Book Chapter

GIS in Water Cadaster in Romania

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Abstract

In order to solve and regulate the problems imposed by efficient and complex water resources management, it is necessary to know, through the Information System specific for water management, the data sets that characterize these resources. In our country, Romania, the National Data Fund for water management was established in 1958 as an inventory required for the preparation of complex development of watershed plans and the national program of water development in Romania. In the first stage, the information system specific for water management conducted a primary inventory and a systematic ordering of the morphometric characteristics of the river's basins.

For this purpose, coding was done first for the 15 first-order river basins, of all tributaries (up to the order six, inclusive), which satisfy the conditions that the length of the watercourse is at least 5 km, and the catchment area is less than 10 km2 (*Water Cadastre Atlas of Romania, 1992*). The Information system specific for water management is the surface water, groundwater, and the natural frame of water. The purpose of the information system is to solve the knowledge and improve the inventory and systematic record, quantitative and qualitative, of all data regarding the natural water conditions, and also the waterworks for control, use, and protection of water resources and water quality (embankments, dams, canals, drains, etc.) for all waters in Romania. Such a system would facilitate equitable water distribution to all the users' communities and optimize water conservation for sustainable use and reuse.

Keywords

GIS; Water Cadastre; Romania; Morphometric Characteristics; Information System

Specialized Information Systems: Necessity, Legislation, Characteristics, Connection with the General Cadastre

The general framework in which the Cadastre activity is carried out in Romania is established by Law no. 7/1996 of the Real Estate Cadastre and Advertising (Official Gazette no. 61 / 26.03.1996). The original text of this law distinguished between the "General Cadastre" and the "Specialized Cadastre". Thus, according to Article 1, “The General Cadastre is the unitary and obligatory system of technical and legal records, through which the identification, registration, representation on maps and cadastral plans of all lands, as well as other real estates throughout the country, regardless of their destination and owner”. The basic entities of this system are the plot, construction, and owner. For the purpose of this law, the building means the plot of land, with or without constructions".

On the other hand, according to Article 4 of the same text, "Ministries, other central state institutions, autonomous utilities, and other legal entities organize the specialized cadastre in the fields: agricultural, forestry, water, industrial, extractive, real estate, road transport, railway, naval, air, tourism, natural and built-up protected areas, those at high risk of natural disasters or subject to pollution and degradation and others". The specialized cadastres are subsystems of evidence and systematic inventory of real estate from a technical and economic point of view, in compliance with the technical norms developed by the National Office of Cadastre, Geodesy, and Cartography and basic data from the general cadastre, regarding the area, use category and owner.

After its promulgation, Law no. 7/1996 was amended and supplemented several times by Emergency Ordinances (Official Gazette no. 266 / 23.05.2001, Official Gazette no. 154 / 04.03.2002, Official Gazette no. 509 / 07.06.2004). The above-mentioned article 4 has been deleted from the current text, thus eliminating the phrase "specialized cadastre". In this context, it is proposed to replace the notion of "specialized cadastre" with "Specific Information Systems" to record the occupation and use of land in various fields of activity (urban planning, public administration, environmental protection, agriculture, civil protection, etc.). An important clarification, meant to eliminate some confusion and misinterpretations, refers to the fact that these Specific Information Systems do not have as an object the registration of the property right over the land, this being the exclusive attribution of the National Agency for Cadastre and Real Estate Advertising – ANCPI.

Thus, according to the economic destination of the lands, specialized cadastres (specific information systems) can be drawn up for the following fields: agricultural land fund, forest land fund, land fund with water, urban land fund, land fund with networks and urban installations, special purpose land fund, land fund with mining operations, industrial land fund, the fund of lands destined for transports (road, railway, naval, air), the land fund for national defense needs, other land funds.

The National Situation Regarding the Information System Specific to the Field of Water Management

Among the various natural elements that condition the socio-economic development of a country, water is of particular importance both for its use and for meeting the growing demands of consumer uses (population, industry, animal husbandry, irrigation, fish farming), electricity production, navigation, approval etc. This importance is also highlighted by the destructive effects that water can produce under certain conditions (floods, excess moisture, and soil erosion), the actions to combat them being a permanent concern of society.

The use and capitalization of water resources are conditioned both by their quantitative limitation and their uneven distribution in space and time and by the need to ensure appropriate quality conditions, which is one of the environment's determining factors [1].

In the context of Romania's situation among the European countries with relatively low water resources, all these problems make the management and capitalization of the waters in our country a priority issue of special importance.

In order to solve and regulate the numerous problems imposed by the inefficient and incomplete management of water resources, it is necessary to know, through the activity of the information system specific to the field of water management, the set of data that characterize these resources [2].

In our country, the national fund for water management data was organized in 1958, as a necessary inventory for elaborating the complex management plans of the hydrographic basins and the national water management program in Romania. In the first stage, an information system specific to the field of water management was developed based on a primary inventorization and systematic ordering of the morphometric and hydrographic characteristics of the watercourses. To this end, a codification was first carried out in 15 first-order river basins of all tributaries (up to and including the sixth-order river basins) (Figure 1), which meet the conditions for the length of the watercourse to be at least 5 km. The surface of the water catchment basin should be at least 10 km2 [3].

Number	River basin	Basin Order
1	Upper Tisa	I
2	Someş	II
3	Crişuri	II
4	Mureş-Aranca	IV
5	Bega	V
6	Caraş	VI
7	Nera	VII
8	Jiul	VIII
9	Olt	IX
10	Vedea	X
11	Argeş	XI
12	Ialomiţa	XII
13	Siret	XIII
14	Prut	XIV
15	Danube and seaside	XV

Figure 1: First order river basins.

The first codification (completed in 1964) included a number of 4,295 watercourses, representing a hydrographic network with a length of 66,029 km, and based on this codification and morpho hydrographic data was drawn up (1962-1964), the first Atlas of water cadastre in Romania [4].

Cadastral data were grouped by river basins, rivers, and types of water management works in three volumes: hydrographic network, works for water control, use, and protection, and water resources.

The special development in the last years of the water management works, as well as the accumulation of new data and measurements regarding the water resources, highlighted the need to update the atlas of the water cadastre in Romania.

