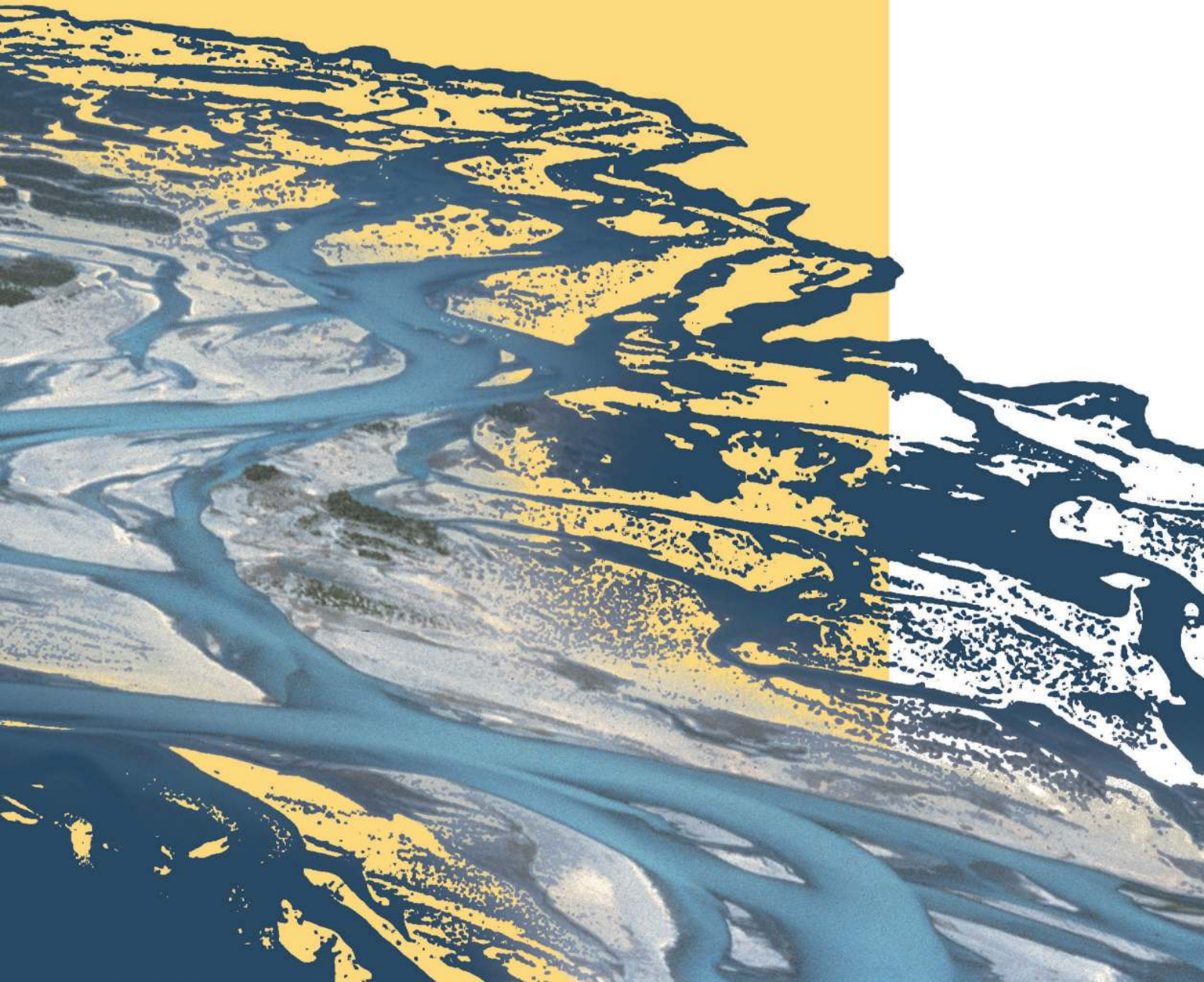




# SYSTEM MANUALS

*of* **BASEMENT**





# INTRODUCTION & INSTALLATION

---

*of* **BASEMENT**





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---

# Preamble

**VERSION 2.8.1**

*November, 2020*

## Credits

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For list of contributors see [www.basement.ethz.ch](http://www.basement.ethz.ch)



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Hydrology and Glaciology



Eidgenössische Technische Hochschule Zürich  
Swiss Federal Institute of Technology Zurich

### **Citation Advice**

*For System Manuals:*

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*For Website:*

BASEMENT – Basic Simulation Environment for Computation of Environmental Flow and Natural Hazard Simulation, 2020. <http://www.basement.ethz.ch>

*For Software:*

BASEMENT – Basic Simulation Environment for Computation of Environmental Flow and Natural Hazard Simulation. Version 2.8.1 © ETH Zurich, VAW, 2006-2020.



## License

### BASEMENT SOFTWARE LICENSE

between

**ETH**

**Rämistrasse 101**

**8092 Zürich**

**Represented by Prof. Dr. Robert Boes**

**VAW**

**(Licensor)**

and

**Licensee**

#### 1. Definition of the Software

The Software system BASEMENT is composed of the executable (binary) file BASEMENT and its documentation files (System Manuals), together herein after referred to as “Software”. Not included is the source code.

Its purpose is the simulation of water flow, sediment and pollutant transport and according interaction in consideration of movable boundaries and morphological changes.

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*By using this software you indicate your acceptance.*

(License version: 2018-05-31)

**THIRD PARTY SOFTWARE**

BASEMENT uses third party software. For instance, the BASEMENT executable directly links the following external libraries:

- CGNS
- HDF5
- Qt5 (non-cluster version only)
- Qwt (non-cluster version only)
- Shapelib
- TecIO
- VTK (non-cluster version only)

The libraries (and their dependencies) are included in the BASEMENT distribution if they are not provided by the operating system.

Please refer to `ThirdPartySoftwareLicenses.txt` in the distribution and/or the operating system documentation for the third party software licenses and copyright notices. The external libraries for Windows 10 have been built using `vcpkg` version 2020.07 (HDF5 was compiled without `szip`).

---

# Summary of Contents

## 1.1 Introduction

The intention of the BASEMENT system manual is to guide and support the user in carrying out numerical simulations with BASEMENT. The documentation, in particular the introductory and theoretical chapter, shall provide a deeper insight into the implemented numerical models, their application and the according preparation of necessary input data.

As a matter of fact, the application of state-of-the-art numerical models for channel flow, flood plain and natural hazard simulation is a demanding task. For this reason and despite of its incompleteness, this manual should provide helpful information to gain satisfying simulation results in terms of quality and time.

The BASEMENT system manuals are made up of four main parts – the user manual (denoted by the letter “U”), the reference manual (letter “R”), the tutorials (letter “T”) and the test cases (letters “TC”). These parts are available as individual download packages. In the following, a short description of each main part is given.

## 1.2 Content of System Manuals

### 1.2.1 User Manual

The user manual mainly gives an introduction to the basic simulation environment and its application. All necessary input data and its preparation are discussed. The procedure to setup a running model and the command file, which strictly defines a scenario to be simulated, are described in detail herein.

#### **The Basic Simulation Environment**

The first part of the user manual describes the basic concepts and the components of the software system BASEMENT and gives a general introduction to its application. Get into

it and learn more about the meaning of “BASEchain” and “BASEplane”.

### **Pre Processing**

The careful preparation of input data, such as topographical data or a discharge hydrograph of a flood event, is crucial for the scope and the quality of the result of numerical simulations. This chapter provides basic information on how to obtain and prepare the necessary input data for the models. If you don't understand the terms “aspect ratio” or “SMS”, this chapter is worth reading.

### **Model Setup**

After the preparation of all input data, a simulation has to be setup. By the use of a command file, all necessary simulation parameters have to be set and the input data is linked therein. The command file can be viewed and edited using a graphical user interface (GUI). This chapter explains the usage of the GUI and its features.

### **1.2.2 Reference Manual**

On the one hand, the reference manual covers the theoretical part of the implemented models of the software system BASEMENT. On the other hand, the detail syntax description of the input files, especially the command file, is given in this section of the manual – maybe the most important part for a proficient user of BASEMENT.

### **Mathematical Models**

The implemented models for water flow and sediment transport are either physical conservation laws, such as the shallow water or Saint Venant equations, or empirically based balance equations, all in the form of partial differential equations. This chapter shows the so-called “governing equations” which constitute the available simulation models. To correctly describe the mathematical problem, the necessary boundary conditions and source terms are given also.

