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INFORMATION TECHNOLOGY RISK MANAGEMENT FOR WATER QUALITY MONITORING IoT INFRASTRUCTURE: A CASE STUDY AT TASIK CHINI UNESCO BIOSPHERE RESERVE

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ABSTRACT

Due to its rich and diverse biodiversity of flora and fauna, Tasik Chini, a UNESCO Bisosphere Reserve, is a national heritage that must be preserved and protected. Ensuring healthy water quality here is vital for the survival of the ecosystem. Water quality was constantly being monitored through the use of a network of sensors and telemetry system that collect parameters to determine Water Quality Index since 2004. However, two events have rendered the setup to be inadequate: the economic activities around the lake and the big flood of 2014. Both events has proven that the IoT infrastructure at Tasik Chini is inadequate to mitigate major disaster. The risk of both natural and man-made disasters happening always increased yearly and has a huge impact on water quality monitoring as well as the dissemination and sharing of data and results. A proper management plan to mitigate these risks is needed. The purpose of this paper is to highlight a successful research methodology that has been proposed and done in monitoring and improving Tasik Chini water quality. First, needs analysis were carried out through face-to-face interaction with researchers and the indigenous community living within the vicinity of the lake. Historical water quality data were also compiled and analyzed to validate the degradation of water quality over the years. Second, a proper risk registers and risk respond plan was developed. The current telemetry and network of sensors were reengineered by introducing new online tools for sharing and disseminating of water quality data to more diverse stakeholders. Cloud and 4G services are now the integral part of monitoring. Third, an early warning system has been developed to complete the setup.

Keywords: Risk Management, Water Quality, Telemetry System

INTRODUCTION

Tasik Chini is the second largest natural lake in Malaysia. It extends between the coordinates of 3°24'40''N to 3°26'42'' N and 102°52'18''E to 102°55'54'' E to form a lentic water body from a combination of 12 open bodies of water known as 'sea' by the native indigenous people. The 202-hectare lake is surrounded by 6923 hectares of swamp forests and freshwater swamps forming an area known as Tasik Chini Forest Reserves (Kutty et. al. 2005, Toriman et. al. 2010).

The natural environment in Tasik Chini that includes the flora and fauna, rivers, swamps, lowland and hill forests as well as the indigenous people form a unique ecosystem. The lake has extensive natural habitats such as riparian forests, freshwater forests, forested hills and lowland forested areas. Many species of flora and fauna are endemic or unique to Tasik Chini - 87 species of freshwater fish, 189 species of birds, 51 low forest species, 15 freshwater swamp forest species, and 25 aquatic plant from the latest report by NST Leader (2019). About

800 indigenous people (known as Orang Asli) from Jakun tribe made their homes within the vicinity of the lake. They used this lake as their main source of sustenance as well as source of water.

Due to its rich and diverse biodiversity of flora and fauna, UNESCO designated Tasik Chini for inclusion in the World Network of Biosphere Reserves in May 2009. The recognition is to provide a sanctuary for hundreds of freshwater species. The representation in this networks means that we are “devoted to conserving biological diversity, promoting research and monitoring as well as seeking to provide models of sustainable development in the service of humankind” as stated in the UNESCO proclamation (2009).

The presence and complexity of Tasik Chini's ecosystem makes it an infinite asset in terms of aesthetics, heritage, socioeconomics, ecotourism and ecological importance. It should and must be preserved as an important heritage to the nation and future generations. If we lose it, the loss will be permanent and irrevocable.

WATER QUALITY MONITORING

Universiti Kebangsaan Malaysia established Tasik Chini Research Centre (TCRC) to promote biotic and abiotic aspects of research based on the diversity of flora and fauna, water, soil and air. It’s 20-hectare site houses ultra-modern labs, accommodation and community center dedicated to conducting research, teaching, field work, environmental awareness and disseminating information on integrated lake management to the community. TCRC has three lab complexes, each dedicated to hydrology and climatology, microbiology and instrumentation, and water quality researches. In addition, there is a social science group dedicated to conducting research on the engagement of Orang Asli “to provide models of sustainable development in the service of humankind” as per described in UNESCO declaration.

