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Development of Data and Information Centre System to Improve Water Resources Management in Indonesia

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Abstract Most provinces in Indonesia will be facing water scarcity problems in the next decades due to increasing water demands resulting from population growth, urbanization and economic and industrial developments. As a consequence, they will also be facing a number of problems with regards water resource management, such as a lack of data and information needed to evaluate the real status of water resources, the unsystematic development of relevant infrastructure and economic instruments, inadequate human resources for the operation and maintenance of water resources, and a lack of interest in improving research and development activities. This paper examines the application of data and information management for improved water resources management in Indonesia through "one door data service system" linked among the related institutions from different sectors and levels both at the central and regional government agencies. One of the key solutions to help solve water resource problems would therefore be to obtain supporting data and information by developing an information system and water resources data centre (WRDC). Rapid developments in information and communication technology (ICT) could be used to support data communication and management requests in order to build capacity of the water resources sector, and as a prerequisite for an integrated water resources management program. Improved efficiency and effectiveness could be achieved by making relevant data and information available, as well by

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establishing a communication system among related institutions. Further, provinces should also prioritize developing human and social capital through education, service delivery and career development, as well as training for water resources development and management. Data and information such as the hydrological and water quality data, information of water resources potential, irrigation areas, population and economic growth as well as the others related data need to store in both the tabular and spatial formats. The water resources data management and warehouse system is a web-enabled application that permits spatial data to be stored with tabular data in a standard database management system. This system permits a dynamic generation of output from the tabular and spatial data and enables users to generate answers to their queries online, rather than simply presenting static maps and tables from the database. The WRDC applications were developed and chosen by gathering the ideas suggested by users at the ministerial, provincial and river basin levels. Within the resulting inventory system, information was grouped into irrigation scheme system; water resources potential; natural disaster; hydrological data and station networks; and other information. For the users at the ministerial level access the system by using local area network (LAN) connections and other users at the provincial and river basin levels or elsewhere in the world can use the internet for connections and regular browser software for system operation.

Keywords Water resources management · Data · Information · Indonesia

1 Introduction

The impact of economic development and population growth as well as forest and land degradation due to legal and illegal logging and also increasing the opening of lands for agriculture purposes has negatively impacted on available water resources in Indonesia. Over the coming decades, the country is facing increasing water scarcity, exacerbated by increased flooding in the rainy season and more droughts in the dry season, as well as high water pollution in major rivers—especially in big cities—if an optimal and comprehensive approach to integrated water resources management is not instigated.

Since 1998, after downfall of the new order—authoritarianism regime—era (1965–1998) under former President Soeharto, the Republic of Indonesia has been concerned about the need to confront this problem. Pursuant to the reformation era (1998–2002)—by adopting of the new paradigm of governance mechanism system, the government initiated by issuing the Law 22/1999 on autonomy and decentralization for transferring part of responsibility from the central to local government. The government has also considered the need to reform the water resources policy which is setting up under the water resources sector adjustment programme (WATSAP) frameworks (ADB 2005). The law 7/2004 on water resources, after approved by the parliament, has been issued on March 18th, 2004 including reference to water resources information system.

This information system should be able to produce quality data and information to support the demands of data exchange and water resource management, coordination and integration among various relevant institutions (Flügel 2007), such as the Directorate General of Water Resources (DGWR)—Ministry of Public Works

(MPW), central and regional governments and cross-sector institutions, non-governmental organizations and universities. To achieve this, support from the regional water resource services at the provincial and district levels and related communities is required. By using the system to increase planning and development, the DGWR and other related institutions as well as consultancy's companies and other stakeholders including individual experts are expected to greatly benefit.

In general, the water resources development program and information system has multiple utilities applications, such as mapping existing basic infrastructure, in order to plan for national infrastructure development (Fulazzaky and Akil 2004a, b). It is also intended to increase the availability, to some degree, of digital data that describes the natural resources and physical condition of existing infrastructures.

The water resources data management and warehouse system comprises a website tool which enables spatial data to be stored and used together with tabular data in a standard database management system, available in response to user needs (Fulazzaky and Akil 2004a, b). Users can instantaneously and interactively generate answers to their queries online (Andrews et al. 1999).

The information system and application of WRDC was developed by Directorate General of Water Resources (as mentioned in the Report of Capacity Building Project—Component 7 2002) and chosen by gathering ideas through a multi-stage public consultation with users at the ministerial, provincial and district levels. Based on their recommendations, the resulting system was categorized as follows:

- Irrigation scheme system;
- Water resources potential, such as: river, lake, groundwater and reservoir;
- Natural disaster, such as: flood and drought monitoring;
- Hydrological data and station networks; and
- Other information, such as: products of regulation and policies, institutions.