### **Numerics Kernel**

Most often governing equations for flow can't be solved analytically for general boundary conditions. For this reason, the mathematical equations have to be discretized accordingly the desired spatial and temporary scale of the model. This section of the manual discusses the discretization methods, mainly the finite volume method, the explicit Euler scheme and especially the applied Riemann approach to solve the governing hyperbolic equation system.

### **1.2.3 Tutorials**

This chapter guides the user through the necessary steps to setup a numerical model up working by example. With good reason, the chosen case studies are demanding in setup and

application. This part of the manual lives with your experience! The development team of BASEMENT is looking forward to enrich the tutorials section with your suggestions and practical know-how.

#### **1.2.4 Test Cases**

To validate the implemented numerical models and to check for their reliability, different well-known and well-documented test cases have been carried out. The models have been tested against analytical solutions and flume data. This chapter is mainly intended for experts, but also interesting for general users, who like to explore the capabilities and limits of the provided models.





# 2

---

## Setup and First Start

### 2.1 System Requirements

#### 2.1.1 Microsoft Windows

*BASEMENT* is available for the following MS Windows systems:

- Windows 7
- Windows 8
- Windows 10

Releases are tested on Windows 7, 8 and 10. According to reports from users of earlier releases, *BASEMENT* also runs on Windows Vista and Windows 2000.

For the latest news concerning new features and current changes, please visit the webpage <http://www.basement.ethz.ch> .

#### 2.1.2 Linux

*BASEMENT* is available for the following Linux systems. The binary was compiled and tested on the following:

LINUX (x86-64):

- Ubuntu 14.04 (LTS), alias “Trusty Tahr”:
  - Kernel version 3.13
  - GNU C Library (glibc) version 2.19
  - VTK-version: 5.8
- Ubuntu 16.04 (LTS), alias “Xenial Xerus”:

- Kernel version 4.4
- GNU C Library (glibc) version 2.23
- VTK-version: 5.10

If you need a binary for a different version feel free to contact us. Furthermore, there is a binary without GUI and without real-time visualization (VTK). This binary should run on most (debian-based) linux systems and clusters.

### 2.1.3 Virtualization with Docker

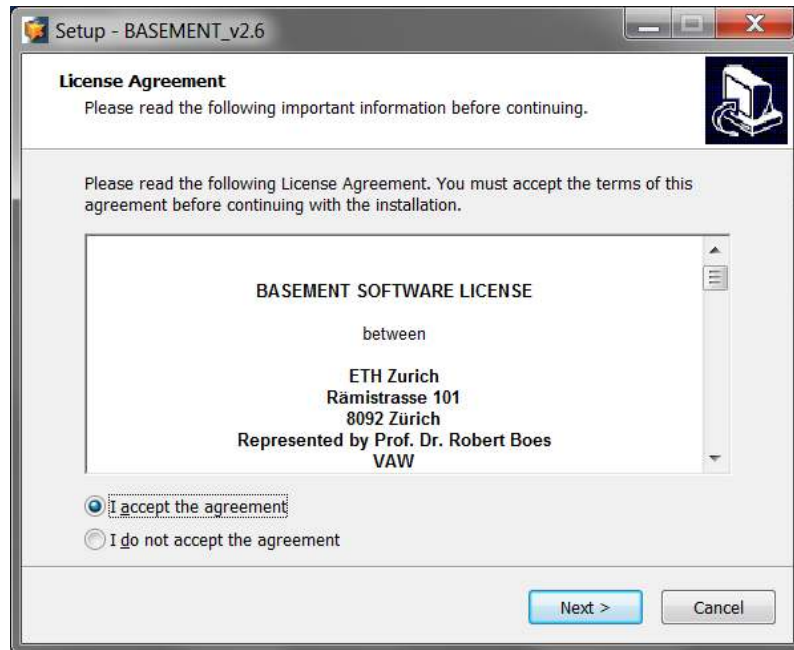
If you want to run *BASEMENT* on any other operating system (OS) than the ones mentioned above (e.g. Mac OS X, non-debian linux distributions, etc.), we suggest to set up a virtual environment using the [docker engine](#). Get a running version of the docker engine for your OS by following [online installation instructions](#). We provide a Dockerfile to create the virtual environment and the corresponding *BASEMENT* binary on <http://www.basement.ethz.ch> for download.

### 2.1.4 Hardware Configuration

We recommend the following hardware configuration:

- single- or multi-core processors (x86/x86-64):
  - Intel (Xeon, Core 2, Pentium 4)
  - AMD (K7, K8, K10)
- RAM: 1 GB per core
- shared memory architecture

Up to this moment, *BASEMENT* was successfully tested on 1 to 16 core Intel and AMD computers.



*Figure 2.1 License Agreement*

## 2.2 Installing under Windows

### 2.2.1 Getting the binaries

First of all, you need to get a copy of the recent software package. You can either download the most recent version from the projects webpage (<http://basement.ethz.ch>) free of charge or you can order the official manual as print version including a CD and a specially illustrated ring binder using the order form on the project webpage (only production costs will be charged, approx. CHF 100).

Then, you need to get a copy of the latest software package. Therefore go to the project webpage <http://basement.ethz.ch> and download the latest version free of charge. There are two different installers available. Choose the ‘noadmin’ to install BASEMENT when having no administrator privileges on your computer. Please note that with the ‘noadmin’ installer, double clicking on a BASEMENT command file (\*.bmc) in the Windows Explorer for example will not open BASEMENT automatically. Therefore, no BASEMENT symbol will be displayed with BASEMENT command files.

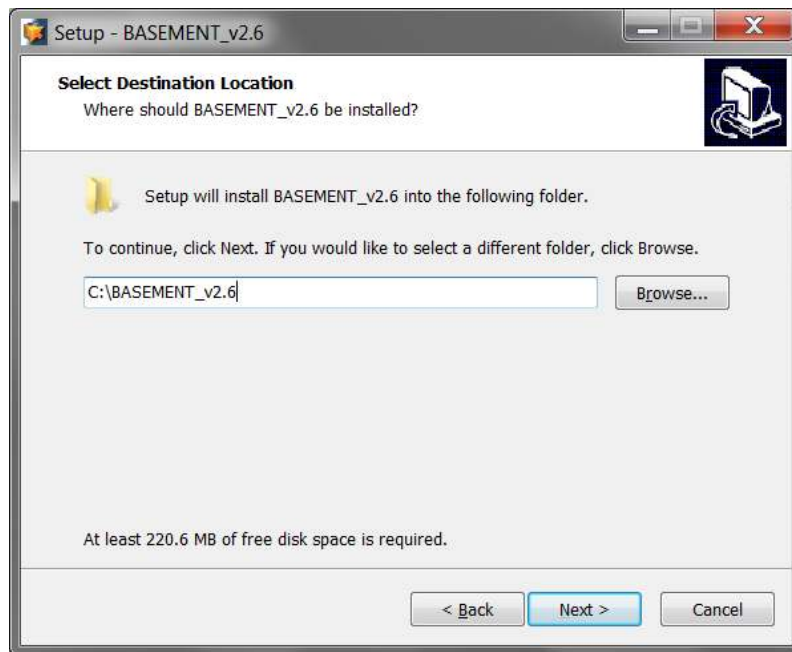
The installation procedure remains the same for both regular and ‘noadmin’ installers.

### 2.2.2 Installation procedure

Before installing the latest version, please deinstall all previous versions on your computer. After downloading the latest 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 activate the ‘I accept the agreement’ button to accept the terms and conditions and proceed with the installation.



*Figure 2.2 Installation folder*

#### *Step 2: Select the Installation Folder*

After accepting the License agreement, you can choose where to install the binaries. Default proposition is “C:\Program Files (x86)\BASEMENT\_vX.Y” respectively “C:\BASEMENT\_vX.Y” for the noadmin version. You are free to choose any other directory.

The regular version is installed for all users whereas the noadmin version is installed for the current user only.

#### *Step 3: Select program’s shortcuts*

Select a Start Menu folder to create the program’s shortcut. Optionally an additional shortcut can be placed on the desktop and the application directory can be added to your system path (Figure 2.4). Please note that this is necessary in case you plan running BASEMENT in headless mode from command line for instance.

