Abdelhafid University Center Bousouf - Mila

2024-2025 Semester 1

Water distribution and collection:

HAS PART I: DRINKING WATER SUPPLY

– Lesson 4 –

Chapter 04 : Diagnostic methodology in drinking water supply networks .

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Students concerned			
Institute	**Department**	**Year**	**Speciality**
Science and Technology	GC and hydraulics	2nd year master's degree	Urban hydraulics

Course Objectives 4

- Describe the methodological approaches for analyzing the operating status of a drinking water supply network.
- Identify the tools, indicators and parameters needed to assess hydraulic performance, water quality and losses.
- Provide a systematic framework for locating and prioritizing malfunctions (leaks, insufficient pressure, contamination, obsolete pipes).
- Establish a solid foundation for proposing corrective actions, preventive maintenance and optimization of network management.

Introduction

The efficiency of a drinking water network depends on its ability to continuously provide quality water, in sufficient quantity and at pressures adapted to the needs of users.

However, over time, these networks are subject to various constraints: aging pipes, water losses, occasional contamination, or even insufficient capacity in the face of growing demand.
In this context, the implementation of a rigorous diagnostic methodology is essential. It constitutes an essential preliminary step to any improvement or rehabilitation strategy. By combining field observations, technical measurements, data analysis and hydraulic modeling, the diagnosis provides a clear and hierarchical vision of the state of the network.

Diagnosis is an operation that allows us to check the condition of the drinking water supply system, in order to detect anomalies in this system.

"Diagnostic" aspect: Qualitatively and quantitatively analyze all the hazards that may exist on the network and manifest themselves through observations and solutions.

The study will include four mandatory phases and one mandatory option:
· **PHASE 1** : data collection, inventory, establishment of network plans, sectorization and pre-diagnosis,
· **PHASE 2** : measurement on the network,
· **PHASE 3** : leak detection,
· **PHASE 4** : assessment of the study, development of an action program,
· **PHASE 5** : in-depth analysis of network operation based on modeling.

IV.1 PHASE 1: data collection, inventory, establishment of network plans and pre-diagnosis

IV .1 .1 Establishment of network plans

The service includes:

· Recovery of cadastral maps in dwg format ,

· Researching network plans,

· The collation of these plans and the creation of a complete document on a scale of 1/10,000,

· Research and testing of sector valves, drains, suction cups and fire hydrants,

· Duplication of the winnowing logbook in three paper copies and three computer copies,

Figure 01. Map of the Drinking Water Supply Network.

IV *.1.2 Visit to the works*

In order to fully understand how the networks operate, the design office will have to visit the service's facilities:

· Catchments,

· Production station,

· Tanks,

· Regulatory bodies on main pipes,

A summary sheet will be drawn up for each work, including at least:

· A photograph,

· A diagram of the operating principle

· A description of the operation,

M'kimen pumping station and the 1000 m³ reservoir of Lac des Oiseaux: Need for urgent intervention.

IV.1.3 Analysis of production and volumes introduced by distribution sector

This analysis was carried out during the study on the restructuring of the drinking water supply, and during the development of the work program. There are no plans to repeat it.

IV.1.4 Estimation of unaccounted volumes

The design office will draw up as exhaustive a list as possible of unaccounted consumption (collective use, interference, fire protection, operation and losses).

Each community must be met to determine all unaccounted public uses of water. (See table 01).

IV .1.5 Estimation of under-accounted volumes

The design office will produce a list of the age of the subscribers' meters.

To do this, the design office will proceed to:

· A phase of data collection from local authorities (age of meters if available, meter renewal program, town planning documents, etc.),

· A field survey phase during which the age of the meters will be recorded at approximately 5%.

