input parameters used in running the tool
- EF_01_Parameters_<RunName>.csv
    - Input parameters used in the RAEF run. This file can be used as the input parameter file in a batch run.
    - <RunName> is the name for the RAEF run given by the user
- EF_02_Output_<RunName>.csv
    - Results of the economic filter run showing the RAEF computation steps and results for each simulated deposit
- EF_03_Aggregated_Totals_<RunName>.csv
    - Results aggregated by the simulation run index: cumulative ore tonnage of the deposits, the tonnage of the in-ground contained resources, the tonnage of the recovered resources, and the NPV estimates
- EF_04_Contained_Stats_<RunName>.csv
    - Summary statistics for in-ground contained resources and the recovered resources
- EF_05_Depth_Stats_<RunName>.csv
    - Estimates of mean contained and recovered resources by commodity for the user-defined depth intervals
- EF_06_10Depth_Stats_<RunName>.csv
    - Mean resources for 10 equal depth intervals defined by the depth range specified for the assessment
- <RunName>_CUEQ_MetricTons.jpg
    - A jpeg file containing a copper equivalent (CuEQ%) grade/tonnage plot showing cut-off grade versus deposit tonnage as a function of depth to top of the deposit in meters
- <RunName>_CUEQ_MetricTons.tiff
    - A high resolution tiff file containing the same plot as <RunName>_CUEQ_MetricTons.jpg

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- <RunName>_CUEQ_MetricTons1.eps
    - An encapsulated postscript file containing the same plot as <RunName>_CUEQ_MetricTons.jpg
- <RunName>_OV_MetricTons.jpg
    - A jpeg file containing an ore value/tonnage plot showing cut-off ore value versus deposit tonnage as a function of depth to top of the deposit in meters
- <RunName>_OV_MetricTons.tiff
    - A high resolution tiff file containing the same plot as <RunName>_OV_MetricTons.jpg
- <RunName>_OV_MetricTons.eps
    - An encapsulated postscript file containing the same plot as <RunName>_OV_MetricTons.jpg
- The following intermediate result output is not documented in the RAEF manual
    - EF_08_10Depth_MineTypes.csv
    - <RunName>_Depth10Agg6.csv
    - <RunName>_Depth10MMFF.csv
    - <RunName>_DepthCat10_Agg_Totals8.csv
    - <RunName>_NewBEOut10.csv
    - <RunName>_NewBEOut10WO0.csv

9.5. References

Shapiro J.L. & Robinson G.R., Jr. 2019. Resource Assessment Economic Filter (RAEF)—A graphical user interface supporting implementation of simple engineering mine cost analyses of quantitative mineral resource assessment simulations. U.S. Geological Survey Techniques and Methods, book 7, chap. C23, 18 p., https://doi.org/10.3133/tm7c23.

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10. Aggregate tract results tool

The aggregate results tool combines estimates of the number of undiscovered deposits for a group of permissive tracts and produces an aggregated estimate, which can be used as input to the Undiscovered deposits tool to estimate the probability mass function for the number of deposit in all the tracts in the group. The tool is based on the R code of Schuenemeyer et al. (2011), which is also used in the USGS ATAGUI software (Shapiro and Robinson 2019).

10.1. Functioning of the tool

The tool can be run either in interactive mode or in batch mode.

The batch mode requires as input the number-of-deposits probability distribution csv file of each tract to be aggregated or a combination of these files. Another required input is a correlation matrix of user-defined dependencies between the tracts as a csv file. The batch mode has to be used when there are many tracts to be aggregated (more than ten).

The interactive mode allows the user to select the tracts to be aggregated from a drop-down list. It automatically reads the number-of-deposits probability distribution files of the selected tracts and constructs the correlation matrix between the tracts on the screen. The interactive mode is convenient to use with a small number of tracts (less than ten).