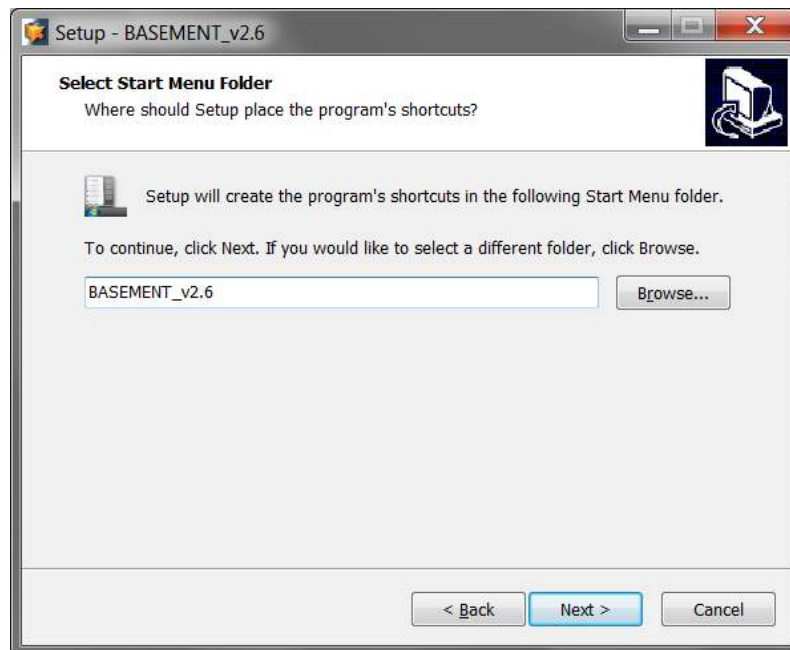
#### *Step 4 and 5: Confirming and Finishing the Installation*

Clicking ‘Install’ will start the installation process. After all files are copied, a final window (Figure 2.6) informs about the success of the installation. Click ‘Finish’ to close the installer and launch the program.

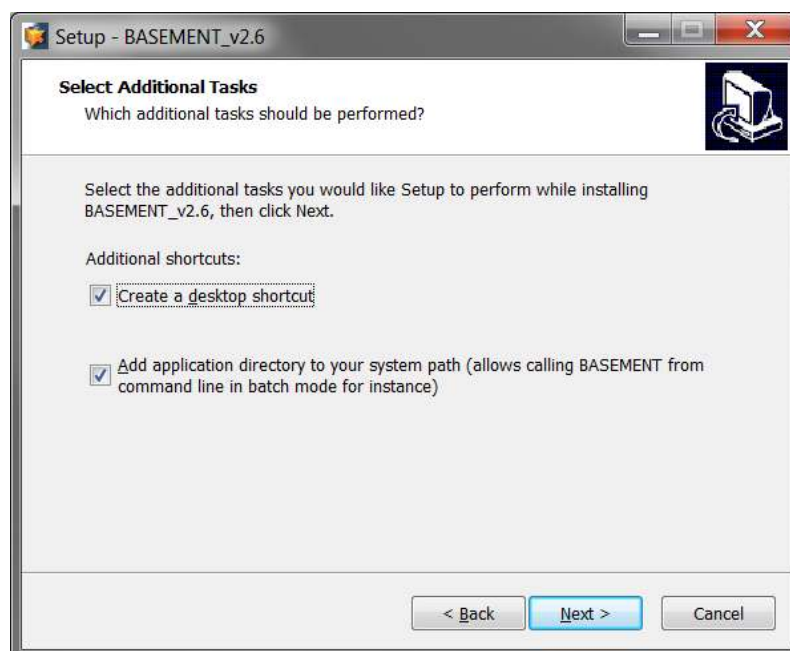
## 2.3 Running BASEMENT on Microsoft Windows

### 2.3.1 Running BASEMENT using the Graphical User Interface

After having successfully installed the program, you may notice the icon for BASEMENT on your desktop:



*Figure 2.3 Start Menu shortcut*



*Figure 2.4 Additional shortcuts*

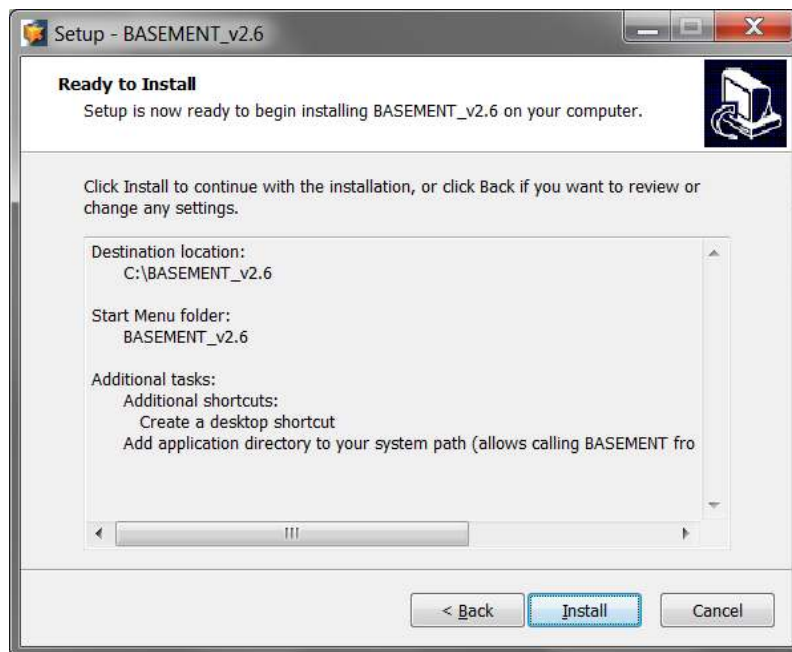


Figure 2.5 Confirm installation

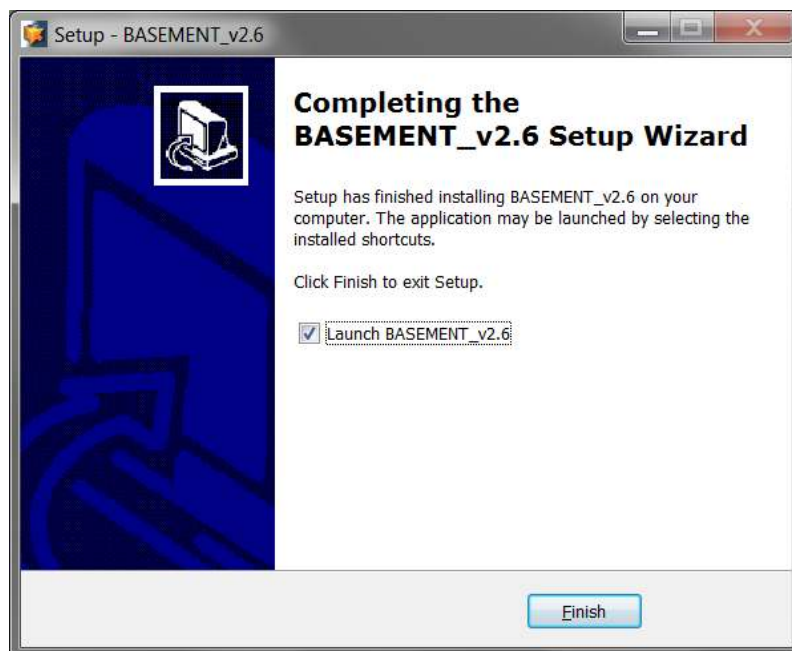
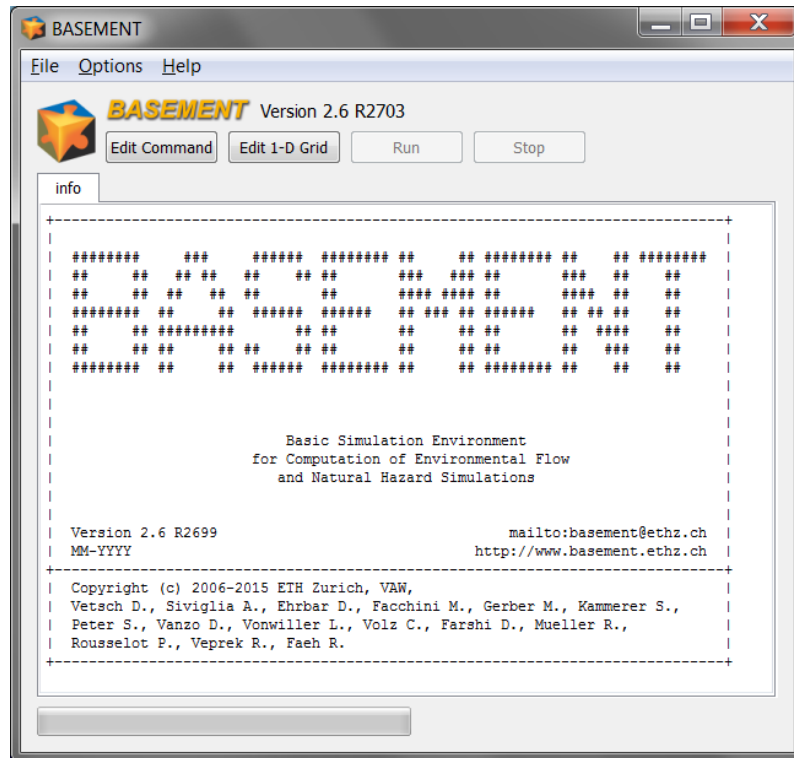


Figure 2.6 Installation complete



Figure 2.7 BASEMENT icon



*Figure 2.8 BASEMENT GUI*

This is the icon used for the program executable. The command files have a similar icon but are additionally identified by “CMD” within the logo. To get the icon for a command file displayed, the command file must end with “.bmc”.

