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WP3 Deliverable 10
Modelling hydraulic performance
Conclusive report

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CARE-S - Computer Aided REhabilitation of Sewer networks

COMPUTER AIDED REHABILITATION OF SEWER NETWORKS
RESEARCH AND TECHNOLOGICAL DEVELOPMENT PROJECT OF EUROPEAN COMMUNITY

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Report D10

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Report contents

1 INTRODUCTION 5
1.1 Task and aims 5
1.1.1 Task and task contents 5
1.1.2 Report structure and contents 5
1.2 Role in the rehabilitation planning process 6
2 LITERATURE REVIEW 7
3 BASIC CONCEPTS AND METHODOLOGY APPLIED 7
4 HYDRAULIC AND ENVIRONMENTAL CRITERIA 9
4.1 C1, C2 and C3 – Filling level criteria 10
4.1.1 Filling level classification 10
4.1.2 Critical level 12
4.1.3 Theoretical background 12
4.1.3.1 Frequency 12
4.1.3.2 Probability 13
4.1.4 Filling level criteria definitions 15
4.1.5 Example of Filling level criteria 16
4.2 C4 - WeightLink 16
4.3 C5 - InsufficientCapacity 17
4.4 C6 - Velocity 17
4.4.1 Minimum Velocity Criteria 17
4.4.2 Maximum Velocity Criterion 19
4.4.3 Total Velocity criterion 20
4.5 C8 - SewerTypology 21
4.6 C9 - InfiltrationWeight 21
5 THE HELLMUD TOOL 22
5.1 Description of the tool 22
5.2 Installing the tool 22
5.3 Application scope 23
5.4 HELLMUD final results 23
5.4.1 Hydraulic deficiency 24
5.4.2 Velocity deficiency 24
5.4.3 Infiltration deficiency 24

5.4.4 Exfiltration deficiency 25
5.4.5 CSOs evaluation 25
5.5 INPUTS 27
5.5.1 Layout file 27
5.5.2 Hydraulic files 28
5.5.2.1 Single Event simulation (SE) 28
5.5.2.2 Historical Rain Data simulation (HRD) 28
5.5.3 CAT output file 29
5.5.4 GAT output file 29
5.5.5 Design Year Period “N” 29
5.5.6 Velocity criteria of the Country 30
5.6 OUTPUTS 31
5.6.1 HELLMUD Process Results 31
5.6.2 HELLMUD Final Results 32
5.7 Data acquisition 33
5.7.1 Data for HRD simulation 33
5.7.2 Data for SE simulation 33
5.8 HELLMUD Glossary 34
6 SUMMARY 35
7 REFERENCES 36
Annex I – Examples of input data 39
Annex II – Examples of output data 44
Annex III – HELLMUD inputs from MOUSE 46
Annex IV – HELLMUD inputs from InfoWorks 48
Annex V – HELLMUD inputs from SWMM 50
Annex VI – HELLMUD Help file 52

1 INTRODUCTION

The research project CARE-S (Computer Aided REhabilitation of Sewer Networks) deals with public sewer and storm water networks of any dimension. CARE-S aims to analyse structural and functional reliability of wastewater networks at minimum cost and disturbance. The ultimate product will be a Decision Support System (DSS) that will enable municipal engineers to establish and maintain effective management of their sewer networks.

The project work plan follows a logical structure for the necessary work. It is divided into 10 Work Packages (WP) and each WP is distributed among several project partners.

The performance of a sewer system can be considered as its ability to transport storm and wastewater without hydraulic overload, as well as creating minimal environmental impact and retaining good structural integrity. This can be achieved by judging performance against the following criteria: water quantity standards, maximum water levels, allowable discharges, water quality standards, overflow frequency and structural condition standards.

The work package 3.4 aims to provide hydraulic and environmental criteria, methods and evaluation to derive values for the inclusion of reliability aspects of sewer systems in the decision support system. The reliability analysis can be used in the decision making process for assessing or ranking rehabilitation projects, or to design or assess long term rehabilitation strategies.

1.1 Task and aims

1.1.1 Task and task contents

The project is organized in the following Working Packages (WP):

WP 1: Construction of a control panel of performance indicators (PI) for rehabilitation
WP 2: Description and validation of structural condition
WP 3: Description and validation of hydraulic performance
WP 4: Rehabilitation technology information system
WP 5: Socio-economic consequences
WP 6: Multi-criteria decision support
WP 7: Wastewater network rehabilitation manager
WP 8: Testing and validation
WP 9: Result presentation and dissemination
WP 10: Project management

WP3 includes four separate tasks concerning description and validation of hydraulic performance:

- Task 3.1 Evaluation of current best practise
- Task 3.2 Modelling of hydraulic performance temporal decline
- Task 3.3 Environmental impacts of rehabilitation strategies
- Task 3.4 Combining hydraulic and reliability model

TU Brno is responsible for task 3.4 "*Combining hydraulic and reliability model".* The results of the task 3.4 are presented in this deliverable D10.

The MOUSE, SWMM and InfoWorks model can be used as the hydrodynamic tool (Deliverable D7 and D8). The CAT and GAT model support an environmental evaluation (Deliverable D9). A software tool HELLMUD has been developed to carry out the reliability calculations in the frame of task 3.4.

1.1.2 Report structure and contents

On the base of literature study (chapter 2) and in cooperation with other WPs, the basic concepts and methodologies were assessed (chapter 3). Consequently, a tool for calculation of process WP3 criteria and final hydraulic and environmental deficiencies was developed. The development of this HELLMUD Tool is a core of task 3.4 contribution to CARE-S project.

In this report, WP3 hydraulic and environmental criteria are defined and described (chapter 4) as well as HELLMUD Tool procedures, inputs and outputs (chapter 5). A brief Glossary is included to provide a quick overview of important terms used during work with HELLMUD Tool. Examples of input and output data can be found in Annexes together with data transformation from hydraulic models (MOUSE, InfoWorks and SWMM). HELLMUD Help file is put at the end to give insight into HELLMUD user interface.

1.2 Role in the rehabilitation planning process

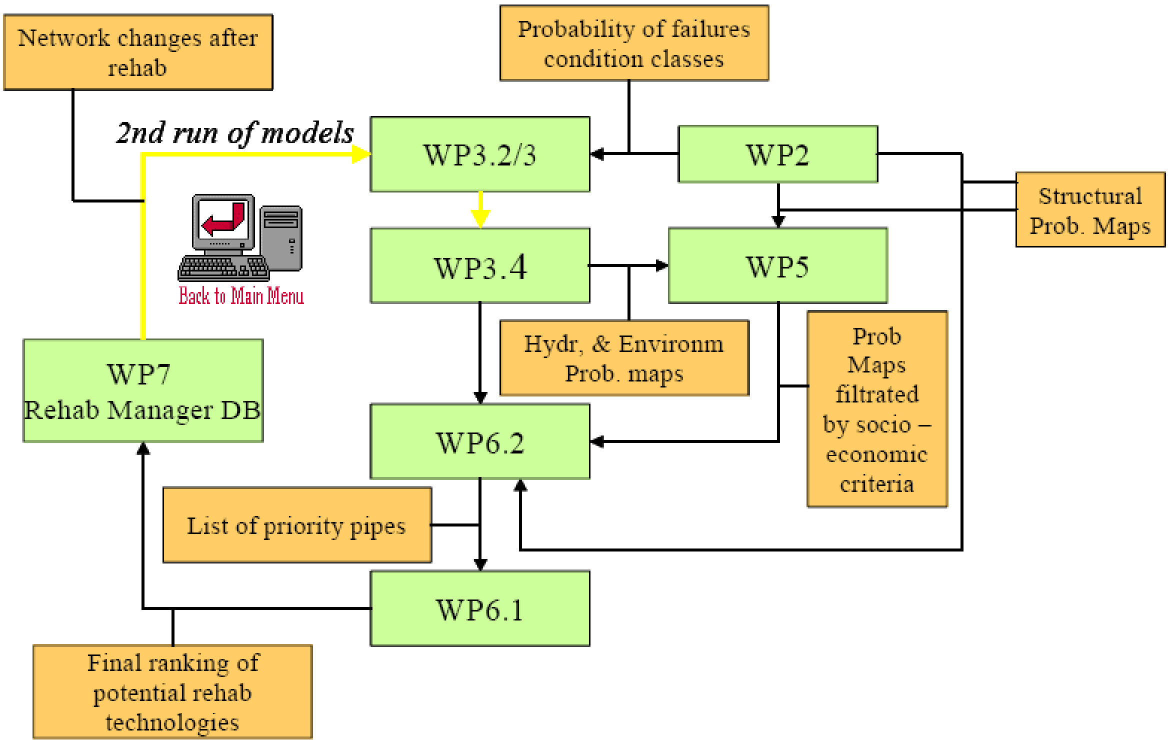
Reliability considerations for sewer and storm water networks are an integral part of all decisions regarding the planning, design and operation phases of such systems. The task 3.4 is focused on the integrated performance of the whole sewer system and forms a basis for identifying potentially high-risk sewers. Task 3.4 interactions with other WP3 tasks as well as external WP3 links are shown in Figure 1.

The results of the hydraulic, structural, environmental and operational investigations carried out in tasks 3.2 and 3.3 (resp. WP2) are used as a basis for processing in newly developed reliability model HELLMUD.

Results provided by task 3.4 are visualized by the Rehabilitation Manager GIS system as hydraulic and environmental “probability maps” able to present in a direct way the most critical components for hydraulic and environmental aspects at different detail levels.

The probabilistic maps provide inputs to both WP5 and task 6.2. Within WP5, the probabilistic maps are filtrated by socio – economic criteria and go to task 6.2 too. From the analysis of the maps, task 6.2 produces the list of priority pipes in terms of rehabilitation request and sends this list to task 6.1 which defines the final ranking of potential rehabilitation technologies. The effect of rehabilitation technologies on the network conditions is recorded in the Rehabilitation Manager. Changes produced in the system are defined and the hydraulic input can be corrected. With the new input files, it is possible to run the procedure again and to develop new probability maps after rehabilitation.

Figure 1 WP 3.4 interactions within CARE-S project



2 LITERATURE REVIEW

A literature review was the first step of work within task WP3.4. According to description of work, suitable ways for reaching of required results were investigated and consulted with other CARE-S partners.

Among the main information sources concerning sewer and storm water networks including sewer rehabilitation are publications as Krejci et al. (2002), Marsalek et al.(1998), Harremoës and Rauch (1996) and Pliska and Metelka (2001). Chow et al. (1998) deals with rain data processing and evaluation used in HELLMUD methodology.

Mathematical statistics and statistical methods used are described in Mandenhhall and Sincich (1988). Theoretical base for the analysis of the reliability on the pipe level using probability theory is described in Melchers (2001). By term “reliability” is understood not only reliability against extreme events such as structural collapse or total blockage, but also against the violation of any structural requirements which the structure is expected to satisfy. This is used for assessment of different filing levels analysis on pipe level in the frame of the whole network and complex hydraulic deficiency for each link.

Velocity criteria are based on an international and national standards as well as information obtained e.g. from Yallin (1997), Imhoff (1928) and Koudelak (2002).

3 BASIC CONCEPTS AND METHODOLOGY APPLIED

Reducing the impact of flooding on the build environment, as well as controlling combined sewer overflows or to avoid sediment deposit inside pipes due to flow conditions or protect receiving water quality during storms are all aspects of an overall reliability analysis of the system. The aim can be potentially addressed using a portfolio of adaptation strategies which tackle one or more of the three elements of risk:

(1) eliminate the hazard,
(2) reduce the exposure,
(3) control the vulnerability to the consequences.

The approaches described in this report are focused on hazard and exposure, not on vulnerability. Vulnerability to consequences of system deficiencies is an evaluation produced within the interaction of task 3.4 results weighted with socio – economic aspects and multicriteria analysis.

The WP3 first step to perform a reliability analysis was to define the hydraulic and environmental criteria on pipe level able to quantify reliability parameters.

The criteria proposed and evaluated are classified as hydraulic and environmental. The list of hydraulic criteria, described in the following chapter 4, includes:

- Frequency and probability of a specific filling water levels (B, C, D)
- Weight of the link in terms of flow capacity (the bigger dimension of the pipe, the more critical flooding event can caused)
- Insufficient Capacity (evaluation whether flooding events detected on the pipe are produced by this pipe or caused e.g. by backwater from downstream)
- Flow velocity (comparison with standard in order to evaluate problems with either minimal or maximal velocity)
- Sewer typology (combined or separated)
- Infiltration weight (infiltration of the link with regards to the whole network)

While environmental criteria base on data derived from task 3.3 analysis are:
- Exfiltration (vulnerability of the groundwater)
- CSOs impacts criteria (level of hazard and range)

A HELLMUD Tool was developed in the frame of the task 3.4 for calculation and further processing of the criteria above. HELLMUD provides two mail outputs - Process results and Final results. Process results covers calculation of WP3 criteria listed above, input data are loaded from tasks 3.2. and 3.3. Consequently HELLMUD combines these criteria and produces five complex hydraulic and environmental criteria on the pipe and CSO level:

- Hydraulic deficiency
- Velocity deficiency
- Infiltration deficiency

Complex hydraulic criteria

- Exfiltration deficiency
- CSO evaluation

Complex environmental criteria

Developing of methodology able to link both hydraulic and environmental indicators is based on classical statistic methods to determinate the occurrence of undesirable phenomena and hence possible hazard, as presented in the following.

4 HYDRAULIC AND ENVIRONMENTAL CRITERIA

In the frame of WP3, hydraulic and environmental problems of sewer network are evaluated by means of 13 criteria (Tab. 1). Originally, number of criteria 16 was suggested, and during developing of the tool and in cooperation with other WPs three criteria were removed from the list:

- C7 – overflow volume

The C7 was not criterion in fact. Overflow volume of particular CSO is calculated in CAT Tool and consequently used as input for calculation of C11-C14 criteria.

- C15 and C16 – WWTP performance

These criteria were substituted by a report concerning consequences on WWTP due to rehabilitation.

WP3 criteria evaluate each pipe and CSO either separately or in relation to the others, so the results can be used for assessment of sequenced list of the pipes and CSOs according their contribution to the failure occurrence on the network.

Tab. 1 WP3 Hydraulic and Environmental criteria overview

Name	Unit	Range	For	Input data		Description
				from	tool	
C1	[-]	A, B, C, D	pipe	WP3.2		filling level
C2A	$[year^{-1}]$	<0.02 ; 5>	pipe	WP3.2		frequency - class A *)
C2B	$[year^{-1}]$	<0.02 ; 5>	pipe	WP3.2		frequency - class B *)
C2C	$[year^{-1}]$	<0.02 ; 5>	pipe	WP3.2		frequency - class C *)
C3B	[-]	<0 ; 1>	pipe	WP3.2		probability P(B) **)
C3C	[-]	<0 ; 1>	pipe	WP3.2	HELLMUD	probability P(C) **)
C3D	[-]	<0 ; 1>	pipe	WP3.2		probability P(D) **)
C4	[-]	(0 ; 1>	pipe	WP3.2		weight of link
C5	[-]	<0 ; 1>	pipe	WP3.2		insufficient capacity
C6	[-]	yes/no	pipe	WP3.2		velocity
C8	[-]	S/C	pipe	WP3.2		sewer typology
C9	[-]	<0 ; 1>	pipe	WP3.2		infiltration weight
C10	[-]	High Moderate Low	pipe	WP3.3	GAT	exfiltration
C11	yes/no absolute value, %		CSO	WP3.3		overflow total load
C12	yes/no absolute value, %		CSO	WP3.3	CAT	overflow frequency / spills
C13	yes/no absolute value, %		CSO	WP3.3		overflow volume
C14	yes/no absolute value, %		CSO	WP3.3		overflow duration

*) Frequency for which filling level B (C, D) is exceeded just once.
**) Probability appropriate to criterion C2.

Criteria C1 – C9 processed within HELLMUD are described in this report. Their summary and specification together with brief definition is listed in Tab. 2. For more detailed specification of data format see chapter 5.6.1, example of file *HE_Proces_name_XX.csv* can be found in Annex II.

Criterion C10 concerning exfiltration from the pipe comes from GAT Tool. HELLMUD processes C10 and produces Exfiltration criterion in Hellmud Process results. Criteria C10 - C14 concern CSOs and are calculated by means of CAT Tool. HELLMUD works with CAT output file and provides evaluation of each particular CSO as separate object on the network. Detail description of GAT and CAT Tools as well as results of these tools (criteria C10 – C14) can be found in Report D9 – "Environmental impacts of rehabilitation" (Schulz, Krebs, 2004) and Report "Tools in Work Package 3.3" (Schulz, 2004).

Tab. 2 HELLMUD process results (WP3 Criteria)

Name of criterion	Criterion	Range	Unit
	LinkID		[-]
C1	FillingLevel	A, B, C, D	[-]
C2A	FrequencyFillingLevelA	<0.02 ; 5>	[year^{-1}]
C2B	FrequencyFillingLevelB	<0.02 ; 5>	[year^{-1}]
C2C	FrequencyFillingLevelC	<0.02 ; 5>	[year^{-1}]
C3B	ProbabilityB	<0 ; 1>	[-]
C3C	ProbabilityC	<0 ; 1>	[-]
C3D	ProbabilityD	<0 ; 1>	[-]
C4	WeightLink	(0 ; 1>	[-]
C5	InsufficentCapacity	<0 ; 1>	[-]
C6	Velocity	yes/no	[-]
C8	SewerTypology	S/C	[-]
C9	InfiltrationWeight	<0 ; 1>	[-]

4.1 C1, C2 and C3 – Filling level criteria

4.1.1 Filling level classification

The hydraulic reliability strategy of the model distinguishes four classes (A, B, C, D) to classify all pipes (Figure 2). Class A includes design volume of the pipe – whole range of the water levels inside the particular pipe, from the bottom to the top of the pipe. The behaviour of the sewer is reliable and safe, no overloading is detected. Class B covers safe storage volume of manholes, low overloading of the sewer is permitted. The class exceeds the top of the pipe and reaches to the critical level (see chapter 4.1.2). Class C spans between the critical level and ground level. Dangerous volume is filled and the sewer is medium overloaded. It is supposed that in particular level between top of the pipe and surface level are situated basements of houses, the situation starts to be unsafe for the connected properties and their flooding via sanitary connections is expected. And finally, Class D involves all water levels exceeding the ground level; wastewater flows out from the sewer, floods the surface and can caused dangerous environmental problems. Classes B, C and D are considered to be unreliable. Overview of the pipe classification used in HELLMUD Tool is in Tab. 3.

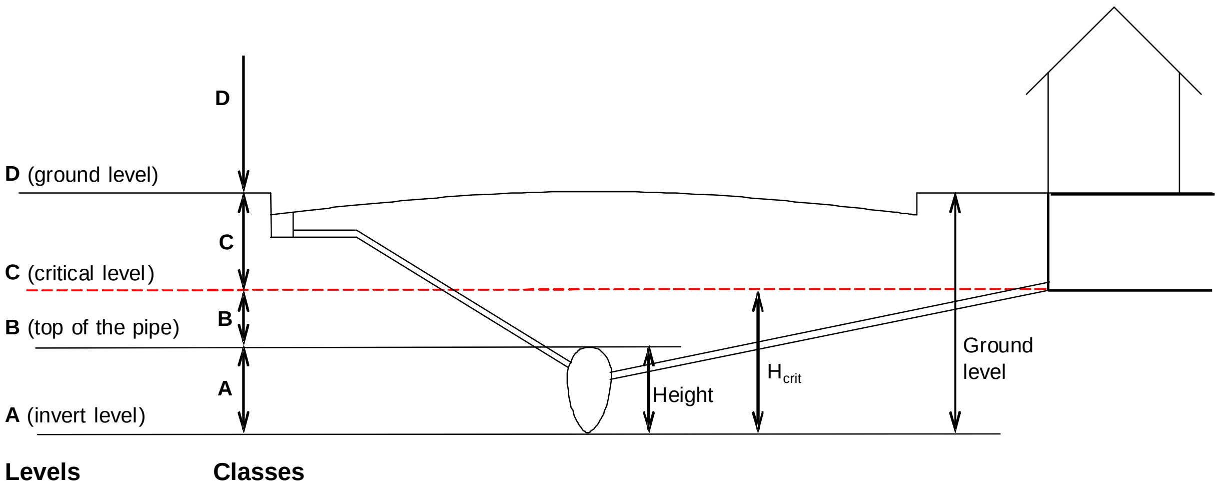
Values of Height (perform diameter or height of the pipe in the HELLMUD Tool), H_{crit} and the Ground level as well as relation between Levels and Classes are shown in Figure 3.

Figure 2 Pipe classification for assessing of hydraulic efficiency and environmental impacts of sewer systems.

Tab. 3 Overview of pipe classification in HELLMUD Tool

Class	Range	Area	System behaviour	Status of the system	Overloading
A	from invert level up to full pipe	design	reliable within the range of design	safe	non-overloading
B	from top of the pipe up to critical level	storage	unreliable	safe	low overloading
C	from critical level to ground level	dangerous	unreliable	unsafe	medium overloading
D	above ground level	flooding	unreliable	dangerous	high overloading

Figure 3 Overview of Levels, Classes and altitudes for pipe classification



4.1.2 Critical level

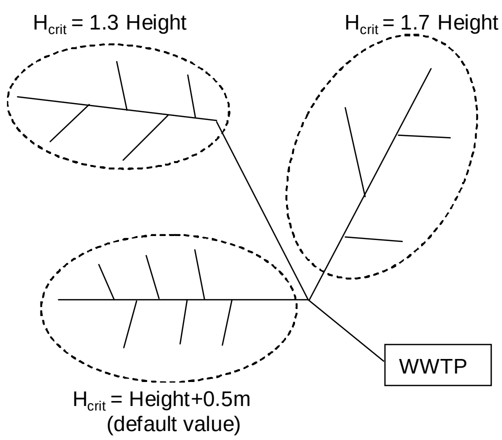
The hydraulic hazard of the system is interpreted by means of so-called **"*critical level*"** $\mathbf{H_{crit}}$. Critical level is fictive line between Class B and Class C, the level has got the range between the top of the pipe and the ground level of the elementary catchment of each pipe. The critical level is defined as a sewer network water level that, if exceeded, starts to bring damages on properties within the urbanized catchment assigned to the pipe. All hydraulic events above the critical level are unsafe or dangerous and have to be controlled.