This update begins by editing the first part of the Water Cadastre, including the synthetic data related to the surface hydrographic network. The volume mainly includes coding of the hydrographic network, data tables characteristic of the hydrographic network, data on natural and accumulation lakes, and morpho hydrographic data of the Danube Delta and the Romanian Black Sea coast.

Compared to the cadastral atlas published in 1964, this edition additionally contains data on the Danube Delta, the stage of realization of the cadastral axis, the characteristics of the accumulation lakes, and forest fund.

A water cadastre objective is the "cadastral water axis" or "mileage-leveling axis". It was made on the main watercourses and was materialized on the ground by a number of approx. 20,000 concrete bollards, some of which have been included in the country's precision leveling network.

Another objective achieved is to write and graphically inventory the objectives on the watercourses or in connection with them on medium-scale maps (1: 50,000 - 1: 100,000).

The synthesis data regarding the record of all the coded watercourses and the objectives on them (without tracking in the cadastral sense the occupied areas) are included in the Atlas of the water cadastre of Romania. The second edition of the Atlas of the Romanian Water Cadastre was developed between 1986-1990 by a multidisciplinary team of specialists from several central and local research institutions. This edition of the atlas consists of two volumes, namely:

- Volume 1 contains the written part with morpho hydrological data on hydrological basins, characterizations, graphs, analyses and syntheses on large hydrographic units, and an alphabetical index of watercourses with references to the code and the map sheet.
- Volume 2 contains 130 drawings of hydrographic maps at a scale of 1: 100,000 containing morphological, topographic, and hydrographic data regarding approx. 5,000 watercourses

and approx. 10,000 river basins in a network with a length of 66,029 km.

At the elaboration of the current edition of the text volume of the Atlas of the Romanian Water Cadastre, compared to the 1964 edition of the same atlas, the following criteria were based:

- In the volume of text and the volume of maps, all the delimitations and determinations of morpho hydrographic data took into account numerous changes that occurred in the configuration of the hydrographic network due to the influence exerted on it by the construction on the territory of the country, during 1964-1990 of water management works, namely: dams, reservoirs, dikes, and riverbed settlements, drainage, irrigation, surface or groundwater diversions, fisheries, hydropower facilities and the hydrographic network modified by management works have been restored and, existing or in progress;
- All the morpho hydrographic data were remeasured to establish more precisely the routes of some watercourses, the origin of the valleys, and the watercourses that cross the karst areas;
- The general concept regarding the coding of the hydrographic network within a number of 15 hydrographic basins of order 1 has been kept, with the consideration of tributaries up to order 6 inclusive, respecting the minimum coding condition: the length of the watercourse of 5 km and the surface of 10 km2 basin clearly individualized valley in terms of geomorphology, and permanent flow of the watercourse for most of the year. On each stream, the numbering of the tributaries was made from the source to the outflow;
- The codification of other watercourses that meet the mentioned conditions were also taken into account and were not included in the previous edition;
- To the main categories of information contained in the cadastral atlas of the 1964 edition as: the name of the watercourse, the length of the course from the spring, the surface of the receiving basin, the code of the watercourse (order 1-6), some data were added. Location of the presented

section: position of the confluence of the watercourse concerning the collector, the altitude at the source or the source of the valley, as well as at the confluences, average slope, sinuosity coefficient. Also, data on natural lakes, accumulation lakes, forest area, and water surface area were added;

- Hydronymy was treated as a special problem, aiming to nominate all watercourses, which were specified as the official name, and the local secondary names were presented. In order to establish the hydronyms, the existing cartographic documents were researched (topographic maps at 1: 100,000, 1: 50.000,1: 25.000 scales, topographic plans at 1: 10,000 and 1: 5000 scales, maps, and cadastral plans, tourist maps, geographical studies, and other materials). Also, for the correct establishment of hydronyms, field surveys and observations made by the former County Water Management Offices were taken into account, and for their correct writing, the guidelines of the Romanian Language Cultivation Commission of the Romanian Academy were followed [5].
- All morphological and hydrographic data on watercourses per river basins were obtained by measurements and topographic maps at a scale of 1: 50,000. To specify some ambiguities regarding the routes of some watercourses, the valleys' origin, and the reception basins' limits, the topographic maps were also used at a scale of 1: 25.000.
- The data regarding the Danube Delta, the Black Sea, and the Romanian Black Sea Coast were structured in separate chapters to present the main morpho hydrographic elements that characterize them.
- The volume of maps contains 130 sheets of 1: 100,000 scale maps with the following characteristics:
- The maps in a print run of 350 copies are printed in a reverse system;
- All the water management works, existing on the territory of the country in 1986, are included on the maps, including those in progress;
- The maps include the hydrographic network of order 1-6, including the modifications that occurred by it following the

hydro-technical works executed on the watercourses and in the territory;
- The maps also contain natural lakes, swamps and ponds, forest bottom;
- The boundaries of the basins from order 1 to 6 and their codes were written on the maps;
- As planimetry elements, the maps include: localities (municipalities, common cities, villages), roads (roads, roads, railways), administrative boundaries (state border, boundaries of municipalities, cities, communes);
- The level curves are represented with an equidistance of 200 m in the hill, mountain, and 100 m areas in the plain area.
- In addition to the 1964 edition of the Cadastral Atlas, the following was presented: a map of the Danube river basin with the river network that makes up this basin, a color map at a scale of 1: 300,000 comprising the Danube Delta and the Romanian Black Sea Coast.

The Information System Specific to the Field of Water Management

The object of the information system specific to the field of water management is the surface waters (surfaces occupied by the water mirror, land surfaces periodically occupied by waters, islands, ponds, ponds, etc.), works of protection, control, and use of surface waters, of groundwater, as well as the natural environment of the waters [6].

The purpose of the information system specific to the field of water management is to solve the knowledge, inventory, and systematic, quantitative, and qualitative evidence of all data on natural water conditions, as well as on the management, use, and protection of water resources and water quality (dams, dams, drains, canals, hydro technical arrangements, retentions, water supply, irrigation, etc.) for all waters on the Romanian territory.