The WRDC users at the ministerial level working under the DGWR could access the system by using the local area network (LAN) connections and other users at the provincial and district levels or elsewhere in the world can use the internet facility for connection and regular browser software for operation.

2 Capacity Building for the Water Resources Sector

Chapter 18 of Agenda-21 the UN framework for sustainable development states that the capacity building is a prerequisite to integrated water resources management. The Agenda-21 has four basic elements pertaining to "capacity building", which is deemed to be a long-term continuing process focused on:

- The creation of an enabling environment that has appropriate policy and legal framework;
- Institutional strengthening and development, including local participation;
- Human resources development, including the strengthening of managerial system and water users interest; and
- Awareness building and education at all levels of society.

In relation to these foci, Indonesia has established several institutions for the purpose of implementing water resource policies at national and regional levels, to

improve performance of water resources management. Unfortunately, to date they have tended to be inefficient and ineffective, due to:

- Lack of management and monitoring tools needed to ensure the involvement and commitment of the communities and the general public;
- Inadequate funding and human resources; and
- An under-resourced working environment for the individuals responsible for implementing the water policies.

Under a good working environment and supporting the adequate budget and human resources, data management system will help to access the real-time data and information to facilitate the decisions making on water resources planning and management.

3 Needs for Data Management and Warehousing

Capacity building is needed to support the implementation of an integrated approach to water resources development and management (Barmawi and Amirwandi 1999). One solution could be based on water resources assessment, meaning not only an inventory of the available water resources, but also the extent to which a county can satisfy its water requirements, particularly in terms of matching water supply with demand.

To overcome the existing problems and shortcomings mentioned above, it was decided that an information system and WRDC must be established under the auspices and management of a water resources institution. The DGWR was chosen as the institution to deliver to all potential users the following services:

- Organize, store and manage relevant data on water resources;
- Provide the access to the existing data (network, diskettes, reports);
- Provide the tools for the uses of the data;
- Retrieval tools;
- Presentation tools;
- Develop the standard analytical tools;
- Spatial tools;
- Linkage of databases;
- Provide the training and support for the users of the tools; and
- Supply the data's documentation.

The use of an information system and data management, such as data acquisition and processing, can play a critical role in addressing water shortages by determining the best approach to reduce pollution and minimize the gap between water availability (supply) and water use (demand). However, without coordination or adequate dissemination or access to information, the data acquisition and processing undertaken by a single institution remained ineffective: it could not easily be accessed by other researchers and decision-makers, or meet public information demands. As a public service institution, the DGWR could also disseminate critical information as an early warning to all stakeholders.

Fortunately, the rapid development of the information and communication technology (ICT) sector and its application to an integrated water resources management

program, aided the capacity of data communication and management (Horlitz 2007). On the one hand, this fundamental process advocated in WAS Initial Assessment Report (Woodward 1997) has entailed improved efficiency and effectiveness of water resource management through the appropriate access to and use of water-related data and information, as well as the establishment of a communication system among related institutions (Berger et al. 2007). On the other hand, provincial institutions related to water resource management should also prioritize human resource development through a compulsory education, services, and career development system as well as training for enhanced water resources development and management.

4 Importance of the Data Management System

The water resource data-warehouse system is embedded in an application that permits spatial data to be stored with tabular data in a standard database management system, such as Microsoft SQL Server. This application system permits a dynamic generation of output coming from the tabular and spatial data holdings of the system, using core database management (DBM) software like ESRI ArcSDE (where SDE = Spatial Data Engine).

The system also has a comparative advantage in terms of usability and functionality: the internet-based web-enabled applications and software are more advanced than other conventional systems, such that users can generate responses to their queries online, rather than the simply presenting static maps and tables from the database.

For all of the users from DGWR, access to the system can be gained by using the local area network (LAN) through existing LAN connections. Other users from national, provincial and district level institutions, as well as users elsewhere in the world can connect to the system via the Internet and using regular browser software (Fulazzaky and Akil 2004a, b; Andrews et al. 1999). To support the application of the WRDC and further enhance its usability, including the search for contacts, website development has been programmed as a major activity. An online messaging system provides client support and a help desk room at the WRDC assists people needing advice on the application of the system.

5 Architecture of the Information System and Water Resources Data Centre

The DGWR is already undertaking the process of integrating all computing activities. The information system and WRDC provide the physical infrastructure as the hardware system to link the WRDC system to the other information systems as a water resources database network and also services the software system to maintain the sustainability of network connections (as mentioned in the Report of Capacity building Project—Component 1 1998).

