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# Strategic Asset Management

## SIROCO, a decision support system for rehabilitation adapted for small and medium size water distribution companies

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# I - Context of the SIROCO project

- European Care_W project combined tools and methods into an integrated decision support system for the rehabilitation of drinking water networks.
- Care_W integrated system is adapted for large utility services. Small and medium networks don't have enough data to use statistical models of break prediction.
- The SIROCO project, funded by the french research ministry, was set up to develop an integrated decision support system which is adapted to small and medium sized water companies

# I - The SIROCO approach

- Project team :
  - G2C Environnement, a private company. Designer of the geographic information system "Cart@jour"
  - Cemagref, a public research institute. Designer of the break prediction software "Casses" and the hydraulic reliability software "Criticité"
  - 16 water distribution companies. Providing data and project feedback.
- Guiding principles
  - Creating a database that amalgamates data from several networks : Amalgamated database
  - Using a GIS in order to standardise and manage the data efficiently

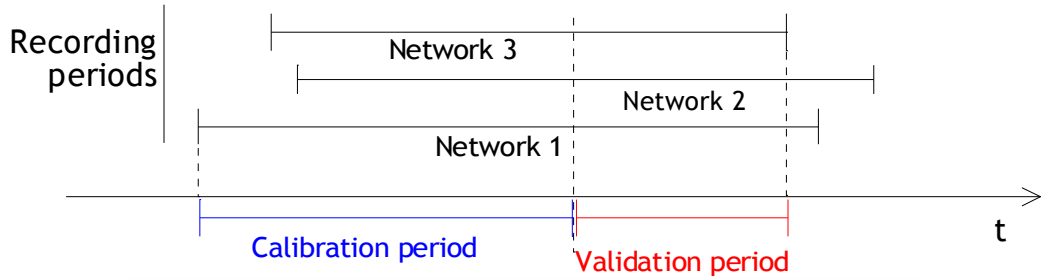
# II - The break prediction model

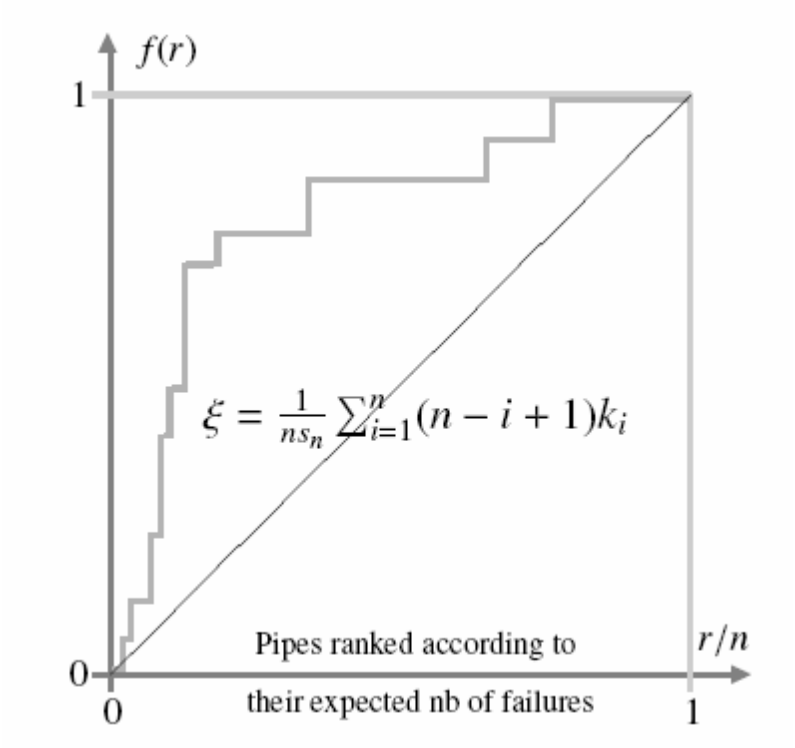
- The break prediction model used in this study was developed by Cemagref, Bordeaux (Legat, Eisenbeis, 2000)
- It is a Weibull-type multi-parameter model in which the probability of failure is linked to the values of different parameters (length, diameter, material, soil, traffic…)
- The main result is the average number of breaks predicted for each pipe over a future period in the future.

