International Journal of u- and e- Service, Science and Technology
Vol.9, No. 7 (2016), pp.349-360
http://dx.doi.org/10.14257/ijunesst.2016.9.7.35

Development of a River Basin Monitoring System for Malaysia

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Abstract

Flood is a natural disaster that can destroy and damage a lot of properties, infrastructures, facilities, homes, vehicles and can even cause loss of lives. To minimize the hazard risk and loss due to the floods, intensive measures have to be considered. Monitoring any drastic changes in water level or river stage at river basin may not prevent the flood, but this measure benefits the community as early prediction of flood can be done before the water reaches the general population. This paper discusses the development of an informative and interactive river basin monitoring system for online hydrological stations in Kelantan, Malaysia. The first trial version has been assembled using Visual Basic.

Keywords: *Flood, Real-time Monitoring, River Basin, River Stage*

1. Introduction

Natural disasters are inevitable and cannot be prevented. Flood is one of the most common disasters that occur all over the world. In general, it is an aftermath of continuous heavy rains, in which the nearest floodplains are overflowed by water as the river banks are no longer capable of containing the extremely huge amount of water. In Malaysia, major rainy season takes place around November to March every year. Thus, it is expected that floods would hit some places around the country, especially Kelantan, Terengganu, Pahang and east of Johor, which are located in the east coast region of Peninsular Malaysia [1].

In the massive tragedy that took place in December 2014, Kelantan has become the most affected state hit by the most severe floods ever occurred since 1967. Almost all districts were submerged especially Kuala Krai, Gua Musang, Pasir Mas and Tumpat. Over 150,000 people had to be evacuated and about 1821 families had lost their homes as the houses had been swept away by rapid current of water. Figure 1 shows the Sultan Muhammad IV Stadium in Kota Bharu, Kelantan dipped in the water during the flood occurrence.

ISSN: 2005-4246 IJUNESST

Figure 1. Sultan Muhammad IV Stadium in Kota Bharu, Kelantan Dipped in the Water during 2014 Flood [2]

The effects of the giant flood were beyond words. Thousands of victims permanently lost their houses while hundreds of thousands of them suffered from damages or loss of properties, crops, livestock, vehicles and many others. Several infrastructures were mostly wrecked such as buildings, schools, hospitals, railways roads as well as bridges. These destructions and losses have given big impacts to the state's social life and economy.

Flood has been contemplated under different contemplations and approaches, for example, remote sensors system [3-5], implanted framework with middleware [4], Internet-based ongoing information securing [6] and surge displaying and estimating [7-9]. Every one of these techniques is proposed to enhance the exactness of flood checking frameworks.

Moreover, execution of an improved constant surge observing structure can diminish the harm brought on by floods [10]. In China, the Po Yang Lake is the biggest new lake, however flooding debacle happens every now and again [11]. The fiasco data checking in Po Yang Lake ranges mainly through on-spot investigation, manual social occasion, and the standard preparing report structure. Such strategies are tedious and challenging.Monitoring river stage at the river basins gives a huge advantage as early prediction of flood can be done before the water reaches the general populations. According to [12], the term 'river basin' refers to the land area which receives the rainfall before the surface run-off flows into the chain of rivers, streams, and even lakes, towards the sea through a river mouth, estuary or delta. Figure 2 illustrates a river basin and Figure 3 describes the river basin and its main features. As shown in the figure, a confluence is a joint of two rivers, while tributaries are referred to the flow of smaller rivers to a larger river. Watershed is a highland area which surrounds the river basin. Including river mouth and source, all of these are the features of a river basin.

