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Proposal for Technical Registry of Sanitation Networks Through an Open Structure Using SpatiaLite Database

Proposta de Cadastro Técnico de Redes de Saneamento por Meio de uma Estrutura Aberta Usando Banco de Dados SpatiaLite

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Abstract

Investment in sanitation and infrastructure is essential to ensure quality of human life, so its absence or fragility can lead to a scenario of calamities. Among the elements that constitute the infrastructure of a sanitation system is the technical register responsible for gathering all the information inherent to the system from the implementation of the network to the final destination of the effluent, provided for in the stages of design, execution and continuity of operations. As a result, GIS have become fundamental tools for the registration of sanitation networks, as they provide the integration of descriptive and graphic data in the same base. In this context, the objective of this study was the implementation of a database in free software through the SpatiaLite extension, aggregated georeferenced spatial information of components of a sanitary sewage network, producing a proposal for a Technical Registry. Processing was developed in the software QGIS 3.16, in which the elements of "Inspection Box" were used in the model, being represented vectorially by geometry of "Point" and "Extension" represented by "Line" to form a spatial system on the structure and location by means of vectorization on screen. As a result, the implementation of the register through the SpatiaLite platform, ensured fast processing, positional accuracy, conformity of cartographic representation, topology between classes, format consistency and completeness. However, the database enabled to analyze together all the components interrelated with the sewage system, through technical information for the management and efficiency of basic sanitation services.

Keywords: Sanitary Sewage; Water supply; Geoprocessing

Resumo

O investimento em saneamento e infraestrutura é fundamental para garantir a qualidade de vida humana, por isso sua ausência ou fragilidade pode levar a um cenário de calamidades. Dentre os elementos que constituem a infraestrutura de um sistema de saneamento está o cadastro técnico responsável por reunir todas as informações inerentes ao sistema desde a implantação da rede até a destinação final do efluente, previstas nas etapas de projeto, execução e continuidade de operações. Com isso, os SIGs tornaram-se ferramentas fundamentais para o cadastro de redes de saneamento, pois proporcionam a integração de dados descritivos e gráficos em uma mesma base. Nesse contexto, o objetivo deste estudo foi a implementação de um banco de dados em software livre por meio da extensão SpatiaLite, agregando informações espaciais georreferenciadas de componentes de uma rede de esgotamento sanitário, produzindo uma proposta de Cadastro Técnico. O processamento foi desenvolvido no software QGIS 3.16, no qual os elementos de "Caixa de Inspeção" foram utilizados no modelo, sendo representados vetorialmente pela geometria de "Ponto" e "Extensão" representada por "Linha" para formar um sistema espacial na estrutura e localização por meio de vetorização na tela. Como resultado, a implementação do cadastro através da plataforma SpatiaLite, garantiu rapidez de processamento, precisão posicional, conformidade da representação cartográfica, topologia entre classes, consistência de formato e completude. No entanto, o banco de dados permitiu analisar em conjunto todos os componentes inter-relacionados com o sistema de esgotamento sanitário, por meio de informações técnicas para a gestão e eficiência dos serviços de saneamento básico.

Palavras-chave: Esgotamento sanitário; Abastecimento de água; Geoprocessamento

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1 Introduction

The lack of sanitation infrastructure and water supply is a public health problem. Investments in these services guarantee several externalities that impact quality of life, health and the environment (Pereira et al. 2022). In addition, the deficiency in universal coverage of water and sanitation services, or even its fragility in terms of structure, efficiency and quality, can induce a calamity scenario with an exponential increase in diseases, especially those related to water transmission (Medeiros et al. 2020; Massa & Chiavegatto 2020).

One of the most significant governmental challenges in Brazil is to ensure the universalization of water and sanitation services, regardless of all the geographical difficulties for service provision in certain regions (Ferreira et al. 2021). However, the use of data and information to define, monitor and analyze the impact of public policy in Brazil is still limited, compromising the monitoring of the results of State actions.

The Brazilian National Sanitation Information System (SNIS) was created with the purpose of disseminating information on sanitation, contributing to the national sanitation policy (Faria et al. 2022). This database contains information and indicators on water supply, sanitary sewage services, urban solid waste management, and drainage and stormwater management, which are provided annually by service providers. However, sharing this information is still a challenge because it depends on the integration between the sanitation and environment sectors and the health sector (Silva et al. 2017).