The tool estimates a probability distribution for the number of deposits for the aggregated tracts. It reports the results for three scenarios: assuming total independence between the tracts, assuming total dependence between the tracts, and using the user-defined matrix of correlations between the tracts.

10.2. Input window

Use preset parameters subtab (batch mode)

Name of the tract combination

Give a name to the combination of tracts for which the number of deposits estimates are to be aggregated.

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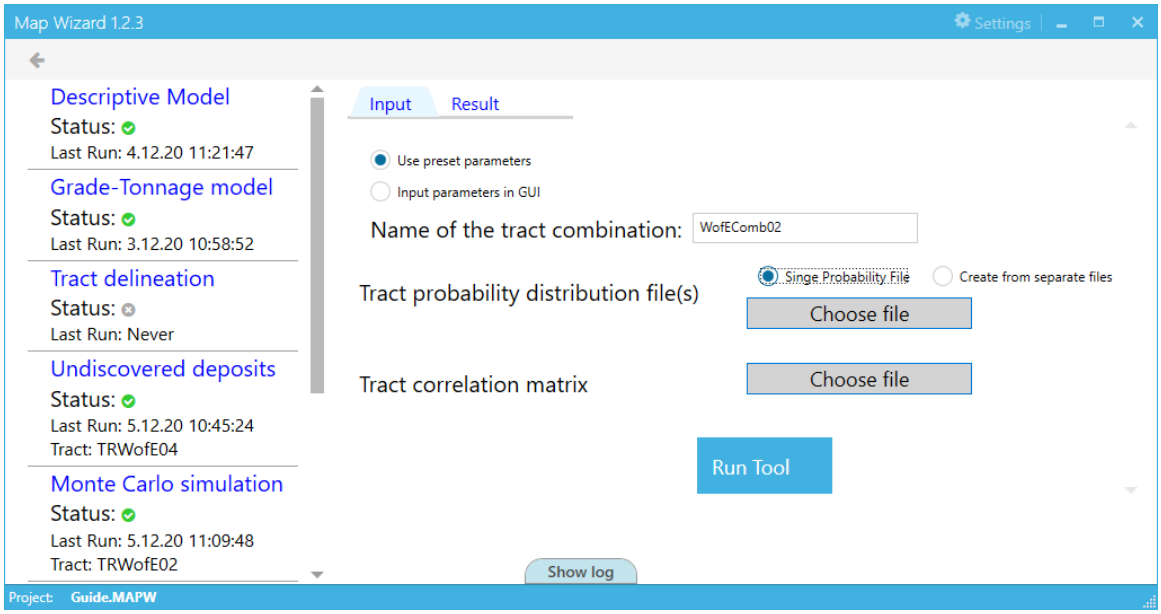
Single probability file / Create from separate files

Select whether to input one probability distribution file containing the data for all tracts to be aggregated or separate probability distribution files for each tract.



Tract probability distribution file(s)

Location of the csv file containing a list of number of deposits estimates and corresponding probabilities for several permissive tracts, or locations of several files, each containing the information for one permissive tract. If several files are given, the tool will combine these into one file. An example of a probability distribution file is given below. Note that the order of files must be the same as in the tract correlation matrix.

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TractID	NDeposits	RelProbs
T1	0	0.010286
T1	1	0.038395
T1	2	0.078281
T1	3	0.115398
T1	4	0.137535
T1	5	0.140622
T1	6	0.127897
T1	7	0.106008
T1	8	0.081451
T1	9	0.058751
T1	10	0.040165
T1	11	0.026222
T1	12	0.016446
T1	13	0.009958
T1	14	0.005844
T1	15	0.003335
T1	16	0.001856
T1	17	0.00101
T1	18	0.000539

Tract correlation matrix

Location of the file containing the correlation matrix for the permissive tracts. An example of a correlation matrix file is given below. Note that the order of tracts must be the same as in the probability distribution file(s).

