

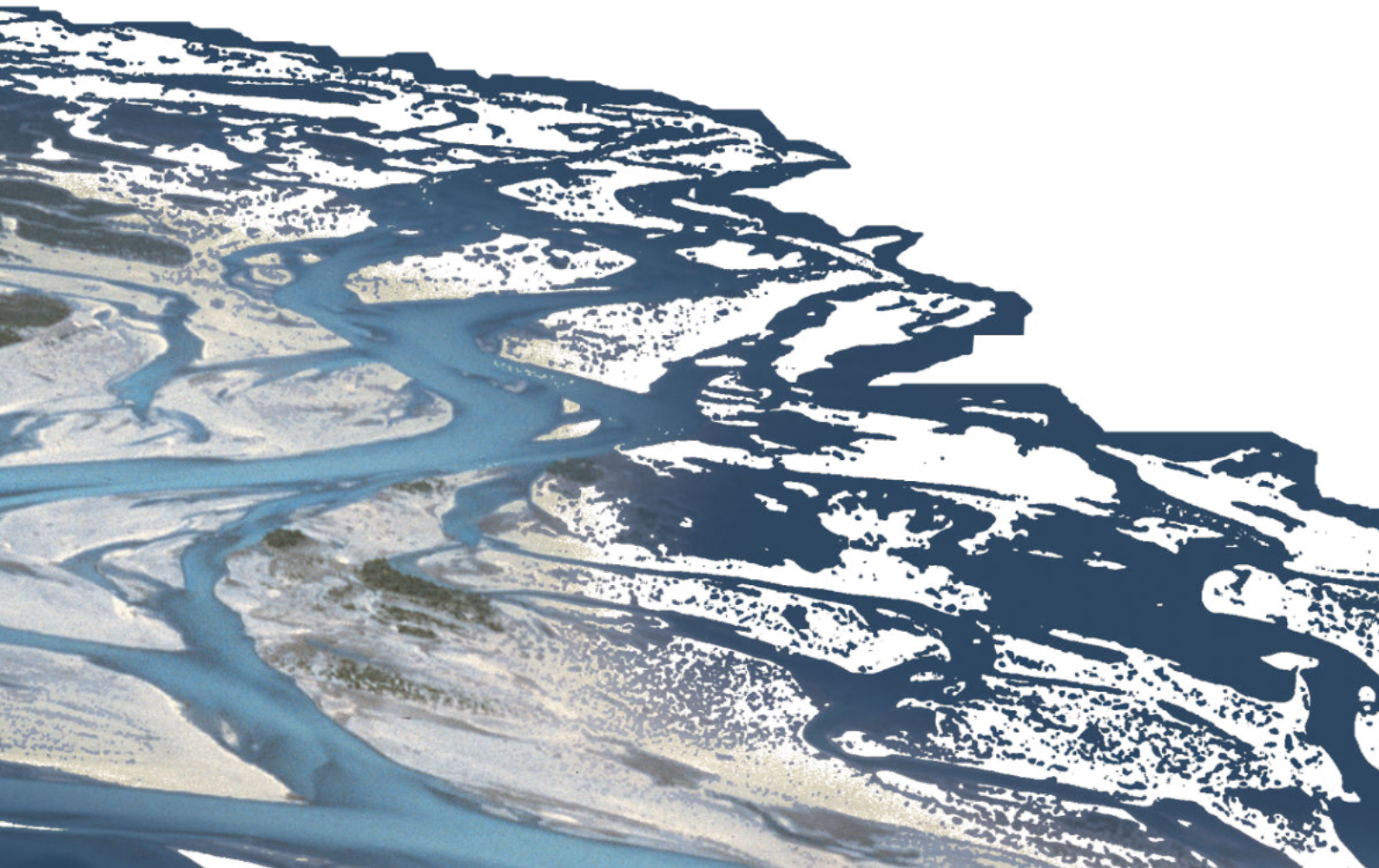


BASEMENT

**BASIC SIMULATION ENVIRONMENT
FOR MODELLING OF ENVIRONMENTAL
FLOWS AND NATURAL HAZARDS**

SYSTEM MANUALS

**VERSION 4.0.2
OCTOBER 2023**



Preamble

VERSION 4.0.2

October 2023

Credits

Contributors

Over the years, many enthusiastic engineers and developers have contributed to the development, testing and documentation of BASEMENT. An up-to-date overview of the current development team, along with current and former contributors, can be found on our website:

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**BASIC SIMULATION ENVIRONMENT
FOR MODELLING OF ENVIRONMENTAL
FLOWS AND NATURAL HAZARDS**

INTRODUCTION & INSTALLATION

**VERSION 4.0.2
OCTOBER 2023**



BASEMENT

Contents

1	Summary of Contents	5
1.1	Introduction	5
1.2	Content of System Manuals	5
1.2.1	Introduction & Installation	5
1.2.2	User Manual	5
1.2.3	Reference Manual	6
1.2.4	Tutorials and Test Cases	6
2	Setup and First Start	7
2.1	Setup and First Start	7
2.1.1	Operating System Requirements	7
2.1.1.1	Microsoft Windows	7
2.1.1.2	Linux	7
2.1.1.3	Hardware Configuration	8
2.1.2	Installing under Windows	9
2.1.2.1	Getting the binaries	9
2.1.2.2	Installation procedure under Windows 10 and 11	9
2.1.3	Installing under Linux	10
2.1.3.1	Getting the binaries	10
2.1.3.2	Installation procedure	10
2.2	Running BASEMENT	12
2.2.1	Windows 10 and 11	12
2.2.2	Linux	12
3	Migration Guide	15
3.1	General	15
3.2	Migration from version 2.8.2	15
3.2.1	Convertor for command (BMC) files	15
3.2.1.1	Conversion in the GUI	15
3.2.1.2	Conversion with BMv4_BASEMD_converter	16
3.2.2	Restart simulation from result (h5) file	16
3.2.3	Adapt setup file	17
4	Release Notes	19
4.1	Version 4.0.2	19
4.1.1	General	19
4.1.1.1	Known Issues	19

4.1.2	Module BASEHPC	19
4.1.2.1	Bug fixes	20
4.1.3	Module BASEMD	20
4.1.3.1	Bug fixes	20
4.1.3.2	Known Issues	20
4.2	Version 4.0.1	21
4.2.1	General	21
4.2.1.1	Known Issues	21
4.2.2	Module BASEHPC	21
4.2.2.1	Bug fixes	21
4.2.3	Module BASEMD	21
4.2.3.1	Bug fixes	21
4.2.3.2	Known Issues	22
4.3	Version 4.0	22
4.3.1	General	22
4.3.2	Known Issues	23
4.3.3	Module BASEHPC	23
4.3.3.1	Bug fixes	23
4.3.4	Module BASEMD	23
4.3.4.1	General	23
4.3.4.2	Bug fixes	23
4.3.4.3	Known Issues	23
4.4	Notes on older releases	24
5	Summary of Features Version 4.0	25
5.1	Features of module BASEMD	25
5.1.1	Submodule BASEchain	25
5.1.1.1	Numerics	25
5.1.1.2	Geometry	25
5.1.1.3	Hydrodynamics	25
5.1.1.4	Sediment Transport: Bed load	26
5.1.1.5	Sediment transport : Suspended load	26
5.1.1.6	Sediment transport : Gravitational induced transport	26
5.1.1.7	Output Variables/Formats	26
5.1.2	Submodule BASEplane	27
5.1.2.1	Numerics	27
5.1.2.2	Geometry	27
5.1.2.3	Hydrodynamics	27
5.1.2.4	Sediment Transport: Bed load	28
5.1.2.5	Sediment transport : Suspended load	28
5.1.2.6	Sediment transport : Gravitational induced transport	28
5.1.2.7	Output Variables/Formats	28
5.1.3	Submodule BASEsub	29
5.1.3.1	Numerics	29
5.1.3.2	Geometry	29
5.1.3.3	Hydrodynamics	29
5.1.3.4	Output Variables/Formats	29
5.2	Features of module BASEHPC	30
5.2.1	Hydrodynamics	30

5.2.2	Morphodynamics	32
5.2.2.1	Bed load transport	32
5.2.2.2	Suspended load transport	33
5.2.3	Tracers	35
5.2.4	Vegetation	35
5.2.5	Output Variables Summary	36
6	References	39

Summary of Contents

1.1 Introduction

BASEMENT version 4 is a freeware simulation tool for hydro- and morphodynamic modelling developed at the Laboratory of Hydraulics, Hydrology and Glaciology (VAW) of ETH Zurich. The software provides a powerful tool for the simulation of river hydro- and morphodynamics. BASEMENT system manual provides information about BASEMENT software and guides the user through the process of using BASEMENT version 4.

1.2 Content of System Manuals

The documentation is composed of four parts, the Introduction & Installation, the User Manual, the Reference Manual and the Tutorials & Test Cases.

1.2.1 Introduction & Installation

This part aims at introducing BASEMENT version 4 to the user by presenting the novelties and changes of the released version. First, the installation procedure is explained for Windows and Linux operating systems. Then, the differences between BASEMENT modules BASEMD and BASEHPC are described in the migration guide for the users already familiar with BASEMENT. The release notes summarize the changes introduced by BASEMENT version 4 and the summary of features provides an overview of the available functionalities of the new version.

1.2.2 User Manual

The user manual provides information about the simulation environment of BASEMENT version 4. The modelling procedure presents the three-stage process, namely the pre-processing, the numerical simulation and post-processing. The numerical simulation is

carefully described in the simulation workflow section. The graphical user interface (GUI) provides a user-friendly tool to assist the user during the numerical simulation process.

1.2.3 Reference Manual

The reference manual provides information about the mathematical models and numerical approximations implemented in BASEMENT version 4.