Figure 2. River Basin [13]

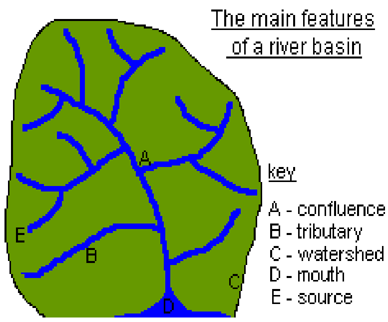


Figure 3. River Basin and Its Features [14]

During a state of emergency, time management is very crucial in order to minimize the impacts of the disaster. Lack of data such as precise locations of affected areas may cause interruptions and delay in conveying information and executing all the necessary actions. A reliable Malaysian River Basin Monitoring System must be an informative and interactive system, in which it should be capable of displaying the real time data from hydrological telemetry stations in the state of Kelantan. There are 25 hydrological telemetry stations altogether, consisting of 13 stations measuring both rainfall rate and water level, 11 rainfall stations and one water level station in Kelantan. However, this research only focuses on 14 water level stations [15]. Table 1 shows the list of water level stations and their corresponding river and river basin covered in this research.

Table 1. List of Water Level Stations and their Corresponding River and River Basin

NO.	STATION NAME	DISTRICT	RIVER	RIVER BASIN
1	Dabong	Kuala Krai	Sg. Galas	Sg. Kelantan
2	Tualang	Kuala Krai	Sg. Lebir	Sg. Kelantan
3	Kuala Krai	Kuala Krai	Sg. Kelantan	Sg. Kelantan
4	Kusial	Tanah Merah	Sg. Kelantan	Sg. Kelantan
5	Kg. Jenob	Tanah Merah	Sg. Golok	Sg. Golok
6	Jeti Kastam	Kota Bharu	Sg. Kelantan	Sg. Kelantan
7	Rantau Panjang	Pasir Mas	Sg. Golok	Sg. Golok
8	Empangan Bukit Kwong	Pasir Mas	-	Sg. Golok
9	Pasir Puteh	Pasir Puteh	Sg. Semerak	Sg. Semerak
10	Kuala Jambu	Tumpat	Sg. Golok	Sg. Golok
11	Kg. Lembaga	Gua Musang	Sg. Galas	Sg. Kelantan
12	Kuala Koh	Gua Musang	Sg. Lebir	Sg. Kelantan
13	Air Mulih	Pasir Mas	Sg. Kelantan	Sg. Kelantan
14	Air Bol	Jeli	Sg. Pergau	Sg. Pergau

The structure of the paper is as per the following; Section 1 depicts a brief presentation of this examination, Section 2 gives a brief portrayal of estimation set-up and accumulation of information. Section 3 and Section 4 comprises of examination system and preparatory results, separately. At long last, Section 5 finishes up the paper.

2. Measurement Set-up and Data Collection

2.1. Measurement Set-up

Water level stations are equipped with several types of water level sensors and tools, which are governed by Malaysian Department of Irrigation and Drainage (DID) [16]. For real-time recording stations, a data logger is connected to specific sensors or tools to automate the self-recording process. In Malaysia, measurement tools that are used in this process are digital shaft encoder, submersible pressure sensor, gas bubblers or pneumatic water level recorder, and ultrasonic or acoustic sensor. All of these sensors and tools are installed at certain stations based on specific requirements. Figure 4 illustrates the typical installation of shaft encoder.

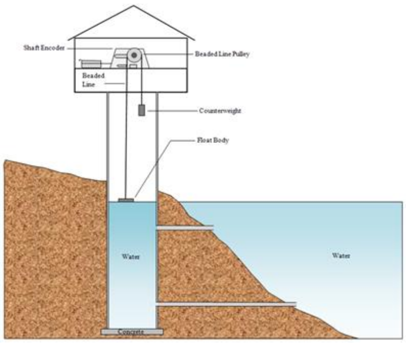


Figure 4. Drawing of Typical Installation of Digital Shaft Encoder [16]

In Figure 5(a), a submersible-type pressure sensor with external standalone data logger is shown, while Figure 5(b), 5(c) and 5(d) describe the different types of pressure sensor installation. Figure 6(a) and 6(b) are the images of gas bubbler system and its installation, respectively.