	T1	T2	T3	T4	T5	T6	T7
T1	1						
T2	0.75	1					
T3	0.75	0.75	1				
T4	0.75	0.75	0.75	1			
T5	0.75	0.75	0.75	0.75	1		
T6	0.75	0.75	0.75	0.75	0.75	1	
T7	0.75	0.75	0.75	0.75	0.75	0.75	1

Run Tool

The tool uses the input files to estimate the number of undiscovered deposits in all the tracts in the combination and outputs the results assuming no dependence, user specified correlations and total dependence between the tracts.

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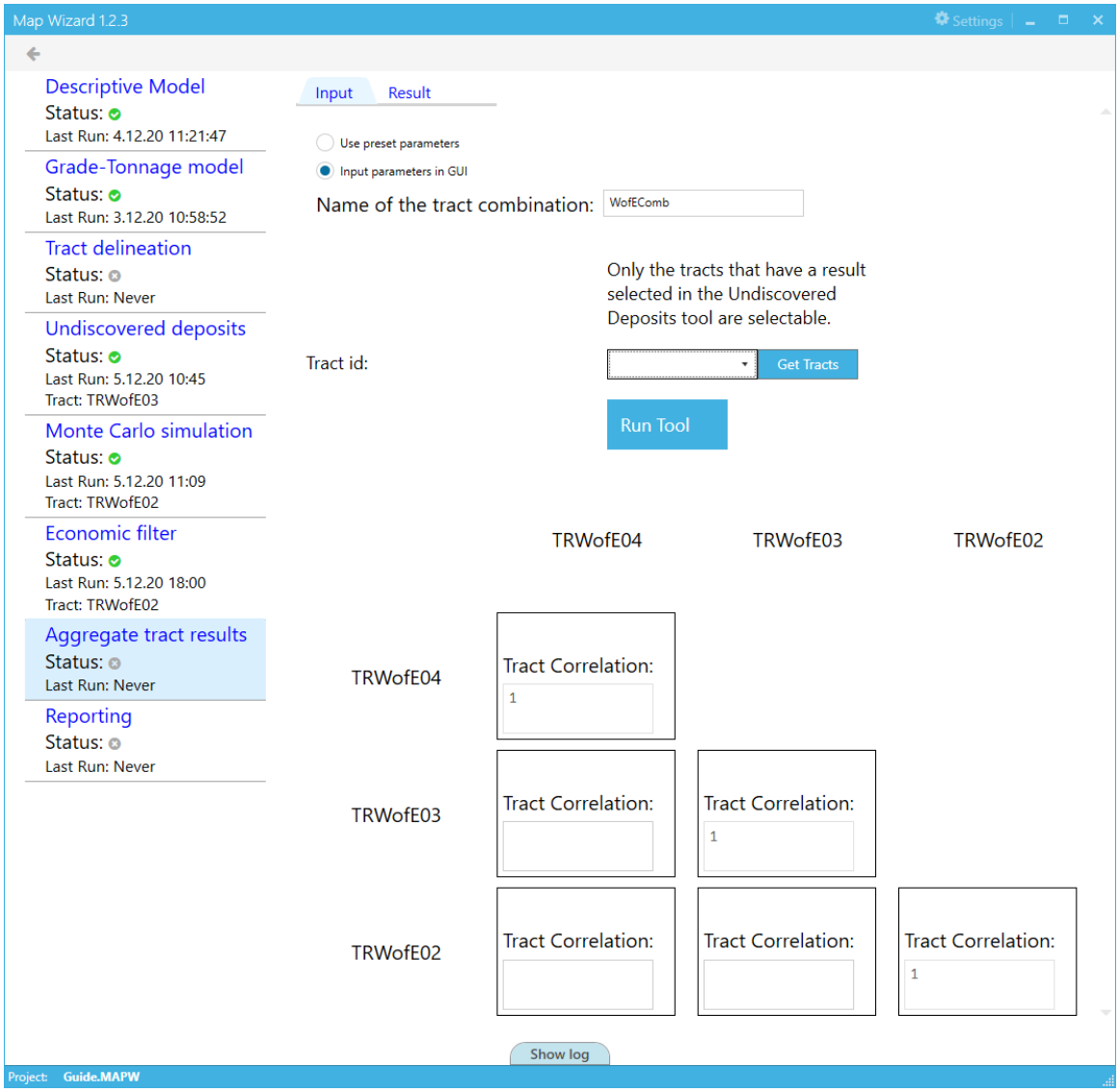
Input parameters in GUI subtab

