



## Assessing Infiltration and Exfiltration on the Performance of Urban Sewer Systems

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### DELIVERABLE 8.2

## Training workshop notes and WWW presentation

Z. Pliska  
Hydroprojekt CZ

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Czech Technical University in Prague  
Faculty of Civil Engineering



Swiss Federal Institute  
for Environmental Science  
and Technology



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# 1 Preamble

## *Training notes*

According to APUSS project proposal and work description the methodologies, models and ideas developed in work packages “Development of a conceptual model for infiltration and ex-filtration” and “Model scale-up to the sewer system” should be transformed into a database supported software.

This database software should hold all necessary data of particular pilot catchment data holders and should be able to apply main APUSS project results to sewer system described by mentioned data as well. Therefore, it was decided to make use of existing software tool 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. AQUABASE complies with all mentioned requirements.

This document provides information on how to store user data in selected system and how to work with AQUABASE in order to make use of implemented APUSS features together with comfort of system environment. However, this document serves as a support for practical workshops and cannot substitute User Guide, user experience with system environment, real data and ideas released in AQUABASE.

## *WWW presentation*

Web presentation follows in structure training notes. Currently, the problem of moving the whole www presentation from computer to media like CD-ROM is solved.

## 2 Short AQUABASE description

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.

Following paragraphs of this chapter represents brief abstract of AQUABASE structure, environment and “how-to” description. Full software description and various modes of functioning description can be found in AQUABASE User Guide.

### 2.1 Interface

#### 2.1.1 Database

The database part of AQUABASE is based on integrated relational database system 602SQL (documentation is a standard part of AQUABASE installation).

The database processes a large number of data, offers standard and special services (for more details see AQUABASE User Guide). The database is open to the user, therefore, database views, outputs, communication formats and list boxes can be defined by user.

#### 2.1.2 Graphics

Graphics represents the content of database and the results of database operations and/or the analyses routines. All graphical forms (horizontal plan and/or longitudinal profile) provide possibility of graphical layers use. This feature allows user to enhance final graphical presentation by own inputs (description etc.).

#### 2.1.3 Tools

There are number of various useful tools under continual development. The tools are integrated to the AQUABASE to speed up the data processing. Useful tools are usually working on registered data. APUSS features are typical example of tool.

#### 2.1.4 External programs

The AQUABASE stores information about the files that have relation to the data set, e.g. text documents, time series, raster files etc. The programs registered in Windows can be very easily run from the database.

## 2.2 Data structure

The basic elements of data structure are **nodes** (sewer manholes) and **pipes** (sewer pipes). These basic elements have their own identification and basic information. All other information (including other objects) are connected to these basic elements.

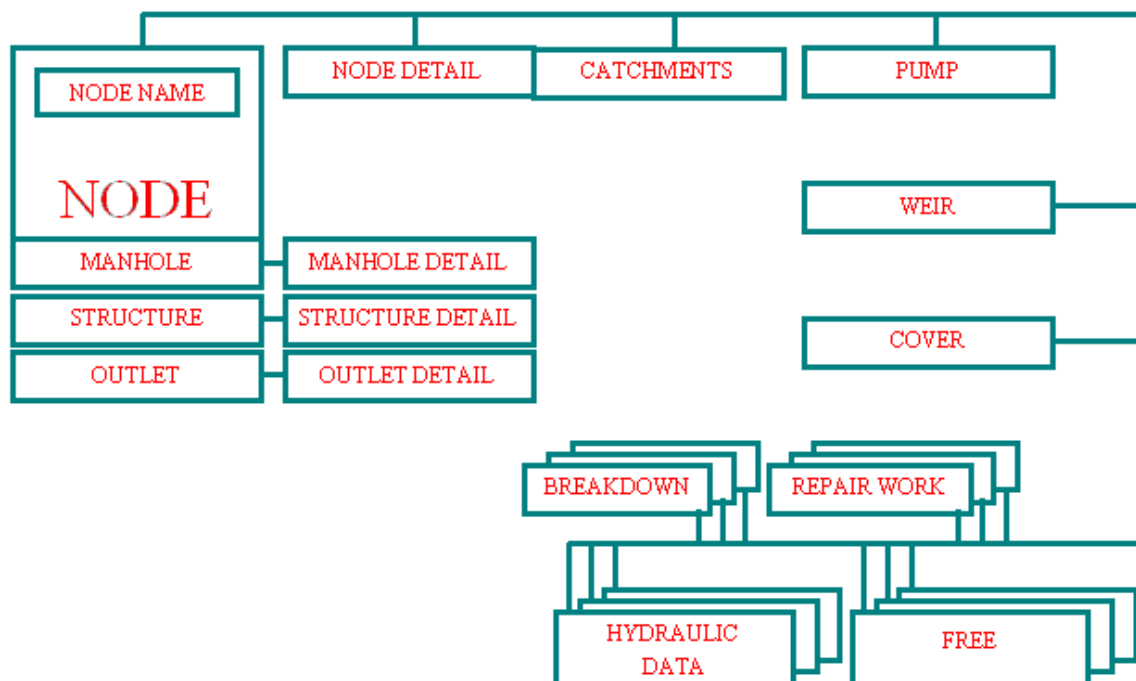


Fig. 2.1 - Structure of node connected information

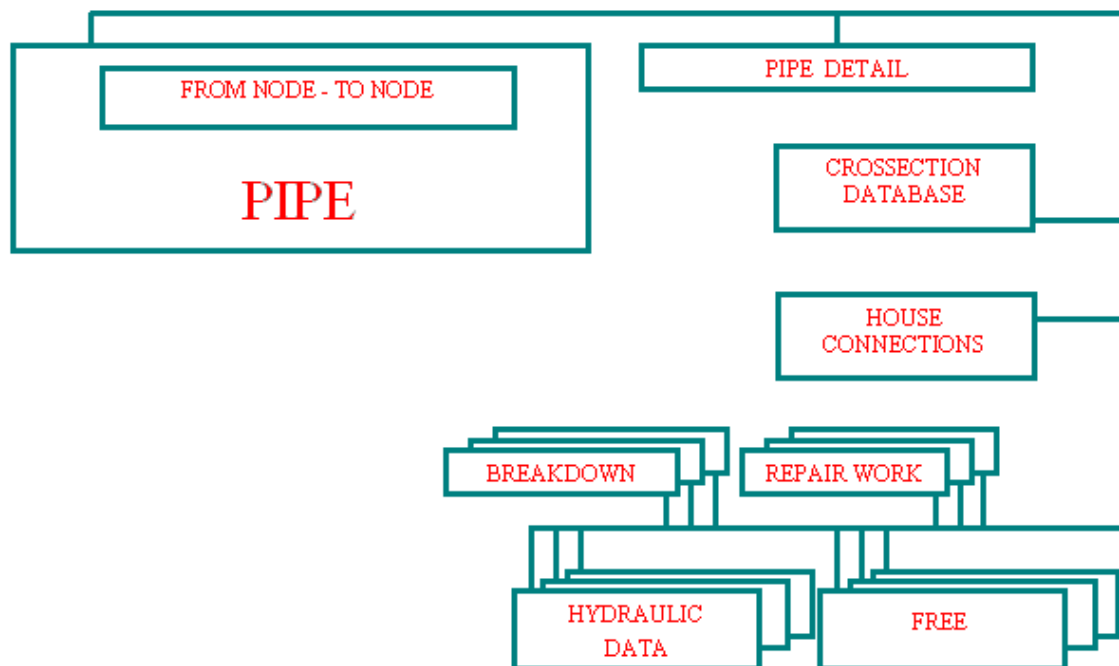


Fig. 2.2 - Structure of pipe connected information

### 2.2.1 Node

Node is a point in a space defined by name and XY coordinates. For sewer system there are other basic information connected (see figure Fig. 2.3) like ground and invert levels, type (manhole, outlet, basin, storage, fictive), diameter etc.