Figure 5(a). Submersible-Type Pressure Sensor with External Standalone Data Logger [16]

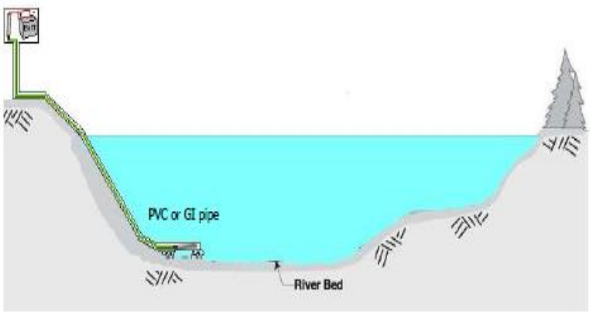


Figure 5(b). Submersible Pressure Sensor Connected to External Data Logger, Battery and Solar Panel [16]

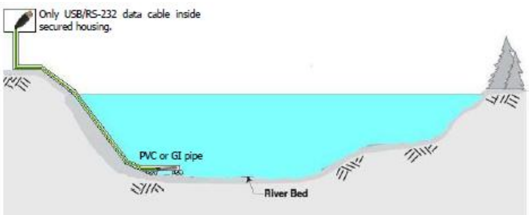


Figure 5(c). Submersible Pressure Sensor with Onboard Logger [16]

Figure 5(d). Submersible Pressure Sensor with Standalone Data Logger [16]

Figure 6(a). Gas Bubbler System [16]

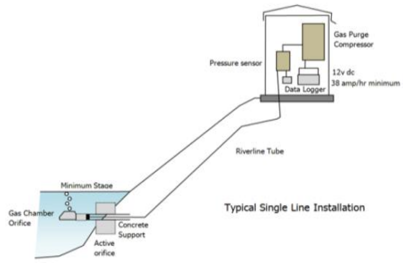


Figure 6(b). Installation of Gas Bubbler System [16]

Another tool that is used to measure water level in an open channel is stick gauge. This non-recording tool must be equipped at all stations regardless of other tool or sensor that has been installed at the station. Figure 7 shows the standard stick gauge.

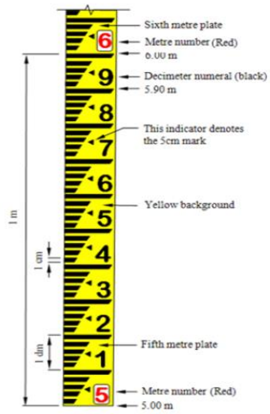


Figure 7. Standard Stick Gauge [16]

2.2. Data Collection

For the purpose of flood monitoring and forecasting, DID implements the use of telemetry systems in order to obtain real-time data remotely from each station [16]. Figure 8 illustrates DID's telemetry system for water level monitoring. Water level sensor detects the changes of the river stage, in which the data is recorded in the data logger.