# II - Validating the models 1/2

- To check the validity of using an amalgamated database, models using data from a single network were compared with models based on data amalgamated from several networks.
- To compare different models, we used the validity test defined by Yves Legat (Legat, 2002)
- The basic principle is to compare the breaks that did occur during a past period with break predictions calculated on the same period.

# II - Validating the models 2/2



# II - Comparison of the models

| Area under the performance curve for **large networks** | Network 1 | Network 2 | Network 3 |
|---|---|---|---|
| Model based on data from a single network | 0.83 | 0.72 | 0.86 |
| Model based on amalgamated database | 0.85 | 0.72 | 0.81 |

| Area under the performance curve for **medium networks** | Network A | Network B | Network C |
|---|---|---|---|
| Model based on data from a single network | 0.63 | 0.66 | 0.58 |
| Model based on amalgamated database | 0.56 | 0.69 | 0.55 |

- By using an amalgamated database it is possible to produce significant models.
- When using a model with single network data is possible, a model with amalgamated data doesn't work significantly better.

# III - Hydraulic reliability model

$$HCIV_j = \left( \sum_{i=1}^{n} (d_i - c_{ij}) \times \omega_i \right) \times 3.6 \times tr_j \times \frac{\delta_j \times l_j}{1000} \times \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \omega_i \times d_i}$$

$HCIV_i$ Hydraulic criticality of pipe j in $m^3$ per year

$d_i$ Average annual demand at node i in l/s

$c_{ij}$ Demand available at node i when j fails in l/s

$\omega_i$ Importance of node i

$tr_j$ Unit time for repairing pipe j in hours

$\delta_j$ Rate of breaks in pipe j (breaks/year/km)

$l_j$ Length of pipe j in m

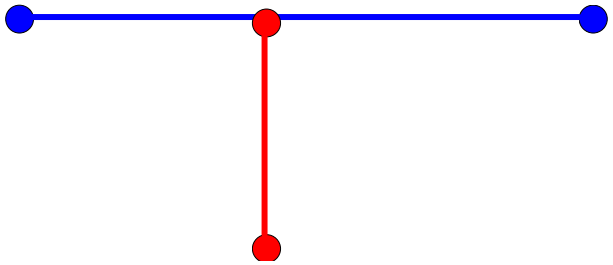
$$C_i^{\varepsilon}(h_i) = \begin{cases} 0 & \text{Si } h_i < h_i^m - \varepsilon \\ d_i \cdot \sqrt{\frac{h_i - h_i^m}{h_i^s - h_i^m}} & \text{Si } h_i \in [h_i^m + \varepsilon,\ h_i^s - \varepsilon] \\ d_i & \text{Si } h_i > h_i^s + \varepsilon \end{cases}$$

# III - Basic rules of network topology

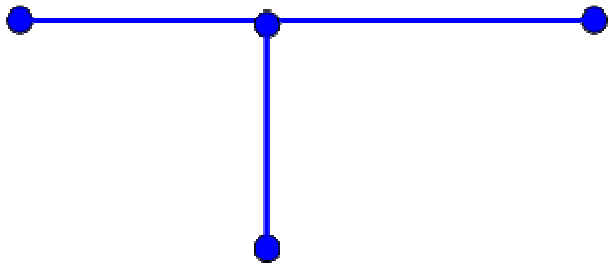
The basic unit on which hydraulic reliability is calculated is the hydraulic sector.

- Rule 1 : Sectors should be independent. No node is common to two pipes from two different sectors.
- Rule 2 : Within a sector, pipes should all be closely linked. There should always be a route from one pipe to another, linking together any two nodes in the sector.
- Rule 3 : Each sector should contain at least one node associated with a reservoir or a source. Pressure should be sufficient to supply each node for consumption use.