There can be “family” of connected information joined to each node (see figure Fig. 2.1):

- various information on geodetic survey accuracy (Node Detail)
- connected watershed description (Catchment)
- hydraulic object definition (Weir, Pump, Orifice)
- number information on survey and inspection (Inspection, Breakdown, Survey, Documents, Asset)
- monitoring data (Hydraulic Data, Time Series)
- etc.

	Node	Invert Level	Ground Level	Diameter
→	CH_SF2570	497.120	499.970	1.00
	CH_SF2571	497.540	501.840	1.00
	OK_D01	501.280	505.490	1.00
	SF742	510.050	512.030	1.20
	SF743	510.380	513.410	1.00

Fig. 2.3 - Basic information connected to node (sewer system)

### 2.2.2 Pipe

Pipe is a connection of two nodes. Each pipe is defined by upstream and downstream node names. For sewer system there are other basic information connected (see figure Fig. 2.4) like shape type, material, diameter, upstream and downstream invert etc.

There can be “family” of connected information joined to each pipe (see figure Fig. 2.2):

- various information on geodetic survey accuracy, sewer and sewerage type (Pipe Detail)
- shape and state definition (Cross-section, Sediment)
- number information on survey and inspection (Inspection, Breakdown, Documents, Asset)
- monitoring data (Hydraulic Data)
- etc.

The screenshot shows a software window titled "Pipe : S" with various input fields and a table. The input fields include:

- Name? (empty)
- From Node? (empty)
- To Node? (empty)
- Type? (dropdown menu)
- Name: 1
- From Node: SF775
- To Node: SF774
- Type: Circular
- Diameter: 0.6000
- Material: Other
- Infiltration: 0.000000
- Slope: 0.001
- Upstr Inv.: 513.30
- Dnstr Inv.: 513.28
- Length: 23.463
- Press. Main: No
- Description: (empty)

Below the input fields is a table with the following data:

	Name	From Node	To Node	Type	Material	Diameter
→	1	SF775	SF774	Circular	Other	0.600
	6	F_OK_D03	SF772	Circular	Ceramic	0.600
	7	SF772	VD03	Circular	Ceramic	0.600
	8	SF978	OK_D010	Circular	Plastic	0.600

Fig. 2.4 - Basic information connected to pipe (sewer system)

## 2.3 User environment

In AQUABASE data are represented in database views and in graphic window (either horizontal plan and/or longitudinal profile). Selecting particular line in database view picks up graphic presentation in graphic form and, simultaneously, selection of node or pipe in graphic window highlights particular record in database view.

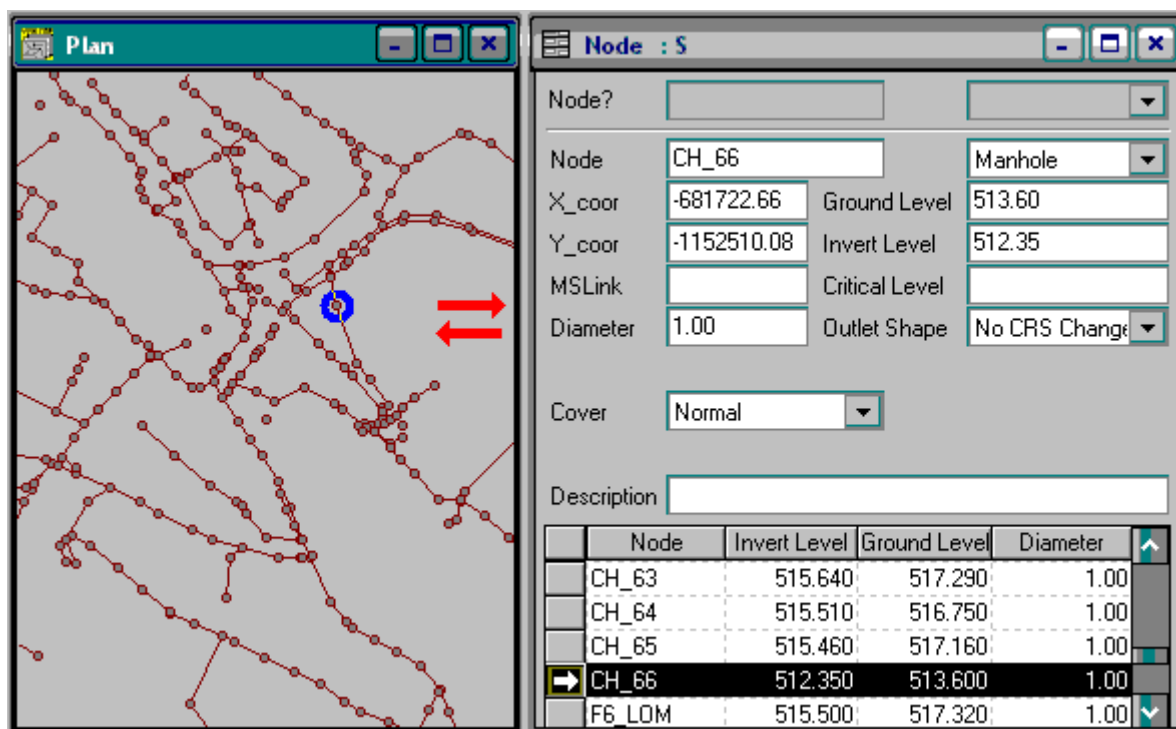


Fig. 2.5 - Data presentation - combination of graphic and database

Each database view consist of three parts:

- Fast query area is upper gray part of dialogue. Editing part of name or selecting object type sends query by example (QBE) into database and activates “data filter” according to selection.
- Data editing area is middle part of dialogue. It consists of text fields and combo boxes allowing to user to edit particular data value of selected object.
- Data listing area is lower part of dialogue. In general, it is a grid representing direct view into database, where each line corresponds to one database record.

Graphic data presentation can be carried out in two types of graphic forms:

- Horizontal plan window – except of presenting node symbol (circle) and pipe symbol (line) there is possibility of background map connection (BMP, DXF, SHP file formats) and use of graphic layers (edited by user).
- Longitudinal profile window – presents longitudinal view of selected part of sewer system. User can make use of graphic cosmetic layer to write remarks and draw its own polygons.



## 2.4 Data management

### 2.4.1 Data generation

Basic data describing sewer system topology can be generated by several ways:

- manual drawing on horizontal plan,
- manual editing database views,
- import through communication center,
- clipboard data pasting to database view.