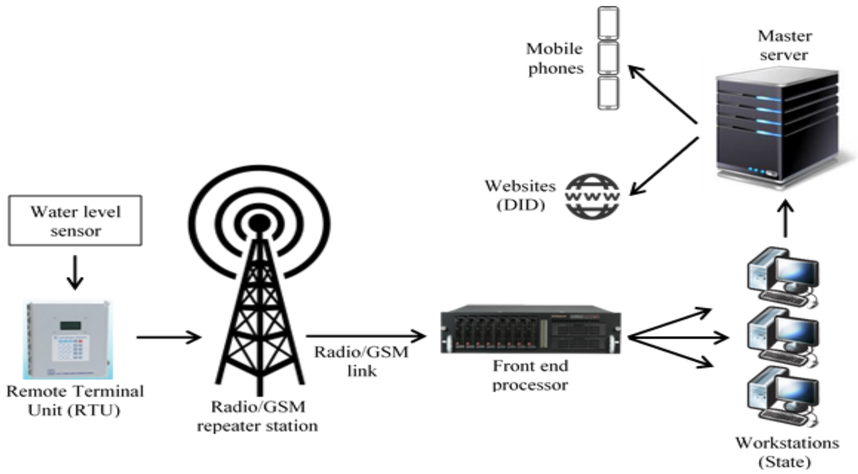


Figure 8. DID Telemetry System for Water Level Monitoring

As shown in the diagram, the data from the sensor is transmitted to Remote Terminal Unit (RTU) via a data cable. RTU is a type of data logger which requests data from measurement tool and sensor. DID also uses GSM technology to relay data to the sates' operation rooms for rural and urban areas, where the coverage is available. Once the data is transferred to the master server, the database is updated. For remote areas, UHF and VHF are used for data transmission.

3. Methodology

The activities in Figure 9 serve as the guideline for the development of the proposed system.

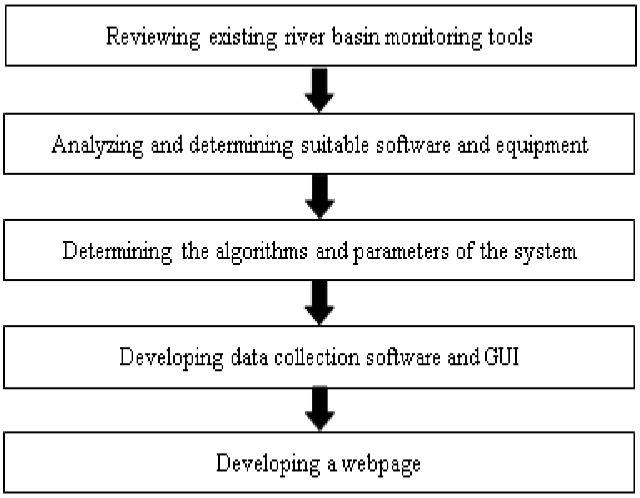


Figure 9. Research Flowchart

Malaysian River Basin Monitoring System consists of two modules; data collection software module and a website module. Figure 10 shows a diagram which outlines the system's overall structure. A collection of online hydrological data which consists of Kelantan's rivers water level from DID can be retrieved from the department's website. The regularly updated data are stored in a database, in which it is then exported to be displayed in the desktop application and web application. Desktop application is designed for the use of specific registered users while web application is meant for the public access.

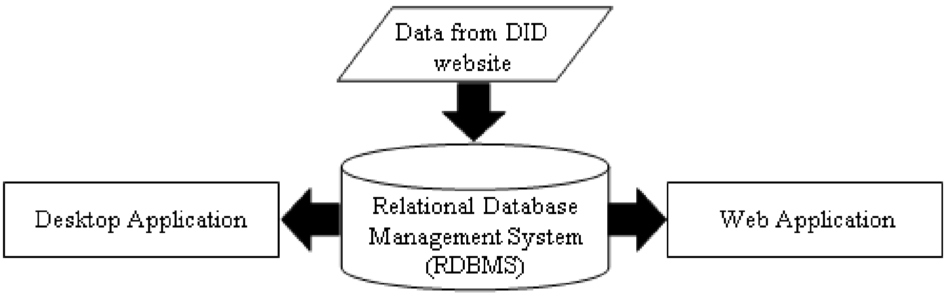


Figure 10. System's Overall Structure

Figure 11 captures the workflow of this research. Consisting of four phases, this workflow describes the activities and processes that were executed throughout the development work. In the preliminary phase, user needs and data requirements were identified and the design of the database was proposed. Second stage consisted of the development of the database, collection of data from the websites, as well as system design and development. In the evaluation phase, the system was evaluated and improved by applying minor changes. The progress would return to the previous phase if any failures or errors were found during this stage. This process would be repeated until all the system's requirements were satisfied. The final phase showed the implementation of the system and its maintenance.

