



Assessing Infiltration and Exfiltration on the Performance of Urban Sewer Systems

Contract number : EVK1-CT-2000-00072 APUSS
Project homepage : <http://www.insa-lyon.fr/Laboratoires/URGC-HU/apuss>

DELIVERABLE 6

Software support and development

S. Vanecek, T. Metelka, K. Pryn
DHI Hydroinform

February 2005



Czech Technical University in Prague
Faculty of Civil Engineering



Table of contents

1	Introduction	3
2	New features in AQUABASE developed for APUSS	4
2.1	Development of interface for input variables	4
2.2	Implementation of ground water depth computation	5
2.3	Implementation of DWF water depth computation	6
2.4	Elaboration of a communication centre for separate tools	7
2.5	Implementation of infiltration and exfiltration models	7
2.6	Calibration of infiltration and exfiltration models	10
2.7	Performance indicators link	10
2.8	Uncertainty analysis of obtained results	11
3	Conclusions	12

1 Introduction

The development of computerised data based management tool will provide additional value through the provision of relevant data directory and visual display menus valuable to end users. The development of the conceptual model and the integration approach result in software development. The software allows the estimation of the in- and exfiltration of sewers and integration over the catchment scale.

This database software holds all necessary data of a particular catchment and it is able to apply main APUSS project results to sewer system described by mentioned data as well.

It was decided to make use of existing software tool AQUABASE with inner structure corresponding to all demands on sewer system data description and with possibility of additional development in order to implement agreed new features to program environment.

The AQUABASE data structure has been extended to be able to consider new data inputs, variables and coefficients used for the calculation of the infiltration and exfiltration rates. System was modified to support the graphical presentation (using colour thematic maps) of the input and result data, connected to pipes and polygons (catchments).

The following main features have been implemented into AQUABASE:

- development of interface for input variables
- implementation of ground water depth computation
- implementation of DWF water level computation
- elaboration of a communication centre for separate tools (I/E data processing)
- implementation of infiltration and exfiltration models
- calibration of infiltration and exfiltration models.
- performance indicators calculation, analyses and links to other PI platforms
- uncertainty analysis of obtained results

The AQUABASE tool including User Manual is available to all project partners and end users involved in the project. Implementation of the tool including training sessions was carried out during the project elaboration, focusing main attention on the APUSS pilot catchments.

A short AQUABASE description including new APUSS features is a part of the Deliverable 8.2. - Workshop notes and WWW presentation.

2 New features in AQUABASE developed for APUSS

AQUABASE is a database 32 bit application for Windows. The data stored in the database can be presented through internal views or in the graphical form of horizontal plans and longitudinal profiles.

The following paragraphs of this chapter represents brief abstract of AQUABASE tools developed for the APUSS project. Detail information and manual are a part of Deliverable 8.2.