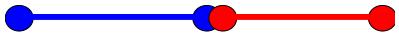
# III - Examples of topological errors



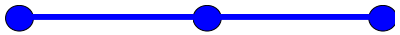
Observed



Desired



Observed



Desired

# IV - Decision support - Criteria

- Two types of criteria were used
  - Impact criteria : Measure nuisance or disturbances caused by breaks of the pipe
  - Opportunity criteria : Take into account factors that are independent of breaks and which may influence the decision to replace a section of pipe
- Impact criteria
  - I1: Linear index of hydraulic criticality
  - I2: Road traffic disturbance index
  - I3: Repair/Replacement cost ratio
  - I4: Linear index of losses
  - I5: Index of local disturbance to continuity of service
- Opportunity criteria
  - O1: Coordination index according to cover
  - O2: Index of need for rehabilitation

# IV - Stages in calculating the score for a pipe

- Calculation of the raw value for each of the 7 criteria
- Standardisation of the values for each criterion
- Aggregation of impact criteria then opportunity criteria in order to calculate the impact and opportunity scores
- Standardisation of the impact and opportunity scores
- Aggregation of the standardised impact and opportunity scores, resulting in an overall score
- Standardisation of the overall score of the pipe

# IV - The standardisation method

A single standardisation method was selected for all criteria and scores.

$$UXk_i = \frac{Xk_i - \min(Xk)}{\max(Xk) - \min(Xk)}$$

- It calculates a percentage of the parameter's scope of values : The pipe that is the least critical is assigned the value 0 and the most critical the value 1.
- This method guarantees the dispersion of values which facilitates intuitive assigning of weights.