The ecosystem depends on the lake for their survival and water supply. Ensuring healthy water quality here is vital for the survival of the ecosystem, and hence must be constantly monitored. In 2010, TCRC built seven telemetry stations to measure and record water quality parameters at seven different rivers that formed part of inflow and outflow streams into the lake. Figure 1 shows the architecture of the telemetry station of TCRC. Every sampling station consists of a tower block that houses solar cell and battery for power supply, a data logger to record readings from sensors, a GSM modem and antenna to transmit the data from data logger to a server at TCRC. The measurement taken are Temperature, Conductivity, Total Dissolved Solid, pH, Turbidity and Dissolved Oxygen. Details of the parameters and methods on water analysis can be found in Suhaimi et. al. (2007) and Azhar (2019).

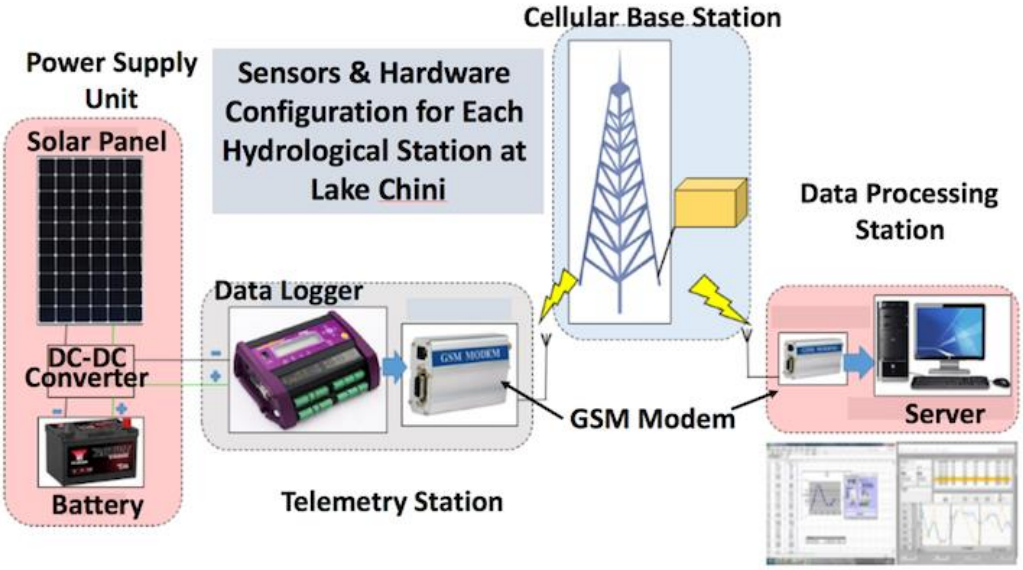

FIGURE 1. Architecture of original telemetry station at Tasik Chini

In addition to water quality, every station was also equipped with sensors for hydrology and climatology. These sensors share the same data logger and GSM modem.

THE NEED FOR REVAMP

Since 2010, the system served its purpose well. However, two events have rendered the setup to be inadequate: the economic activities around the lake and the big flood of 2014. Both events have completely ruined the process of acquiring the valuable water quality as well as decimated our telemetry stations.

The main economic activities around the lake are logging, mining and plantations. They present new challenge in monitoring water quality. In particular, wastes from these activities such as sediment, fertilizer and toxic that flow into the lake gave a lasting effect to the flora and fauna, and threaten the lake biodiversity. Uncontrolled development and use of land is in conflict with its status as an environmentally sensitive area. It has resulted in a degraded environment in the lake basin. This development not only have negatively impacted ecological functions and biological diversity but also affected our sensors. Pollution and sediment had impaired our sensors to a point where frequent routine preventive maintenance has become a necessity.

The real-time updating into a centralized database has been an invaluable task. However, the big flood that began in late December 2014 and lasted for 2 months caused a host of damage to the area. In addition to the damages reported by Akasah and Doraisamay (2014), the flood has totally decimated the telemetry stations and its components. Floods are considered an annual natural disaster in the East Coast of Malaysia. However, the record-setting flood of 2014 was best summed up by Baharuddin et. al. (2015) as “the most significant and largest recorded flood in the history of Kelantan. It was considered to be a ‘tsunami-like disaster’ in which 202,000 victims were displaced.”

The big flood completely destroyed the IT infrastructure. Some of the stations were submerged and unreachable for more than a week. Due to the flood, devices vital to our sampling such as data loggers, power supplies and routers were unserviceable. Water quality sensors were not badly affected since they were designed to be submerged in water. However, due to the absence of supporting devices and power supply, vital data for the next few months were not logged and not transmitted to the server by GSM modem.