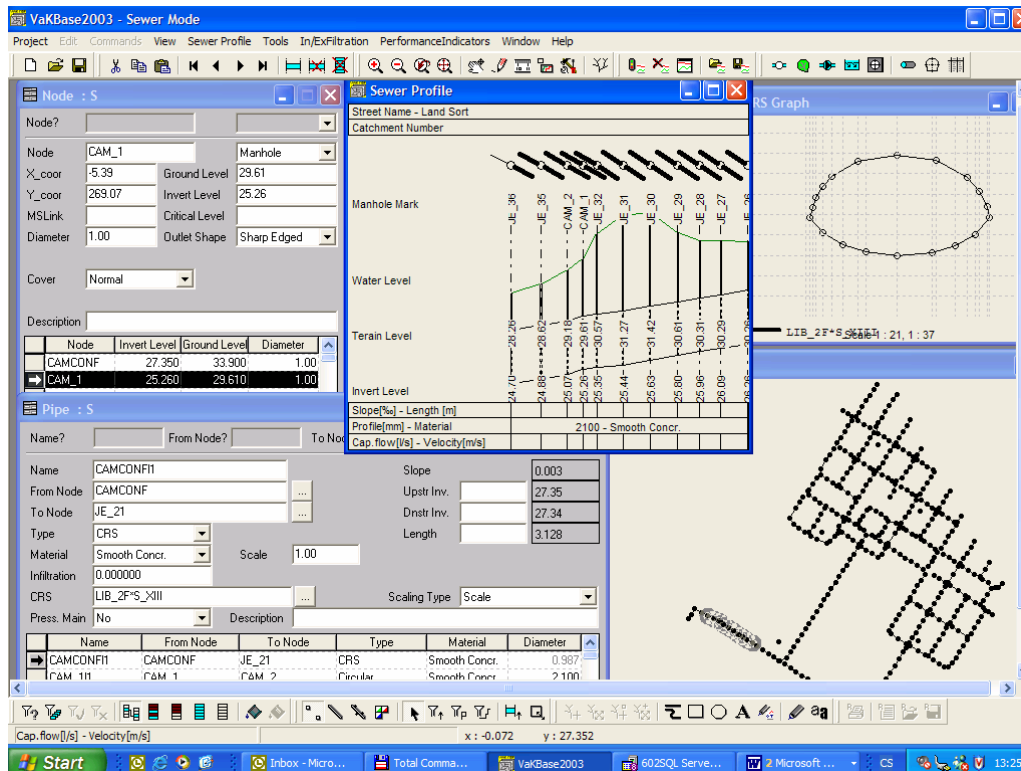


Figure 1 The AQUABASE environment

2.1 Development of interface for input variables

All new tools were implemented into AQUABASE environment with purpose of maximal usage functionality. The APUSS features are located under menu Tools, they are divided into two main subgroups:

- In/Ex filtration
- Performance Indicators

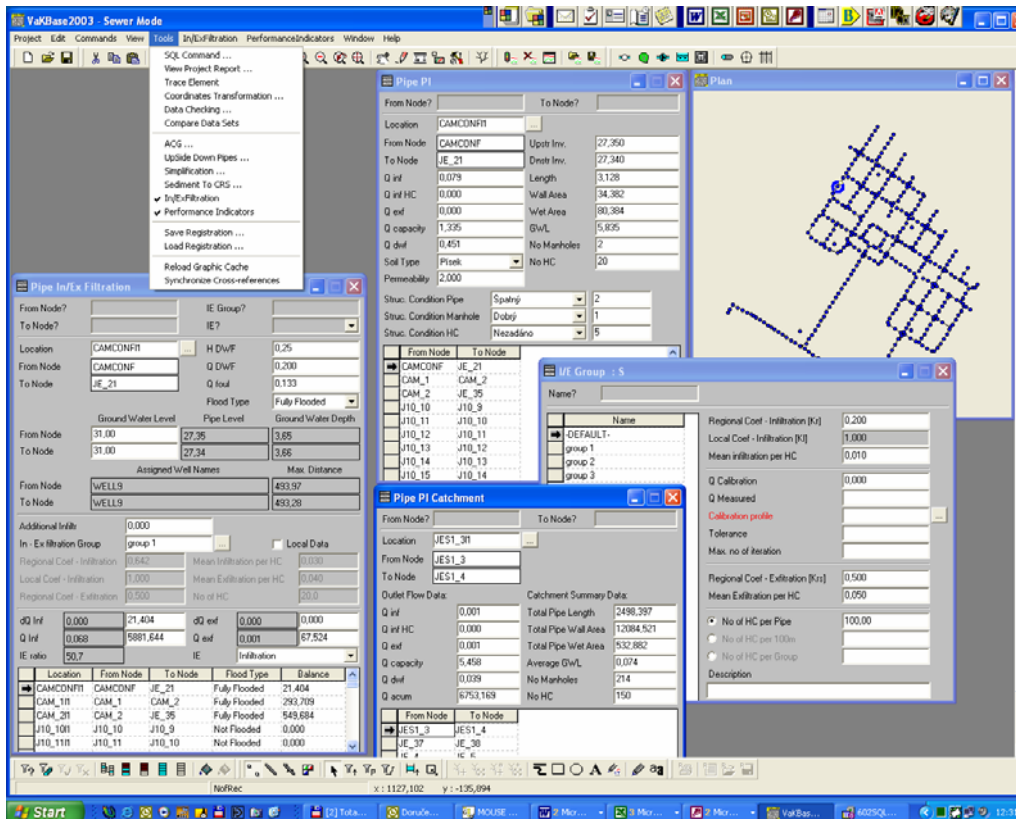


Figure 2 The general overview of the APUSS features in AQUABASE environment

2.2 Implementation of ground water depth computation

The ground water level is assigned to each pipe in the system. The ground water depth is consequently computed from pipe invert level and ground water level. The system understands a ground water level as a time static value. The value ground water level can be defined to each pipe manually entered /edited or computed based on a water level assigned to a wet well.

