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TITLE:

HYPERMEDIA BASED IRRIGATION NETWORK MODELING OF MUDA

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CHAPTER 1
INTRODUCTION

In the past (from 1930s to the 1970s) the construction of dams, in the eyes of many, became synonymous with development and economic progress symbols of modernizations. During the 20^{th} century, dams, especially large one, emerged as one of the most significant and visible tools for the management of water resources. Thus, then and now, dams are still considered as instruments of development. Current estimates suggest that some 30-40% of irrigated land worldwide now relies on dams. In Malaysia alone, 57% of the arable lands are irrigated with water sourced from dams (WCD, 2000).

The scenario of water use in other parts of the world and also in Malaysia concerns about access, equity, and the response of growing needs. In Kedah, a state located in the northwest peninsular of Malaysia, three main dams, namely Muda Dam, Pedu Dam, and Ahning Dam, perform these functions. The purpose of these dams is to provide irrigation, drainage and other facilities for the double cropping of rice in the coastal plain of Kedah and Perlis. The gross area covers approximately 126,000 hectares. Out of which the net paddy area is about 96,000 hectares (The Malaysian Water Association, 2001).

The Muda irrigation network which is located in the rice bowl area of Kedah, is the largest rural development project initiated during the First Malaysia Plan (1966 – 1970). The rice bowl area being serviced by Muda irrigation network is known as the Muda area as shown in Figure 1.1. The water resources for Muda Irrigation Network are derived from three main sources namely direct rainfall, river flow, and dam release. Storage system consists of three reservoirs, namely Muda, Pedu, and Ahning reservoirs. An extensive network of open channels designated as primary and secondary canal irrigates the Muda Irrigation Scheme that comprises of 173 irrigation blocks (MADA, 2003).

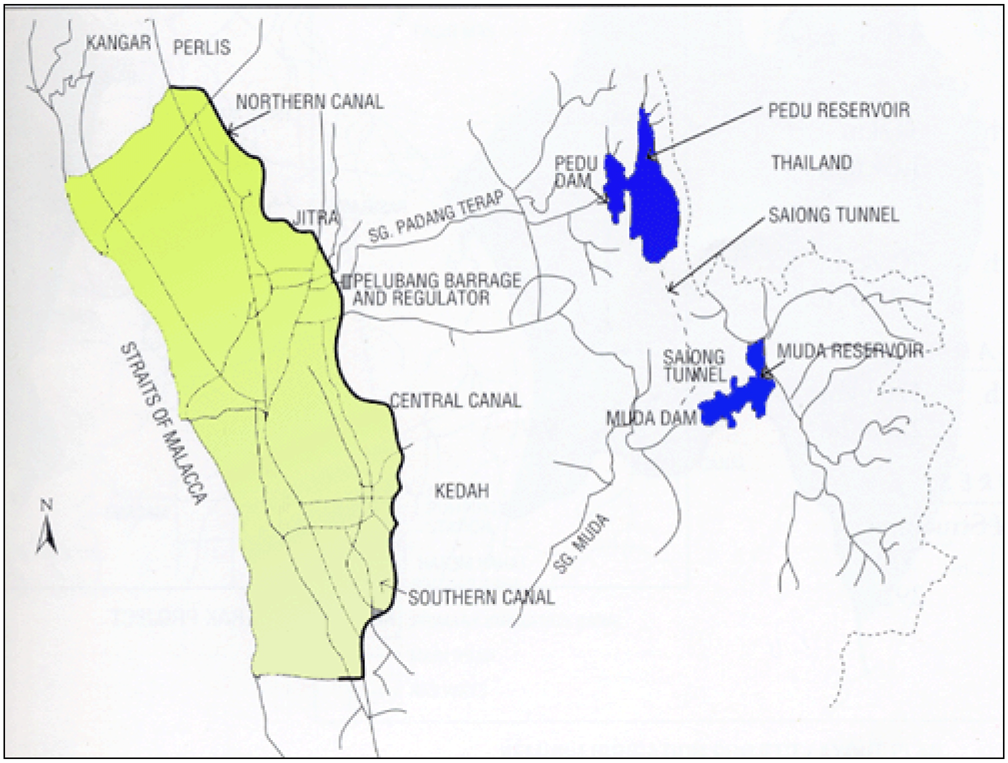

Figure 1.1: Muda Irrigation Network Area

The Malaysian Agriculture Development Authority (MADA) is responsible for the irrigation of the Muda area. MADA uses a telemetric hydrological network system, consisting of a master controller in the MADA headquarters and 84 remote terminal units (RTU) evenly distributed over the whole of Muda area and catchments area. The telemetric stations have enabled MADA to acquire timely rainfall and river flow data. Other hydrological data collected include the daily evaporation data from 20 stations, and the actual irrigation supply to the field. With all field data and available water for distribution collected, the department will assess the irrigation water requirement and arrange distribution of water in the fields. This is realized through a daily water balance at each irrigation block level as shown in Figure 1.2. The computation of the water balance is done using a model and software developed in-house by MADA.

