A Sewage Outfall Management System Based on WebGIS: Design and Implement

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***Abstract*—The problem of China's coastal water pollution is becoming more and more serious. Thus the management of sewage outfall with technology methods is gaining more attention. WebGIS technology such as ArcGIS Server, ArcGIS Online and Flex, etc. may be of great help. We can establish a B/S structure system with the advantages of easy building up and function expansion, high information sharing and strong user interaction capability, low cost, and so on. The approach to design and Implement a Sewage Outfall Management System based on WebGIS technology is discussed in this article. The results show that this system can better manage the outfall information and provide support to decision-making than traditional ones, and it also has broad application prospects in other fields of environmental protection. This system has been applied to our project so far and just went through the interim review.**

Keywords—sewage outfall management; WebGIS; ArcGIS Server; RIA; Flex

I. INTRODUCTION

Coastal cities are among the most economically developed regions in China; however, the oceans there are also seriously polluted. In 2013, the situation of sewage disposal into the sea was not optimistic at all. Several coastal regions were heavily polluted, the marine ecological environment was degenerating, and environmental disasters broke out from time to time. Generally speaking, the quality of the environment along the coast was rather poor, and more than 80% couldn't meet the requirements of environmental protection of marine functional zone. Sub-healthy estuaries accounted for 67% [1]. China is facing increasingly serious water pollution problems.

As the sewage outfall has significant geographic features, processing the outfall information and the data which is collected by the sensors nearby with the help of geographic information system is expected. In previous years, the outfall information and monitoring data were stored in tabular form in the database. They were accessed through database management software or some other self-developed client software. We call this kind of system the electronic archival mode [2]. This mode can only satisfy the needs of information storage, but it becomes less available when the data volume is huge or faced with the problem of information interaction and data visualization.

With the rapid development of computer technology, a few researchers have applied GIS technology to the sewage outfall information management system in recent years. Such system ran on a stand-alone computer, and it managed or displayed the information and data on the GIS platform. Developers accomplished specific business functions on the basis of this framework. For instance, in the paper "Implement of the Sewage Outlet Management and the Forecast of Water Quality Information System Based on ArcGIS Engine", Mintao Ma proposes two systems as outfall management subsystem and data management subsystem. The implement procedure can be summarized in three steps: establishment of a spatial database, data entry and data interoperability. The last part involves data query and statistics, spatial query, buffer analysis and so on [3]. All these functions are achieved using the ArcGIS Engine developer components [4]. Although this kind of system puts forward a better solution to information unified storage and management issues and has some interactive features, it has some fundamental disadvantages. First, this system is built on the C/S structure, so information sharing capability is relatively poor. Second, an electronic map of the specific region with appropriate resolution is necessary, which increases development costs. And then, system function expansion is not that flexible.

WebGIS technology is the application of geographic information in the Internet/Intranet environment [5]. System developed in this method has a B/S structure, so the information sharing capability is largely reinforced. The presentation layer technology based on rich Internet applications (RIA) can effectively improve system interoperability, and thus enhance user experience. Furthermore, electronic cloud maps can be used directly instead of offline maps because of the B/S structure. Finally, it is very flexible to extend system functions using plug-in development approach.

II. RELATED WORK

GIS technology has made much progress in recent years. It has been used in many fields such as management of land resources [6], forestry resources [7] and water resources. The research on water resources management using GIS is focused on the following topics: hydrology analysis [8], groundwater distribution and pollution assessment [9], rivers and lakes management [10] and environmental emergency treatment

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[11].Generally speaking, the application of GIS technology in the field of outfall management is fairly rare. In 2009, Y. W. Zhao proposed a method to estimate whether some area was suitable for locating an outfall or sewage treatment facilities [12]. He mainly focused on the evaluation system and visualized the results using GIS software. In 2014, we made an on-the-spot investigation in Dalian, China. The local Environmental Protection Agency tried to establish an outfall management platform that they called Electronic map/archives. This platform was well performed in management of outfall information but relatively poor in GIS functionalities as well as data operation.