From this data, a statistical analysis will be carried out in order to create an age pyramid of the meters in 5 main groups:

· ≤ 5 years,

· Between 5 and 10 years old,

· Between 10 and 15 years old,

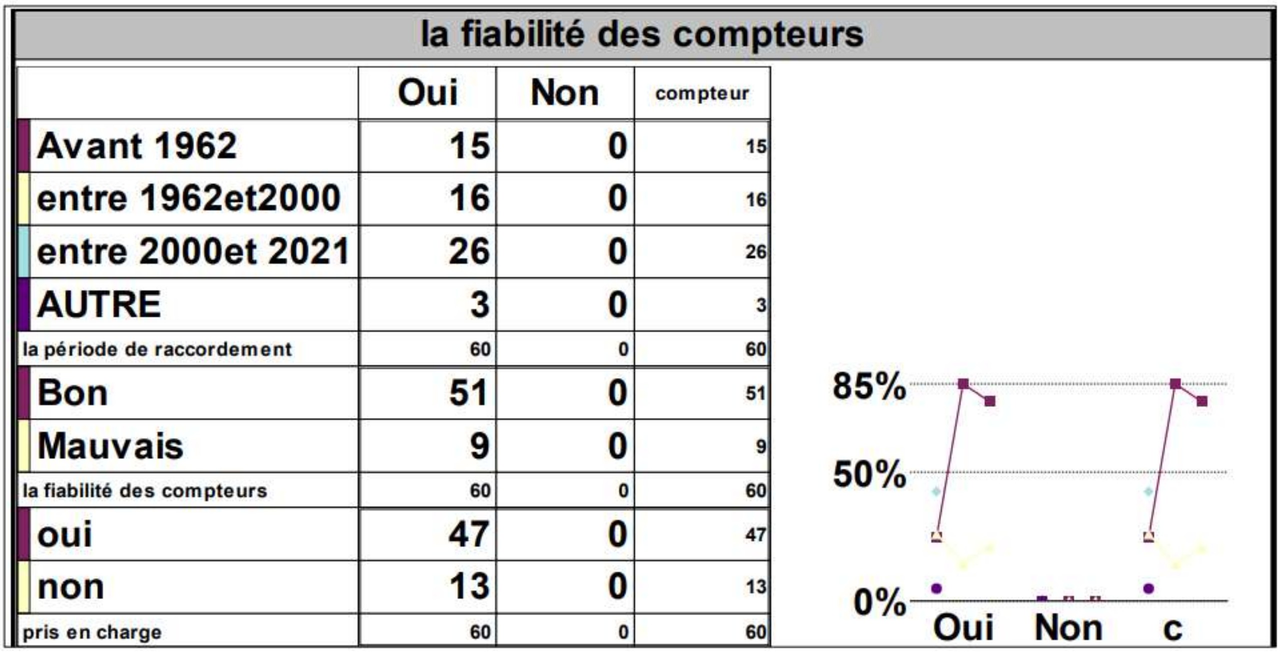
· Between 15 and 20 years old,

· > 20 years.

At the end of this stage, the study team will propose an action plan for the renewal of meters in the municipalities, prioritizing needs.

Table 01: different volumes of water in the network.

	Authorized consumption	Unauthorized consumption
Authorized consumption billed	Volume counted	Volume without counting
Authorized consumption not billed	Volume consumed for service	Diverted volume
Volume consumed	Billed volume	Leakage volume (unbilled)



la fiabilité des compteurs

	Oui	Non	compteur
Avant 1962	15	0	15
entre 1962et2000	16	0	16
entre 2000et 2021	26	0	26
AUTRE	3	0	3
la période de raccordement	60	0	60
Bon	51	0	51
Mauvais	9	0	9
la fiabilité des compteurs	60	0	60
oui	47	0	47
non	13	0	13
pris en charge	60	0	60

IV .1.6 Analysis of network incidents

The analysis will be carried out over a period of at least 5 years and will distinguish between the different types of incidents:

· Nature (joints, breakage, fountain equipment , etc.)

· Geographic distribution (sectors and sub-sectors)

· Difficulties in operating and locating leaks.

Problem areas will be shown on the plan.

Figure 03. Degradation and leak on a pipe.

IV .1.7 Review of the quality of distributed water

The purpose of testing the quality of distributed water is to assess whether the water supplied to consumers meets health standards and potability criteria. It includes the analysis of various parameters such as pH, turbidity, microorganism concentration, the presence of heavy metals, and chemical contaminants.