The event demonstrates that the IT infrastructure at Tasik Chini is unprepared for any eventuality. Risk Management was never carried out by both DOE and TCRC prior to the disaster. Jamali et. al. (2018a) carried out an IT Risk Management for the TCRC as a consequence of the flood. She observed that TCRC needs to promote some aspects of IT risk management policies such as developing a special risk management system or a special model for risk registration and data storage. The risk of both natural and man-made disasters happening always increased yearly and has a huge impact on water quality monitoring as well as disseminating and sharing of data and results. Therefore, TCRC requires a proper management plan to mitigate these risks.

THE DEVELOPMENT OF IT RISK MANAGEMENT

The risk in this study refers to any potential impacts of natural and man-made disasters on water quality in Tasik Chini according to the National Lake Water Quality Standard (NLWQS). In addition to mitigate risks, the risk management system can also be used as a medium for the delivery of water quality information to all stakeholders which include selected government agencies, researchers and Orang Asli community. The preferred channel will be mobile devices since it is pervasive, fast and easy integration with data access systems (Idris et. al. 2009, Aziz et. al. 2018)

In order to achieve our aim, we performed the following activities:

1. collect disaster management needs from both researchers and Orang Asli working and living at the vicinity of the lake.
2. review risk management methods and develop risk management systems based on best management practices or standard frameworks.
3. develop mitigation plans derived from activity (2).

NEEDS ANALYSIS

In the first phase of our work, we conducted face-to-face interactions with the researchers of TCRC and Orang Asli community. Since they are lake dwellers, through the direct interaction with them, we can gain first-hand knowledge on their concerns of the impact of disasters on their daily life and lake ecosystems. We also seek to understand their needs and preferences as well as usability if we were to develop a proper risk management system.

Primary data was obtained from five TCRC researchers and 25 Orang Asli collaborated in in this exercise. The Orang Asli were randomly selected from two different villages for better representation. One village, Kampung Cendahan, is located deep inside the forest without modern conveniences and only accessible by boat whereas another village, Kampung Gumum, is diabolically opposed. Their concerns, needs and preferences may be different.

Since there is a causal link between the effect of economic activities and disasters on water quality and subsequently on quality of ecosystems, historical water quality data from two rivers were compiled and will be analyzed to validate the degradation of water quality over the years. River Jemberau is the inflow into the lake while River Chini is its outflow. This trend is important since the Orang Asli will be able to communicate their efforts, over the years, to lessen the impact of degradation on their lives. They can also narrate, based on their observation, how nature’s balancing act seek to stability.

Choosing the framework for risk management systems wasn’t really a difficult choice. Although the field of risk management has been around for the decades, its implementation within TCRC is still in its infancy. Risk management can be defined as a logical and continuous process consisting of three main steps: identifying risks, selecting risk response strategies and monitoring outcomes (Reim et. al. 2016). However, Tranchard (2018) convinced us that yesterday’s risk management practices are no longer adequate to deal with today’s threats and they need to evolve. The world is changing rapidly as reported by Byatt (2018) and “the need to anticipate and adapt, and to learn new knowledge quickly as the speed of change increases”.

TCRC needs to develop a risk management system for water quality monitoring. Some uncertainties are beyond their control. It has to take a systemic approach. The higher the external and internal uncertainty of their works, the higher the importance of both risk identification and quantification, and the importance of appropriate measures that counter the negative effects of risk. Often risk judgments related to very complex situations need to be made.

ISO 31000:2018 was chosen as the framework to TCRC risk management Implementation. The updated ISO 31000:2018 is clearer and more concise, and takes an integrated approach to help organization improve planning and make better decisions. Tranchard (2018) encourages us to embed this integrated approach to think through “what might happen” with risk-informed decision-making. Jason Brown, Chair of technical committee ISO/TC 262 on risk management that developed the standard, says: “The revised version of ISO 31000 focuses on the integration with the organization and the role of leaders and their responsibility. Risk practitioners are often at the margins of organizational management and this emphasis will help them demonstrate that risk management is an integral part of business.” (Tranchard, 2018).

Tranchard (2018) also outlined the following changes in the updated version which make it particularly apt for our purpose:

1. Review of the principles of risk management, which are the key criteria for its success.
2. Focus on leadership by top management who should ensure that risk management is integrated into all organizational activities, starting with the governance of the organization.
3. Greater emphasis on the iterative nature of risk management, drawing on new experiences, knowledge and analysis for the revision of process elements, actions and controls at each stage of the process.
4. Streamlining of the content with greater focus on sustaining an open systems model that regularly exchanges feedback with its external environment to fit multiple needs and contexts.