Inside HELLMUD, the critical level as well as all other filing levels are used in relation to Height of the pipe as non-dimensional parameter (e.g. H_{crit}/Height, H_{max}/Height etc.). Height is loaded from hydraulic model as vertical dimension of the pipe (see chapter 5.5.1).

"High degree of surcharging" is set as default value for assessment of critical level inside HELLMUD. High degree of surcharging is defined as water level at least 0.5 m above the pipe crown (external top of the pipe), regardless of pipe diameter. High degree of surcharging is used also within WP1 for calculation of Physical Performance Indicator "sPh3 – High sewer surcharging" by means of Utility Information "sC49 – Highly surcharged sewer" (CARE-S Report D1, Matos et al., 2003).

User can change this default value when an operational value is available or if national standards are preferred or required. In both cases, critical level is loaded as ratio to the Height (see above). Example of assessment of $\mathbf{H_{crit}}$ value is shown in Figure 4.

*Figure 4 Example of critical level (**H_{crit}**) assessment on the sewer network*



4.1.3 Theoretical background

4.1.3.1 Frequency

Following paragraphs describe methodology for assessment of the criterion C2 from HELLMUD input data. For both SE and HRD simulation the procedure is the same, the only difference is internal HELLMUD assessment of shape of the curve outlined in Figure 5.

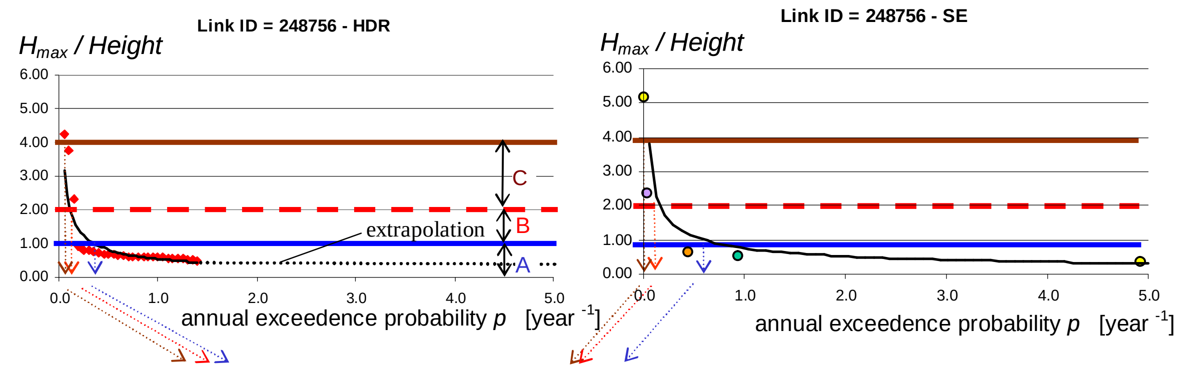
i) Firstly, the dependence of relation $\mathbf{H_{max}}$**/Height** on frequency ***p*** (= annual probability of exceedance) has to be found. $\mathbf{H_{max}}$ are water levels appropriate to the particular link loaded from the hydraulic model (SE of HRD simulation); **Height** is the vertical dimension of the pipe. For input values (points in Figure 5) of the simulation, exponential function for the dependence is found (the curve).

ii) Secondly, intersections of the curves with three levels (B, C and D) are calculated. The value of **H_{max}/Height** for level B is always “1”, because the supposed maximal water level for level B is top of the pipe, i.e. height (diameter). Class C corresponds to **H_{crit}** and class D corresponds to surface level.

iii) And finally, readings on x-axis are required results, frequencies *p*(A), *p*(B) and *p*(C), which are listed in Tab. 1 and Tab. 2 as part of HELLMUD process results (criteria C2A, C2B, C2C).

*Figure 5 Relationship between the water level (**H_{max}/Height**) and frequency (C2)*
a) the regression on historical rain data simulation (HRD)
b) the regression on single event simulation (SE), p = 5; 1; 0.2; 0.1 and 0.333 year^{-1}

a) b)



pipe ID	p(A)	p(B)	p(C)
248756	0.6	0.4	0.06
248757	0.03	0.02	0.01
24...	...	...	...

4.1.3.2 Probability

Similarly to many other cases of engineering practice where natural phenomena of accidental character both in time and space such as storms, waves, winds, floods, etc. are to be assessed, the probability of the exceeding of sought indicators was made with the use of the formulae below based on binomial probability distribution. Characteristics of binomial random variable are following:

1. The experiment consists of *N* identical trials.
2. There are only 2 possible outcomes on each trial (“event will occur” x “will not occur”).
3. The probability of “event will occur” is the same from trial to trial (*p*).
4. The trials are independent.
5. The binomial random variable *r* is the number of “event will occur” in *N* trials.

The binomial probability distribution:

$$P_{(N,r)} = \binom{N}{r} p^r (1-p)^{N-r} = P_{(N,r)} = \frac{N!}{r!(N-r)!} p^r (1-p)^{N-r} \tag{1}$$

Explanation of the particular variables is listed in Tab. 4

Tab. 4 Binomial probability distribution and variables

variable	unit	binomial probability distribution	explanation	HELLMUD Tool
N	[year]	number of trials (events)	number of years, after which occurrence of given event (given filling level) is admitted, e.g. the useful design life of the structure or duration of insurance	"Design Year Period" defined by the user
r	[-]	number of events in ***N*** trials	total number of achieved water levels within Classes B, C or D	***r*** = 0
P(N,r)	[-]	probability of ***r*** events occurring in ***N*** possible events		*P*(C2) C3=1-P(C2)
p	[year^{-1}]	probability of single event occurring in ***N*** possible events	annual probability of exceedance (frequency) ***p*** = 1/***T***	C2
T	[year]	recurrence interval	return period ***T*** = 1/***p***	1/C2

For better understanding of relationship among the variables see Tab. 5.

If ***r*** = 0, no floods will occur during the period ***N*** and the formula above is simplified into:

$$P_{(N,0)} = (1-p)^N \quad ; \quad p \in \langle 0.01\,;1\rangle \tag{2}$$

This is the probability that a flood (level B, C and D) with an annual exceedance probability ***p*** will not be exceeded at all in the period of N years.

Generally, hydraulic hazard *R* can be counted as complement-on-one to probability *P*. The result of hydraulic performance is hydraulic hazard for each pipe assessed by means of probability that water level appropriate to the particular pipe is equal or higher then appropriate level (B, C or D).

$R = 1 - P_{(N,0)}$, when $P_{(N,0)} = P(H \geq \text{level B, resp. C or D})$ (3)

Where *R* – hydraulic hazard for each pipe
H – water level appropriate to the particular pipe (link)
P, N – see above

Tab. 5 shows percent occurrence of the risk of one or more exceedance during the Design Year Period. The values of the risk are listed in % (interval of < 0,100 >) while in the Table 1 they are reduced to non-dimensional values in the range of < 0, 1 >. The basic formula and its parameters is explained and demonstrated by means of arrows. For example, a 20-year recurrence flood has a 10 percent chance of being exceeded within any 2-year period.

Tab. 5 Percent occurrence of the hazard R [%] of one or more exceedance in a Design Year Period

$$R = 1 - P_{(N,0)} = 1 - (1-p)^N$$

Recurrence Interval (*T*)	**Annual Probability of Exceedence (*p*=1/*T*)**	**Design Year Period (*N*) [years]** (Time period, after which is admitted occurence of given event. Defined by end-user)								
[years]	**[years^{-1}]**	**N=1**	**N=2**	**N=5**	**N=10**	**N=15**	**N=20**	**N=25**	**N=50**	**N=100**
50	**0.02**	2	4	10	18	26	33	40	64	87
30	**0.03**	3	7	16	29	40	49	57	82	97
20	**0.05**	5	10	23	40	54	64	72	92	99
10	**0.10**	10	19	41	65	79	88	93	99	100
5	**0.20**	20	36	67	89	96	99	100	100	100
2	**0.50**	50	75	97	100	100	100	100	100	100
1	**1.00**	100	100	100	100	100	100	100	100	100

4.1.4 Filling level criteria definitions

Criteria C1, C2 and C3 together perform hydraulic evaluation of every link. Criteria C2 and C3 each provide three separate values (C2A, C2B, C2C and C3B, C3C, C3D) which means that total number of Filling level criteria is seven.

C1 - FillingLevel

Criterion C1 defines the filling level in the pipe corresponding the annual probability of exceedance equals 0.05 (1 / 20 = 0.05 $year^{-1}$). That means that during 20-year period (recurrence interval) the maximal reached filling level belongs to the resulting class (A, B, C or D). The value 0.05 is default and end user cannot change it by any way.

Range: A, B, C or D
Meaning: The higher Class the worse hydraulic failure is supposed to occur on the pipe.

C2 – Frequencies

Criterion C2 expresses annual probability of exceedance (frequency) for which appropriate level (B, resp. C or D) is exceeded just once. All reached filling levels within this time period are up to the class A, resp. B or C.

Range: <0.02 ; 5> $year^{-1}$
Meaning: The greater value of C2 the worse hydraulic failure can occur on the pipe.
Thresholds: 0.02 $year^{-1}$ – the level is exceeded once 50 years
5 $year^{-1}$ – the level is exceeded once 0.2 years, i.e. 5 times per year.

Range of the criterion C2 is limited by <0.02 ; 5> $year^{-1}$ that means return period from 50 to 0.2 years. The minimal value 0.02 is assigned to all results less than 0.02 and similarly, the maximal value 5 is assigned to all results greater than frequency of 5. This is because dependence of relation **H_{max}/Height** on frequency ***p*** is expressed by means of an exponential function and for extreme values the extrapolation reduces accuracy of results.

C3 - Probabilities

Consequently, criterion C3 is counted as complement-on-one to probability of appropriate criterion C2. Probability of criterion C2 is the probability that appropriate level (B, C or D) - with an annual exceedance probability C2 - will not be exceeded at all during the period of N years ("N" is Design Year Period).
Then, criterion C3 is hazard – probability, that appropriate level (B, C or D) will be exceeded one or more times during the Design Year Period.

Criteria C2 and C3 each provide three separate values (C2A, C2B, C2C and C3B, C3C, C3D).
The relationship between C2 and C3 criteria is included in following Tab. 6:

Tab. 6 Relationship between C2 and C3 criteria

C2A	FrequencyFillingLevelA	⇔	C3B	ProbabilityB
C2B	FrequencyFillingLevelB	⇔	C3C	ProbabilityC
C2C	FrequencyFillingLevelC	⇔	C3D	ProbabilityD

Range: <0 - 1>
Meaning: The greater value of C3 the worse failure is supposed to occur on the pipe.
Thresholds: 0 - pipe without any problem, that appropriate level will not be exceeded at all
1 - a significant problem identified, probability that appropriate level will be exceeded one or more times during Design Year Period is 100%.

4.1.5 Example of Filling level criteria

Design Year Period: N = 4 years (during 4 years any appropriate flood can occur)
Criterion C1: C1 = “C”
Criteria C2 and C3:

C2A	0.49	⇔	C3B	0.74
C2B	0.31	⇔	C3C	0.52
C2C	0.04	⇔	C3D	0.08

Meaning:

That means, that during 20-year period the maximal reached filling level belongs to the class “C”, i.e. exceeds the critical level, but does not reach the surface level.

Level B (top of the pipe) is exceeded just once for frequency equals 0.49 year^{-1}, i.e. once 2.04 years (return period 1 / 0.49 = 2.04 years). All reached filling levels within this time period are within the class A. Probability that level B (with an annual exceedance probability 0.49 year^{-1}) will be exceeded one or more times during 4 years is 0.74.

Level C (critical level) is exceeded just once for frequency equals 0.31 year^{-1}, i.e. once 3.23 years (return period 1 / 0.31 = 3.23 years). All reached filling levels within this time period are within the class B. Probability that level C (with an annual exceedance probability 0.31 year^{-1}) will be exceeded one or more times during 4 years is 0.52.

Level D (surface level) is exceeded just once for frequency equals 0.04 year^{-1}, i.e. once 25 years (return period 1 / 0.04 = 25 years). All reached filling levels within this time period are within the class C. Probability that level D (with an annual exceedance probability 0.04 year^{-1}) will be exceeded one or more times during 4 years is 0.08.

4.2 C4 - WeightLink

Weight of the link is calculated as following ratio:

$$C4 = Q_{cap} / \max \text{ of } Q_{cap} \tag{4}$$

where:

Q_{cap} - capacity flow of full section inside the pipe (uniform steady condition). This value does not depend on the simulation done, but it is related with the hydraulic parameters and total flow capacity of the pipe.

max of Q_{cap} - maximum of capacity flows. From the comparison between all the Q_{cap} evaluated for all the pipes, the maximum is selected.

The ratio between these values is information of the weight of the specific pipe considered, in terms of flow capacity compared with all the other pipes. This criterion is defined in order to weight in the simplest way the pipe responsibility to flooding events, and to give to WP5 more information about the flooding event magnitude.

<u>Range:</u> (0 - 1>
<u>Meaning:</u> The greater value of C4 the more critical flooding event can the pipe caused.
<u>Thresholds:</u> 0 - cannot be reached
1 - assigned to the biggest pipe of the system and, of course, if flooding event is produced by this pipe the situation is really more critical than a flooding event produced by a pipe with a ratio value as 0.2, for example.

4.3 C5 - InsufficientCapacity

Criterion C5 was originally named ”Flow capacity”, but with cooperation with other WPs better expression ”Insufficient Capacity” was agreed.
When we calculate the C1, C2, C3 criteria we have to evaluate if the filling levels C or D and their frequency are produced by an insufficient flow capacity of the pipe or by downstream failures (collapse, reduced flow capacity etc.). In the latter situation we have to rehabilitate the right pipe and this is not the pipe where the level exceeds the critical one. The question is: How to find out the particular pipe that has produced that unsafe or dangerous level? Without considering the system layout we have not so many choices. Using the hydraulic models result, to complete the analysis of “weighting” the pipe for flooding, another criterion (to link with the previous C4 criterion) is used:

$$C5 = Q_{max}/Q_{cap} \tag{5}$$

Where:

Q_{max} - the maximum flow value inside the pipe during rain event of return period equals Design Year Period N. This value is obtained from regression of input data “Q_{max}” in hydraulic files (HRD of SE) by exponential function and assessment of Q_{max} for N-year period.

Q_{cap} - see C4 criterion

This ratio evaluates the possible insufficient flow capacity of a pipe, because the flooding event localized on a specific pipe could be produced by a downstream back-water due to another insufficient pipe.

Range: <0 - 1>

Meaning: The greater value of C5 the worse hydraulic capacity of the pipe is detected.

Thresholds:
- 0 - pipe without problem
- 1 - $Q_{max} = Q_{cap}$ and the pipe starts to be of insufficient capacity. The pressure flow can be observed in the pipe and wastewater can even overload from the pipe in manholes.
  Range of the criterion C5 is limited by <0 - 1>. When the ratio is greater than 1, the pipe is insufficient in terms of flow capacity but C5 keeps the value 1. That means HELLMUD does not define how much is the pipe overloaded, only indicates pipes with insufficient capacity.

4.4 C6 - Velocity

Two extreme situations concerning problems with velocity can occur in a drainage area. Firstly, too low velocity in sewer causes sedimentation of materials on the bottom and walls of the pipe, and consequently undesirable reduction of diameter. Secondly, high velocity in sewer will probably lead to abrasion of the pipe structure.

There are no uniform and objective methods for assessment of minimum and maximum velocity (slope) in sewer. Many authors, standards and directions define different methods and HELLMUD module uses five of them. Following subchapters describe a general overview of the methods and principles included in the tool.

End user can tick required criteria as well as change the default value in a dialogue window. For each country, velocity criteria can be stored in HELLMUD and used for later running the tool.

4.4.1 Minimum Velocity Criteria

Assessment of minimum acceptable velocity in sewer is closely connected with assessment of minimum slope. Hydraulic, technical, operational and financial aspects should be taken into account. Too low slope in sewer reduces the cross section (the velocity is low too), the pipe is clogged by waste materials and has to be cleaned quite often. In the other hand, when the higher slope is designed, the

pipe need not to be cleaned so often, but on a plain area wastewater pumping could be required (increasing of investments and operational costs).
HELLMUD module uses four methods for evaluation of minimum velocity criteria:

I. Self-cleaning Slope Criterion

Minimal self-cleaning slope depends on diameter according to recommended national / local standards or operational experiences. If the slope of the link is lower then the Minimal Slope (Tab. 7) appropriate to diameter then the criterion is calculated by the following expression:

$$SCS = 1 - (Slope / Minimal\ Slope) \tag{6}$$

Where: SCS - Self-cleaning Slope Criterion [-]
Slope - real slope of the link (input data from hydraulic model) [‰]
Minimal Slope - min. slope that is appropriate to diameter of this pipe (from Tab. 7) [‰]

Input default values
Default Minimal Slope for each diameter in HELLMUD for Combine and Separate sewer system is listed in the Tab. 7:

Tab. 7 Default Minimal Slope [‰] for Combine and Separate sewer system

DN [mm]	300	400	500	600	700	800	900	1000	1200	1400
Combine sewer	4.90	4.63	4.43	4.27	4.15	4.03	3.89	3.85	3.00	2.00
Separate sewer	14.00	9.00	7.00	6.00	5.50	5.00	4.50	4.00	3.00	2.00

Inside HELLMUD, the minimal slope value can be changed according to user consideration.

Range: <0; 1>
Meaning: The greater value of SSC the lower velocity and the worse self-cleaning ability inside the pipe.
Thresholds: SCS = 0 … the real slope of the link is greater or equal to Minimal Slope, no problem occurs.
SCS = 1 … the real slope equals 0, the worst case (velocity is near 0m/s). In case of negative slope loaded from the hydraulic model the notice occurs with requirement to correct input data.

II. Minimal Shear Stress Criterion

Natural flush with certain shear stress occurring with certain Annual Return Period is able to regularly clean the sediments in sewer, which is sufficient for operation of the sewer. Shear stress t_k depends on several parameters:

$$t_k = \rho \,.\, g \,.\, R \,.\, Slope \quad [Pa] \tag{7}$$

where: t_k - calculated shear stress [Pa]
ρ - density of transported wastewater [kg/m^3]
g - gravitation constant [m/s^2]
R - hydraulic radius [m]
Slope - real slope of the pipe [-]

Input default values: Minimal shear stress = 4 Pa
Annual Return Period (ARP) = 5 year^{-1}
Inside HELLMUD, the default values can be changed according to user consideration.

Range: <0; 1>
Meaning: The greater value of Minimal Shear Stress Criterion (MSS) the worse ability to clean the sediments in sewer by natural flush.
Thresholds: MSS = 0 … no problem with low velocity occurs
MSS = 1 … significant problem, velocity equals 0

III. Sediment Transport Velocity Criterion

According to English Standard, minimal slope is the slope for which Sediment Transport Velocity of wastewater is at least 0.75 m/s.

STV = 1 - (Sediment Transport Velocity / Minimal Sediment Transport Velocity) (8)

where: STV - Sediment Transport Velocity Criterion [1]
Sediment Transport Velocity - is calculated inside HELLMUD Tool. It is the velocity corresponding to Hmax during rain event of return period equals defined Annual Return Period. Sediment Transport Velocity is obtained from regression of input data "Hmax/D" in hydraulic files (HRD or SE) by exponential function and assessment of Hmax for defined Annual Return Period. Consequently, Sediment Transport Velocity for this Hmax is calculated. [m/s]
Minimal Sediment Transport Velocity - defined minimal sediment transport velocity [m/s]

Input default values: Minimal Sediment Transport Velocity = 0.75 m/s (variable parameter but it is strongly recommended not to change this default value).
Annual Return Period (ARP) for Combined Sewer System = 5 $year^{-1}$
Annual Return Period (ARP) for Separated Sewer System = 4 $year^{-1}$
Inside HELLMUD, these default values can be changed according to user consideration.

Range: <0; 1>
Meaning: The greater value of this criterion the lower velocity coming down to 0.
Thresholds: STV = 0 … pipe without problems
… Sediment Transport Vel. ≥ Minimal Sediment Transport Velocity
STV = 1 … significant problem, velocity equals 0

IV. Full Pipe Velocity (Imhoff criterion)

According to German practice, minimal slope is the slope for which wastewater filling full pipe (full cross-section) has velocity 1 m/s.

FPV = 1 - (Capacity Velocity / MinimalVelFullPipe) (9)

where: FPV - full pipe velocity criterion [-]
Capacity Velocity - calculated velocity within full pipe [m/s]
MinimalVelFullPipe - specified minimal velocity of full pipe [m/s]

Input default values: MinimalVelFullPipe = 1.0 m/s (variable parameter but it is strongly recommended not to change this default value).
Range: <0; 1>
Meaning: The greater value of this criterion the lower velocity coming down to 0.
Thresholds: FPV = 0 … pipe without problems
… Capacity Velocity = MinimalVelFullPipe
FPV = 1 … significant problem, velocity equals 0

4.4.2 Maximum Velocity Criterion

Sewer should be usually protected against abrasion, dynamic effects of wastewater and cavitation in case of higher velocity in the sewer.
Maximum Velocity criterion is assessed according to particular pipe material (clay, asbestos cement, concrete, polyvinyl chlorine, polyethylene, iron, steel, stone, brick and other known). For unknown materials this criterion is not taken into account.

Maximum Velocity is compared to the reference velocity corresponding to Hmax during rain event of return period equals Design Year Period N. This reference value is calculated inside HELLMUD Tool and it is obtained from regression of input data "Hmax/D" in hydraulic files (HRD or SE) by exponential function and assessment of Hmax for defined Annual Return Period. Consequently, the reference velocity for this Hmax is calculated.

Input default values: Maximum Velocity According to Material:
3 m/s - clay, asbestos cement and concrete
5 m/s - polyvinyl chlorine, polyethylene, iron, steel, stone, brick, other known material
Inside HELLMUD, these default values can be changed according to user consideration.