In this context, geographic information systems (GISs) are software applications that allow the integration of information about the study area in the form of maps, images, graphs, symbols, texts, mathematical and statistical representations or animations (Oyedotun & Moonsammy 2021). Uniting different information from the same area in a single database, enabling global understanding about the spatial nature of the location, expanding the universalization of access to data and information. Ensuring dynamism and practicality in all stages of a Sanitation System and Water Supply, from deployment (design and implementation of the network) to future management (maintenance and expansion).

Among the studies that have correlated GIS applications with sanitation planning and structuring, the following stand out: Oyedotun and Moonsammy (2021), analyzed methodological approaches in GIS to demonstrate how decisions based on geospatialization and information integration can be taken for the water management sector waste. Chakraborty et al. (2022) mapped COVID-19 hotspots during peak hours in the first and second waves of the pandemic through GIS databases to demonstrate the need and usefulness of the wastewater surveillance strategy in the Indo-Ganga-Brahmaputra River Basin, in India during the ongoing pandemic. Aragão (2020) who described a process of building a Web GIS with free and no cost technologies and its implementation in a public service concessionaire in the area of basic sanitation.

In this sense, this study aims to analyze a GIS-based structuring through free access software, integrating layers of spatial information of the sewage network, at the level of a technical record, inherent to the process of design, execution and continuity of the network, resulting in a integrated management of basic sanitation.

2 Methodology and Data

2.1 Materials

The technical record of the Sanitation System is the set of geospatial information: attributes and graphic representations, which covers Water Supply and Sanitary Sewage data, containing information about the Network, elements that compose it and points of final disposal of effluents. With this, elements that cover the design, execution, maintenance and continuity of the system are identified.

The preparation of technical records of the water supply and sanitary sewage system is guided by ABNT according to NBR 12.586/92, which sets the conditions required for the preparation of a water supply system record and NBR 12.587/92, which sets the conditions required for the preparation of a sanitary sewage system registry (Bonavita & Fonseca 2019).

As materials in this study, information bases of national sewage and water supply systems were used, which integrate their data through GIS, such as the Companhia Pernambucana de Saneamento (COMPESA 2021). The Company is responsible for managing sanitation in the state of Pernambuco, this system is carried out independently by each municipality that, at the end of the process, sends its information through a SIG provided by COMPESA for approval and grouping of data to the existing base. In this GIS, information is inserted with reference to NBR 12587/92 and NBR 12586/92 and DTSTV for the technical specifications for structuring digital vector geospatial data. With this, the attributes describe the static characteristics of the objects, descriptive information related to the represented feature. They are alphanumeric, and can be text, numeric or associated with the domain list.

In this study, information inherent to the design and execution of a Sanitary Sewage System in GIS was implemented, through the open access software QGIS 3.16, through the SpacialLite extension, enabling the sharing and integration of databases for free and with data accuracy, such as the open source library SpatiaLite.

2.2 QGIS

QGIS is a free, open-source, cross-platform geographic information system (GIS) software that allows the visualization, editing and analysis of georeferenced data. Similar to other GIS software, QGIS allows the user to analyze and edit spatial information, as well as create multi-layer maps using different projections, which can be assembled in different formats and for different uses. QGIS allows composing maps from raster and/or vector layers. Typical of this type of software, data can be stored as points, lines, or polygons. Different types of raster images are supported and the software has the ability to georeference images.

2.3 SpatiaLite

SpatiaLite is an open source library intended to extend the SQLite core to support full Spatial SQL capabilities by providing vector geodatabase functionality. SpatiaLite has the ability to support virtual tables. Furthermore, the entire SQL engine is directly built into the application itself: a complete database is simply an ordinary file that can be freely copied and transferred from one computer to another without any special precautions. QGIS supports the use of a SpatiaLite database format, which is a lightweight and portable way to store an entire spatial database in a single file (SpatiaLite 2018).

2.4 Technical Registry of Sanitation Networks and Geospatial Database

Sanitation systems aim at the process of converting wastewater into water that can be dumped into springs, without changing their quality (Calijuri & Cunha 2013). In a sewage collection network, wastewater is collected in a building connection and is drained by gravity through a collection network to a trunk collector. The sewage flows through pipes installed on public roads at depths and slopes that allow it to be moved by gravity to lower regions, even interceptors, pipes that do not receive direct connections, which in turn direct it to the outfalls that in turn lead to it. the Sewage Treatment Station, for the treatment and final destination of the effluent (Abraham 2017).