The goal is to ensure that water remains clean, safe, and safe for human health, while identifying any anomalies or failures in the distribution system that could compromise its quality. This process involves regular testing and monitoring at various stages of the water supply and distribution network.

Figure 04. Water quality control as part of the diagnosis of the drinking water supply network .

IV.1.8 Determination of the different service ratios

And at the end of the first phase, a general assessment of all the data collected will be established.

The design office will calculate the following ratios in general, and by distribution sector:

· Primary and net yields,

· Linear loss indices (ILP m3/km/d) updated from the pipeline lengths recalculated following the updating of the network plans,

· Linear repair indices on pipes (ILCr in number of leaks on Pipeline/km),

· Linear repair indices on connections (ILCb in number of leaks on Connections/100 connections).

IV.1.9 Proposal for a sectorization plan

Following the updating of the plans, the design office will propose a justified network sectorization plan.

The requested procedure includes:

- A first phase of theoretical division on plan (objective of division into sectors of 500 m x 1000 m),
- A field verification phase (methodology to be developed by the candidates at the stage of The offer),
- An update of the theoretical plan based on the results of the tests,
- A proposal for a "compromise" plan that sets a minimum number of valves has been replaced.

The sectorization plans, valid at the end of phase 1 meeting, will be provided on computer media (Autocad or GIS) and on paper in 2 copies.

The degree of accuracy and testing methodology will be proposed by the candidates and taken into account in the technical merit rating.

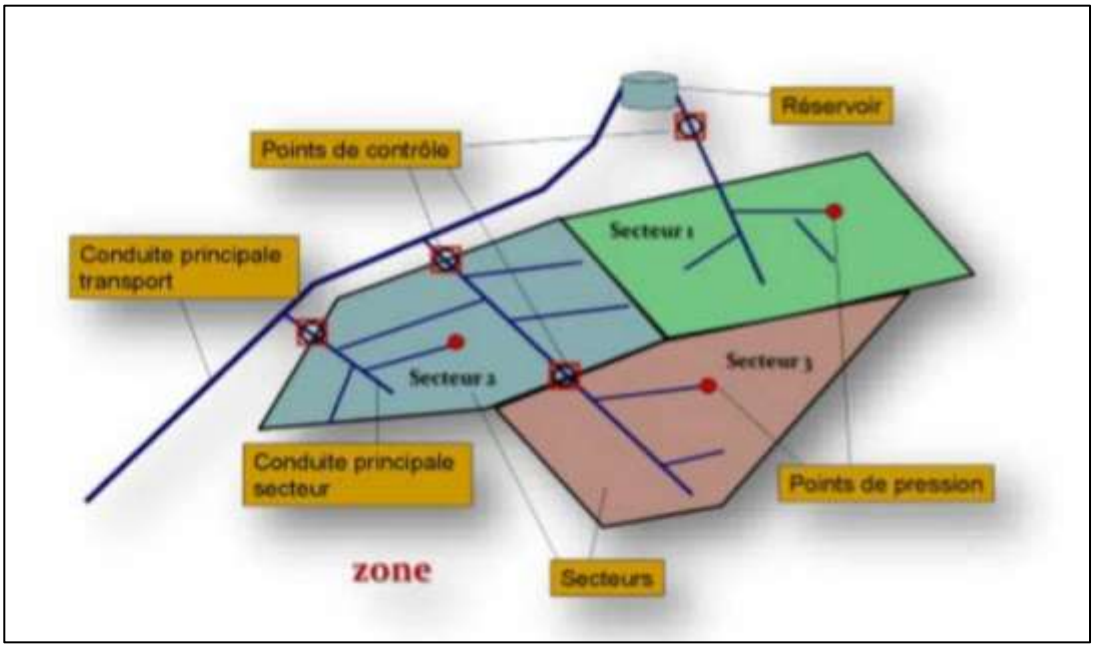


Figure 05. Example of a sectorization diagram (Brachmi , 2017).

IV .1.10 Emergency action program

If necessary, the design office will propose emergency work to be carried out before the second phase of the study (valves, meters, etc.).