1.2.4 Tutorials and Test Cases

This part is composed of three tutorials and two test cases. The tutorials guide the user throughout the pre-processing, the numerical simulation and post-processing stages of BASEMENT version 4 by taking a section of the river Flaz in Graubünden as example for the numerical simulation. The test cases aim at testing the performance and accuracy of the simulations performed with BASEMENT version 4 by standardized test cases, namely the circular dam break and the conical dune.

2

Setup and First Start

2.1 Setup and First Start

2.1.1 Operating System Requirements

2.1.1.1 Microsoft Windows

BASEMENT version 4 has been tested for MS Windows 10 and 11. For the latest news concerning new features and current changes, please visit the webpage <https://www.basement.ethz.ch>.

2.1.1.2 Linux

BASEMENT version 4 is available for the following Linux (x86-64) systems:

- Ubuntu 18.04 (LTS), alias “Bionic Beaver”:
 - Kernel version 5.4
 - GNU C Library (glibc) version 2.27
 - VTK-version: 6.3
 - GPU driver version:
 - * Kepler architecture and later: at least 418.39
 - * Tesla architecture: in [384.111, 385.00) or in [410.72, 411.00)
- Ubuntu 20.04 (LTS), alias “Focal Fossa”:
 - Kernel version 5.13
 - GNU C Library (glibc) version 2.31
 - VTK-version: 9

- GPU driver version:
 - * Kepler architecture and later: at least 418.39
 - * Tesla architecture: in [384.111, 385.00) or in [410.72, 411.00)
- Ubuntu 22.04 (LTS), alias “Jammy Jellyfish”:
 - Kernel version 5.15
 - GNU C Library (glibc) version 2.35
 - GPU driver version:
 - * Kepler architecture and later: at least 418.39
 - * Tesla architecture: in [384.111, 385.00) or in [410.72, 411.00)

The binaries were compiled and tested on both Linux systems. Binaries without GUI should run on debian-based linux systems.

2.1.1.3 Hardware Configuration

We recommend the following hardware configurations:

2.1.1.3.1 CPU multi-core processors (x86/x86-64)

- Intel (Xeon, 12 to 18 Cores, dual socket)
- 1 GB per core
- Minimum of 2.8 GHz

2.1.1.3.2 Graphical Processing Units (GPUs)

Please note that the GPU-support of BASEMENT version 4 is **only** possible for CUDA-enabled (Compute Unified Device Architecture) GPUs produced by NVIDIA. BASEMENT version 4 has been specifically tested with GPUs listed in [2.1](#).

Table 2.1 GPU hardware used for the numerical simulations

Card	Tesla K20	Tesla P100	GTX 1080 Ti	GTX 1070 Ti	GTX 1050 Ti	RTX 2080Ti
Memory [GB]	5	12	11	8	4	11
Architecture	Kepler	Pascal	Pascal	Pascal	Pascal	Turing
Bandwidth[GB/s]	208	549	484	256	112	616
CUDA cores	2496	3584	3584	2432	768	4352

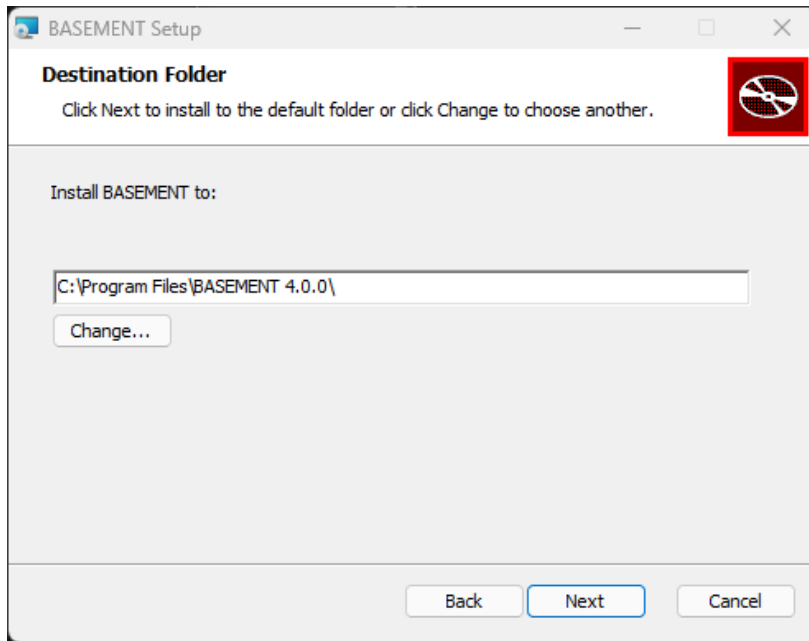


Figure 2.1 Select the installation folder.

2.1.2 Installing under Windows

BASEMENT version 4 is available for Microsoft Windows Windows 10 and 11 operating system.

2.1.2.1 Getting the binaries

First of all, you need to get a copy of the latest software package. Therefore go to the project webpage <https://basement.ethz.ch> and download the latest version (BASEMENT version 4.x) free of charge.

2.1.2.2 Installation procedure under Windows 10 and 11

Please note, that existing installations may not automatically detected by the installer. Therefore, uninstall any previous BASEMENT version before installing a more recent version e.g. using the link in the start menu. After downloading the version from the project webpage, start the installation by double-clicking on the BASEMENT installer.

Step 1: Accepting the license agreement

Please read the License Agreement carefully and click on the 'I accept' button if you accept the terms and conditions and proceed with the installation.

Step 2: Select the installation folder

After accepting the License agreement, you can choose where to install the binaries. The recommended location is "C:\Program Files\BASEMENT 4.0" (Figure 2.1). You are free to choose any other directory.

Step 3 and 4: Confirming and finishing the installation

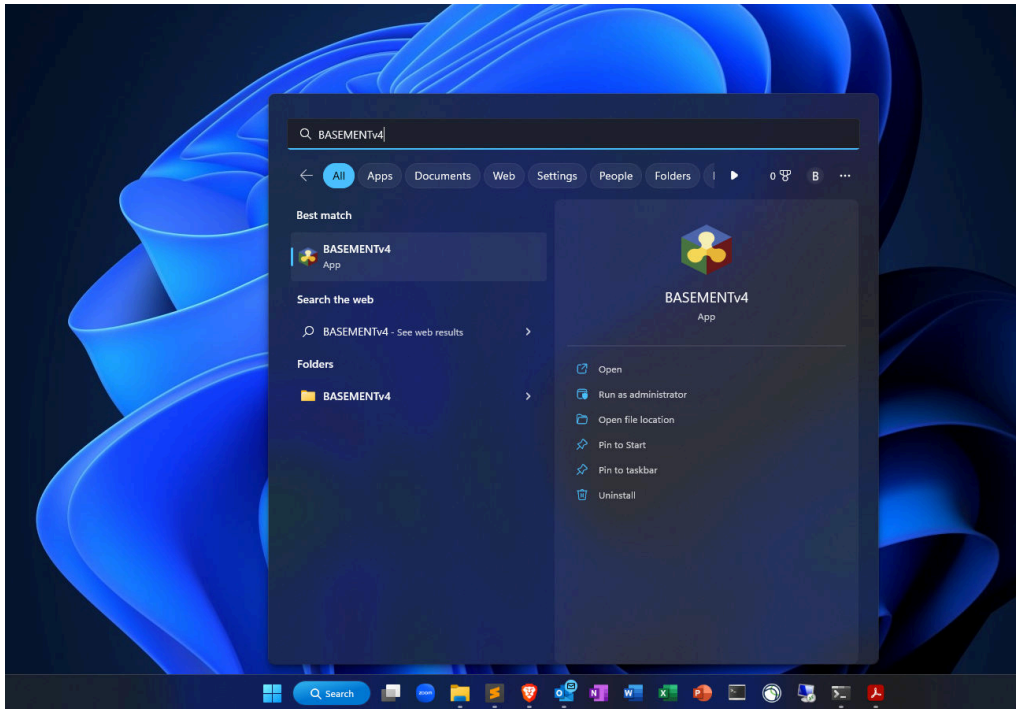


Figure 2.2 Start BASEMENT over the icon in the Start Menu folder.

Clicking ‘Install’ will start the installation process. After all files are copied, a final window informs about the success of the installation. Click ‘Finish’ to close the installer.

Step 5: Start BASEMENT

You can start the program by opening the Start Menu, navigating to the Start Menu folder of BASEMENT and clicking on the program icon of BASEMENT version 4 (Figure 2.2). To create a Desktop shortcut, simply drag the program icon to your Desktop. Clicking on the BASEMENT icon runs the program as a standalone application including a simple graphical user interface (to run BASEMENT in batch mode see the section Run the programm in the User Manual documentation part).

The graphical user interface should appear as in Figure 2.3.

2.1.3 Installing under Linux

2.1.3.1 Getting the binaries

You need to get a copy of the actual distribution as described in the Windows installation section. You can download the most recent version from the projects webpage <https://basement.ethz.ch>.