However, during the execution process of the Network, it is common the appearance of interferences in the network to be implemented with existing sanitary sewage networks, water supply networks, telephony, energy, among others, as shown in Figure 1, 2, 3 and 4, with this, it is necessary to implement as much information as possible in order to provide dynamics in the process of project change and/or network execution.

The cases presented in Figure 1, 2, 3 and 4 occurred during the execution of sanitation works in Recife, in which, in several executive processes, the network installations foreseen in the project, did not follow the original idea due to the meeting with drainage networks. It is noticeable the numerous problems that arise during the execution due to the absence of a solid base of technical registration. For example, interference with drainage networks, which cause losses to the water supply, delay in execution, project rework to redirect the network in order to comply with the existing network, loss of material, among others.

According to Rocco (2006), the absence of registration of the elements of the infrastructure networks makes the elaboration of the executive project difficult, which can often cause its impracticability or even its alteration, increasing the costs of the works. The occurrence of interference may be associated with the lack of technical registration of the existing concessionaire networks in the place, during the elaboration of the executive projects of the networks to be implemented (Bonavita & Fonseca 2019). The cited authors also affirm that the technical register of the already installed networks is of paramount importance for the elaboration of the executive project of the networks to be implanted in the same place.

Based on this, the elements used in the methodology for the formation of the database sought to ensure solid information on important stages in the sanitary sewage system such as: design, execution and future maintenance.

2.5 Data Structuring

For the implementation of the database and spatial queries on the data to be inserted, a data model was initially created, based on the exhaustion system for the box-branch components. Some structural variables of each component were considered, such that allow consultations, such as: ID (unique identifier of the asset), location, conditions of the asset (diameter, composition/material), physical conditions of the area to be implanted (type of pavement), altimetric information (top/ground elevation, bottom elevation, depth and slope).

Figure 1 Damage to the drainage network, at Rua Feliciano Lins, Recife during excavation for the construction of Collector.

Figure 2 Damage to the drainage network, at Rua Feliciano Lins, Recife during excavation for the execution of Collector.

Figure 3 When executing the collector, deactivated drainage networks were found at Rua Feliciano Lins, Recife.

Figure 4 When carrying out the extension, drainage networks were found, on Rua Rolândia, Recife.

The descriptive data of a DB store information about spatial objects, these data vary according to the structure according to the nature of what is being stored (Burrough 1986; Valdevino 2010). As a result, the domain type was gradually organized according to the respective attributes. Table 1 and 2 detail the conceptualization of each attribute and the type of integrated domain.

Table 1 List of domains and class of the Box object.

Field	Type	Description
ID	integer	Unique identifier code of the asset necessary for the integration of corporate systems.
Nome	String	Asset's unique identifier name.
Data_da_Instalacao	date	Asset installation date.
Condicao_da_caixa	text	Condition of the asset regarding conservation.
Tipo_pavimento	text	Material used in the pavement over the stretch of deployment of the asset.
Cota_terreno	int (5)	Dimension of the center of the asset cover.
Profundidade	int (5)	Difference in level between the terrain surface and the lower generatrix
Material	text	Material with the highest percentage of asset composition

Table 2 Domain list and Extension object class relationship.

Field	Type	Description
ID	integer	Unique identifier code of the asset necessary for the integration of corporate systems.
Nome	text	Asset unique identifier name
Data_da_Instalacao	date	Asset installation date.
Comprimento	int (5)	Tube length
Cota_Montante	int (5)	Dimension of the lower generatrix of the upstream tube.
Cota_Jusante	int (5)	Dimension of the lower generatrix of the downstream tube.
Material	text	Material with the highest percentage of asset composition

After designing the fields to be used in the database as well as their domains, the database model was established using the Object Modeling Technique (OMT-G) methodology associated with the Visio Professional software, version 5.0. The OMT model starts from the primitives defined for the Universal Modeling Language (UML) class diagram, introducing geographic primitives with the objective of increasing the semantic representation capacity of that model, reducing the distance between the mental model of the space to be modeled and the usual representation model (Davis & Laender 2000). Furthermore, this model has the object as its basic structure, combining the structure and behavior of the data in a single element (Rumbaugh et al. 1994). The OMT-G model is an extension of the OMT model plus notations capable of representing the geometric primitives of the modeled elements, as well as their relationships (Valdevino 2010).