The mission of the holder then includes:

- Analysis of the positioning of meters and valves (see previous paragraph),
- The choice of counting technique,
- The sizing of the equipment (for the valves to be changed, an identical renewal will simply be requested),
- The establishment of project-level plans and specifications.

Table 02: Age of network pipes according to materials.

Material	Age
Grey cast iron, concrete	53 years old
Ductile iron, Asbestos cement	30 years old
PVC (Polyvinyl chloride)	15 years old

IV .1.11 Summary of the first phase

At the end of phase **1** , the investigations carried out by the design office will be presented in the phase **1 report** . It will include at least:

· The results of site visits (summary sheets),

· Up-to-date network maps,

· Network sectorization plans,

· Summary tables showing undercounts and non-counts,

· A summary table of loss indices. (See table 03)

$$ILP = \frac{débit\ minimum\ de\ nuit}{linéaire\ du\ réseau} \quad en\ m^3/j/km$$

· Proposals for urgent work.

Table 11: Reference table of ILP values.

ILP (m^3/d/km)	Rural	Semi-rural	Urban
Good	<1.5	<3	<7
Acceptable	<2.5	<5	7<ILP<10
Poor	2.5<ILP<5	5<ILP<10	10<ILP<15
Bad	>5	>10	>15

IV.2 PHASE 2: Measurements on the network

IV .2.1 Preliminary note

At the end of PHASE **1** , a study interruption is necessary to allow the municipalities to install the meters and valves.

PHASE **2** is launched at the end of this interruption which can be quite long (6 months minimum).

For all measures, it is requested:

- A measurement point sheet with a photograph of the point and assembly diagram,
- To organize a visit of the points with the project owner,
- To note down the key information on the campaign precisely, with at least (counter index, date of installation, time of installation, etc.),

IV .2.2 Flow measurements

The design office will have to carry out flow measurements at existing metering points and those installed during the study.

The design office will establish its offer on the basis of 20 flow measurement points on the meter and 3 flow measurement points via flow meter.

He will specify in his offer:

· The materials envisaged,

· The checks carried out (methods, frequency, etc.),

· Quality procedures,

IV.2.3 Pressure measurements

The design office will have to carry out network pressure measurements.
The recording interval will be less than or equal to five minutes. The design office will establish its offer on the basis of 12 measurement points.

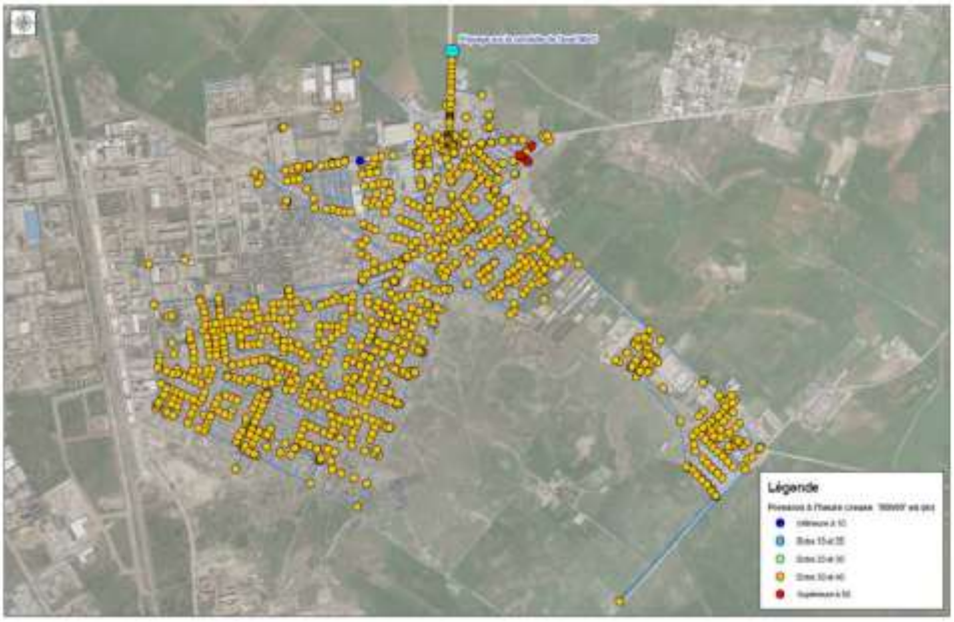


Figure 06. Simulation results for midnight pressure distribution.