# IV - The aggregation methods

1 - The weighted sum on a cardinal scale

$$SCI_i = \sum_{n=1}^{5} \alpha_n \times UIn_i$$

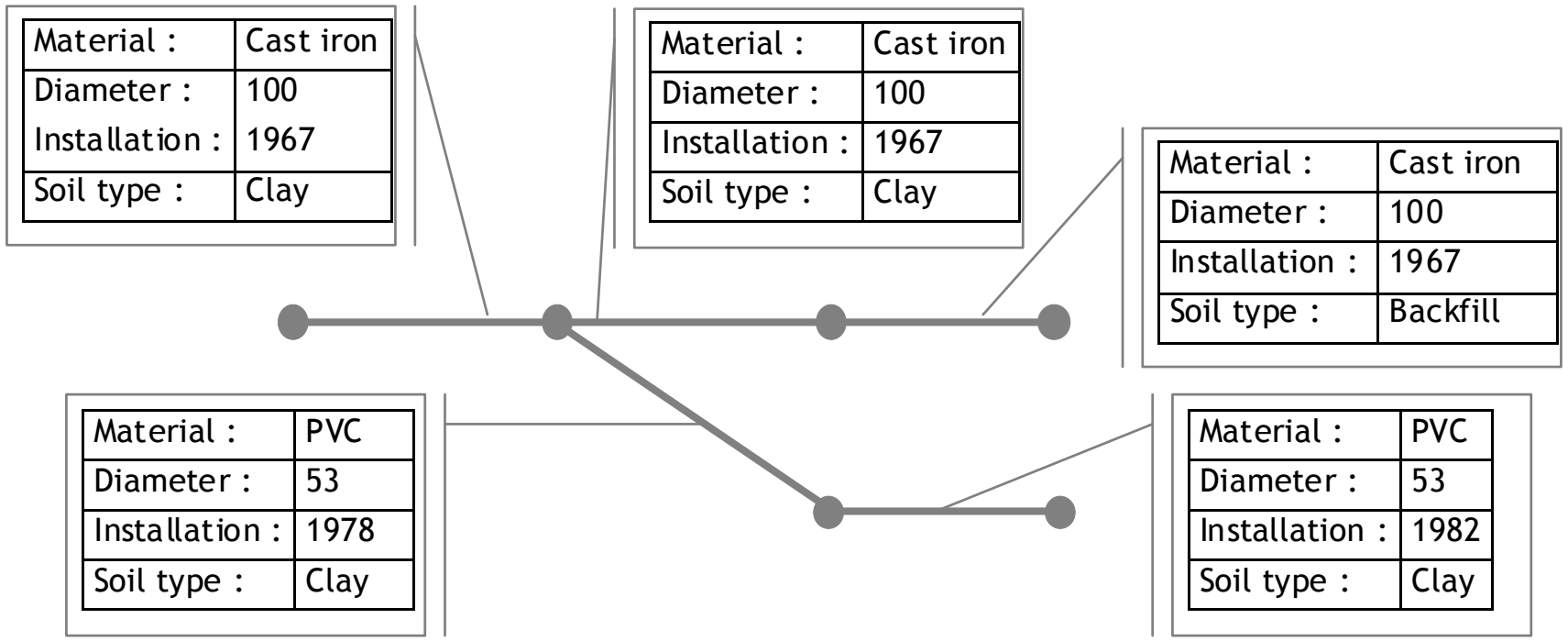
2 - Lounis and Vanier's method

$$SCI_i = \sqrt{\sum_{n=1}^{5} UIn_i^2}$$

3 - Hybrid method combining a product and a weighted sum

$$SCG_i = USCI_i \times (USCI_i + \lambda \times USCO_i)$$

# V - Data : Definition of a pipe 1/2



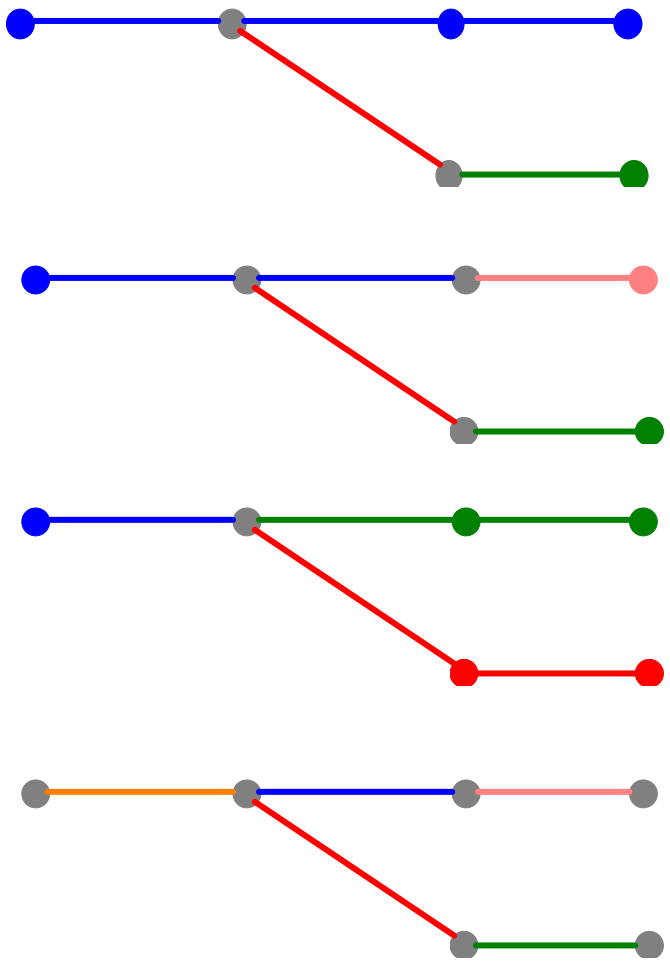
# V - Data : Definition of a pipe 2/2

Pipe according to the GIS

Pipe according to the break prediction software

Pipe according to the hydraulic reliability software

Pipe according to SIROCO



# V - Collection of the data

- Protocol
  - Digitalisation and integration of each network into the same type of GIS
  - Verification of topology
  - Installation of GIS in the company and staff training
  - Data collection and entry
- variables collected
  - Date of installation: dated as-built drawings, municipal archives …
  - Soil type: sanitation master plan, geological studies
  - Road traffic : Road traffic figures to identify major axes
  - Pressure of service: Reports from use surveys
  - Linear loss indices (by sector): Network diagnostic reports
  - Pipelines requiring reinforcement: network diagnostic report, development plan
  - Elevation numbers: topographical maps, or contour lines (.dwg or other formats)
  - Consumption at network nodes: customer billing files
  - Failures on pipelines: incident forms (or logbook)