Name of the tract combination

Give a name to the combination of tracts for which the number of deposits estimates are to be aggregated.

Tract ID

Select the tracts to include in the combination using the drop-down list. Only tracts for which an undiscovered deposits estimate result is selected in Undiscovered deposits tool can be selected. Clicking on the **Get Tracts** button will create a correlation matrix of tracts on the screen. (It might be necessary to click on the button twice.)



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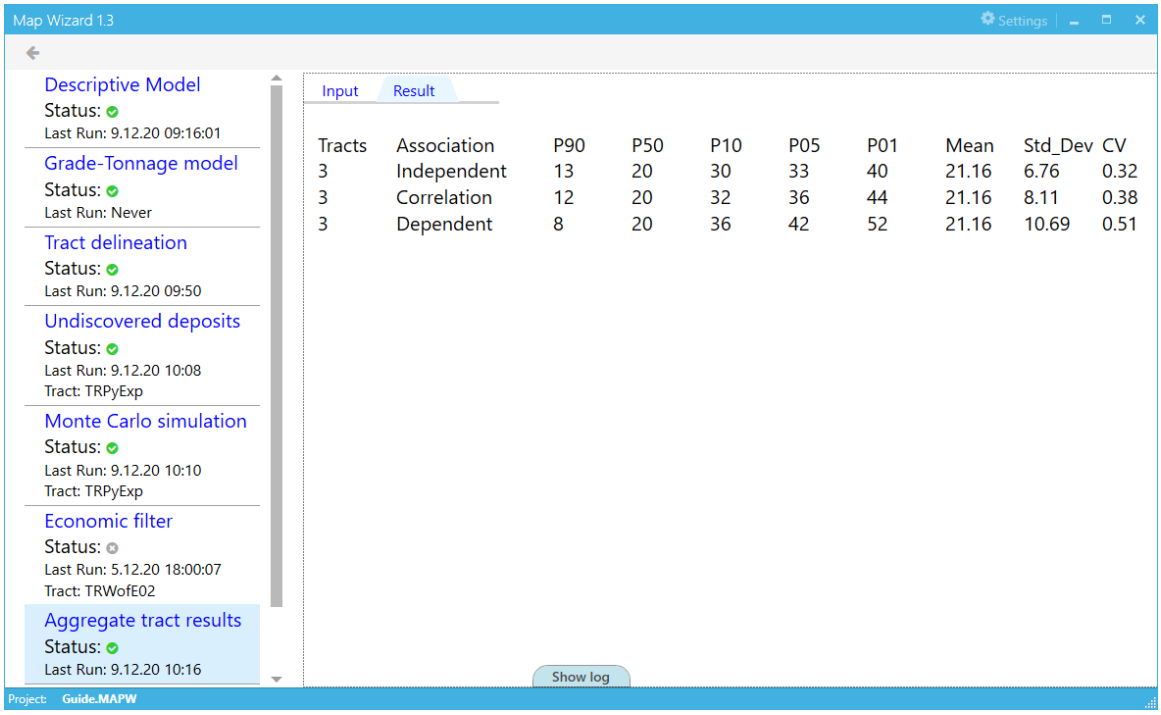
The user can type the correlations between the tracts in the empty cells of the matrix, and then click on the **Run Tool** button. The tool reads the number-of-deposits probability distribution files of each tract in the combination from their folders under <ProjectRoot>\TractDelineation\Tracts and combines the files into one. It uses this combined file together with the correlation matrix to estimate the number of undiscovered deposits in all the tracts in the combination. It outputs the results assuming no dependence, user specified correlations and total dependence between the tracts.