There are two ways to start the program. Either by clicking on the program symbol or directly by double clicking a command file (File with “.bmc” ending) for BASEMENT. Since version 2.0, BASEMENT runs as a standalone application including a simple graphical user interface (to run BASEMENT in batch mode see Section 2.3.2):

The difference between the two starting mechanisms however is simple: Starting the program by clicking the input file sets the path for the working folder and the scenarios name automatically according to the position of the input file and its content.

If you just start the program by clicking the executable, you have to select the scenario by pressing the “Edit command” button, which will open the command file editor. Using this editor, you can load (“Open File”) your command file and thereby setting the working directory to the directory where the command file is located.

Once you loaded a command file it remains the active until you load the next one or save the current one with a new name.

When a command file is available to BASEMENT, the “Run” button is enabled. Pressing it starts the simulation. The console messages of BASEMENT are printed to the console view (Figure 2.9)

Below the console, the progress of the simulation is shown, together with the elapsed time and a guess of the required overall time. At the lower right, the real time speedup (RTS) of the simulation is shown. The real time speed up gives the number of seconds calculated in the simulation within one real time second.



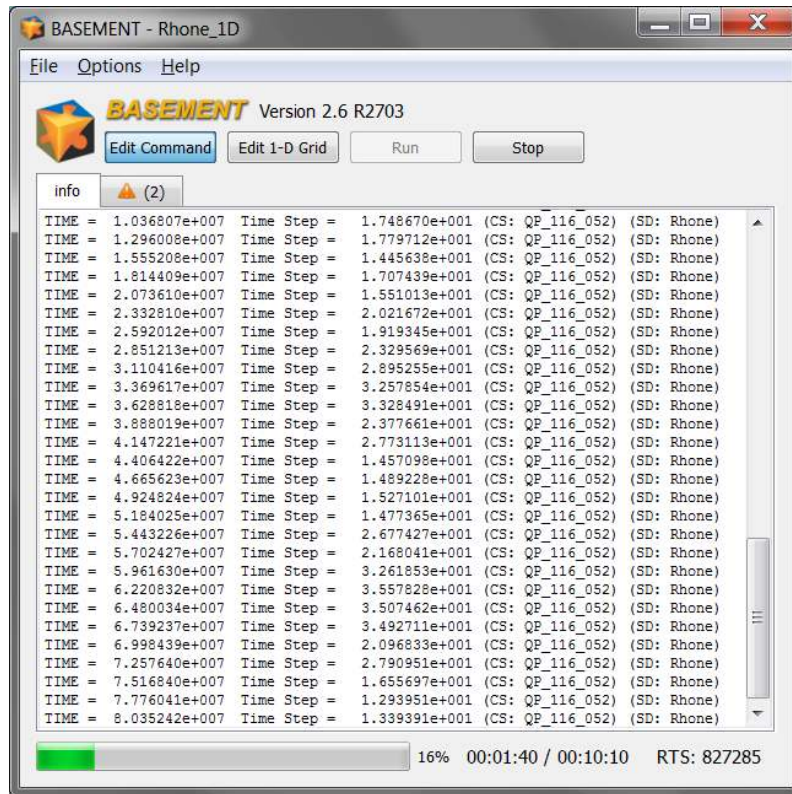


Figure 2.9 BASEMENT GUI simulation

All files containing the results will be saved in the working directory containing the command and auxiliary files.

Further details concerning the GUI of BASEMENT are explained in ‘BASEMENT Graphical User Interface’ of the user manual.

*Notice:*

**The command filename must not contain any spaces or special characters like ä, ö, ü, è, etc.**

### 2.3.2 Running BASEMENT on the Console

The following command line arguments are available, which can be also obtained in the command prompt (console) with the help command ‘-h’ (typing BASEMENT\_vX.Y.exe -h, whereas ‘X.Y’ has to be replaced by the actual version number):

- **version** display BASEMENT version (0 args)
- **h** display help information (0 args)
- **f “filename.bmc”** name of commandfile to be executed (1 arg)
- **t** pares input file and validate for errors (combination with -f)
- **b** no user inputs required (0 args)
- **verbose** detailed information outputs (0 args)



- **no\_cls** no clear screen (0 args)
- **log** log level of output (1 arg, [2-6])
- **doc** output of documentation in html-format

Of particular interest is the possibility to run BASEMENT in the batch mode. The batch mode is started by calling the BASEMENT executable using the `-b` command line switch. The command line switch `-b` selects the batch mode and prevents the GUI to be started. The desired command file is defined using the `-f` command line switch.

In a batch file several simulations can be runned consecutively (for example over the weekend). To generate a batch file just create an empty text file and replace the ending `'txt'` by `'bat'`. In this file several command lines can be defined as for example:

```
"C:\Programs\Basement\BASEMENT_v2.2.1.exe" -f F:\Project_1\run.bmc -b  
"C:\Programs\Basement\BASEMENT_v2.2.1.exe" -f F:\Project_2\run.bmc -b  
"C:\Programs\Basement\BASEMENT_v2.2.1.exe" -f F:\Project_3\run.bmc -b
```

Then run the batch file by double clicking.

## 2.4 Installing under LINUX

### 2.4.1 Getting the binaries

You need to get a copy of the actual distribution as described in the Windows installation section. One can either download the most recent version from the projects webpage <http://basement.ethz.ch> or one has an official manual including a CD which can be ordered on the same webpage.

### 2.4.2 Installation procedure

The installation of program and documentation on LINUX systems is to be done via the console. Please replace all occurrences of 'X.Y' in the installation introduction by the actual version number.

#### Step 1: Preparation of the installation

Before unzipping the zipped installation file you probably want to create a temporary directory ('/tmp') and copy the downloaded file into this directory. Change to this directory where the downloaded zip-file is located. Unzip the file by typing:

```
unzip BASEMENT_vX.Y_linux.zip
```

#### Step 2: Installation of BASEMENT and license agreement

Under the unzipped files you can find an executable named 'setup' and an 'install.txt' which has additional information on the installation process. To start the installation, run setup

```
./setup
```

and follow the instructions. The license text of BASEMENT is displayed and must be agreed on to proceed with the installation. After running setup the password protected zip-file is extracted and the debian package file is available.

#### Step 3: Installation of debian (\* .deb)-package

To ease the installation of BASEMENT a debian-package is created which automatically installs all needed files, the documentation and the tutorials and test cases on the pc. To install this package administrator rights are needed. Therefore on Ubuntu the 'sudo' command is needed. To start installation type

```
sudo dpkg -i basement-X.Y-XXX.deb
```

The debian package automatically detects if your configuration misses one of the needed requirements. In such a case you can use ‘apt-get install ...’ on Ubuntu systems to install the missing packages. Previous versions of basement are automatically detected by the installer and deleted before the installation starts.

If the installation of the package was successful, than the binary file is copied to

```
/usr/bin
```

and the program files, the documentation, the test cases and the tutorial are available under

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

## 2.5 Running BASEMENT on LINUX

If the installation succeeded, start BASEMENT with its graphical user interface in a terminal window with a shell command prompt just by typing:

```
basement
```

Selecting an actual simulation, running a simulation on LINUX or using batch mode works the same way as it does on Windows (see Section 2.3.1 and Section 2.3.2).