Following these recommendation, risk registers and risk respond for TCRC were developed based on the ISO 31000 standard. The registers and respond were discussed in detail in Jamali (2018b).

MITIGATION PLAN: EXAMPLE

Moving beyond capturing vital data on a daily basis, TCRC need to constantly provide accurate and speedy information to enable the environment to be monitored and able to benefit users of local communities and relevant agencies. These new necessities need to be incorporated within the risk management system. A few adjustments to the daily operations are needed. A dashboard and early warning system is needed. Dashboard should be able to:

1. display raw data and the Water Quality Index periodically.
2. visualize parameters taken from the sensors.
3. interactive maps showing the location of all seven sampling stations and the parameters.
4. access data anytime and anywhere using various devices.

A flexible early warning system allows TCRC to set a threshold for certain parameters and warn the communities and agencies for further action if sensor readings are beyond a threshold. This is necessary for TCRC to detect any event that demand immediate mitigation such as flooding and pollution. The dashboard displaying the parameters of water quality and status of early warning are shown in Figure 2. The parameters shown on the graph in Figure 2 are Conductivity, Dissolved Oxygen, pH, Total Dissolved Solid (TDS), Turbidity and Water Temperature. The graph lines show the trend of the data sent by the sensor to the dashboard which then will be interpreted by expert in water quality.

Another important issue is for TCRC to disseminate their findings to interested researchers, communities and agencies. It is essential for the recipients to transform the digital footprint into something meaningful and practical. In order to provide this initiative, current and future data must be made accessible. A physical server current being deployed is not particularly apt for such purpose.

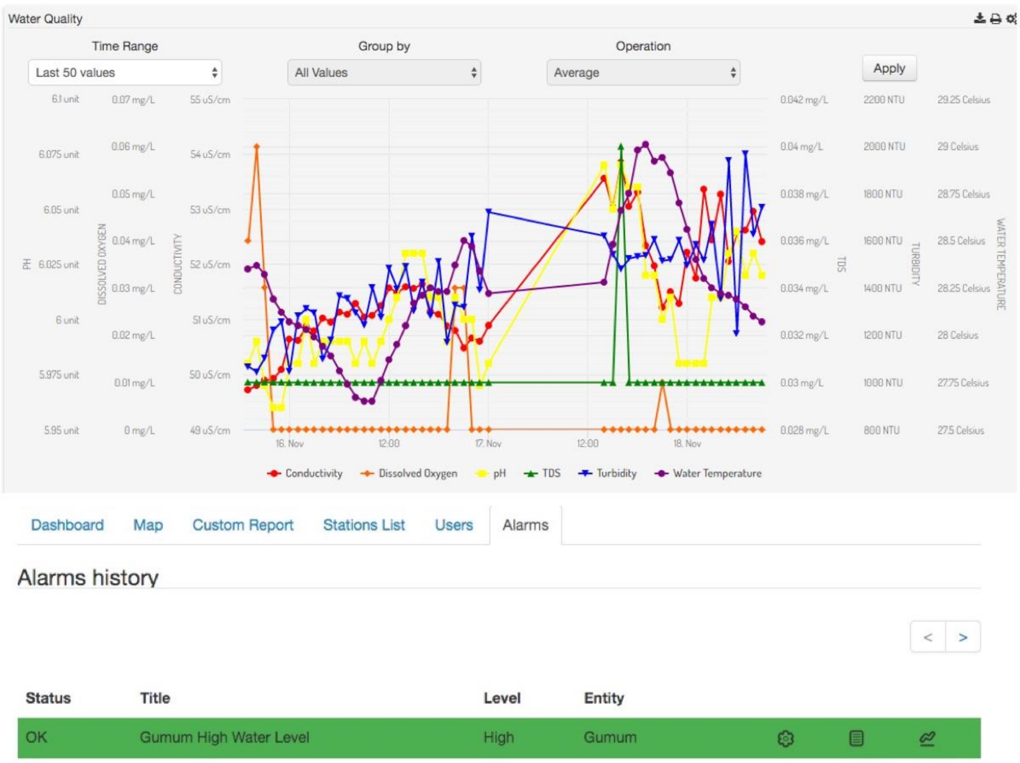

FIGURE 2. Dashboard Displaying Water Quality Parameters and Early Warning

Current and future data will be moved into a cloud to mitigate the risk of failing telemetry station and server. Moving data into public cloud will ensure public accessibility as well as discharge TCRC from daily operations of maintaining a physical server such as security and backup. The cloud will also be hosting the dashboard and early warning system. This public repository will make it easier for real-time data from data logger to be accessed by the dashboard and early warning system as well as in-situ calculation of Water Quality Index.