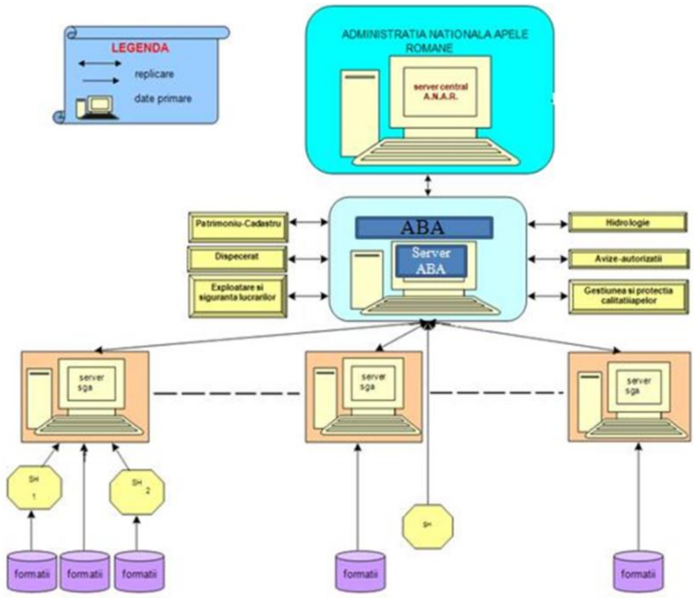

Figure 2: Information flow diagram for cadastral records.

By knowing the data about surface and groundwater throughout the country, a fundamental database is provided for the study, design, and implementation of water management, water resources, water sampling, and restitution in optimal conditions for the service and development of economic, social and ecosystem activities, related to the existence and use of water.

Romanian legislation provides the following:

The national fund for water management and the evidence of waters belonging to the public domain are included in the water cadastre, except for geothermal waters. The organization of the information system in the field of water management is established by the Ministry of Waters, Forests, and Environmental Protection, and the Romanian Waters Basin Administration ensures its up-to-date maintenance.

The national network of observations for water management comprises autonomous units and installations that provide hydrological, hydrogeological, and meteorological information and also, quantitative and qualitative characteristics of water resources (Figure 2).

The delimitation of the minor riverbeds is carried out by the Romanian Waters Basin Administration, the cadastre authority, and the owners of the riparian lands. This provision is an element of the general cadastre and connects with the other provisions of Law No. 7/1996 with specific information systems.

Administration of the Database of the Information System Specific to the Field of Water Management

The coordination of the cadastre activity presupposes the following activities

- controls, verify, and guides the activity of the water cadastre at the basin and country level;
- coordinates the design and implementation of software applications for the centralization of cadastral data in the country;
- methodologically ensures the uniqueness of the way of organizing, managing, and conserving the water cadastre; elaborates methodologies and instructions regarding the exploitation of the database of the information system specific to the field of water management;
- approves the basin cadastral synthesis;
- monitors, analyzes, and proposes the improvement of the GIS of the information system specific to the field of water management;
- organizes at least once a year cadastral training with the cadastral managers of the territory and with the computer scientists who collaborate in this activity;
- elaborates themes and follows the realization of cartographic materials at various stairs, atlases, and other works necessary for the activity of water cadastre;
- The Water Basin Administration ensures the application of the information system methodology specific to the field of water management at the territorial and basin level, supports, controls, and ensures with technical endowment the activity of the water cadastre, corresponding to the informational requirements (Figure 3).

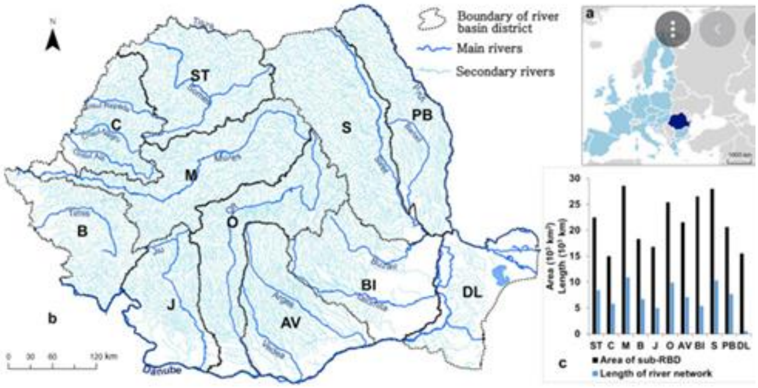

Figure 3: Romanian Waters National Administration [7].

The following are the tasks of the administrator of the database of the information system specific to the field of water management at the basin level:

- coordinates the activity of the water cadastre at basin level;
- aims at carrying out the controls at the cadastral objectives;
- verifies the updating of the information from the objective file and the database after controls and from the activity of issuing the regulatory documents;
- follows the inventory of the cadastral objectives within the basin;
- ensures the training of the personnel with tasks in the cadastral activity;
- monitors and ensures the uniqueness of the cadastral information at the basin level;
- provides on request existing information in the cadastral records;
- realizes the cadastral synthesis of the hydrographic basin;
- ensures the approval of the basin synthesis together with all those who have contributed to the collection, upload, and validation of data;
- responds, controls, guides, and reports on the way of carrying out this activity up to the training level;
- collaborates with the IT services of the Water Basin Administrations, which have an obligation to support the cadastre offices on the IT line permanently;

Information Flow of Data

The main actions followed in the realization of the water cadastre are:

- control of cadastral objectives;
- collection of information,
- preparation of the objective file;
- systematization and storage of information in files;
- centralization and data processing.

Organizing the Information System Specific to the Field of Water Management

The central public authority in the field of water has the following main tasks:

- establishes the organization methodology and the evidence of the water cadastre, adapting it to the organizational requirements at the country level;
- ensures the connection with the general cadastre to create the possibility of applying the Law on cadastre and real estate advertising no. 7/1996 in the water management activity;
- monitors the updating of water management information, including the water cadastre database;
- approves the content of cadastral syntheses and data at the basin level;
- centralizes the information on water management from the water cadastre at the national level.