*Notice:*

**The command filename must not contain any spaces or special characters like ä, ö, ü, è, etc.**

## 2.6 Installing under virtual environment

Follow the instructions to get *BASEMENT* successfully run in a virtual environment using the docker engine:

- open your shell where docker engine is running
- build user:basement image

```
$ docker build -t basement:user <pathToDownloadedDockerfile>/.
```

- run the container and mount a local volume, where you want to have stored the simulation data, into the container

```
$ docker run -it -v <absolutePathToMountVolume>:/home/basement/media  
--name basement-user basement:user
```

- you are now in a Ubuntu “Xenial” bash shell
- the password for the user ‘basement’ is ‘BM#user-16’
- copy the downloaded zip-file *BASEMENT\_vX.Y\_docker.zip* to the local directory that is mounted into the container
- unzip the archive and run the setup

```
$ cd media  
$ unzip BASEMENT_vX.Y_docker.zip  
$ ./setup
```

- you should now find the *BASEMENT* binary ready for execution (without GUI and VTK)

```
$ ./BASEMENT_vX.Y
```

- you can exit the virtual environment and re-entering the other day simply by

```
$ docker start -i basement-user
```

# 3

---

## Release Notes

### 3.1 Version 1.3

#### *Subsystem BASEdomain:*

A logical error check is performed between reading the input file and the start of the simulation. In case of logical errors (contradictions, missing information), the simulation will stop immediately. In any case, a file 'inputerror.err' is created, where all errors and warnings are listed for the current simulation. It is highly recommended to have a look at this file for every simulation being started.

#### *Subsystem BASEchain:*

- problem in computation of cross section area fixed
- problem with omission of values in topography file fixed
- sediment transport fixed
- new output: difference of water volume
- new output: difference of sediment volume
- bed load formula of "Rickenmann"
- output of topology of cross section not automatic any more
- output of sediment mixtures not automatic any more

#### *Subsystem BASEplane:*

- Computation of the inlet bed load from the bed load hydrograph has been modified.
- The jacobian matrix has been corrected to calculate the slopes for the quad. Elements.
- The coefficient "C" for the weir calculation has been improved!
- The output for the cell centres is modified. For this instead of the xyz output, a mesh file including the centres coordinates with the elements number are written.

- The flux over the weir has been corrected!
- The time step computation has been also extended to the boundary edges. In the previous version only the internal edges were considered for the time step computation.
- A new parameter “node\_elevation\_method” has been added to the Morphology-Parameter block. The calculation of the nodal elevation based on the “node\_elevation\_method” can be done with interpolation or slope method.

*System Manuals:*

- Part UIV has a new tutorial for 2-D simulations.
- Part RIV and corresponding structures in UIV are completely revised.
- Wrong assigned page numbers in some TOCs are corrected.
- Header of part “Index / Appendix” corrected.
- **Update your hardcopy version with the documentation patch.**

## 3.2 Version 1.4

### General Notice:

All users working on a project with v1.3 at the moment should use v1.3 until the project ends and update for version 1.4 afterwards. Changes made to the boundary condition will lead to a slightly different behaviour of v1.4 compared to v1.3. Therefore, a calibrated scenario for v1.3 is not calibrated to work with v1.4!

*Subsystem BASEparse:*

- New command file structure allowing for distinction of bed load and suspended load in 1-D. The structure also changed in 2-D for similar reason.
- New structure of command file in HYDRAULICS: All friction parameters are now defined in their own block FRICTION instead of the SOURCE block as in v1.3

**Attention:** The changes of the command file’s structure are not backwards compatible! Input files for v1.3 will not work with v1.4 and vice versa. We recommend all users to update to version 1.4.

*Subsystem BASEchain:*

- problem with HQ-Relation stored in a file fixed
- problem with update of hydraulic tables after geometry change due to bed load fixed
- necessity for a comment for each cross section in HEC-RAS files eliminated
- problem with cross section names ending with one or more 0 in HEC\_RAS files fixed
- beta values in Tecplot file are now mean values over the whole bed width instead of value of the first slice
- new friction type: Manning
- new binary Tecplot files for longitudinal profile data

- new binary output file for cross section topology
- new suspended load simulation
  - advection by QUICKEST scheme
  - advection by Holly-Preissmann scheme
  - advection by MDPM scheme
  - sediment exchange between water and bed
  - diffusion by given factor or internal computation

*Subsystem BASEplane:*

- Inner Boundary Conditions (weir and gate) implemented
- Weir Boundary Condition modified (velocity component in momentum equation)
- UCD-Output for AVS enabled (Universal Cell Data)
- additional friction types implemented (strickler, darcy, chezy, etc)
- new wall friction added to optionally consider wall friction at boundary edges
- hydrograph boundary redesigned with momentum flux at inflow (please use an external source if you want an inflow without momentum flux)
- new h-Q boundary implemented which allows the specification of a h-Q relation as outflow
- ascii and binary Tecplot output
- performance tuning of some subroutines and file outputs
- additional geometry check for ambiguous gradients
- minor bug fixes

*Subsystems BASEchain and BASEplane:*

- Parallelization for shared memory multi-core systems implemented
- New LINUX version prepared
- BASEviz visualization tool added (currently ONLY for Windows version)

*System Manuals:*

- Please read the credits and the new preface, which are introducing a new team member and are giving citation advice
- Part UI-5: new chapter about parallel processing
- Part UII-3.3: some hints concerning mesh quality, especially how to deal with ambiguous elements
- Part UIII: almost complete revision. Examples for and comments on newly added features
- Part UIV: overall correction.
- **Part RI: complete revision**

- Part RII-2.3: treatment of inner boundaries
- Part RII-3.2: schemes for suspended sediment transport
- Part RIII: additional test cases for suspended sediment transport and parallel execution
- **Part RIV: complete revision**
- **Update your hardcopy version with the documentation patch.**

### 3.3 Version 1.5

General:

- *New Features:*
  - Batch Mode (running BASEMENT with program arguments)

Subsystem BASEchain:

- *New Features:*
  - Source and sink of suspended load
  - Conservation of sediment exchange between bed and suspended load improved
- *Bug fixes:*
  - Wrong warning concerning friction definition eliminated

Subsystem BASEplane:

- *New Features:*
  - Gate Boundary
  - HLLC Riemann solver
- *Bug fixes:*
  - Value Check hQ-Relation
  - Correction of Hydrograph boundary at supercritical flow conditions
  - Bug fix of edges memory reservation in case of very large grids with many holes
  - Vector length scaling added for the vtk velocity vector output
  - Prevent output of negative flow depths



### 3.4 Version 1.6

Subsystem BASEchain:

- *New Features:*
  - Implicit solution of hydrodynamics
  - Smart-Jaeggi bed load formula
- *Bug fixes:*
  - Correction transport diagram
  - Conveyance computation (negative areas)

Subsystem BASEplane:

- *New Features:*
  - Revision of sediment transport (Dual Mesh concept)
  - Kinematic viscosity and algebraic turbulence model
  - Wu bed load formula
  - Improved treatment of bed source terms for quadrilateral elements
  - New approach of slope calculation for quadrilateral elements
  - Improved concept of wall friction treatment
  - Flux correction algorithm implemented to enhance mass conservation
  - New outflow boundary: ZHydrograph
- *Bug fixes:*
  - HQ-Relation and Hydrograph boundaries

*System Manuals:*

- Part UIII: Introduction to new features
- Part UIV: Corrections
- Part RI: Complete revision and additions, e.g. sediment transport
- Part RII: Complete revision and additions, e.g. partially wetted elements, sediment transport, dual mesh approach and implicit time integration.
- Part RIII: Additions and corrections
- Part RIV: Documentation of new features

## 3.5 Version 1.7

General:

- *New Features:*
  - Coupling of subsystems BASEchain and BASEplane, i.e. sub-domains
  - Flow control in river systems

Subsystem BASEchain:

- *New Features:*
  - Multiple boundaries at in- and outflow cross sections
  - Speed improvements for explicit simulations
  - Improvements of zhydrograph-boundary condition
  - Changed behaviour of qlateral source (now uses one cross section)
- *Bug fixes:*
  - Batch execution mode corrected

Subsystem BASEplane:

- *New Features:*
  - Suspension transport 2-D
  - Improvements of inner boundaries
  - New procedure for updating velocities at partially dry elements (prevention of high velocities at wet-dry interfaces)
  - ZHydrograph boundary condition enhanced to be used as outflow or inflow
- *Bug fixes:*
  - Correction of hydrograph boundary in case of no inflow
  - Negative area for element prevented (only occurs when .2dm is manually changed so that nodes are not counter clockwise)
  - Bug fixes in Tecplot output routines
  - Default behaviour of HQ relation changed, partially dry edges are treated as zero\_gradient instead of wall

*System Manuals:*

- new chapters on model coupling and flow control
- additions and corrections

## 3.6 Version 2.0

General:

- *New Features:*
  - Graphical user interface (GUI) for BASEMENT with integrated reference manual. Enables faster and correct setup of command files, setup and interpolation of BASEchain topography files and running a simulation.
  - Visualization (BASEviz) revised and improved to be more interactive.
  - Additional Q-t-Table implemented for flow control.
  - All sediment transport formulas can now be used for BASEchain and BASEplane.
  - Additional bedload transport formula implemented with Meyer-Peter Müller approach for multi-grain with critical shear stress correction according to Ashida and Michiue.