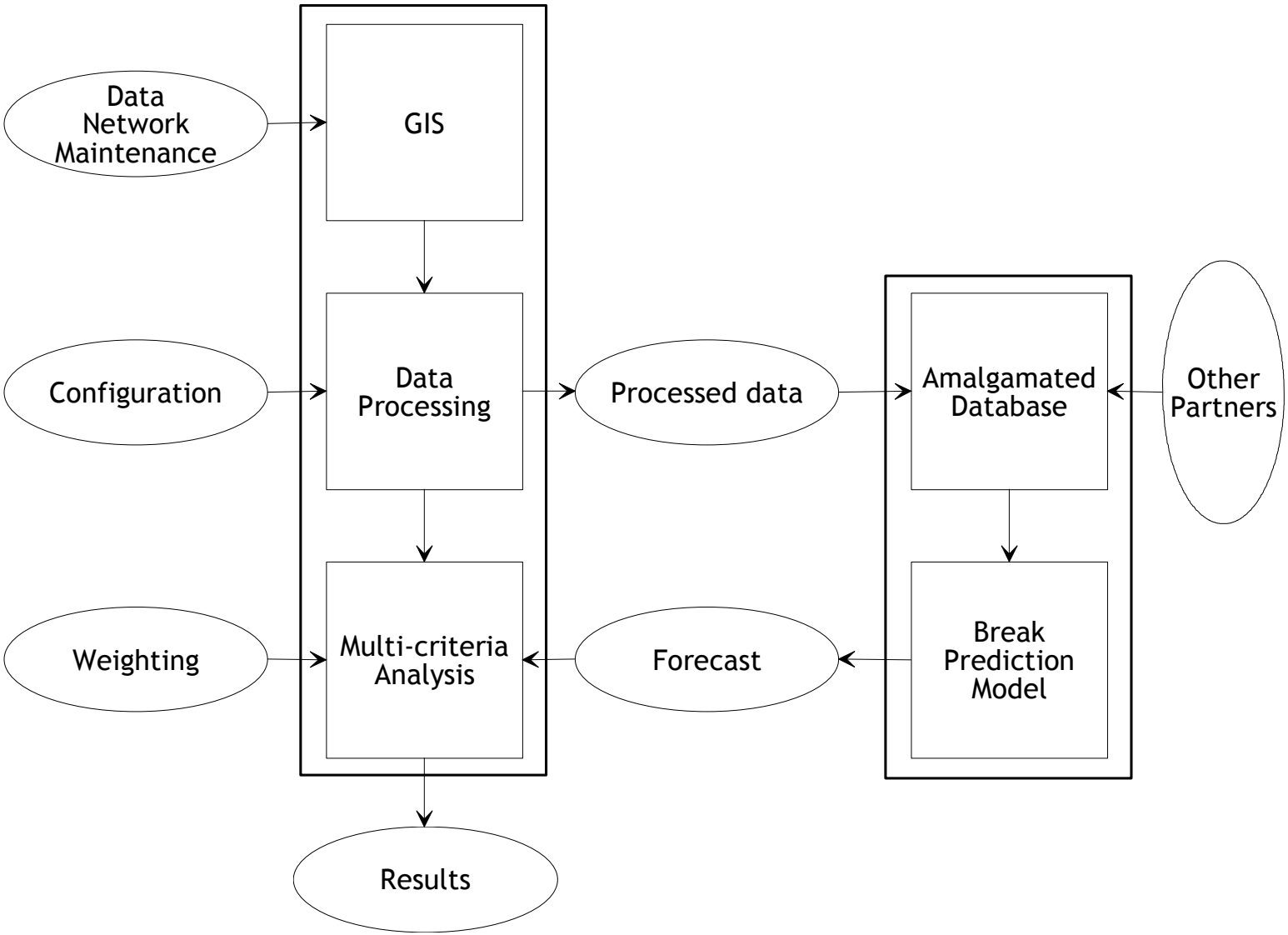
# V - Difficulties encountered with data

- It was difficult to find complete information on all the variables.
- Responses from the companies were not always homogeneous. In particular for "soil type" or "material" we noted considerable variations according to the local context.
- The number of recorded failures integrated into the amalgamated database was insufficient to use the break prediction model (we needed to use complementary data from foreign networks)
- Company networks contained errors in topology which could jeopardise any hydraulic modelling.