III. System Architecture

Flex is a highly efficient, open source framework for building up expressive web applications. These applications can be operational in different browsers, desktops, and operation systems, taking advantage of Adobe Flash Player and Adobe AIR. ArcGIS Server provides three development methods through Web APIs [4]. Flex API is one of them, and with its help we can develop enterprise-class RIA applications. The Sewage Outfall Management System uses multi-model architecture in order to gain high efficiency, good flexibility and scalability. The system is divided into three layers: data layer, application layer and presentation layer. The overall architecture is shown in Fig. 1.

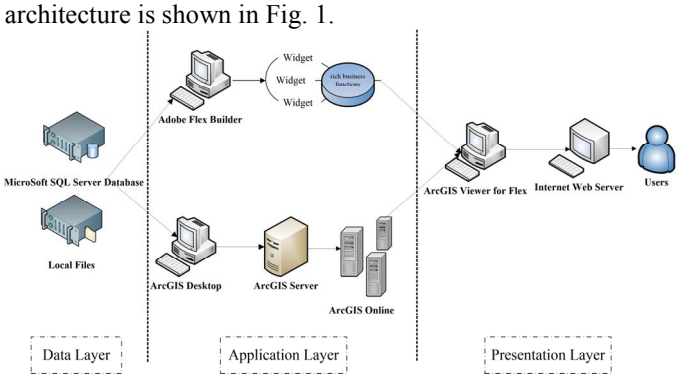

Fig. 1. Sewage Outfall Management System architecture.

A. Data Layer

Data layer is the place where sewage outfall information and monitoring data are stored. This layer provides the access to spatial data and non-spatial data to ensure all kinds of functions. The spatial data mainly involve the latitude and longitude data of sewage outfall and the shape files of environmental functional area and marine function area. The non-spatial data include monitoring data from different sensors around the outfall, such as the COD, BOD, suspended solids, pH, volatile phenol, and so on. ArcGIS Desktop accesses spatial data through ArcSDE which is a powerful middleware in managing spatial data and integrating them with non-spatial data [13].

Adobe Flex Builder is linked to the database by using java library, and mainly deals with attribute data. The formation of data layer is shown in Fig.2.

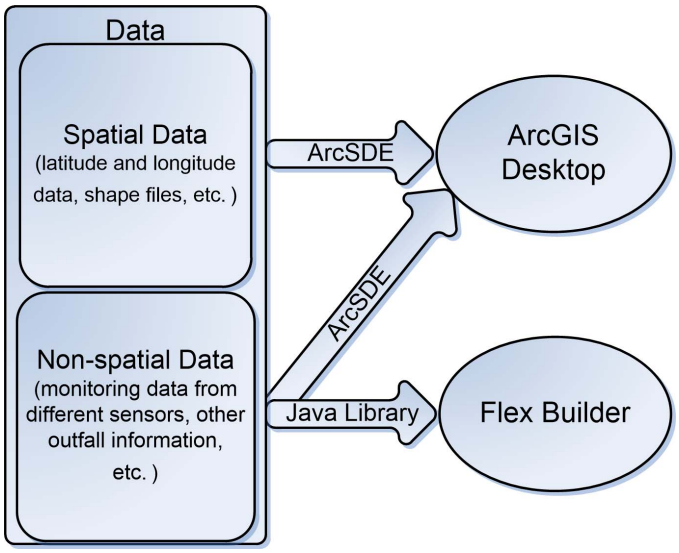

Fig. 2. Formation of data layer.

B. Application Layer

This layer is the key layer of the whole system which responds to the requests from browsers and provides various services. ArcGIS Server is meant to generate map services as well as geocoding services which run on the Internet. The representational state transfer interfaces of these services are exposed by ArcGIS Server. ArcGIS Online is a mapping platform that gives us everything we need to create interactive web maps and apps that we can share with anyone. With ready-to-use content, apps, and templates, we can be productive right away. And no matter what we use—desktops, browsers, smartphones, or tablets—we can always have access to our content [14]. The ready-to-use base maps make it easy for us to create maps for the program we are working on. What we need to do is just combining our data or map layers with the data or maps on this online platform. Flex Builder is an IDE for developing Flex applications. With the help of this tool, we can implement our business logic with specific data sets. Each function is packaged into one widget. However, the widgets are not strictly independent, they can communicate with one another when necessary [15, 16]. Compiled widget is an independent SWF file, containing a series of business logic.