Range: <-1; 0>
Meaning: The greater value of this criterion the better condition in terms of maximal velocity.
Thresholds: Maximum Velocity Criterion = -1 … velocity inside the pipe exceeds limit 10m/s
Maximum Velocity Criterion = 0 … pipe without problems

4.4.3 Total Velocity criterion

The HELLMUD Tool processes both low and high velocity problem and combines them, so that the result of the evaluation is deliverance whether or not the problem with velocity occurred. When problem with low velocity occurred, the value of pre-final evaluation is positive, within interval (0; 1>. In case of problem with too high velocity, the value of pre-final evaluation is negative, within interval < -1; 0). For pipe without any velocity problem the value is “0”. The HELLMUD total result for each pipe is absolute value of the number, i.e. in the range <0; 1>, where values near “1” indicated serious problems with velocity (but without specification “too low / too high”).

There are two presentations of the Total Velocity criterion inside the HELLMUD Tool. In the frame of WP3 hydraulic criteria overview (HELLMUD Process results), this criterion evaluates whether or not the problem with velocity is detected (range “yes” or “no”), while in HELLMUD Final evaluation of velocity deficiencies the results are expressed by means of absolute numerical value described above (range <0; 1>), see chapter 5.4.2.

Here in WP3 hydraulic criteria overview is velocity evaluated as following:
Range: “yes” / “no”
Meaning: The criterion answers the question: “Is there any problem with velocity?”
Thresholds: “yes”- Total Velocity criterion > 0, resp. (0, 1> , some problem with velocity detected (too low or too high velocity, without specification)
“no” - Total Velocity criterion = 0, pipe without any velocity problems

End user can choose one or more criteria (or no one as well) for detection of problems with velocity. The total result is obtained by means of combination of chosen criteria. Tab. 8 shows results of comparison of some methods described above. While methods I and III individually have quite high evaluation error (26 and 18 %), their combination reduces the error only to 8%.

Tab. 8 Comparison of selected methods for evaluation of velocity problems on the link [Koudelak 2002]

Criterion	I	II	III	
	Minimal self-cleaning slope (SCS)	Minimal Shear Stress (MSS)	Minimal sediment transport velocity (STV)	Combination of criterion I and III (SCS + STV)
	i_{min}	τ_k	v_t	$i_{min} + v_t$
Unit	[‰]	[Pa]	[m/s]	[‰ + m/s]
Criterion value	according to diameter	4.0	0.75	slope according to diameter + 0.75 m/s
Evaluation error	26 %	39 %	18 %	8 %

4.5 C8 - SewerTypology

The C8 criterion is defined to determine a type of sewer system on the pipe level. Separated and combined system can be distinguished for each pipe. This information is important for evaluation of minimal velocity criteria as well as for the different impact produced by overflows.

Range: C / S
Meaning: "C" - for Combined system
"S" - for Separated system

4.6 C9 - InfiltrationWeight

This criterion uses infiltration volume inflow per 1 m of a pipe length loaded, and by means of simple calculation transforms it into weight – "contribution" of the link with regard to the whole network:

$$C9 = \frac{q_{infiltr} \cdot Length}{\max\left(q_{infiltr} \cdot Length\right)} \tag{10}$$

Where: $q_{infiltr}$ – unit infiltration of the link, volume inflow per 1m of the pipe [$m^3/s/m$]
Length – length of the link (pipe) [m]

Range: <0 - 1>
Meaning: The greater value of C9 the worse conditions of the pipe – the greater infiltration volume inflow into pipe.
Thresholds: 0… pipe without infiltration problem
1… pipe with the greatest infiltration volume on the network

5 THE HELLMUD TOOL

5.1 Description of the tool

The HELLMUD (**H**ydraulic and **E**nvironmental re**L**iabi**L**ity **M**odel of **U**rban **D**rainage) mathematical model is focused on service reliability, which reflects the probability of hydraulic efficiency and environmental impacts of a sewer system for one predetermined scenario. The model aims at a definition of several criteria that can be used for the assessment of reliability aspects on the current sewer system or for the examination of proposed scenarios of the urban drainage system rehabilitation. As the piping represents the most critical system component with respect to hydraulic and environmental deficiencies, the criteria are highlighted at the pipe level. The data is in relation to the risk assessment on combined sewer overflows (CSOs) which are perceived by the hydraulic model as commissioned marginal conditions of the mathematical modelling for each scenario. The assessment of environmental impacts is based on the national legislation, being defined in the CARE-S by CAT and GAT modules, task 3.3. The process and final results are saved in a text form (*.csv files) in the Project Manager database, being available to GIS and other tools. The criteria will be delivered via the CARE-S Rehabilitation Manager to WP5 and WP6.2 as input data for further processing and support of the decision-making process of sewer rehabilitation.

The tool cannot be used without hydraulic simulation of the catchment. Environmental parameters for network probabilities of deficiency analyses are evaluated as defined by CAT and GAT tools. For a better understanding of the system conditions and status, final results will be visualized as maps. The CARE-S GIS system support is used to display the model results.

The HELLMUD tool was developed for two main purposes. The first is to process results of the tools developed within WP3 and provide an integrated overview of the WP3 criteria (HELLMUD process results, see chapter 4) and the second is to evaluate the sewer network on base of the WP3 criteria in terms of service reliability and show where hydraulic and environmental problems probably occur (HELLMUD final results, chapter 5.4).

5.2 Installing the tool

<u>Minimum System Requirements:</u>
- IBM Compatible PC
- Microsoft Windows 2000 or Microsoft Windows XP (no guarantee can be given for other versions)
- 5 MB free disk space

<u>Installation:</u>
The HELLMUD Tool is included into CARE-S software and can also be used as stand alone application. In the latter case, HELLMUD Tool does not need an installation. If problems occur, following files needs to be registered by executing the setup.bat:
- comdlg32.ocx
- mshflxgd.ocx
- mscomct2.ocx
- tabctl32.ocx

The help file Hellmud.chm needs to be stored in the application path.

<u>Personal Preferences:</u>
This version of HELLMUD Tool saves user’s personal preferences in the application directory.

5.3 Application scope

The HELLMUD Tool evaluates the network in terms of hydraulic and environmental point of view on a pipe level. It can be used for the whole network or part of it, without consideration of integrated topology (layout) of the network. Evaluation of CSO performance is assigned to each CSO separately in the frame of the network.

Accuracy of result strongly depends on input data available. Hydraulic information of the network, results form the hydraulic model and loading of Design Year Period value are necessary conditions for running the tool. In addition, CAT and GAT output files can be loaded for evaluation of environmental deficiencies. In case CAT and /or GAT file is not loaded, appropriate evaluation of CSO and / or exfiltration is not available (N/A).

5.4 HELLMUD final results

Besides providing of WP3 hydraulic and environmental criteria overview, the HELLMUD tool was developed firstly for evaluation of the sewer network based on these criteria in terms of service reliability and secondly for assessment where hydraulic and environmental deficiencies will probably occur. The final Hellmud results provide five complex criteria describing and evaluating each pipe and CSO:

- Hydraulic deficiency
- Velocity deficiency
- Infiltration deficiency

Complex hydraulic criteria

- Exfiltration deficiency
- CSO evaluation

Complex environmental criteria

Hydraulic, velocity, infiltration and exfiltration deficiencies are evaluated on the pipe level while CSO evaluation is provided for each Combine Sewer Overflow on the network (without linkage to particular pipes or catchment). Schematic overview of the HELLMUD results can be found in Tab. 9. and Tab. 10. For more detailed specification of data format see chapter 5.6.2, example of file *HE_Final_name_XX.csv* can be found in Annex II.

Tab. 9 HELLMUD Final results - pipes

Deficiency	**Range**	**Unit**
Link ID		[-]
Hydraulic	<0 ; 1>	[-]
Velocity	<0 ; 1>	[-]
Infiltration	<0 ; 1>	[-]
Exfiltration	<0 ; 1>	[-]

Tab. 10 HELLMUD Final results - CSOs

Evaluation	**Range**	**Unit**
Link ID		[-]
Hazard	*REL, LOW, MED, HIGH, UNREL*	[-]
Range	<0 ; 1>	[-]

Range of hydraulic and environmental HELLMUD results on pipe level is an interval of real numbers <0; 1>. The pipe without problem has appropriate criterion equals “0”. In all other cases, some problem occurs, and the closer is the value to “1”, the worse failure is detected. The final decision concerning acceptable failure should make end user, e.g. according to amount of financial resources available. He can rehabilitate the worst links with evaluation near “1” and by steps continue to less value according to his financial possibilities. In advance, it is not possible to assess hard thresholds for any of five parameters listed on HELLMUD results. HELLMUD compares pipes in relation to each other and gives the comparison of all pipes in four pipe-level parameters. It would not be recommended to synthesize the parameters into the only one parameter expressing total reliability of the link without sensitivity analysis of particular parameters. During the calculation, several (1-4) methods with result in the range of < 0, 1 > are used and it is impossible to know in advance how many of them are used.

5.4.1 Hydraulic deficiency

Hydraulic deficiency criterion corresponds to criterion ”C3D – Probability P(D)” of WP3 hydraulic criteria overview. It is hazard – probability, that surface level will be exceeded one or more times during the Design Year Period “N”.

Range: <0 ; 1>
Meaning: The greater value of Hydraulic deficiency the worse failure is supposed to occur on the pipe.
Thresholds:
0 - pipe without any problem, surface level will not be exceeded at all
1 - a serious problem identified, probability that surface level will be exceeded one or more times during Design Year Period is 100%.

For detailed information and explanation, see chapter 4.1.

5.4.2 Velocity deficiency

Velocity deficiency criterion corresponds to criterion “C6 – Velocity” of WP3 hydraulic criteria overview, presented by Total Velocity criterion as combination of several minimum and one maximal velocity criteria according to user’s preferences. While in HELLMUD Process results (WP3 criteria overview) was simply defined whether or not some problem with velocity probably occurs (“yes”/”no”), here in for deficiency assessment numerical evaluation is required.

In HELLMUD final results, velocity is evaluated as following:
Range: <0; 1>
Meaning: The greater value of this criterion the worse velocity problem is supposed.
Thresholds:
0 - Total Velocity criterion = 0, pipe without any velocity problems
1 - Total Velocity criterion = 1, a serious problem with velocity detected (too low or too high velocity, without specification)

For detailed information and explanation, see chapter 4.4.

5.4.3 Infiltration deficiency

Infiltration deficiency criterion equals the criterion ”C9 – Infiltration Weight” of WP3 hydraulic criteria overview, including range, meaning and thresholds of C9.
For detailed information and explanation, see chapter 4.6.

5.4.4 Exfiltration deficiency

Exfiltration deficiency criterion is based on GAT model results (WP3.3). GAT Tool (Groundwater Assessment Tool) is software to assess the vulnerability of groundwater concerning exfiltration from the sewer. It provides four vulnerability values listed in Tab. 11.

Tab. 11 Four groundwater vulnerability values (GAT outputs)

Method	Range	Source / description
HML (Eaton)	High (H1-H9) Moderate (M1-M9) Low (L1-L9)	described by Eaton and Zaporozec
Drastic	<11 – 110>	Used in the USA (3 parameters: exfiltration rate, groundwater rate and soil type)
ExGround	High Moderate Low	Simplified DRASTIC (2 parameters: combination of exfiltration rate and groundwater rate)
PermGround	High Moderate Low	Simplified DRASTIC (2 parameters: combination of groundwater rate and soil type)

In the frame of HELLMUD, exfiltration deficiency assessment includes combination and transformation of four vulnerability values from GAT model into the range of real numbers of interval <0; 1>. GAT vulnerability values are averaged according to number of used methods evaluating exfiltration within GAT model (max. 4 values). When no input data are available from GAT model, appropriate links are qualified as „not available" (N/A).

Range:	<0 ; 1>
Meaning:	The greater value of Exfiltration deficiency the worse failure is supposed to occur on the pipe.
Thresholds:	0 - pipe without any exfiltration problem 1 - pipe with serious exfiltration problem

Detail description of GAT Tool is given in Report D9 – "Environmental impacts of rehabilitation" (Schulz, Krebs, 2004) and Report "Tools in Work Package 3.3" (Schulz, 2004).

5.4.5 CSOs evaluation

CSOs evaluation is based on CAT model results (WP3.3). CAT Tool (Combined sewer overflow Assessment Tool) is software to assess the performance of combined sewer overflows. It provides information on compliance to selected standards and deviation from the standards for four parameters:

- Number
- Volume
- Load
- Duration

of combine sewer overflow based on national legislation.

HELLMUD combines and transforms these four parameters from CAT model into the range of real numbers of interval <0; 1>. CAT parameters are averaged according to number of chosen methods evaluating CSO within CAT model and each CSO is consequently assigned to one of five hazard classes. Division into categories corresponds to numerical evaluation of CSO according to Tab. 12, showing range, meaning and thresholds for HELLMUD CSOs evaluation.

Tab. 12 Hazard and range of CSOs evaluation in HELLMUD Tool

	Hazard class	**Range**
Range	REL, LOW, MED, HIGH, UNREL	<0 ; 1>
Meaning	the level of the hazard	The greater value the worse failure is supposed to occur on the CSO.
Thresholds	REL – CSO is reliable LOW – low hazard MED – medium hazard HIGH – high hazard UNREL – CSO is unreliable	= 0 (0 – 0.33) <0.33 – 0.66) <0.66 – 1) ≥1

From the HELLMUD point of view, CSOs, analysed via CAT tool, are included as boundary conditions within hydraulic model. It is presumed, that CSOs conditions are in compliance with national standards in term of the impact on water body and its pollution. HELLMUD checks distribution of storm water discharge in drainage area, not water quality in the watershed.

Detail description of CAT Tool is given in Report D9 – “Environmental impacts of rehabilitation” (Schulz, Krebs, 2004) and Report “Tools in Work Package 3.3” (Schulz, 2004).

5.5 INPUTS

Input data comes into HELLMDUD from following sources:

- Layout file
- Hydraulic files SE, HRD
- CAT Tool
- GAT Tool
- Design year period N
- Velocity

} from hydraulic model (MOUSE, InwoWorks or SWMM)

} from WP3.3 Tools

} HELLMUD internal inputs

5.5.1 Layout file

The layout data are prepared in the ***name_XX_layout.csv*** file. There are three parts within the file – Heading part, List of links and List of nodes (each separated by one free line). Currently, version of layout input file is “Hellmud4”. Heading part (Tab. 13) includes also specification of the catchment, scenario ID and hydraulic model used for data preparation. Data necessary for sewer network description are listed in Tab. 14 (links) and Tab. 15 (nodes).

Tab. 13 Layout file – heading part (first two lines)

Version	NameOfCatch	Scenario	Model
Version of the file *(Hellmud4)*	Name of the catchment *(Name)*	Scenario ID *(XX in file name)*	Hydraulic Model (S, M, I)

Tab. 14 Layout file – list of links

	Obligatory / Optional	Quantitative / qualitative	Type of data	Unit	Description
LinkID	obligatory	qualitative	alphanumeric	-	link ID
From Node	obligatory	qualitative	alphanumeric	-	beginning node of the link
To Node	obligatory	qualitative	alphanumeric	-	end node of the link
Up - Invert Level	obligatory	quantitative	numeric	m above sea level	invert level of the beginning node
Down - Invert Level	obligatory	quantitative	numeric	m above sea level	invert level of the end node
Drainage system	obligatory	qualitative	alphanumeric	-	type of drainage system combined / separate
Length	obligatory	quantitative	numeric	m	length of link
Slope	obligatory	quantitative	numeric	‰	slope of pipe
Qcap	obligatory	quantitative	numeric	m^3/s	flow capacity
Critical Level	obligatory	quantitative	numeric	H_{crit}/Height	ratio of critical level to Height (critical level - beginning of hydraulic problems in network)
Material	obligatory	qualitative	alphanumeric	-	material of pipe (in compliance with WP1)
Shape	obligatory	qualitative	numeric	-	cross-sectional shape
qInfiltr	obligatory	quantitative	numeric	$m^3/s/m$	infiltration of pipe
Manning roughness	obligatory	quantitative	numeric	$m^{-1/3}/s$	Manning roughness
CW roughness (k)	obligatory	quantitative	numeric	mm	White-Colebrook roughness (k)
Height	obligatory	quantitative	numeric	m	height of pipe
Width	obligatory	quantitative	numeric	m	width of pipe

Tab. 15 Layout file – list of nodes

	Obligatory / Optional	Quantitative / qualitative /	Type of data	Unit	Description
NodeID	obligatory	qualitative	alphanumeric	-	node ID
Ground Level	obligatory	quantitative	numeric	m above sea level	ground level of the node

5.5.2 Hydraulic files

Hydraulic data can be loaded by two different ways according to data available. During loading of ***name_XX_hydraulic.csv*** file, either Single Event simulation (SE) or Historical Rain Data simulation (HRD) can be chosen (see chapter 5.7). There are some small differences in input data, but data processing inside HELLMUD is similar. There is written name of catchment and XX as ID of scenario in the name of the appropriate file.

5.5.2.1 Single Event simulation (SE)

Synthetic rains with certain periodicity are loaded in the file *name_XX_hydraulic.csv*. Input data is described in Tab. 16 and Tab. 17, differences from the heading part of *name_XX_layout.csv* are lightly marked.

Tab. 16 SE - Heading part

Version	NameOfCatch	Scenario	DataFrom
Version of the file *(Hellmud4)*	Name of the catchment *(Name)*	Scenario ID *(XX in file name)*	**"0"** 0 = SE 1 = HRD

Tab. 17 SE – List of links

	Obligatory / Optional	Quantitative / qualitative	Type of data	Unit	Description
LinkID	obligatory	qualitative	alphanumeric	-	link ID
Hmax/Height	obligatory	quantitative	numeric	-	ratio of maximum filling level to Height according to annual return period
Qmax	obligatory	quantitative	numeric	m^3/s	maximum flow according to annual return period

If the end user has no data available for long term simulations or if he is not interested in that kind of simulations, the model can be run on at least 3 single event simulations

= there must be available at least 3 synthetic design rain events + their frequency (see chapter 5.7.2)

= after hydraulic simulation, into HELLMUD must be loaded at least 3 double-columns every with Hmax/Height and Qmax data (at least 6 columns totally). Appropriate annual return period must be listed in the first line of SE *name_XX_hydraulic.csv* file (see Annex I). These return periods are used for HELLMUD calculation.

Example: SE simulation will be run on computation boundary data, which presents return period of e.g. 1; 0,5; 0,2 and 0,1 $year^{-1}$. Total number of columns is eight.

For single event simulation, it is accepted when the failure produced by the specific event will have the same return period as the event.

5.5.2.2 Historical Rain Data simulation (HRD)

In case of historical rain series, name of the file is the same as for Single Event simulation (*name_XX_hydraulic.csv*). Input data is listed in Tab. 18 and Tab. 19 (differences in the heading part are lightly marked).

Tab. 18 HRD - Heading part

Version	NameOfCatch	Scenario	DataFrom	Duration
Version of the file *(Hellmud4)*	Name of the catchment *(Name)*	Scenario ID *(XX in file name)*	**"1"** 0 = SE 1 = HRD	**Duration of rain series used for data preparation (in years)**

Tab. 19 HRD - List of links

	Obligatory / Optional	Quantitative / qualitative	Type of data	Unit	Description
LinkID	obligatory	qualitative	alphanumeric	-	link ID
Hmax/Height	obligatory	quantitative	numeric	-	ratio of maximum filling level to Height for every rain event simulated
Qmax	obligatory	quantitative	numeric	m^3/s	maximum flow for every rain event simulated

Hydraulic analyses will be performed by user via MOUSE DHI, InfoWorks or SWMM. Hydraulic analysis of the run-off relations concerning the storm water disposal system is based on the results from the numeric simulation. The data selected by means of mathematical modelling using "Duration - length of historic rain database" is considered to be the optimum data source. The minimum number of years of simulation should be defined for long term simulations to make the analysis statistically "true". For HELLMUD calculation, 25 storms is minimum:

= there must be available at least 25 historical rain events (see chapter 5.7.1)

= after hydraulic simulation, into HELLMUD must be loaded at least 25 double-columns every with Hmax/Height and Qmax data (at least 50 columns totally). In the first line of HRD *name_XX_hydraulic.csv* file is simply filled rain specification which is not used for calculation at all (see Annex I).

A long-term simulation model can be substitute by series of separated events instead of a continuous simulation (this allows a considerable reduction of the total simulated time span).

5.5.3 CAT output file

HELLMUD Tool used CAT output file for calculation of CSO evaluation. CAT output is not necessary required input for running HELLMUD, but in the case CAT output is not loaded into HELLMUD, the result of CSO evaluation is not available (N/A).
Detail description of CAT output file is given in Report "Tools in Work Package 3.3" (Schulz, 2004).
Example of CAT output file is shown in Annex I – Examples of input data.

5.5.4 GAT output file

GAT output file is used by HELLMUD Tool for calculation of exfiltration deficiency calculation. GAT output is not necessary required input for running HELLMUD, but in the case GAT output is not loaded into HELLMUD, the result of exfiltration deficiency is not available (N/A).
Detail description of GAT output file is given in Report "Tools in Work Package 3.3" (Schulz, 2004).
Example of GAT output file is shown in Annex I – Examples of input data.

5.5.5 Design Year Period "N"

Design Year Period "N" is entered as HELLMUD internal input in the dialogue window similarly as velocity criteria (see Annex VI - HELLMUD Help file). For definition and meaning see chapter 4.1.3.2.

5.5.6 Velocity criteria of the Country

Velocity criteria are entered as HELLMUD internal input in the dialogue window similarly as Design Year Period (see Annex VI - HELLMUD Help file). Detailed description of these criteria is listed in chapter 4.4.

In HELLMUD, default velocity criteria values listed in Tab. 20 - Tab. 23 are given. User can change the default values and save him own thresholds for selected country for further calculations.