Subsystem BASEparse:

- Various changes and standardizations of input tags in the command file parser.

**Attention:** The changes of the command file's structure are not backwards compatible! Input files for v1.7 will not work with v2.0 and vice versa. We recommend all users to update to version 2.0.

*Guidance on how to convert old command files into the new format:*

There are several possibilities to update old command files. Maybe the easiest way is to use the new graphical user interface (GUI). Start the program BASEMENT and open your old command file. The message “parsing failed” will pop up and ask you to open your file in the raw editor to fix it. Confirm with the OK button. In the raw editor the parse errors will appear in the lower section in red colour. Invalid tags are pointed out and possible tags are proposed. Apply the proposed changes and click on the “Validate” button to see if your correction was successful. If some proposed tags should be unclear to you have a look at the Block List in the Reference Manual R IV. In the information-rich Block List all input blocks and possible tags are described.

Another possibility is to build up a new command file with the GUI of BASEMENT. This way you will learn to use the new GUI and will be provided with all possible input blocks, tags and information.

Subsystem BASEchain:

- *New Features:*
  - New topography format implemented for BASEchain (.bmg). Please use this file format as the default format for all new projects.
  - Python-script to convert files from old Floris-format to new input format. The script can be downloaded from the website and requires ‘python’ to be installed ([www.python.org](http://www.python.org)).

- Tool in graphical user interface (GUI) for cross section interpolation.
- Tool in graphical user interface (GUI) to automatically thin out grid points and thus speed up simulations.
- Significant speed improvements especially for hydraulic calculations.
- Coupling via “off-channel” source enabled.
- *Bug fixes:*
  - Bug fix in Roe solver.

**Please note:** Due to revision works, at the moment only one soil may be specified for a cross section in morphological simulations. Usage of multiple soils will be enabled again in future.

Subsystem BASEplane:

- *New Features:*
  - New framework for data output with additional features and output variables.
  - Geometric approach for gravitational bed load transport (slope failures).
  - Some speed improvements for hydraulic calculations.
  - Additional sediment inflow boundary condition which sets inflow to transport capacity.
  - Changes in calculation of sediment fluxes. Upwind-factor now has more effect.
- *Bug fixes:*
  - H-Q iterations and default precision in Hydrograph boundary conditions fixed.
  - Bug fix in treatment of fixed bed regions based on material index.
  - Bug fix in deletion of layers.
  - Bug fix for sediment restart.
  - Error at simultaneous binary tecplot output of hydraulic and sediment data fixed.

System Manuals:

- Additions and corrections.
- Revision of hydraulic tutorial for BASEchain.
- New hydraulic and sediment tutorial for BASEplane.
- HTML-documentation files can be automatically generated by starting BASEMENT with command line flag “-doc”.

## 3.7 Version 2.1

General:

- *New Features:*
  - Controller extended for external sources
  - Support of jpeg-output of BASEviz visualization (experimental)

#### Subsystem BASEchain:

- *New Features:*
  - A simple consideration of internal levees
  - Time dependent grain mixtures as new upper boundary for bed load.
  - Multiple soils in one cross section are possible again, a factor is available to define from which degree of submersion a soil is considered to be wetted and will be moved.
  - For bed load transport the definition of the bed bottom is needed again!
- *Bug fixes:*
  - Transport diagram
  - Monitoring point integration for simulations starting after time 0.
  - No more elimination of elevations smaller than h dry in hydraulic balance.
  - Initialisation of initial\_time\_step.

#### Subsystem BASEplane:

- *New Features:*
  - New upwind method for suspended transport
  - New binary restart file format (CGNS) contains all restart data and enables restart from different solution times (hydraulics, bed load and suspension)
  - Reduced mesh dependence in many situations due to changed formulation of Riemann problem on edges
  - Initial depth is set to zero over the domain (and no longer to depth\_min)
  - Several improvements in data output (depth/wse output are consistent now, sediment balancing improved, added specific discharge, renaming of “z\_bed → z\_element” and “zcoord → z\_node”)
  - Some speed improvements for parallel execution
  - Improvements and parallelization of gravitational transport
- *Bug fixes:*
  - Bugfix for inner gate because unphysical flux could be generated in dry cells
  - Bed load transport rate was determined too small in some cases !
  - Bugfix of 2dm mesh input. Internal edges of last nodes of the mesh could be falsely treated as boundary edges.
  - Tecplot output was restricted to 6 digits, now changed to 8 digits

- Bugfix in layer interpolation on sediment elements

System Manuals:

- New manual for the graphical user interface (GUI) replaced old UIII manual
- New sediment tutorial for fractional transport for BASEplane
- Additions and corrections

## 3.8 Version 2.2

General:

- *New Features:*
  - External coupling implemented for data exchange with external programs over TCP/IP (experimental stage)
  - 64-bit linux version available for Ubuntu Natty (11.04)

Subsystem BASEchain:

- *New Features:*
  - Account for grain abrasion due to mechanical stress after Sternberg
- *Bug fixes:*
  - Bugfix in layer creation for sediment transport
  - Bugfix in grain sorting in fractional sediment transport
  - Bugfix in BASEviz-output, pause-function did not work

Subsystem BASEplane:

- *New Features:*
  - Cycle step for quasi-steady bed-load & suspension transport to speed up morphological simulations
  - zhydrograph boundary improved. Ghost cell velocities can be set to zero (e.g. lake) or to the upstream cell velocity (e.g. stream).
  - Threshold value can be set in water surface output in case of dry conditions.
  - Upwind-factor for bed-load transport is assigned now for each material index
- *Bug fixes:*
  - Correction in water balance for partially saturated elements
  - Bugfix in dynamic-depth solver, partially wetted cells were not treated correctly

- Gravitational transport no longer requires an additional BEDLOAD or a SUSPENSION block to be defined
- External sources for bed-load & suspension moved to MORPHOLOGY-block
- INITIAL-block in MORPHOLOGY-block is now mandatory
- Bugfix in output of sediment inflow at first time step
- Bugfix critical shear stress of incipient motion ( $\theta_{critic}$ ) was not correctly initialized

System Manuals:

- Additions and corrections

### 3.9 Version 2.3

General:

- *New Features:*
  - New pre- and post-processor BASEmesh for unstructured 2-D mesh creation, setting of material indices and visualization. Usable as plugin in the free software Quantum GIS (QGIS) on Windows and Linux.
  - Enhancement of lateral coupling; automatic creation of connections between 1-D cross sections and 2-D edges (experimental)
- *Bugfixes:*
  - Bugfix of HEC-RAS conversion script for non-georeferenced files
- *Subsystem BASEparse*
  - New TIMESTEP block introduced in command file
  - Improved documentation of controller-features
  - Units of sediment boundaries and sources clarified
  - Ranges of tag values in command file are now shown correctly
  - Additional warnings added for non-plausible inputs

**Attention:** The changes of the command file structure are not backwards compatible! Input files for v2.2 will not work with v2.3 and vice versa. We recommend all users to update to version 2.3.

