

GGU-CONTAM-FE manual

Contaminant transport analysis (FEM)

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Theorie. Und Praxis.

Geotechnische Softwarelösungen können so einfach sein. Denn Theorie und Praxis lassen sich mit **GGU-Software** und den neuen Angeboten der **civilserve Academy** prima kombinieren: Knackige theoretische Aufgaben lösen und als Sahnehäubchen Ihr

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1 GGU-CONTAM-FE: Preface

The **GGU-CONTAM-FE** program allows modelling of contaminant propagation in horizontal-plane, vertical-plane and axis-symmetrical groundwater systems using the finite-element method. A record containing the basic steady-state data must be previously generated using the **GGU-2D-SSFLOW** program.

The **GGU-PLGW** program is available for evaluation and visualisation of modelling results. It enables impressive, time-dependent animation or presentation of concentrations along sections through the system.

It is not the task of this manual to give an introduction to contaminant propagation analysis using finite-element methods. For details, please refer to the literature.

The program includes convenient data input. The system is permanently displayed on the screen. Every change to the data is displayed on the screen, so that optimum control of the input data is guaranteed.

There are "?" and "Info" buttons in the dialog boxes for many technical and program-specific questions. Click on the "?" buttons or "Info" buttons to obtain the necessary information.

The graphic output supports the true type fonts provided by WINDOWS, so that an excellent layout is guaranteed. Colour output and numerous graphic formats (BMP, TIF, JPG etc.) are supported. PDF and DXF files can also be imported via the integrated **Mini-CAD** system (see "**Mini-CAD**" manual).

The program has been extensively tested. No errors have been found. Nevertheless, liability for completeness and correctness of the program and the manual, and for any damage resulting from incompleteness or incorrectness, cannot be accepted.

2 GGU-CONTAM-FE: Licence protection

To protect the GGU software from unauthorised access, each GGU program is equipped with the **CodeMeter software protection system** from WIBU-Systems. Each GGU program is bound to a so-called **CmContainer** via a licence with the corresponding product code.

To be able to use the GGU licences in a CmContainer, a runtime environment, the **CodeMeter Runtime Kit**, must be installed on your computer via driver software. You can obtain the current version from [Software for Users - Wibu-Systems](#) (CodeMeter User Runtime for Windows).

You can work with the following CmContainer types on your PC with the CodeMeter Runtime Kit installed (= **CodeMeter licence server**):

- **CmStick**
The licence for your GGU program is stored in a USB dongle.
- **CmActLicense** (soft licence, not for virtual PC/servers)
The licence for your GGU program is stored in a licence file that is linked to the hardware of a computer.
- **CmCloudContainer**
The licence is located on a CmCloud server of WIBU-Systems and is mirrored to your CodeMeter licence server. The advantages of this type of licence binding are described on the following website: [Licence binding | GGU Software](#).

The GGU programs check at start-up and during runtime whether a corresponding license is available in a CmContainer.

3 GGU-CONTAM-FE: Language selection

The GGU programs can be used in German and English. The program always starts with the language in which it was terminated.

The language preferences can be changed at any time in the "**Info**" menu, using the menu item "**Spracheinstellung**" (for German) or "**Language preferences**" (for English).

4 GGU-CONTAM-FE: Starting the program

After starting the program, you will see two menus at the top of the window:

- File
- ?

After clicking on the "**File**" menu, a system processed with the **GGU-2D-SSFLOW** program can be loaded by means of the "**Load steady-state GW data**" menu item.

The processed system record is saved in **GGU-2D-SSFLOW** using the ".da1" extension, in order to make it available for **GGU-CONTAM-FE**. The program function to be activated for this purpose can be found in **GGU-2D-SSFLOW** in the "**System/Analyse**" menu item.

Then, the menu bar will show seven menus:

- File
- Editor
- Check
- Modelling
- Graphics preferences
- Page size + margins
- ?

After clicking one of these menus, the so-called menu items roll down, allowing you access to all program functions.

The program works on the principle of ***What you see is what you get***. This means that the screen presentation represents, overall, what you will see on your printer. In the last consequence, this would mean that the screen presentation would have to be refreshed after every alteration you make. For reasons of efficiency and as this can take several seconds for complex screen contents, the screen is not refreshed after every alteration.

If you would like to refresh the screen contents, press either **[F2]** or **[Esc]**. The **[Esc]** key also resets the screen display to your current image zoom, which is usually preset to 1.0, which corresponds to an A3 or A4 sheet in most GGU programs (see menu item "**Graphics preferences/Refresh and zoom**").

5 Tips and tricks

5.1 GGU-CONTAM-FE: Keyboard and mouse

You can scroll the screen with the keyboard using the cursor keys and the **[Page up]** and **[Page down]** keys. By clicking and pulling with the mouse, with **[Ctrl]** pressed, you activate the zoom function, i.e. the selected section will fill the screen. Use the mouse wheel to zoom in or out of the screen view or to pan.

In addition, scale and coordinates of the system graphics (drawing area within the plotting margins) can be altered directly using the mouse wheel. The following mouse wheel functions are available

Change system graphics (new values can be checked in "Page size + margins/Manual resize (editor)"):

- Mouse wheel up = move screen image up
- Mouse wheel down = move screen image down
- **[Ctrl]** + mouse wheel up = enlarge screen image (zoom in)
- **[Ctrl]** + mouse wheel down = shrink screen image (zoom out)
- **[Shift]** + mouse wheel up = move screen image right
- **[Shift]** + mouse wheel down = move screen image left
- **[Shift]** + **[Ctrl]** + mouse wheel up = move system graphics right
(change in system coordinates)
- **[Shift]** + **[Ctrl]** + mouse wheel down = move system graphics left
(change in system coordinates)

Change screen coordinates:

- Mouse wheel up = move screen image up
- Mouse wheel down = move screen image down
- **[Alt]** + **[Ctrl]** + mouse wheel up = enlarge screen image (zoom in)
- **[Alt]** + **[Ctrl]** + mouse wheel down = shrink screen image (zoom out)
- **[Alt]** + **[Shift]** + mouse wheel up = move screen image right
- **[Alt]** + **[Shift]** + mouse wheel down = move screen image left

By double-clicking the left mouse button on legends or **Mini-CAD** objects, the editor for the selected object immediately opens, allowing it to be edited.