Flowchart in the Figure 5 presents the registration process for the sanitary sewage system cadastral survey service, displaying the type of topological relationship of the object class.

2.6 Database Processing and Modeling

For the processing step, the asset classes and domains were generated. This process took place through the QGIS 3.16 software, in which a SpatialLite layer was created without associated geometry, entitled *Sewer*.

After this step, in the SQL query window of the DB manager, through the *Structured Query Language* (SQL) command lines, a table was created in which the columns containing registration information are inserted and later transformed into geometry through the *AddGeometryColumn* command. This function is intended to add columns and define geometry to an existing attribute table. For this, the command requires the name of the table, schema, EPSG code (Geodesic Reference System), in this study the SIRGAS 2000 system, officially used for cartographic works in Brazil, type and geometry format was adopted.

The attributes "*Material_cover*" and "*Material*" of the Cashier and Branch layers respectively were formed by predetermined sequential objects, that is, a drop-down menu that facilitated the filling of information in cases of uncertainty, since these fields have nomenclatures specific. For this operation it is necessary to insert the predetermined objects in text format (.csv) allowing the characterization of a drop-down list of values with the predetermined material names exemplified in Figure 6.

Through the database schema shown in Figure 1, it was possible to implement the code based on SQL language in the SpatiaLite-QGIS extension, resulting in the geospatial database of information registration of the "*Caixa*" and "*Ramal*" elements in the Esgoto file. sqlite (Figure 7).

Within the model, the labeled attributes (*Primary Key*) are representing the primary keys. This inclusion is produced automatically.

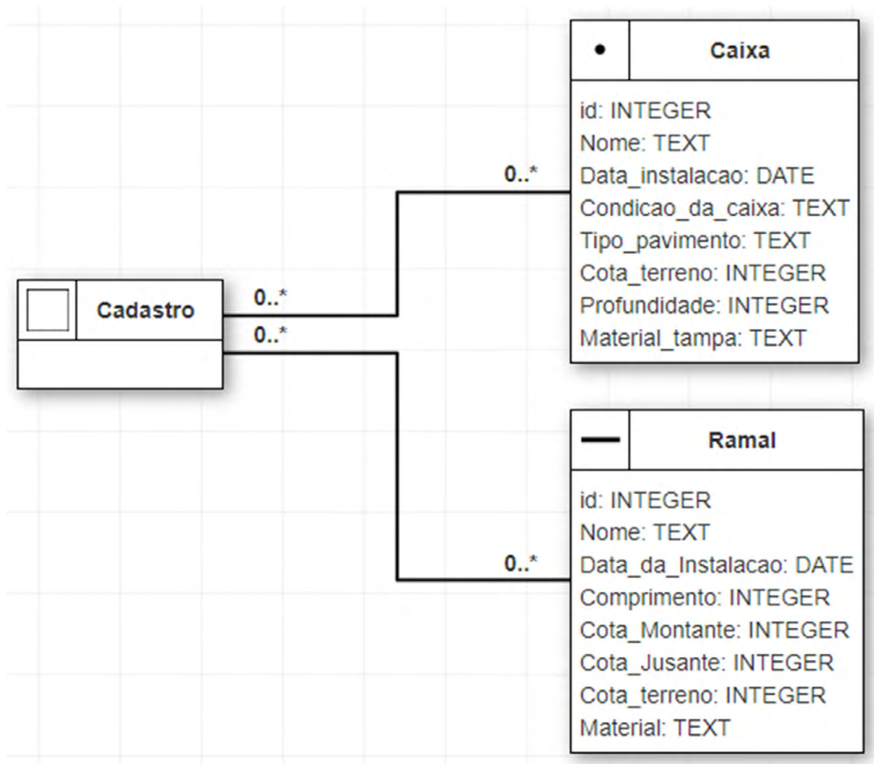

Figure 5 Flowchart of the registration process for the sanitary sewage system cadastral survey service, which shows the type of topological relationship of the object class.