The wet well is identified as a node, to distinguish between wet well node and sewer manhole node a node type “fictive” can be assigned to wet well node. The corresponding ground water level in the wet well is stored in a table Node - Time Series. The value can be defined in two basic ways:

- Direct value
- Time series

In case of time series a specific date and time is required to load corresponding water level value from the time series.

To assign the water level to the pipe three methods can be used.

- Nearest well
- Average from set of wells in particular distance.
- Average from wells in particular distance with implementation of quadrant selection

2.3 Implementation of DWF water depth computation

Dry weather flow water level can be defined by direct entering/importing the value or computing using one of routines implemented.

The DWF water level definition is divided into two particular steps:

- Dry weather flow computation
- DWF Water level computation.

For Dry weather flow computation three methods can be used:

- Computation using standard catchment data
- Computation using distribution of global value to pipe –non weighted method
- Computation using distribution of global value to pipe – weighted method by pipe length

Note: Dry weather flow is understood as a sum of foul flow and in/Ex filtration. Because the amount of the In/Ex filtration is usually not known on the beginning of the process, the dry weather flow can be assumed as the foul flow.

Computation of DWF water level can be done by one of following methods:

- Computation based on flow data. Computation is based on steady flow using Manning formula.
- Computation from pipe profile height as % of pipe filling with, this computation has no relation to flow data.

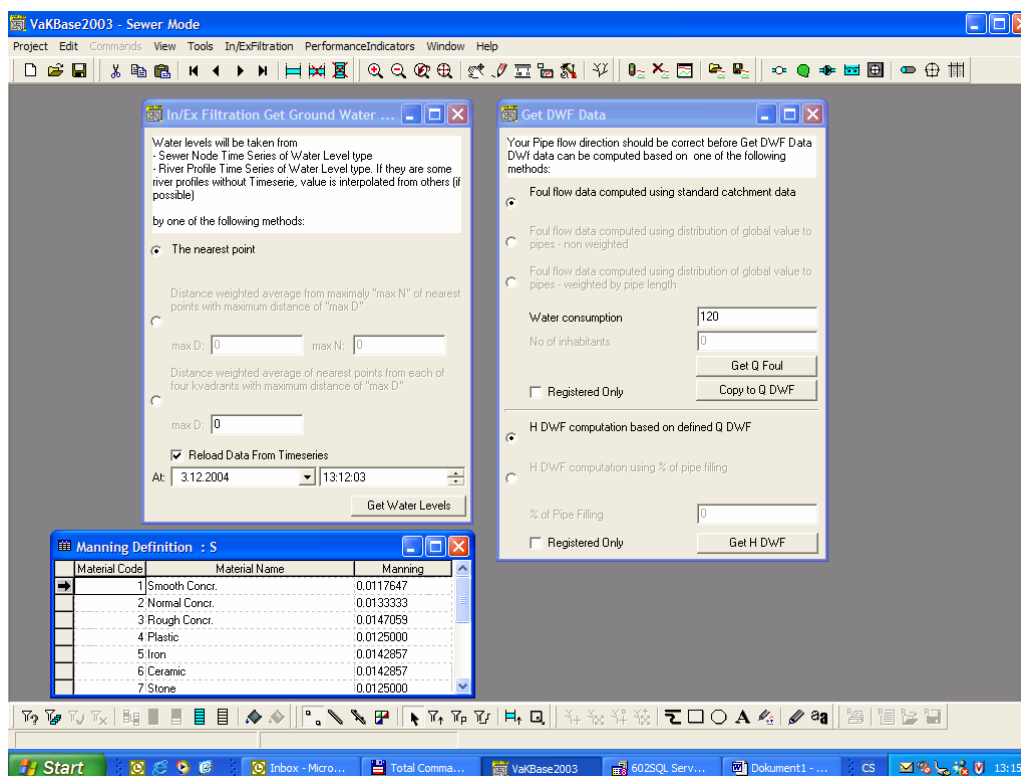


Figure 3 The interface for the Ground water level and Dry weather flow level computation