10.3. Result window

The Result window contains a table listing the aggregated estimates of the number of undiscovered deposits for three cases: assuming total independence between the tracts, assuming user-defined correlations between the tracts, and assuming total dependence between the tracts.



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10.4. Output

The tool creates a folder for the tract combination in Tract delineation tool folder structure: <ProjectRoot>\TractDelineation\Tracts\AGG<CombID>. Due to this folder, the tract combination can be identified by Undiscovered deposits tool, Monte Carlo simulation tool, Economic filter tool and Reporting tool.

Output of the tool is stored in folder <ProjectRoot>\AggResults\AGG<CombID>, where <CombID> is the user-defined identifier for the tract combination.

The following output is produced by the tool:

- AggSummary.txt
    - A text file containing a summary of the aggregation run
- AggEstSummary.csv
    - A csv file containing a table of the aggregation results
- AggCorrelation.csv
    - A csv file containing the aggregation results in the case of user-defined correlation between the tracts
- AggDependent.csv
    - A csv file containing the aggregation results in the case of total dependence between the tracts
- AggIndependent.csv
    - A csv file containing the aggregation results in the case of total independence between the tracts
- TractProbDists.csv
    - A csv file containing the input probability distributions for all tracts
- TractCorrelations.csv
    - A csv files containing the correlation matrix for the tracts

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10.5. References

Schuenemeyer J.H., Zientek M.L & Box S.E. 2011. Global Mineral Resource Assessment—Aggregation of estimated numbers of undiscovered deposits—an R-script with an example from the Chu Sarysu Basin, Kazakhtan. U.S. Geological Survey Scientific Investigations Report 2010-5090-B.

Shapiro, J.L., and Robinson, G.R, Jr., 2019. User's guide for Assessment Tract Aggregation GUI (ATA GUI)—A graphical user interface for the AggtEx.fn R script. U.S. Geological Survey Techniques and Methods, book 7, chap. C21, 9 p., https://doi.org/10.3133/tm7c21.

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11. Reporting tool

The Reporting tool uses output from several other MapWizard tools, as well as interactive input and user-defined files containing additional information. The tool produces a standard format report of the assessment results concerning a specific permissive tract or an assessment report concerning a group of tracts.

11.1. Functioning of the tool

The Reporting tool reads three types of input: input provided by the user interactively into text fields, input in files provided by the user and input in files produced as output by other MapWizard tools.

For a tract report, the tool lists all tract folders in <ProjectRoot>\TractDelineation\Tracts and lets the user select the target tract. The tool collects the relevant output of other tools for the selected tract and combines it with other information provided by the user. The tool produces the Tract report in Microsoft Word format (.docx).

For an assessment report, the tool lists all tract combination folders in <ProjectRoot>\TractDelineation\Tracts and lets the user select the target combination. The tool collects the relevant output of other tools for the selected tract combination and combines it with other information provided by the user. The tool produces the Assessment report in Microsoft Word format (docx).

11.2. Input window

Tract Report tab

Tracts to include
Select the tract for which the report will be generated from a drop-down list.

Author list
Input the names of authors for this tract report.

Country
Input the country in which the tract is located.