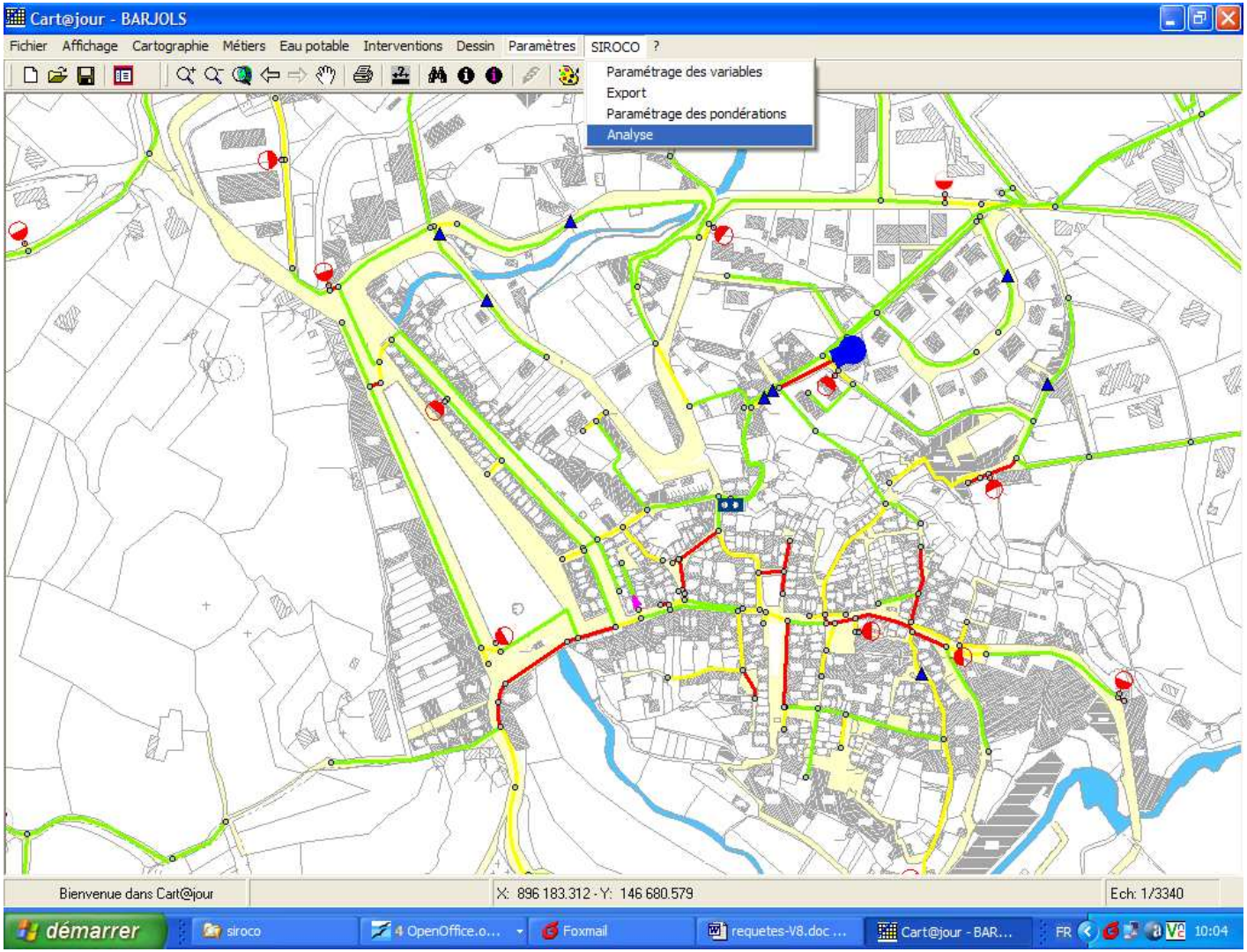
# VI - Integrated SIROCO software - Procedure

- Preparation of database
- Configuration of a set of hypotheses
- Production of data files, exported to Cemagref
- Processing at Cemagref and production of result file
- Importation of result file by user
- Definition of weighting
- Analysis

# VI - Data flow and processing



# VI - Visualisation on the GIS



# VII - Conclusion

- It is possible to use an amalgamated database to forecast breaks using a statistical model.
- Provided certain topological rules are respected, it is possible to carry out hydraulic reliability calculations using data from a GIS.
- As a result of this project, the SIROCO software is now on the market.
- An "autonomous" version of the SIROCO software will be offered to meet the needs of medium-sized companies with sufficiently large databases.

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# Thank you for your attention!

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