C. Presentation Layer

Presentation layer is responsible for showing the results to the system users. Here we use ArcGIS Viewer for Flex [17] to realize this task. ArcGIS Viewer for Flex is the use of ArcGIS API for Flex and the Flex Framework to design and implement web applications, which supports for ArcGIS Online, ArcGIS Server and other server services (GeoRSS, etc.) access [18]. We can upload and configure the widgets developed, compile them in Flex Builder, and then deploy them into existing Flex Viewer application.

IV. System Implementation

A. Data Preparation

This Sewage Outfall Management System is aimed to store and manage data uniformly in a scientific way. So data preprocessing is needed before entry into database [19]. The outfall information table ensures to include, but are not limited to the following information: serial number, province, city, enterprise or factory name, outfall code etc., and also outfall longitude and latitude. In order to analyze and process the data related to each outfall, the attribute data are also required. Monitoring data are divided into two categories, the concentration data and the total amount of data. They are stored separately in the tables in database.

B. WebMap Generation

The system uses Microsoft SQL Server 2008 as the database. The 2008 version supports special data storage; both vector data and attribute data are stored in the database in the form of tables [20]. ArcGIS Desktop is connected to SQL Server through ArcSDE. In this way, we can create a spatial database. ArcMap calls the table of sewage outfall information, which will be displayed in the form of coordinate points using the WGS_1984 coordinate system. The outfall layer is finished after some decoration and configuration. The symbol species and size or the layers mark can be modified, for example. To make sure that the layer is simple and clear, we set outfall of different levels to display within the specified scale range. When it's done, ArcMap publishes the outfall layer to ArcGIS Server. Now it becomes a ready-to-use map service. ArcGIS Online offers high-resolution, multi-POI base map of China for free. We can combine the map service on the ArcGIS Server and the base map to generate a WebMap on our own purpose. The appearance and the content of the popups can also be defined.

C. Function Realization

ArcGIS Viewer for Flex provides a convenient way of web application development that is the so-called plug-in method. The source code of ArcGIS Viewer for Flex framework can be found on GitHub [21], and widgets with different functions are developed and tested on the basis of it in Flex Builder. The functions of Sewage Outfall Management System are shown in Fig.3. Functions of environmental functional areas display and charting are shown in Fig.4 as examples. The whole system is divided into six functional modules which are fundamental map operation, information display, spatial query, spatial statistics, spatial analyses and printing out. One or more widgets are developed for each module.

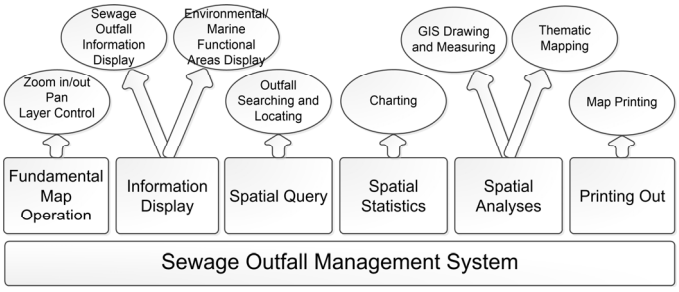

Fig. 3. Functions of Sewage Outfall Management System.

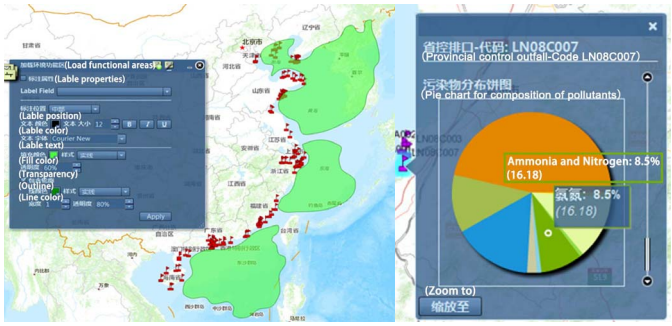

Fig. 4. Functions of environmental functional areas display and charting. Users can upload local files containing at least .shp and .dbf in a single zip file to show the areas of focus. Charting widget can deal with the monitoring data and display them in the form of charts. The figure above shows the proportion of some pollutants discharged by an outfall.