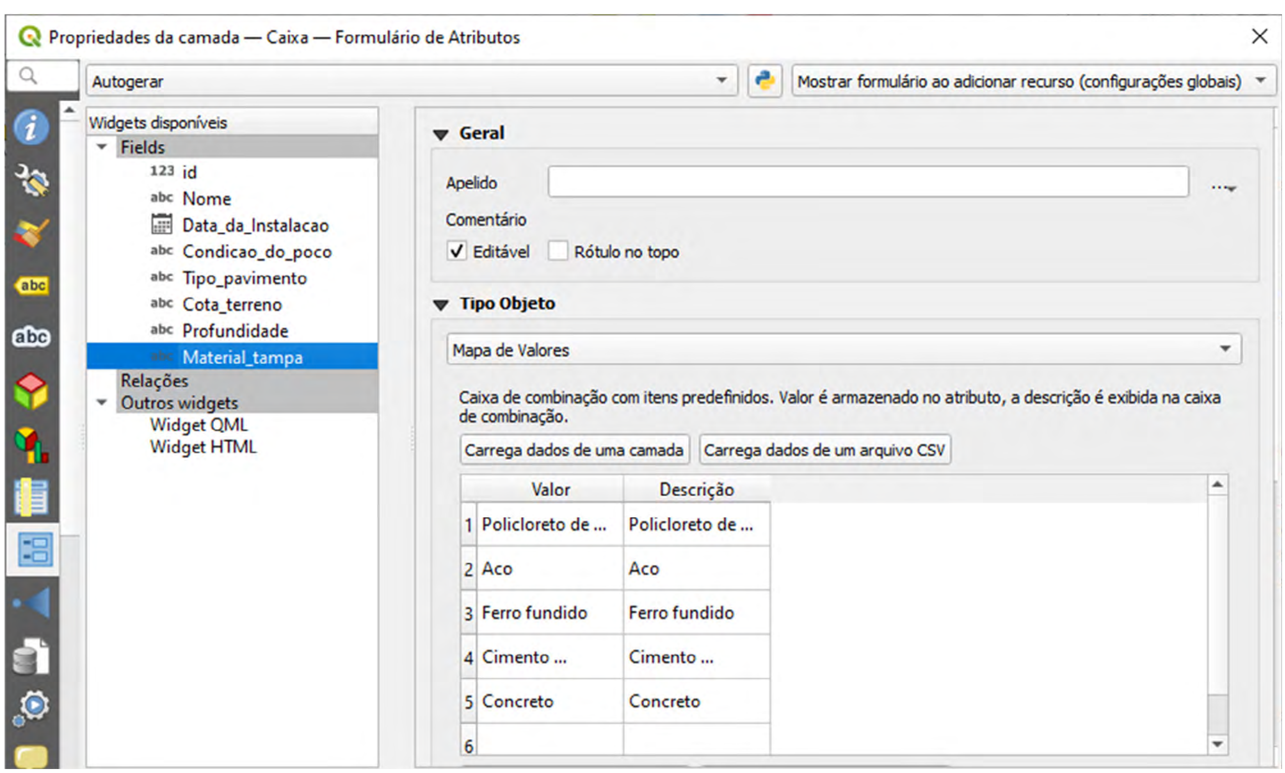

Figure 6 Construction of the value map for generating drop-down list classes in QGIS.

```
CREATE TABLE Caixa (
  id INTEGER
  PRIMARY KEY AUTOINCREMENT,
  Nome TEXT,
  Data_da_Instalacao DATE ,
  Condicao_caixa TEXT,
  Tipo_pavimento TEXT,
  Cota_terreno INT (6),
  Profundidade INT (6),
  Material_tampa TEXT(20));
SELECT AddGeometryColumn('Caixa', 'the_geom',4674, 'POINT', 'XY');
CREATE TABLE Ramal (
  id INTEGER
  PRIMARY KEY AUTOINCREMENT,
  Nome TEXT,
  Data_da_Instalacao DATE,
  Comprimento INT (6),
  Cota_Montante INT (6),
  Cota_Jusante INT (6),
  Cota_terreno INT(6),
  Material TEXT(20));
  SELECT AddGeometryColumn ('Ramal','geom_line',4674,'LINESTRING');
```

Figure 7 SQL command lines implemented to generate the SpatiaLite database for the Cashier and Extension objects.