5.2 GGU-CONTAM-FE: Function keys

Some of the function keys are assigned program functions. The allocations are noted after the corresponding menu items. The individual function key allocations are:

- **[Esc]** refreshes the screen content and resets from a screen section to your current image zoom, which is usually preset to 1.0 (see “
- **[F1]** opens the manual file.
- **[F2]** refreshes the screen without altering the current magnification.
- **[F11]** activates the menu item "**Move objects**", which appears in the GGU programs under various menu titles, e.g. "**Page size + margins**", "**Graphics preferences**" or "**Output preferences**".

In this GGU program, the following function keys are also assigned to program functions:

- **[F5]** opens the menu item "**Modelling/Start**".
- **[F9]** activates the menu item "**Page size + margins/Auto-resize**".

5.3 GGU-CONTAM-FE: "Copy/print area" icon

A dialog box opens when the "**Copy/print area**" icon

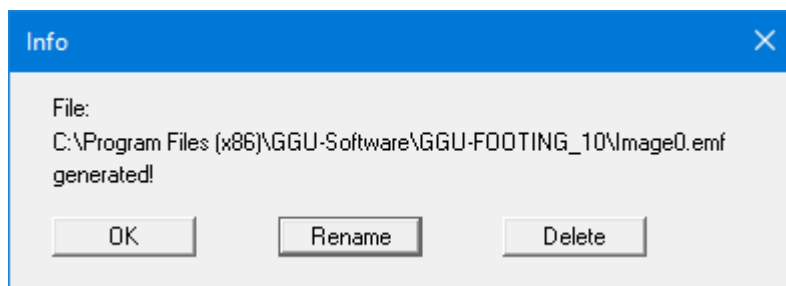


in the menu toolbar is clicked, describing the options available for this function. For example, using this icon it is possible to either copy areas of the screen graphics and paste them into the report, or send them directly to a printer.

In the dialog box, first select where the copied area should be transferred to: "**Clipboard**", "**File**" or "**Printer**". The cursor is displayed as a cross after leaving the dialog box and, keeping the left mouse button pressed, the required area may be enclosed. If the marked area does not suit your requirements, abort the subsequent boxes and restart the function by clicking the icon again.

If "**Clipboard**" was selected, move to the MS Word document (for example) after marking the area and paste the copied graphics using "*Edit/Paste*".

If "**File**" was selected, , the following dialog box appears after defining the area, shown here as an example for the **GGU-FOOTING** program:



The default location of the file is the folder from which the program is started (here: GGU-FOOTING_10) and, if several files are created, the file is given the file name "**Image0.emf**" with sequential numbering. If the

"**Rename**" button in the dialog box is clicked, a file selector box opens, and the copied area can be saved under a different name in a user-defined folder. Saving can be aborted by pressing the "**Delete**" button.

If the "**Printer**" button was pressed in the first dialog box, a dialog box for defining the printer settings opens after marking the area. Following this, a dialog box for defining the image output settings opens. After confirming the settings, the defined area is output to the selected printer.

6 GGU-CONTAM-FE: Program concept

The flow field is required in order to model contaminant propagation (velocities with magnitude and direction). **GGU-CONTAM-FE** acquires this initial condition from a record (e.g. "**plgw.da1**") generated during a previous modelling using the **GGU-2D-SSFLOW** application. It is therefore necessary to load this file first after opening the program. The flow field contained in this file remains constant for subsequent calculations.

Besides the flow field, the **GGU-CONTAM-FE** program requires information on the initial contaminant distribution conditions at time $t = 0$. These so-called initial concentrations can be arbitrarily defined. If you do not define any values, the program will assume an initial concentration of '0' at all nodes.

Apart from the flow field, the "**plgw.da1**" example file also includes the effective pore space n_{eff} , upon which steady-state modelling is based. This **steady-state** soil property (n_{eff}) cannot be altered from within the **GGU-CONTAM-FE** program. If amendment of this value were allowed, the flow field would no longer correlate to the computed potentials and contaminant propagation modelling would produce nonsensical results. However, additional soil properties, which are required for contaminant propagation, must be provided.

Further to these additional soil properties, time-dependent boundary conditions can also be defined with **GGU-CONTAM-FE**. You must define boundary values (concentration or concentration source) as a function of time, by means of polygon courses. These polygon courses can then be assigned system nodes, either individually or in groups. Soil properties (for contaminant propagation) and polygon courses, as well as their allocations to system nodes, can be saved in a separate file (known as boundary data), in order to make them available again for later modelling.

Generally, when modelling contaminant propagation, a flood of result values is generated. Modelling results are saved by the **GGU-CONTAM-FE** program in a file ("***_kon.plw**"). Contaminant propagation data cannot be evaluated using the **GGU-CONTAM-FE** program. The **GGU-PLGW** program is available for evaluation purposes and is described in a separate user-manual.

The **GGU-CONTAM-FE** program is started using conventional WINDOWS operations. The program is equipped with many error queries. Nonsensical input will usually be caught by the program and an error message displayed on the screen. Independently of this you should, for security reasons, intermittently save longer input, if only to save renewed input in the case of a power cut.

7 GGU-CONTAM-FE: Short description

Since I know from personal experience that reading user-manuals is quite a chore, there will now follow a short description of the main program functions. After studying this section, you will be in a position to model contaminant propagation based on steady-state groundwater flow. You can learn about the details of the program in the subsequent chapters.