Subsystem BASEchain:

- *New Features:*
  - Dredge source improved and enhanced for additional features
- *Bug fixes:*

- Bugfix of cross section geometry update in case of non-rectangular geometries

Subsystem BASEplane:

- *New Features:*
  - Extension and enhancement of hydro-stepping to allow for increased computational performance in case of quasi-steady flow and sediment transport
  - New output format as SHAPE file (for GIS-applications)
  - New output data type of specific discharge
  - New output option for min/max-values; time of occurrence of min/max-values now can be tracked
  - New computational method for the determination of suspended-load concentrations which limits concentrations to max. 1.0
  - Pick-up calibration factor suspended-load transport can now be set for each grain class separately
  - Corey shape-factor added for the determination of settling velocity after Wu and Wang
  - New output for suspended-load transport for multiple grain classes
  - New output data types for debug data (source terms, etc.)
  - New output option for ASCII-output; possibility to write external IDs instead of coordinates
  - New output option for TECPLOT; possibility to split TECPLOT files into several output files, one for each output value, to prevent too large file sizes
- *Bug fixes:*
  - Bugfix and improvement of wall friction computation; original concept was flawed
  - Bugfixes for external couplin
  - Bugfix of sediment restart (hotstart) in case of multiple soil layers
  - Bugfix of determination of removable water volume in water sinks

System Manuals:

- Additions and corrections
- New manual and tutorial for BASEmesh (QGIS Plugin)

## 3.10 Version 2.4

General:

- *New Features:*



- New computation of Zhang’s settling velocity
  - New 3-D seepage model BASEsub (experimental)
  - Lateral 1-D/2-D Model coupling improved: automatic assignment of 1D and 2D elements, new options and tutorial. Redesign of block-structure.
  - Added ‘documentation’ option to help menu.
- *Bugfixes:*
    - Bugfix: restart (hot-start) for coupled simulations corrected.
    - Bugfix: coupling type ‘confluence\_wse’ could not be properly activated.
    - Improved parsing of series file: comments are possible at the end of a line (everything after ‘#’ or ‘//’ is discarded).

#### Subsystem BASEparse

- New tag ‘start\_time’ in TIME\_STEP block introduced (replaces ‘restart\_start\_time’ in BASEplane).
- STRINGDEF output improved, considering the flow direction. Each STRINGDEF definition now needs the tag ‘upstream\_direction’ to be defined!
- New block LATERAL\_COUPLING introduced for lateral coupling.

**Attention:** The changes of the command file structure are not backwards compatible! Input files for v2.3 will not work with v2.4 and vice versa. We recommend all users to update to version 2.4.

#### Subsystem BASEchain:

- *New Features:*
  - Smart & Jaeggi sediment transport formula extended to multi grain with hiding & exposure according to Ashida & Michiue
  - VTK visualization (BASEviz) now takes geo-referencing into account.
  - HecRas conversion script redesigned and enhanced. Script integrated into BASEmesh.
- *Bug fixes:*
  - Bugfix: zhydrograph now applicable for upper and lower boundary.
  - Suspension calculations slightly modified (especially exchange rates sources).

#### Subsystem BASEplane:

- *New Features:*
  - SMS outputs (\*.sol) enhanced with reference time in Julian date format.
  - Enhanced output for external water source, separately for each element.

- Added output in VTK-Format (use free visualization program Paraview).
- New boundary type: movement of bed elevation, enforced via file input. Defined in GEOMETRY->BOUNDARY block.
- New output for external (hydraulic) discharge source: “external\_source\_discharge” shows the element-history of the external source.
- *Bug fixes:*
  - MDPM scheme works now for pollutant transport only.
  - Bugfix: output of tracked variables (‘min’, ‘max’, ‘sum’,...) did crash in some cases.
  - Bugfix: polygons in shape output need to be closed.
  - Bugfix/feature for cycle-step-algorithm: very small correction time steps are now neglected, if they are smaller than the minimum time step size.
  - Bugfix: bad memory allocation for restart simulations with suspended-load

System Manuals:

- Additions and corrections
- Documentation of transport formula of van Rijn
- New tutorial added for lateral coupling (BASEMENT)
- New tutorial added for 1D cross-section generation using HEC-GeoRAS (BASEmesh)

## 3.11 Version 2.5

General:

- *New Features:*
  - see subsystems for new features.
- *Bugfixes:*
  - Minor fixes to HECRAS-BASEMENT conversion script

Subsystem BASEparse

- New INITIAL block for 1D morphological simulations introduced
- SOURCE block for 1D morphological simulations moved from BEDLOAD to MORPHOLOGY block
- Renamed tag ‘theta\_critic’ to ‘theta\_critical’ in PARAMETER block in BEDLOAD block for 2D morphological simulations

**Attention:** The changes of the command file structure are not backwards compatible! Input files for v2.4 will not work with v2.5 and vice versa. We recommend all users to update to version 2.5.

Subsystem BASEchain:

- *New Features:*
  - Additional monitoring output added: mean cross section bottom elevation
  - Monitoring output for multiple cross-sections can now be written to a single file
  - Modification of sediment discharge source (additional checks in case of sediment sink, print volumes to file)
  - Added tag ‘use\_energy\_slope’ (on/off) for sediment transport formula of ‘smartjaeggi’ and ‘smartjaeggi\_multi’ for the calculation of the slope
- *Bug fixes:*
  - Fixed and improved ‘start\_time’ parameter, which allows for starting a simulation at times different from 0.0
  - Removed debug-message indicating too high sediment fluxes

#### Subsystem BASEplane:

- *New Features:*
  - New inner hQ-boundary added (e.g. to simulate culverts, pipes, bridges).
  - New dredge source added. Sediment can be dredged to prevent sediment deposits from exceeding a specified bed-level. The sediment also can be redistributed at a downstream location (allowing for sediment continuity at inner boundary conditions).
  - Added second bed-load flux computation method (it is recommended to use the old version with averaged bed-load fluxes, rather internal parameter)
  - Added special output of ‘sediment grid’ as shape file (enables visualizations of hydraulic + sediment grids in GIS)
  - Added tag ‘scale\_lateral\_transport’ for lateral\_transport in order to define only a rotation or a rotation with increased transport
  - Additional ‘stringdef\_history’ outputs (mean values on a stringdef, approximations): mean[velocity], mean[wse], mean[depth], mean[energy\_head], mean[zbed]
- *Bug fixes:*
  - Fixed header description for sms output files
  - Fixed behaviour of ‘dynamical\_depth\_solver’. Previous implementation led to violation of well-balancing
  - Fixed VTK output: vtk does not allow for same variable names in scalar and vector data; resolved by new naming scheme
  - Bux fix for sediment restart with cgns (Windows)
  - Improved and more user friendly concept for considering bedforms

#### System Manuals:

- Additions and corrections

- Description of hQ-inner-boundary for 2D simulations
- Description of dredge source for 2D simulations

### 3.11.1 Version 2.5.1

General:

- *Bugfixes:*
  - Improved correction of the overdraft cells (including WARNING in case of failed correction)
  - Output files changed for combined time histories: nd, el, sd in filename
  - Headers in output files: matching the value names of the input parser, adding the units
  - File .sol readable again

### 3.11.2 Version 2.5.2

General:

- *Bugfixes:*
  - Crash of Basement prevented in case of output values that cannot be generated due to missing simulation blocks; now an error message will appear in case of missing simulation blocks
  - Gate formula improvement:
    - \* Correction of discharge calculation
    - \* Added possibility of dynamic calculation of weir coefficient ‘mu’
    - \* Added possibility of taking into account backwater effects (only inner boundary conditions and dynamic ‘mu’)
  - Tag ‘tau\_erosion\_start’ available for multi grain simulations
  - Improved ascii and vtk output files for vector data, vector components are not written separately anymore
  - Removed output format “qgis” (deprecated). QGIS plugin crayfish can now read the file format standard of sms (\*.sol)

### 3.11.3 Version 2.5.3

General:

- *Bugfixes:*
  - QGIS SMS output linux: new time step TS was not properly written on a new line. Therefore SMS and QGIS were not able to detect all time steps
  - Bugfix ‘tau\_erosion\_start’ for multi grain simulations

## 3.12 Version 2.6

General:

- *New Features:*
  - New Windows installers for users with and without admin permission
  - New handling of errors and warnings:
    - \* Writing two files: run.log with log-info and run.err with all warnings and errors
    - \* The same philosophy is applied in the GUI: two tabs, one for info, the other for warnings/errors
    - \* Consoles in GUI are cleaned in case of re-run
    - \* New log levels: (1) Error, (2) Warning, (3) Info, (4) Debug
  - Open the whole block-tree with command in GUI menu bar (expand all, ctrl+A)
- *Bugfixes:*
  - No segmentation fault if user requests to stop simulation AND simulation has already finished

Subsystem BASEparse

- New FORMULA block in BEDLOAD block (1D and 2D)
- Renamed tag ‘bedload\_transport’ to ‘bedload\_formula’ inside FORMULA block
- New DIRECTION block in BEDLOAD block (2D), with new feature curvature\_effect\_static (option lateral\_bed\_slope replaces former tag lateral\_transport in PARAMETER block)
- Deleted obsolete and misleading tag ‘output\_time\_step’ in OUTPUT block (2D)

**Attention:** The changes of the command file structure are not backwards compatible! Input files for v2.5 will not work with v2.6 and vice versa. We recommend all users to update to version 2.6.