3 Results

3.1 Tabular Data

After executing the command lines (Figure 7), the database with the cadastral layers was generated, where it was possible to perform the registration of the network on the software screen, through the vectorization of the point for the "Caixa" feature and line for the feature "Extension" from the SpatialLite file. With raw data in hand, the filling of data for the Box and Branch layers was obtained (Figure 8).

The "*date*" attribute is interactive and can be filled in by editing the day, month and year manually. The attributes "*Material_cover*" and "*Material*" of the Box and Branch layers respectively, were filled in the drop-down list format (Figure 9).

For users in the sewage network technical registration area, the main initial objects for the registration are boxes, manholes and parts, such as saddle and tilde. For the case of the boxes, the form of representation visual reference by point was adopted at the beginning of the construction of the geographic database. This representation is sufficient to locate each inspection box, in addition to allowing the topological verification of branch and inclusion relationships in a block.

3.2 Spatial Graphical Representation

As a result of the processing, the geospatial characterization was also obtained through vectors of the elements that make up the system through the technical registration of the assets: branches, geometrically represented by lines, interconnected by two inspection boxes, or generically by several points. This alternative as well as the first one, which allowed some additional types of analysis to be performed, such as the provision of a geometric data, which is the length of the tube (Figure 10).

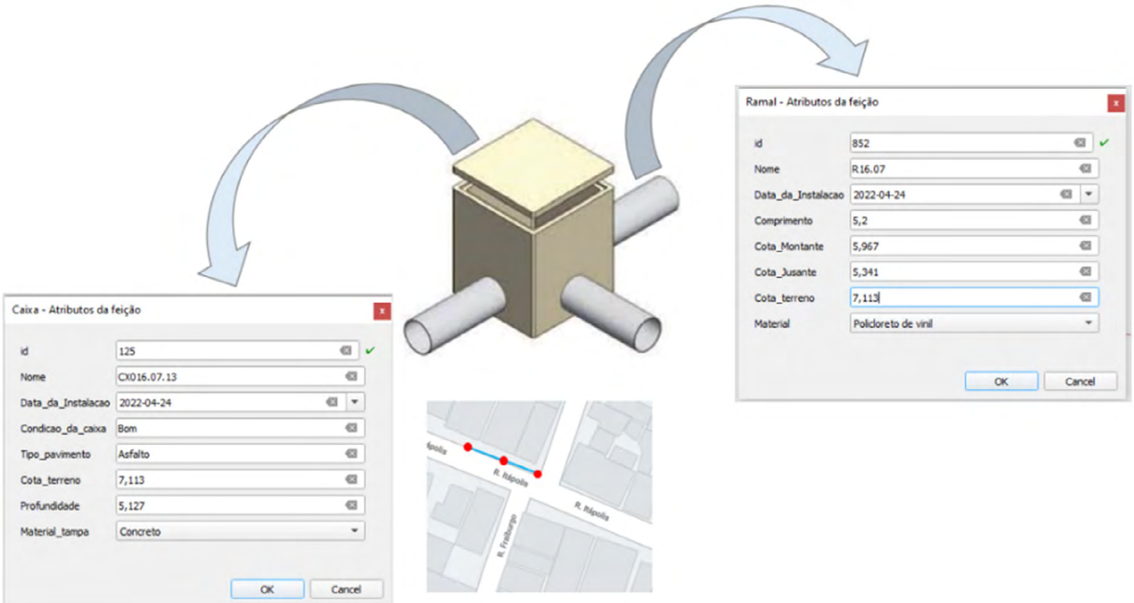

Figure 8 Example of filling in the data in the database.

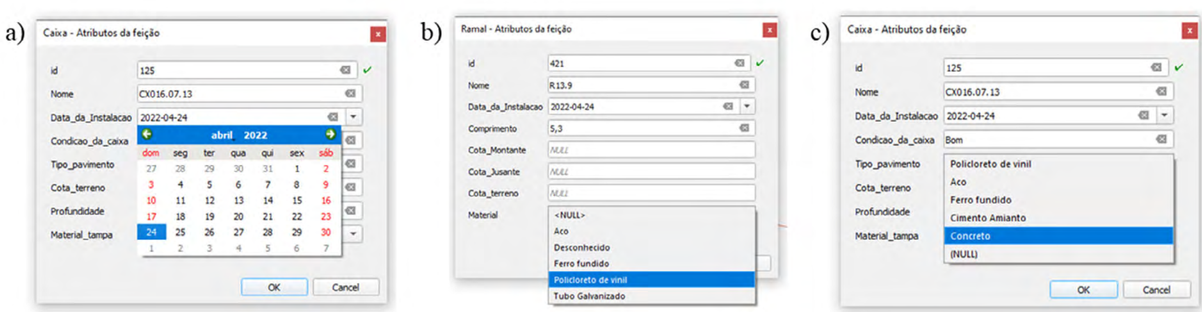

Figure 9 Example of filling in the data in the database in the fields date and drop-down list.