The basin authorities follow the inventory and verify all the objectives that use water or are related to the waters distributed in the following groups of cadastral categories:

a) Works, constructions, and installations that ensure the complex management of waters, including the attenuation of floods, by modifying the natural flow regime:

- dams (technical data);
- permanent or non-permanent accumulation lakes, fish ponds (technical data);
- river flow derivations (capture, technical data, discharge).

b) Water use works with the afferent constructions and installations, respectively works, constructions and installations for water quality protection or which influence the water quality:

- water uses for populated centers, industrial platforms, socio-economic and zootechnical objectives (technical data related to water intakes, catchments, treatment plants, distribution nodes, discharges, treatment plants, drilling sectors, drilling, pumping stations, etc.);
- fishing facilities that are not made by damming a watercourse (technical data related as appropriate to outlets, catchments, discharges, pumping stations, etc.);
- water supplies for irrigation (related as appropriate - outlets, catchments, pumping stations, discharges, etc.);
- hydromechanical uses (technical data related as appropriate to outlets, catchments, discharges, pumping stations, etc.);
- hydroelectric power plants (technical data related, as the case may be, to capture, evacuation, pumping stations, etc.);
- navigable areas, ports (technical data);
- spa, tourist, and leisure facilities (technical data related, as the case may be, to catchments, discharges, pumping stations, etc.);
- floating bridges, ferries (technical data);

c) Constructions of defense against the destructive action of water:

- dykes on the watercourse;
- riverbed regularization works and works for the protection of riverbeds and banks;
- drainage works;
- floodable enclosures (related as appropriate to compartments and spillways).

d) Crossings of watercourses with the related works:

- bridges and footbridges;
- crossings of pipes, and canals;
- electric and telephone lines.

e) Arrangements and installations for the extraction of mineral aggregates from the riverbeds or banks of watercourses, accumulation lakes, and the sea shore:

- areas of exploitation of materials and useful aggregates from the riverbeds;
- exploitation of materials and useful mineral aggregates from the riverbeds.

f) The natural environment:

- watercourses, minor and major riverbeds;
- transverse / longitudinal profiles;
- natural lakes, ponds, wetlands;
- degradation of riverbeds, banks, and cliffs;
- the terminals of the cadastral reference axis of the watercourses;
- floods of land and property.

g) Monitoring:

- meteorological stations;
- hydrological stations;
- automatic stations and data transmission relays;
- flow meters (related to the intended uses);
- quality stations.

h) Prospecting, exploration/exploitation works through drilling:

- hydrogeological drilling

i) Other constructions and hydro-technical works:

- constructions (branch offices, operations, systems, cantons, etc.).

Drawing Up and Updating the Water Cadastre Database

The construction and updating of the database are as follows:

a) the files of the cadastral objects are drawn up and kept at the territorial level, where the information is uploaded to the database, and periodic checks are made;
b) the basin authority verifies the information by sampling and introduces new objectives, as the case may be;
c) the national authority has access to information directly by calling the database;
d) the central public authority in the field of water can obtain the centralized information at the country level from the national authority from the water cadastre database, or through the reports and summaries generated by the water cadastre application.

The Stages of Drawing up the Water Cadastre

The elaboration of the water cadastre represents a laborious and large-scale stage activity, which is executed in several stages, grouped as follows:

A. Primary cadastral inventory;
B. Cadastral records;
C. Realization on the field of the cadastral reference system;
D. Processing, systematization, and synthesis of primary cadastral data.

E. Topographic surveys specific to the water cadastre

Primary Cadastral Inventory

The primary cadastral inventory is performed on river basins, following the realization of the following cadastral branches:

- the cadastre of natural conditions (natural framework);
- the cadastre of water control works;

- cadastre of water use works;
- cadastre of works for water quality protection.

a) The cadastre of natural conditions

It refers to watercourses, lakes, reservoirs, ponds, and the sea coast, in the following aspects:

- degradation of riverbeds and neighboring lands (bank collapses, erosions, deposits, changes of courses, bottlenecks, torrents, ravines, floods);
- groundwater sources: hydrostatic levels, flows, water quality.

b) The cadastre of water control works

- hydrometric installations: location, installations, periods for making observations, etc.
- hydro-technical works for the protection and regulation of the riverbed: dams, dams, bank consolidations;
- drainage and drainage works: drains, canals, pumping stations, etc.

c) Cadastre of water use works

- installations and constructions for water use to capitalize on the hydropower potential, drinking and/or industrial water supply, irrigation, fish farming, and fishing facilities, navigation, balneo-therapeutic waters, recreational waters, ballast exploitation in riverbeds.

d) Cadastre of water protection works

- outflows and outlets for the discharge of domestic and/or industrial wastewater;
- domestic and/or industrial wastewater treatment plants
- the sanitary protection areas of the water sources, drinking water treatment and transport installations, or spa treatment.

Cadastral Evidence

After carrying out the primary cadastral inventory, systematic field checks must be made periodically to record the changes produced in the natural environment at the works of control, use, and protection of water quality. On this occasion, new cadastral files are drawn up, which represent the cadastral records and the files drawn up for the primary cadastral inventory.

Cadastral records are prepared as follows:

- annually for the natural environment;
- whenever there are changes in the works of control, use, and protection of water quality.

For example, here is the content of a primary cadastral inventory sheet.

Inventory sheet for drawing up the primary cadastre and the cadastral record regarding the degradation of the riverbed and the neighboring lands.

One or more inventory sheets and cadastral records are drawn up, depending on the area where the riverbed is degraded or in the process of degradation, as well as where there are floodplains, which is clearly shown.

- In stage I, the following data are completed:

- administrative and hydrographic position of the degraded riverbed or floodplain area;
- the 1: 5000 scale sketch of the sector of interest is drawn up, stating: the local name (toponymy) of the cadastral area, the position of the area described in the file, the kilometer landmarks, and the nearest localities, the isolated constructions existing in the area, the river code, the distances required to recognize the place, the degraded place and the length on which the degradation takes place. The type of degradation is specified if it is shore erosion, torrent, ravine, landslide, riverbed change, clogging, etc. The causes

that led to the degradation are shown (deforestation, irrational crop rotations, plowing on the highest slope line, earthquakes, high groundwater levels, long torrential rains, infiltrations from degraded water pipes or sewers, etc.).

- Stage II includes the group of characteristic technical data, as follows:

- brief description of the degradation characteristics and how the degradation evolved, speed, shore, slope, depth, nature of the material brought, etc .;
- size and extent of degradation;
- the type of vegetation or culture before degradation and after degradation, if the land is still in use before degradation or is transferred to unproductive, degraded land;
- the age in years of the degradation or of the floods (incipient, evolutionary, stationary, advanced, etc.);
- immediate or subsequent consequences of degradation (interruption of circulation, reduction of agricultural production, etc.);
- in the comments section, assessments are made on the urgency of the measures for consolidating or rectifying the riverbeds in the areas exposed to degradation, etc.