Tab. 20 Self-cleaning slope (minimal slope)

	Self-cleaning Slope [‰]	
DN [mm]	Combined	Separated
300	4.90	14.00
400	4.63	9.00
500	4.43	7.00
600	4.27	6.00
700	4.15	5.50
800	4.03	5.00
900	3.89	4.50
1000	3.85	4.00
1200	3.00	3.00
1400	2.00	2.00

Tab. 21 Shear stress

Minimal shear stress	4.0	[pa]
Annual Return Period (ARP)	5	[1/year]

Tab. 22 Full pipe velocity

Minimal shear stress	1.0	[m/s]

Tab. 23 Sediment transport velocity

Minimal sediment transport velocity	0.75	[m/s]
Annual Return Period (ARP) – combined system	5	[1/year]
Annual Return Period (ARP) – separated system	4	[1/year]

5.6 OUTPUTS

5.6.1 HELLMUD Process Results

Output data included within *HE_Process_name_XX.csv* file are shown in the Tab. 24.
For detailed description of the criteria see chapter 4.

Tab. 24 HE Process output file

Name of criterion	Head of column in Hellmud output file (*.csv)	Quantitative / qualitative	Type of data	Range	Unit	Short description
	LinkID	qualitative	alphanumeric		[-]	link ID
C1	FillingLevel	quantitative	alphanumeric	A, B, C, D	[-]	filling level
C2A	FrequencyFillingLevelA	quantitative	numeric	<0.02 ; 5>	[$year^{-1}$]	frequency - class A
C2B	FrequencyFillingLevelB	quantitative	numeric	<0.02 ; 5>	[$year^{-1}$]	frequency - class B
C2C	FrequencyFillingLevelC	quantitative	numeric	<0.02 ; 5>	[$year^{-1}$]	frequency - class C
C3B	ProbabilityB	quantitative	numeric	<0 ; 1>	[-]	probability P(B)
C3C	ProbabilityC	quantitative	numeric	<0 ; 1>	[-]	probability P(C)
C3D	ProbabilityD	quantitative	numeric	<0 ; 1>	[-]	probability P(D)
C4	WeightLink	quantitative	numeric	(0 ; 1>	[-]	weight of the link Q_{cap} / *max of* Q_{cap}
C5	InsufficientCapacity	quantitative	numeric	<0 ; 1>	[-]	insufficient capacity Q_{max}/Q_{cap}
C6	Velocity	quantitative	alphanumeric	yes/no	[-]	Is there any problem with flow velocity? *(yes / no)*
C8	SewerTypology	qualitative	alphanumeric	S/C	[-]	sewer typology C/S - Combined / Separate
C9	InfiltrationWeight	quantitative	numeric	<0 ; 1>	[-]	infiltration weight q_{inf} * Length / Max(q_{inf} * Length)

5.6.2 HELLMUD Final Results

Output data included within *HE_Final_name_XX.csv* file are shown in the Tab. 25 and Tab. 26. For detailed description of the criteria see chapter 5.4.

Tab. 25 HE Final Results - list of links

Head of column in Hellmud output file (*.csv)	Quantitative / qualitative	Type of data	Unit	Range	Short description
Link ID	qualitative	alphanumeric	[-]		link ID
Hydraulic	quantitative	numeric	[-]	<0 ; 1>	solution of hydraulic deficiency
Velocity	quantitative	numeric	[-]	<0 ; 1>	solution of velocity deficiency
Infiltration	quantitative	numeric	[-]	<0 ; 1>	solution of infiltration deficiency
Exfiltration	quantitative	numeric	[-]	<0 ; 1>	solution of exfiltration deficiency

Tab. 26 HE Final Results - CSOs Impacts

Head of column in Hellmud output file (*.csv)	Quantitative / qualitative	Type of data	Unit	Range	Description
Link ID	qualitative	alphanumeric	[-]		link ID
Hazard	qualitative	alphanumeric	[-]	*REL, LOW, MED, HIGH, UNREL*	the level of the hazard
Range	quantitative	numeric	[-]	<0 ; 1>	Numerical evaluation of the CSO deficiency

5.7 Data acquisition

HELLMUD Tool works at two accuracy levels according to the user's approach to the hydrological data input into the validated deterministic simulation model:

- Historical Rain Data simulation (HRD) – at least 25 "worst" storms during 20 years
- Single Event simulations (SE) – at least 3 design rains, optimum is 5 events

Preparation of hydraulic input files for HELLMUD is similar for HRD and SE simulations. The difference is in amount of input rain data available.

5.7.1 Data for HRD simulation

The HRD simulation requires at least 25 "worst" storms during at least 20 years period.
This means, that end user needs at least 20-years rain data series. According to Wussow, following formulae are recommended for assessment of storms and catastrophic storms (the shape of the boundary curve is drawn in Figure 6):

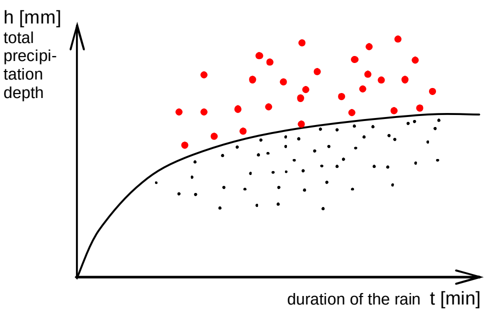
catastrophic storms : $h \geq 2\sqrt{5t}$

storms : $h \geq \sqrt{5t}$

where *h* [mm] - total precipitation depth
t [min] - duration of the rain

All rains are compared firstly with the first formula, and when within the 20-years rain data series is not sufficient number of catastrophic storms (25), the second formula is used for finding the rest of the heavy rains. Remember, that number 25 is minimum; it is very desirable to select more rain events.

Figure 6 Assessment of the "worst" storms for historical rain data simulation



5.7.2 Data for SE simulation

The SE simulation **requires at least 3 design rains** (optimum is 5) **+ appropriate frequency** (for example 5; 0.5; 0.05 year $^{-1}$, that means return period 0.2; 2; 20 years.)
The frequency can be of various values (e.g. 5; 1; 0.5; 0.333; 0.2; 0.1 and 0.05 year $^{-1}$), any reasonable combination is applicable and depends on end-user data available.

5.8 HELLMUD Glossary

Term	Definition	Unit	Where required	See Chapter
HRD	Historical Rain Data simulation			4.1.3.1 5.5.2.2 5.7.1
SE	Single Event simulation			4.1.3.1 5.5.2.1 5.7.2
Critical level **H_{crit}/Height**	Filling water level that, if exceeded, starts to bring damages on properties within the urbanized catchment assigned to the pipe. In HELLMUD, critical level is always expressed as ratio (H_{crit}/ Height).	[-]	HELLMUD input file *Layout*	4.1.2
Filling level **H_{max}/Height**	**H_{max}** are water levels appropriate to the particular link loaded from the hydraulic model (SE of HRD simulation). **Height** is the vertical dimension of the pipe (e.g. diameter). In HELLMUD, water levels are always expressed as ratio (H_{max}/ Height).	[-]	HELLMUD input file *Hydraulic* (HRD and SE)	4.1
Duration	Duration of historical rain series used for data preparation (in years)	[year]	HELLMUD input file *Hydraulic* (HRD)	5.5.2.2
Design Year Period "**N**"	Number of years, after which occurrence of given event (given filling level) is admitted, e.g. the useful design life of the structure or duration of insurance	[year]	HELLMUD separate input	4.1.3.2 4.4 5.5.5
Annual Return Period (ARP)	return period $T = 1/p$ (p annual probability of exceedance, frequency) Used for calculation of minimal velocity criteria.	[$year^{-1}$]	HELLMUD separate input	4.4.2
<0; 1>	interval of real numbers from 0 to 1	[-]		

6 SUMMARY

Conclusive report D10 is part of task 3.4 – “Combining hydraulic and reliability model” and provides overview of WP3 results including tasks 3.2 and 3.3. It is aimed especially on assessment of WP3 criteria and their processing within WP3 in order to evaluate the network from hydraulic and environmental points of view.

The basic concepts and methodologies were assessed on the literature study. On this base, a tool for calculation of process WP3 criteria and final hydraulic and environmental deficiencies was developed. This HELLMUD Tool (Hydraulic and Environmental reLiabiLity Model of Urban Drainage) is mathematical model focused on service reliability, which reflects the probability of hydraulic efficiency and environmental impacts of a sewer system for one predetermined scenario. The model aims at definition of several criteria that can be used for the assessment of reliability aspects on the current sewer system or for the examination of proposed scenarios of the urban drainage system rehabilitation. The development of the HELLMUD Tool is main contribution of task 3.4 to CARE-S project.

The assessment of environmental impacts is based on the national legislation, being defined in the CARE-S by CAT and GAT modules developed within task 3.3. The process and final results are saved in the Project Manager database, being available to GIS and other tools. The criteria will be delivered via the CARE-S Rehabilitation Manager to WP5 and WP6.2 as input data for further processing and support of the decision-making process of sewer rehabilitation.

In this report, WP3 hydraulic and environmental criteria are defined and described as well as HELLMUD Tool procedures, inputs and outputs. The MOUSE, SWMM and InfoWorks models can be used as the hydrodynamic tool for HELLMUD hydraulic input data preparation. The CAT and GAT Tools support an environmental evaluation of the network. A brief Glossary is included to provide a quick overview of important terms used during work with HELLMUD Tool. Examples of input and output data can be found in Annexes together with data transformation from hydraulic models. HELLMUD Help file is put at the end to give insight into HELLMUD user interface.

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Annex I – Examples of input data

Layout file Brno_01_layout.csv

Version	NameOfCatch	Scenario	Model
Hellmud4	Brno	1	M

LinkID	From Node	To Node	Up - Invert Level	Down - Invert Level	Drainage System	Length	Slope	Qcap
[-]	[-]	[-]	[m]	[m]	[-]	[m]	[‰]	[m3/s]
1	1	4	242.35	236.10	C	250	25	0.329
2	2	4	242.35	236.10	C	250	25	0.329
3	3	4	242.35	236.10	C	250	25	0.329
4	4	5	235.70	229.45	C	250	25	2.091
…	…	…	…	…	…	…	…	…

Critical Level	Material	Shape	qInfiltr	Manning roughness	CW roughness (k)	Height	Width
[-]	[-]	[-]	[m3/s/m]	[m-1/3/s]	[mm]	[m]	[m]
1.5	sC13	1	0.02	0.013	0	0.4	0.5
1.5	sC13	1	0.02	0.013	0	0.4	0.5
1.5	sC13	1	0.02	0.013	0	0.4	0.5
1.5	sC13	1	0.02	0.013	0	0.8	0.8
…	…	…	…	…	…	…	…

NodeID	Ground Level
[-]	[-]
1	245.75
2	245.75
3	245.75
4	239.50
…	…

Comma Separated Values File Format

Brno_01_layout - Notepad

File Edit Format Help

```
Version,NameOfCatch,Scenario,Model
Hellmud4,Brno,1,M

LinkID,From Node,To Node,Up - Invert Level,Down - Invert Level,Drainage
System,Length,Slope,Qcap,Critical Level,Material,Shape,qInfiltr,roughness,CW
roughness (k),Height,Width
[-],[-],[-],[m],[m],[-],[m],[‰],[m3/s],[-],[-],[-],[l/s/m],[m-1/3/s],[mm],[m]
,[m]
1,1,4,242.35,236.1,c,250,25,0.329,1.5,sC13,1,0.02,0.013,0,0.4,0.5
2,2,4,242.35,236.1,c,250,25,0.329,1.5,sC13,1,0.02,0.013,0,0.4,0.5
3,3,4,242.35,236.1,c,250,25,0.329,1.5,sC13,1,0.02,0.013,0,0.4,0.5
4,4,5,235.7,229.45,c,250,25,2.091,1.5,sC13,1,0.02,0.013,0,0.8,0.8
5,5,6,229.45,223.2,c,250,25,2.091,1.5,sC13,1,0.02,0.013,0,0.8,0.8
```

...

```
22,22,V,215.8,215,c,200,4,1.516,1.5,sC13,1,0.02,0.013,0,1,1
100,100,COV,215.05,215,c,50,1,4.814,1.5,sC13,1,0.02,0.013,0,2,2

 NodeID,Ground Level
[-],[-]
1,245.75
2,245.75
3,245.75
4,239.5
5,233.25
6,227
7,224.5
```

Single event simulation Brno_01_hydraulic.csv

Data from SE

Return periods

Version	NameOfCatch	Scenario	DataFrom
Hellmud4	Brno	1	0

LinkID	0.05	0.05	0.5	0.5	...(min 3 x 2)	5	5
[-]	[hmax/height]	[Qmax]	[hmax/height]	[Qmax]	…	[hmax/height]	[Qmax]
1	7.71	0.43	1.12	0.29	…	0.45	0.13
2	7.71	0.43	1.12	0.29	…	0.45	0.13
3	7.71	0.43	1.12	0.29	…	0.45	0.13
4	4.29	0.26	1.21	0.18	…	0.76	0.08
5	5.15	0.33	1.32	0.22	…	0.66	0.1
…	…	…	…	…	…	…	…

Comma Separated Values File Format

Brno_01_hydraulic - Notepad

File Edit Format Help

```
Version,NameOfCatch,Scenario,DataFrom
Hellmud4,Brno,1,0

LinkID,0.05,0.05,0.5,0.5,1,1,5,5
[-],[hmax/height],[Qmax],[hmax/height],[Qmax],[hmax/height],[Qmax],[hmax/heig
ht],[Qmax]
1,7.71,0.43,1.12,0.29,0.89,0.24,0.45,0.13
2,7.71,0.43,1.12,0.29,0.89,0.24,0.45,0.13
3,7.71,0.43,1.12,0.29,0.89,0.24,0.45,0.13
4,4.29,0.26,1.21,0.18,1.08,0.15,0.76,0.08
5,5.15,0.33,1.32,0.22,1.13,0.18,0.66,0.10
6,3.99,0.34,1.36,0.24,1.19,0.19,0.78,0.10
7,3.04,0.39,1.23,0.26,0.98,0.22,0.42,0.12
8,8.16,0.45,1.00,0.34,0.73,0.29,0.50,0.16
9,6.30,0.47,0.95,0.30,0.76,0.25,0.46,0.13
10,4.63,0.31,1.30,0.19,1.13,0.16,0.74,0.09
11,2.48,0.37,0.96,0.24,0.80,0.19,0.40,0.11
12,3.85,0.24,1.49,0.16,1.21,0.13,0.65,0.07
13,7.32,0.45,1.08,0.30,0.87,0.25,0.46,0.13
14,4.57,0.32,1.61,0.21,1.26,0.17,0.56,0.10
15,9.80,0.42,1.92,0.29,1.59,0.24,0.83,0.13
16,6.01,0.47,0.86,0.34,0.71,0.28,0.48,0.15
17,3.85,0.23,1.49,0.16,1.21,0.14,0.65,0.07
18,2.24,0.38,1.16,0.25,0.99,0.20,0.58,0.12
19,1.61,0.31,0.82,0.19,0.71,0.16,0.45,0.09
20,1.38,0.55,0.77,0.35,0.69,0.29,0.46,0.15
21,1.10,0.53,0.71,0.32,0.61,0.27,0.42,0.13
50,0.76,0.50,0.58,0.30,0.55,0.26,0.39,0.13
22,0.23,0.04,0.09,0.00,0.00,0.00,0.00,0.00
100,0.72,0.49,0.56,0.30,0.52,0.26,0.37,0.13
```

Historical Rain Data simulation   *Brno_02_hydraulic.csv*

Data from HRD

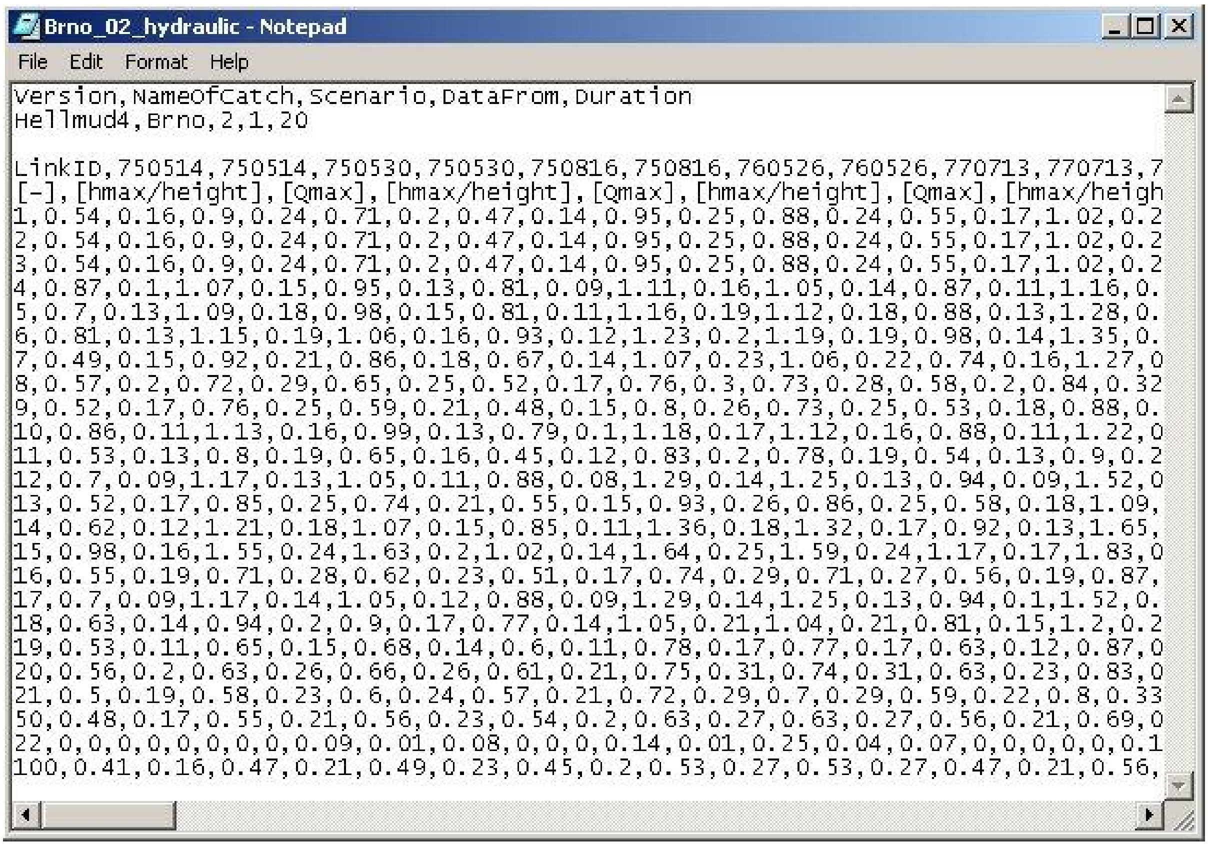
20-year rain series

Names/specification of the rain

Version	NameOfCatch	Scenario	DataFrom	Duration
Hellmud4	Brno	2	1	20

LinkID	1	1	2	2	3	3	… (min 25 x 2)
[-]	[hmax/height]	[Qmax]	[hmax/height	[Qmax]	[hmax/height	[Qmax]	…
1	0.54	0.16	0.90	0.24	0.71	0.20	…
2	0.54	0.16	0.90	0.24	0.71	0.20	…
3	0.54	0.16	0.90	0.24	0.71	0.20	…
4	0.87	0.10	1.07	0.15	0.95	0.13	…
5	0.70	0.13	1.09	0.18	0.98	0.15	…
…	…	…	…	…	…	…	…