Regarding the processing capacity state, the generated file size of 6.33 MB obtained a processing time of 0.03 s, considered effective for the number of information produced. In addition, the database implemented in SpatiaLite enabled the relationship between the blocks and the sewage system, simplifying the task of locating the components included in the System, facilitating the correlation between the registered technical network and the existing real estate register. These results are also assured by Aragão (2020), stating that the implementation of GIS for sanitation networks made geographic data more accessible to a greater number of users, in addition to ensuring improvements for commercial and operational management.

In general, the convenience of different forms of representation in the same database is validated from the point of view of the structural formation of the sewage network components. That is, in the same database, the "Box" elements will be represented by point, as this will allow the representation of the data in the most accurate way and allow an exact description of position, size and dimension, instead, for example, line representation.

Project files are crucial points in all geographic information systems, as they contain all sorts of graphical interpretations grouped together (layer style, thematic mapping, labeling, subject-specific symbols, etc.). They are continually improved and are valuable as a model for future projects. In the case of sewer system data, dot symbols can show a type of system nodes, the length of the line represents the length of the pipes. These attributions contribute to the analysis of overlap with other systems, such as drainage and gas, in addition to the identification of possible interferences for the implementation of the sewage network stored in the project file.

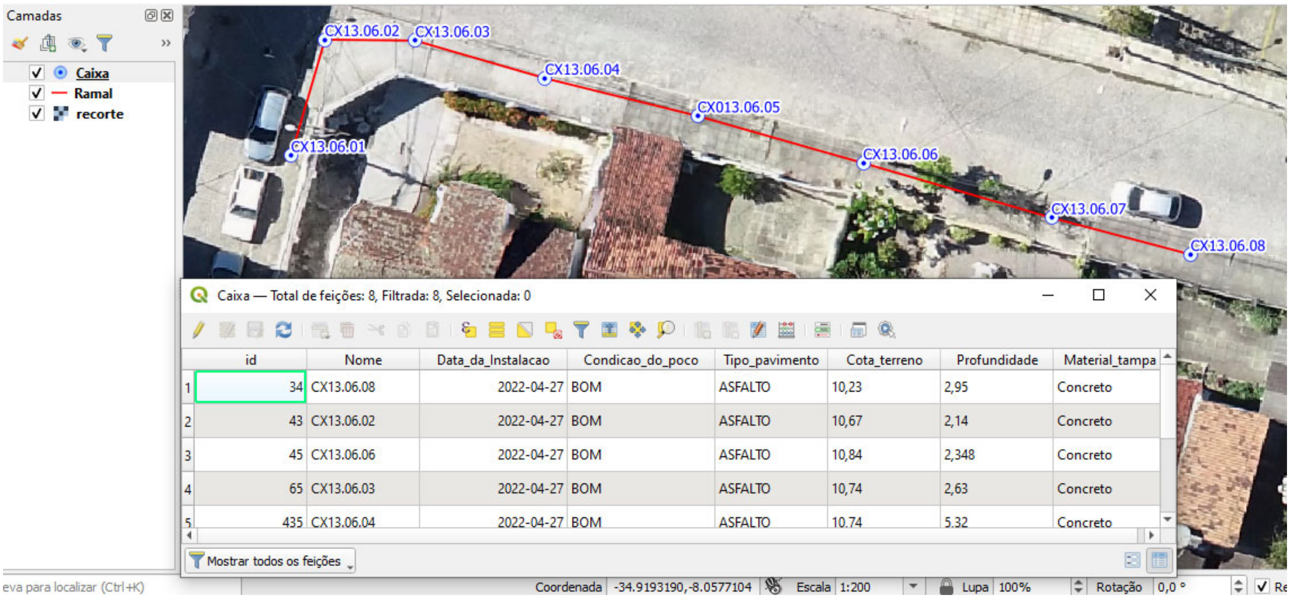

Figure 10 Demonstration of the data in the attribute table on the QGIS canvas with the active database.