2.1.3.2 Installation procedure

Step 1: Preparation of the installation

Extract the downloaded package and change to the directory containing the installation script. Make the installation script executable by running (replace * by the BASEMENT and Ubuntu version number):

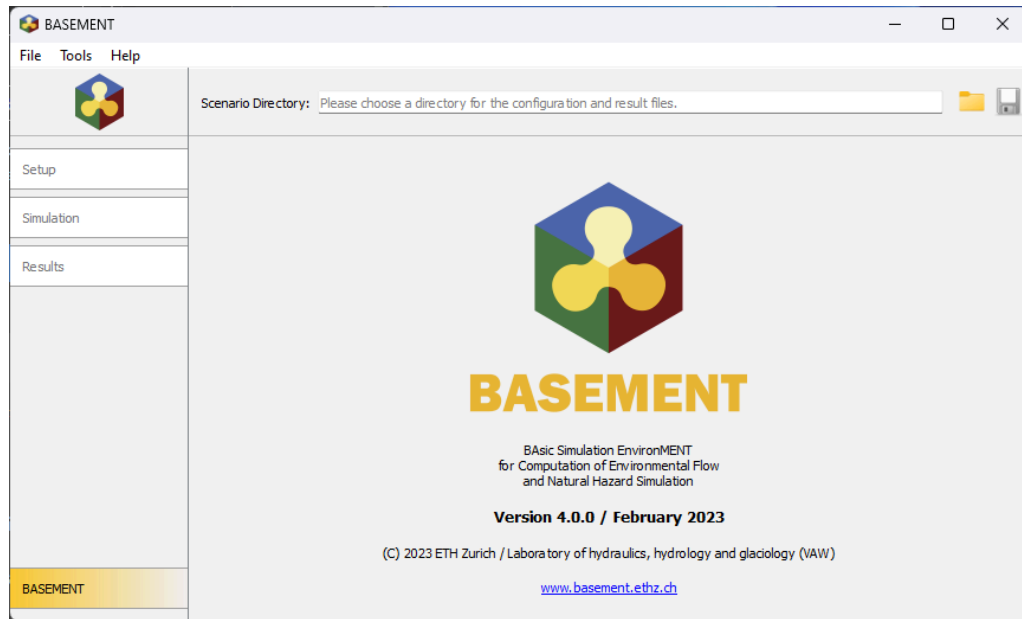


Figure 2.3 The graphical user interface.

```
$ chmod +x BASEMENT_v*_linux64_ubuntu*.sh
```

To run the setup enter

```
$ ./BASEMENT_v*_linux64_ubuntu*.sh
```

and follow the instructions. You have to read and accept the license text.

The BASEMENT Debian package file (*.deb) is extracted.

Step 2: Install the Debian package

Administrative rights are required to install the package using dpkg. Therefore prefix the command with “sudo” (replace *** by the version number):

```
$ sudo dpkg -i BASEMENT-***.deb
```

The Debian package automatically detects if your configuration misses one of the required packages. In such a case you can either use

```
$ sudo apt-get -f install
```

to install all missing packages automatically or, in case you want to install dependencies manually, you can perform

```
$ sudo apt-get install MISSING_PACKAGE
```

to install the missing packages from the repository. Replace `MISSING_PACKAGE` with the missing package name.

Previous versions of `basement` are automatically detected by the installer and deleted before the installation starts.

Step 3: Run basement

If the installation of the package was successful, then the executables are copied to

```
/usr/bin
```

and the other program files are copied to

```
/usr/share/basement
```

You can now run `Basement` from the console by typing:

```
$ basement
```

Step 4: In case of trouble

Report your issue and get in touch with other users in the `BASEMENT` forum: <https://people.ee.ethz.ch/~basement/forum/>

2.2 Running BASEMENT

2.2.1 Windows 10 and 11

When running `BASEMENT` under Microsoft Windows operating system, the easiest way to start a simulation is by clicking on `BASEMENT` icon. After running, `BASEMENT` will open the graphical user interface. You have to select the scenario directory that contains all the configuration files and binaries by pressing on the folder icon, where you can load the path to the scenario directory.

The configuration is done in three steps (three `.json` files) that can be edited using `BASEMENT` graphical user interface or `JSON` editors. Each step is executed independently (setup, simulation and results) and the generated files are saved in the scenario directory containing the command and auxiliary files. The procedure to run numerical simulations with `BASEMENT` using the graphical user interface (GUI) or in batch mode is explained in the User manual.

2.2.2 Linux

`BASEMENT` runs as a console application without program icon. On Linux, open a console and type:

```
$ basement
```

to start the program (if no environment variables have been set, change into your `'bin'` directory of the installation path). The GUI starting page is appearing. You have now to select or create the scenario directory in the scenario directory field. The configuration

of the .json files (3 steps) is the same as for Microsoft Windows (see Section 2.2.1) and information about the use of the GUI is given in the section ‘BASEMENT Graphical User Interface’ of the User Manual. Selecting the executables and running a simulation on Linux or using batch mode works the same way as it does on Windows explained in the User Manual. *Notice:* **The command filename must not contain any spaces or special characters like ä, ö, ü, è, etc.**

3

Migration Guide

3.1 General

BASEMENT version 4 consists of two main modules, namely BASEMD (MD stands for Multi Domain) and BASEHPC (HPC stands for High Performance Computing, based on the possibility to use GPGPUs). The BASEMD module refers to the former version 2.8.2 and the BASEHPC module to the version 3.2. Version 4 combines all the functionality of the previous versions, providing an unified GUI and workflow. The migration of existing model setups for versions 2.8.2 and 3.2 will be explained in the following.

3.2 Migration from version 2.8.2

3.2.1 Convertor for command (BMC) files

Running simulations with BASEMENT version 4 requires the model setup to be defined in files with the JSON format (model.json), while for version 2.8.2, model definitions were done in command (BMC) files. In order to migrate an existing model from version 2.8.2, the command file must first be converted into the JSON format. The conversion of a BMC file to a JSON file can be done either with the graphical user interface (GUI) of BASEMENT version 4, or with the standalone executable BMv4_BASEMD_converter.

3.2.1.1 Conversion in the GUI

A BMC file can be converted into a model.json file with the following steps:

1. Select the scenarion directory in the GUI, that contains the command (BMC) file.
2. Convert the BMC file via the “Import BMC file” function in the File-Menu.
3. Follow the simulation workflow as described in the User Manual.

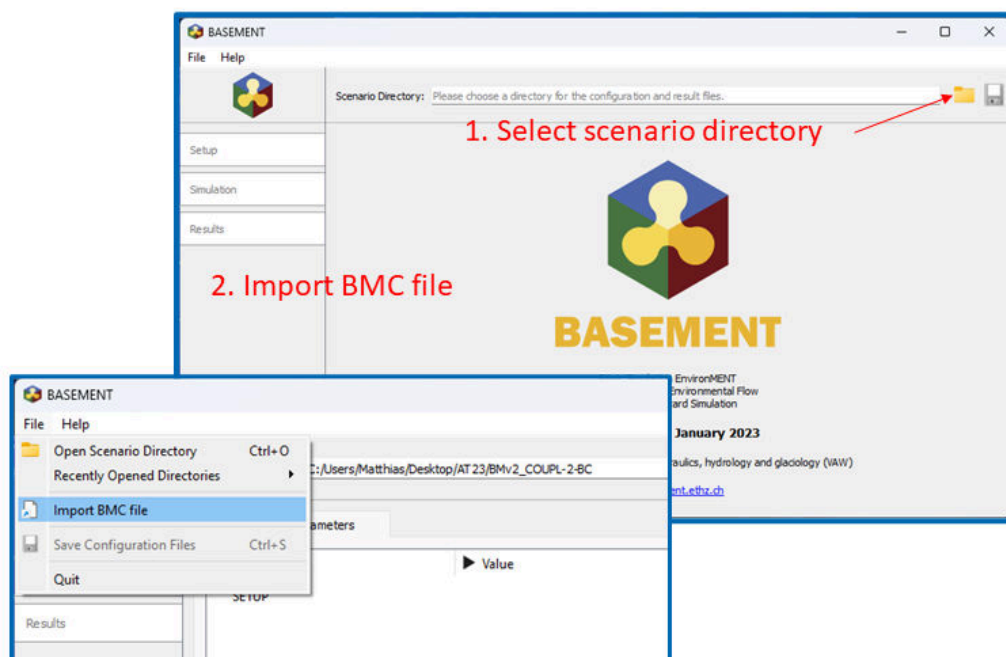


Figure 3.1 Migration from version 2.8.2 by selection of a scenario directory and importing a BMC file.

3.2.1.2 Conversion with BMv4_BASEMD_converter

Alternatively, a BMC file can be converted into a model.json file with the executable BMv4_BASEMD_converter via the command line.

On linux, run the command:

```
$ BMv4_BASEMD_converter myModel.bmc -o model.json
```

On Windows, run the command (assuming you added the installation location of BASEMENT to the Path environment variable)


```
> BMv4_BASEMD_converter.exe myModel.bmc -o model.json
```

3.2.2 Restart simulation from result (h5) file

The output format CGNS became deprecated with BASEMENT version 4 and was replaced by the h5 format. In order to restart a simulation with a restart file in CGNS format, the file must be converted to h5 format. Therefore, the python script cgns_to_h5.py is provided on the BASEMENT website <https://basement.ethz.ch/download/tools/python-scripts.html>.

The script requires python 3 and the module h5py, which can be installed, e.g. with 'pip install h5py'. To convert a CGNS file into an h5 file run the following command:

```
$ python cgns_to_h5.py restart.cgns
```



```
{
  "SETUP":{
    "simulation_name":"Flaz_A_run",
    "DOMAIN": {
      "PHYSICAL_PROPERTIES": {
        "gravity": 9.81
      },
      "BASEPLANE_2D": {
        "GEOMETRY": {
          "mesh_file": "Flaz_mesh.2dm",
          "INTERPOLATION": {
            "method": "weighted"
          }
        }
      }
    }
  }
}
```

```
{
  "SETUP":{
    "simulation_name":"Flaz_A_run",
    "BASEHPC": {
      "PHYSICAL_PROPERTIES": {
        "gravity": 9.81
      },
      "BASEPLANE_2D": {
        "GEOMETRY": {
          "mesh_file": "Flaz_mesh.2dm",
          "INTERPOLATION": {
            "method": "weighted"
          }
        }
      }
    }
  }
}
```

Figure 3.2 Migration from version 3.2 by replacing the keyword “DOMAIN” with “BASEHPC” the setup file.

Then follow the simulation workflow as described in the User Manual. # Migration from version 3.2

3.2.3 Adapt setup file

The combination of all the functionalities of the previous versions required a minor modification in the structure of the setup file (model.json). Therefore, the migration of an existing simulation from version 3.2 requires to adapt the setup file (model.json) in a text editor of choice and replace the keyword “DOMAIN” to “BASEHPC” as illustrated in (Figure 3.2).