2.4 Elaboration of a communication centre for separate tools

The AQUABASE contains as a standard feature a communication centre. The Communication centre offers various data formats for data import and export. In parallel with the Communication centre Copy/Paste functionality can be used in each table. These communication features are used for data communication in frame of APUSS project.

Table 1 – The AquaBase – supported data formats

Communication format	Import	Export
Internal format data file	YES	YES
Column assigned text (PRN)	YES	YES
Comma separated value text (CSV)	YES	YES
Common PFS file	YES	YES
Structured text	YES	YES
Mouse 2001 (*.SWF) file	YES	YES
Mouse 2001 PFS (*.UND) file**	YES	YES
Mouse 2001 PFS (*.HGF) file**	YES	YES
Mouse 2001 PFS (*.MEX) file ***	YES	YES
Mouse4.0 CRS	YES	YES
Mapinfo *.mid, *.mid Files	YES	YES
ArcInfo *.shp, *.shx, *.dbf files	YES	YES
DBF format (memo z dBase IV)	NO	YES
DBF format (memo z FoxPro 2.0)	NO	YES
AutoCAD *.dxf	YES	YES
MIKE SWMM *.dat files	YES	YES
GOPHM Mapinfo - *.mid, mif	YES	YES
DMT Atlas - *.psp *.pbd files	NO	YES

2.5 Implementation of infiltration and exfiltration models

The AQUABASE calculates Infiltration and Exfiltration values based on formulas presented bellow. Formulas used are based on a relationship between ground water levels near by the pipe and dry water flow water level in he pipe. The criterion for the formula used is presented on the figure bellow. If the pipe is partly submerged appropriate formulas are used for each part of the pipe.

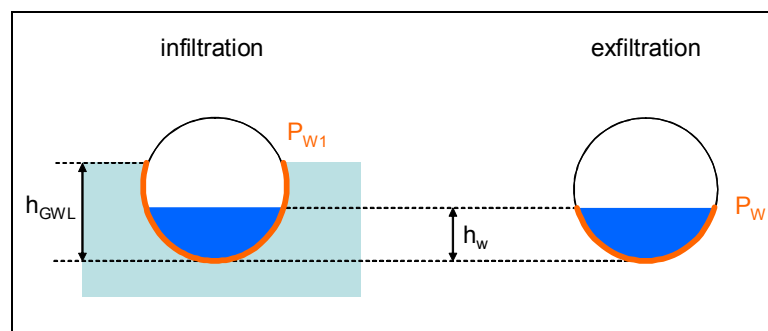


Figure 4. Conditions for conditions of Infiltration / Exfiltration

The input data (formula's coefficient) can be defined in two levels

- In/Ex filtration group data – assigned to set of pipes
- Local data – valid for particular pipe only

This concept gives to user high variability for parameters definition and it allows an efficient data management too.

To be able to check a data consistency and allocate potential error in computation a set of the existing system of data checks was extended for special routine related to APUSS features. Data checks are implemented in to menu Tool/Data checking.