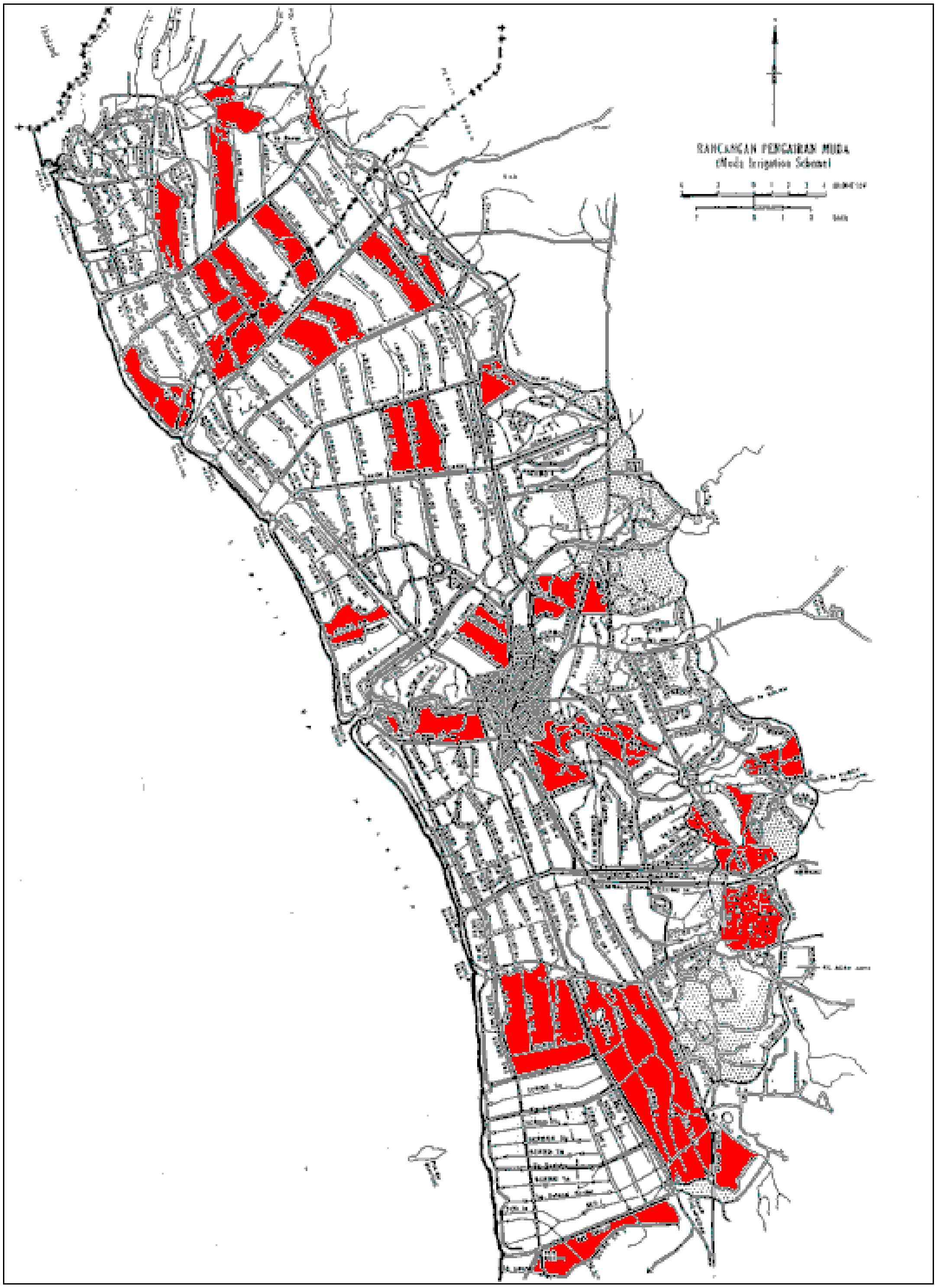

Figure 1.2: The Irrigation Blocks (MADA, 2003)

MADA uses several systems for the management of its irrigation operation apart from the Telemetry System (TS). The systems that are related to irrigation operations are the Agriculture Information System (AIS), Water Management System (SPA), Farmer Subsidy System (SBPKP) and Farmer Information System (PPK). The systems integrate with each other as shown in Figure 1.3. Farm Management System (FMS-GIS), which is under development, will be used to predict the paddy production based on satellite images of the plant a few weeks before the plant is supposed to bear the paddy. The AIS is used to monitor and manage the activities of the paddy planting while SPA provides the information of water. The allocation of subsidy to farmers is controlled by SBPKP while PPK provides information on farmers such as their personal information, farms ownership and farmers' activities. Apart from the systems for the management of its irrigation operation, MADA uses other systems for its management as an organisation.