Release Notes

4.1 Version 4.0.2

4.1.1 General

- A new panel has been added to the GUI. This panel displays the information previously shown as tool-tip information, but also includes additional information on units, default values or admissible parameter ranges.

4.1.1.1 Known Issues

- Visualization of results in QGIS requires manual modification of .xdmf file: change `<Xdmf Version="3.0">` to `<Xdmf Version="2.0">`.
- Model setup fails if there is a dot ‘.’ in the working directory path. For example: “MySimulations/Sim1.1/” does not work, while “MySimulations/Sim1_1/” works.
- Aborting a simulation using Ctrl+C can corrupt the HDF5 result file.
- Abort bottom may no work as intended, i.e. simulation does not stop.

4.1.2 Module BASEHPC

- For LINKED boundary conditions and the INTERNAL boundary condition `hqrelation_internal`, the inflow conditions at the downstream boundary can be better controlled by the user via the newly introduced tag `type_downstream`. Four options are available as downstream inflow conditions. For all options, the mass inflow flux is calculated based on outflow at upstream boundary as previously. The difference lies in the calculation of the momentum flux over the boundary:
 - `no_momentum`: No momentum flux over the boundary.

- `froude_downstream`: Momentum flux calculated based on Froude number in the elements of the downstream nodestring.
- `froude`: Momentum flux calculated based on the Froude number specified via the parameter `froude_number`.
- `uniform`: Momentum flux calculated based on uniform flow conditions for the slope specified via the parameter `slope`. In previous versions, the various INTERNAL and LINKED boundary differed in how the momentum flux at the downstream boundary was calculated. The following combinations correspond to the implementation of the boundary conditions in previous versions:

type	type_downstream
<code>hqrelation_internal</code>	<code>no_momentum</code>
<code>weir_linked_constant</code>	<code>froude_downstream</code>
<code>weir_linked_dynamic</code>	<code>froude_downstream</code>
<code>hqrelation_linked</code>	<code>no_momentum</code>
<code>2way_hqrelation_linked</code>	<code>no_momentum</code>
<code>zhydrograph_linked</code>	<code>no_momentum</code>
<code>zhydrograph_linked_kinE</code>	<code>froude_downstream</code>

With this new feature, the LINKED boundary condition `zhydrograph_linked_kinE` became obsolete and has been removed.

4.1.2.1 Bug fixes

4.1.3 Module BASEMD

4.1.3.1 Bug fixes

- Absolute file paths on BASEMD simulations resulted in errors. This has been fixed.
- A bugfix implemented in v4.0.1 resulted many parameters of the BASEMD module being mandatory. This has been reverted. Those parameters are again initialized in the background if not explicitly defined by the user, results in the same behaviour as not explicitly specifying them in BASEMENT version 2.8.2 and earlier.

4.1.3.2 Known Issues

BASEplane

- The upstream and downstream stringdefs of the inner boundary weir must be of the same length, otherwise mass might not be conserved.

BASEchain

- Fixed bed starts eroding if both suspended load and bed load transport are activated if the suspended load is below transport capacity.

- Van Rijn formula does not result in any sediment being transported (1D-model).

Note: Existing installations are not automatically detected by the updated installer. Therefore uninstall any previous version of BASEMENT e.g. using the link in the Start Menu before installing the newest version.

4.2 Version 4.0.1

4.2.1 General

- Log and error messages during setup, simulation and results steps of the workflow are now written to a file.
- The latest GPU architectures Ada and Hopper should now be supported, but have not been explicitly tested. An upgrade to the latest NVIDIA driver might be necessary.

4.2.1.1 Known Issues

- Visualization of results in QGIS requires manual modification of .xdmf file: change `<Xdmf Version="3.0">` to `<Xdmf Version="2.0">` .
- Model setup fails if there is a dot ‘.’ in the working directory path. For example: “MySimulations/Sim1.1/” does not work, while “MySimulations/Sim1_1/” works.
- Aborting a simulation using Ctrl+C can corrupt the HDF5 result file.
- Tool tip text is too long to be displayed completely.
- Abort bottom may no work as intended, i.e. simulation does not stop.

4.2.2 Module BASEHPC

4.2.2.1 Bug fixes

- A bug during writing the .xdmf output file resulted in unresponsive behaviour when visualizing the results in ParaView or even errors in QGIS. This bug has been fixed for visualizing the results in ParaView. Since the QGIS mesh layer does not yet support XDMF Version 3.0 it is necessary to manual replace the line `<Xdmf Version="3.0">` at the top of the .xdmf output file by `<Xdmf Version="2.0">` in order to load the simulation results onto the mesh layer.

4.2.3 Module BASEMD

4.2.3.1 Bug fixes

- A bug in the initialization of several model parameters (e.g. `theta_critical`, `theta_critical_approach`, etc.) resulted in BASEMD simulations to crash or not respond. Those parameters were previously intialized in the background if not

explicitly defined by the user. The tags of those parameters are now mandatory in the `model.json` and are initialized with default parameters. The use of the default parameters results in the same behaviour as not explicitly specifying them in BASEMENT version 2.8.2 and earlier.

4.2.3.2 Known Issues

BASEplane

- The upstream and downstream stringdefs of the inner boundary weir must be of the same length, otherwise mass might not be conserved.

BASEchain

- Fixed bed starts eroding if both suspended load and bed load transport are activated if the suspended load is below transport capacity.
- Van Rijn formula does not result in any sediment being transported (1D-model).

Note: Existing installations are not automatically detected by the updated installer. Therefore uninstall any previous version of BASEMENT e.g. using the link in the Start Menu before installing the newest version.

4.3 Version 4.0

4.3.1 General

BASEMENT version 4 consists of two modules, BASEMD and BASEHPC; MD stands for “Multi-Domain” and corresponds to the previous version 2.8.2, HPC stands for “High-Performance Computing” and corresponds to the previous version 3.2. Thus, all features from the two previous versions are retained and integrated into a common simulation workflow. The selection of the modules occurs via the keywords “BASEHPC” or “BASEMD” in the model definition file.

- BASEMENT now provides an installer package for Ubuntu 22.04, while the version for Ubuntu 16.04 was discontinued. Also, BASEMENT now requires CUDA 11.7.0.
- Keys in JSON configuration files were sorted by the GUI. This problem has been fixed.
- The trees representing the JSON files in the GUI are now expanded by default.
- Items in JSON objects can now be reordered using the GUI via drag and drop.
- The 1-D Grid Editor previously contained in version 2.8.2 is now integrated into the GUI of version 4.
- The migration of existing simulations from version 2.8.2 and 3.2 to version 4 are described in the migration guide (Section [3.1](#))

4.3.2 Known Issues

- Model setup fails if there is a dot ‘.’ in the working directory path. For example: “MySimulations/Sim1.1/” does not work, while “MySimulations/Sim1_1/” works.
- Aborting a simulation using Ctrl+C can corrupt the HDF5 result file.
- Tool tip text is too long to be displayed completely.
- Abort bottom may no work as intended, i.e. simulation does not stop.

4.3.3 Module BASEHPC

4.3.3.1 Bug fixes

- A bug causing a segmentation fault when using the MORPHOLOGY and TRACER block has been fixed.

4.3.4 Module BASEMD

4.3.4.1 General

BASEplane

- Implementation of time range for controller. Within the time range, the controller will be active (manipulated variable is based on PID/HID control). Outside of the time range, a default value for the manipulated variable must be specified.
- The CGNS format for saving simulation states was discontinued and replaced by the .h5 format. Existing CGNS files may be converted to the .h5 format with a Python-script provided on the website.

4.3.4.2 Bug fixes

BASEchain

- A bug in the gravitational transport feature for mixed size sediment transport has been fixed.
- A bug in the implementation of the hiding_exponent (mpm_h and parker formulation) in mixed size sediment transport has been fixed.

4.3.4.3 Known Issues

BASEplane

- The upstream and downstream stringdefs of the inner boundary weir must be of the same length, otherwise mass might not be conserved.

BASEchain

- Fixed bed starts eroding if both suspended load and bed load transport are activated if the suspended load is below transport capacity.
- Van Rijn formula does not result in any sediment being transported (1D-model).

Note: Existing installations are not automatically detected by the updated installer. Therefore uninstall any previous version of BASEMENT e.g. using the link in the Start Menu before installing the newest version.

4.4 Notes on older releases

Release notes of previous version can be found on the webpage: <https://basement.ethz.ch/download/software-download/release-notes>

Summary of Features Version 4.0

5.1 Features of module BASEMD

5.1.1 Submodule BASEchain

5.1.1.1 Numerics

Spatial Discretization	Finite Volumes
Time Integration	explicit Euler
Riemann Solvers	Roe, HLL, upwind

5.1.1.2 Geometry

Type	Cross sections : simple, composite (flood plains, main channel)
Slices	Friction and soil description, no flow consideration
Mobile bed	Fixed bed consideration, uniform distribution of deposition and erosion over wetted part of cross section, partially wetted soils (suspended load)
Input Formats	BASEMENT (*.bmg)

5.1.1.3 Hydrodynamics

Model	1D Saint-Venant equations
Conservative Variables	A (continuity), Q (momentum)
Source Terms	Friction (semi-implicite), bed slope, lateral source/sink
Friction	Strickler (kstr), Manning (n), grain size friction
Determination of $z(A)$	Interpolation from table or iteration or consideration of levees

Boundary Conditions	Wall, hydrographs, hQ-relation, in/out, zhydrograph, weir, gate, multiple boundary, zero_gradient
Initial Conditions	Sub-critical backwater calculation, dry, from input file
Inner boundary	Weir/Gate