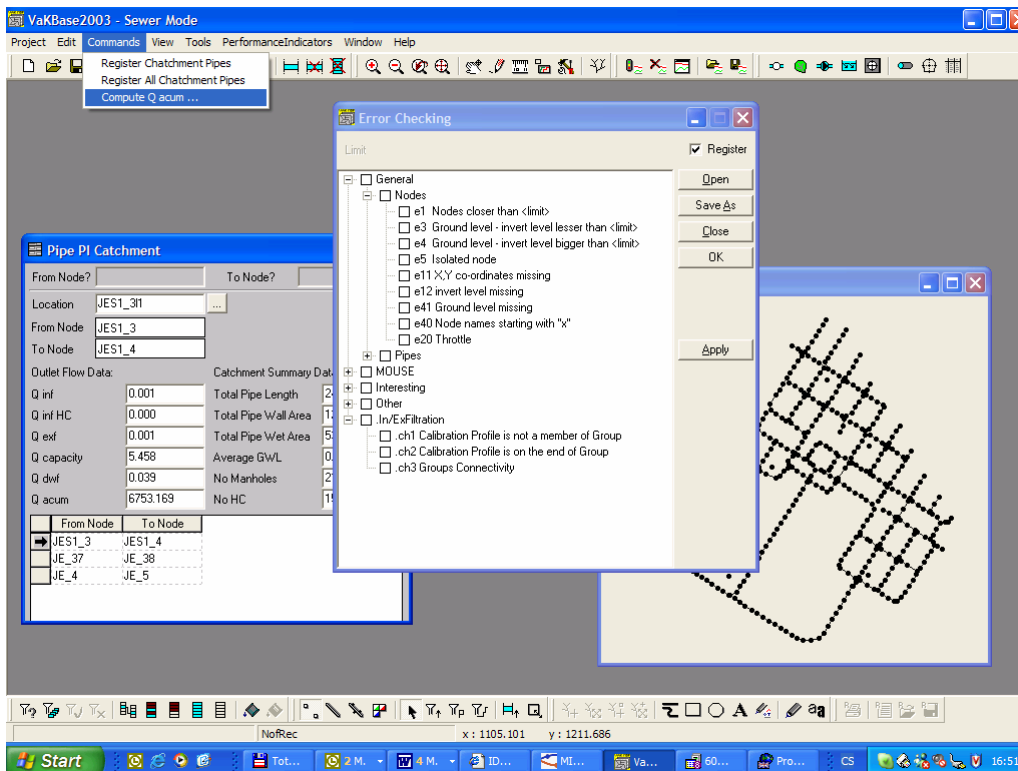


Figure 5 The In/Exfiltration data checking tools

The result of the calculation is assigned to each pipe. The result represent the In/Ex filtration value related to each single pipe and summary value of In/Ex filtration colleted by upstream pipes and transported by the pipe.

Table 2 – The infiltration formula

$$Q_{inf} = (h_{GWL} - h_w) \cdot P_{wl} \cdot L \cdot K_l \cdot K_r + q_{0inf} + \overline{q_{inf HC}} \cdot N_{HC} \quad \text{if } h_{GWL} > h_w \quad (1)$$

- where:
- Q_{inf} - infiltration flow (m³/d) for a given pipe
 - h_w - water level in the pipe (m)
 - h_{GWL} - groundwater level around the pipe (m)
 - P_{W1} - external wet perimeter (m²) (i.e. due to the surrounding groundwater)
 - L - length of the pipe (m)
 - K_l - local coefficient (-) (i.e. specific value for a given pipe – default

value is equal to 1)

K_r - regional coefficient (d-1) (i.e. value determined for a group of pipes according to field measurements for the sub-catchment located upstream the measurement point)

$q_{o\ inf}$ - infiltration flow from other infiltration sources (pumping, leakages from drinking water pipes...) in (m3/d). This contribution may possibly be described as a time series at hourly time step, with a sum of 24 hourly values per day.

$q_{inf\ HC}$ - mean infiltration flow for a single house connection (m3/d)

N_{HC} - number of house connections to the pipe

Table 3 – The exfiltration formula

$$Q_{exf} = h_w \cdot P_w \cdot L \cdot K'_{RS} + \overline{q_{exf\ HC}} \cdot N_{HC} \quad (2)$$

where:

Q_{exf} - exfiltration flow (m3/d) for a given pipe

h_w - water level in the pipe (m)

L - length of the pipe (m)

P_w - internal wet perimeter (m²)

K'_{RS} - coefficient at reach scale (d-1)

$q_{exf\ HC}$ - mean exfiltration flow for a single house connection (m3/d)

N_{HC} - number of house connections to the pipe.