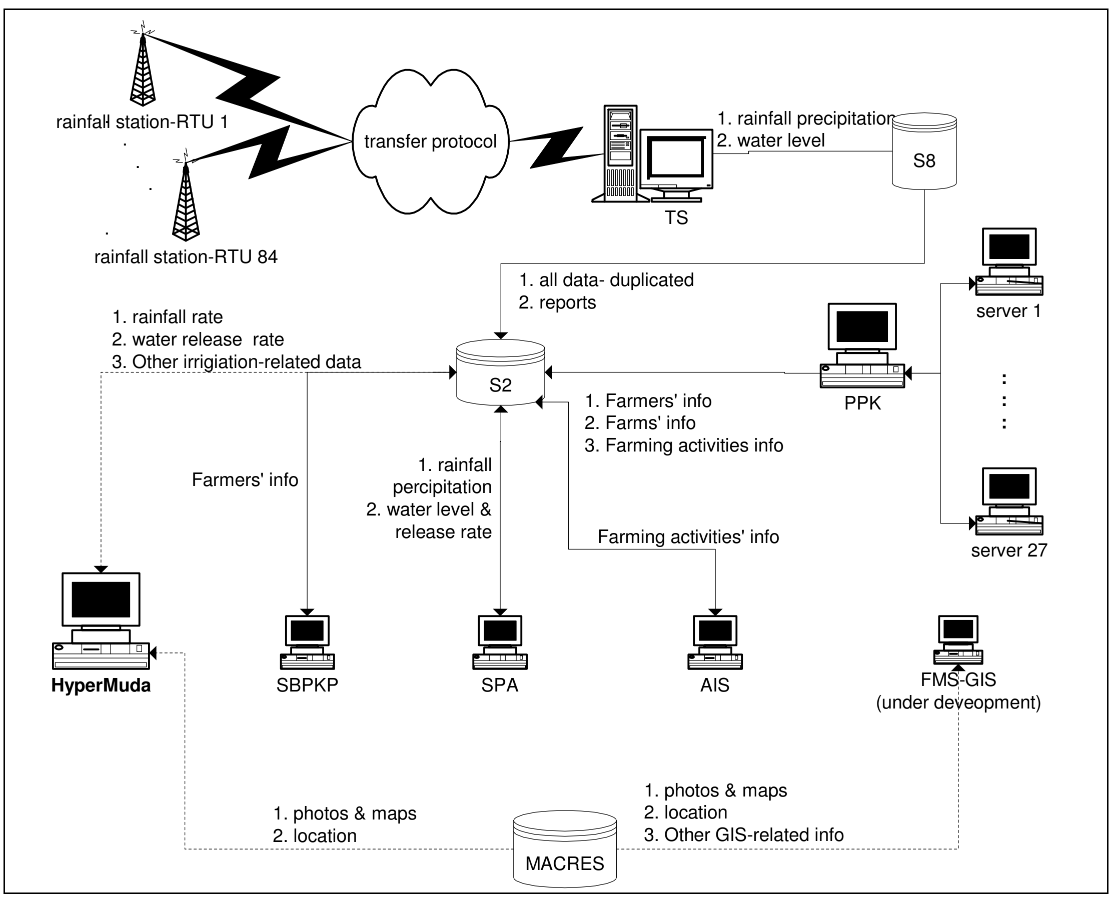

Figure 1.3: The Context Diagram of MADA System and its Relationship to HyperMuda

An effective irrigation network model is an important concern for MADA. Such model would increase the level of confidence in the ability of nations and communities to meet its future water needs (Pallottino et al., 2002; Jayatilaka et al., 2003). In this study, a system called HyperMuda has been developed to provide a one-stop centre for information on the Muda irrigation network in Kedah. It is hoped that this system can be integrated with other systems that are currently being used by MADA.

1.1 Problem Statement

As described above, the compilation of all field data and available water for distribution is manually collected and processed, thus MADA normally take quite a long time to make irrigation-related decision. The department, at present, does not have a one-stop information centre to deal with such huge amount of data and most of the data are kept in printed version. As a consequence, relevant information is often not available on time or is incomplete.

1.2 Objective

The objective of the research is to develop a model of the Muda network irrigation system. The model can be used to measure various attributes (gauge, levels, range, water system - demand, release, stored, waste) involved in irrigation operation. Based on the model, a hypermedia-based system for the irrigation network was developed. The system can be used to assist MADA in irrigation decision-making and thus, enable them to plan future development.

1.3 Scope, Assumption and Limitation

The study only covers the irrigation area under the management of MADA. The aspect included is the irrigation network that covers attributes such as dam/reservoir, river, canal, feeder, irrigation block, gate, barrage, water level, rainfall station and precipitation, evaporation rate, telemetry station and Public Work Department access point. The deliverable is in the form of a prototype, which consists of the integration of prototype's GUI and its respective database. The prototyped developed is tested exhaustively. We also prepared the test cases, instruments, and details steps for the prototype evaluation process, however the evaluation activity itself is beyond the scope of this study.

Data is assumed to be correct at the time it is collected for the research. However, some limitations exist in doing the study. MADA cannot provide the latest map of the area under study. Maps that are obtained are in drawing form and not in digital form or taken from original image (satellite image). Therefore, precise representation of the area is not obtained. Some of the maps have to be reproduced according to the needs of the prototype after scanning of the maps.

1.4 Significance of the Study

The development of HyperMuda is based on the problem faced by Water Management department in MADA. HyperMuda is a one-stop information centre prototype that can facilitate the management tasks by providing necessary information of Muda Irrigation Network to improve their operation. The model, when transformed into a hypermedia-based system would allow management to better understand the irrigation network. The system enables visualization of, and interaction with various relations of irrigation interest such as relations (1) within and between areas; (2) between upstream and downstream interest; and (3) between agricultural, industrial, and domestic sectors.

1.5 Organisation of the Report

This chapter has started with an introduction to the usage of water in irrigation. Next, the Muda irrigation system is described, and this is followed by a discussion on the study motivation and requirements. Lastly, the objective, scope, and significance of the study are presented.

Chapter 2 provides the literature on irrigation management projects and practices that have been done and applied. This is followed by the descriptions on irrigation information systems that have been developed and used by various irrigation authorities such as in Malaysia and China.

The step-by-step approach used in this study is presented in Chapter 3. All the steps starting from overview the current system in MADA, data collection, irrigation system analysis, database and GUI design, and prototype development, testing and evaluating are discussed.

The Information Gathering and Analysis of MADA irrigation system is discussed in Chapter 4. The irrigation system covers the collection, storage and usage of water as well as transportation of water to end-users. This is followed by the network analysis to identify the supply chain infrastructure and the administration structure.

The explanation then continues with designing the conceptual, logical and physical database in Chapter 5. Relationships between the entities are identified in the conceptual design stage and are later detailed out in the logical database design, which includes the identification of the primary and foreign keys. This is also known as the logical schema. The physical design describes the base relationships, file organisations and indexes used to achieve efficient access to the data.

Chapter 6 concentrates on the development, testing and evaluating the HyperMuda prototype. Details of the network irrigation, databases and GUI developments are given. Extensive testing of the prototype is also described and this is followed by the description of predefined test cases that can be used in the prototype evaluation stage.

The conclusion and recommendation of the study are presented in Chapter 7. Highlights on the prototype that has been developed are discussed and recommendations for future work that are related to this study are also provided.

1.6 Summary

Water is no doubt one of the most important elements in our lives. Water for irrigation is an aspect that needs proper management as it contributes towards the way we live.

Malaysia has one of the most extensive irrigation networks in the world, and the irrigation is focus on paddy planting. Although the irrigation network is extensive, the management of it semi automated. Fast decision making on irrigation problems can only be made if data are available in a stop information centre.

As a consequence, the development of HyperMuda, a hyper media based network irrigation system has to be undertaken. HyperMuda is a one-stop information centre prototype that can facilitate the management tasks by providing necessary information of Muda Irrigation Network to improve their operation. The system enables visualization of, and interaction with various relations of irrigation interest such as relations (1) within and between areas; (2) between upstream and downstream interest; and (3) between agricultural, industrial, and domestic sectors. The system can be used to assist multi criteria decision-making by managers thus, enable them to plan future development. The proposed system will cover the irrigation area under the management of MADA.

