Application of GIS on building the spatial database for supporting drainage management in Ninh Kieu District

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Abstract. Ninh Kieu District is located in the center of Can Tho City, established under the Government's Decree No. 05/2004/ND-CP. This is a modern and rich district, with a history of formation and development associated with the Mekong Delta. According to statistics in 2019, Ninh Kieu District has an average population of 280,792 people, with a population density of 9,605 people/km² and an area of 29.23 km². In the current period, the urbanization process in Ninh Kieu District takes place at a fast and strong pace. This has made it impossible for the urban drainage system to keep up with this change, thereby creating great difficulties for the drainage management here. In order to deal with these enormous challenges, the managers in this area need to incorporate new technologies into drainage management. This paper presents the main result of building a spatial database to support drainage management for Ninh Kieu District. This is considered as a fundamental source of data for application of GIS in urban drainage research and management in Ninh Kieu District.

Keywords: GIS, spatial database, drainage management, Ninh Kieu District.

1. Introduction

Ninh Kieu District is one of the important economic, political and socio-cultural centers of the Mekong Delta in general and Can Tho City in particular, located on the right bank of the Hau River [1]. This district was officially established in 2004 under the Government's Decree No. 05/2004/ND-CP [2]. According to the Statistics Office of Can Tho City, Ninh Kieu District has an average population of 280,792 people, an area of 29.23 km² and a population density of 9,605 people/km² in 2019 [3]. The Can Tho City Department of Construction pointed out that the receiving source of the Ninh Kieu District's drainage system includes a system of rivers and lakes, canals, sewers and pumping stations. The whole district has a network of rivers and canals with a density of about 2.0 km/km² [4]. As of 2016, Ninh Kieu District's drainage system is still using a common network of pipes and culverts to collect and drain rainwater and wastewater, which has not been treated and discharged directly into rivers and canals [4]. Most of the sewer system in this area has been damaged and eroded, greatly hindering the ability to drain water [4]. In the current period, Ninh Kieu District is facing the process of population growth and urbanization taking place at a rapid and complex pace. These processes have created great pressure on drainage management in this area. This pressure has revealed many inadequacies in the district's drainage management, among which are the limitations in terms of policy mechanisms and the
lack of coordination among stakeholders. For this reason, management agencies need to apply new technologies to improve the efficiency of drainage management in this area. One of the new technologies that can be applied to Ninh Kieu District to solve this problem is the application of a Geographic Information System (GIS).

This advanced technology has been used to support drainage management in many parts of the world and has yielded practical and positive results [5-10]. Shamsi (1996) integrated a lumped parameter hydrologic model (Penn State Runoff Model) with a planning level GIS in implementing a stormwater management plan on a basin in Pennsylvanıa [5]. Northcott et al. (2000) used remote sensing and GIS technology to locate and delineate existing Subsurface Drainage Systems in the Midwest USA [6]. Nie et al. (2002) developed a GIS-based hydrological approach to generate urban watersheds, compute their features and delineate flow networks at a locality in Norway [7]. Singh (2018) researched the applications of GIS and remote sensing techniques in managing the problems of salinization and drainage of water resources in irrigated areas, thereby providing suitable solutions to map the degree and severity of drainage-induced land salinization [8]. Martin et al. (2020) developed a tool on the basis of Smart GIS technology that allows the integration of heterogeneous data sources to facilitate the digitization of the integrated urban drainage system [9]. Shedekar and Brown (2020) introduced steps to collect and process related GIS and GPS data, methods for applying that data to drainage planning and design, and guidelines for system management drainage system [10].