5.1.1.4 Sediment Transport: Bed load

Model	Hirano-Exner equation, sorting equation for sediment mixtures
Transport Formula	MPM, MPM-multi, power law, MPM-H, Parker, Rickenmann, Smart-Jaeggi, Smart-Jaeggi-multi, Wu, Van Rijn, parametrized shear stress, abrasion-law of Sternberg, Wilcock and Crowe, Engelund and Hansen, Ashida and Michiue
Boundary Conditions	Hydrograph, IOUp and IODown, transport capacity, fractionated hydrograph
Active Layer	Constant, variable thickness
Source Terms	Local source/sink, dredge source, bed-load function

5.1.1.5 Sediment transport : Suspended load

Transport Equation	Advection-Diffusion Equation
Discretization	QUICK, QUICKEST, Holly-Preissmann, MDPM, Upwind
Exchange Terms	Concentration: Van Rijn, Zyserman et al., constant factor Shear stresses: Xu
Source Terms	Local source/sink

5.1.1.6 Sediment transport : Gravitational induced transport

Approach	Geometrical modelling in longitudinal direction (1D) based on critical failure angles
Features	Single and multiple grain classes

5.1.1.7 Output Variables/Formats

- Variables

General Information	Geometry and characteristics of cross sections
Bed load	Total and for each grain class
Grain mixtures	For each cross section, slice and layer

- Format

Standard output	Talweg: z_{dam} (left/right), z_{bottom} (mean), friction, Q_b^{cap} , C_{tot} Cross section: Water surface elevation WSE, energy level EL, velocity v , wetted area A , discharge Q , Froude number Fr , friction
Special output	Edge: continuity flux, momentum flux, $Q_{b,i}$, Q_s^{adv} , Q_s^{diff} Tecplot Format: Bed level, water surface elevation, energy level, discharge, wetted area, dike levels, bed load, grain class concentrations and suspended sediment concentration in active layer Monitoring Output: Q , Q_b , A , WSE, v , geometry, C , b (=mean bottom level), energy_line (EL), Fr , h (=mean flow depth) Restart files: Hydrodynamics, bedload, suspended load Volume files: Variation of water volume, variation of sediment volume, suspended sediment volume, transport capacity volume

5.1.2 Submodule BASEplane

5.1.2.1 Numerics

Spatial Discretization	Finite Volumes
Time Integration	explicit Euler
Riemann Solvers	exact, HLL, HLLC

5.1.2.2 Geometry

Cell/Grid Type	Triangular, quadrilateral, hybrid
Mobile bed	Fixed bed consideration, bed armor consideration, uniform distribution of deposition and erosion over wet elements
Input Formats	Grid-file *.2dm (SMS, QGIS)
Moving bed	User enforced vertical movement of selected nodes

5.1.2.3 Hydrodynamics

Model	Shallow Water Equations
Conservative Variables	h , $u \cdot h$, $v \cdot h$
Source Terms	Friction, bed slope, local discharge source/sink, diffusive fluxes (kinematic and turbulent viscosity)
Friction	Strickler (roughness k_{str}), Manning (roughness n), Chézy, Darcy-Weissbach, Log. friction law, Yalin, Bezzola
Boundary Conditions	Wall, inlet (hydrograph), outlet (weir, gate, zero gradient, h - Q relation, z Hydrograph), inner boundaries (inner weir, inner gate)
Initial Conditions	Dry, user defined condition (based on material index), continuing old simulation

5.1.2.4 Sediment Transport: Bed load

Model	Hirano-Exner equation, sorting equation for sediment mixtures
Transport Formula	MPM, MPM-multi, power law, MPM-H, Parker, Rickenmann, Smart-Jaeggi, Wu, Van Rijn, Wilcock and Crowe, Engelund and Hansen, Ashida and Michiue
Direction	lateral bed slope effect (Ikeda), curvature effect (Engelund)
Boundary Conditions	Wall, inlet (hydrograph, transport capacity), outlet (outflow = inflow), inner boundaries (open, weir)
Active Layer	Constant, variable thickness
External source Terms	Local source/sink, dredge source

5.1.2.5 Sediment transport : Suspended load

Transport Equation	Advection-Diffusion Equation
Discretization	Upwind-Scheme
Exchange Terms	Van Rijn of Zyserman et al./Lin
Source Terms	Local source/sink

5.1.2.6 Sediment transport : Gravitational induced transport

Approach	Geometrical modelling based on critical failure angles
Features	Unstructured mesh, single and multiple grain classes

5.1.2.7 Output Variables/Formats

- Variables

General Information	Input file, element data (water depth, velocities, bed shear stress, etc), node data (bed elevation, etc), balances
Bed load	Element data (theta_critical, etc.), node data (bedload, delta_z, etc.)
Grain mixtures	Grain size distribution for selected elements

- Format

Standard output	SMS Format and ASCII tables
Monitoring Output	String discharge, Boundaries, Balances, Debug-output
Time History	Time history of selected elements, nodes or edges
Additional Formats	Tecplot, Shape (GIS), AVS-UCD, VTK (Paraview)
Restart file	Binary format (CGNS), hydraulic computation, bed load computation, suspended load computation

5.1.3 Submodule BASEsub

5.1.3.1 Numerics

Spatial Discretization	LBM (Lattice-Boltzmann Method)
Time Integration	explicit Euler

5.1.3.2 Geometry

Cell/Grid Types	Structured mesh, cubic cells
Input Formats	Self-generated block mesh, parts can be de-activated

5.1.3.3 Hydrodynamics

Model	3-D Richards equations, Saturation-formulation, mixed Saturation-Pressure formulation
Primary Variables	Effective water saturation, Pore-water pressure
Source Terms	Water source (infiltration)
Constitutive Models, Material properties	Van Genuchten-Mualem, Brooks-Corey, kf-conductivity value of soil
Boundary Conditions	Bounce-back boundary, Pressure boundary, Effective water saturation boundary, Seepage boundary
Initial Conditions	Constant values: Pores-water pressure, effective water saturation Hydrostatic pressure distribution Hot-start from old simulation file

5.1.3.4 Output Variables/Formats

- Variables:
 - Primary variables: Effective water saturation, pore-water pressure
 - Secondary variables: Darcy velocities

General Information Cut-plane or cul-lines through 3-D mesh, seepage line

- Format

Standard output	ASCII (Gnuplot)
Additional Formats	Tecplot, SMS/QGIS
Restart file	Binary file containing values of probability distribution functions

5.2 Features of module BASEHPC

5.2.1 Hydrodynamics

Riemann Solver

- HLLC, with hydrostatic reconstruction based on modified states (Duran et al., 2013).

Hydraulic Initial Conditions

- Dry
- Continue
- Region defined (regiondef) for water surface elevation or water depth, u and v

Parameters

- CFL
- Minimum water depth
- Fluid density
- Maximum time step

Boundary Conditions

- WALL : inviscid, default
- STANDARD (in parenthesis user-required data):
 - INFLOW: uniform (discharge; slope), froude (discharge, froude number), hq_relation (H-Q relation), zhydrograph (water surface elevation, inflowPossible)
 - OUTFLOW: uniform (slope), zero_gradient (-), weir (weir height, constant or dynamic poleni factor), hq_relation (H-Q relation), dynamic wall (collapse time), zhydrograph (water surface elevation, inflowPossible)
- INTERNAL: dynamic wall (collapse time), internal wall (-), hq_relation (H-Q relation)
- LINKED: hq_relation (H-Q relation), 2 way hq_relation (2 H-Q relations, time lag, water surface elevation upstream and downstream), weir (weir height, constant or dynamic poleni factor), zhydrograph (water surface elevation)

Inflow boundary conditions for INTERNAL and LINKED boundaries: - no_momentum: no momentum flux over the boundary. - froude_downstream: momentum flux calculated based on Froude number in the elements of the downstream nodestring. - froude: momentum flux calculated based on the Froude number specified via the parameter *froude_number*. - uniform: momentum flux calculated based on uniform flow conditions for the slope specified via the parameter *slope*.

Friction

- Type: implicit Runge-Kutta 2nd order integration
- Closure types:
 - Manning
 - Strickler
 - Chezy
 - Bezzola

All require a default (or index defined) friction value.

Turbulence

- Parameters:
 - Turbulence start time
 - On/off switch for diffusion of turbulent species (tke, epsilon)
 - Relaxation parameter for turbulent diffusion
 - On/off switch for friction generated turbulence
- Closure model for Reynolds stress:
 - Constant viscosity (default)
 - k-epsilon model
 - Mixing length model
- Initial conditions:
 - Zero, i.e. no turbulence (default)
 - Uniform values for tke and epsilon
 - Region defined values for tke and epsilon
 - Continue
- Boundary conditions (k-epsilon model)
 - STANDARD: k_eps_in, zero_gradient_out
- Source:
 - Type: k_eps (force k-epsilon values directly)
 - Sink behaviours: exact (as prescribed), available (as prescribed or less), infinity (as much as possible)

Flood

- Flood tracking of water front arrival time, maximum water depth, maximum flow velocity, maximum specific discharge, maximum bed shear stress (tracking time step)

Source (water volume)

- Type: total (as discharge, m³/s), distributed (as rain, mm/h)
- Sink behaviors:
 - Exact (as prescribed)
 - Available (as prescribed or less)
 - Infinity (as much as possible)

5.2.2 Morphodynamics

5.2.2.1 Bed load transport

- HLL-type Approximate Riemann Solver (Soares-Frazão and Zech, 2011)

Parameters

- Morphodynamic start time
- Sediment porosity
- Sediment density

Initial conditions

- Mesh file
- Continue

Incipient motion

- van Rijn (1989) and Chen et al. (2010)
- Angle of repose

Closure formula

- MPM (coefficient = 8, exponent = 15, critical threshold = 0.047)
- MPM-like (coefficient, exponent, critical threshold are adaptable)
- GRASS-like (coefficient, exponent, critical threshold are adaptable)
- Engelund and Hansen
- Smart and Jaeggi (1983)