- ***Campaign duration***

All measures will be monitored continuously over a period of around 10 to 15 days, including two weekends and outside the summer period.

IV.3 PHASE 3: Leak detection

IV.3.1 Leak detection

The study manager will carry out a sectorization of the leaks. The objective is a relocation on the scale of the sectors defined above.
It will define its methodology precisely at the stage of its offer. The following rules must however be verified:
- The relocation will be carried out at night with the assistance of a fountain operator (the candidates will establish their offer considering that a fountain operator will actually be present on 75% of the network but that for certain municipalities the holder will have to operate the valves himself),
- It will lead to a map of the leaking (illicit) sectors **with an indication of the lost flows** .

IV .3.2 Fine location of leaks

Depending on the results obtained during the leak detection campaign, the project owner will decide whether or not to supplement the investigations with a detailed leak search.

IV.3.3 Repairing leaks

Leak repairs will be the responsibility of the project owner and will be carried out as quickly as possible.

Table 14: Some interventions to address the problem of leaks.

Operations	Actions to be taken
Network upgrades	- More detailed network sectorization; - Network rehabilitation studies and works; - Development and updating of equipment maintenance and upkeep programs; - Studies on improving connections (sources of loss in the network); - Fight against illegal connections (fraud); - On non-metallic pipes, increase in the number of water access points.
Prohibit the rules for laying pipes and the reliability of leak repair work	- Take into account the nature of the ground (instability of conditions and external corrosion); - Install the pipeline at the correct depth (protection against frost and rolling loads); - Prepare the laying bed; - Ensure leveling and pipework to give it a good foundation and facilitate air evacuation at high points; - Create stops to prevent clogging of the pipelines due to the movements of the self-butted tubes; - Install joints according to the manufacturers' requirements with the appropriate tools; - Adapt the fountain equipment and connections to the maximum operating pressure; - Ensure the traceability of the tightness of the equipment on the network (valves, gate valves, fire hydrants, etc.). - Designate an organization to check that the devices, if installed, are properly watertight; - Correctly repair the various pipelines (choice of repair parts according to materials and diameters).
Operations	**Actions to be taken**
Generalization of the pressure regulation and modulation system	- Installation of pressure reducers; - Regular monitoring of high pressure areas; - Implementation of the modulation system; - Generalization of the telemetry system.
Plan actions and structures against hydraulic phenomena of water hammer on the network	- Operate the network gate valves as slowly as possible, both for opening and closing; - Anti-ram tanks; - Suction cups; - Flywheel; - Balance stack; - Relief valve.
Improving the counting service	- Verification of meter installation conditions; - Installation of sector meters; - Implementation of an annual program for monitoring and calibrating management and billing meters; - Replacement of blocked meters; - Renewal of old meters; - Choice of type and calibration of meters (correct calibration of the meter in relation to the customer's needs); - Improvement of measurement reliability; - Provision of water sampling points with a metering system for the estimation of unaccounted for water.
Update of network maps	- Action of permanent updating of plans following the renewal and extension of the network; - Acquisition of IT tools for updating plans (GIS).

IV .3.4 Post-work inspection

Once the leaks have been repaired, the design office will carry out a new flow measurement at the head of each sector concerned in order to estimate the benefit obtained compared to the basic situation.

IV.4 PHASE 4: Master plan of works

At the end of phase **4,** a complete assessment of the diagnostic study will be established.

It will include:

· Reminder of the situation before diagnosis,

· Description of the missions carried out within the framework of the study,

· The main conclusions of the previous phases,

· Listing of leaks detected, located and repaired,

· For repaired leaks, the gain compared to the basic situation,

· Various recommendations for maintaining the performance obtained at the end of the study.

An action program will be developed by the design office to enable the network to function properly; and to maintain performance in the short, medium and long term.