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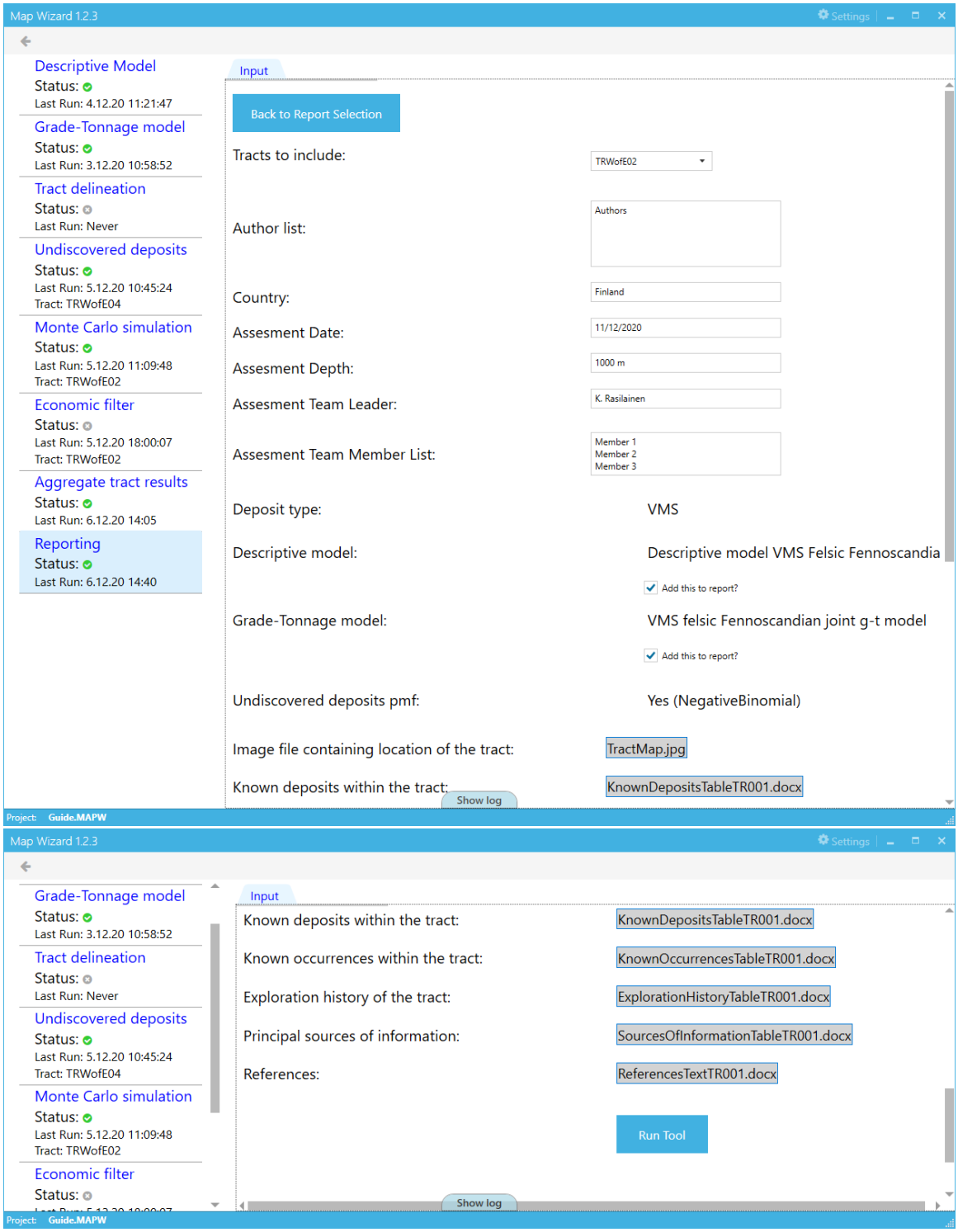

Assessment date

Input assessment date/tract report date.

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Assessment depth
Input the depth limit of the assessment.

Assessment team leader
Input the name of the assessment team leader.

Assessment team member list
Input names of other assessment team members.

Deposit type
The deposit type is automatically taken from the assessment project file.

Descriptive model
If a descriptive model has been selected in the Descriptive model tool, it is associated with the project and listed here. The user can select whether to add the model as an appendix to the tract report.