Following description is given in very brief form. For detail information refer to AQUABASE User Guide.

#### *Manual drawing on horizontal plan*

Horizontal plan form has to be active. On “Mode” toolbar “Pipe mode” and “Insert” modes have to be switched on (see figure Fig. 2.6). Then mouse data button single click on horizontal form generates node. Any other single click generates node and pipe between consecutive nodes. Double click stops drawing process.

Values describing elevation information, object type etc., have to be edited manually in particular database view (see next paragraph).



Fig. 2.6 - Toolbar - working mode

#### *Manual editing database views*

It is very important to understand data structure implemented in AQUABASE (see chapter 2.2 Data structure). To insert one pipe means to insert two nodes first.

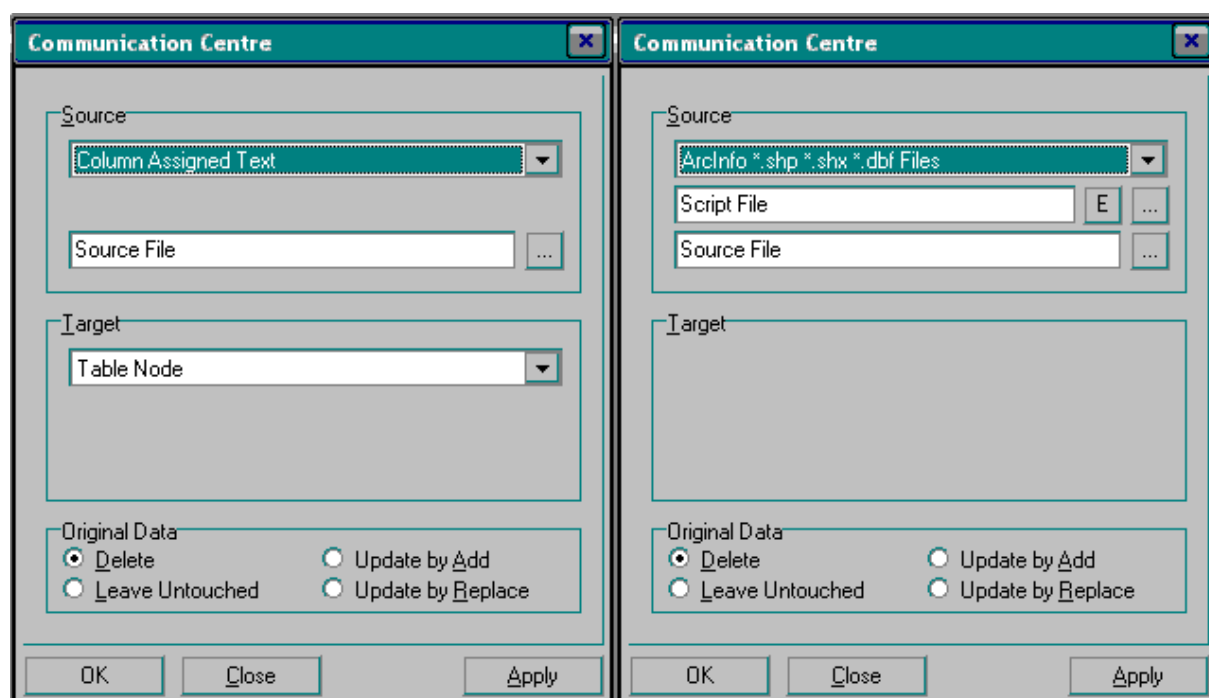
Selecting menu “View – Node – Node” opens and activates Node dialogue (database view to sNode table). To insert new node into database it is necessary to select menu “Edit - New Record” or to press “Insert” button on a keyboard. User values specifying name and XY coordinates are needed.

Selecting menu “View – Pipe – Pipe” opens and activates Pipe dialogue (database view to sPipe table). To insert new pipe into database it is necessary to select menu “Edit - New Record” or to press “Insert” button on a keyboard. Then user has to specify upstream node (From Node) and downstream node (To Node) in order to generate graphic presentation of new inserted pipe. User values specifying shape type, diameter and material are needed.

*Import through communication center*

Menu item “Project – Communication Center” activates Communication Center dialogue. The dialogue consist of three parts (see figure Fig. 2.7):

- Data source defines type and structure of input data. It can be either single file to fill one table in database (left dialogue on figure Fig. 2.7) or single file or group of files to fill the part/whole database structure (right dialogue on figure Fig. 2.7).
- Data target defines where to put input data. It can be either one or more database tables.
- Original data replacement part describes what to do with data already written in database.



**Fig. 2.7 - Communication center - data import**

Form mode detail information see AQUABASE User Guide.

*Clipboard data pasting to database view*

Once database view is activated, user can make use of functions run by menu “Edit – Copy All Records” and “Edit – Paste All Records”. These functions copy all records of particular table (represented by database view) into/from clipboard.

Very important point in pasting data process is the structure of particular table has to be followed. Moreover, header labeling each item of the block of data (horizontal tab divided data block in columns) has to be provided as the first line.

## 2.4.2 Data handling

### *Database*

In the database it is possible to list all the data in database tables, edit tables delete and insert tables, edit table items, execute group filling of items or make data selection and sorting on defined parameters.

Data selections are made through SQL query sent directly to database or through QBE query defined on particular database view. Selection is possible to register for further use. For reference to QBE and registration see AQUABASE User Guide.

### *Graphic form*

In horizontal plan form it is possible to insert and move elements, make interactive selection, make selection for longitudinal profile presentation. Horizontal plan form provides option for data presentation setting.

## 2.4.3 Data presentation

There are two possible ways to present data: tabular and with the use of thematic maps.

*Tabular data presentation* is based on application of sorting, QBE and similar approach in database view or in external tabular processor.

*Thematic map* consists in colored graphic presentation of selected variable of particular data type.

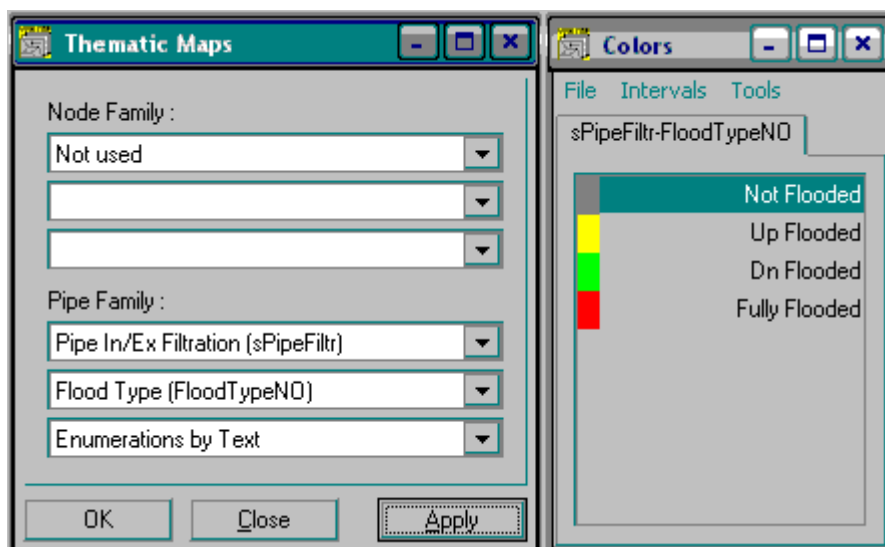


Fig. 2.8 - Dialogues for thematic maps definition

Dialogue Thematic map is activated by menu “View – Thematic Map” (see left part of figure Fig. 2.8). After selection of database table, variable and enumeration mode database generates classes of particular value ranges represented by unique color (see right part of figure Fig. 2.8). At the same time horizontal plan form presents thematic map of selected variable (see figure Fig. 2.9).