Comma Separated Values File Format



Brno_02_hydraulic - Notepad

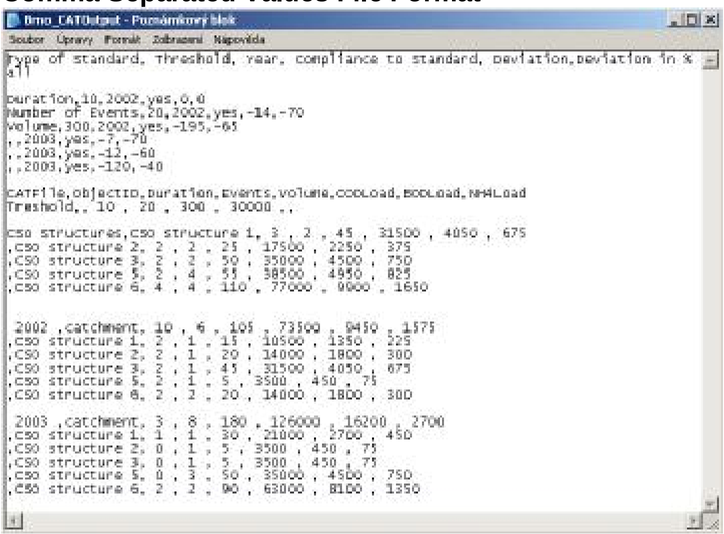
File Edit Format Help

```
Version,NameOfCatch,Scenario,DataFrom,Duration
Hellmud4,Brno,2,1,20

LinkID,750514,750514,750530,750530,750816,750816,760526,760526,770713,770713,7
[-],[hmax/height],[Qmax],[hmax/height],[Qmax],[hmax/height],[Qmax],[hmax/heigh
1,0.54,0.16,0.9,0.24,0.71,0.2,0.47,0.14,0.95,0.25,0.88,0.24,0.55,0.17,1.02,0.2
2,0.54,0.16,0.9,0.24,0.71,0.2,0.47,0.14,0.95,0.25,0.88,0.24,0.55,0.17,1.02,0.2
3,0.54,0.16,0.9,0.24,0.71,0.2,0.47,0.14,0.95,0.25,0.88,0.24,0.55,0.17,1.02,0.2
4,0.87,0.1,1.07,0.15,0.95,0.13,0.81,0.09,1.11,0.16,1.05,0.14,0.87,0.11,1.16,0.
5,0.7,0.13,1.09,0.18,0.98,0.15,0.81,0.11,1.16,0.19,1.12,0.18,0.88,0.13,1.28,0.
6,0.81,0.13,1.15,0.19,1.06,0.16,0.93,0.12,1.23,0.2,1.19,0.19,0.98,0.14,1.35,0.
7,0.49,0.15,0.92,0.21,0.86,0.18,0.67,0.14,1.07,0.23,1.06,0.22,0.74,0.16,1.27,0
8,0.57,0.2,0.72,0.29,0.65,0.25,0.52,0.17,0.76,0.3,0.73,0.28,0.58,0.2,0.84,0.32
9,0.52,0.17,0.76,0.25,0.59,0.21,0.48,0.15,0.8,0.26,0.73,0.25,0.53,0.18,0.88,0.
10,0.86,0.11,1.13,0.16,0.99,0.13,0.79,0.1,1.18,0.17,1.12,0.16,0.88,0.11,1.22,0
11,0.53,0.13,0.8,0.19,0.65,0.16,0.45,0.12,0.83,0.2,0.78,0.19,0.54,0.13,0.9,0.2
12,0.7,0.09,1.17,0.13,1.05,0.11,0.88,0.08,1.29,0.14,1.25,0.13,0.94,0.09,1.52,0
13,0.52,0.17,0.85,0.25,0.74,0.21,0.55,0.15,0.93,0.26,0.86,0.25,0.58,0.18,1.09,
14,0.62,0.12,1.21,0.18,1.07,0.15,0.85,0.11,1.36,0.18,1.32,0.17,0.92,0.13,1.65,
15,0.98,0.16,1.55,0.24,1.63,0.2,1.02,0.14,1.64,0.25,1.59,0.24,1.17,0.17,1.83,0
16,0.55,0.19,0.71,0.28,0.62,0.23,0.51,0.17,0.74,0.29,0.71,0.27,0.56,0.19,0.87,
17,0.7,0.09,1.17,0.14,1.05,0.12,0.88,0.09,1.29,0.14,1.25,0.13,0.94,0.1,1.52,0.
18,0.63,0.14,0.94,0.2,0.9,0.17,0.77,0.14,1.05,0.21,1.04,0.21,0.81,0.15,1.2,0.2
19,0.53,0.11,0.65,0.15,0.68,0.14,0.6,0.11,0.78,0.17,0.77,0.17,0.63,0.12,0.87,0
20,0.56,0.2,0.63,0.26,0.66,0.26,0.61,0.21,0.75,0.31,0.74,0.31,0.63,0.23,0.83,0
21,0.5,0.19,0.58,0.23,0.6,0.24,0.57,0.21,0.72,0.29,0.7,0.29,0.59,0.22,0.8,0.33
50,0.48,0.17,0.55,0.21,0.56,0.23,0.54,0.2,0.63,0.27,0.63,0.27,0.56,0.21,0.69,0
22,0,0,0,0,0,0,0,0,0.09,0.01,0.08,0,0,0,0.14,0.01,0.25,0.04,0.07,0,0,0,0,0,0.1
100,0.41,0.16,0.47,0.21,0.49,0.23,0.45,0.2,0.53,0.27,0.53,0.27,0.47,0.21,0.56,
```

CAT output file

Type of Standard	Threshold	Year	Compliance to Standard	Deviation	Deviation in %		
all							
Duration	10	2002	yes	0	0		
Number of Events	20	2002	yes	-14	-70		
Volume	300	2002	yes	-195	-65		
		2003	yes	-7	-70		
		2003	yes	-12	-60		
		2003	yes	-120	-40		
CATFile	ObjectID	Duration	Events	Volume	CODLoad	BODLoad	NH4Load
Treshold		10	20	300	30000		
CSO Structures	CSO structure 1	3	2	45	31500	4050	675
	CSO structure 2	2	2	25	17500	2250	375
	CSO structure 3	2	2	50	35000	4500	750
	CSO structure 5	2	4	55	38500	4950	825
	CSO structure 6	4	4	110	77000	9900	1650
2002	catchment	10	6	105	73500	9450	1575
	CSO structure 1	2	1	15	10500	1350	225
	CSO structure 2	2	1	20	14000	1800	300
	CSO structure 3	2	1	45	31500	4050	675
	CSO structure 5	2	1	5	3500	450	75
	CSO structure 6	2	2	20	14000	1800	300
2003	catchment	3	8	180	126000	16200	2700
	CSO structure 1	1	1	30	21000	2700	450
	CSO structure 2	0	1	5	3500	450	75
	CSO structure 3	0	1	5	3500	450	75
	CSO structure 5	0	3	50	35000	4500	750
	CSO structure 6	2	2	90	63000	8100	1350

Comma Separated Values File Format

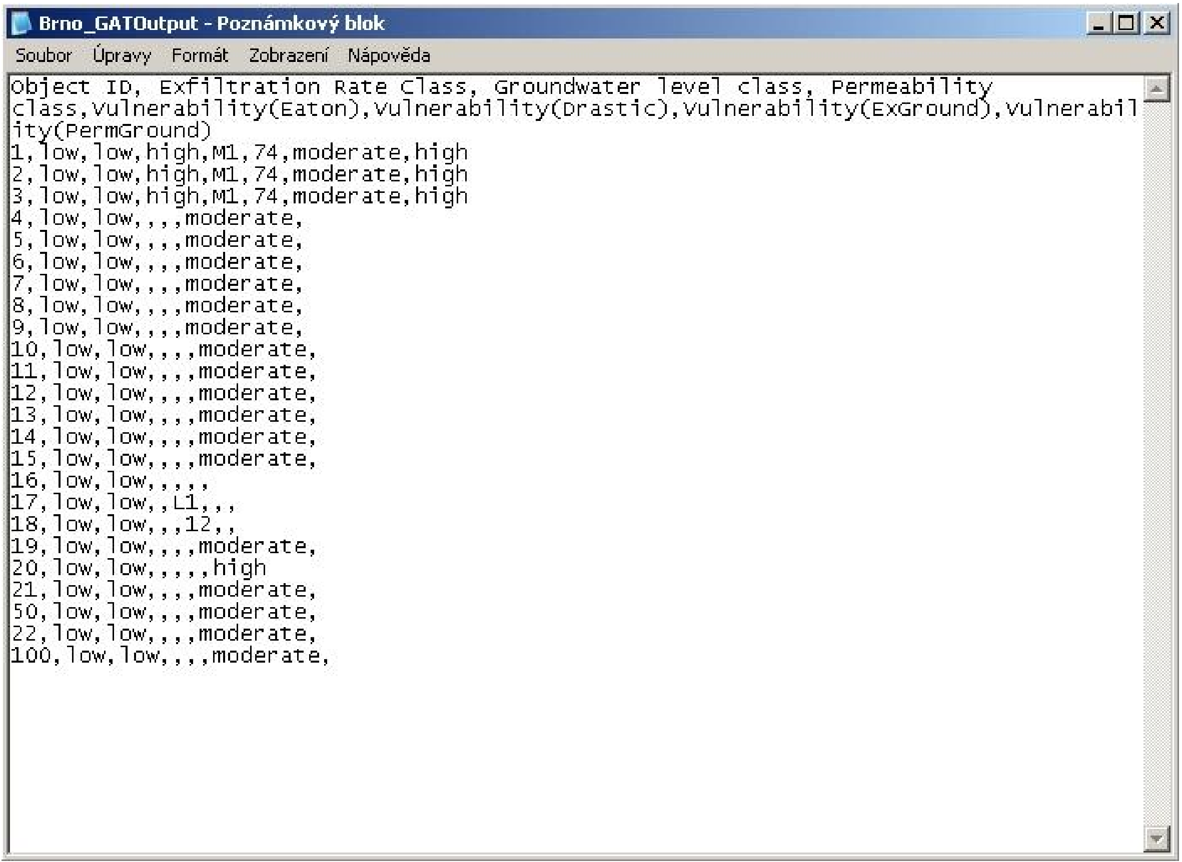


```
Type of standard, Threshold, Year, compliance to standard, Deviation,Deviation in %
all

Duration,10,2002,yes,0,0
Number of Events,20,2002,yes,-14,-70
Volume,300,2002,yes,-195,-65
,,2003,yes,-7,-70
,,2003,yes,-12,-60
,,2003,yes,-120,-40

CATFile,ObjectID,Duration,Events,Volume,CODLoad,BODLoad,NH4Load
Treshold,, 10 , 20 , 300 , 30000 ,,

CSO Structures,CSO structure 1, 3 , 2 , 45 , 31500 , 4050 , 675
,CSO structure 2, 2 , 2 , 25 , 17500 , 2250 , 375
,CSO structure 3, 2 , 2 , 50 , 35000 , 4500 , 750
,CSO structure 5, 2 , 4 , 55 , 38500 , 4950 , 825
,CSO structure 6, 4 , 4 , 110 , 77000 , 9900 , 1650


 2002 ,catchment, 10 , 6 , 105 , 73500 , 9450 , 1575
,CSO structure 1, 2 , 1 , 15 , 10500 , 1350 , 225
,CSO structure 2, 2 , 1 , 20 , 14000 , 1800 , 300
,CSO structure 3, 2 , 1 , 45 , 31500 , 4050 , 675
,CSO structure 5, 2 , 1 , 5 , 3500 , 450 , 75
,CSO structure 6, 2 , 2 , 20 , 14000 , 1800 , 300

 2003 ,catchment, 3 , 8 , 180 , 126000 , 16200 , 2700
,CSO structure 1, 1 , 1 , 30 , 21000 , 2700 , 450
,CSO structure 2, 0 , 1 , 5 , 3500 , 450 , 75
,CSO structure 3, 0 , 1 , 5 , 3500 , 450 , 75
,CSO structure 5, 0 , 3 , 50 , 35000 , 4500 , 750
,CSO structure 6, 2 , 2 , 90 , 63000 , 8100 , 1350
```

GAT output file

Object ID	Exfiltration Rate Class	Groundwater level class	Permeability class	Vulnerability (Eaton)	Vulnerability (Drastic)	Vulnerability (ExGround)	Vulnerability (PermGround)
1	low	low	high	M1	74	moderate	high
2	low	low	high	M1	74	moderate	high
3	low	low	high	M1	74	moderate	high
4	low	low				moderate	
5	low	low				moderate	
…	…	…	…	…	…	…	…

Comma Separated Values File Format


Brno_GATOutput - Poznámkový blok

Soubor Úpravy Formát Zobrazení Nápověda

```
Object ID, Exfiltration Rate Class, Groundwater level class, Permeability
class,Vulnerability(Eaton),Vulnerability(Drastic),Vulnerability(ExGround),Vulnerabil
ity(PermGround)
1,low,low,high,M1,74,moderate,high
2,low,low,high,M1,74,moderate,high
3,low,low,high,M1,74,moderate,high
4,low,low,,,,moderate,
5,low,low,,,,moderate,
6,low,low,,,,moderate,
7,low,low,,,,moderate,
8,low,low,,,,moderate,
9,low,low,,,,moderate,
10,low,low,,,,moderate,
11,low,low,,,,moderate,
12,low,low,,,,moderate,
13,low,low,,,,moderate,
14,low,low,,,,moderate,
15,low,low,,,,moderate,
16,low,low,,,,,
17,low,low,,L1,,,
18,low,low,,,12,,
19,low,low,,,,moderate,
20,low,low,,,,,high
21,low,low,,,,moderate,
50,low,low,,,,moderate,
22,low,low,,,,moderate,
100,low,low,,,,moderate,
```

Annex II – Examples of output data

<u>HE Process Results</u> *HE_Process_Brno_01.csv*

LinkID	Filling Level	Frequency FillingLevelA	Frequency FillingLevelB	Frequency FillingLevelC	ProbabilityB	ProbabilityC
1	C	0.49	0.31	0.04	0.74	0.52
2	C	0.49	0.31	0.04	0.74	0.52
3	C	0.49	0.31	0.04	0.74	0.52
4	C	0.69	0.25	0.02	0.9	0.44
5	C	0.73	0.36	0.05	0.93	0.59
…	…	…	…	…	…	…

ProbabilityD	Weight Link	Insufficient Capacity	Velocity	Overflow Typology	Infiltration Weight
0.08	0.04	0.73	no	C	1
0.08	0.04	0.73	no	C	1
0.08	0.04	0.73	no	C	1
0.04	0.23	1.00	yes	C	1
0.09	0.23	1.00	yes	C	1
…	…	…	……	…	…

Comma Separated Values File Format

HE_Process_Brno_01 - Poznámkový blok

Soubor Úpravy Formát Zobrazení Nápověda

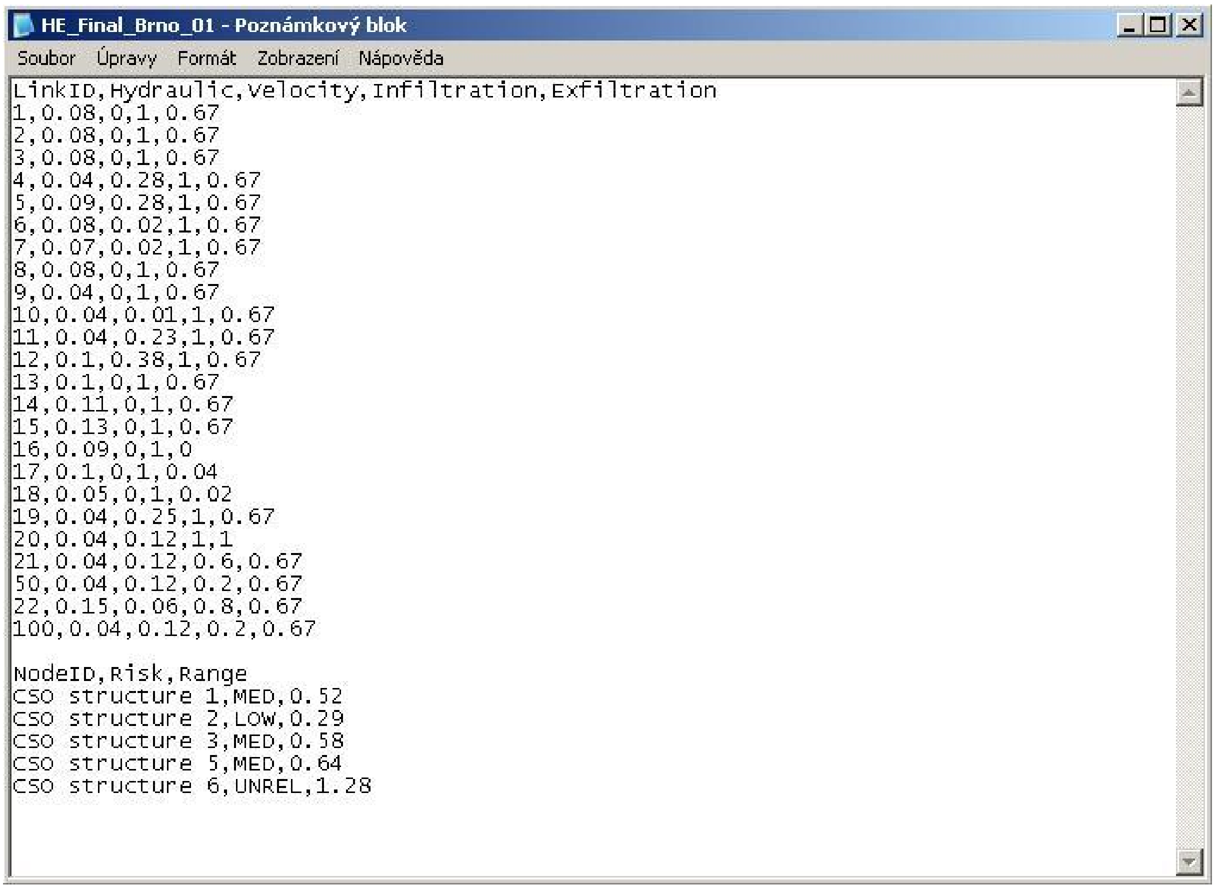
```
LinkID,FillingLevel,FrequencyFillingLevelA,FrequencyFillingLevelB,FrequencyFillingLe
velC,ProbabilityB,ProbabilityC,ProbabilityD,WeightLink,InsufficientCapacity,Velocity
,OverflowTypology,InfiltrationWeight
1,C,0.49,0.31,0.04,0.74,0.52,0.08,0.04,0.73,no,C,1.00
2,C,0.49,0.31,0.04,0.74,0.52,0.08,0.04,0.73,no,C,1.00
3,C,0.49,0.31,0.04,0.74,0.52,0.08,0.04,0.73,no,C,1.00
4,C,0.69,0.25,0.02,0.90,0.44,0.04,0.23,1.00,yes,C,1.00
5,C,0.73,0.36,0.05,0.93,0.59,0.09,0.23,1.00,yes,C,1.00
6,C,0.89,0.36,0.04,0.99,0.59,0.08,0.27,1.00,yes,C,1.00
7,C,0.52,0.24,0.04,0.77,0.43,0.07,0.27,0.93,yes,C,1.00
8,C,0.52,0.33,0.04,0.77,0.56,0.08,0.04,0.71,no,C,1.00
9,C,0.42,0.24,0.02,0.66,0.42,0.04,0.04,0.69,no,C,1.00
10,C,0.69,0.27,0.02,0.90,0.47,0.04,0.07,1.00,yes,C,1.00
11,C,0.28,0.12,0.02,0.48,0.23,0.04,0.11,0.71,yes,C,1.00
12,D,0.84,0.37,0.05,0.97,0.61,0.10,0.43,1.00,yes,C,1.00
13,D,0.53,0.33,0.05,0.78,0.55,0.10,0.04,0.79,no,C,1.00
14,D,0.82,0.41,0.06,0.97,0.66,0.11,0.12,1.00,no,C,1.00
15,D,1.13,0.66,0.07,1.00,0.88,0.13,0.04,1.00,no,C,1.00
16,C,0.45,0.27,0.05,0.70,0.47,0.09,0.07,0.70,no,C,1.00
17,D,0.84,0.37,0.05,0.97,0.61,0.10,0.21,1.00,no,C,1.00
18,C,0.54,0.18,0.02,0.79,0.33,0.05,0.51,1.00,no,C,1.00
19,C,0.24,0.07,0.02,0.42,0.14,0.04,1.00,0.81,yes,C,1.00
20,B,0.19,0.04,0.02,0.34,0.09,0.04,0.54,0.80,yes,C,1.00
21,B,0.13,0.03,0.02,0.24,0.05,0.04,0.54,0.74,yes,C,0.60
50,A,0.04,0.02,0.02,0.08,0.04,0.04,0.54,0.69,yes,C,0.20
22,D,0.12,0.10,0.08,0.22,0.20,0.15,0.17,0.00,yes,C,0.80
100,A,0.02,0.02,0.02,0.04,0.04,0.04,0.54,0.58,yes,C,0.20
```

HE Final Results *HE_Final_Brno_01.csv*

LinkID	Hydraulic	Velocity	Infiltration	Exfiltration
1	0.08	0.00	1	0.67
2	0.08	0.00	1	0.67
3	0.08	0.00	1	0.67
4	0.04	0.28	1	0.67
5	0.09	0.28	1	0.67
…	…	…	…	…

NodeID	Risk	Range
CSO structure 1	MED	0.52
CSO structure 2	LOW	0.29
CSO structure 3	MED	0.58
CSO structure 5	MED	0.64
CSO structure 6	UNREL	1.28
…	…	…

Comma Separated Values File Format


HE_Final_Brno_01 - Poznámkový blok

Soubor Úpravy Formát Zobrazení Nápověda

```
LinkID,Hydraulic,Velocity,Infiltration,Exfiltration
1,0.08,0,1,0.67
2,0.08,0,1,0.67
3,0.08,0,1,0.67
4,0.04,0.28,1,0.67
5,0.09,0.28,1,0.67
6,0.08,0.02,1,0.67
7,0.07,0.02,1,0.67
8,0.08,0,1,0.67
9,0.04,0,1,0.67
10,0.04,0.01,1,0.67
11,0.04,0.23,1,0.67
12,0.1,0.38,1,0.67
13,0.1,0,1,0.67
14,0.11,0,1,0.67
15,0.13,0,1,0.67
16,0.09,0,1,0
17,0.1,0,1,0.04
18,0.05,0,1,0.02
19,0.04,0.25,1,0.67
20,0.04,0.12,1,1
21,0.04,0.12,0.6,0.67
50,0.04,0.12,0.2,0.67
22,0.15,0.06,0.8,0.67
100,0.04,0.12,0.2,0.67

NodeID,Risk,Range
CSO structure 1,MED,0.52
CSO structure 2,LOW,0.29
CSO structure 3,MED,0.58
CSO structure 5,MED,0.64
CSO structure 6,UNREL,1.28
```

Annex III – HELLMUD inputs from MOUSE

Layout file – List of links

	model	**Mouse**	
	file type	input file	output file
	file name extension	*.und	*.htm
	heading	[MOUSE_LINKS]	Links - Data
	sub-heading		
LinkId	[-]	LINKID	
From Node	[-]	FROMNODE	
To Node	[-]	TONODE	
Up - Invert Level	[m above sea]	UPLEVEL	
Down - Invert Level	[m]	DWLEVEL	
Drainage System	[-]	manually	
Length	[m]	SPECIFIEDLENGTH	
Slope	[‰]		Slope
Qcap	[m3/s]		Qf
Critical Level	[-]	manually	
Material	[-]	materialno	
Shape	[-]	SCALINGTYPENO	
qInfiltr	[m3/s/m]	INFILTRATION	
Manning roughness	[m-1/3/s]	materialno	
CW roughness (k)	[mm]	0	
Height	[m]	HEIGHT	
Width	[m]	SCALEORWIDTH	

Layout file - List of nodes

	heading	[MOUSE_NODES]	
NodeID	[-]	NODEID	
Ground Level	[-]	GROUNDLEVEL	

SE simulation – hydraulic file

model	Mouse
file type	output
file name extension	*.htm
heading	Links - Result Summary

LinkID	[-]	LINKID
0.05	[hmax/height, non-dimensional]	Hmax/D
0.05	[Qmax, in $m^3.s^{-1}$]	Qmax
0.5	[hmax/height, non-dimensional]	Hmax/D
0.5	[Qmax, in $m^3.s^{-1}$]	Qmax
1	[hmax/height, non-dimensional]	Hmax/D
1	[Qmax, in $m^3.s^{-1}$]	Qmax
…	…	…
…	…	…
5	[hmax/height, non-dimensional]	Hmax/D
5	[Qmax, in $m^3.s^{-1}$]	Qmax

HRD simulation – hydraulic file

model	Mouse
file type	output
file name extension	*.htm
heading	Links - Result Summary

LinkID	[-]	LINKID
1	[hmax/height, non-dimensional]	Hmax/D
1	[Qmax, in $m^3.s^{-1}$]	Qmax
2	[hmax/height, non-dimensional]	Hmax/D
2	[Qmax, in $m^3.s^{-1}$]	Qmax
3	[hmax/height, non-dimensional]	Hmax/D
3	[Qmax, in $m^3.s^{-1}$]	Qmax
4	[hmax/height, non-dimensional]	Hmax/D
4	[Qmax, in $m^3.s^{-1}$]	Qmax
...	...	...
12	[hmax/height, non-dimensional]	Hmax/D
12	[Qmax, in $m^3.s^{-1}$]	Qmax
13	[hmax/height, non-dimensional]	Hmax/D
13	[Qmax, in $m^3.s^{-1}$]	Qmax
...	...	...
...	...	...