CHAPTER 2
LITERATURE REVIEW

This chapter provides an overview to irrigation management and the irrigation project practice in area of the study i.e. Muda Area. After that the importance of information system in irrigation management will be discussed. Several examples of information system application to irrigation are presented. These examples include a few available applications on irrigation designed to help farmers optimize decision on when and how much to irrigate, as well as planners and managers to orient decisions on allocation and deliveries according farm strategies.

2.1 Irrigation Management

Plants need water to grow and survive. In humid areas, the water demands of most plants are satisfied by rainfall. In arid or semi-arid regions however, plant water requirements are generally larger than what rainfall can provide. Therefore, additional water needs to be provided in the form of irrigation. Improper irrigation not only wastes water and resources, but also, if more than needed water is applied, it can leak off nutrients and other amendments. Conversely, if insufficient water is applied, productivity of the soil is impaired, thus affecting plant development. Therefore, a major part of irrigation management is deciding when to irrigate and how much water to apply.

Irrigation management can be defined as the process of implementation of suitable operation and maintenance in order to meet the objectives of the concerned irrigation system and monitoring of the activities to assure that the objectives are met (IAA's, 2004). Three implications can be drawn from the above definition. First, irrigation management is not a routine job. The management decisions have to be made with great care, as they have to match with the operation and maintenance objectives. Secondly, even though the overall goal may be the same, operation and maintenance objectives vary from system to system, hence management decisions have to take account of these inter system differences. Thirdly, monitoring is an integral part of management thus management decisions have to be continuously refined according to the feedback obtained from monitoring and evaluation.

Many irrigation projects throughout the world never fulfil the expectations envisioned at planning and design stage (Pervez, 2002). The land irrigated is often less than planned, efficiencies are lower, and crop yields are not as high as expected. A major reason is the lack of incentives and a working knowledge about proper water management, including scheduling at the farm level on the part of project planners, designers, system operators, and agricultural personnel, as well as farmers. To maximize returns from irrigation development and from efficient on-farm water application, there is a recognized need for knowing how water deficits and surpluses influence crop production, how to determine water requirements, and the best methods and proper timing of irrigation applications (Charles and Ha Long, 1995).

Irrigation agencies also recognize that of equal importance is their capacity to evaluate existing schemes, to analyze systems for rehabilitation, and to improve the management of water on the farm for increased yields and benefits. For good decision and analysis, managers require good and easy to access data and information.

Irrigation management is one of the major challenges for the irrigation professionals (Molden, 1997). It is important as it decides the benefits derived from the irrigation system. The job is difficult, as it cannot be conducted with any blueprint approach. Hence, it is a complex task, as a lot of factors have to be taken into consideration. Several manuals are available to assist in the management of irrigation schemes (FAO, 1982;

ASCE, 1991; Skogerboe and Merkley, 1996), which set out concepts for managing these facilities, and describe relevant planning, operational, maintenance, administration, monitoring, assessment activities and procedure. However implementing appropriate management concepts and procedures is not always straightforward in practice.

2.2 Information System in Irrigation Management

Information systems are methodologies aiming at supporting decisions. Two main types of information systems are used in water resources planning and management. These are the geographical information systems (GIS), and information systems analysis and design. Geographical information systems are powerful database systems, which combine data banks, spatial data processing, thematic mapping and graphic/geometric data processors. GIS are essential support of information for decision-making and are often associated with systems analysis for building decision support tools.

Systems analysis and design is a broad methodology of using models for solving engineering and management problems by decomposing them into interdependent processes of different nature. Modelers represent the processes involved and their inter-relationships according to the nature of the processes which are the physical, economical, social, and ecological. The objectives have to be attained include the planning, design, management, and operation.

Systems analysis and design can be applied to a very large number of problems in irrigation and agricultural water management. These comprise on-farm decisions, project operation and management, water resource planning and allocation, water quality management, and environmental impacts assessment. In any case an optimal solution is searched but the optimal result can be expressed in particular forms or satisfying specific requisites.

A few studies by Loucks (1992), Yeh (1992), Goulter (1992), Simonovic (1992), Uber et al. (1992) and Orlob (1992) give complete information on systems analysis and design methods and their application in irrigation planning and management.

Linear programming (LP) is one of the techniques used for managerial purposes in water resources (Yeh, 1992), including linearization procedures when dealing with non linear equations. This optimization technique is common in agriculture when the objective function is expressed in monetary terms. Linear programming is also common to optimize pipe distribution networks (Goulter, 1992).

Techniques derived from linear programming like dynamic programming and non-linear programming are also common, with both deterministic and. stochastic approaches. As for linear programming, they are particularly useful for water resources management, namely for water allocation purposes and for reservoir management (Simonovic, 1992). Several other formulations of mathematical optimization models have been developed in the last decade to response to complex systems or multi-objective and multi-criteria problems. They are applied in particular to optimize water allocation and to evaluate water quality strategies and alternatives (Uber et al., 1992; Orlob, 1992; Kindler, 1992).

The use of simulation models in making decision is at large. These models cover a great variety of situations and approaches (Loucks, 1992). A simulation model can be utilized alone creating alternative solutions or scenarios, which help the user to make a decision. This is typically the case for irrigation scheduling (Stockle, 1991; Pereira et al., 1992). The model can generate state variables, which allow the best operation decisions, as it happens with canal models (Burt & Gartrell, 1991; Clemmens et al., 1991).

Decision support systems (DSS) become more widely used because they combine, in a holistic and interactive approach, simulation and design models, optimization models, databases and geographical information systems embedded in a friendly and graphical user interface. This facilitates the use of models and should increase the interaction and communication between analysts and users (Loucks, 1992). Examples of DSS in irrigation and agricultural water management are growing, both for design (Bralts et al., 1990; Garcia et al., 1990) and management at farm (Hoogenboom et al., 1991; Wilmer et al., 1991) and project management level (Ait Kadi et al., 1990; Zagona & Strzepek, 1991).

2.3 Examples of Information System Application in Irrigation

According to Pereira (1987), for irrigation and agricultural water management, three levels of decision must be considered. The levels are the farm, irrigation project and the basin. At the farm level, farmers are required to decide on crops, cropping systems, irrigation methods and irrigation management practices while at the irrigation project level, decisions are been made by the operation, maintenance and management (OM&M) authorities. The basin level made decisions which are related to the country or regional water resources policies and influence agriculture through water allocation and water quality criteria. Examples described in this section are related to the second levels of decision-making and relate to applications that have been developed.