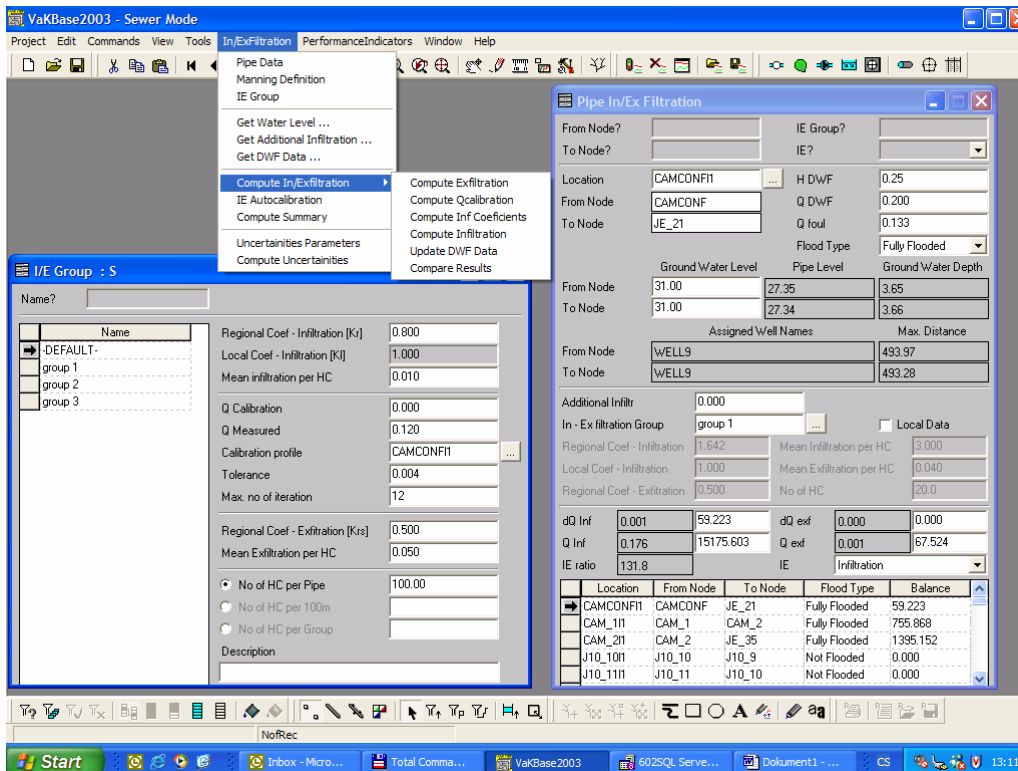


Figure 6 The In/Exfiltration interface

2.6 Calibration of infiltration and exfiltration models.

To derive an Infiltration formula coefficient K_r (regional infiltration coefficient) directly from measured data a special procedure was developed.

The procedure is based on topology of the system (location of measurement/calibration profile), measured flow value and dry weather flow value. The coefficients can be calibrated manually – running each step of the calibration procedure separately as well as automatic. And errors or potential uncertainties locations are announced during the procedure execution if relevant.

A calibration of Exfiltration coefficient K_{rs} (coefficient at reach scale) was not implemented. The coefficient K_{rs} has to be defined before calibration starts by the user.

2.7 Performance indicators link

A Performance indicator tool was defined and developed. The tool represents a system of collection, computation and management of relevant data. The data are defined in two scales

- Pipe data

- Catchment data

Data are collected based on detailed records in other AQUABASE tables or they are computed using topology, pipe geometry or In/Exfiltration routines.

The system of the implementation allows to use full spectrum of AQUABASE tools for data management and completion. When data are ready they are transferred into next Performance indicator tool using one of the data communication possibilities.