Direction

- Lateral bed slope effect (e.g. Ikeda, 1982, p. Talmon1995)
- Curvature effect

Bedload boundary conditions

- WALL: inviscid, default
- STANDARD:
 - INFLOW: equilibrium (reference_bed_elevation), sedimentograph (sediment_discharge), transport capacity (boundary_factor)
 - OUTFLOW: equilibrium (reference_bed_elevation)
 - Weighting scheme for transport capacity and sedimentograph: geometrical (default), wetted area, conveyance
- LINKED: equilibrium (reference_bed_elevation at upstream boundary)

Bed material

- Grain class
- Fixed bed

Gravitational Transport

- Critical angle for wet/dry material
- update time step
- maximum settling velocity
- minimum bed elevation change

Source (sediment volume)

- Type: total (as discharge, m³/s)
- Sink behaviors:
 - Exact (as prescribed)
 - Available (as prescribed or less)
 - Infinity (as much as possible)

5.2.2.2 Suspended load transport

Parameters

- Relaxation parameter
- Diffusivity coefficient (isotropic, longitudinal/transversal)
- Turbulent diffusivity coefficient (isotropic, longitudinal/transversal)
- Scaling (beta) factor for the suspended source terms

Settling Velocity

- Closure model for the grain settling velocity:

- Van Rijn
- Wu and Wang
- Zhang
- Shape factor parameter (

Shear partition

- Skin friction parameter for suspended load computations
- Default value or region defined

Erosion rate

- Closure model for the erosion rate:
 - Van Rijn
 - Zyserman and Fredsoe
- Critical shields parameter (both)

Deposition rate

- Closure model for the deposition rate:
 - Lin
 - Xu
- Critical shields parameter (Xu)

Initial conditions

- Zero, i.e. no suspended load concentration (default)
- Uniform initial concentration
- Region defined values for concentration
- Continue

Boundary conditions

- STANDARD:
 - INFLOW: concentration_in, discharge_in, discharge_in_warea
 - OUTFLOW: zero_gradient_out

Source (suspended sediment volume)

- Type: total (as discharge, m³/s) or concentration (-)
- Sink behaviors:
 - Exact (as prescribed)
 - Available (as prescribed or less)
 - Infinity (as much as possible)

5.2.3 Tracers

Parameters

- Tracer start time
- Number of tracers (max. 5)
- Molecular diffusivity coefficient (isotropic, longitudinal/transversal)
- Turbulent diffusivity coefficient (isotropic, longitudinal/transversal)

Initial conditions

- Zero, i.e. no tracer concentration (default)
- Uniform initial concentration
- Region defined values for concentration
- Continue

Boundary conditions

- STANDARD:
 - INFLOW: concentration_in, discharge_in, discharge_in_warea
 - OUTFLOW: zero_gradient_out

Source (tracer volume)

- Type: total (as discharge, m³/s) or concentration (-)
- Sink behaviors:
 - Exact (as prescribed)
 - Available (as prescribed or less)
 - Infinity (as much as possible)

5.2.4 Vegetation

Parameters:

- Flow resistance modification (Strickler approach)
- Shear stress partitioning
- Critical Shields parameter modification (with MPM formula)
- Vegetation uprooting
- Plant burial

Initial conditions:

- Continue
- Region defined (regiondef)

Output variables:

- Aboveground biomass [-]
- Belowground biomass [-]
- Rooting depth [m]

5.2.5 Output Variables Summary

The output are generated on the mesh elements (cell centered) or at nodestrings and are stored in a binary file format (.h5).

The output type available are summarized in Table 5.22.

Table 5.22 Output types and description.

Output	Description
Cell-centered	
water_surface	Water surface elevation [m]
water_depth	Water depth [m]
bottom_elevation	Bottom elevation [m]
friction_chezy	Dimensionless squared chezy friction coefficient [-]
delta_z	Change in bottom elevation of during the course of the simulation [m]
spec_discharge	Specific hydraulic discharge (q_x, q_y) [m ² /s]
flow_velocity	Flow velocity (u_x, u_y) [m/s]
turb_k	Turbulent kinetic energy (κ) [m ² /s ²]
turb_reynolds	Turbulent Reynolds stresses [Nm/m ²]
flow_velocity	Flow velocity (u_x, u_y) [m/s]
flow_curvature	Flow curvature (inverse of flow radius) [m ⁻¹]
flow_radius	Flow radius [m]
theta	Non-dimensional effective bed shear stress for bedload transport [-]
theta_critical	Non-dimensional critical bed shear stress [-]

Output	Description
trsp_capacity	Bedload transport capacity ($q_{b,x}$, $q_{b,y}$) [m^2/s] as compact volume, no porosity
trsp_capacity_abs	Bedload transport capacity magnitude q_b [m^2/s] as compact volume, no porosity
suspended_conc	Suspended sediment concentration [-]
suspended_theta	Non-dimensional effective bed shear stress for suspended sediment transport [-]
bed_gradient	Local bed gradient ($\partial z/\partial x$, $\partial z/\partial y$) [-]
flood_tracking	Water front arrival time [s] Max. water depth [m] Max. flow velocity [m/s] Max. specific discharge [m^2/s] Max. bed shear stress [Pa]
tracer1-5	Concentration of tracer specie 1 [-] ... Concentration of tracer specie 5 [-]
aboveground_biomass	Above ground biomass of vegetation [-]
belowground_biomass	Above ground biomass of vegetation [-]
rooting_depth	Rooting depth of vegetation [m]
Nodestring	
ns_hyd_discharge	Hydraulic output variables on the Nodestrings
ns_mor_discharge	Morphologic output variables on the Nodestrings

6

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**BASIC SIMULATION ENVIRONMENT
FOR MODELLING OF ENVIRONMENTAL
FLOWS AND NATURAL HAZARDS**

APPENDIX

**VERSION 4.0.2
OCTOBER 2023**



BASEMENT

Third Party Software

1.1 Third party software licenses

Abseil

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Version 2.0, January 2004
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Julian Seward, jseward@acm.org
bzip2/libbzip2 version 1.0.8 of 13 July 2019

Curl

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Mesa 3-D graphics library
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However, unrestricted linking of non-free programs would deprive the users of those programs of all benefit from the free status of the libraries themselves. This Library General Public License is intended to permit developers of non-free programs to use free libraries, while preserving your freedom as a user of such programs to change the free libraries that are incorporated in them. (We have not seen how to achieve this as regards changes in header files, but we have achieved it as regards changes in the actual functions of the Library.) The hope is that this will lead to faster development of free libraries.

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table, the facility still operates, and performs whatever part of its purpose remains meaningful.

(For example, a function in a library to compute square roots has a purpose that is entirely well-defined independent of the application. Therefore, Subsection 2d requires that any application-supplied function or table used by this function must be optional: if the application does not supply it, the square root function must still compute square roots.)

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This option is useful when you wish to copy part of the code of the Library into a program that is not a library.

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It may happen that this requirement contradicts the license

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To apply these terms, attach the following notices to the library. It is safest to attach them to the start of each source file to most effectively convey the exclusion of warranty; and each file should have at least the "copyright" line and a pointer to where the full notice is found.

```
<one line to give the library's name and a brief idea of what it does.>
Copyright (C) <year> <name of author>
```

```
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modify it under the terms of the GNU Library General Public
License as published by the Free Software Foundation; either
version 2 of the License, or (at your option) any later version.
```

```
This library is distributed in the hope that it will be useful,
but WITHOUT ANY WARRANTY; without even the implied warranty of
MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU
Library General Public License for more details.
```

```
You should have received a copy of the GNU Library General Public
License along with this library; if not, write to the Free
Software Foundation, Inc., 51 Franklin Street, Fifth Floor, Boston,
MA 02110-1301, USA
```

Also add information on how to contact you by electronic and paper mail.

You should also get your employer (if you work as a programmer) or your school, if any, to sign a "copyright disclaimer" for the library, if necessary. Here is a sample; alter the names:

```
Yoyodyne, Inc., hereby disclaims all copyright interest in the
library `Frob' (a library for tweaking knobs) written by James Random Hacker.
```

```
<signature of Ty Coon>, 1 April 1990
Ty Coon, President of Vice
```

That's all there is to it!

Libjpeg-turbo

libjpeg-turbo Licenses =====

libjpeg-turbo is covered by three compatible BSD-style open source licenses:

- The IJG (Independent JPEG Group) License, which is listed in [README.ijg] (README.ijg)

```
This license applies to the libjpeg API library and associated programs
(any code inherited from libjpeg, and any modifications to that code.)
```

- The Modified (3-clause) BSD License, which is listed below

```
This license covers the TurboJPEG API library and associated programs, as
well as the build system.
```

- The [zlib License] (<https://opensource.org/licenses/Zlib>)

```
This license is a subset of the other two, and it covers the libjpeg-turbo
SIMD extensions.
```

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1. You cannot alter or remove any existing copyright or license notices from the source.

```

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- Clause 1 of the Modified BSD License
- Clauses 1 and 3 of the zlib License

```

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```

**Origin**
- Clause 1 of the IJG License
- Clause 2 of the zlib License

```

3. You must include the IJG README file, and you must not alter any of the copyright or license text in that file.

```

**Origin**
- Clause 1 of the IJG License

```

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```

This software is based in part on the work of the Independent JPEG
Group.