Annex IV – HELLMUD inputs from InfoWorks

Layout file – List of links

	model	**InfoWorks**	
	file type	input file	
	file name extension	*.csv	
	heading	hw_conduit	
	sub-heading	Object table	field description
LinkId	[-]	us_node_id + link_suffix	US Node ID + Link Suffix
From Node	[-]	us_node_id	US Node ID
To Node	[-]	ds_node_id	DS Node ID
Up - Invert Level	[m above sea]	us_invert	US Invert Level
Down - Invert Level	[m]	ds_invert	DS Invert Level
Drainage System	[-]	system_type	system type (native)
Length	[m]	conduit_lenght	Lenght
Slope	[‰]	gradient	Gradient (m/m)
Qcap	[m3/s]	capacity	Conduit full capacity
Critical Level	[-]	manually	
Material	[-]	conduit_material	Conduit Material
Shape	[-]	Shape	Shape ID
qInfiltr	[m3/s/m]	inflow	inflow
Manning roughness	[m-1/3/s]	bottom_roughness	Bottom Roughness
CW roughness (k)	[mm]	bottom_roughness	Bottom Roughness
Height	[m]	conduit_height	Height
Width	[m]	conduit_width	Width

Layout file - List of nodes

	heading	hw_node	
NodeID	[-]	node_id	Node ID
Ground Level	[-]	ground_level	groundlevel (m)

SE simulation – hydraulic file

	model	**InfoWorks**
	file type	output
	file name extension	*.prn
	heading	Link data
LinkID	[-]	link reference
0.05	[hmax/height, non-dimensional	max depth *)
0.05	[Qmax, in $m^3.s^{-1}$]	Max Flow
0.5	[hmax/height, non-dimensional	max depth
0.5	[Qmax, in $m^3.s^{-1}$]	Max Flow
1	[hmax/height, non-dimensional	max depth
1	[Qmax, in $m^3.s^{-1}$]	Max Flow
…	…	…
…	…	…
5	[hmax/height, non-dimensional	max depth
5	[Qmax, in $m^3.s^{-1}$]	Max Flow

HRD simulation – hydraulic file

model	**InfoWorks**
file type	output
file name extension	*.prn
heading	Link data

LinkID	[-]	link reference
1	[hmax/height, non-dimensional]	max depth *)
1	[Qmax, in $m^3.s^{-1}$]	Max Flow
2	[hmax/height, non-dimensional]	max depth
2	[Qmax, in $m^3.s^{-1}$]	Max Flow
3	[hmax/height, non-dimensional]	max depth
3	[Qmax, in $m^3.s^{-1}$]	Max Flow
4	[hmax/height, non-dimensional]	max depth
4	[Qmax, in $m^3.s^{-1}$]	Max Flow
...	...	...
12	[hmax/height, non-dimensional]	max depth
12	[Qmax, in $m^3.s^{-1}$]	Max Flow
13	[hmax/height, non-dimensional]	max depth
13	[Qmax, in $m^3.s^{-1}$]	Max Flow
...	...	...
...	...	...

*) Ratio "hmax/height" has to be computed outside InfoWorks as (max depth / conduit_height)

Annex V – HELLMUD inputs from SWMM

Layout file – List of links

	model	**SWMM**	
	file type	input file	output file
	file name extension	*.dat	*.out
	heading	$EXTRAN	CONDUIT SUMMARY STATISTICS
	sub-heading	lines C1	
LinkId	[-]	NCOND	
From Node	[-]	NJUNC1	
To Node	[-]	NJUNC2	
Up - Invert Level	[m above sea]	ZP(1)	
Down - Invert Level	[m]	ZP(2)	
Drainage System	[-]	manually	
Length	[m]	LEN	
Slope	[‰]		CONDUIT SLOPE
Qcap	[m3/s]		DESIGN FLOW
Critical Level	[-]	manually	
Material	[-]	special column	
Shape	[-]	NKLASS	
qInfiltr	[m3/s/m]	Q0	
Manning roughness	[m-1/3/s]	ROUGH	
CW roughness (k)	[mm]	0	
Height	[m]	DEEP	
Width	[m]	WIDE	

Layout file - List of nodes

	heading	$EXTRAN - D1	
NodeID	[-]	JUN	
Ground Level	[-]	GRELEV	

SE simulation – hydraulic file

	model	SWMM
	file type	output
	file name extension	*.out
	heading	CONDUIT SUMMARY STATISTICS
LinkID	[-]	CONDUIT NUMBER
0.05	[hmax/height, non-dimensional	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS - UPSTREAM
0.05	[Qmax, in $m^3.s^{-1}$]	MAXIMUM COMPUTED FLOW
0.5	[hmax/height, non-dimensional]	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS - UPSTREAM
0.5	[Qmax, in $m^3.s^{-1}$]	MAXIMUM COMPUTED FLOW
1	[hmax/height, non-dimensional]	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS - UPSTREAM
1	[Qmax, in $m^3.s^{-1}$]	MAXIMUM COMPUTED FLOW
5	[hmax/height, non-dimensional]	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS - UPSTREAM
5	[Qmax, in $m^3.s^{-1}$]	MAXIMUM COMPUTED FLOW
…	…	…
…	…	…

HRD simulation – hydraulic file

	model	SWMM
	file type	output
	file name extension	*.out
	heading	CONDUIT SUMMARY STATISTICS
LinkID	[-]	CONDUIT NUMBER
1	[hmax/height, non-dimensional]	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS - UPSTREAM
1	[Qmax, in $m^3.s^{-1}$]	MAXIMUM COMPUTED FLOW
2	[hmax/height, non-dimensional]	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS - UPSTREAM
2	[Qmax, in $m^3.s^{-1}$]	MAXIMUM COMPUTED FLOW
3	[hmax/height, non-dimensional]	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS - UPSTREAM
3	[Qmax, in $m^3.s^{-1}$]	MAXIMUM COMPUTED FLOW
4	[hmax/height, non-dimensional]	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS - UPSTREAM
4	[Qmax, in $m^3.s^{-1}$]	MAXIMUM COMPUTED FLOW
...	...	...
13	[hmax/height, non-dimensional]	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS - UPSTREAM
13	[Qmax, in $m^3.s^{-1}$]	MAXIMUM COMPUTED FLOW
...	...	...
...	...	...

*) Ratio "hmax/height" has to be computed outside SWMM as (MAXIMUM DEPTH… / DEEP)

Annex VI – HELLMUD Help file

Hellmud

Version **3.3.0**

A mathematical model HELLMUD is oriented on service reliability, which reflects the probability of hydraulic efficiency and environmental impacts of sewer system for one predetermined scenario.

The model aims to define particular criteria that can be used for assessment of the reliability aspects on existing sewer system or examination of proposed scenarios of the urban drainage rehabilitation.

Minimum System Requirements:

- IBM Compatible PC
- Microsoft Windows 2000 or Microsoft Windows XP (no guarantee can be given for other versions)
- 5 MB free disk space

Installation:

Hellmud Tool does not need an installation. If problems occur, please register comdlg32.ocx, mshflxgd.ocx, mscomct2.ocx, tabctl32.ocx by executing the setup.bat (Hellmud application directory).

The help file Hellmud.chm needs to be stored in the application path.

Personal Preferences:

This version of Hellmud Tool saves your personal preferences in the application directory.

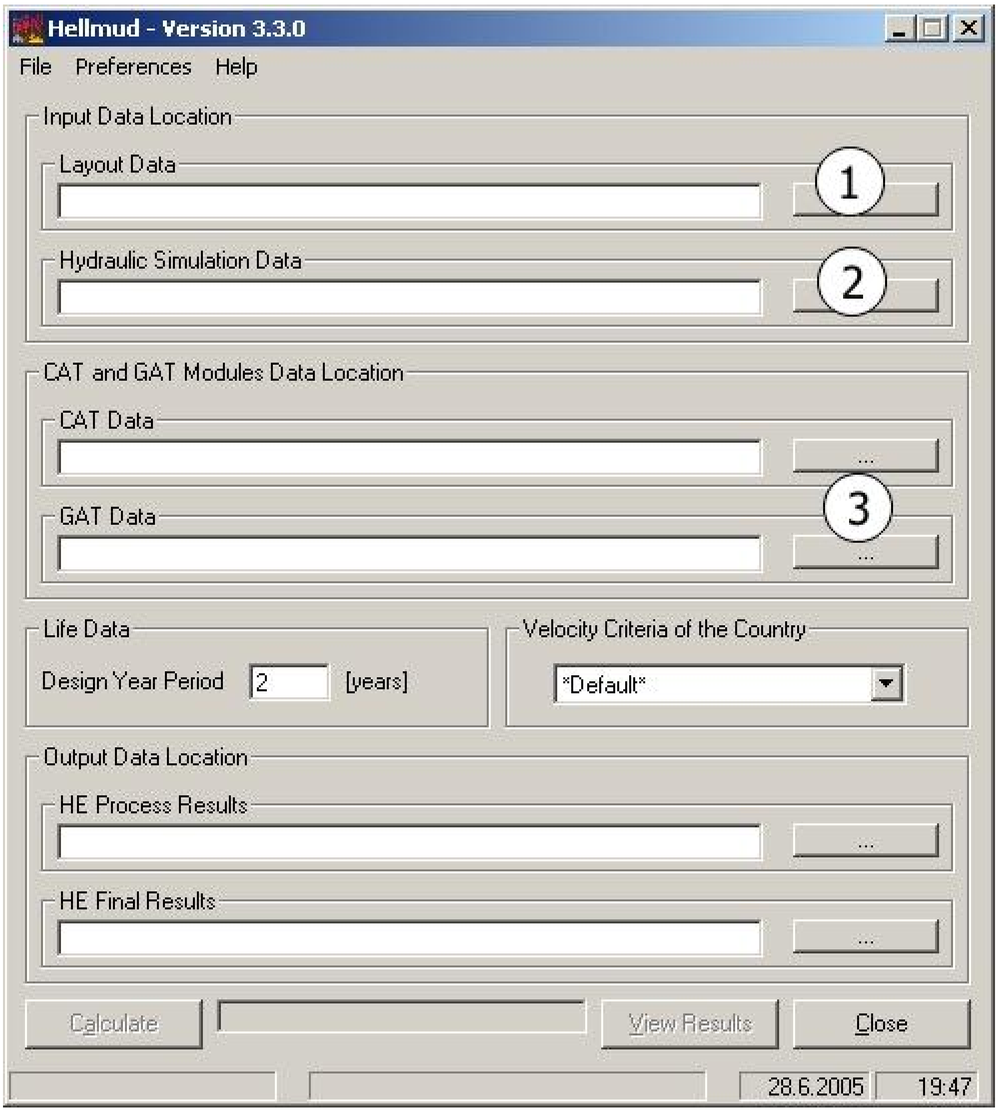
Input data

Input data are loaded in following three phases:

1. **Layout Data**
2. **Hydraulic Simulation Data**

   2.1 Single event simulation,
   2.2 Historical Rain Data (HRD)

3. **CAT and GAT Data**



1. Layout Data File (name_XX_layout.csv)

In this phase, data concerning layout of sewer system are loaded. The data are loaded in the file name_XX_layout.csv. There are three parts within the file – Heading part, List of links and List of nodes (each separated by one free line): Layout import - Heading part = first 2 lines of the file (see "Illustrative example")

Layout file - Heading part:

Version	NameOfCatch	Scenario	Model
Version of the file *(Hellmud4)*	Name of the catchment *(Name)*	Scenario ID *(XX in file name)*	Hydraulic Model *(S, M, I)*

Layout file – List of links

	Obligatory / Optional	Quantitative / qualitative / Both possible	Type of data (Numeric or alphanumeric)	Unit (if Quantitative)	Description
LinkID	obligatory	qualitative	alphanumeric	-	link ID
From Node	obligatory	qualitative	alphanumeric	-	beginning node of the link
To Node	obligatory	qualitative	alphanumeric	-	end node of the link
Up - Invert Level	obligatory	quantitative	numeric	m above sea level	invert level of the beginning node
Down - Invert Level	obligatory	quantitative	numeric	m above sea level	invert level of the end node
Drainage system	obligatory	qualitative	alphanumeric	-	type of drainage system *combined / separate*
Length	obligatory	quantitative	numeric	m	length of link
Slope	obligatory	quantitative	numeric	‰	slope of pipe
Qcap	obligatory	quantitative	numeric	m^3/s	flow capacity
Critical Level	obligatory	quantitative	numeric	-	ratio of critical level to height *critical level - beginning of hydraulic problems in network*
Material	obligatory	qualitative	alphanumeric	-	material of pipe - in compliance with *"WP1 - Construction of a control panel of performance indicators for rehabilitation - Specification for the collection of the PI values and for the tentative definition of PI thresholds" - Appendix 4*
Shape	obligatory	qualitative	numeric	-	cross-sectional shape
qInfiltr	obligatory	quantitative	numeric	$m^3/s/m$	infiltration of pipe
Manning roughness	obligatory	quantitative	numeric	$m^{-1/3}/s$	Manning roughness
CW roughness (k)	obligatory	quantitative	numeric	mm	White-Colebrook roughness
Height	obligatory	quantitative	numeric	m	height of pipe
Width	obligatory	quantitative	numeric	m	width of pipe

Layout file - List of nodes

	Obligatory / Optional	Quantitative / qualitative / Both possible	Type of data (Numeric or alphanumeric)	Unit (if Quantitative)	Description
NodeID	obligatory	qualitative	alphanumeric	-	node ID
Ground Level	obligatory	quantitative	numeric	m above sea level	ground level of the node

2. Hydraulic data

Hydraulic data can be loaded by two different ways according to data available. During loading of name_XX_hydraulic file, either Single event simulation (rain with certain periodicity) or Historical Rain Data (HRD) simulation can be chosen. There are some small differences in input data. There is written name of project and XX as ID of scenario in the title of the appropriate file.

2.1. Single Event Simulation *(name_XX_hydraulic.csv)*

Synthetic rains with certain periodicity are loaded in the file *name_XX_hydraulic* (input data are described bellow, differences from the heading part of *name_XX_layout.csv* are in bold.

Single event simulation - Heading part = first 2 lines of the file (see "Illustrative example"):

Version	NameOfCatch	Scenario	DataFrom
Version of the file *(Hellmud4)*	Name of the catchment *(Name)*	Scenario ID *(XX in file name)*	"0" 0 – single event simulation 1 – HRD

Single event simulation – List of links

	Obligatory / Optional	Quantitative / qualitative / Both possible	Type of data (Numeric or alphanumeric)	Unit (if Quantitative)	Description
LinkID	obligatory	qualitative	alphanumeric	-	link ID
hmax/height	obligatory	quantitative	numeric	-	ratio of maximum filling level to Height according to annual return period
Qmax	obligatory	quantitative	numeric	m^3/s	maximum flow according to annual return period

If the end user has no data available for long term simulations or if he is not interested in that kind of simulations, the model can be run on at least 3 single event simulations
= there must be available at least 3 synthetic design rain events + their frequency
= after hydraulic simulation, into HELLMUD must be loaded at least 3 double-columns every with Hmax/Height and Qmax data (at least 6 columns totally). Appropriate annual return period must be listed in the first line of SE name_XX_hydraulic.csv file. These return periods are used for HELLMUD calculation.

Example: SE simulation will be run on computation boundary data, which presents return period of e.g. 1; 0,5; 0,2 and 0,1 year-1. Total number of columns is eight.

For single event simulation, it is accepted when the failure produced by the specific event will have the same return period as the event.

2.2. Historical Rain Data Simulation (HRD) *(name_XX_hydraulic.csv)*

In case of historical rain series, name of the file is the same as for Single event simulation (*name_XX_hydraulic.csv*) and input data are listed bellow (differences are in bold).

HRD - Heading part = first 2 lines of the file (see "Illustrative example"):

Version	NameOfCatch	Scenario	DataFrom	Duration
Version of the file *(Hellmud4)*	Name of the catchment *(Name)*	Scenario ID *(XX in file name)*	"1" 0 – single event simulation 1 – HRD	Duration of rain series

HRD - List of links

	Obligatory / Optional	Quantitative / qualitative / Both possible	Type of data (Numeric or alphanumeric)	Unit (if Quantitative)	Description
LinkID	obligatory	qualitative	alphanumeric	-	link ID
hmax/height	obligatory	quantitative	numeric	-	ratio of maximum filling level to Height for every rain event simulated
Qmax	obligatory	quantitative	numeric	m^3/s	maximum flow for every rain event simulated

Hydraulic analyses will be performed by user via MOUSE DHI, InfoWorks or SWMM. Hydraulic analysis of the run-off relations concerning the storm water disposal system is based on the results from the numeric simulation. The data selected by means of mathematical modelling using "Duration -length of historic rain database" is considered to be the optimum data source. The minimum number of years of simulation should be defined for long term simulations to make the analysis statistically "true". For HELLMUD calculation, 25 storms is minimum:
= there must be available at least 25 historical rain events
= after hydraulic simulation, into HELLMUD must be loaded at least 25 double-columns every with Hmax/Height and Qmax data (at least 50 columns totally). In the first line of HRD name_XX_hydraulic.csv file is simply filled rain specification which is not used for calculation at all.

A long-term simulation model can be substitute by series of separated events instead of a continuous simulation (this allows a considerable reduction of the total simulated time span).

3. CAT and GAT modules

Data was taken from CATOutput.csv and GATOutput.scv. Detail description of them can be found in Draft Report – Tools in work package 3.3. (Nora Schultz, October 2004).

Layout Example (Brno_01_layout.csv)

Version	NameOfCatch	Scenario	Model
Hellmud4	Brno	1	M

free line

LinkID	From Node	To Node	Up - Invert Level	Down - Invert Level	Drainage System	Length	Slope	Qcap	Critical Level	Material	Shape	qInfiltr	Manning roughness	CW roughness (k)	Height
[-]	[-]	[-]	[m]	[m]	[-]	[m]	[‰]	[m3/s]	[-]	[-]	[-]	[m3/s/m]	[m-1/3/s]	[mm]	[m]
1	1	4	242.35	236.1	C	250	25	0.329	1.5	sC13	1	0.02	0.013	0	0.4
2	2	4	242.35	236.1	C	250	25	0.329	1.5	sC13	1	0.02	0.013	0	0.4
3	3	4	242.35	236.1	C	250	25	0.329	1.5	sC13	1	0.02	0.013	0	0.4
4	4	5	235.7	229.45	C	250	25	2.091	1.5	sC13	1	0.02	0.013	0	0.8
5	5	6	229.45	223.2	C	250	25	2.091	1.5	sC13	1	0.02	0.013	0	0.8

free line

NodeID	Ground Level
1	245.75
2	245.75
3	245.75
4	239.5
5	233.25

Brno_00_layout - Notepad

File Edit Format Help

```
Version,NameOfCatch,Scenario,Model
Hellmud4,Brno,1,M

LinkId ,From Node,To Node,Up - Invert Level,Down - Invert Level,Drainage
System,Length,Slope,Qcap,Critical Level,Material,Shape,qInfiltr,roughness,CW
roughness (k),Height,Width
[-],[-],[-],[m],[m],[-],[m],[‰],[m3/s],[-],[-],[-],[m3/s/m],[m-1/3/s],[mm],[m
],[m]
1,1,4,242.35,236.1,c,250,25,0.329,1.5,sC13,1,0.02,0.013,0,0.4,0.5
2,2,4,242.35,236.1,c,250,25,0.329,1.5,sC13,1,0.02,0.013,0,0.4,0.5
3,3,4,242.35,236.1,c,250,25,0.329,1.5,sC13,1,0.02,0.013,0,0.4,0.5
4,4,5,235.7,229.45,c,250,25,2.091,1.5,sC13,1,0.02,0.013,0,0.8,0.8
5,5,6,229.45,223.2,c,250,25,2.091,1.5,sC13,1,0.02,0.013,0,0.8,0.8
```

...