- In order to be able to use the system entered in your **GGU-2D-SSFLOW** groundwater flow program for contaminant propagation modelling using the **GGU-CONTAM-FE** program, you must create a file in the **GGU-2D-SSFLOW** program with the file extension ".da1". You can create this file by going to "System/Analyse" and activating the check box "Generate record for transient modelling".
- Start the **GGU-CONTAM-FE** program and using the menu item "File/Load steady-state GW data", select the desired record of a flow system.
- Using the "Editor" menu you can define your "Soil properties". A description of the individual constants can be found in the "Info" function field.
- The initial system concentration is specified via the menu item "Editor/Individual initial concentrations". It is possible to set the concentration individually for specific nodes, or for several nodes in section.
- Using the "Editor/Boundary condition polygons" menu item, you specify the temporal changes in concentration as polygon courses. This is initially independent of location. By clicking on the menu item you will see a dialog box within which, by clicking the "New" field and then "Edit polygon course", you can specify the number of polygon points, i.e. the number of temporal changes in your concentrations.
- The selection of the menu item "Editor / Assign polygons individually" enables you to assign a boundary condition polygon to a specific node of your system or a specific section.
- Contaminant propagation modelling is started by selecting "Modelling/Start". Specify the desired end time at which the calculations are to cease. Subsequently, checks are carried out by the program (Peclet and Courant criteria). The Courant criterion determines the maximum permissible time step for your system. Before actual analysis begins, you will see this value in a dialog box. You can edit this value. The Peclet criterion principally concerns the element size; if this criterion is not satisfied, you will generally have no other choice but to analyse with a finer mesh (**GGU-2D-SSFLOW**).
- Use the **GGU-PLGW** program for evaluation and visualisation of the modelling results; it also provides a means of printing an impressive graphic of the results. To do this, load the file generated by **GGU-CONTAM-FE** ("*_kon.plw") into **GGU-PLGW**.

8 Contaminant propagation theory

8.1 GGU-CONTAM-FE: Overview

The primary aim of contaminant propagation modelling is the prognosis of future conditions on the basis of given initial data and, on occasion, pre-specified countermeasures.

Using a numerical analysis approach, even complicated systems can be investigated and assessed. Precise modelling of the natural conditions is difficult, due to the multitude of initial parameters required and the inhomogeneity of aquifers. Before any contaminant analysis, you should therefore ensure that your initial data justify this.

8.2 GGU-CONTAM-FE: Mechanisms relevant to contaminant propagation

Five important mechanisms describe contaminant propagation in groundwater and must be entered as initial data for propagation simulation:

- **Convection**

is the migration of contaminants in the direction, and with the apparent flow velocity, of groundwater flow. This propagation mechanism is normally dominant in a flowing system but is superimposed upon and influenced by others. Mathematically, this mechanism enters the differential equation in the shape of the apparent flow velocities u_x and u_y .

- **Dispersion**

includes the local deviation from the mean flow velocity. One differentiates between dispersion caused by the grain skeleton, which describes, amongst other factors, deviations in the flow course around the grain skeleton, and macro-dispersion, which is the dominant mechanism in wide-area contaminant propagation, e.g. in sand lenses and layering. This mechanism is described by the mathematical values of longitudinal (in flow direction) dispersivity α_L (m) and transverse (perpendicular to flow direction) dispersivity α_T (m).

- **Diffusion**

This type of propagation is determined by the concentration gradient. It is normally only effective in systems with extremely low velocity. In water at 10 °C, the diffusion coefficient D_m is 10^{-9} m/s².

- **Adsorption**

expresses the inhibition of contaminant migration due to adsorption onto the grain skeleton and is described by the sorption constant $sorp$ (-). The sorption constant is the product of grain density and the adsorption coefficient. Contaminant propagation is retarded by adsorption.

- **Decay**

As a result of physical, chemical and biological reworking, contaminants are eliminated from the groundwater. This process is described by the decay constant λ (l/s).

A mass balance equation and a space- and time-dependent, analysable differenzial equation results from these values:

Mass balance:

Increase in dissolved contaminant mass =

net input by convection

- net input by diffusion and dispersion
- input from contaminant sources
- extraction from wells
- loss through decay reactions
- adsorption onto the grain matrix

8.3 Contaminant propagation modelling with FEM models

8.3.1 GGU-CONTAM-FE: The Peclet criterion

As you know, FEM allows almost unlimited subdivision of the system into triangular elements. Concentrations are assumed to be linearly distributed across each element. Where the contaminant front is discrete, such an approach is no longer capable of precisely modelling contaminant distribution. The contaminant fronts then become **smeared**. This effect is known as numerical dispersion. It occurs predominantly when the proportion of convection is large compared to other mechanisms (dispersion and diffusion). This can be avoided by selecting a denser triangular mesh.

The "**Peclet criterion**" serves to check whether a system displays a tendency towards numerical dispersion and thus to compute the necessary mesh density. This criterion is checked by the program after modelling has begun. If it is exceeded, mesh refinement will be required. You will then need to reprocess the system using **GGU-2D-SSFLOW**. Under certain conditions, however, a very dense mesh is required. If necessary, you can obtain a solution using the RANDOM-WALK method, as this procedure does not recognise the numerical dispersion effect (**GGU-CONTAM-RW** program).

8.3.2 GGU-CONTAM-FE: The Courant criterion

The precision of all numerical procedures is influenced by the time step Δt . Precise results can be achieved with small time steps, but analysis time increases correspondingly. The optimum time step size can be derived from the "**Courant criterion**".

After starting modelling, the program examines the Courant criterion and suggests the determined time step.

9 File menu

9.1 GGU-CONTAM-FE: "Load" menu item

Import the data from a steady-state groundwater model previously analysed using the **GGU-2D-SSFLOW** program using this menu item to form the basis for your contaminant transport modelling. This file has the default name of **".da1"**. In order to enable generation of this record by the **GGU-2D-SSFLOW** program, you must activate the **"Generate record for transient modelling"** check box in the **"System/Analyse"** menu item.

9.2 GGU-CONTAM-FE: "Save as" menu item

For parameter studies - e.g. when adopting various polygon courses - it is advisable to generate individual **".da1"** initial records, because you cannot influence the naming of your transient analysis result files. The program stores the base data automatically in a **".dat"** file under the name of the initial file and extended by a **"_t"**. The results required for subsequent evaluation in **GGU-PLGW** are automatically saved in a **"_t.plw"** file. It is therefore possible that different transient systems are mistakenly exported to the same result files if the same initial record is used.

Using this menu item the data are saved in an existing or a new file with the file extension **".da1"**. If you do not enter an extension when saving **".da1"** will be used automatically.

9.3 GGU-CONTAM-FE: "System info" menu item

Upon opening this menu item you will be presented with information on the currently loaded system, the number of triangular elements and on the nodes.

9.4 GGU-CONTAM-FE: "Load boundary values" menu item

Using this menu item you can reload a file containing boundary values which was previously defined and saved with the **"File/Save boundary values"** menu item, in order to further process this or to use it as the basis for contaminant transport modelling. The file contains the soil properties and the polygon courses, as well as the allocations of the polygon courses to the system nodes.