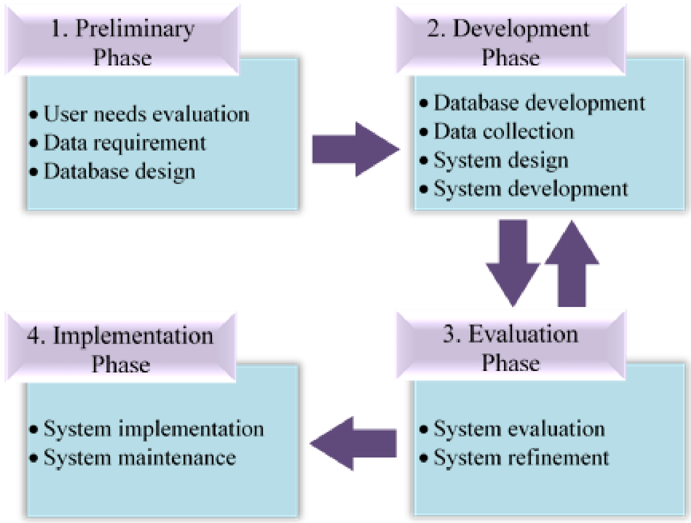


Figure 11. Research Workflow

Table 2 shows various tools and software used in the development of the system. A desktop application was developed using Visual Basic programming language in Visual Studio Community 2015. The database used to store the data is PostgreSQL, an open source object-relational database system, while the web application was developed using PHP scripting language. Open-source Geographic Information System (GIS) software, Quantum GIS (QGIS) was used to generate the map of the state of Kelantan along with the stations location.

Table 2. Tools/Software Used for System Development

Tools/Software Used in System Development	
Equipment	Dell Inspiron 2350 (Intel Core i7)
OS Platform	Windows 10
Open-source GIS Software	QGIS 2.12 (Lyon)
Integrated Development Environment (IDE)	Visual Studio Community 2015
Programming Languages	Visual Basic
Scripting Language	- PHP - JavaScript
Open-source Database	PostgreSQL 9.3
Open-source Web Server	Apache
Text Editor	- Sublime Text 2 - Notepad++
Web Browser	Google Chrome
Other tools	Windows PowerShell, HTML

4. Preliminary Results and Discussions

A trial, first prototypes of desktop application and its web-based application, called 'Kelantan River Basin Monitoring System' were programmed. The desktop application is made accessible only for registered users with different levels; administrators and operative employees. An additional privilege to add new registered users, edit or remove existing users is given to the administrator.

Figure 12 shows the login page of the desktop application, where only registered users with legal username and password can log into the system. Users whom are intended to have access to the system need to contact the administrator to get the username and password. Information of users such as name, position, staff ID and email address are required upon registration.

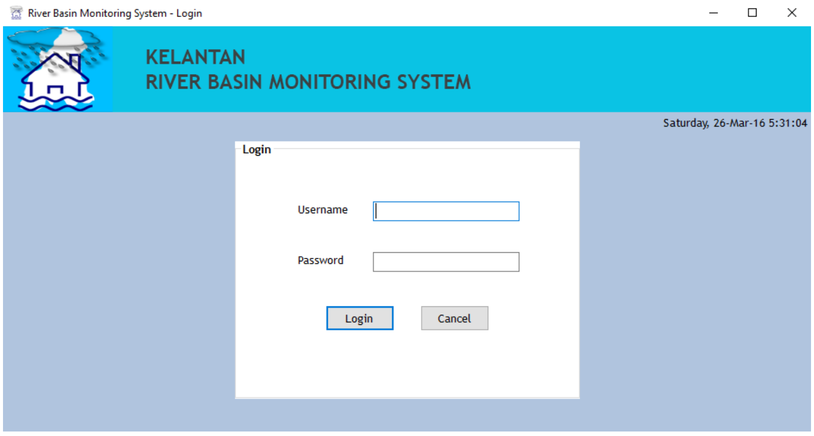


Figure 12. System's Login Page

Figure 13(a) shows the main page, in which the locations of the hydrological telemetry water level stations are shown on a map along with some information of each station in a pop-up, as in Figure 13(b). In this figure, information for Rantau Panjang Station such as its GPS coordinates, district in which it is located, as well as related river and river basin are popped-up.