IV.5 PHASE 4 BIS OPTION: Analysis of network operation and modeling

- **Additional network measurements** : Data collection in parallel with those of phase 2.
- **Modeling** : Creation of the network model, calibration with real data and proposal of optimization solutions with costing.
- **Summary report** : Summary of results, proposed solutions and estimated costs.

The goal is to provide a detailed analysis of the network and solutions for its improvement.

IV.6 . Methodology proposed for diagnosis in the Algerian context:

Introduction

In Algeria, water supply systems are not operated efficiently. It is estimated that more than 50% of water production is lost through leaks in supply and distribution pipes.

In general, distribution network plans are inaccessible or do not exist in detail for several areas.

For this, it is necessary to implement a methodology for diagnosing drinking water networks.

IV .6.1 The stages of the methodology proposed for the diagnosis in the Algerian context.

Step 1: Entering plans and data from the existing system (Mapping)

The objective of this step is to update the plans for the city's drinking water supply system.

A number of existing plans and data will be put for field verification; at the same time, a GIS computer entry of the network plans will be carried out. Implementation will take place in the following phases:

- **Preparation of the base plans**

Updating existing plans; taking into account current urbanization, which should be limited. For areas where additional surveying is required due to city expansion, the method for preparing the base plans will be of the **“** direct survey **” type** and will include:

• Survey of streets and facades.

• Altimetric and planimetric details of streets.

• Implementation of a basic polygon linked to the cartographic system in use in Algeria.

• Connection by GPS determinations.

- **Data collection**

The collection of existing data and information relating to collection, supply and distribution networks, as well as to works from the relevant services such as; ADE, DHW, design offices, etc.

A synthesis of this information to identify and qualify the available information. All this information will be standardized in a geographic information system (GIS) in order to constitute the reference file.

For civil engineering works we proceed:

• Archive and reproduce existing plans.

• Report corrections after field visits.

• Produce, from existing plans and field visits, functional diagrams specifying the hydraulic and electromechanical equipment, with their main characteristics and their respective arrangements.

- **Checking the AEP system**

Once the existing data is entered into a geographic information system (GIS), it will have an analysis of the network and note the anomalies that appear (departure of pipes without valves, illogical connections, areas without network, etc.).

This analysis will serve as a guide for verifying the AEP system.

This task of verifying the drinking water system will be carried out in cooperation with the staff of water services such as ADE; DHW, etc., who have a certain knowledge of the network.

The procedure is as follows:

• Verification of distribution network plans by field visit with ADE staff; DHW.

• When collecting technical data: diameter, material and age of the pipe based on staff knowledge; when the information is unknown such as age or materials; it will be necessary to estimate this information based on general knowledge of the sector.

• Excavation survey to locate pipes when necessary such as:

- the complete lack of plans for new sectors,
- incorrect or incomplete plans;
- material undetectable from the surface.

• Researches metals to locate valves that do not appear on the plans even though their existence is presumed or to qualify special equipment.

- **Preparation of plans for the existing drinking water system**

The preparation of the GIS technical database will lead to:

• Preparation of the codification system (sectors, pipes, nodes, structures, connections) and codification of all elements of the AEP system itself

• Identification of pipes (code, diameter, materials, age, etc.).

• Identification of knots (type, code, diameter, material, age, etc.)

With particular attention to sectoring valves.

• Identification of connections (type, code, diameter, age, etc.)

All this information will be used to prepare specific reports on a component of the system by element or by geographical area, and to highlight, based on the state of the equipment and constraints, the rehabilitation work to be carried out **.**