9.5 GGU-CONTAM-FE: "Save boundary values" menu item

After selecting this function, you can save the defined boundary values in order to have the data available again at a later date. The file with the suffix **".kon_gw"** contains the soil properties and the polygon courses, as well as the allocations of the polygon courses to the system nodes.

9.6 GGU-CONTAM-FE: "Output preferences" menu item

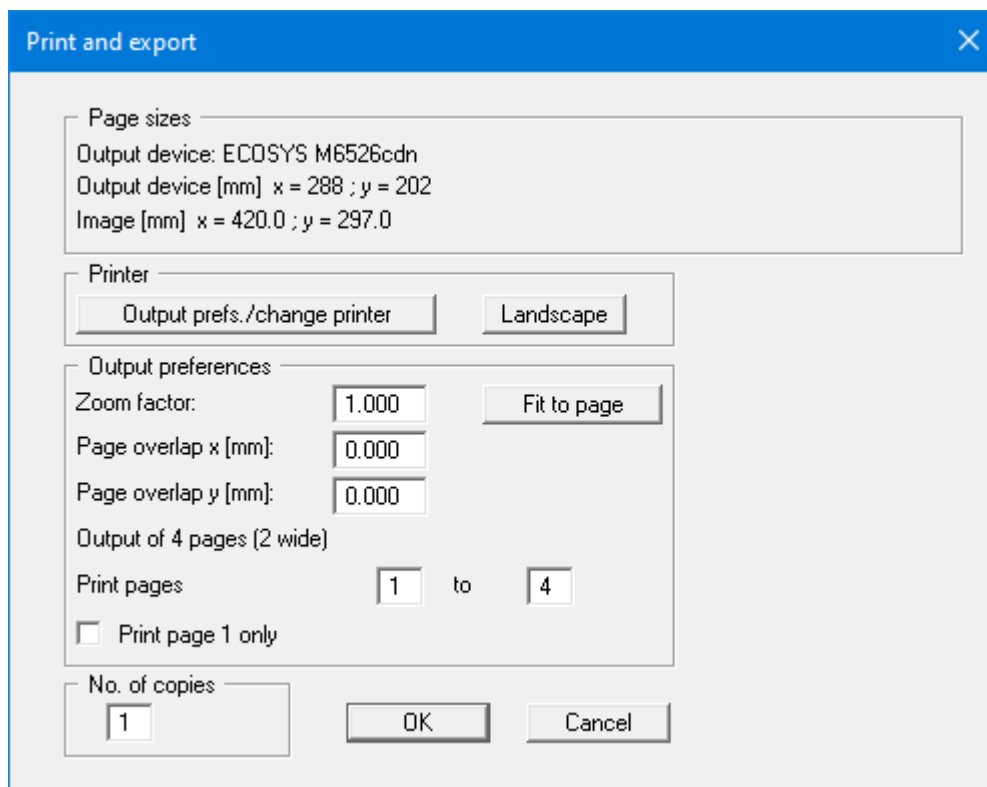
You can edit output preferences (e.g. swap between portrait and landscape) or change the printer in accordance with WINDOWS conventions.

9.7 GGU-CONTAM-FE: "Print and export" menu item

You can select your output format in a dialog box. You have the following possibilities:

- **"Printer"**

allows graphic output of the current screen contents (graphical representation) to the WINDOWS standard printer or to any other printer selected using the menu item **"File/Output preferences"**. But you may also select a different printer in the following dialog box by pressing the **"Output prefs./change printer"** button.



In the upper group box, the maximum dimensions which the printer can accept are given. Below this, the dimensions of the image to be printed are given. If the image is larger than the output format of the printer, the image will be printed to several pages (in the above example, 4). To facilitate better re-connection of the images, the possibility of entering an overlap for each page, in x and y direction, is given.

Alternatively, you also have the possibility of selecting a smaller zoom factor, ensuring output to one page ("**Fit to page**" button). Following this, you can enlarge to the original format on a copying machine, to ensure true scaling. You can also print only the 1st page with zoom factor = 1.0, in which case the bottom left-hand area is printed. Furthermore, you may enter the number of copies to be printed.

- **"DXF file"**
allows output of the graphics to a DXF file. DXF is a common file format for transferring graphics between a variety of applications.
- **"GGU-CAD file"**
allows output of the graphics to a file, in order to enable further processing with the **GGU-CAD** program. Compared to output as a DXF file this has the advantage that no loss of colour quality occurs during export.
- **"Clipboard"**
The graphics are copied to the WINDOWS clipboard. From there, they can be imported into other WINDOWS programs for further processing, e.g. into a word processor. In order to import into any other WINDOWS program, you must generally use the "*Edit/Paste*" function of the respective application.
- **"Metafile"**
allows output of the graphics to a file in order to be further processed with third party software. Output is in the standardised EMF format (Enhanced Metafile format). Use of the Metafile format guarantees the best possible quality when transferring graphics.

If you select the **"Copy/print area"** tool



from the toolbar, you can copy parts of the graphics to the clipboard or save them to an EMF file. Alternatively you can send the marked area directly to your printer (see "**Tips and tricks**").

Using the **"Mini-CAD"** program module you can also import EMF files generated using other GGU applications into your graphics (see menu item "**Graphics preferences/Mini-CAD**").

- **"Mini-CAD"**
allows export of the graphics to a file in order to enable importing to different GGU applications with the Mini-CAD module.
- **"GGUMiniCAD"**
allows export of the graphics to a file in order to enable processing in the GGUMiniCAD program.
- **"Cancel"**
Printing is cancelled.

9.8 GGU-CONTAM-FE: "Exit" menu item

After a confirmation prompt, you can quit the program.

9.9 GGU-CONTAM-FE: "1, 2, 3, 4" menu items

If you have not stored a working directory for the program icon, the program jumps to the program directory after starting to load or save a file.

Under the menu items "**1,2,3,4, ...**", the most recently edited files are displayed with the respective storage path. Selecting one of these files loads the selected file. The next time you call up the menu items "**File / Load**" or "**File / Save**", the program is automatically located in the directory of the last file loaded.