In the same way, the files are drawn up for the works of arrangement and protection of the riverbeds and the neighboring lands, or drainages and the protection against floods, for the works of protection of water quality, etc.
The cadastral works of primary inventory and cadastral evidence are drawn up in primary inventory sheets, which include the main technical data and an adequate scale sketch of the cadastral objective. The completion of the forms is done according to the specific instructions. Each sheet is numbered and coded in order from the confluence with the emissary to the spring. During the inventory works, the provisional numbering can be done, and at the end of the work, the final numbering on basins and sub-basins is done [8].

Cadastral Reference System

The cadastral reference system is necessary for the location in the field and on the cadastral plan of all the elements that are the object of the water fund cadastre and is executed by the specialized institutions of the National Administration. "Romanian Waters".

The cadastral axis represents a homogeneous and unitary system of geodetic points necessary in different activities such as elaboration and execution of water management projects and efficient exploitation of water resources by keeping the information system specific to the field up to date of water management. In addition, the cadastral axis is usable in the activity of other stakeholders in the area (roads, land improvements, forestry, etc.)

The reference system consists of the mileage-leveling axis, chosen along the waters, materialized on the ground by terminals, and determined topographically by planimetric routes.
The mileage-leveling axis is placed, as far as possible, as a line parallel to the major water bed, located near the shore, without cutting the large elbows of the bed.
The distance between the reference axis and the river depends on the size of the watercourse, the width of the floodplains, varying between a few hundred meters and a kilometer, or very close to the shore in the case of mountainous areas.

The mileage axis must not follow the loops of watercourses smaller than 1 km, and their origin is taken at the point of water discharge into the emissary, based on the mileage-leveling axis of the water into which it flows and to which it is connected.

The following points are bounded on the mileage-leveling axis:

- points marking kilometers;
- the intermediate points of breaking the axis due to the configuration of the terrain and the course;
- the points marking the origins of the tributary axis;

- important points along the route: bridges, dams, hydrometric gauges, etc.

The mileage-leveling markings type terminals must be resistant, visible, with absolute dimensions in the general leveling system, having the respective kilometer painted on it.

The mileage is planted so that:

- be accessible all year round;
- be protected from flooding, erosion, or other degradation, preferably on the higher and more consolidated shore;
- bank slopes and cultivated land should be avoided (recommended location on the border between two properties).
- Usually, the landmarks are placed at distances of 1 km between them, but exceptions are imposed by the terrain configuration, by passages from one shore to another, when distances of 1 km are allowed, and on the terminal are written the kilometer and meters.

The topo-geodetic traces through which the mileage-leveling axis is determined can be located on a single bank or pass as rectangular as possible from one bank to another, bypassing obstacles, and are connected to the triangulation network of the country. The elevations of the mileage-leveling axis points are determined only by geometric leveling, starting from the general leveling network of the country and only in exceptional cases is allowed the quotation in local, arbitrary systems, but which will later be linked to the general leveling of the country [9].

The mileage-leveling axis is useful for reporting all the elements inventoried within the water cadastre and as a reference system for future riverbed surveys. All the cadastral objects identified and inventoried are represented by distances and elevations from this reference system, which are checked periodically to determine their possible changes in time.

Also, from the points of the mileage-leveling axis are determined the absolute altitudes of the hydro-technical works, the evolutions of the riverbed changes, as well as the delimitation of the floodable areas.

The cadastral inventory and record sheets are also located in relation to the mileage-leveling axis by indicating the kilometer at which the cadastral object is located.

Cadastral maps are drawn up only after the cadastral reference system and include the topo-hydrographic works of the major riverbed and the surrounding area (for locating cadastral objects), floodable areas, points of the kilometer axis, boundaries of administrative territories of communes, urban outlines, etc. .

The river basins are delimited using the reference system formed by the mileage-leveling axis. The boundary of a river basin runs on the ridge line or the watershed line, practically exceeding two water receiving basins, in which the waters flow to two different collectors.

Processing and Systematization of Cadastral Data. Syntheses and Atlases Specific to the Water Field

The departmental institutions of the National Administration "Romanian Waters" annually prepare summaries regarding the water fund cadastre, on hydrographic basins, based on the primary data sent by the water directorates for water management. These data include elements specifying the name, length, altitude upstream and downstream, average slope, river sinuosity coefficient, basin area, forest floor area, natural lakes, etc., technical elements related to protection works and installations, and water use and arrangement [10].

The decimal coding of each watercourse allows the classification of the cadastral data regarding the waters in files that make up the database of the water cadastre in Romania. The files are designed to allow updating, retrieval, and easy exploitation of the information they contain.

The database allows the automatic preparation of annual summaries, the management and automatic recording of data on watercourses to obtain the area of a basin, the surface of the forest fund in the basin, the surface of natural or artificial lakes, filling in information related to the etymology of the name of rivers, etc.

Syntheses and atlases specific to the field of water management according to Order no. 1276/2005 are the following:

- *The atlas of the codified hydrographic network in Romania and the evidence of the waters belonging to the public domain*
    - part I, text: "Morphohydrographic and basic data on the coded hydrographic network, groundwater and evidence of waters belonging to the public domain";
    - part II, maps: "The hydrographic atlas of Romania", with the evidence of the waters belonging to the public domain.
    - *Atlas of surface and groundwater resources in Romania*
    - Part I, text: "Data on hydrometric, hydrological and evaporimeter activity on watercourses, natural lakes and reservoirs and hydrological data on surface and groundwater resources";
    - part II, maps: "Atlas of surface and groundwater resources of Romania".
- *Atlas of water management works and water-consuming and non-consuming uses*
    - part I, text: "Data on water management works and water consuming and non-consuming uses";
    - part II, maps: "Map of water management works and of consuming and non-consuming water uses".
- *Atlas of flood defense works and combating the destructive action of waters*
    - part I, text: "Data on flood protection works and control of destructive water actions";
    - part II, maps: "Atlas of flood defense works and combating the destructive action of waters".
- *Atlas of surface water quality, water treatment, and purification works, and water pollution sources*

- Part I, text: "Data on surface water quality, treatment, and waterworks and sources of water pollution";
- Part II, maps: "Surface water quality atlas, water treatment, and purification works and water pollution sources in Romania";

- *Atlas of Water Bodies*
  - Part I, text: "Data on water bodies with main characteristics";
  - Part II, maps: "Atlas of water bodies".
- *The cadastral synthesis of the Danube on Romanian territory,* in the form of centralizers at national level, with details on hydrographic basins and counties.