In previous periods, the application of GIS to support drainage management has also been implemented by some Vietnamese scientists in many localities in the country [11-14]. Trung et al. (2014) applied GIS technology to support urban water management to adapt to climate change in Can Tho City, the result of the project is that the related data and information is summarized into a GIS database and displayed as a Map Book and WebGIS [11]. Dang and Kumar (2017) used remote sensing techniques combined with hydrological modeling based on GIS technology to identify flood risk in urban areas in District 8 of Ho Chi Minh City [12]. Nguyen and Dao (2018) researched GIS technology to analyze and map flood warning services for flood prevention, rescue and traffic, providing people with forecasts on the change of travel routes through flood areas and apply functional processes of planning management models to support zoning planning management [13]. Dung et al. (2021) developed a calculation model of Sustainable Urban Drainage System (SuDS) integrating GIS and remote sensing technology to assess and forecast the level of flooding in the Nhieu Loc – Thi Nghe basin of Ho Chi Minh City [14].

To be able to apply GIS to drainage management, one of the indispensable factors is the spatial data component. This paper introduces the main results of using GIS to build a detailed spatial database to support drainage management in Ninh Kieu District. The main research area of this topic is the whole district with all 11 wards.

2. Methods and data

2.1. Research methods

In order to build a spatial database to support drainage management, a directional approach using Quantum GIS (QGIS) software is deployed. QGIS is chosen because it is open source software, not only free of purchase but also free of copyright, users can freely copy, publicly study, work without having to ask for permission. Meanwhile, commercial GIS software such as ArcGIS, MapINFO, AutoCAD Map 3D have to cost quite a lot to buy the license when implementing research projects, but the functions are similar to QGIS. Besides, QGIS is also used with many different types of GIS data formats and is easy to deploy for small projects such as drainage management for an urban district. In this research, the solution of building spatial database on single computer is chosen because of the simple implementation process, moderate amount of data, small number of managed objects and low cost when implemented in practice. The process of building this spatial database consists of six main stages: (1) collecting relevant data, (2) processing data and digitizing maps, (3) building spatial database, (4) evaluating the accuracy of digital map data layers, (5) creating thematic maps, (6) drawing conclusions and making
recommendations. Of the above five stages, two stages (2) and (3) are considered the most important because these stages directly affect the accuracy and reliability of the spatial database. The selected format for this spatial database is SpatiaLite for the following reasons: spatial data storage is topology relational, allows multiple objects to be used at the same time, has the ability to compress reduce storage capacity, can be used on many software, high data security features. The data layers in this spatial database are compared with published official maps of Can Tho City to evaluate the accuracy of geospatial data. The detailed research process of the project is shown in Figure 1.

2.2. Research data
Two main types of data are used to build a spatial database to support drainage management in this research including: (1) reports and statistics on drainage management in Ninh Kieu District, (2) digital map data of Ninh Kieu District. The digital map data of Ninh Kieu District is collected from many sources with three main formats: CAD file (*.dwg), Shapefile (*.shp) and TAB file (*.tab). These digital
maps are collected from two sources, the Mekong Delta Geographic Information Systems Project and management agencies of Can Tho City. They are divided into six categories: (1) administrative map, (2) traffic map, (3) topographic map, (4) housing map, (5) land use map, (6) drainage network map. The drainage network maps are built in the form of AutoCAD drawings by the Can Tho City Department of Construction. The administrative boundaries of the study area are shown in Figure 2.

![Figure 2. The map of the study area - Ninh Kieu District.](image)

3. Results and discussion

3.1. Results of building spatial database to support drainage management

Two tools Create Layer and DB Manager of QGIS software are used to build a spatial database to support drainage management for Ninh Kieu District. The main data source for building this spatial database is the digital map of the study area with vector data model. The base maps were developed mainly in 2018, while the drainage network maps were built in 2016. These digital maps are converted to the same format and geographic coordinate system before processing and import into the spatial database.