10 Editor menu

10.1 GGU-CONTAM-FE: "Soil properties" menu item

After going to this menu item, a system-specific dialog box opens allowing input of the soil properties. The steady-state property neff imported from the GGU-2D-SSFLOW program can no longer be amended here.



Soil	neff	alpha_l	alpha_t	Dm	sorp	lambda
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

In the example above, three soils have been defined for the system (groundwater modelling with **GGU-2D-SSFLOW**). Enter the soil parameters relevant to contaminant transport in the input boxes:

- **"Info"**
This menu item provides some information on the meaning of the properties and their units. Take care to always use the same units, as these are not pre-specified by the program. The result will be given in terms of the units with which you entered your data.
- **"alpha_l"**
Enter the value of the longitudinal dispersivity α_l . This is a function of grain size and varies between a few centimetres (laboratory tests in sand) and over 100 metres (jointed rocks).
- **"alpha_t"**
The transversal dispersivity α_t is generally a magnitude smaller than the longitudinal. In field tests, ratios around 0.01 were determined. Values of up to 0.3 are given in the literature.
- **"Dm"**
Enter the value of the diffusion coefficient D_m . This value only influences contaminant distribution at very low flow velocities. For water at 10°C, this value is $10^{-9} \text{ m}^2/\text{s}$.
- **"Sorp"**
Enter the value of the sorption constant $sorp$. The sorption constant is dimensionless and is the product of grain density and the adsorption coefficient.
- **"lambda"**
Enter the value of the decay constant λ .

10.2 GGU-CONTAM-FE: "Individual initial concentrations" menu item

This menu item at first generates a dialog box in which you specify the number of decimal points for concentrations, and the font size.

If you confirm with **"OK"**, the FEM mesh will be displayed on the screen. Click on the appropriate point with the left mouse button. The current system coordinates of the mouse pointer are shown in the status bar at the bottom of the screen. Enter the desired initial concentration in the following dialog box.



The length unit must also coincide with the permeability length unit. If you click on a node with the right mouse button, any current initial concentration will be deleted and the node set to '0'.

10.3 GGU-CONTAM-FE: "(Initial concentrations) In section" menu item

Click on four points in a counter-clockwise direction to define the desired section. You will then be asked for the initial concentration you would like to apply to all nodes in the section. Alternatively, you have the possibility of deleting all initial concentrations, i.e. setting them all to '0'.

10.4 GGU-CONTAM-FE: "(Initial concentrations) From file" menu item

You can load concentrations from a previous analysis as initial concentrations. The first time step after the given time will be read.

10.5 GGU-CONTAM-FE: "Boundary condition polygons" menu item

The temporally variable (transient) system boundary conditions for the system are defined using this menu item, or previously defined polygon courses may be edited. You enter the concentrations for the specified time intervals. Polygon course input is initially location-independent. Existing polygon courses are called up in the dialog box of this menu item using the button with the respective polygon course number



The same dialog box appears as when you click the "**New**" button, which offers you the following options:

- "**Done**"
Once all changes to the selected polygon course are complete, exit the dialog box using this button. By clicking the "**New**" button once again further polygon courses can be defined.
- "**Edit polygon course**"
The following dialog box appears for example:

No.	Time [T]	Value [M/T] or [M/L³]
1	0.000000E+0	0.0000E+0
2	1.000000E+0	0.0000E+0

You define the number of polygon course modelling points via the **"2 polygon points to edit"** button. It is possible to define up to 100 polygon points. Once you have done this you can define the temporal course with your corresponding boundary condition value. Take care to note the units you are using. **GGU-CONTAM-FE** works with true units. Times must therefore be given in the time unit used for permeability. For example, if permeability was entered in m/s, times must be entered in seconds. The polygon value must be entered in mass/time (e.g. mg/s) for concentration sources, or mass/length³ for concentrations. The length units must also correspond to the permeability length units.

After clicking on the "Done" button, you will return to the initial dialog box.

- **"Display polygon course"**

Using this button you have presented your polygon course in a diagram for viewing and checking.

- **"Delete polygon course"**

By clicking this button you can delete the current polygon course after a confirmation prompt.

10.6 GGU-CONTAM-FE: "Assign polygons individually" menu item

After asking for the font size, this menu item allows allocation of a boundary condition polygon to a specific node.

Once you have clicked on a node with the left mouse button, the following dialog box appears:



In the example above you can select from two pre-defined boundary condition polygons. Further, you can specify whether the boundary condition is to be a concentration or a concentration source.

If you click on a node with the right mouse button, any current polygon allocation will be deleted.

10.7 GGU-CONTAM-FE: "In section" menu item

By selecting this menu item you can assign a boundary condition polygon to a system section. By means of an info dialog box, you can define a section with the left mouse button, which you can then assign a previously specified polygon course after being asked if you would like to set or delete a condition.

11 Check menu

11.1 GGU-CONTAM-FE: General note

The menu items in this menu serve to check the transient data and to aid your memory. You can have the mesh presented on the screen together with the desired parameters. With the following menu items, you cannot edit any of the mesh analysis parameters.

11.2 GGU-CONTAM-FE: "Preferences" menu item

In this dialog box you can specify preferences for the FEM mesh presentation.

11.3 GGU-CONTAM-FE: "Mesh" menu item

When you select this menu item the FEM mesh is displayed.

11.4 GGU-CONTAM-FE: "Outline" menu item

When you select this menu item the system outline is displayed.

11.5 GGU-CONTAM-FE: "Outline (coloured)" menu item

After going to this menu item, the system is outlined, and the soil colours displayed.

11.6 GGU-CONTAM-FE: "Contours" menu item

After going to this menu item coloured contours can be displayed, e.g. for the initial steady-state of the potentials.



The following preferences can be defined in the dialog:

- "Contour data" group box

Press the "**Determine extreme values...**" button. The program then determines the minimum and maximum values for the corresponding layer base. You can then edit these values, for example in achieve a defined start value.

- **"Colour fill"** group box

You can control the colour subdivisions of the contour diagram using **"No. of colours"**. In the example above, 16 colours will be displayed between **"Colour 1"** and **"Colour 2"**. The default setting is a colour course from red to blue. These colours can be edited as required after selecting the **"Colour 1"** and **"Colour 2"** buttons, or simply reverse the choice by selecting the **"Change colour series"** check box.