Collection of Geospatial Data Specific to the Water Cadastre

Modern spatial data collection technologies offer important advantages of accuracy, processing time, and spatial resolution, which increase security in tracking the behavior over time of various engineering works. These technologies also come with important software support that offers possibilities for complex and automated analysis of a large volume of spatially repeated time data that lead to the exact and correct quantification of all the changes that occurred during the operation of various engineering sites. Another significant advantage of modern spatial data collection technologies is that the spatial information has a continuous character (mesh surfaces, orthophoto plane, numerical terrain model, etc.) which serves as a comprehensive tool for assessing the behavior of the objectives over time [11].

In the case of hydro-technical arrangements, the following parameters are measured:

- Upper basin
- The lower basin
- Slope consolidations
- The development of shrub vegetation that will replace the consolidation in time
- The general impact on the environment of the whole ensemble (dam, drain pipe, basins, and consolidations)

Used Equipment

The collection of geospatial data specific to hydro-technical objectives can be done using modern technologies supported by modern equipment capable of highlighting all relevant geometric elements of cadastral objectives with increased efficiency and accuracy (Figure 4).

The usable equipment covers almost the entire spectrum of terrestrial measurements and is exemplified together with the technical characteristics below:

South 82 GNSS multi-frequency receiver with built-in multipath technology and satellite fixing technology for a good calculation of positions in urban areas and forests [12];

High static positioning accuracy
Horizontal = 3 mm ± 0.3 ppm
Vertical = 4 mm ± 0.5 ppm

Static determination accuracy qualifies these GNSS receivers to create a freely compensated base network capable of being the topographic basis for detailed topographic surveys [13].


Receptor GNSS South 82-2013 Precision Level Leica DNA03 Digital

SmartStation Leica system
Total station TCR 1205-PinPoint R100;
GNSS receiver SmartAntenna ATX 1230 GG

Figure 4: Equipment for spatial data collection

Precision Level DNA Leica

The accuracy of 0.3 mm / Km from the technical specifications can ensure optimal conditions for transmission and determination of the elevations of the hydrometric stations by creating a network of precision geometric leveling.

Smart Total Station is safe and accurate support for X.Y, Z spatial measurements that would ensure three-dimensional accuracy on the three dimensions for positioning the 3D scanner or for measuring the characteristic points in the minor bed.

Maptek terrestrial laser scanner with the good spatial resolution is an important technical support for spatial measurements of objectives with complex morphologies within river basins (Figure 5).

Figure 5: Maptek_I-Site_8820 terestrial laser scanner.

Figure 6: Altura Zenith ATX4.

Drone for GIS helicopter platform investigations - ALTURA ZENITH ATX equipped with a multispectral sensor with 16 Mp resolution is an efficient tool in mapping vegetation of all types in the minor riverbeds (Figure 6) [14].

Spatial Data Collection Method

The realization of the support network for performing the measurements can be constituted by six basic planimetric landmarks located as follows:

- two basic planimetric landmarks outside the buildable site (not further than 2000m)
- two basic planimetric landmarks near the upper basin
- two basic planimetric landmarks near the lower basin

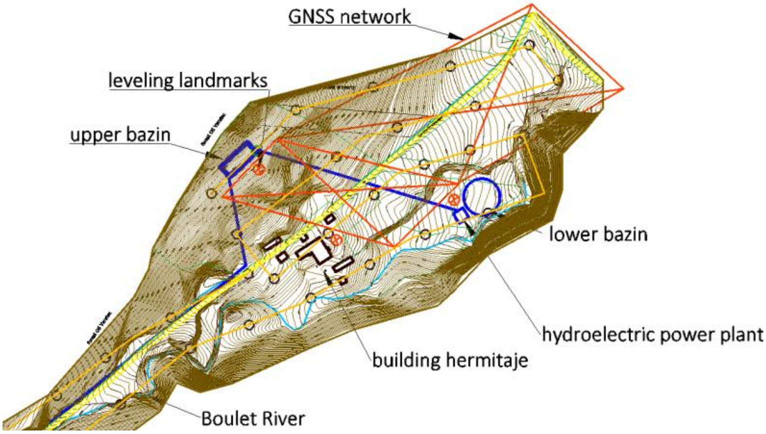

Figure 7: Location of the basic atmospheric and planimetric support network

If one or more basic landmarks are damaged, the following measurements will be based on the remaining landmarks [15].

Static GNSS measurements can determine the ground planimetric network. For this purpose, three South 82 GNSS receivers can be used, measuring three vectors in each satellite observation session. The entire network will be determined from four measurement sessions of one hour each (Figure 7) [16].

For photogrammetric tracking, the 3D scanning topographic base, both for the scanner station points and the points in the point cloud required for registration, will determine static GNSS or SmartStation total station as appropriate, depending on visibility and other technical conditions from the terrain [17].

The collection of the geospatial data that characterize the areas of the hydro-technical arrangement with complex morphologies can be performed using Maptek 3D scanner with a high spatial resolution (min 2 cm) with support for point cloud recording, coordinates of station points of the scanner statically determined from the basic network, and points in the point cloud (same for each type of measurement) determined statically or with the total Smart station as the case may be. The basic points used for the point cloud registration will be materialized by painting on the rock or by planting terminals in the stable land in the area.