```

```

**Origin**
- Clause 2 of the IJG license

```

2. If your binary distribution includes or uses the TurboJPEG API, then your product documentation must include the text of the Modified BSD License (see below.)

```

**Origin**
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```

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```

**Origin**
- IJG License
- Clause 3 of the Modified BSD License

```

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```

**Origin**
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- Modified BSD License
- zlib License

```

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 =====

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Why Three Licenses?

=====

The zlib License could have been used instead of the Modified (3-clause) BSD License, and since the IJG License effectively subsumes the distribution conditions of the zlib License, this would have effectively placed libjpeg-turbo binary distributions under the IJG License. However, the IJG License specifically refers to the Independent JPEG Group and does not extend attribution and endorsement protections to other entities. Thus, it was desirable to choose a license that granted us the same protections for new code that were granted to the IJG for code derived from their software.

Liblzma

XZ Utils Licensing

=====

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- xz, xzdec, and lzmadec command line tools are in the public domain unless GNU getopt_long had to be compiled and linked in from the lib directory. The getopt_long code is under GNU LGPLv2.1+.
- The scripts to grep, diff, and view compressed files have been adapted from gzip. These scripts and their documentation are under GNU GPLv2+.
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- Translated messages are in the public domain.
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- Test files and test code in the tests directory, and debugging utilities in the debug directory are in the public domain.
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If you have questions, don't hesitate to ask the author(s) for more information.

Libogg

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For example, if you distribute copies of the library, whether gratis or for a fee, you must give the recipients all the rights that we gave you. You must make sure that they, too, receive or can get the source code. If you link other code with the library, you must provide complete object files to the recipients, so that they can relink them with the library after making changes to the library and recompiling it. And you must show them these terms so they know their rights.

We protect your rights with a two-step method: (1) we copyright the library, and (2) we offer you this license, which gives you legal permission to copy, distribute and/or modify the library.

To protect each distributor, we want to make it very clear that there is no warranty for the free library. Also, if the library is modified by someone else and passed on, the recipients should know that what they have is not the original version, so that the original author's reputation will not be affected by problems that might be introduced by others.

Finally, software patents pose a constant threat to the existence of any free program. We wish to make sure that a company cannot effectively restrict the users of a free program by obtaining a restrictive license from a patent holder. Therefore, we insist that any patent license obtained for a version of the library must be consistent with the full freedom of use specified in this license.

Most GNU software, including some libraries, is covered by the ordinary GNU General Public License. This license, the GNU Lesser General Public License, applies to certain designated libraries, and is quite different from the ordinary General Public License. We use this license for certain libraries in order to permit linking those libraries into non-free programs.

When a program is linked with a library, whether statically or using a shared library, the combination of the two is legally speaking a combined work, a derivative of the original library. The ordinary General Public License therefore permits such linking only if the entire combination fits its criteria of freedom. The Lesser General Public License permits more lax criteria for linking other code with the library.

We call this license the "Lesser" General Public License because it does Less to protect the user's freedom than the ordinary General Public License. It also provides other free software developers Less of an advantage over competing non-free programs. These disadvantages are the reason we use the ordinary General Public License for many libraries. However, the Lesser license provides advantages in certain special circumstances.

For example, on rare occasions, there may be a special need to encourage the widest possible use of a certain library, so that it becomes a de-facto standard. To achieve this, non-free programs must be allowed to use the library. A more frequent case is that a free

library does the same job as widely used non-free libraries. In this case, there is little to gain by limiting the free library to free software only, so we use the Lesser General Public License.

In other cases, permission to use a particular library in non-free programs enables a greater number of people to use a large body of free software. For example, permission to use the GNU C Library in non-free programs enables many more people to use the whole GNU operating system, as well as its variant, the GNU/Linux operating system.

Although the Lesser General Public License is Less protective of the users' freedom, it does ensure that the user of a program that is linked with the Library has the freedom and the wherewithal to run that program using a modified version of the Library.

The precise terms and conditions for copying, distribution and modification follow. Pay close attention to the difference between a "work based on the library" and a "work that uses the library". The former contains code derived from the library, whereas the latter must be combined with the library in order to run.

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A "library" means a collection of software functions and/or data prepared so as to be conveniently linked with application programs (which use some of those functions and data) to form executables.

The "Library", below, refers to any such software library or work which has been distributed under these terms. A "work based on the Library" means either the Library or any derivative work under copyright law: that is to say, a work containing the Library or a portion of it, either verbatim or with modifications and/or translated straightforwardly into another language. (Hereinafter, translation is included without limitation in the term "modification".)

"Source code" for a work means the preferred form of the work for making modifications to it. For a library, complete source code means all the source code for all modules it contains, plus any associated interface definition files, plus the scripts used to control compilation and installation of the library.

Activities other than copying, distribution and modification are not covered by this License; they are outside its scope. The act of running a program using the Library is not restricted, and output from such a program is covered only if its contents constitute a work based on the Library (independent of the use of the Library in a tool for writing it). Whether that is true depends on what the Library does and what the program that uses the Library does.

1. You may copy and distribute verbatim copies of the Library's complete source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice and disclaimer of warranty; keep intact all the notices that refer to this License and to the absence of any warranty; and distribute a copy of this License along with the Library.

You may charge a fee for the physical act of transferring a copy, and you may at your option offer warranty protection in exchange for a fee.

2. You may modify your copy or copies of the Library or any portion

of it, thus forming a work based on the Library, and copy and distribute such modifications or work under the terms of Section 1 above, provided that you also meet all of these conditions:

- a) The modified work must itself be a software library.
- b) You must cause the files modified to carry prominent notices stating that you changed the files and the date of any change.
- c) You must cause the whole of the work to be licensed at no charge to all third parties under the terms of this License.
- d) If a facility in the modified Library refers to a function or a table of data to be supplied by an application program that uses the facility, other than as an argument passed when the facility is invoked, then you must make a good faith effort to ensure that, in the event an application does not supply such function or table, the facility still operates, and performs whatever part of its purpose remains meaningful.

(For example, a function in a library to compute square roots has a purpose that is entirely well-defined independent of the application. Therefore, Subsection 2d requires that any application-supplied function or table used by this function must be optional: if the application does not supply it, the square root function must still compute square roots.)

These requirements apply to the modified work as a whole. If identifiable sections of that work are not derived from the Library, and can be reasonably considered independent and separate works in themselves, then this License, and its terms, do not apply to those sections when you distribute them as separate works. But when you distribute the same sections as part of a whole which is a work based on the Library, the distribution of the whole must be on the terms of this License, whose permissions for other licensees extend to the entire whole, and thus to each and every part regardless of who wrote it.

Thus, it is not the intent of this section to claim rights or contest your rights to work written entirely by you; rather, the intent is to exercise the right to control the distribution of derivative or collective works based on the Library.

In addition, mere aggregation of another work not based on the Library with the Library (or with a work based on the Library) on a volume of a storage or distribution medium does not bring the other work under the scope of this License.

3. You may opt to apply the terms of the ordinary GNU General Public License instead of this License to a given copy of the Library. To do this, you must alter all the notices that refer to this License, so that they refer to the ordinary GNU General Public License, version 2, instead of to this License. (If a newer version than version 2 of the ordinary GNU General Public License has appeared, then you can specify that version instead if you wish.) Do not make any other change in these notices.

Once this change is made in a given copy, it is irreversible for that copy, so the ordinary GNU General Public License applies to all subsequent copies and derivative works made from that copy.

This option is useful when you wish to copy part of the code of the Library into a program that is not a library.

4. You may copy and distribute the Library (or a portion or derivative of it, under Section 2) in object code or executable form under the terms of Sections 1 and 2 above provided that you accompany it with the complete corresponding machine-readable source code, which must be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange.

If distribution of object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place satisfies the requirement to distribute the source code, even though third parties are not compelled to copy the source along with the object code.

5. A program that contains no derivative of any portion of the Library, but is designed to work with the Library by being compiled or linked with it, is called a "work that uses the Library". Such a work, in isolation, is not a derivative work of the Library, and therefore falls outside the scope of this License.

However, linking a "work that uses the Library" with the Library creates an executable that is a derivative of the Library (because it contains portions of the Library), rather than a "work that uses the library". The executable is therefore covered by this License. Section 6 states terms for distribution of such executables.

When a "work that uses the Library" uses material from a header file that is part of the Library, the object code for the work may be a derivative work of the Library even though the source code is not. Whether this is true is especially significant if the work can be linked without the Library, or if the work is itself a library. The threshold for this to be true is not precisely defined by law.

If such an object file uses only numerical parameters, data structure layouts and accessors, and small macros and small inline functions (ten lines or less in length), then the use of the object file is unrestricted, regardless of whether it is legally a derivative work. (Executables containing this object code plus portions of the Library will still fall under Section 6.)

Otherwise, if the work is a derivative of the Library, you may distribute the object code for the work under the terms of Section 6. Any executables containing that work also fall under Section 6, whether or not they are linked directly with the Library itself.

6. As an exception to the Sections above, you may also combine or link a "work that uses the Library" with the Library to produce a work containing portions of the Library, and distribute that work under terms of your choice, provided that the terms permit modification of the work for the customer's own use and reverse engineering for debugging such modifications.

You must give prominent notice with each copy of the work that the Library is used in it and that the Library and its use are covered by this License. You must supply a copy of this License. If the work during execution displays copyright notices, you must include the copyright notice for the Library among them, as well as a reference directing the user to the copy of this License. Also, you must do one of these things:

a) Accompany the work with the complete corresponding machine-readable source code for the Library including whatever changes were used in the work (which must be distributed under Sections 1 and 2 above); and, if the work is an executable linked with the Library, with the complete machine-readable "work that uses the Library", as object code and/or source code, so that the user can modify the Library and then relink to produce a modified executable containing the modified Library. (It is understood that the user who changes the contents of definitions files in the Library will not necessarily be able to recompile the application to use the modified definitions.)

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the user installs one, as long as the modified version is interface-compatible with the version that the work was made with.

- c) Accompany the work with a written offer, valid for at least three years, to give the same user the materials specified in Subsection 6a, above, for a charge no more than the cost of performing this distribution.
- d) If distribution of the work is made by offering access to copy from a designated place, offer equivalent access to copy the above specified materials from the same place.
- e) Verify that the user has already received a copy of these materials or that you have already sent this user a copy.

For an executable, the required form of the "work that uses the Library" must include any data and utility programs needed for reproducing the executable from it. However, as a special exception, the materials to be distributed need not include anything that is normally distributed (in either source or binary form) with the major components (compiler, kernel, and so on) of the operating system on which the executable runs, unless that component itself accompanies the executable.

It may happen that this requirement contradicts the license restrictions of other proprietary libraries that do not normally accompany the operating system. Such a contradiction means you cannot use both them and the Library together in an executable that you distribute.

7. You may place library facilities that are a work based on the Library side-by-side in a single library together with other library facilities not covered by this License, and distribute such a combined library, provided that the separate distribution of the work based on the Library and of the other library facilities is otherwise permitted, and provided that you do these two things:

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- b) Give prominent notice with the combined library of the fact that part of it is a work based on the Library, and explaining where to find the accompanying uncombined form of the same work.

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```

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```
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library `Frob' (a library for tweaking knobs) written by James Random Hacker.
```

```
<signature of Ty Coon>, 1 April 1990
Ty Coon, President of Vice
```

That's all there is to it!