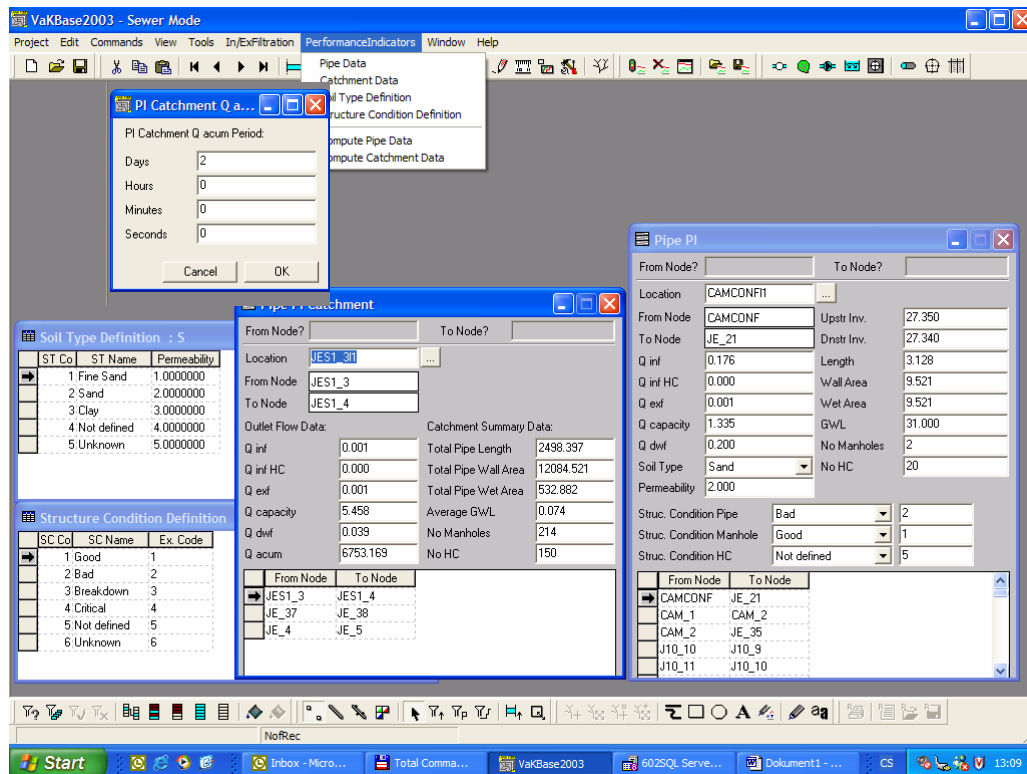


Figure 6 The Performance Indicators interface

2.8 Uncertainty analysis of obtained results

The routine implemented transfers the uncertainty of inputs to uncertainty of outputs. The uncertainty is computed as an uncertainty of the system above from defined pipe (e.g. outlet pipe).

Before start of uncertainty analyses the standard computations of Infiltration and Exfiltration have to be finished. Values reached by this computation are used as reference values in next process.

The uncertainty of the In/Exfiltration computation is based on sensitivity analyses of key parameters of Infiltration and Exfiltration formulas. Following six parameters were defined as input parameters for the uncertainty computation:

- Ground water level
- DWF water level
- Regional infiltration coefficient K_r
- Mean infiltration per a house connection
- Regional exfiltration coefficient K_{rs}
- Mean exfiltration per a house connection

The routine implemented generates new sets of input data for In/Exfiltration computation. Parameters in each data set vary within defined range. Number of data sets and particular value of each parameter depends on method selected.

Two basic methods for the data sets generation are implemented

- Range limits
- Monte Carlo

When data sets are ready the In/Exfiltration computation is executed for each data set. The defined pipe (called outlet pipe) the results are evaluated using statistic. Statistical analysis process following results: Minimum, Maximum, Average, Median, Standard Deviation, Most Sensitive Parameter and Uncertainty. The value of Uncertainty is computed from minimum and maximum values reached related to original value.