The adoption of QGIS/SpatiaLite as a spatial database was found to be effective in facilitating the portability of models and datasets to end users (eg public authorities, managers and policymakers). In fact, once the model is produced, it can be easily shared with all other stakeholders in the management of basic sanitation in a municipality, thus allowing the possibility for all stakeholders to directly analyze the generated product without the cost of proprietary software licenses. Model portability also simplifies the maintenance and updating of the developed model, maximizing the reuse of the work performed. This statement corroborates the conclusions obtained by Caminha (2005) when analyzing the correlation between the loss of efficiency of the sanitation system and the technical register, in which the lack of a technical register has been one of the factors of greatest influence on the loss of revenue by of sanitation companies. According to that author, the lack of accurate information makes urgent actions have solutions that do not meet the shortness of time required, leading to the adoption of a solution that is not always the most adequate, resulting in a loss of revenue. Bonavita and Fonseca (2019), also conclude in their studies that an integrated base of reliable technical records is essential, which accurately express the disposition of underground networks, for the correct elaboration of future executive projects, in order to avoid encumbrance. of the projects of the new networks and the possible interferences.

Relying on robust and freely licensed software such as QGIS is relevant in low-income countries. The portability characteristics of the developed models are essential in a cooperation framework. This does not imply the need for complementary software for processing input data and analysis of output results, facilitating, ie, preparation of maps, contours, analysis of vector data. That is, the vector data coming from the bank and configured in the print composer, is a very powerful tool for the consulting engineer to prepare printed layout plans.

4 Conclusion

The implementation of a database, as an interface to register spatial, qualitative and quantitative information of a residential sewage system and its various elements determined to abstract a representation and storage of data in a satisfactory way was the objective of this work. Through free access software in QGIS/SpartiaLite - SQL format, allowing adaptations for the elaboration of cadastral records of all spheres that involve a sanitation system: Sanitary Sewage and Water Supply. As a result, the main conclusions were drawn:

The resulting model achieved applications of conventional SpatiaLite/SQL system requirements identification commands. The implementation of all data in a single spatial database linked to SQL codes, facilitated the construction of the model in a dynamic representation of hydrological systems without relevant costs of processing time and data storage space.

Integration into QGIS has resulted in the possibility to use database for raster/vector analysis, data pre-processing and post-processing of model results effectively and within a single environment, integrating executive and design information, which can be associated with other variables and databases such as the registration of interferences, reducing losses and mistakes during the network execution.

The association of vector features with the municipal cartographic base provided the organization and spatialization of data, facilitating the visualization of future problems, such as the restoration of the pavement in case of system maintenance, helping in the decision-making at the sanitation concessionaire.

In addition, in case of expansion of the sanitation system, the database opens the possibility of integration with databases of drainage, gas pipeline, telephony, among others, allowing the evaluation of supply systems and the fight against losses. of water, a frequent event in coastal cities such as Recife, which are below the mean sea level.

However, it is recommended that the implemented database (*.sqlite*) should be in the path compatible with the QGIS workplan (*project.qgs*) and only this file should be opened directly. Otherwise, the database will not recognize the fields in the attribute drop-down list. In addition, other types of data can be imported into QGIS even with the database active, but it is recommended that these data be in the same coordinate reference system adopted in the database code, to avoid spatial incompatibilities and errors in saving the file. project. For greater dissemination of technology, we provide the cadastre.sqlite file and the code through free access on Google Drive: https://drive.google.com/drive/folders/1Y7wjE2r9UQlaaBXUeNAbE_xxE_49LUUn?usp=share_link

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Author contributions
Juarez Antônio da Silva Júnior: conceptualization; formal analysis; methodology; validation; writing-original draft; writing – review and editing; visualization; supervision. **Ubiratan Joaquim da Silva:** methodology; validation. **Thaisa Manoela Silva França:** methodology; writing – original draft. **Wallamys Alexandre Ramos Venancio:** writing – original draft.

Conflict of interest
The authors declare no potential conflict of interest.

Data availability statement
Model data are freely available on: https://drive.google.com/drive/folders/1Y7wjE2r9UQlaaBXUeNAbE_xxE_49LUUn?usp=share_link

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