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[This is the first released version of the library GPL. It is numbered 2 because it goes with version 2 of the ordinary GPL.]

Preamble

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To protect your rights, we need to make restrictions that forbid anyone to deny you these rights or to ask you to surrender the rights. These restrictions translate to certain responsibilities for you if you distribute copies of the library, or if you modify it.

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Our method of protecting your rights has two steps: (1) copyright the library, and (2) offer you this license which gives you legal permission to copy, distribute and/or modify the library.

Also, for each distributor's protection, we want to make certain that everyone understands that there is no warranty for this free library. If the library is modified by someone else and passed on, we want its recipients to know that what they have is not the original version, so that any problems introduced by others will not reflect on the original authors' reputations.

Finally, any free program is threatened constantly by software patents. We wish to avoid the danger that companies distributing free software will individually obtain patent licenses, thus in effect transforming the program into proprietary software. To prevent this, we have made it clear that any patent must be licensed for everyone's free use or not licensed at all.

Most GNU software, including some libraries, is covered by the ordinary GNU General Public License, which was designed for utility programs. This license, the GNU Library General Public License, applies to certain designated libraries. This license is quite different from the ordinary one; be sure to read it in full, and don't assume that anything in it is the same as in the ordinary license.

The reason we have a separate public license for some libraries is that they blur the distinction we usually make between modifying or adding to a program and simply using it. Linking a program with a library, without changing the library, is in some sense simply using the library, and is analogous to running a utility program or application program. However, in a textual and legal sense, the linked executable is a combined work, a derivative of the original library, and the ordinary General Public License treats it as such.

Because of this blurred distinction, using the ordinary General Public License for libraries did not effectively promote software sharing, because most developers did not use the libraries. We concluded that weaker conditions might promote sharing better.

However, unrestricted linking of non-free programs would deprive the users of those programs of all benefit from the free status of the libraries themselves. This Library General Public License is intended to permit developers of non-free programs to use free libraries, while preserving your freedom as a user of such programs to change the free libraries that are incorporated in them. (We have not seen how to achieve this as regards changes in header files, but we have achieved it as regards changes in the actual functions of the Library.) The hope is that this will lead to faster development of free libraries.

The precise terms and conditions for copying, distribution and modification follow. Pay close attention to the difference between a "work based on the library" and a "work that uses the library". The former contains code derived from the library, while the latter only works together with the library.

Note that it is possible for a library to be covered by the ordinary General Public License rather than by this special one.

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You may charge a fee for the physical act of transferring a copy, and you may at your option offer warranty protection in exchange for a

fee.

2. You may modify your copy or copies of the Library or any portion of it, thus forming a work based on the Library, and copy and distribute such modifications or work under the terms of Section 1 above, provided that you also meet all of these conditions:

- a) The modified work must itself be a software library.
- b) You must cause the files modified to carry prominent notices stating that you changed the files and the date of any change.
- c) You must cause the whole of the work to be licensed at no charge to all third parties under the terms of this License.
- d) If a facility in the modified Library refers to a function or a table of data to be supplied by an application program that uses the facility, other than as an argument passed when the facility is invoked, then you must make a good faith effort to ensure that, in the event an application does not supply such function or table, the facility still operates, and performs whatever part of its purpose remains meaningful.

(For example, a function in a library to compute square roots has a purpose that is entirely well-defined independent of the application. Therefore, Subsection 2d requires that any application-supplied function or table used by this function must be optional: if the application does not supply it, the square root function must still compute square roots.)

These requirements apply to the modified work as a whole. If identifiable sections of that work are not derived from the Library, and can be reasonably considered independent and separate works in themselves, then this License, and its terms, do not apply to those sections when you distribute them as separate works. But when you distribute the same sections as part of a whole which is a work based on the Library, the distribution of the whole must be on the terms of this License, whose permissions for other licensees extend to the entire whole, and thus to each and every part regardless of who wrote it.

Thus, it is not the intent of this section to claim rights or contest your rights to work written entirely by you; rather, the intent is to exercise the right to control the distribution of derivative or collective works based on the Library.

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Once this change is made in a given copy, it is irreversible for that copy, so the ordinary GNU General Public License applies to all subsequent copies and derivative works made from that copy.

This option is useful when you wish to copy part of the code of the Library into a program that is not a library.

4. You may copy and distribute the Library (or a portion or derivative of it, under Section 2) in object code or executable form under the terms of Sections 1 and 2 above provided that you accompany

it with the complete corresponding machine-readable source code, which must be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange.

If distribution of object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place satisfies the requirement to distribute the source code, even though third parties are not compelled to copy the source along with the object code.

5. A program that contains no derivative of any portion of the Library, but is designed to work with the Library by being compiled or linked with it, is called a "work that uses the Library". Such a work, in isolation, is not a derivative work of the Library, and therefore falls outside the scope of this License.

However, linking a "work that uses the Library" with the Library creates an executable that is a derivative of the Library (because it contains portions of the Library), rather than a "work that uses the library". The executable is therefore covered by this License. Section 6 states terms for distribution of such executables.

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6. As an exception to the Sections above, you may also compile or link a "work that uses the Library" with the Library to produce a work containing portions of the Library, and distribute that work under terms of your choice, provided that the terms permit modification of the work for the customer's own use and reverse engineering for debugging such modifications.

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```

```
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Utfcpp

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Vcpkg

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Vtk

/*****

Program: Visualization Toolkit
Module: Copyright.txt

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Zlib

ZLIB DATA COMPRESSION LIBRARY

zlib 1.2.12 is a general purpose data compression library. All the code is thread safe. The data format used by the zlib library is described by RFCs (Request for Comments) 1950 to 1952 in the files <http://tools.ietf.org/html/rfc1950> (zlib format), [rfc1951](http://tools.ietf.org/html/rfc1951) (deflate format) and [rfc1952](http://tools.ietf.org/html/rfc1952) (gzip format).

All functions of the compression library are documented in the file `zlib.h` (volunteer to write man pages welcome, contact zlib@gzip.org). A usage example of the library is given in the file `test/example.c` which also tests that the library is working correctly. Another example is given in the file `test/minigzip.c`. The compression library itself is composed of all source files in the root directory.

To compile all files and run the test program, follow the instructions given at the top of `Makefile.in`. In short `./configure; make test`, and if that goes well, `make install` should work for most flavors of Unix. For Windows, use

one of the special makefiles in win32/ or contrib/vstudio/ . For VMS, use make_vms.com.

Questions about zlib should be sent to <zlib@zip.org>, or to Gilles Vollant <info@winimage.com> for the Windows DLL version. The zlib home page is <http://zlib.net/> . Before reporting a problem, please check this site to verify that you have the latest version of zlib; otherwise get the latest version and check whether the problem still exists or not.

PLEASE read the zlib FAQ http://zlib.net/zlib_faq.html before asking for help.

Mark Nelson <markn@ieee.org> wrote an article about zlib for the Jan. 1997 issue of Dr. Dobbs's Journal; a copy of the article is available at <http://marknelson.us/1997/01/01/zlib-engine/> .

The changes made in version 1.2.12 are documented in the file ChangeLog.

Unsupported third party contributions are provided in directory contrib/ .

zlib is available in Java using the java.util.zip package, documented at <http://java.sun.com/developer/technicalArticles/Programming/compression/> .

A Perl interface to zlib written by Paul Marquess <pmqs@cpan.org> is available at CPAN (Comprehensive Perl Archive Network) sites, including <http://search.cpan.org/~pmqs/IO-Compress-Zlib/> .

A Python interface to zlib written by A.M. Kuchling <amk@amk.ca> is available in Python 1.5 and later versions, see <http://docs.python.org/library/zlib.html> .

zlib is built into tcl: <http://wiki.tcl.tk/4610> .

An experimental package to read and write files in .zip format, written on top of zlib by Gilles Vollant <info@winimage.com>, is available in the contrib/minizip directory of zlib.

Notes for some targets:

- For Windows DLL versions, please see win32/DLL_FAQ.txt
- For 64-bit Irix, deflate.c must be compiled without any optimization. With -O, one libpng test fails. The test works in 32 bit mode (with the -n32 compiler flag). The compiler bug has been reported to SGI.
- zlib doesn't work with gcc 2.6.3 on a DEC 3000/300LX under OSF/1 2.1 it works when compiled with cc.
- On Digital Unix 4.0D (formerly OSF/1) on AlphaServer, the cc option -std1 is necessary to get gzprintf working correctly. This is done by configure.
- zlib doesn't work on HP-UX 9.05 with some versions of /bin/cc. It works with other compilers. Use "make test" to check your compiler.
- gzdopen is not supported on RISCOS or BEOS.
- For PalmOs, see <http://palmzlib.sourceforge.net/>

Acknowledgments:

The deflate format used by zlib was defined by Phil Katz. The deflate and zlib specifications were written by L. Peter Deutsch. Thanks to all the people who reported problems and suggested various improvements in zlib; they are too numerous to cite here.

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```
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