Figure 3 shows the architecture of new sampling station. A solar panel and battery will provide power supply to data logger which will accept readings from water quality, hydrology and climatology sensors. The readings will be pushed to a router for data transfer to the cloud via a mobile network. Each monitoring station is equipped with a mobile / wireless network technology that has high reliability with no interruptions and security issues. In this, 4G wireless network has been used to transfer data from the water stations to the cloud. All monitoring stations form a separate network infrastructure and operate on the data plan allocated to it. Data transfer will be regular and continuous. By using software such as Microsoft Power BI, data collected from water stations are accessed from the cloud and then be displayed in form of graphs and dashboard. Data then can be manipulated by the experts to see the trend of water-quality in real-time.

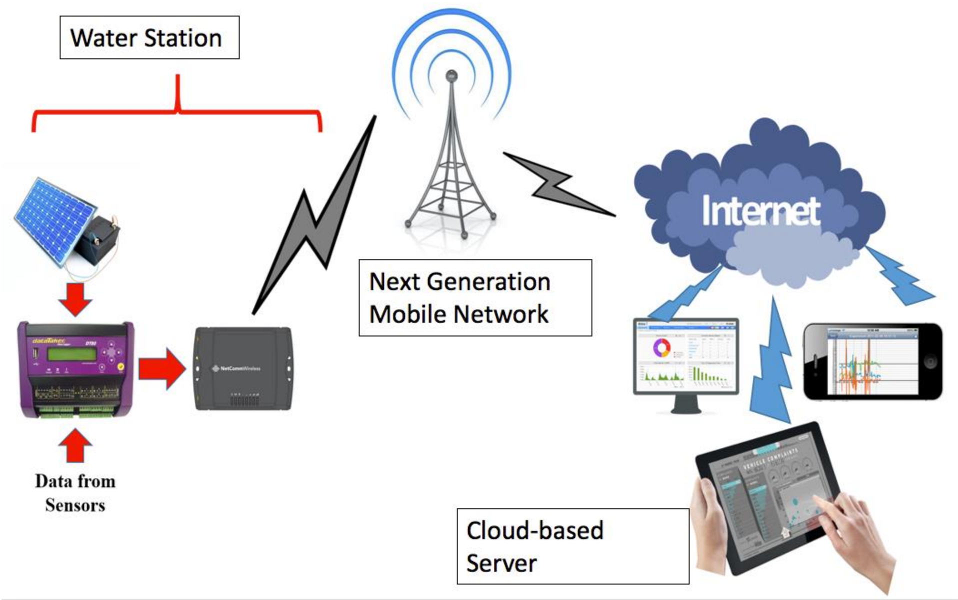

FIGURE 3. New architecture for telemetry station.

CONCLUSION

The big flood of 2014 has been an eye opener. The devastation to our telemetry and, subsequently, our ability to monitor water quality at Tasik Chini were severely handicapped. Needs analysis were carried out through face-to-face interaction with researchers at Tasik Chini as well as the indigenous community living within the vicinity of the lake. The work of Jamali et. al. (2018a) and Jamali (2018b) which develop a proper risk registers and risk respond based on ISO 31000:2018 standard was the first step in introducing IT Risk Management practice here. Subsequence activities in revamping the current telemetry and network of sensors enabled the sharing and dissemination of water quality data to more diverse stakeholders. Cloud and 4G services became the integral part of monitoring. An early warning system has been developed to complete the setup. All these three activities done in this research have shown that there are six parameters that matter the most for mitigating risk of flood in Tasik Chini which are Conductivity, Dissolved Oxygen, pH, Total Dissolved Solid (TDS), Turbidity and Water Temperature. By using sensors set up at every station at Tasik Chini has helped to show the real-time data that can be used by the water quality experts. These data are analysed and used by experts to monitor the current water quality at Tasik Chini and on the same time helped to predict the future flood that about to occur.

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