Subsystem BASEplane:

- *New Features:*
  - Index based definition of river curvature (radius) to simulate curvature effect on sediment transport (change of bedload direction) in new DIRECTION block
- *Bugfixes:*
  - Review of HLL and HLLC Riemann solvers
  - Fixed coupling sediment boundary ‘coupling\_IODown’
  - Tag ‘use\_cell\_averaged\_bedload\_flux’ in PARAMETER block in BEDLOAD block is set to ‘off’ per default

- `factor_reference_height` set to 0.1 by default (not 1.0) for suspended load
- Flux orientation in wall flux boundary

System Manuals:

- New Tutorial Post-Processing of 2D Simulation Results
- Updated Tutorial Pre-Processing in QGIS with BASEmesh
- Additions and corrections in System Manual
- Review of HLL and HLLC testcases

### 3.13 Version 2.7

General:

- *New Features:*
  - New bedload transport formulae: Wilcock and Crowe, Engelund and Hansen (for single-grain)
  - Definition of external sediment and hydraulic source over material index
  - Improved and extended `mpm_multi` and `smartjaeggi_multi` using hiding function according to Ashida and Michiue (1972) with new options to choose reference critical Shields parameter: based on mean, median, geometric diameter, or diameter of fractions
  - New logarithmic friction laws: Yalin, Bezzola
- *Bugfixes:*
  - User-defined settling velocities
  - New tag `bedload_exponent` used for `mpm` and `mpm_multi`, correction of Wong and Parker formulation
  - `dynamic_depth_solver_precision`: eliminated dependency on `min_water_depth`
  - Minor others

Subsystem BASEchain:

- *New Features:*
  - HLL Riemann solver
- *Bugfixes:*
  - Fix Matlab output

Subsystem BASEplane:

- *New Features:*
  - New *local\_slope\_correction* concept: *local\_slope\_longitudinal* and *local\_slope\_lateral* suppressed, introduced *local\_slope\_vanriijn* and *local\_slope\_chen*
  - New tag *theta\_critical\_default* with *theta\_critical\_vanriijn* and *theta\_critical\_yalin*
  - Dynamic determination of flow curvature based on water surface inclination
  - Dynamic determination of flow curvature based on local streamline reconstruction
  - Hydraulic boundary *hydrograph* with dynamic slope in case of erosion
  - New element output *momentum* that returns flow intensity (water depth times velocity)
- *Bugfixes:*
  - Local slope: updating local slope correction due to changed bed slope
  - Correction of *zero\_gradient* downstream boundary condition
  - Revision of upwinding in bed load transport (bed load flux averaging)
  - Write *sediment\_grid.shp* file to the right location (where *.bmc* file and result files are written)
  - Revision and new concept for creation and initialization of layers (*create\_new\_layers*)
  - Improved *node\_history* output for *grain\_size*
  - *control\_volume\_type*: replaced *dmean* by *d90*
  - Fix *grain\_size\_friction* on fixed bed
  - Fix high velocities in upstream BCs for inner weir, inner gate and inner h-q relation
  - Minor others

System Manuals:

- New BASEMENT manuals in pdf and html format for offline and online consultation

## 3.14 Version 2.8

General:

- Software environment updated for Windows 10 - 64 bit
- Update to latest 3rd party libraries
- *New Features:*
  - Vegetation model
  - User defined *hiding\_exponent* also available for Parker formula

- Colorblind friendly GUI
- Ashida and Michiue transport fomula (non-uniform sediment)
- Output timestep matches exactly given intervall
- OpenMP parallelization revised
- *Bugfixes:*
  - Wilcock and Crowe bug fixes
  - `output_time_step` and `restart_time_step`

#### Subsystem BASEchain:

- *NOTE* : Implicit scheme for time integration not available in v2.8. Please refer to v2.7 for implicit time integration calculation.
- *New Features:*
  - Initial state for suspended load transport (mixture and concentration) can be defined with global values instead of providing a file with initial state for every cross section
  - Water depth and Froude number are available as output (including the tracking of minimum and maximum values)
  - Simple upwind approach for suspended load transport available
  - Inner boundaries improved and extended (weir/gate)
- *Bugfixes:*
  - Matlab output fixed and optimised
  - Sediment exchange between suspended load and bed load with “shear stress” approach
  - Mass conservation in dual-mode sediment transport (combination of bed load and suspended load) improved
  - Mass conservation with QUICKEST scheme improved

#### Subsystem BASEplane:

- *New Features:*
  - Vegetation model: new BLOCK and all related features added
  - Dynamic slope available for ‘hqrelation’ (uniform flow) at downstream boundary with the same slope adjustment as at the upstream ‘hydrograph’ boundary (due to erosion/deposition)
  - Definition of `control_volume_thickness` over the material index with new tag `control_volume_thickness_index`
  - INNER Boundary Conditions for MORPHOLOGY (BEDLOAD): “open” and “weir” type



- Suspended load exchange term: `exchange_type= shear_stress` and additional parameters: `tk`, `factor_m` and `factor_n`
- Generation of the sediment grid parallelized
- *Bugfixes:*
  - Possible to get the output value ‘saturation’ without BASESUB-block
  - `string_def` output of flow velocity and improvement of the averaged velocity weighted by wetted area of relevant edges
  - INNER GATE and WEIR in BASEplane reviewed

#### System Manuals:

- Revision of test cases
- Reference Manual:
  - Ashida and Michiue transport formula (non-uniform sediment)
  - Suspended load
  - Bed perturbation
  - Sediment boundary conditions
  - Description of vegetation model
  - Discretisation of Boundary Conditions (inner boundaries)

### 3.15 Version 2.8.1

#### General:

- The third party libraries and the installers were updated.
- The vegetation feature was revised.
- The time-integrated transport capacity is now included in the output “`transport_diagram`”.
- The documentation was revised.
- *Known Issues:*
  - 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).
  - The upstream and downstream stringdefs of the inner boundary weir must be of the same length, otherwise mass might not be conserved. Summary of Features  
=====

## 3.16 Subsystem BASEchain

### 3.16.1 Numerics

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

### 3.16.2 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)   |

### 3.16.3 Hydraulics

|                        |   |
|------------------------|---|
| 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   |

### 3.16.4 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  |

### 3.16.5 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<br>Shear stresses: Xu |
| Source Terms       | Local source/sink   |

---

### 3.16.6 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: $z_{\text{dam}}$ (left/right), $z_{\text{bottom}}$ (mean), friction, $Q_b^{\text{cap}}$ , $C_{\text{tot}}$<br>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, $Q_{b,i}$ , $Q_s^{\text{adv}}$ , $Q_s^{\text{diff}}$<br>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<br>Monitoring Output: $Q$ , $Q_b$ , $A$ , WSE, $v$ , geometry, $C$ , $b$ (=mean bottom level), energy_line (EL), Fr, $h$ (=mean flow depth)<br>Restart files: Hydrodynamics, bedload, suspended load<br>Volume files: Variation of water volume, variation of sediment volume, suspended sediment volume, transport capacity volume |

---

## 3.17 Subsystem BASEplane

### 3.17.1 Numerics

---

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

---

**3.17.2 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  |

---

**3.17.3 Hydraulics**


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

---

**3.17.4 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   |

---

**3.17.5 Sediment transport : Suspended load**


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

---

### 3.17.6 Sediment transport : Gravitational induced transport

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

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### 3.17.7 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 |

---

## 3.18 Subsystem BASEsub

### 3.18.1 Numerics

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

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### 3.18.2 Geometry

---

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

---

### 3.18.3 Hydraulics

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|       |   |
|-------|---|
| Model | 3-D Richards equations, Saturation-formulation, mixed Saturation-Pressure formulation |
|-------|---|

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

---

### 3.18.4 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

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- Format

---

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

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