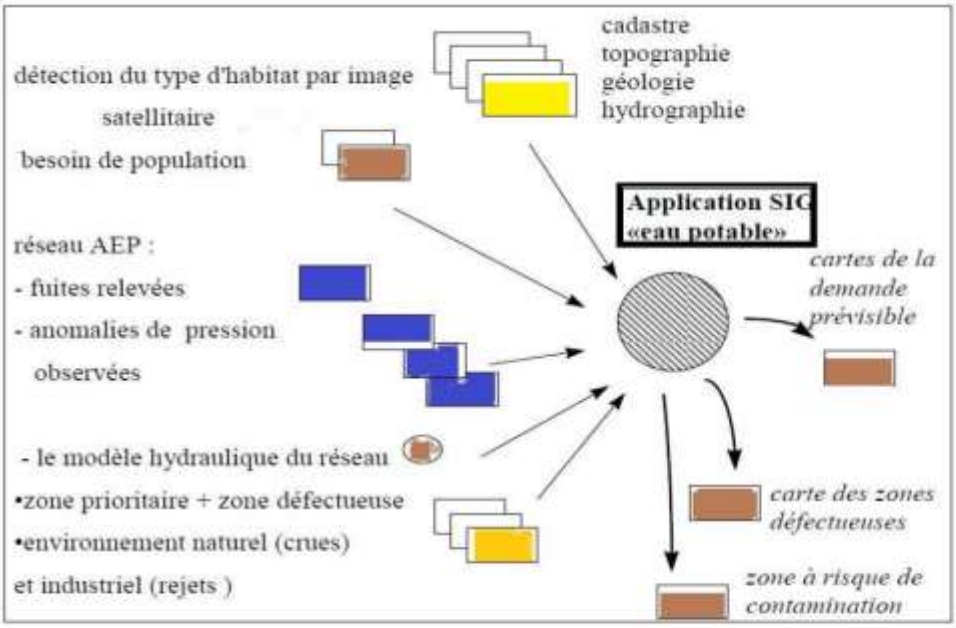


Figure 07. "Drinking water GIS" application: data used as input to the module and information produced BLINDU.I, 2004

- **Geographic Information Systems (GIS)**

A Definition of a GIS

A GIS is a computer system of hardware, software, and processes designed to enable the collection, management, manipulation, and display of spatially referenced data to solve planning and management problems.

To transform a real object into spatially referenced data, the territory is broken down into thematic layers (relief, roads, buildings, etc.) structured in digital databases.

The databases that feed GIS must be georeferenced, that is to say, share a common reference framework called a projection system.

GIS allows, among other things :

• To store large volumes of geographic data in digital form in a centralized and sustainable manner. Compared to paper or cards, current computer media (CD-ROMs , DVD-ROMs) ensure better data preservation; it is said that GIS perpetuates memory.

• Display and consult data on the screen, superimpose several layers of information, bring together information of different types (topographical, environmental, economic).

• Update or modify data without having to recreate a document.

• To analyze data by performing, for example, surface or distance calculations.

• Add or extract data, transform it to make it available to a service provider (surveyor, architect, network manager, etc.) or a decision-maker.

• To publish plans and maps on demand and in large numbers at low cost.

A GIS mainly includes 5 components:

1. Computer hardware
2. GIS software
3. Data organized in databases
4. Methods
5. Human resources (users).

B- Geographic information

The definition of each of the components, information system and geographic information helps to clarify its outline:

• *Information system: set of* interrelated components that collect information, process it, store it and disseminate it in order to support decision-making and control within the organization.

• *Geographic information:* information is said to be geographic when it relates to one or more places on the surface of the Earth. This information has the characteristic of being located, identified or geocoded.

C- Interest of GIS

Geographic information systems are mainly used to:

• Recording information on the territory is the primary function of GIS.

• Question the information on the territory,

• Produce thematic maps,

• Analyze information on the territory,

• Carry out simulations;

For the development of the GIS several operators are used such as:

• ArcGIS (Arc Info, Arc View…)

• AutoCAD Map 3D

• Epanet

• MapInfo,…

Conclusion

The diagnostic methodology in drinking water supply networks is a strategic tool for ensuring the sustainability and performance of hydraulic infrastructure. It provides a rational framework for identifying failures, measuring their impact, and prioritizing interventions. By relying on an integrated approach that combines technical data, performance analyses, and feedback, it allows for the transformation of a malfunction into an operational action plan.
Thus, the diagnosis is not an end in itself, but an essential step in the overall process of sustainable management of drinking water supply networks, ensuring health safety and user satisfaction.

Useful links

https://youtu.be/4u633ITH4mw

https://youtu.be/lPgKKEsH5vY

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