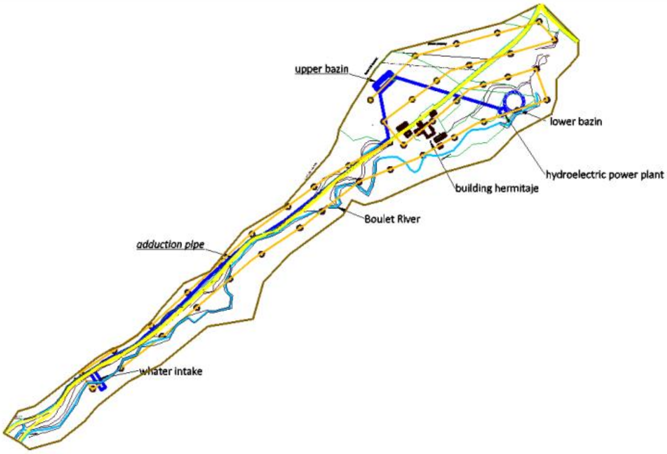

Figure 8: Flight project.

The collection and subsequent centralization of information about the vegetation that develops in the river basins are based on the data collected by the multispectral sensor located on the Drone and helicopters - ALTURA ZENITH ATX [18]. (Figure 8)

The monitoring cycles will be based on a static GNSS-determined photogrammetric trace supported on the same basic network.

By combining various information collected from the multispectral sensors, different information can be obtained, such as the development of vegetation types, humidity, temperature, and sun exposure, all spatially related and can be exploited in valuable analyses on the evolution of the microclimate in the area [19].

In case of disappearance or damage of the basic landmarks, additional measurements will be performed to evaluate the degree of confidence of the following measurements statistically.

Topographic Surveys Specific to the Water Cadastre

The topographic survey of the valleys of rivers and lakes includes the planimetric and altimetric survey of riverbeds, banks, and adjacent areas (Figure 9). The support network of these measurements must meet the following conditions:

- To ensure the planimetric representation of the land (existing objectives, bends and meanders of the riverbed, islands, sandbanks, etc.
- To ensure the representation of the relief (altimetry) of the land of the riverbed, the elevation of the water level along the river, and transversely on the river.
- As a rule, the support network for raising the valley and the riverbed consists of planimetric polygonometric and geometric leveling roads fixed on a single bank or both banks when the width of the riverbed exceeds 150 m.

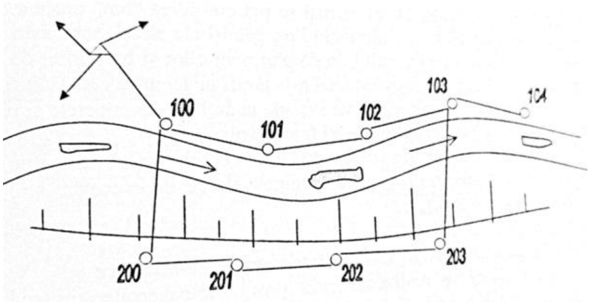

Figure 9: The topographic survey network.

The main route of the topo-geodetic tracing, which is approximately parallel to the river banks and at the limit of the middle water level, has a wide shape, with the sides approximately equal to approx. 500 m [20].

It will be supported at endpoints in the national triangulation and leveling network. The maximum length of the trips is 8-10 km.

All points of the planimetric route will be points of the geometric levelling route.

In the meadows of lowland rivers, with meanders covered with dense forests on the banks, reducing visibility, planimetric and geometric levelling is projected alternately on both banks, near water, on grids, etc.

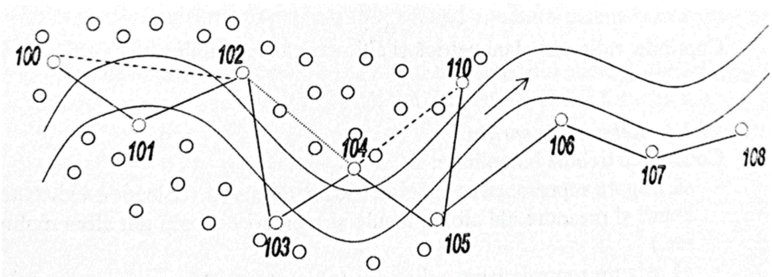

Figure 10: The planimetric and altimetric details.

If the water width is large, the topo-geodetic tracing can be replaced by micro- triangulation. The travel points are marked with reinforced concrete bollards so that they are also landmarks.

The notation of the planimetric and altimetric details is made by transversal profiles, the perpendicularity on the general transversal direction of the river valley at intervals of 50 - 300 m, and between the profiles, the details will be raised by spatial erasure (X, Y, Z) (Figure 10) [21].

Proposed Case Study-Procedure

With all the new technologies discovered in the field of terrestrial measurements, there are difficult areas in terms of relief and vegetation where the only possibility to perform the topographic survey is the classical one. The minor riverbeds represent such a situation with forest vegetation where transversal profiles must be measured with the highlighting of the wet areas in order to model the hydrological processes and the cadastral axis. In such areas, GNSS measurements are impossible due to the vegetation, and topographic measurements with the total station are much more difficult due to the relief and the precarious visibility conditions [22].

The most efficient procedure proposed is based on modifying the total station by adding a prism that allows simultaneous and reciprocal aiming between two devices.

This process solves the problem of spatial topographic hiking in poor visibility conditions, such as minor riverbeds of rivers with shrub forest vegetation.

The peculiarities of the proposed procedure consist of the following:

- reciprocal and simultaneous aiming between two devices with the same angular and distance precision parameters;
- the lack of materialization of the stations in the field (the materialization of the stations is not completely eliminated, this being done in the open areas at intervals of 1 km - 20 stations).

The classic method analyzed consists of performing measurements with a single device and two prisms, the necessary staff being composed of three operators: two at the milestone and one at the device.

The sequence of operations is the classic one and is described synthetically in the Gantt chart (Figure 15), in which the economic analysis of the process is done.

The proposed procedure involves using two devices and a single milestone for measuring radiated points. From the point of view of staff, the need is the same for three operators: two for the devices and one for the milestone.

The Principle of the Method

The proposed method is based on a modification to the total station, which consists of mounting a prism - mini prisms on the handle of the device according to the sketch below (Figure 11):

Figure 11: Changing the total station by mounting a mini prism.

This allows simultaneous and reciprocal aiming between two devices on which this change has been made.

Although the constants of the prisms are known for their use on the milestone, after their mounting on the devices, it is necessary to redetermine because there are differences after the mounting.

To check the safety of the installation, the determination of the prism constants is done both before and after the measurements, obtaining the same values, which means that the installation is safe.