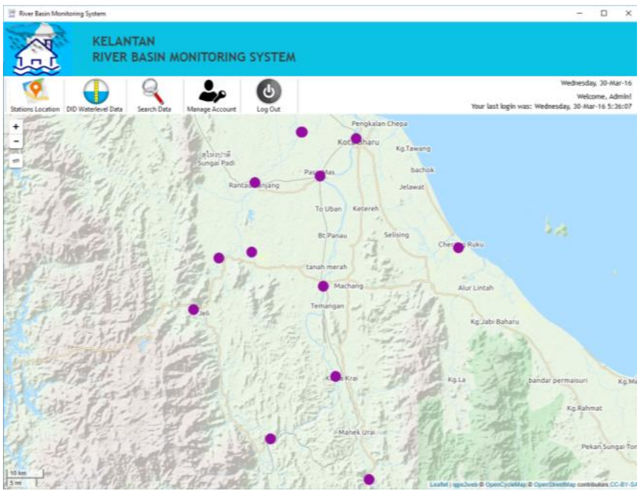


Figure 13(a). Location of Water Level Stations in Kelantan

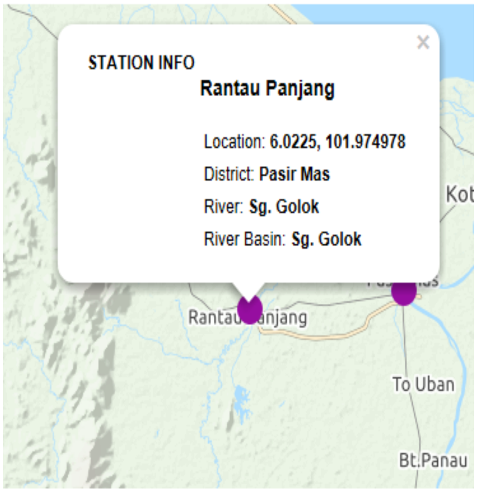
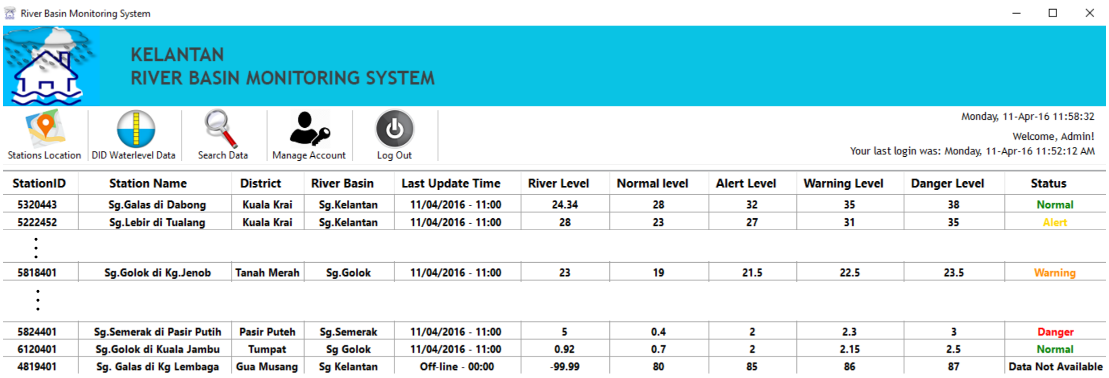