The first example is the irrigation water management at Jingtai Chuan, China. The Jingtai Chuan Irrigation Scheme is located in Gansu province of North-west China. To improve the water management of Jiantai Chuan Irrigation Scheme, water management program was developed with several attractive features (Zhanyi, 1999). The water distribution model was based on real water distribution process and is dynamic. It focuses on solving the problem of conflict between water supply and demand. There are several modules which are integrated together to form the core of the management system. Each function of the system is represented by one module. The system has a friendly user interface which has menu system that can guide users to use the software easily. The system was also designed to facilitate the extension of the system. Reports produced by the system can be in the form of tables and figures.

The modules or functions available in the systems are the basic data, water application, water planning, statistical analysis, communication and print and preview. Basic data module is for recording data and information related to water diversion and distribution, such as canal features of irrigation district, climate, hydrology, irrigation areas, and water users. Water application module is used to collect and calculate water application volumes from all users and different canals. Water users can apply water according to their need. The water planning module is used to schedule water diversion and distribution. Decision on water diversion and distribution is based on water application, water sources condition and canal capacity. If some changes occurred during the irrigation season, such as rainfall without prediction, the module can modify the water diversion and distribution plan on time. The statistic module is used to record the water distribution process and irrigation progress. It can timely show the irrigated areas and irrigation schedule. This experience is useful information for future irrigation water management. Communication between water management center and water management stations, and among users is provided by the communication module. The module that is used to print and preview reports and information is called the print and preview module.

This decision-making support system for Irrigation Water Management of Jingtai Chuan Pumping Irrigation Scheme has been put into since 1996. Significant economic and social benefits have been achieved due to the improvement of water management in the irrigation scheme by adopting the system. Both water using efficiency and water distribution uniformity have been increased since the application of the system. The system is with great potential to extend in other irrigation district in China.

Decision support system for irrigation scheme management called SIMIS (FOA, 2001) is another example of the IS application in irrigation. SIMIS has been developed under the funding of the Food and Agriculture Organization (FOA). It began in 1993 as a DOS-based information system designed to help managers and staff responsible for irrigation schemes in their daily tasks by providing a comprehensive database application. Training courses and field verifications were carried out in Argentina, Egypt, Cuba and Thailand. It was converted into MS Windows-based in 1998. It is intended to be valid for all the most common planning, water delivery, maintenance, administrative, and performance assessment activities carried out in any irrigation scheme. SIMIS has also become a training tool for illustrating the application of technical concepts to the practical operation and maintenance of irrigation schemes.

The water management module in SIMIS deals with four key issues namely the crop water requirements, seasonal irrigation planning, water delivery scheduling, and recording water consumption. The crop water requirements sub-module calculates the daily crop water requirements for all possible crop-planting date combinations in the irrigation projects, using the input data for the climate variables and the crop water use characteristics. In irrigation plan sub-module, the net irrigation requirements throughout the season can be calculated for different cropping patterns with staggered planting dates. The net irrigation requirements are converted to continuous flow in operating hours, taken the distribution efficiency into account. The results are then compared with the system's capacity and the available flow.

The water delivery-scheduling sub-module is the core of SIMIS. The physical structure, together with the social and institutional constraints of the scheme, determines the water delivery mode selected by the user. This sub-module is applicable to any branched irrigation distribution system, but it mainly addresses open canal system. The scheduling periods can be varied from a few days to several weeks, but the schedule and actual deliveries can be stored for seasonal analysis.

In the water consumption sub-module, the user enters the actual volume of water delivered to each plot or distribution component on every day, if measurements are available. The default values are the scheduled volumes and dates. These data can be used later for other purpose such as performance assessment.

SIMIS is user-friendly software in which the user enters and retrieves information through forms. The input data can be edited in various ways and displayed in tables. Many inputs and outputs can be graphically displayed and printed in reports. All the geo-referenced information can be visualized through the geographic information system contained within SIMIS.

Other valuable features of SIMIS include the use of a password to limit the risk of unauthorized access, the incorporation of many controls over the data entered to reduce typographic and other kinds of error, and its modular form, which permits selection of modules that are most relevant to the user. SIMIS has been developed in Microsoft Access© 97. The calculations and graphics are programmed in Access Basic. The whole package is compiled using Microsoft Developer© to produce a run-time Microsoft Access application. Although SIMIS has been applied in several irrigation schemes around the world, it would still be desirable to apply SIMIS in a selected set of test cases in order to test the validity of the approaches used in the model.

Irrigation scheduling simulation called ISAREG is another example of IS application for irrigation. ISAREG performs the soil water balance test for irrigation in combination with water-yield routine. Thus irrigation scheduling is evaluated through two parameters, the relative crop evapotranspiration and the relative yield loss. The program has a friendly user interface, with Portuguese and English versions, which permit the users to select, introduce, modify or update the data files on crops, soils and meteorological variables (evapotranspiration and effective rainfall). Users can also choose the simulation options for (i) fulfilling the crop water requirements (maximal yield), (ii) applying deficit irrigation using a selected irrigation threshold, (iii) irrigating with restricted available depths and at fixed periods; (iv) optimizing the irrigation dates when water supply is limited. Users can perform the operation of repeating any calculation with new thresholds or new assumptions for the computational procedures, thus comparing alternative irrigation strategies. Users are able to make new computations for alternative crops or crop systems, as well as other environmental data.

This simulation model is therefore a tool for selecting alternative strategies for irrigation management, helping the farmer to plan irrigation of several crops in more than one location. Present developments include the development of a program to help designing irrigation projects using simulated scenarios of crop patterns and irrigation management rules and the development of program to simulate the demand in an irrigation system aiming at improving deliveries and operation. Development on the integration with a geographical information system is also under way to utilise ISAREG at the regional scale.