The determination of the constants of the two prisms consists of the simultaneous measurement of the inclined distances and the corresponding zenith angles and their comparison with the distance measured with a dystoma (considered correct) - between the two total stations (Figure 12).

Figure 12 (Foto and scheme): Determination of the two mounted mini prisms constants (foto).

Where

D_{disto} - the (real) inclined distance between the points determined by the intersection (VV', OO')
D_{odd} - the inclined distance measured between the "odd" station to the "even" station through the prism installed on the "even" device
D_{even} - the inclined distance measured between the "even" station to the "odd" station through the prism installed on the "odd" device
Z_{odd} - the horizontal angle corresponding to the distance D_{odd}
Z_{even} - the horizontal angle corresponding to the distance D_{even}

- the corresponding horizontal angle D_{disto} (measured with the dystomat), the angle being measured at the intersection of the reticular wires of the "even" device
- the corresponding horizontal angle D_{disto}(measured with the dystomat), the angle being measured at the intersection of the reticular wires of the "odd" device
  D^0 - reduced horizon distance (horizontal)

Since in the proposed procedure, the topo-geodetic tracing points are measured alternately: with one device the even points and with the other the odd points, we will differentiate the two devices between them as even and odd [23].

Field Work Mode

The way of working in the field is similar to the classic one, except that both ends of a side of the road are parked simultaneously at the 'even' and 'odd' points (Figure 13).

$$\sin Z_{impar} = \frac{D^0}{D_{impar}}$$

$$\sin Z_{impar}^{disto} = \frac{D^0}{D_{disto}^{impar}}$$

$$D_{disto}^{impar} = D_{impar}\frac{\sin Z_{impar}}{\sin Z_{impar}^{disto}} \;;\quad C^{impar} = D_{disto}^{impar} - D_{disto} = 0.011m$$

analog

$$D_{disto}^{par} = D_{par}\frac{\sin Z_{par}}{\sin Z_{par}^{disto}} \;;\quad C^{par} = D_{disto}^{par} - D_{disto} = 0.009m$$

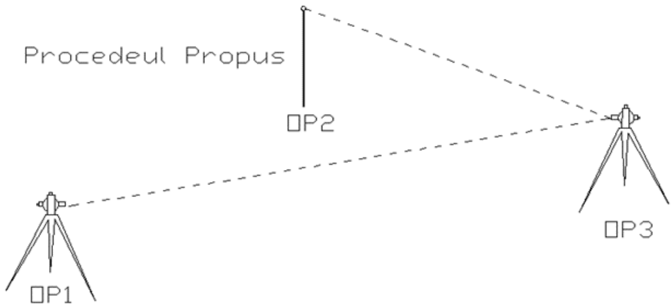

Figure 13: How to work in the field the proposed procedure.

After aiming reciprocally back to the 'even' point and forward to the 'odd' point, the operator from the 'back-even' point can move to the other 'even' point of the route, station, and set the station, during which the radiated points can be measured. by the 'odd' point operator. After installing the 'even-forward' point in the station, the reciprocal and simultaneous visa can be made forward to the 'even-forward' point and back to the 'odd-back' point, thus freeing the operator from the 'odd-back' point to move. to the other point of the 'odd-forward' journey thus ending a whole cycle of measurement.

The materialization of the station points will not be completely absent, this being done at intervals of 20 station points; this means in conditions of difficult visibility, about a kilometer of travel.

Testing the Proposed Method

To test the proposed method, a section of about one kilometer of the lower course of the Nicolina River was chosen. The route of topographic route on which the proposed model will be tested occurs along the forested bed of the Nicolina river and aims, in principle, to measure the transverse profiles of the bed with the identification of the wet section (water gloss, trough, water gloss). This forces the route near the riverbed to follow its winding route (Figure 14).

On this route, the topo-geodetic tracing was performed (measured) by the classical method with a device and two milestones (three operators), materializing the station points and timing all operations: station materialization, centering, riding, measuring radiated points, movement between station points, etc. to determine the average time for each operation carried out in those conditions of relief and visibility. After this, in the same meteorological and visibility conditions, the measurements were performed using the proposed procedure with two devices and a milestone (three operators) timing and all the operations to calculate the average execution times for Gantt charts.

The bases of departure and arrival were materialized with terminals and determined by GNSS in four measurement cycles keeping their average.

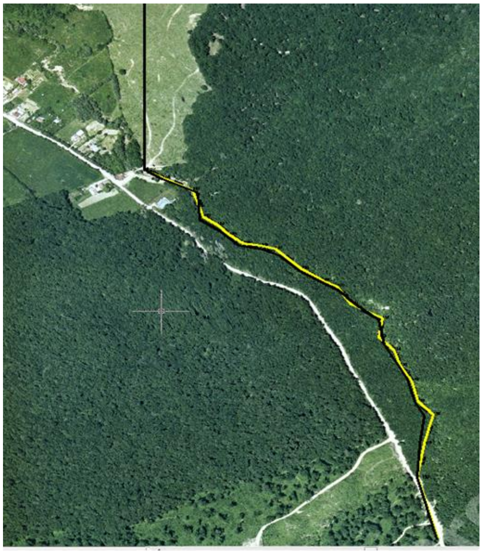

Figure 14: The route of the two topo test geodetic traces

Evaluation from an Economic Point of View

Analysis of the economic efficiency of the two processes: proposed and classic based on Gantt charts (Figure 15).

The graphs for the two processes were plotted based on the average execution time of each work operation. The average time was calculated from the timing of each operation in the field.

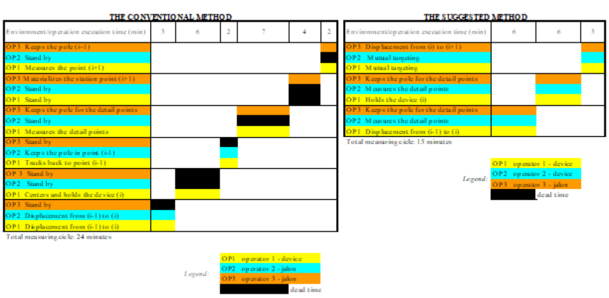

Figure 15: Gantt charts for the two processes: Classic and Proposed.

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