- **"Further preferences"** group box

In addition to the colour presentation you can also have the triangle mesh and/or the outline displayed. Additional contour lines can also be drawn. Line labelling preferences can be defined by means of the **"Labelling preferences"** button.

- **"OK"**

The colours will be drawn after confirmation.

A colour bar at the right edge of the sheet allows correlation between the colour and the corresponding value. If this colour bar is drawn in the right page margin, specify a larger value for the right plotting margin (e.g. 25 mm) in the **"Page size + margins/Page size and margins"** menu item.

12 Modelling menu

12.1 GGU-CONTAM-FE: "Start" menu item

After clicking on this menu item or, alternatively, by pressing [F5], several dialog boxes appear with information and queries about the Peclet and Courant criteria (cf. Section 7), which you may accept or edit. The following dialog box then appears:

Transient vertical-plane groundwater flow [X]

Modelling

End time: 1000.000

Data output

Output file:
C:\...\Examples\de\Bsp2_4_Berechnet_kon.plw

Display entire file name

☒ At all polygon course modelling points

☐ Always after [T]: 1.00

☐ At each nth time step
x = 2

OK Cancel

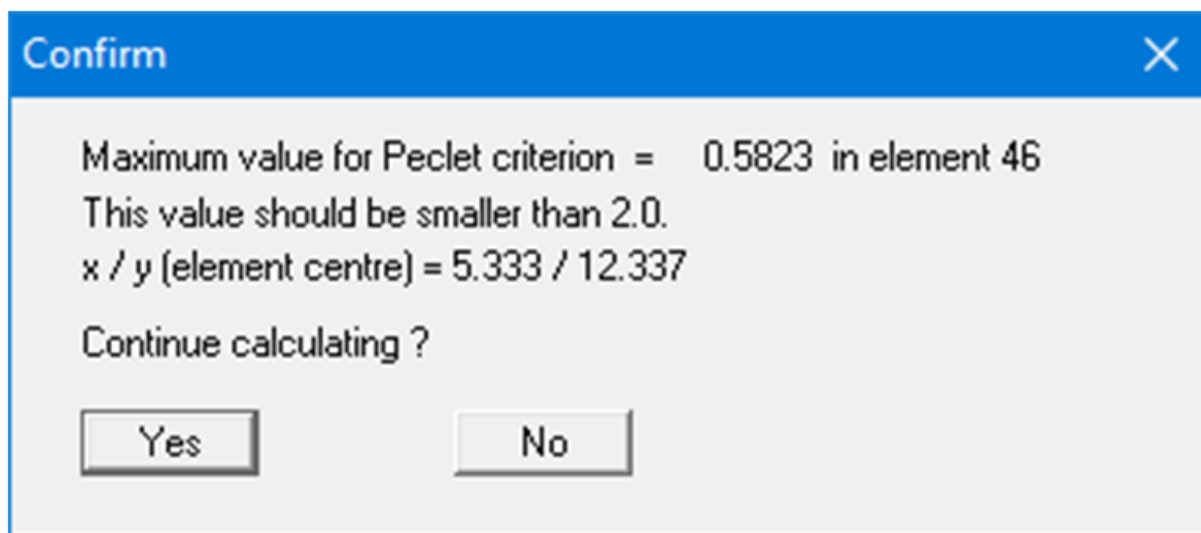
The example shown is for a vertical-plane system. You will see the name of the output file (here "**RW-Vertikal_kon.plw**"). When calculations are complete, this file contains all result data, which can then be evaluated with **GGU-PLGW**.

A flood of results is usually provided for contaminant propagation analyses, with correspondingly large result files. Often, a small time step must be selected in order to achieve sufficiently precise results. You can therefore specify the times at which data output should follow.

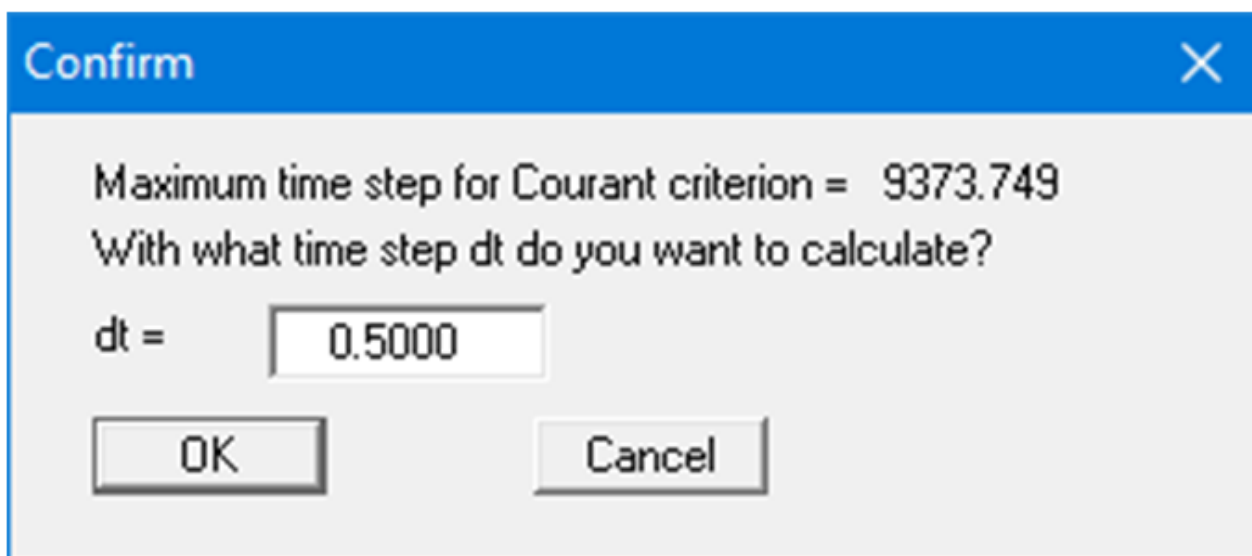
Independently of the selected time step, the program automatically proceeds to all times associated with boundary polygons. If you activate the "**Data output at polygon points**" switch, the results for these times will be issued additionally, independent of the previous entry. It is conceivable, for example, to enter a very large value for "**Data output every nth time step**" and to temporally subdivide a boundary condition polygon such that output only occurs at the times specified by you.