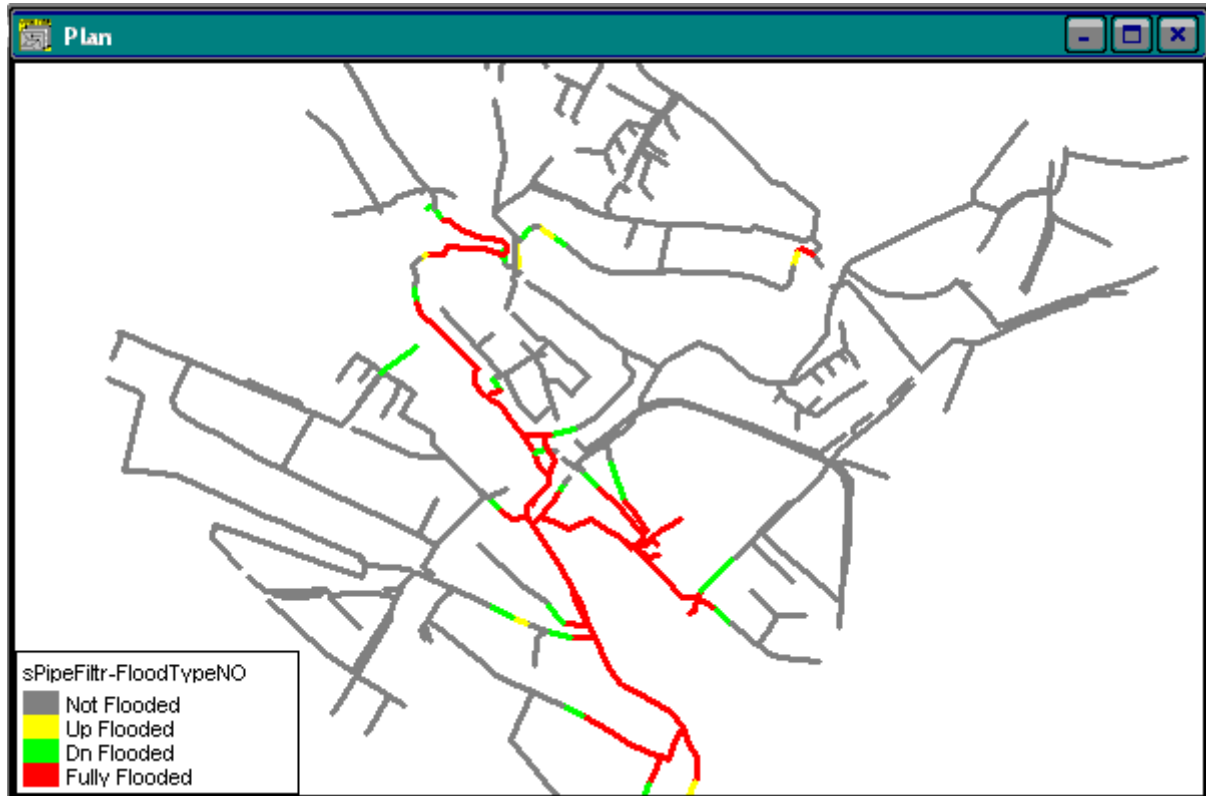


Fig. 2.9 - Thematic map presentation

### 3 APUSS features

To make use of implemented APUSS features it is necessary to follow given procedure:

- set data describing sewer system topology,
- set information on ground water level in drained area,
- compute ground water depth near each sewer pipe,
- summarize all sources of additional infiltration,
- set dry weather flow and dry weather water depth in sewer pipes,
- divide sewer system into In/Ex filtration groups,
- run In/Ex filtration computation.

APUSS features are implemented as a tool. Therefore, to run this tool it is necessary to click on menu item “Tools – In/Ex Filtration”. Then main menu “In/Ex Filtration” appears with all under mentioned features available (see figure Fig. 3.1).

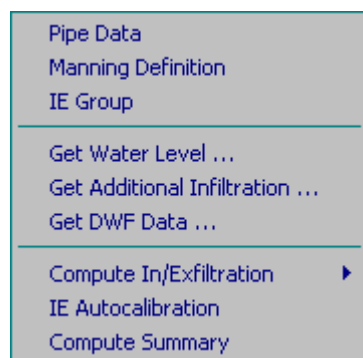


Fig. 3.1 - APUSS features menu - In/Ex Filtration

#### 3.1 Sewer system topology

Usually, sewer system topology data are stored in digital form in different data storages (GIS, simulation model databases etc.). Therefore, the most important way of data import into AQUABASE is import through communication center (see chapter 2.4.1 Data generation).

#### 3.2 Ground water level inputs

Fundamental idea of ground water level implementation is gaining of information on ground water depth around each pipe. Basically, system needs to know whether the pipe is flooded by the ground water and how much.

Ground water level is measured usually through wells (boreholes). Therefore, it was decided to describe ground water level in AQUABASE by system (or grid) of nodes bearing information on value of ground water level.

The idea of implementation is based on evaluation of one particular state, one point in time. However, user can provide information on long time monitoring in a form of time series as well.