2.4 Summary

Many irrigation projects throughout the world never fulfil the expectations envisioned at planning and design stage because lack of incentives and a working knowledge about proper water management. Various approaches on using information systems to support decision in water resources planning and management, particularly in irrigation have been developed. The approaches include linear programming, mathematical optimization model, simulation, and decision support system.

The use of IS application with dynamic functional capabilities and friendly user interface in managing the irrigation has resulted in better management of water and better communication among the users.

CHAPTER 3
METHODOLOGY

This chapter covers the methodology of the research. The methodology consists of three main steps shown in Figure 3.1, i.e. (1) information gathering and analysis, (2) model conceptualisation, and (3) model validation.

Basically step 1 involves planning the entire project, gathering and comparing information, to enable us to cluster the irrigation information according to groups for analysis. In step 2 we construct the irrigation network model which leads us to system analysis and design for HyperMuda prototype, and in step 3, we develop HyperMuda prototype in order to validate our model.

3.1 Information Gathering and Analysis

The study started with an overview of the Muda system to get the details of the irrigation network layout. The activity involves a series of visiting MADA headquarters and interviewing staffs in Water Management Department. To understand details of their daily operations and decisions, next activity is obtained and examined various documents such as forms and report. The collected data and information which related on network irrigation model for current operation, measures and attributes (such as flow rate, velocity, head loss) that influence the operation, number of connectors (such as junctions, nodes, watergate, pipes, loops) are then analysed and classified. Analysis of the data and information gathered was done to determine the scope of the study.

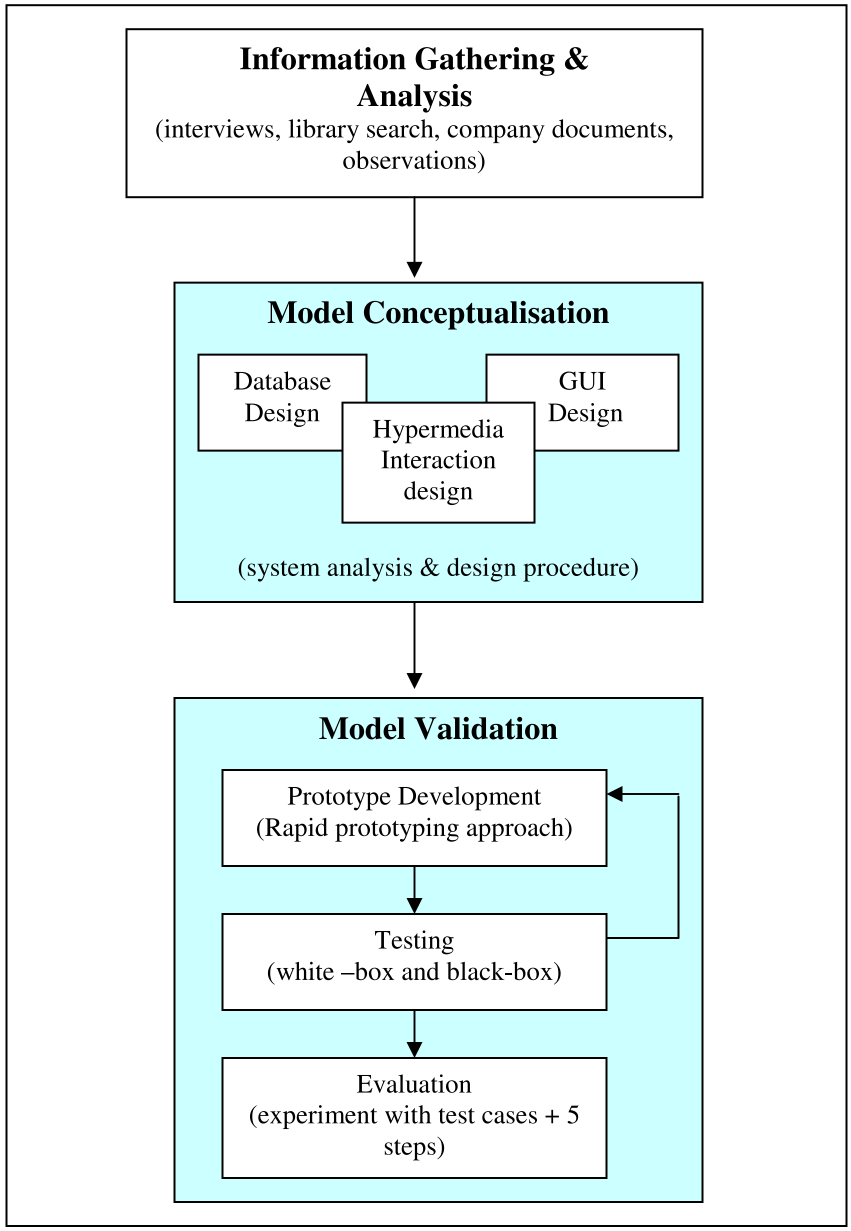

Figure 3.1: Overall framework of the Research Methodology

3.2 Model Conceptualisation

There are three components that we analyse and design during the model conceptualisation stage. They are the database analysis and design, the GUI analysis and design, and the interaction analysis and design.

During this stage, the conceptual and logical models of the irrigation system layout are analysed and designed for both the database and Graphical User Interface (GUI). The conceptual model is produced using Entity Relationship Diagram. Based on the model, a few transformations are done to produce a Logical Data Model of irrigation network. This model was then used in developing the physical database. The design of the GUI defines the way in which different navigational object will appear in the system/prototype while interacting with the end-users. It also shows which interface objects will activate navigation and other application functionality, and which interface transformations will take place and when.

The same applies for the interaction design. The only different is that we involved hypermedia elements during the design as we intended to design a hypermedia-based interaction for the model. The interaction design is modelled in such a way to enable the GUI to communicate and transact with the databases.

3.3 Model Validation

The final step is the process of validating the constructed model. The developed application model must properly represent the data and process requirements. To ensure this, the model needs to be tested and validated. This process is performed through a series of repetitive tasks. The tasks involved in this process are as follows: (1) the development a prototype based on the model; (2) verifies the process and data requirements by testing the prototype with the potential users and getting their feedback, and (3) evaluating the model using a test cases.