The information system and WRDC consist of a database system whereby all the relevant data is stored on the network server, a shell that combines the spatial and non-spatial data, as well as the application tools to retrieve, present or analyze the data (see Fig. 1). Besides the hardware and software, of course, protocols and rules as well as request regulations are needed to organize and manage the data flows.

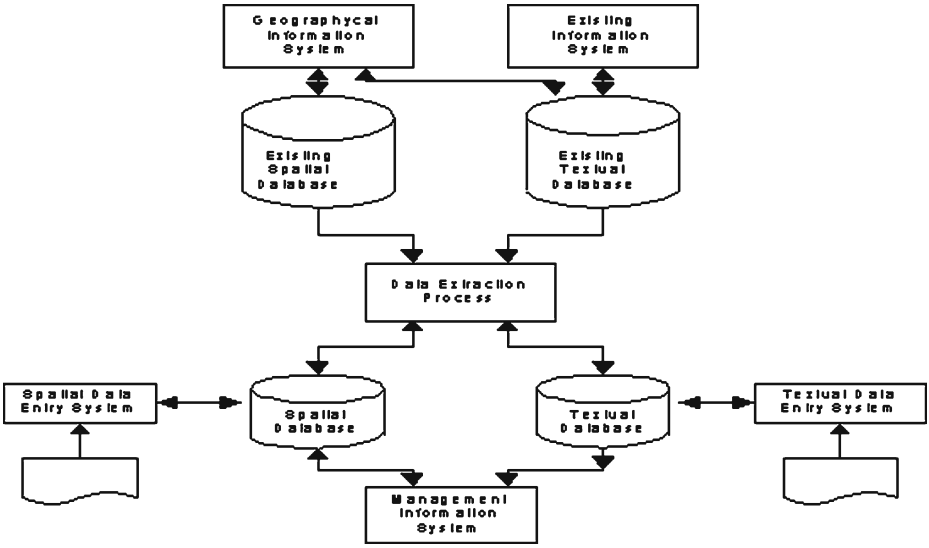

Fig. 1 Architecture of the information system and WRDC

Of particular importance is how to maintain the cooperation among all relevant institutions (Yamout and El-Fadel 2005; Yamout and Jamali 2007).

6 Data Organization and Availability

A data warehouse is a data brokerage. It does not exist to support a single activity or a single project. It exists to receive and give out the information for a wide range of users. In the present case, it exists to support activities related to water resources and water resources development. A data warehouse is therefore an institutional facility that is quite distinct from the databases developed for individual development projects. The components of a water resources system that support data organization and availability are separated into two groups i.e., water resources management and water uses management as shows in Fig. 2. The database management system could be provided to users to enable them to optimize their use of the entire resources and services of the data warehouse to organize, store and develop their data into well-organized reports and/or maps, for example. It is anticipated that such reports will be used for meetings as part of on-going, general reporting processes within relevant organizations.

Given that the data warehouse is based on the need for its functionality as well as individually-tailored, interactive and instantaneous outputs like reports and maps, its success is therefore determined by the availability of data and information. This in principle depends on the type of data requests, users' interests and whether they have direct access to the website. The interested parties within Indonesia and worldwide can use the data warehouse through any of the six applications under the information system and WRDC website.

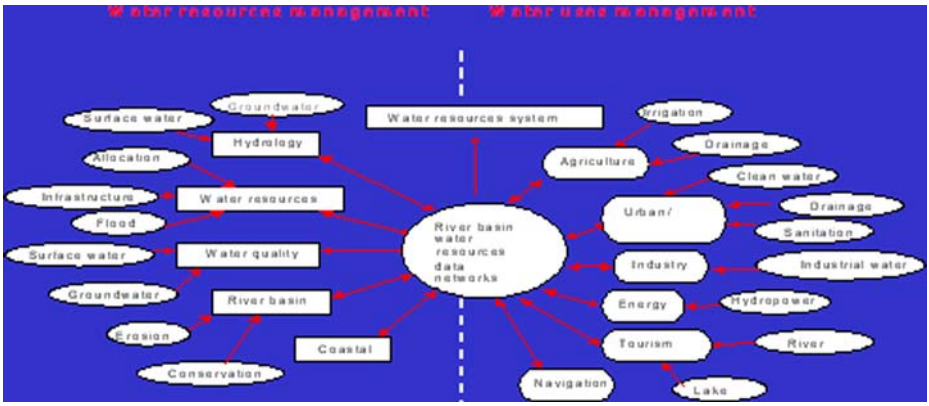

Fig. 2 Components of water resources system

At present, these installed data sets comprise the best available water resource database system in Indonesia. If, in some cases, the requisite data is not held by the data warehouse system, it is possible to search through a linkage system for databases designed especially for specific users. However, in future, the number of system applications could rapidly increase and be modified in response to user requests, whereby new functionality will be continuously developed and modified based on such requests, feedback and changes to application requirements from all kinds of users. For example, if a researcher needs the specific river flow data, s/he could be directly linked to another pertinent, specialized database of the ministry. Conversely, the researcher could link directly to the data requested using conventional communication methods.