### 3.2.1 Sequence of data inputs

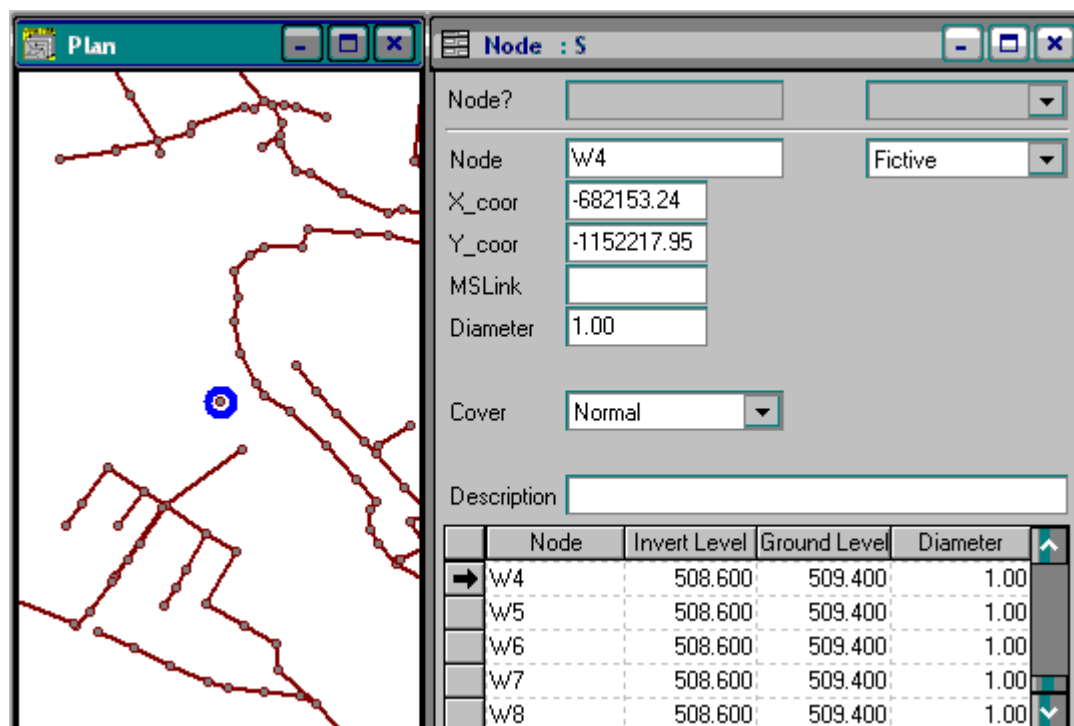
#### *Preconditions*

There are some preconditions of whole data input process:

- user have to know location of each well (XY coordinates) and
- at least one value of ground water level assigned to the well.

#### *First step*

The very first and the most important thing is generation of node (see chapter 2.4.1 Data generation). Then in node dialogue (menu “View – Node – Node”) it is necessary to give proper name and change node type to “Fictive” (see figure Fig. 3.2).



**Fig. 3.2 - Fictive node definition**

#### *Second step*

Menu “View – Node – Time Series” opens dialogue “Node Time Series” (see figure Fig. 3.3). New record is inserted via menu “Edit - New Record” or by pressing “Insert” button on a keyboard.

After new record is inserted, user has to specify:

- time series holder - node that the time series is connected to (“Location”),
- type of time series - water level in this case (“Type”),
- unit of time series – in meters (“Units”),

### Third step

The last step consists in ground water value definition. There are two possibilities according to amount of data user have:

- There is only one value. The value has to be edited into three textboxes marked: “Min. Value”, “Max. Value” and “Actual Value” (see figure Fig. 3.3).
- There is time series available. Then the time series is stored in text file (refer to AQUABASE User Guide). Clicking on “File Name” button allows user to locate mentioned file. Button “Show” presents the time series in Time Series Editor, button “Compute” runs function that evaluates the time series and fills necessary values in textboxes (see figure Fig. 3.3).

Location	Type	Name
W1	W. Level	
W2	W. Level	
W3	W. Level	
W4	W. Level	
W5	W. Level	

Fig. 3.3 - Water level assigning to fictive node

### 3.3 Ground water depth computation

To compute ground water depth along each single pipe it is necessary to synchronize system to the given date and time first. All time series of ground water level defined through fictive nodes (see chapter 3.2 Ground water level inputs) have to have common point in time. Then the computation means actually intersection finding of ground water surface and sewer system.

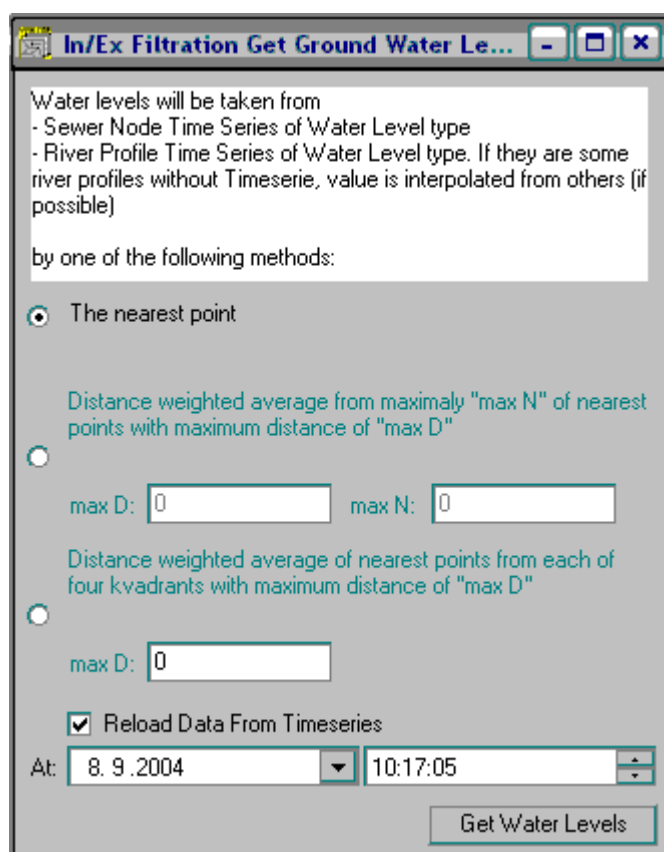


Fig. 3.4 - Dialogue for ground water level computation

The process of computation then follows (see figure Fig. 3.4):

- a) select type of interpolation,
- b) optional: select proper point in time for reloading of data from time series and
- c) run computation by pressing button “Get Water Levels”.

Once computation runs, sPipeFiltr table of dialogue “Pipe In/Ex Filtration” is filled by records joined with sPipe table (dialogue “Pipe”). Then it is possible to view and edit values assigned to each pipe in a scope of IE computation. Computed ground water depth together with assigned wells, levels and other information are written in sPipeFiltr table holding data IE data of pipe (dialogue “Pipe In/Ex Filtration”, see figure Fig. 3.10).



### *Interpolation methods*

There are three different interpolation methods of ground water level:

- Nearest well. Option “Nearest point” in dialogue “Get Water Level” on figure Fig. 3.4. From all wells the nearest one to each node (upstream and downstream) is selected and particular ground water level is assigned. Then ground water depth is difference between node invert level and assigned ground water level value.
- Average from set of wells in particular distance. Option “Distance weighted average from maximally maxN of nearest points with maximum distance of maxD” in dialogue “Get Water Level” on figure Fig. 3.4. User has to specify maximum distance of from node, which is acceptable for well selection into set and maximum number of wells in set. Then the value of assigned ground water level is computed as an average from set of ground water levels with the weight function implementation based on distance of particular well from node
$$\left( \frac{\sum GWL * distance}{\sum distance} \right)$$
- Average from wells in particular distance with implementation of quadrant selection. Option “Distance weighted average of nearest points from each of four quadrants with maximum distance of maxD” in dialogue “Get Water Level” on figure Fig. 3.4. User has to specify maximum distance from node, which is acceptable for well selection into set. Then the space around node is divided into four quadrants with a center in node. From each quadrant is selected one well, which meets criteria of distance. After this selection the value of assigned ground water level is computed the way described in previous paragraph (bullet).