Grade-Tonnage model
If a Grade-Tonnage model has been selected in the Grade-Tonnage model tool, it is associated with the project and listed here. The user can select whether to add the model as an appendix to the tract report.

Undiscovered deposits pmf
The selected result of the Undiscovered deposits tool is automatically included in the Tract report.

Image file containing location of the tract
Location of an image file showing the location of the tract. Accepted formats are jpeg, tiff and png.

Known deposits within the tract
Information on the known deposits of the relevant type in the tract as a table in a Microsoft Word (.docs) format file.

Known occurrences within the tract
Information on the known occurrences of the relevant type in the tract as a table in a Word file.

Exploration history of the tract
Information on exploration conducted in the tract as a table in a Microsoft Word (.docs) format file.

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Principal sources of information

Principal sources of information used by the assessment team as a table in a Microsoft Word (.docs) format file.

References

List of references as text in a Microsoft Word (.docs) format file.

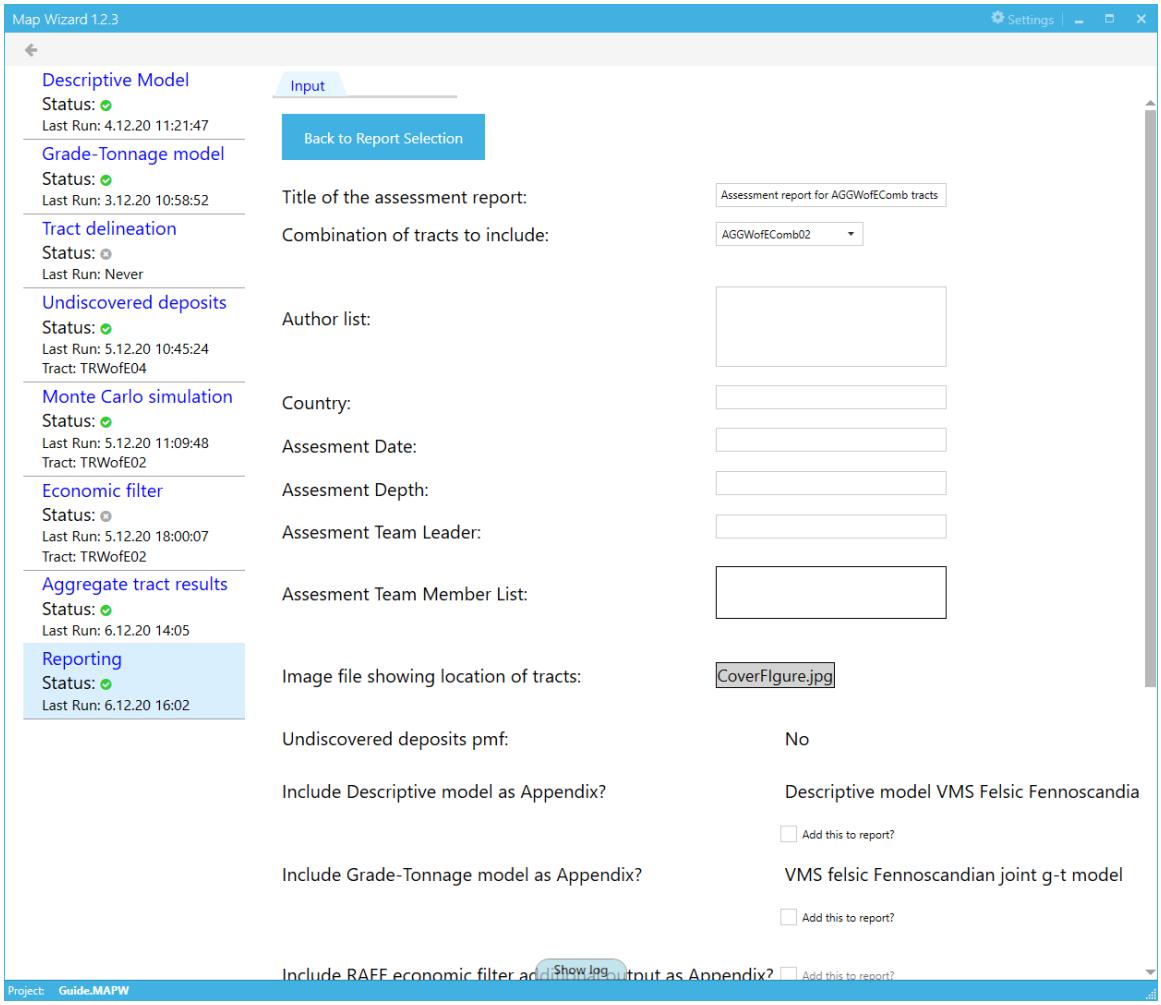
Assessment Report tab

Title of the assessment report

Title of the assessment report for the selected tracts

Combination of tracts to include

Select the tract combination for which the report will be generated from a drop-down list.



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Author list
Input the names of authors for this report.

Country
Input the country in which the tracts are located.

Assessment date
Input assessment date/assessment report date.

Assessment depth
Input the depth limit of the assessment.

Assessment team leader
Input the name of the assessment team leader.

Assessment team member list
Input names of other assessment team members.

Image file showing location of tracts
Location of an image file showing the location of the tracts. Accepted formats are jpeg, tiff and png.

Undiscovered deposits pmf
The selected result of the Undiscovered deposits tool is automatically included in the assessment report.

Include descriptive model as Appendix?
The user can select whether to add the descriptive model for the deposit type as an appendix to the assessment report.

Include Grade-Tonnage model as Appendix?
The user can select whether to add the Grade-tonnage model for the deposit type as an appendix to the assessment report.

Include RAEF economic filter additional output as Appendix?
The user can select whether to add the parameter file produced by the RAEF process as an appendix to the assessment report.