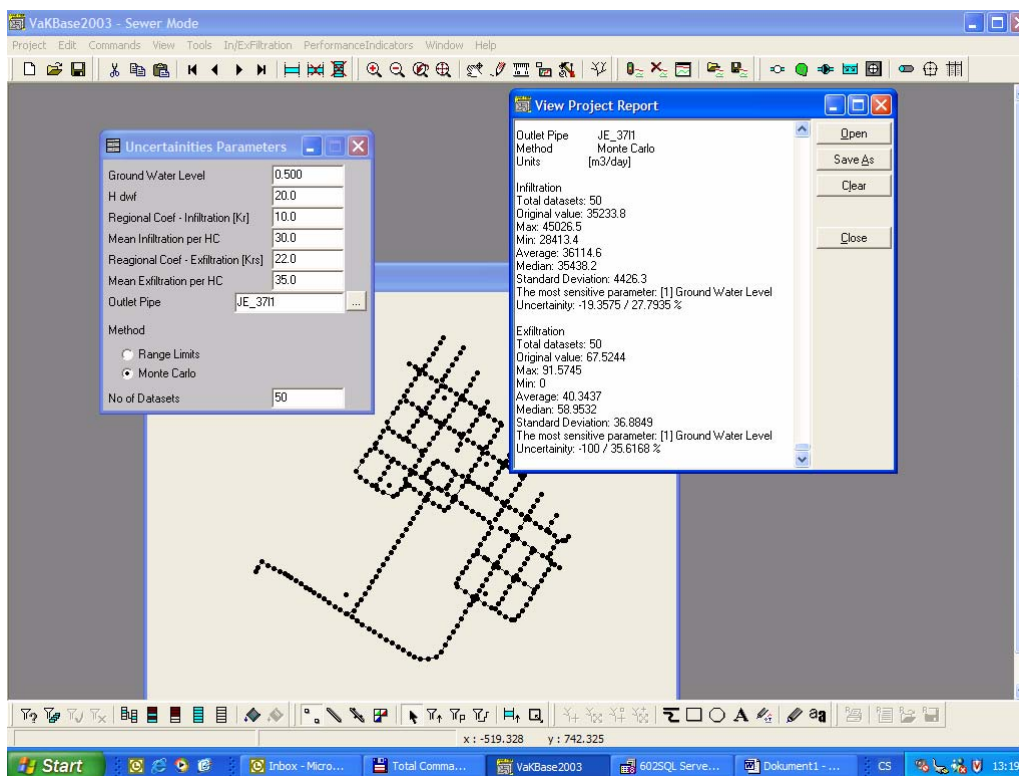


Figure 7 The uncertainty analyses interface

3 Conclusions

The AQUABASE program represents a very useful tool for the easy to use asset data management in Water utility companies. The AQUABASE functions in principle as an urban drainage database with GIS functionalities, user friendly interface and number of specialised functions related to the sewerage system data management. The tool is developed as a client-server architecture based on WinBase database engine. There are no particular hardware requirements related to the use of this application.

The AQUABASE has been developed in a course of several years and the current version profits from numerous practical comments and suggestions from the side of water utility specialists. The tool is very flexible and gives the user very profound insight into the asset (or model) data he/she is manipulating. Specialised queries can detect random as well as systematic errors in the data and propose the way of correcting these data. Very profound system of flagging and selections makes the user possible to work with subsets of the whole data set and to focus areas of his/her priority. Very fast graphics will be appreciated by standard GIS users.

The AQUABASE was chosen as a user friendly software tool, which is enabled to incorporate field data as well as develop internal tool and routines requested for the APUSS project. Main purpose of the WP6 – a development of a software prototype covering different features developed by the APUSS team – was fulfilled using this software platform.

The specialised block of functions related to the Infiltration-Exfiltration (IE) phenomena represents very interesting and useful extension of AQUABASE. It is expected that implemented functionality can be used not only for the research purposes but can be appreciated by urban drainage practice as well.

A couple of multi parametric formulas describing infiltration and exfiltration process in sewer pipe is implemented in the AQUABASE giving the user chance to calculate the rough estimates based on sensitivity analysis on distinct parameters. IE can be then calibrated based on new methods of measurements to reach better accuracy of the final estimate. In order to cope with the uncertainty of the interested phenomena an external modul of AQUABASE was designed and implemented based on the Monte Carlo method. This modul develops a large spactrum of potential results which are then statistically postprocessed and the uncertainty in the selected range of confidence interval defined. This functionality brings ad on value to the AQUABASE and the IE calculation and propagates also to the values of „performance indicators“ (PI), which are generated at the end of the calculation. PI can be then used by practitioners for the planning of reconstruction and investment in the urban drainage system.

The AQUABASE with the IE extension is developed as a clear product of the APUSS project. As such it can be freely used by both scientists as well as practitioners in urban drainage domain. It is expected that this tool can be found useful for Water Utility companies in terms of IE assessment, WWTP functions as well as sewer system reconstruction. The AQUABASE is delivered on installation CD.