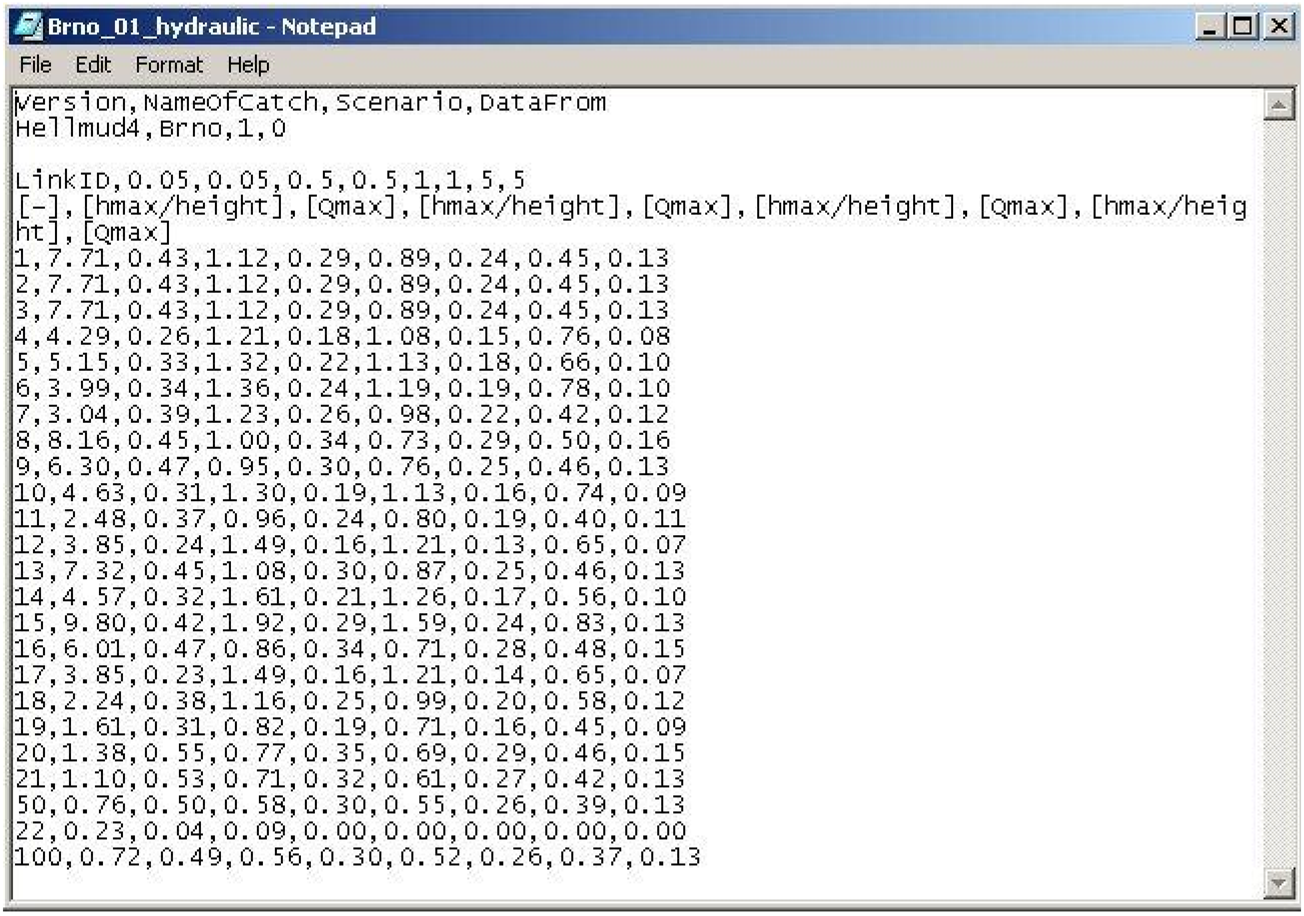
```
22,22,V,215.8,215,c,200,4,1.516,1.5,sC13,1,0.02,0.013,0,1,1
100,100,COV,215.05,215,c,50,1,4.814,1.5,sC13,1,0.02,0.013,0,2,2

 NodeID,Ground Level
[-],[-]
1,245.75
2,245.75
3,245.75
4,239.5
5,233.25
6,227
7,224.5
```

Hydraulic Example (Brno_01_hydraulic.csv) - single event simulation

Version	NameOfCatch	Scenario	DataFrom
Hellmud4	Brno	1	0

free line

LinkID	0.05	0.05	0.5	0.5	1	1	5	5
[-]	[hmax/height]	[Qmax]	[hmax/height]	[Qmax]	[hmax/height]	[Qmax]	[hmax/height]	[Qmax]
1	7.71	0.43	1.12	0.29	0.89	0.24	0.45	0.13
2	7.71	0.43	1.12	0.29	0.89	0.24	0.45	0.13
3	7.71	0.43	1.12	0.29	0.89	0.24	0.45	0.13
4	4.29	0.26	1.21	0.18	1.08	0.15	0.76	0.08
5	5.15	0.33	1.32	0.22	1.13	0.18	0.66	0.10


Brno_01_hydraulic - Notepad

File Edit Format Help

```
Version,NameOfCatch,Scenario,DataFrom
Hellmud4,Brno,1,0

LinkID,0.05,0.05,0.5,0.5,1,1,5,5
[-],[hmax/height],[Qmax],[hmax/height],[Qmax],[hmax/height],[Qmax],[hmax/heig
ht],[Qmax]
1,7.71,0.43,1.12,0.29,0.89,0.24,0.45,0.13
2,7.71,0.43,1.12,0.29,0.89,0.24,0.45,0.13
3,7.71,0.43,1.12,0.29,0.89,0.24,0.45,0.13
4,4.29,0.26,1.21,0.18,1.08,0.15,0.76,0.08
5,5.15,0.33,1.32,0.22,1.13,0.18,0.66,0.10
6,3.99,0.34,1.36,0.24,1.19,0.19,0.78,0.10
7,3.04,0.39,1.23,0.26,0.98,0.22,0.42,0.12
8,8.16,0.45,1.00,0.34,0.73,0.29,0.50,0.16
9,6.30,0.47,0.95,0.30,0.76,0.25,0.46,0.13
10,4.63,0.31,1.30,0.19,1.13,0.16,0.74,0.09
11,2.48,0.37,0.96,0.24,0.80,0.19,0.40,0.11
12,3.85,0.24,1.49,0.16,1.21,0.13,0.65,0.07
13,7.32,0.45,1.08,0.30,0.87,0.25,0.46,0.13
14,4.57,0.32,1.61,0.21,1.26,0.17,0.56,0.10
15,9.80,0.42,1.92,0.29,1.59,0.24,0.83,0.13
16,6.01,0.47,0.86,0.34,0.71,0.28,0.48,0.15
17,3.85,0.23,1.49,0.16,1.21,0.14,0.65,0.07
18,2.24,0.38,1.16,0.25,0.99,0.20,0.58,0.12
19,1.61,0.31,0.82,0.19,0.71,0.16,0.45,0.09
20,1.38,0.55,0.77,0.35,0.69,0.29,0.46,0.15
21,1.10,0.53,0.71,0.32,0.61,0.27,0.42,0.13
50,0.76,0.50,0.58,0.30,0.55,0.26,0.39,0.13
22,0.23,0.04,0.09,0.00,0.00,0.00,0.00,0.00
100,0.72,0.49,0.56,0.30,0.52,0.26,0.37,0.13
```

Hydraulic Example (Brno_02_hydraulic.csv) - HRD simulation

Version	NameOfCatch	Scenario	DataFrom	Duration
Hellmud4	Brno	2	1	20

free line

LinkID	750514	750514	750530	750530	750816	750816	760526	760526	770713	770713
[-]	[hmax/height]	[Qmax]	[hmax/height]	[Qmax]	[hmax/height]	[Qmax]	[hmax/height]	[Qmax]	[hmax/height]	[Qmax]
1	0.54	0.16	0.9	0.24	0.71	0.2	0.47	0.14	0.95	0.25
2	0.54	0.16	0.9	0.24	0.71	0.2	0.47	0.14	0.95	0.25
3	0.54	0.16	0.9	0.24	0.71	0.2	0.47	0.14	0.95	0.25
4	0.87	0.1	1.07	0.15	0.95	0.13	0.81	0.09	1.11	0.16
5	0.7	0.13	1.09	0.18	0.98	0.15	0.81	0.11	1.16	0.19

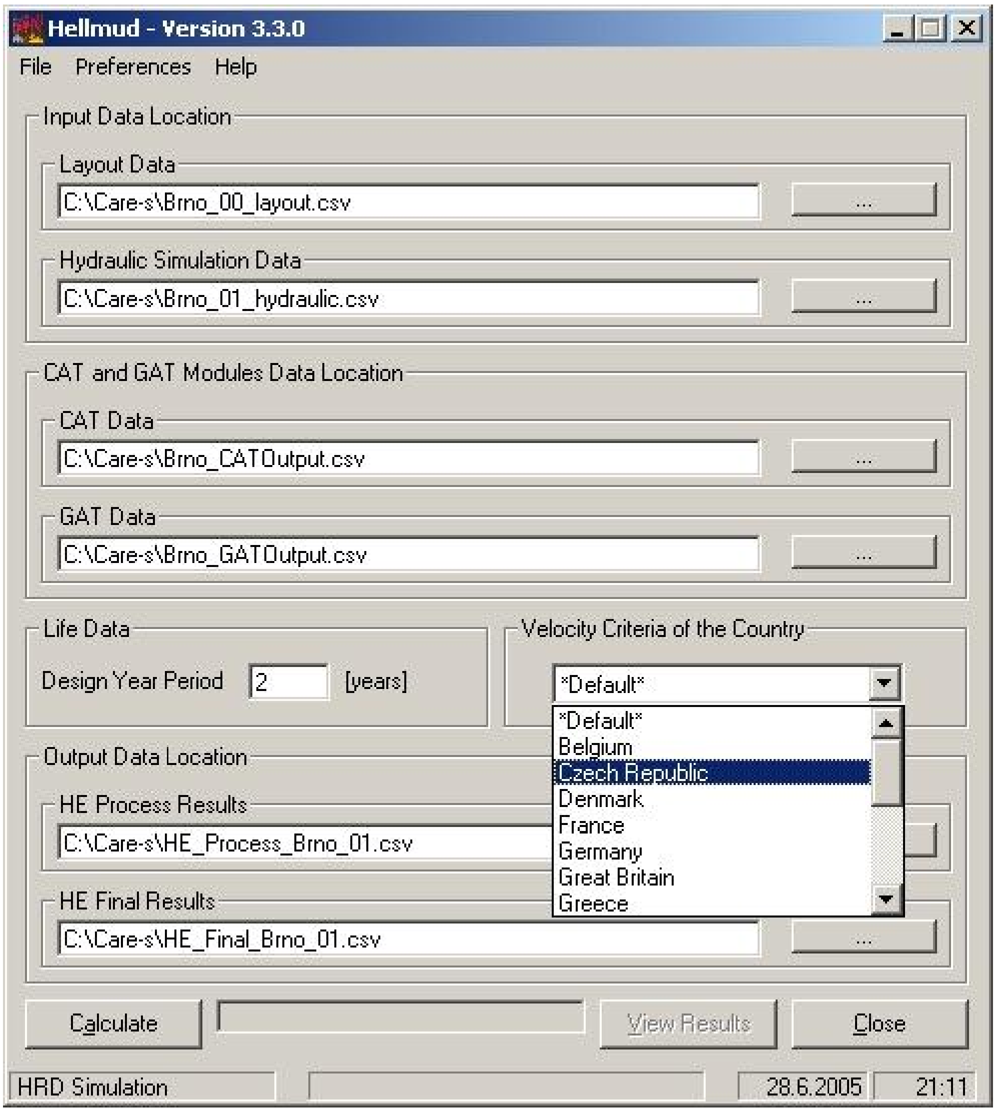
Brno_02_hydraulic - Notepad

File Edit Format Help

```
Version,NameOfCatch,Scenario,DataFrom,Duration
Hellmud4,Brno,2,1,20

LinkID,750514,750514,750530,750530,750816,750816,760526,760526,770713,770713,7
[-],[hmax/height],[Qmax],[hmax/height],[Qmax],[hmax/height],[Qmax],[hmax/heigh
1,0.54,0.16,0.9,0.24,0.71,0.2,0.47,0.14,0.95,0.25,0.88,0.24,0.55,0.17,1.02,0.2
2,0.54,0.16,0.9,0.24,0.71,0.2,0.47,0.14,0.95,0.25,0.88,0.24,0.55,0.17,1.02,0.2
3,0.54,0.16,0.9,0.24,0.71,0.2,0.47,0.14,0.95,0.25,0.88,0.24,0.55,0.17,1.02,0.2
4,0.87,0.1,1.07,0.15,0.95,0.13,0.81,0.09,1.11,0.16,1.05,0.14,0.87,0.11,1.16,0.
5,0.7,0.13,1.09,0.18,0.98,0.15,0.81,0.11,1.16,0.19,1.12,0.18,0.88,0.13,1.28,0.
6,0.81,0.13,1.15,0.19,1.06,0.16,0.93,0.12,1.23,0.2,1.19,0.19,0.98,0.14,1.35,0.
7,0.49,0.15,0.92,0.21,0.86,0.18,0.67,0.14,1.07,0.23,1.06,0.22,0.74,0.16,1.27,0
8,0.57,0.2,0.72,0.29,0.65,0.25,0.52,0.17,0.76,0.3,0.73,0.28,0.58,0.2,0.84,0.32
9,0.52,0.17,0.76,0.25,0.59,0.21,0.48,0.15,0.8,0.26,0.73,0.25,0.53,0.18,0.88,0.
10,0.86,0.11,1.13,0.16,0.99,0.13,0.79,0.1,1.18,0.17,1.12,0.16,0.88,0.11,1.22,0
11,0.53,0.13,0.8,0.19,0.65,0.16,0.45,0.12,0.83,0.2,0.78,0.19,0.54,0.13,0.9,0.2
12,0.7,0.09,1.17,0.13,1.05,0.11,0.88,0.08,1.29,0.14,1.25,0.13,0.94,0.09,1.52,0
13,0.52,0.17,0.85,0.25,0.74,0.21,0.55,0.15,0.93,0.26,0.86,0.25,0.58,0.18,1.09,
14,0.62,0.12,1.21,0.18,1.07,0.15,0.85,0.11,1.36,0.18,1.32,0.17,0.92,0.13,1.65,
15,0.98,0.16,1.55,0.24,1.63,0.2,1.02,0.14,1.64,0.25,1.59,0.24,1.17,0.17,1.83,0
16,0.55,0.19,0.71,0.28,0.62,0.23,0.51,0.17,0.74,0.29,0.71,0.27,0.56,0.19,0.87,
17,0.7,0.09,1.17,0.14,1.05,0.12,0.88,0.09,1.29,0.14,1.25,0.13,0.94,0.1,1.52,0.
18,0.63,0.14,0.94,0.2,0.9,0.17,0.77,0.14,1.05,0.21,1.04,0.21,0.81,0.15,1.2,0.2
19,0.53,0.11,0.65,0.15,0.68,0.14,0.6,0.11,0.78,0.17,0.77,0.17,0.63,0.12,0.87,0
20,0.56,0.2,0.63,0.26,0.66,0.26,0.61,0.21,0.75,0.31,0.74,0.31,0.63,0.23,0.83,0
21,0.5,0.19,0.58,0.23,0.6,0.24,0.57,0.21,0.72,0.29,0.7,0.29,0.59,0.22,0.8,0.33
50,0.48,0.17,0.55,0.21,0.56,0.23,0.54,0.2,0.63,0.27,0.63,0.27,0.56,0.21,0.69,0
22,0,0,0,0,0,0,0,0,0.09,0.01,0.08,0,0,0,0.14,0.01,0.25,0.04,0.07,0,0,0,0,0,0.1
100,0.41,0.16,0.47,0.21,0.49,0.23,0.45,0.2,0.53,0.27,0.53,0.27,0.47,0.21,0.56,
```

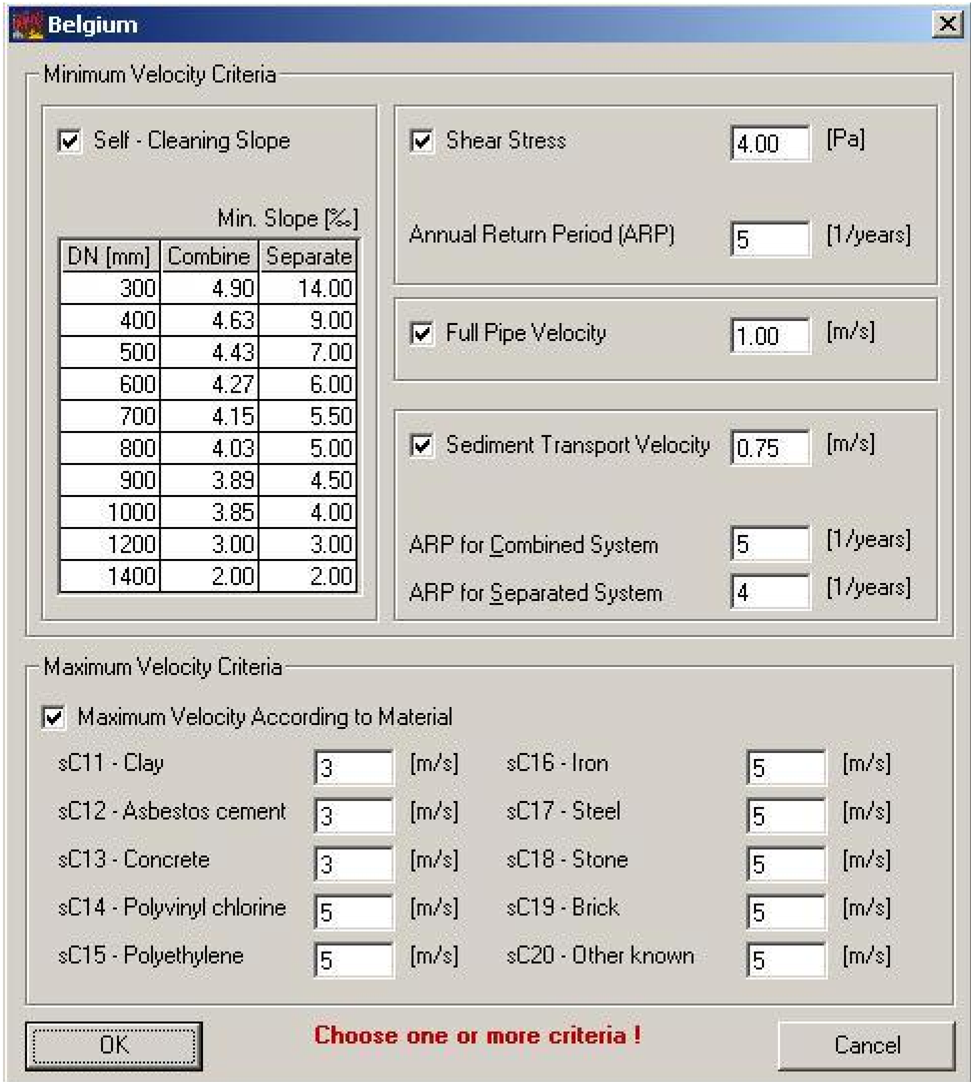
Velocity Criteria

User is able to set/change velocity criteria for selected country, as you can see on picture bellow.



Velocity Criteria

User is able to set/change velocity criteria for selected country, as you can see on picture bellow.



Output data

Output data will be saved as following files (XX means ID of the project):

1. **HE_Process_name_XX.csv**
2. **HE_Final_name_XX.csv**

The names of output files are automatically generated. User has to select the folder location where the files will be saved. Hydraulic criteria C1-C16 defined and calculated by WP3 are shown in table bellow. WP3 Criteria list and its detailed description can be found in the NEW - WP3 CRITERIA UPDATED.doc file.

WP3 Criteria:

	Name	Unit	Range	For	Input data		Description
					from	tool	
1	C1	[-]	A, B, C, D	pipe	WP3.2	Hellmud	filling level
2	C2A	[year^{-1}]	0.02-5	pipe	WP3.2		frequency up to ingress into A *)
3	C2B	[year^{-1}]	0.02-5	pipe	WP3.2		frequency up to ingress into B *)
4	C2C	[year^{-1}]	0.02-5	pipe	WP3.2		frequency up to ingress into C *)
5	C3B	[-]	0-1	pipe	WP3.2		probability P(B) **)
6	C3C	[-]	0-1	pipe	WP3.2		probability P(C) **)
7	C3D	[-]	0-1	pipe	WP3.2		probability P(D) **)
8	C4	[-]	0-1	pipe	WP3.2		weight of link
9	C5	[-]	0-1	pipe	WP3.2		insufficent capacity
10	C6	[-]	[yes/no]	pipe	WP3.2		velocity
11	C8	[-]	[S/C]	pipe	WP3.2		sewer typology
12	C9	[-]	0-1	pipe	WP3.2		infiltration weight
13	C10	[-]	high, moderate, low	pipe/catchment	WP3.3	GAT	exfiltration
14	C11	yes/no absolute value, %		catchment	WP3.3	CAT	overflow total load
15	C12	yes/no absolute value, %		catchment	WP3.3		overflow frequency / spills
16	C13	yes/no absolute value, %		catchment	WP3.3		overflow volume
17	C14	yes/no absolute value, %		catchment	WP3.3		overflow duration

***) **) See Tab. 2.2.**

HE Process Results (HE_Process_name_XX.csv)

Output data included within HE_Process_name_XX.csv file are shown in table bellow.

HE Process output file:

Name of criterion	Head of column in Hellmud output file (*.csv)	Quantitative / qualitative / Both possible	Type of data (Numeric or alphanumeric)	Unit (if Quantitative)	Description
	LinkID	qualitative	alphanumeric	[-]	link ID
C1	FillingLevel	quantitative	alphanumeric	[-]	filling level
C2A	FrequencyFillingLevelA	quantitative	numeric	[$year^{-1}$]	frequency up to ingress into A *)
C2B	FrequencyFillingLevelB	quantitative	numeric	[$year^{-1}$]	frequency up to ingress into B *)
C2C	FrequencyFillingLevelC	quantitative	numeric	[$year^{-1}$]	frequency up to ingress into C *)
C3B	ProbabilityB	quantitative	numeric	[-]	probability P(B) **)
C3C	ProbabilityC	quantitative	numeric	[-]	probability P(C) **)
C3D	ProbabilityD	quantitative	numeric	[-]	probability P(D) **)
C4	WeightLink	quantitative	numeric	[-]	weight of link Q_{cap} / max of Q_{cap}
C5	InsufficentCapacity	quantitative	numeric	[-]	insufficent capacity Q_{max}/Q_{cap}
C6	Velocity	quantitative	alphanumeric	[-]	velocity *(yes / no)*
C8	SewerTypology	qualitative	alphanumeric	[-]	sewer typology *C/S - Combined / Separate*
C9	InfiltrationWeight	quantitative	numeric	[-]	infiltration weight q_{inf} * Length / Max(q_{inf} * Length)

HE Final Results (HE_Final_name_XX.csv)

Output data included within HE_Final_name_XX.csv file are shown in table bellow.