Figure 13(b). Pop-up of Station's Information

In Figure 14, all the data obtained from DID website are displayed in a table. Besides the hourly updated river level, information such as station ID, station name, district, river basin and time of last update are also provided. Each station has different maximum levels, depending on the width and depth of the rivers. River levels are monitored according to mainly three levels; alert, warning and danger levels. Status of the river level will change to 'alert', ' warning' or 'danger' if the river level value exceeds the predetermined values of alert, warning and danger levels respectively. 'Normal' status will be shown if the river level stays below the alert level. Otherwise, if the station is offline, it will show 'no data available' status. When the river level exceeded warning level, the system is programmed to update the data more often, such as in 15 minutes interval. Table 3 shows a clear image of the result obtained in Figure 14.



StationID	Station Name	District	River Basin	Last Update Time	River Level	Normal level	Alert Level	Warning Level	Danger Level	Status
5320443	Sg.Galas di Dabong	Kuala Krai	Sg.Kelantan	11/04/2016 - 11:00	24.34	28	32	35	38	Normal
5222452	Sg.Lebir di Tualang	Kuala Krai	Sg.Kelantan	11/04/2016 - 11:00	28	23	27	31	35	Alert
⋮										
5818401	Sg.Golok di Kg.Jenob	Tanah Merah	Sg.Golok	11/04/2016 - 11:00	23	19	21.5	22.5	23.5	Warning
⋮										
5824401	Sg.Semerak di Pasir Putih	Pasir Puteh	Sg.Semerak	11/04/2016 - 11:00	5	0.4	2	2.3	3	Danger
6120401	Sg.Golok di Kuala Jambu	Tumpat	Sg Golok	11/04/2016 - 11:00	0.92	0.7	2	2.15	2.5	Normal
4819401	Sg. Galas di Kg Lembaga	Gua Musang	Sg Kelantan	Off-line - 00:00	-99.99	80	85	86	87	Data Not Available

Figure 14. Water Level Data

However, the availability of the real-time data from DID website has become the biggest limitation of this system. Once the system lost its connection to the Internet or to the website, the data cannot be retrieved. The purpose of the system is solely to display data obtained from the website in more interactive and informative means.

5. Conclusion

The prototype of River Basin Monitoring System is presented in this paper. This system is created using open-source but powerful resources to develop a system with minimal cost yet reliable. Two main solutions of the system have been highlighted, which are desktop application for registered users and web application for public access. The proposed system is flexible for any changes and enhancement in order to meet new requirements of rapid growth of technologies. However, the current prototype only consists of desktop application and has not fully developed. The next progress will include web application development and enhancement on desktop application's data display.

Table 3. Water Level Data

Station ID	Station Name	District	River Basin	Last Update Time	River Level (m)	Normal Level (m)	Alert Level	Warning Level (m)	Danger Level (m)	Status
5320443	Sg. Galas di Dabong	Kuala Krai	Sg. Kelantan	11/04/2016 – 11:00	24.34	28	32	35	38	Normal
5222452	Sg. Lebir di Tualang	Kuala Krai	Sg. Kelantan	11/04/2016 – 11:00	28	23	27	31	35	Alert
5818401	Sg. Golok di Kg. Jenob	Tanah Merah	Sg. Golok	11/04/2016 – 11:00	23	19	21.5	22.5	23.5	Warning
5824401	Sg. Semerak di Pasir Putih	Pasir Puteh	Sg. Semerak	11/04/2016 – 11:00	5	0.4	2	2.3	3	Danger
6120401	Sg. Golok di Kuala Jambu	Tumpat	Sg. Golok	11/04/2016 – 11:00	0.92	0.7	2	2.15	2.5	Normal
4819401	Sg. Galas di Kg. Lembaga	Gua Musang	Sg. Kelantan	Off-line – 00:00	-99.99	80	85	86	87	Data Not Available

Acknowledgments

This study has been sponsored by Research Management Center of the International Islamic University Malaysia.

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