Finally, you enter the end time at which analysis is to cease.

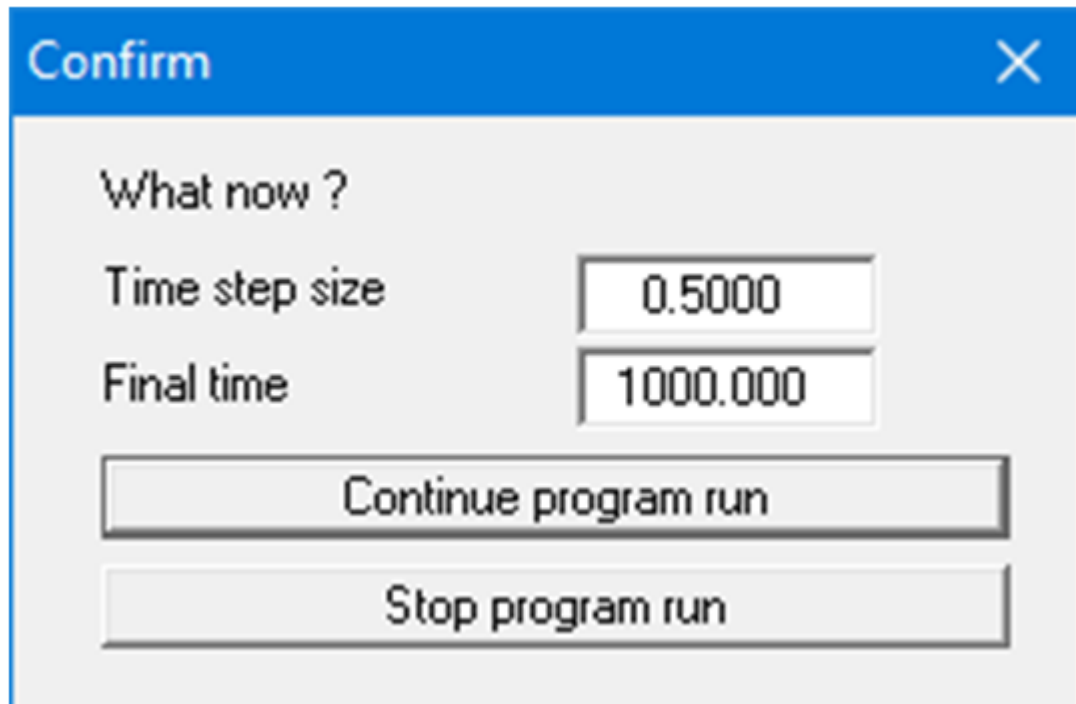
After selecting the "**OK**" button, the program carries out checks. First, the Peclet criterion is checked



The Courant criterion is then checked and the optimum time step shown.



After selecting the "**OK**" button the calculation proper will begin. A dialog box with a "**Cancel**" button will inform you of analysis progress. If you select this button, analysis will not cease immediately, but instead you can edit specific program data and then carry on calculating.



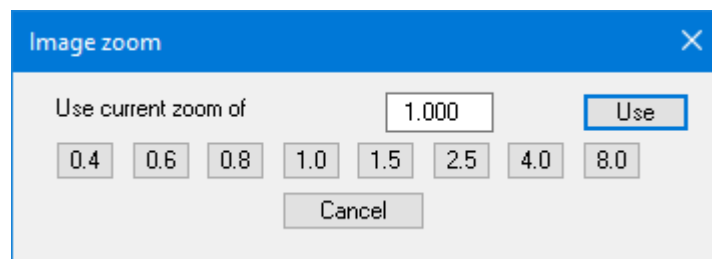
A record with the extension "***_kon.plw**" is generated for the evaluation application during modelling. If, after commencing modelling, you open the **GGU-PLGW** program, you can check and evaluate the current results while modelling is still in progress. The "**Animation**" function is particularly impressive here; it can be executed parallel to the running modelling process.

13 Graphics preferences menu

13.1 GGU-CONTAM-FE: "Refresh and zoom" menu item

The program works on the principle of ***What you see is what you get***. This means that the screen presentation represents, overall, what you will see on your printer. In the last consequence, this would mean that the screen presentation would have to be refreshed after every alteration you make. For reasons of efficiency and as this can take several seconds for complex screen contents, the screen is not refreshed after every alteration.

If, e.g., after using the zoom function (see below), only part of the image is visible, you can achieve a complete view using this menu item.



A zoom factor between 0.4 and 8.0 can be entered in the input box. By then clicking on "Use" to exit the box the current factor is accepted. By clicking on the "0.4", "0.6", etc. buttons, the selected factor is used directly, and the dialog box closed.

It is much simpler, however, to get a complete overview using [Esc]. Pressing [Esc] allows a complete screen presentation using the zoom factor specified in this menu item. The [F2] key allows screen refreshing without altering the coordinates and zoom factor.

13.2 GGU-CONTAM-FE: "Zoom info" menu item

An info box informs you about the activation and options of the zoom function.

The quickest way to enlarge a specific section of the screen is to open a zoom window by holding down the [Ctrl] key and the mouse button.

13.3 GGU-CONTAM-FE: "Pen colour and width" menu item

In order to enhance the clarity of the graphics you can preset the pen settings for various graphic elements in the GGU programs

You can change the pen widths for the elements listed in the dialog box and adjust the pen and/or fill colours by clicking on the button with the element name. In some GGU programs you can also define a line colour for selected elements.

For the graphic output of colours on **monochrome printers** (e.g. laser printers), colours are replaced by an equivalent shade of grey. In the case of very light colours, the corresponding graphic elements are then barely visible on the printer. In such cases, it makes sense to change the colour setting to darker colours.

13.4 GGU-CONTAM-FE: "Legend font selection" menu item

With this menu item you can switch to a different true-type font. All available true-type fonts are displayed in the dialog box.