### **3.4 Additional infiltration summary**

Before dry weather flow computation starts it is necessary to summarize all sources of additional inflow into sewer system. These sources can come as:

- local (point) inflow of waters into sewer system defined in particular node as a time series (see chapter 3.2 Ground water level inputs and/or AQUABASE User Guide),
- value drained by particular pipe defined in basic pipe data set (see figure Fig. 2.4) or
- extra waters defined in detail description of pipe (dialogue Pipe Detail, see AQUABASE User Guide).

Menu “In/Ex Filtration – Get Additional Infiltration” activates dialogue “In/Ex Filtration Get Additional Infiltration” (see figure Fig. 3.5). User has to select option where the summary is computed from. Pressing button “Get Data” runs summary, results are written into pipe table (variable “Additional Infiltration”) holding information on I/E filtration – database view is dialogue “Pipe In/Ex Filtration” (see figure Fig. 3.10).

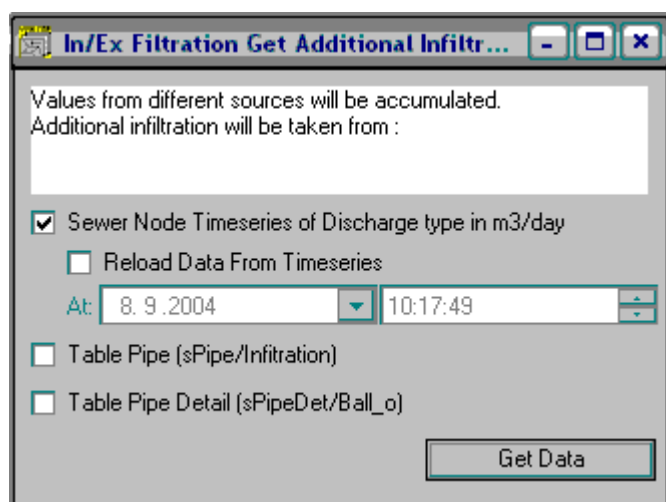


Fig. 3.5 - Dialog for summary of additional inflow into sewer system

### 3.5 Dry weather flow and water depth computation

The reason for dry weather flow computation is to get water depth in each single pipe under dry weather condition. This value is direct input into equations implemented in I/E computation (see chapter 3.7 IE computation).

In a scope of I/E computation the system tries to find particular value of I/E flow in each pipe (form more detail description refer to chapter 3.7 IE computation). The computation runs in circle sequence several times, therefore, correct (and precise) setting of dry weather flow and/or dry weather water depth immediately first time is almost impossible. Only calibration profiles (see chapter 3.6 IE groups definition) can show good precision.

As a result of given facts, the computation of dry weather flow and water depth in each pipe is divided into two parts:

- a) *Initial assessment.* This process is described in this chapter.
- b) *Correction during I/E computation.* This process is described in more detail in chapter 3.7 IE computation.

#### 3.5.1 Dry weather flow computation

For the initial assessment it is possible to suppose the dry weather flow is identical to foul flow. Therefore, discharge computation in this process (see figure Fig. 3.6) is focused more on foul flow computation.

There are more possibilities of dry weather flow value setting implemented. In general, there are two ways of dry weather flow setting:

- a) Direct value setting.

- b) Dry weather flow computation using distribution of global value to pipe. In a scope of computation there are more possibilities:
- flow computation using standard catchment data and
  - flow computation using distribution of global value to pipe.

To set and compute dry weather flow the dialogue “Get DWF data” has to be activated via menu item “In/Ex Filtration – Get DWF data” (see figure Fig. 3.6).

Your Pipe flow direction should be correct before Get DWF Data  
DWF data can be computed based on one of the following methods:

Foul flow data computed using standard catchment data

Foul flow data computed using distribution of global value to pipes - non weighted

Foul flow data computed using distribution of global value to pipes - weighted by pipe length

Water consumption

No of inhabitants

Registered Only

---

H DWF computation based on defined Q DWF

H DWF computation using % of pipe filling

% of Pipe Filling

Registered Only

Fig. 3.6 - Dialogue for setting and computing dry weather flow

### *Direct value setting*

Discharge value of dry weather flow is set using pipe dialog “Pipe In/Ex Filtration” (see figure Fig. 3.10) as a pipe attributes “Q DWF” and “Q FOUL”. To activate this dialogue use menu “In/Ex Filtration – Pipe data”.

### *Dry weather flow computation using standard catchment data.*

In case all necessary data describing spreading of inhabitants over drained area are defined in a form of connected catchments it is possible to make use of computation option “Foul flow data computed using standard catchment data” (see first option in upper dialogue part on figure Fig. 3.6).

User then has to specify value of water consumption valid for either the whole drained area or selected part of sewer system (see chapter 2.4.2 Data handling). Pressing button “Get Q Foul” computes foul flow for each single pipe and button “Copy to Q DWF” copies foul flow value into dry weather flow.

#### *Dry weather flow computation using distribution of global value to pipe.*

In case user does not have detail information on the level of catchment definition it is necessary to deal with more simple approach using option “Foul flow data computed using distribution of global value to pipe” either in “non weighted” or “weighted by pipe length” version (see second and third option in upper dialogue part on figure Fig. 3.6 and Appendix A).

User then has to specify value of water consumption and number of inhabitants valid for either the whole drained area or selected part of sewer system (see chapter 2.4.2 Data handling). Then pressing button “Get Q Foul” first run function for inhabitants redistribution to each single pipe and after that computation of foul flow starts.

Results are written into table holding I/E information on pipes (dialogue “Pipe In/Ex Filtration”, variable “Q foul” and “Q dwf”, see figure Fig. 3.10).

### 3.5.2 Dry weather water depth computation

Water depth value in single pipe can be either set directly or calculated from defined dry weather flow. Calculation from discharge follows equation for steady flow (see Appendix B).

#### *Direct value setting*

Water depth is set using pipe dialog “Pipe In/Ex Filtration” (see figure Fig. 3.10) as a pipe attributes “H DWF”. To activate this dialogue use menu “In/Ex Filtration – Pipe data”.

#### *Dry weather water depth based discharge*

On the dialogue “Get DWF data” (see figure Fig. 3.6) is necessary to select option “HDWF computation based on QDWF”. Then pressing button “Get H DWF” computes water depth in each single pipe according to value of dry weather flow given in sPipeFiltr table, dialogue “Pipe In/Ex Filtration”.

#### *Dry weather water depth based on percentage of pipe filling*

This way of setting of needed information for infiltration computation in single pipe completely omits computation of dry weather flow. User has to select option “HDWF computation using % of pipe filling” and enter demanded value of pipe filling. Then pressing button “Get H DWF” computes water depth in each single pipe according to pipe diameter (basic information in table sPipe, dialogue “Pipe”, figure Fig. 2.4)

### 3.6 IE groups definition

In order to control the whole process of I/E computation it is necessary to measure dry weather flow in several locations of sewer system. These locations divide sewer system into individual parts – I/E groups (see figure Fig. 3.7). The aim of I/E groups definition is to have possibility of infiltration and exfiltration computation and calibration against measured values in closed region (see chapter 3.7 IE computation).