D. System Deployment

When the functions developed have satisfied the needs of our system, the next step is to deploy the system on the Internet. ArcGIS View for Flex can handle this well. The whole project is packaged into a folder which can be published by a web server, such as Apache tomcat or IIS. Until now the system can be accessed and operated by any browser that supports Flash on any platform. The entire implementation process is displayed in Fig.5 and the system outlook is displayed in Fig.6.

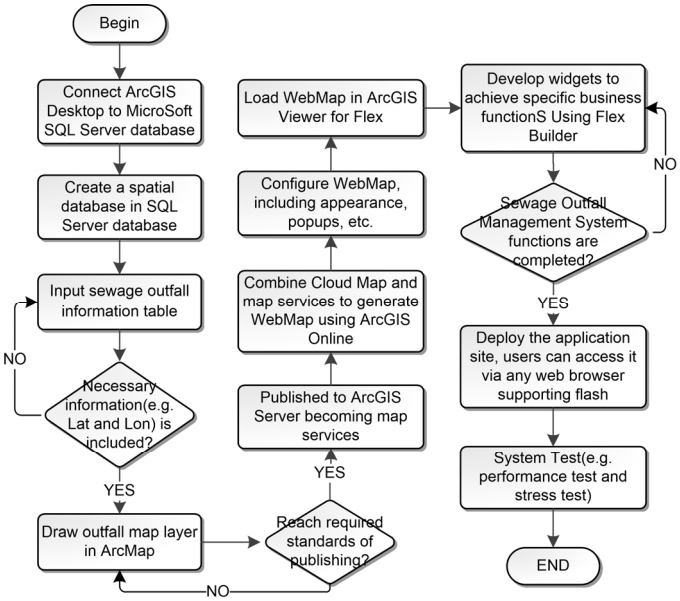

Fig. 5. Flow diagram of implementing the system.

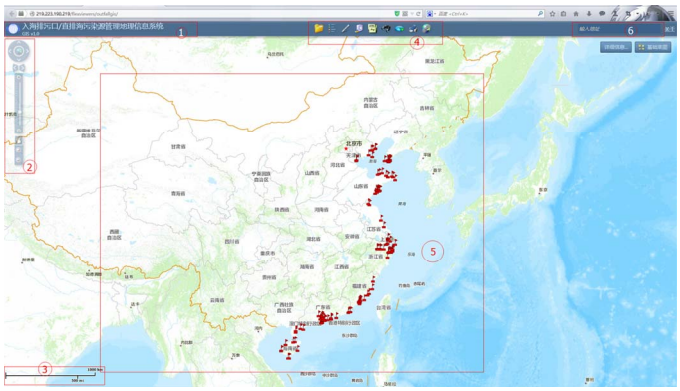

Fig. 6. Overview of the system. Part 1 is title bar, and here are the name, logo and version number of the system. Part 2 is navigation bar, including tools of zoom in/out, pan, and full map. Part 3 is the information of map scale. Part 4 is the widget bar for realizing various functions. Part 5 is the map area where the operation panels and the results are shown. Part 6 is the address locator.

V. CONCLUSION

The research for Sewage Outfall Management System has been limited to the traditional development method of using ArcGIS Engine or some other ArcObjects. However, system developed in this way has some unavoidable defects. The C/S structure can lead to poor information sharing ability, low capacity in application of network resources may increase the system cost, and also the system scalability can be influenced due to the implementation method. Thanks to the rapid development of GIS and RIA technology, we can now build up a system with higher sharing ability, richer user interface, more interactive and faster speed of response based on WebGIS. This framework can greatly improve the operating efficiency of GIS system, enhance the users' experience and thus provide better assistance in decision-making process.

This system may be further enhanced in mainly two aspects, i.e. the spatial analysis and 3D demonstration. There are lots of tools to perform spatial analysis in ArcGIS. Problems such as spatial location [22, 23] and shortest path [24] can be solved using a combination of analysis tools, for example. In addition, the application of 3D technology [25] in GIS can bring more intuitive visual effects in the future.

Now we are seeing a growing sense of environment protection among people in China, and we hope that more and more science and technology achievements can be applied to the environmental protection business

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