The spatial database to support drainage management in Ninh Kieu District is designed based on the relational model, with the degree of data abstraction is physical level. This spatial database is divided into two main components: terrain data and thematic drainage data. The terrain data component is designed based on a standardized structure published by the Environmental Protection Agency in 2006 [15]. Thematic drainage data component is designed based on the specific professional requirements of the management agencies in Ninh Kieu District. This spatial database is built with the SpatiaLite format, a spatial extension of SQLite that provides vector geodatabase functionality. With the choice of SpatiaLite format, this spatial database can be used flexibly across a variety of GIS software. This spatial database is built on the VN2000 coordinate system for Can Tho City with the selected axis meridian of 105°00' and the projection zone of 3 degrees (k = 0.9999) to comply with Vietnamese regulations. The overview diagram of the spatial database structure of drainage management is shown in Figure 3.
Figure 3. Spatial database structure to support drainage management in Ninh Kieu District. The entire spatial database of drainage management has six data groups, divided into 24 vector data layers. In which, thematic data group on drainage management includes seven vector data layers: sewers, ditches, manholes, discharge gates, pumping stations, tidal valves, wastewater treatment plants. This spatial database can be used for subjects such as government officials as well as to support scientists in research on drainage systems in Ninh Kieu District. The data layers in this spatial database are also the basis for creating many different types of maps describing the topographic, population and infrastructure characteristics of the study area. Figure 4 shows the map of elevation points, while Figure 5 shows the map of main residential areas and Figure 6 shows the map of houses and buildings of the study area.

Figure 4. The map of elevation points of Ninh Kieu District.
In addition to building the spatial database component, a system of processes to exploit this database is also drafted to serve the professional work of the drainage management agencies in the study area. The main processes for exploiting spatial database to support drainage management include: adding new data, updating attributes, editing data, querying data, analyzing data, creating maps, extracting reports. These processes make it easy for users to access the data in the spatial database.
3.2. Results of building thematic maps to support drainage management

After the stage of designing and building a complete spatial database to support drainage management, the data layers contained in this spatial database are used to establish thematic maps on drainage management in the study area. The role of these digital maps is to assist the authorities in Ninh Kieu District in managing assets as well as solving problems arising in the process of drainage management. These maps are designed on standard A1 paper, stored in digital image format JPG (*.jpg) with a resolution of 500 DPI.

These thematic maps are built according to two main contents related to drainage management in Ninh Kieu District. The first content is main drainage sewers and ditches within the administrative boundaries of Ninh Kieu District, includes nine types: Sewers D200, Sewers D300, Sewers D400, Sewers D500, Sewers D600, Sewers D800, Sewers D1000, Sewers D1200, Ditches. Figure 7 and Figure 8 show the thematic maps of main drainage sewers and ditches in the study area. The second content is discharge gates and tidal valves within the administrative boundaries of Ninh Kieu District. Figure 9 and Figure 10 show the thematic maps of discharge gates and tidal valves in the study area. As mentioned in the previous section, the drainage management data layers in the spatial database are built based on AutoCAD drawings established in 2016 by the Can Tho City Department of Construction.

![Figure 7. The thematic map of main drainage sewers and ditches of Ninh Kieu District.](image-url)
Figure 8. The detailed maps of the locations of main drainage sewers and ditches in the study area.

Figure 9. The thematic map of discharge gates and tidal valves of Ninh Kieu District.
4. Conclusions and recommendations

The obtained results show that the research has accomplished the initial set of tasks, which is to build a spatial database to support drainage management in Ninh Kieu District with a structure suitable for regulations of the Ministry of Natural Resources and Environment as well as professional requirements of management agencies. This spatial database is built on the VN2000 coordinate system, with six groups of data, divided into 24 vector data layers, including seven thematic data layers on drainage, which can meet requirements of drainage management in the study area. Because it is built in SpatiaLite format, this spatial database can be used both on commercial GIS software as well as open source GIS software. This spatial database is an important scientific basis for the application of GIS at different levels to drainage management in Ninh Kieu District. This spatial database is considered as a technological solution for managers in Ninh Kieu District to solve the existing difficulties and challenges of drainage management. The implementation of this study has enabled the authors to develop a detailed procedure for establishing a spatial database from various types of digital maps as shown in Figure 1. It can be said that this will be a valuable reference for future studies in the field of drainage.

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