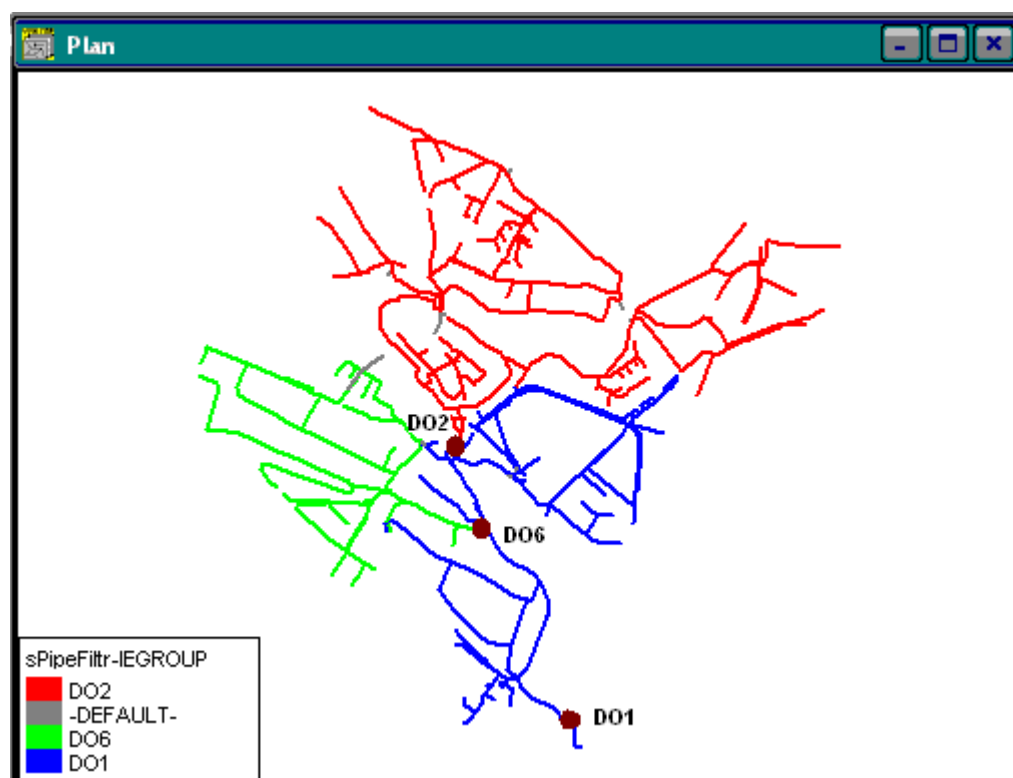






Fig. 3.7 - Definition of I/E groups in sewer system

To create I/E group it is necessary to:

- Insert new record (see chapter 2.4.1 Data generation) in table holding information on I/E groups (dialogue “I/E group”, menu item “In/Ex Filtration – I/E Group”, see figure Fig. 3.8). The most important items to edit are location of calibration profile (pipe, where measurement was carried out), value of measured discharge and number of house connections in the scope of I/E group drained area.
- Select and register part of sewer system (refer to AQUABASE User Guide) belonging to new inserted I/E group.
- Activate dialogue “Pipe In/Ex Filtration” and view only registered pipes (icon  on “Data Selection” toolbar).
- Activate function Global Changes Definition (icon  on “Data Selection” toolbar). This activates dialogue “Pipe In/Ex Filtration” in a form of editable pattern.
- On this dialogue edit (select) I/E group and press button “Apply Global Changes” (icon  on “Data Selection” toolbar).

- Deactivate selection of registered pipes by pressing button “Show All” (icon  on “Data Selection” toolbar).

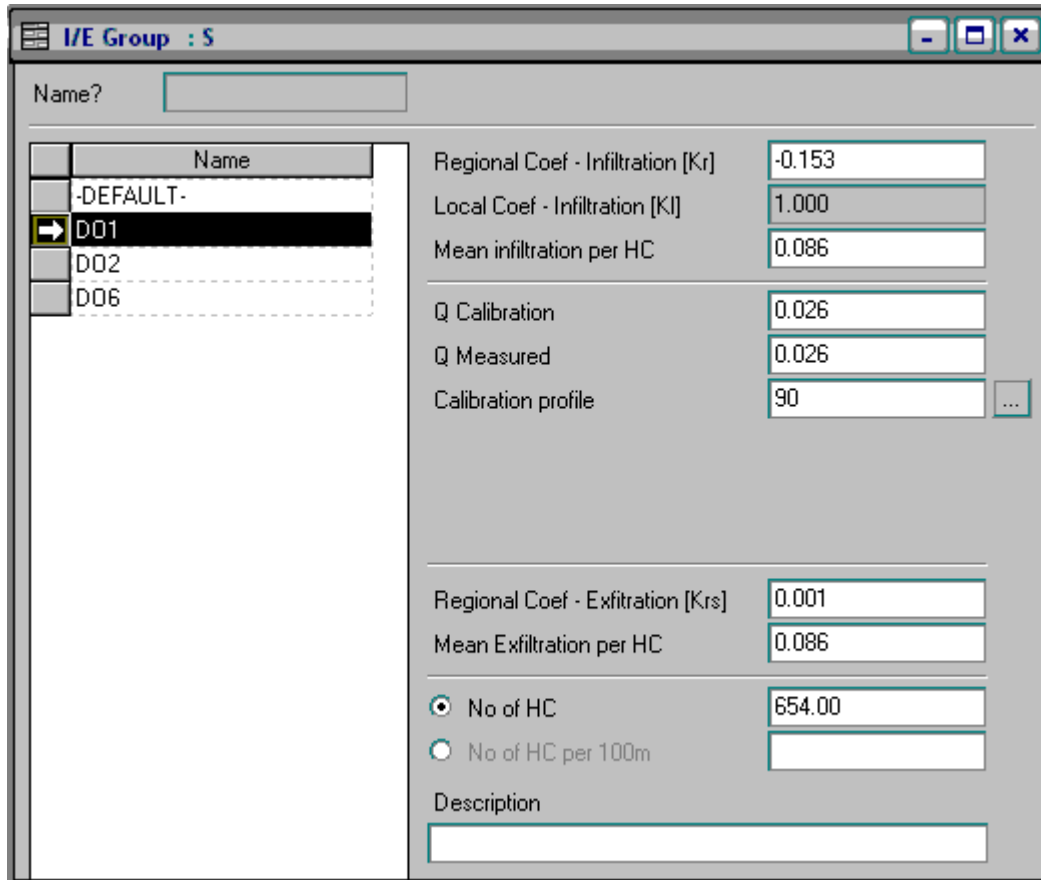


Fig. 3.8 - Dialogue for I/E group setting and definition

### 3.7 IE computation

Computation of infiltration and exfiltration is based on knowledge of ground water depth outside and dry weather water depth inside each single pipe (see figure Fig. 3.9).