13.5 GGU-CONTAM-FE: "Mini-CAD toolbar" and "Header toolbar" menu items

Using this menu item you can add free text, lines, circles, polygons and images (e.g. files in formats BMP, JPG, PSP, TIF, etc.) to the main program graphics. PDF files can also be imported as images. A pop-up menu opens, the icons and functions used are described in more detail in the **Mini-CAD** manual saved in the "**C:\Program Files (x86)\GGU-Software\Manuals**" folder during installation. The differences between the Mini-CAD and Header CAD are as follows:

- Drawing objects created with **Mini-CAD** refer to the coordinate system (generally in [m]) in which the drawing is created and are displayed accordingly. You should therefore select this menu item if you wish to enter additional information on the system. These objects can be saved in a **".mcd"** file using the



icon in the pop-up menu and loaded as such in other GGU programs using the



icon in the pop-up menu.

- Drawing objects created with the **Header CAD** refer to the sheet format (in [mm]). They therefore always remain at the same sheet position, regardless of the coordinate system of the measuring points. You should select this menu item if you want to enter general information on the drawing (e.g. company logo, report number, system number, stamp). If you save this so-called header data in a “.kpf” file using the icon



in the pop-up menu, you can reload this header data for a completely different system (with different system coordinates) and also in other GGU programs using the icon



in the pop-up menu. The saved header data can then be found in the same position. This considerably simplifies the creation of general sheet information.

14 Page size + margins menu

14.1 GGU-CONTAM-FE: "Auto-resize" menu item

This menu item provides a to-scale visualisation, in both x and y coordinates, of the system and result graphics. If you have previously altered the image coordinates graphically or via editor, you can quickly achieve a complete view using this menu item.

This function can also be accessed using the **[F9]** function key.

14.2 GGU-CONTAM-FE: "Manual resize (mouse)" menu item

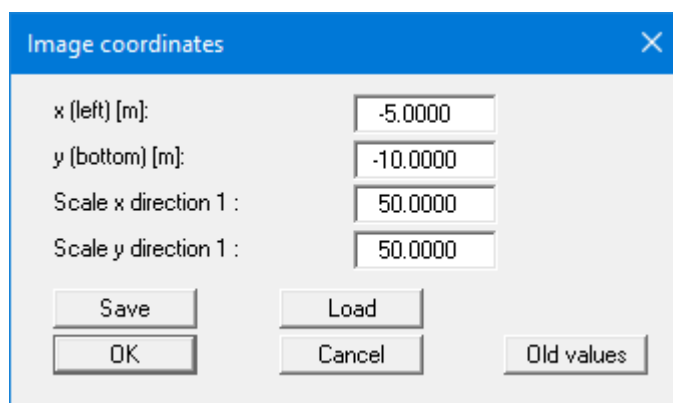
You can transfer the coordinates of a section of your previous graphic display as new image coordinates by holding down the **[Ctrl]** and **[Shift]** keys and marking the desired area with the left mouse button. The scales of the x-direction and y-direction are adjusted accordingly.

In the default setting, the "**Proportional section**" check box is activated. This retains the previous proportions (scale x-direction/scale y-direction).

If you activate the "**Redefine origin**" check box, you can adjust the image coordinates without changing the scale. In this way, you can quickly achieve the desired visualisation without having to try out the x/y coordinates if the scale is set appropriately.

14.3 GGU-CONTAM-FE: "Manual resize (editor)" menu item

You can alter the current image coordinates by direct numerical input in a dialog box. This allows precise scale input. The coordinates refer to the drawing area. This can be defined in the "**Page size + margins/Page size and margins**" menu item by means of the plot margins.



The image coordinates entered here can be saved in a file with the extension ".bxy" and be reloaded later for the same file or for different files.

If you want to recover the previous values during input or use the menu item again after editing the coordinates, you can do this by pressing the "**Old values**" button.

14.4 GGU-CONTAM-FE: "Font size selection" menu item

You can edit font sizes for labelling the various drawing elements.

The font sizes of text within legends are edited in the respective legend editor. Just double-click in a legend to do this.

14.5 GGU-CONTAM-FE: "Page size and margins" menu item

The default page set-up is A3 when the program is started. You can edit the page format in the following dialog box.

Page size

Edit page size and margins

Page in general

Height = 297.00 Width = 420.00

Page margins in mm

Left = 25.00 Right = 8.00
Top = 8.00 Bottom = 8.00

Plot margins in mm

Left = 25.00 Right = 8.00
Top = 25.00 Bottom = 25.00

☒ With borders ☒ With margins

OK Cancel

- "**Page in general**" defines the size of the output sheet. The A3 format is set as default. The program automatically draws thin cutting borders around the page, which are required when using a plotter on paper rolls. The borders can be switched off deactivating the "**With borders**" check box.
- "**Page margins**" define the position of a frame as a distance to the margins. This frame encloses the subsequent diagram. You can switch off the frame deactivating the "**With margins**" check box.
- The "**Plot margins**" define a set distance between the page margin and the actual **drawing area** in which the graphical evaluation of your input is presented.

15 ? menu

15.1 GGU-CONTAM-FE: "Copyright" menu item

You will see a copyright message and information on the program version number.

The "**System**" button shows information on your computer configuration and the folders used by the GGU program.

15.2 GGU-CONTAM-FE: "Maxima" menu item

Here you can check the defaults for maximum values of the program.

15.3 GGU-CONTAM-FE: "Help" menu item

The manual is opened as a PDF document. The help function can also be accessed using the **[F1]** function key.

15.4 GGU-CONTAM-FE: "GGU on the web" menu item

Using this menu item, you can access the [GGU Software website](#).

Check the page of your program module at regular intervals for information about updates and changes. On the "**Changelogs**" subpage, you can also subscribe to an e-mail notification that informs you of all changes on a monthly basis.

15.5 GGU-CONTAM-FE: "GGU support" menu item

This menu takes you directly to the [GGU Software Support Portal](#).

Here you can enter your support request directly and upload your edited GGU program file.

15.6 GGU-CONTAM-FE: "What's new?" menu item

You will see information on program improvements in comparison to older versions.

15.7 GGU-CONTAM-FE: "Language preferences" menu item

This menu item allows you to switch the menus and the graphics from German to English and vice versa. To work in German, deactivate the two check boxes "**Dialoge + Menüs übersetzen (translate dialogues, menus)**" und "**Graphiktexte übersetzen (translate graphics)**".

Alternatively, you can work bilingually, e.g. with German dialog boxes but with graphic output in English. The program always starts with the language setting applicable when it was last ended.