Include individual tract reports as Appendix?
The user can select whether to add the tract reports of the individual tracts in the combination as an appendix to the assessment report. The tracts can be selected from a drop-down list showing the tracts in the combination for which a tract report has been produced.

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11.3. Output

The parameter files of the Reporting tool are stored in folder <ProjectRoot>\Reporting

- tract_report_input_params.json
    - Input parameters used in running the tract report process
- assessment_report_input_params.json
    - Input parameters used in running the assessment report process

The reports produced by the Reporting tool are stored in folder <ProjectRoot>\TractReport\TR<ID> or folder <ProjectRoot>\TractReport\AGG<CombID>, depending on whether the report is a tract report or an assessment report, respectively.

- TractReportTR<ID>.docx
    - Tract report in Microsoft Word format (.docx). <ID> is the identification code for the tract given by the user using the Tract delineation tool.
- AssessmentReportAGG<CombID>.docx
    - Assessment report in Microsoft Word format (.docx). <CombID> is the identification code for the tract combination by the user using the Aggregate tract results too.

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12. Troubleshooting

This section lists known problems with MapWizard. In a default installation, the software produces a settings file “settings.json” in C:\ProgramData\MapWizard and log files in C:\ProgramData\MapWizard\Logs. The log files contain information of the functioning of the tools and error messages.

12.1. Tract delineation tool

The tool is very sensitive concerning the input evidence rasters. All rasters must have the same coordinate system. All rasters must have exactly the same number of rows and columns, and the raster cells must be exactly identically aligned.

At some stages of the delineation and classification processes, it is possible to open intermediate rasters or polygons as pdf files by double clicking on them in the tool window. However, if any of these files remains open in an external viewer when the the next step of the delineaton or classification process in executed, that might cause an error message and terminate the execution.

12.2. Aggregate tract results tool

When the tracts to be aggregated have been selected from the drop-down menu, the Get Tracts button has to be clicked twice before the tool dras te correlation matrix on the screen. The first click oly closes the drop-down menu.

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