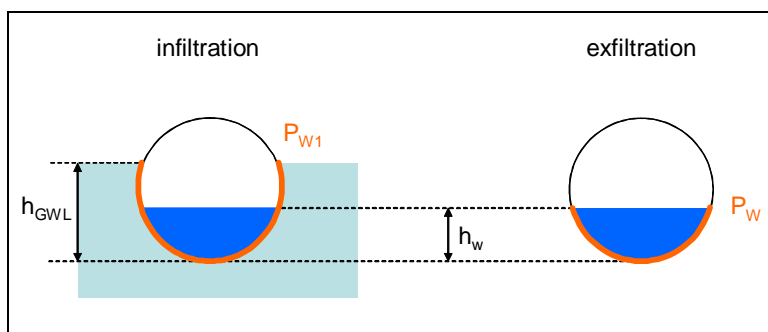


Fig. 3.9 - Water depth inside and outside pipe

There have been two conceptual models proposed, at daily scale: for infiltration at sub-catchment scale and for exfiltration at reach scale.

Location	From Node	To Node	Flood Type	Balance
58	SF743	SF742	Fully Flooded	-65.450
59	SF794	SF795	Dn Flooded	-0.001
60	SF795	SF792	Fully Flooded	-0.007
61	SF792	SF791	Fully Flooded	68.471

Fig. 3.10 - Pipe dialogue for In/Ex Filtration

### 3.7.1 Infiltration

Computation of infiltration is based on knowledge of water balance in particular part of sewer system. The balance is usually represented by time series of discharges measured during monitoring campaign. Approach implemented in AQUABASE is based on difference between ground water depth and dry weather depth in each single pipe. If ground water depth is higher then dry weather depth in particular pipe then infiltration is computed according to equation (1).

$$Q_{inf} = (h_{GWL} - h_w) \cdot P_{w1} \cdot L \cdot K_l \cdot K_r + q_{0inf} + \overline{q_{inf HC}} \cdot N_{HC} \quad \text{if } h_{GWL} > h_w \quad (1)$$

where:

- $Q_{inf}$  - infiltration flow (m<sup>3</sup>/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 (m<sup>2</sup>) (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)
- $q_{0inf}$  - infiltration flow from other infiltration sources (pumping, leakages from drinking water pipes...) in (m<sup>3</sup>/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 (m<sup>3</sup>/d)
- $N_{HC}$  - number of house connections to the pipe

Except for computed infiltration value ( $Q_{inf}$ ) there is regional coefficient ( $K_r$ ) as main unknown in equation (1). In a scope of computation this coefficient is calibrated for each I/E group against measured value (see “Q measured” in dialogue “I/E Group”, figure Fig. 3.8). The calibration process is founded on gradual approximation of sum of calculated infiltration and foul flow on one side and measured discharge on other side ( $Q_{measured} = Q_{foul} + Q_{inf}$ , valid for each pipe). Calibration process runs for each I/E group simultaneously so, results in one I/E group have effect to other one. Therefore, computation process has to be run in loop, usually repeating 3-5 computation leads to satisfactory results.

### 3.7.2 Exfiltration

If ground water depth is lower then dry weather depth in particular pipe then exfiltration is computed according to equation (2). Implemented procedure of exfiltration computation is based on exfiltration coefficient ( $K'_{RS}$ ) knowledge. This coefficient is a value determined for a group of pipes (I/E groups) according to field measurements for the reach between tracer injection and tracer measurement points.

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

where:

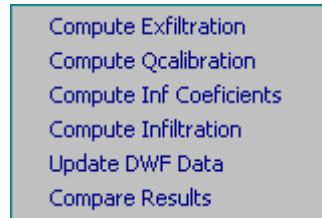
- $Q_{exf}$  - exfiltration flow (m<sup>3</sup>/d) for a given pipe
- $h_w$  - water level in the pipe (m)
- $L$  - length of the pipe (m)
- $P_w$  - internal wet perimeter (m<sup>2</sup>)
- $K'_{RS}$  - coefficient at reach scale (d-1)
- $q_{exf HC}$  - mean exfiltration flow for a single house connection (m<sup>3</sup>/d)
- $N_{HC}$  - number of house connections to the pipe.



### 3.7.3 Computation

There are two possibilities of computation:

- step by step and
- autocalibration.



**Fig. 3.11 - Menu compute InEx Filtration**

Results of computation are written into tables of dialogue “I/E Group” (“Q Calibration” and “Regional Coef – Exfiltration”, see figure Fig. 3.8) and dialogue “Pipe In/Ex Filtration” (“dQinf”, “dQex”, “Qinf”, “Qexf”, see figure Fig. 3.10).

#### *Step by step computation*

This way of computation allows user to have full control on computation process. Each consecutive step computes part of I/E computation and user can check partial result and make its own corrections. Figure Fig. 3.11 (menu item “In/Ex Filtration – Compute In/Ex Filtration”) shows order and connection of all computational steps.

#### *I/E autocalibration*

Autocalibration runs all items of I/E computation in a loop in order to receive the best numeric equality between measured and computed values in all I/E groups.

## 4 Appendix A

This Appendix is focused on background description of approach used for dry weather flow setting.

There are two methods of setting that needs more detail explanation:

1) Dry weather flow computation using standard catchment data. When catchment data are set it is possible to make use of existing information on number of inhabitants. For each catchment node the dry weather flow is calculated from number of inhabitants and water consumption according to equation (1). Computed discharge represents an increment of dry weather flow located in upstream manhole of the pipe. Discharge is summarized from upstream node to downstream and particular value of discharge is assigned to particular pipe. Water depth is calculated according to method described in Appendix B.

$$q_{dwf} = \frac{NI * WC}{86400} \quad (1)$$

where:  $q_{dwf}$  - dry weather flow increment (l/s)  
 $NI$  - number of inhabitants  
 $WC$  - water consumption (l/inhabitant/day)

2) Dry weather flow computation using distribution of global value to pipe. There are values of number of inhabitants, water consumption and optional selection of weight function (see further) needed as an input for computation. Discharge for each single pipe is calculated according to equation (2) as follows:

a) No weight function. There wont be used any pipe significance expression and weight parameter will be simple inverse value of number of pipes.

b) Length as weight parameter. The pipe length will be used for weight function definition. Weight parameter will be computed as  $\frac{pipe\_length}{\sum_{pipes} length}$  ratio.

$$Q_{dwf} = w * \frac{NI * WC}{86400} \quad (2)$$

where:  $Q_{dwf}$  - dry weather flow (l/s)  
 $NI$  - number of inhabitants  
 $WC$  - water consumption (l/inhabitant/day)  
 $w$  - weight parameter for pipe significance expression

## 5 Appendix B

### *Water depth calculation from discharge*

Water depth calculation is based on equation for steady flow. For each single pipe there is consumption curve computed as follows:

- for each single pipe the shape of h/S curve is computed (relation between water depth and flow area),
- for particular water depth the shape of h/R curve is computed (relation between water depth and hydraulic radius),
- from h/R curve for particular water depth is corresponding velocity values calculated using equation (4),
- for each water depth discharge is computed using equation (3) and so consumption curve completed

$$Q = S * v \quad (3)$$

where:                    Q - discharge (m<sup>3</sup>/s)  
                              S - flow area (m<sup>2</sup>)  
                              v - velocity (m/s)

$$v = \frac{1}{n} * R^{\frac{2}{3}} * i^{\frac{1}{2}} \quad (4)$$

where:                    n - Mannings roughness coefficient  
                              R - hydraulic radius  
                              i - pipe slope