The prototype development were performed using a rapid prototyping approach which involves rapid prototyping testing as further elaborated in Chapter 6. The development involved information presentation in a set of user models organised into context. The development of user models is realised through a series of unstructured interview with users of various levels: novice, intermediate, and expert users.

As for the prototype testing, a white-box and black box testing were carried out. Black – box testing aims at testing the functional requirements of the prototype, whereas white-box testing aims at verifying that the prototypes behave properly with unexpected input. This is basically testing the exception handling capability of the prototype.

Although we perform the validation stage, we only carry out the first two activities in the stage. We do not carry out the evaluation activity as it is beyond the scope of the study. However, in this report we provide the details for evaluating HyperMuda which involves the following steps (1) preparation of test cases and instrument for measurement; (2) perform a controlled experiment based on the test cases; (3) collect data using the instrument identified in (1); (4) conduct a debriefing session where a short survey can be carried out, and (5) analyse data collected in (3) and (4). The output of such validation can be used to improve the irrigation management operation of the Muda area.

CHAPTER 4
INFORMATION GATHERING AND ANALYSIS

This chapter describes the information collected from MADA, discusses the Muda irrigation systems and networks in order to analyse the whole network of the said irrigation system. The whole network and process of Muda irrigation is analysed in three aspects. Firstly, we analyse the irrigation system physical networks covering the physical water distribution system facilities. Secondly, the administration structure of the irrigation system aspect and thirdly the decision making structure related to the water controls aspect. These analyses are purposely done to obtain user requirements, task requirements, and user models which serve as inputs for the design of the HyperMuda database and its GUI.

4.1 Pedu, Muda, and Ah Ning Dams

The Muda irrigation scheme is a project designed for the main purpose of regulating water supply to the Muda area, touted as the largest rice supplier area in Malaysia. It covers a total gross area of 126,000 ha of which more than 96,000 ha are cultivated with paddy. The area span coverage of both Kedah and Perlis states in the northern peninsular Malaysia. In general, the importance of Muda irrigation scheme can be illustrated by the fact that it covers more than 51,000 paddy farms of the Muda area. Thus it can be considered as the lifeline of the farmers in the area. The Muda irrigation scheme at its implementation point was one of the two largest of such scheme implemented in Asia.

Central to the Muda irrigation system are the three major dams which function as the main water reservoir for the related water catchment area – The Muda dam, Pedu dam and the Ahning dam. The first two are located in Kedah while Ahning dam is in Perlis. Figure 3.1 shows the location of the two main dams in relation to the Muda agriculture area.

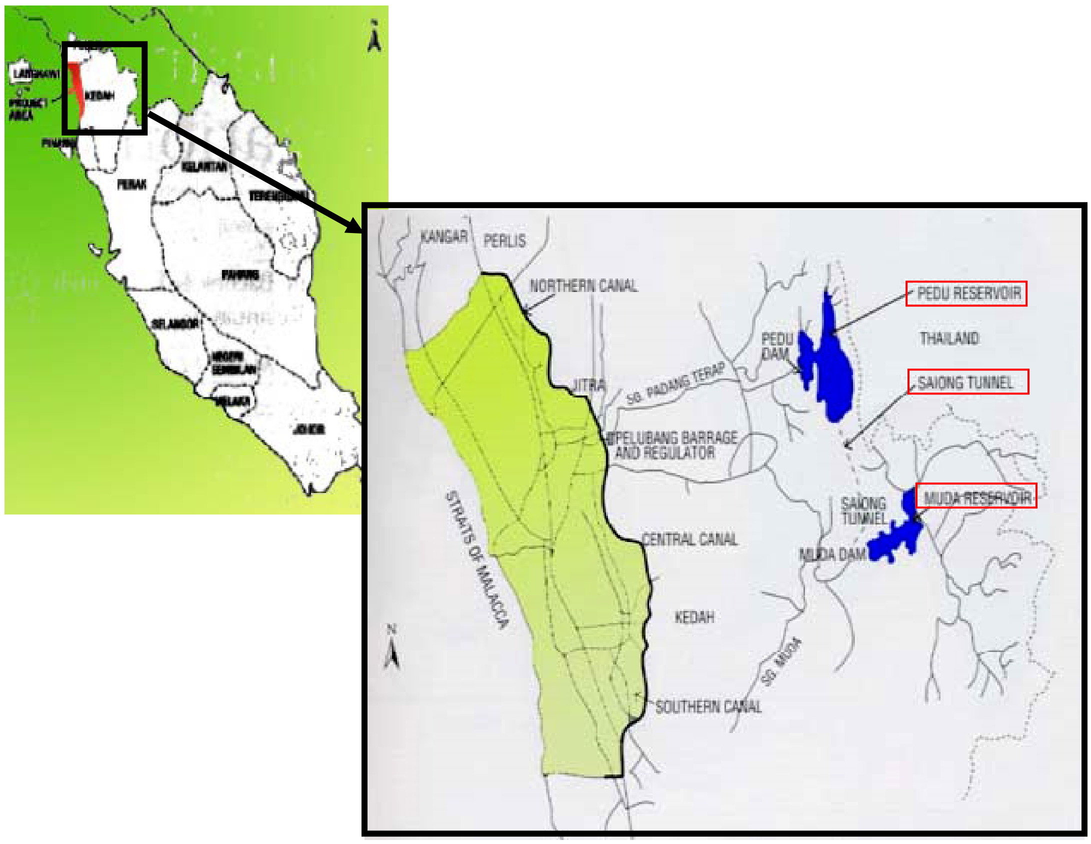

Figure 4.1: Muda and Pedu Reservoirs linked by Saiong Tunnel, located in Kedah, Peninsular Malaysia

The Muda dam, built in the southeast portion of the Muda area can hold up to 120 million m^3 of water while the Pedu dam, located a bit further north can store up to 860 million m^3 water. The Pedu dam is bigger to suit its function as storage for water collected during the wet season when water is abundant and to be used in the dry season when water is scarcer. Pedu dam receives its portion of water supply from the Muda dam via the 6.6 km Saiong tunnel connecting between the two dams. Muda dam is able to supply water to Pedu dam because the water supply in the southeast portion is abundant compared to the more heavily cultivated area along the sea on the western portion of the Muda area. Muda dam catchment also receives more rainfall than the smaller northeast Pedu catchment area (171 km^2 vs. 948 km^2 for the Muda catchment area).