7 Application of the Water Resources Data Management System

In practice, the system will basically provide standard reports and maps for regular users, ideally using updated data that is supplied by users and entered into the database server by staff working for the information system and WRDC. The users are really specialists on the water resources sector domain facing the related to five of six subject areas of web-based applications and the request for each of the staff working is able to operate the system.

Six subject areas were selected for the development of web-based applications. They are all important for water resource management and correlate to different categories of government services/administration, namely:

- Irrigation scheme systems inventory;
- Natural disaster, flood and drought monitoring;
- Water resources inventory;
- Hydrological infrastructure inventory;
- Other information—decrees, regulations and policies and training material; and
- File transfer protocol (FTP) process.

The spatial data are stored in the data warehouse along with the tabular data in ArcSDE and the spatial information and GIS capabilities are available via four applications (irrigation scheme systems inventory, natural disaster and flood and drought monitoring, water resources inventory, and hydrological infrastructure inventory). ArcIMS software permits the generation of maps for all four applications. Several GIS tools are available online for each application, with functionalities such as: zoom, attribute or spatial query, buffer and overlay.

7.1 Irrigation Scheme Systems Inventory

The irrigation scheme systems inventory (ISSI) application was designed and developed as a web-based and stand-alone PC-based application. The ISSI PC-based application is developed in three versions i.e. national, province, and district versions (as reported in the Java Irrigation Improvement and Water Resources Management Project 1996). The web-based and PC-based applications are in principle similar. The data input and update are the main reasons why ISSI is differentiated, as it is costly to update directly online via the website.

The districts and provinces at the local levels can use the PC-based application to enter and sort the data on their own computers, and send the updated data files to the WRDC at the national level via the Internet or by mail. The tabular and spatial data are fully integrated in the website version of this application. The application overview as follow:

- *Purpose of application:* maintain the data and to present and deliver information on the irrigation scheme systems in a particular area to users in the ministry and on the web.
- *Data sources:* the data for the ISSI application was drawn from DGWR—Ministry of PW (1994 data) and covers the entire country of Indonesia. Data for 1999 was also collected from the provincial water resources service (Dinas) of the North Sumatra Province.
- *Output available:* the PC-based users can generate a report for one specific irrigation scheme, as well as a summary report and tabular data. With the web-based version making data available at national level, users can retrieve the aggregate information and create a report which corresponds to the irrigation scheme according the province, district, and irrigation scheme area. The data includes the category of irrigation scheme, class and extent of irrigation area, and length of irrigation canals. The user can also perform attribute or spatial queries to locate the irrigation schemes according to details of the river basin, province, district and name. If the irrigation schemes are located on the map, the details of these schemes can be automatically retrieved from the ISSI tabular data holding.

7.2 Natural Disasters and Flood and Drought Monitoring

The DGWR has collected reports about flooding and droughts from all provinces of Indonesia by developing institutional networks and using telephone and fax communications. On a national level, the staff of the flood and drought monitoring unit (Satgas) record and enter this information into the databank and report it to the Director General and Minister. The WRDC's data warehouse system prepared an application based on the existing system to provide tabular data linked to mapping

reports, thereby adding value to existing information resources via enhanced functionality, as the tabular and spatial data are fully integrated in this application. In future, the application will increase in scope to add information about landslides and other natural disasters such as volcanic eruptions.

The flood and drought monitoring application provides easy access to the flood, drought and water-level data coming from selected hydrological stations network, as well as climate and rainfall data, by linking to the Meteorology and Geophysical Agency (BMG) report system which assists with disaster mitigation management. The application background is as follows:

- *Purpose of application:* the purpose of this application is to maintain the data and to provide the information related to natural disasters, especially flood and drought events, which one of the water resources problems. This application requires in real time to be eventually applied in reason to receive the data coming from a regional reporting network at the time that floods event appear and of course it can be used as the emergency services. And actually, this application used to identify the flood-prone areas by the specific users and planners.
- *Data sources:* the data available for this application are more intensively used for the flood monitoring. And the data relating to the other natural disasters are not available yet in the WRDC system. The flood data are available for the whole of Indonesia for the years of 1998, 1999, 2000, 2001, 2003 and 2003 collected from the Satgas of the DGWR—Ministry of PW.
- *Output available:* the users can get the specific information concerning the flood events based on the user requests through the spatial or the attribute queries. The data servers return the query results to the users in the report and map formats.