HE Final Results - list of links:

	Quantitative / qualitative / Both possible	Type of data (Numeric or alphanumeric)	Unit (if Quantitative)	Description
Link ID	qualitative	alphanumeric	[-]	link ID
Hydraulic	quantitative	numeric	[-]	Hydraulic - Solution of hydraulic deficiency for link, range <0,1> 0 ... reability 1 ... unreability
Velocity	quantitative	numeric	[-]	Velocity - Solution of velocity deficiency for link, range <0,1> 0 ... reability 1 ... unreability
Infiltration	quantitative	numeric	[-]	Infiltration - Solution of infiltration deficiency for link, range <0,1> 0 ... reability 1 ... unreability
Exfiltration	quantitative	numeric	[-]	Exfiltration - Solution of exfiltration deficiency for link, range <0,1> 0 ... reability 1 ... unreability

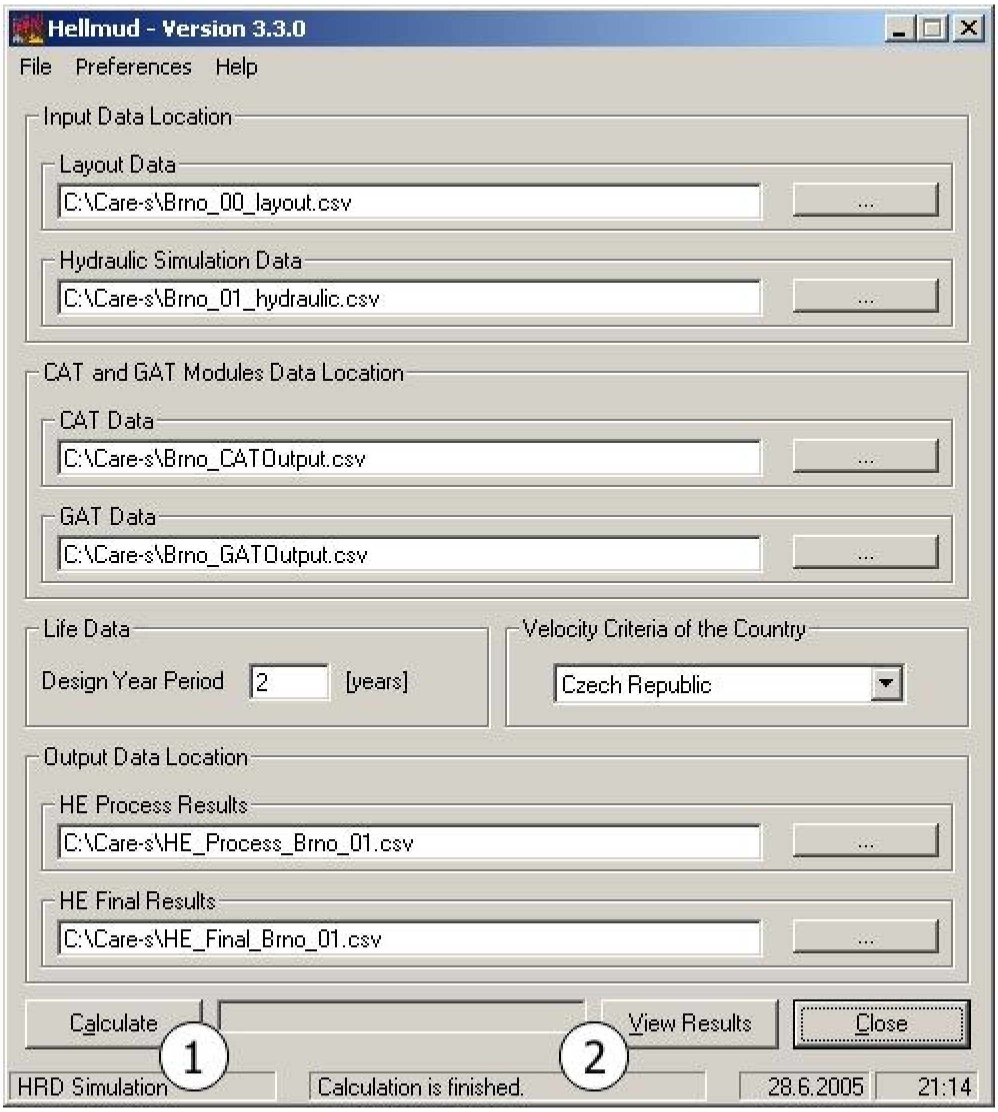
HE Final Results - CSOs Impacts:

	Quantitative / qualitative / Both possible	Type of data (Numeric or alphanumeric)	Unit (if Quantitative)	Description
Link ID	qualitative	alphanumeric	[-]	link ID
Hazard	qualitative	alphanumeric	[-]	the level of the risk *(REL, LOW, MED, HIGH, UNREL)*
Range	quantitative	numeric	[-]	range <0,1> 0 ... reability 1 ... unreability

View Results

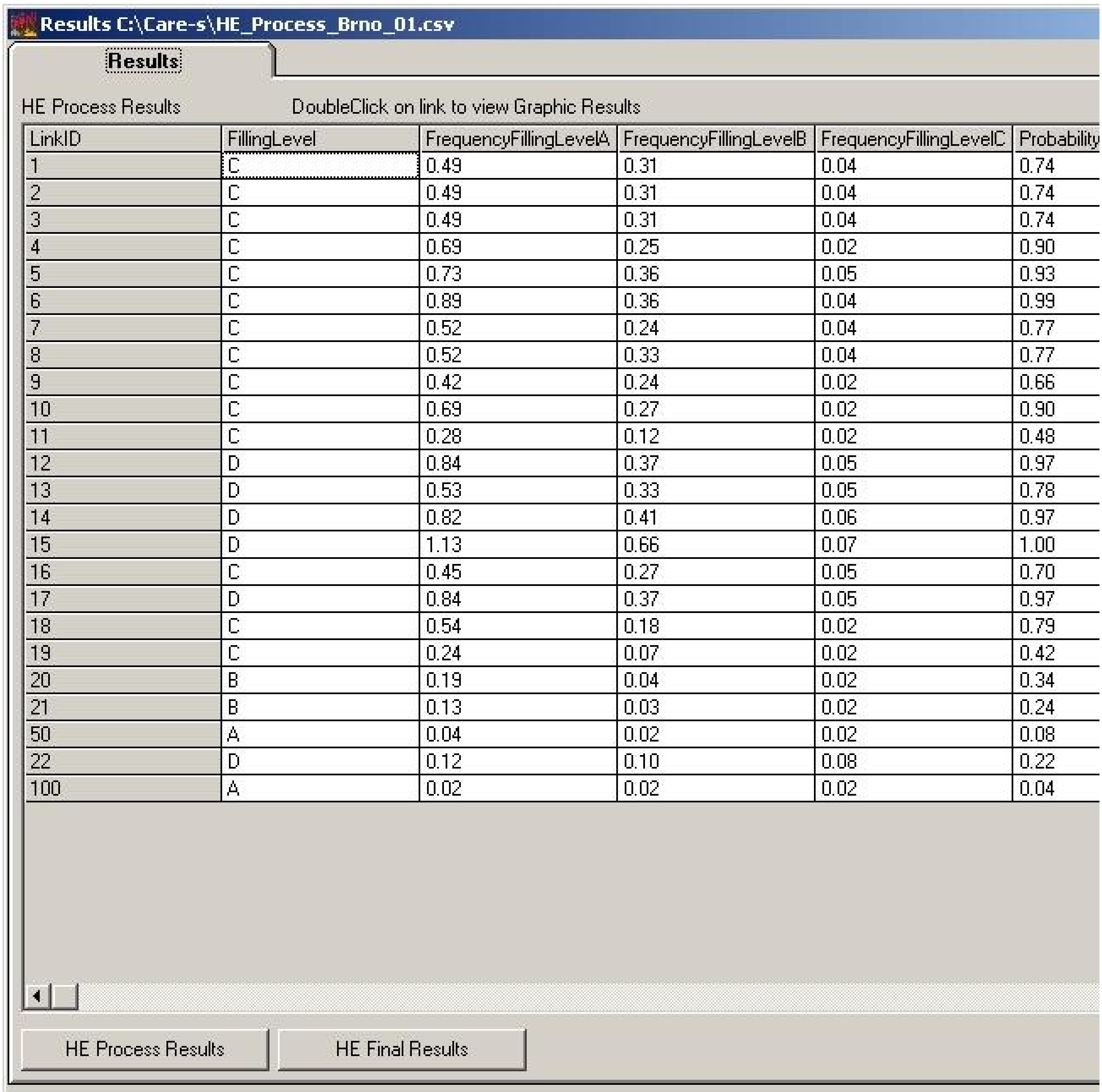
1. Click on "Calculate" button to calculate all criteria and save the results to output files.

2. Click on "View Results" button to view HE Process Results and HE Final Results.



Criteria WP3 Results

By double clicking on table of links you will see Graphic Results. You will see HE Final Results after click on HE Final Results button.



LinkID	FillingLevel	FrequencyFillingLevelA	FrequencyFillingLevelB	FrequencyFillingLevelC	Probability
1	C	0.49	0.31	0.04	0.74
2	C	0.49	0.31	0.04	0.74
3	C	0.49	0.31	0.04	0.74
4	C	0.69	0.25	0.02	0.90
5	C	0.73	0.36	0.05	0.93
6	C	0.89	0.36	0.04	0.99
7	C	0.52	0.24	0.04	0.77
8	C	0.52	0.33	0.04	0.77
9	C	0.42	0.24	0.02	0.66
10	C	0.69	0.27	0.02	0.90
11	C	0.28	0.12	0.02	0.48
12	D	0.84	0.37	0.05	0.97
13	D	0.53	0.33	0.05	0.78
14	D	0.82	0.41	0.06	0.97
15	D	1.13	0.66	0.07	1.00
16	C	0.45	0.27	0.05	0.70
17	D	0.84	0.37	0.05	0.97
18	C	0.54	0.18	0.02	0.79
19	C	0.24	0.07	0.02	0.42
20	B	0.19	0.04	0.02	0.34
21	B	0.13	0.03	0.02	0.24
50	A	0.04	0.02	0.02	0.08
22	D	0.12	0.10	0.08	0.22
100	A	0.02	0.02	0.02	0.04

Results C:\Care-s\HE_Process_Brno_01.csv

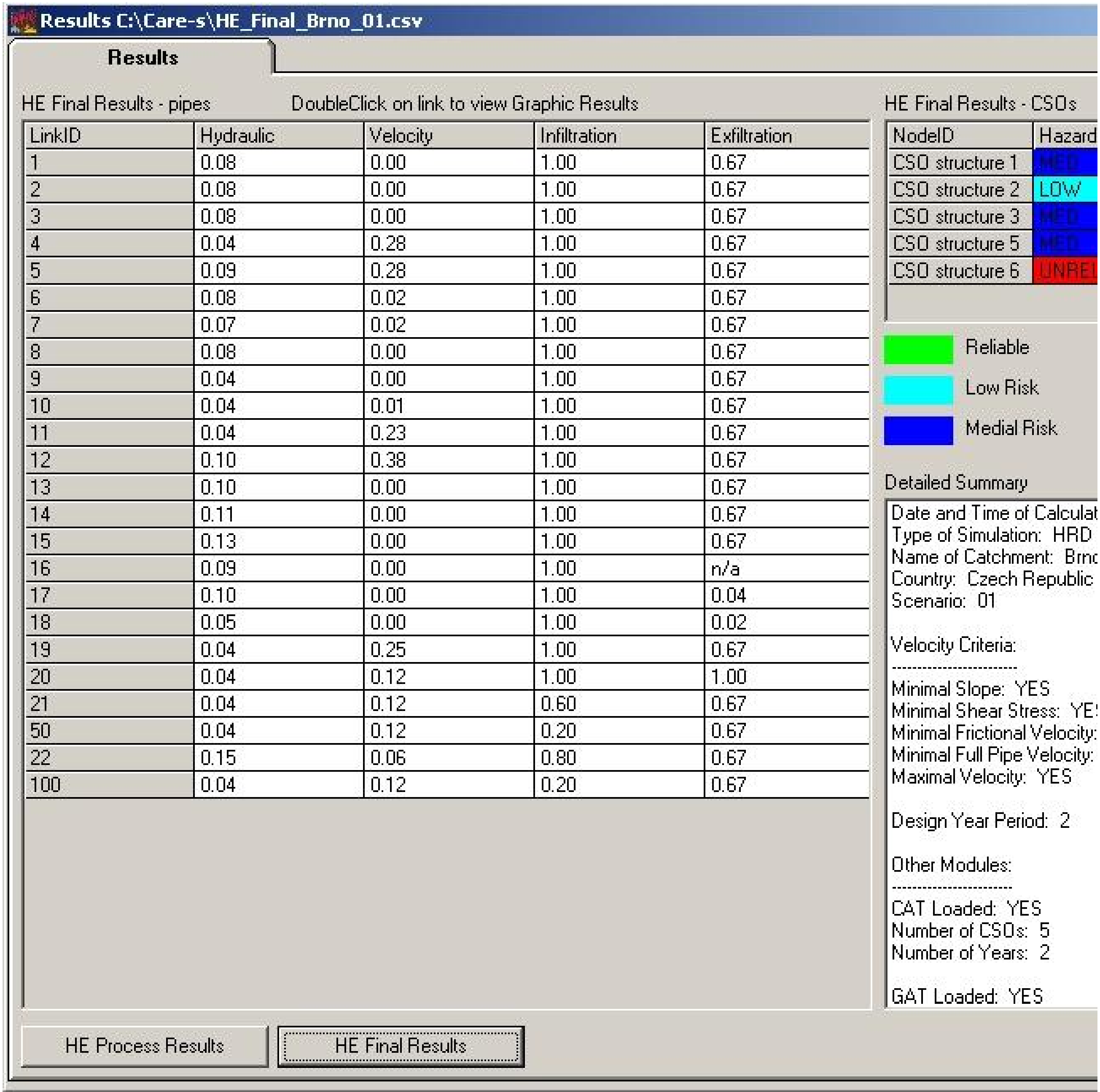
Results

HE Process Results DoubleClick on link to view Graphic Results

LinkID	ProbabilityD	WeightLink	InsufficientCapacity	Velocity	SewerTyp
1	0.08	0.04	0.73	no	C
2	0.08	0.04	0.73	no	C
3	0.08	0.04	0.73	no	C
4	0.04	0.23	1.00	yes	C
5	0.09	0.23	1.00	yes	C
6	0.08	0.27	1.00	yes	C
7	0.07	0.27	0.93	yes	C
8	0.08	0.04	0.71	no	C
9	0.04	0.04	0.69	no	C
10	0.04	0.07	1.00	yes	C
11	0.04	0.11	0.71	yes	C
12	0.10	0.43	1.00	yes	C
13	0.10	0.04	0.79	no	C
14	0.11	0.12	1.00	no	C
15	0.13	0.04	1.00	no	C
16	0.09	0.07	0.70	no	C
17	0.10	0.21	1.00	no	C
18	0.05	0.51	1.00	no	C
19	0.04	1.00	0.81	yes	C
20	0.04	0.54	0.80	yes	C
21	0.04	0.54	0.74	yes	C
50	0.04	0.54	0.69	yes	C
22	0.15	0.17	0.00	yes	C
100	0.04	0.54	0.58	yes	C

HE Process Results HE Final Results

HE Final Results



Results C:\Care-s\HE_Final_Brno_01.csv

Results

HE Final Results - pipes   DoubleClick on link to view Graphic Results

LinkID	Hydraulic	Velocity	Infiltration	Exfiltration
1	0.08	0.00	1.00	0.67
2	0.08	0.00	1.00	0.67
3	0.08	0.00	1.00	0.67
4	0.04	0.28	1.00	0.67
5	0.09	0.28	1.00	0.67
6	0.08	0.02	1.00	0.67
7	0.07	0.02	1.00	0.67
8	0.08	0.00	1.00	0.67
9	0.04	0.00	1.00	0.67
10	0.04	0.01	1.00	0.67
11	0.04	0.23	1.00	0.67
12	0.10	0.38	1.00	0.67
13	0.10	0.00	1.00	0.67
14	0.11	0.00	1.00	0.67
15	0.13	0.00	1.00	0.67
16	0.09	0.00	1.00	n/a
17	0.10	0.00	1.00	0.04
18	0.05	0.00	1.00	0.02
19	0.04	0.25	1.00	0.67
20	0.04	0.12	1.00	1.00
21	0.04	0.12	0.60	0.67
50	0.04	0.12	0.20	0.67
22	0.15	0.06	0.80	0.67
100	0.04	0.12	0.20	0.67

HE Final Results - CSOs

NodeID	Hazard
CSO structure 1	MED
CSO structure 2	LOW
CSO structure 3	MED
CSO structure 5	MED
CSO structure 6	UNREL

Reliable
Low Risk
Medial Risk

Detailed Summary

Date and Time of Calculat
Type of Simulation: HRD
Name of Catchment: Brno
Country: Czech Republic
Scenario: 01

Velocity Criteria:

Minimal Slope: YES
Minimal Shear Stress: YE
Minimal Frictional Velocity:
Minimal Full Pipe Velocity:
Maximal Velocity: YES

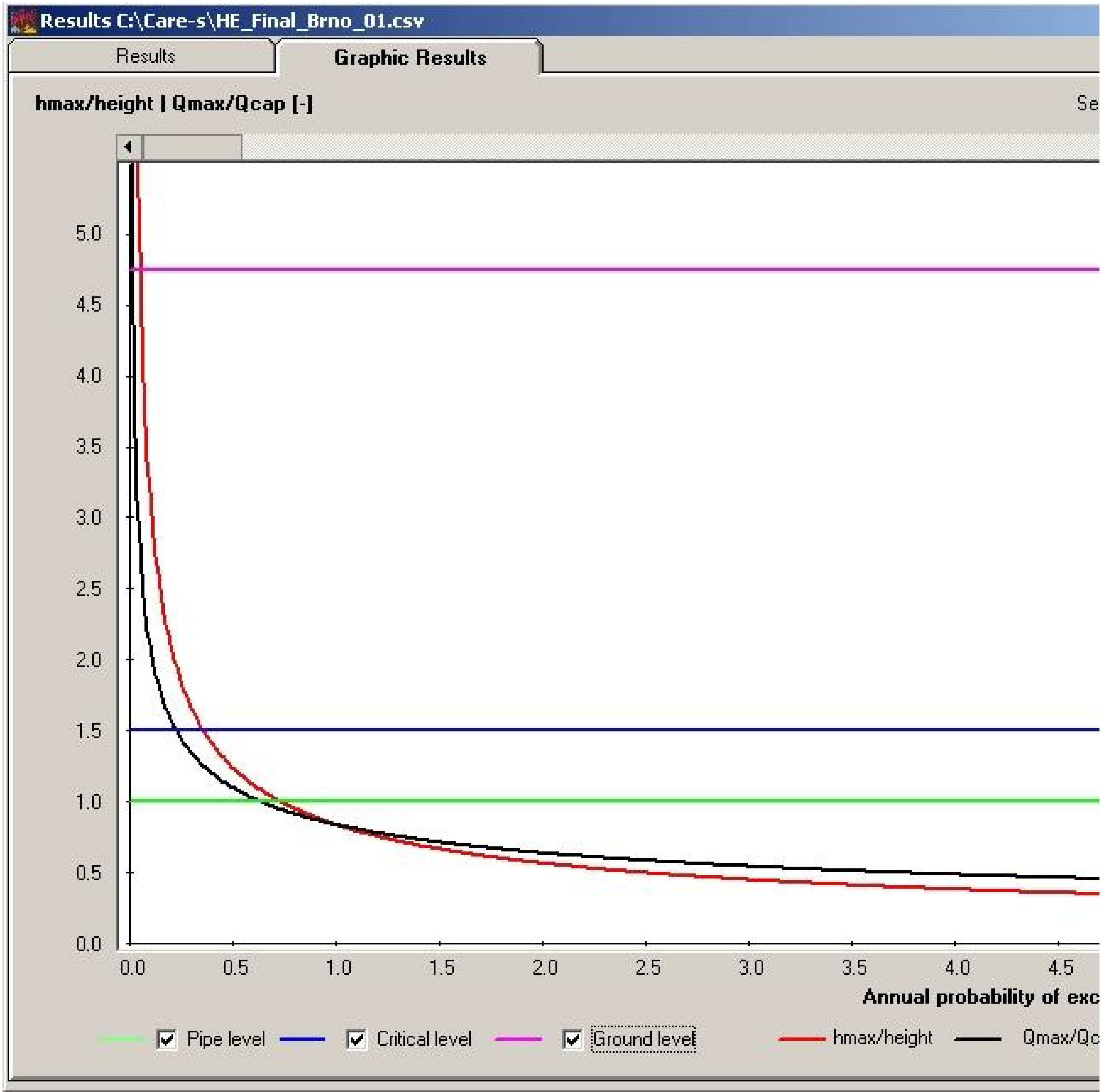
Design Year Period: 2

Other Modules:

CAT Loaded: YES
Number of CSOs: 5
Number of Years: 2

GAT Loaded: YES

HE Process Results   HE Final Results



Results C:\Care-s\HE_Final_Brno_01.csv
Results
Graphic Results
hmax/height | Qmax/Qcap [-]
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Annual probability of exc
Pipe level
Critical level
Ground level
hmax/height
Qmax/Qc

Drainage system:

Code	Name
S	Separate system
C	Combined system

[back]

Modeling software:

Code	Name
M	Mouse
I	InfoWorks
S	SWMM

[back]

Material:

Code	Name
sC11	Clay
sC12	Asbestos cement
sC13	Concrete
sC14	Polyvinyl
sC15	Polyethylene
sC16	Iron
sC17	Steel
sC18	Stone
sC19	Brick
sC20	Other known material
sC21	Unknown material

[back]

Shape:

Code	Name	Mouse	InfoWorks	SWMM
1	Circular	1	CIRC	1
2	Rectangular	3, 6	RECT	2
3	0 shape (oval)	4	OVAL	10
4	Egg shape	5	EGG	4
5	any other	any other	any other	any other

[back]

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WP3, Task 3.4, Deliverable 10

http://care-s.unife.it/