7.3 Water Resources Inventory

This application is expected to become central to the system in terms of water resource management and development. It uses fully integrated map and tabular data and will be a first point of reference, providing ongoing support to all classes of work related to water resources. The application background as follows:

- *Purpose of application:* to hold, build and maintain the data and also to provide information related to water resources.
- *Data sources:* the data are available for the whole of Indonesia, updated in 2000 and collected from the DGWR—Ministry of PW, covering rivers, swamps, lakes, reservoirs and small ponds.
- *Output available:* users can retrieve specific information, as mentioned above, through spatial navigation, the maps button, and through the pre-designed query form and information button.

7.4 Hydrological Infrastructure Inventory

The hydrological infrastructure inventory application provides background information related to the hydrological network stations in the rivers and lakes, as well as the rainfall and climate observation stations. The application presents the tabular data of the observing stations and, where possible, the summary statistics of the features measured. It also provides the contact details of the location and owner

of the observing stations for users who need to access the fully detailed time series data records. The map data are fully integrated with the tabular data, so that the searches can be made from the maps and station details brought up for any location of interest. For future development, direct on-line access to these data will be achieve through linkages between the data warehouse and the specialist databases. For example, a link could be made to the hydrological databases which are currently being developed by the Sub-Directorate of Hydrology within the Ministry of PW. The application background is as follows:

- *Purpose of application:* to maintain and provide information on hydrology and hydrometeorology infrastructures.
- *Data sources:* the data available for this application are for the year of 2000 (as supplied by the Capacity Building Project—Package 1, 1998). The data pertains to eight provinces: West Nusa Tenggara, North Sumatra, South Sulawesi, South East Sulawesi, South Kalimantan, Maluku, Papua, and Bali).
- *Output available:* the users can retrieve specific information, as mentioned above, through the spatial and attribute queries for the map serve. The pre-designed query form on the information page can be used to retrieve the specific station information in the tabular report format.

7.5 Other Information

The objective of the other information application is to provide the collection of other published and unpublished information that is of interest to people working in the water resources sector. It is also called a "soft-copy library". The sample data so far captured is limited just to the recent decrees and regulations as well as to the training material used for this application training. No source of soft-copy data was found during the project except for Project Training documents, and so all of the decrees and regulations have been entered into the system by typing from hard copies of the documents. The application background is as follows:

- *Purpose of application:* to maintain and provide the information about legal aspects, including the decrees, research documents, and the other relevant materials, of water resources.
- *Data sources:* the data are supplied by DGWR—Ministry of PW.
- *Output available:* users can download copies of the decrees, regulations and policy documents and training materials developed for the project.

7.6 File Transfer Protocol

The application background is as follows:

- *Purpose of application:* to provide a tool that can be used to transfer data and files to and from the data warehouse.
- *Data sources:* the data source is the data holdings in the data warehouse system.
- *Output available:* public users can download the free documents and tabular and spatial data held in the system. The extent of password protection will be at the discretion of the Ministry. The private users can download and upload the tabular and map data, insofar as they are authorized.

8 Concluding Remarks

The WRDC as an institutional instrument of water resources management system proposed in this paper is one of the key solutions to help solve water resource problems in Indonesia and would therefore be to obtain supporting the decision makers at the national, provincial and river basin levels. Regarding the importance of improvement of the efficiency and effectiveness water uses such as the irrigation, domestic and industrial purposes as well as reducing the pollution loads and its impact on living environment and, could be achieved by making relevant data and information available as well by establishing a communication system among related institutions. Further, provinces should also prioritize developing human and social capital pursuit the Law 7/2004 through education, service delivery and career development, as well as training for water resources development and management.

To this conclusion, the most apparent measure toward resolving problems—under the present problems and challenges of water resources management in Indonesia—is by means of integrated water resources data management, which first of all must starts from massive campaigning program to develop the public's sense of understanding, so that the water resources managers and actors as a whole are willing to participate in integrated water resources data and information management. If this to be materialized, one may see before too long, the water resources data management, as the inseparable side of the coin—of sustainable development and management—would become instrumental for materializing the desirable and sustainable of water balance to protect the human life and river basin ecosystem in Indonesia.

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