These upland catchment areas are furthermore served by several rivers which later on be made into grid of canals. There are different levels of canals to bring the water further down the stream to the farmers. In a big irrigation project such as the Muda irrigation system, the canal grid is usually built into three levels – the primary level, the secondary level and the tertiary level. The main or primary canal taps water from the source. In the Muda irrigation system the primary canal consists of the three major canal system – the northern, central (upper and lower) and southern canal. The secondary canal system functions as the interface between the primary canal and the tertiary canal. The existence of the secondary canal makes it possible to exert better control of the distribution of water. In the case of the Muda system, the secondary canal consists of smaller canal than the primary one including the Arau canal, Lanabulu canal and Alor Changileh canal. The tertiary canal on the other hand is the smallest grid of canal which actually brings the water to the fields to be used to irrigate the crop.

The water flowing downstream will move through a series of cascading walls or gates and different structures along the way acting as the control points. The control points facilitate the release of water and the amount to be released at the downstream area at the off-take points. Furthermore these control points are also used to facilitate reading measurement for periodical data collection (daily, weekly or monthly) to be used by the headquarters for decision-making purposes.

In terms of the administration structure, the Muda area is divided into four major districts which later on divided further at the secondary level into different irrigation blocks. The Blocks are further divided into irrigation service areas (ISA) which are considered as the tertiary levels development. Each of the units level is controlled by a hierarchy of officers and operators. The detail administration aspects will be discussed later.

On the other side of the system, the decision making part is controlled by the MADA headquarters with inputs coming from readings supplied by different levels of operators, data collection stations and calculations obtained from certain lab studies. The decision making process is done with the help of certain data collections and processing infrastructure.

4.2 Muda Irrigation System

One of the main objectives of the Muda irrigation system is to provide enough water for agricultural use especially for paddy farmers in the Muda area. The water distribution system built for the Muda irrigation system provides the means for: (1) Collecting and storing water; (2) Controlling the usage of the water, and (3) Transporting the water to the end-consumers area when in need.

Four main sources of water for agricultural used especially paddy along with its percentage of the total water supply to the agriculture area are as follows: (1) rainfall at paddy field site (52.2%); (2) water released from the dam (29.5%); (3) water from sub rivers (12.5%), and (4) recycled water (5.4%).

From the statistics it can be seen that the dams play significant roles in supplying big portion of the controllable water supply for the agricultural activities especially paddy cultivation in the Muda area.

In this section of the chapter, the complete irrigation system will be described including the structures used in the system and the process involve in transporting water all the way from the source (dams) to the agriculture area (paddy fields).

The process begins with water from the Muda dam is transferred to the Pedu dam through the Saiong tunnel. Water from the Pedu dam then flows down via the Pedu river which later on becomes the Padang Terap river (they are essentially the continuation of the same river). The water flow from the Padang Terap river will go through the Pelubang barrage and regulator before it flows down to the primary canal systems built along the Muda area stretching from northern part of the Muda area to its southern notch. The barrage is a structure used to deviate the flow of water flowing in certain direction along the river. The regulator is another structures used in the irrigation system. Regulator regulates the amount of water to be supplied to the farmers according to the demand or certain allocation policy decided by MADA. Some of the main regulators in the Muda irrigation system are Pelubang regulator, Jabi regulator, Jitra regulator and Lanabulu regulator just to mention a number of them.

The primary canal system, consisting of the three canals – northern, central and southern canals stretching from the northern part of the Muda area to its southern part acts as the main highway spanning the whole Muda area (refer Figure 3.1). It essentially acts as the backbone of a spanning tree for the system. Along the primary canal, besides diversion to the secondary canal grids, there are several off-takes that divert water for other than the agricultural usage such as industrial usage or for residential used by the Water Works Department (Jabatan Kerja Air – JKA). The off-take usually consists of structures that act as exit points with possibly gates to control its opening. Besides these off-takes, other structures installed along the primary canal are like the pump station and siphon. Pump stations pump the water to be diverted and transferred to a higher land. The siphon is also used to transfer out water from the canal. Currently siphons are being used at points like the Senara and Lengkuas.

One other source of water worth mentioning in the inflows of water introduced along the main or primary canal system. These inflows are actually water supplied to the primary canal from small rivers along the way (refer to Figure 4.2).

From the main canal system, water reaches the districts via the secondary canal system. District 1 and 2 are serviced by the Northern canal while District 3 and 4 are serviced by the central and southern canal. The amount of water diverted to the secondary canals is regulated via the regulators. The districts are furthermore divided into blocks as their subunit. From the blocks it boils down to the irrigation service area (ISA) and irrigation service unit (ISU). The secondary canal system distributes water to the ISA as a unit under each block. The ISA is further serviced by the tertiary systems. The ISU is the subunit of the ISA which is formed to facilitate irrigation-scheduling functions.

The tertiary canal system is smaller system which runs across the farms. Water is transferred from the canal/ditch to the farms via modular unit water pumps, siphon or small aqua duct.

An efficient and elaborate tertiary system is very important to ensure the best service could be delivered to the farmers. One of the concerns of MADA today is to upgrade and expand the tertiary system infrastructures in the ISAs. Besides building more concrete tertiary canal system, earthen tertiary drain and appropriate canal structures support such as off-takes and drainage controls; other supporting components such as the electrical power supply infrastructures, roads for maintenance vehicles access and appropriate delivery systems are also needed to ensure efficient systems of tertiary irrigation can be realized.

In order to improve water utilization rate, MADA has explored another potential source of water which is the recycled water. The recycled water comes from the drainage system and sent back into the irrigation system to be used again. Recycled water is seen as a very potential and important source of water for two main reasons; it increases the rate of water use efficiency (WUE) thus decreases wastage from water loss through the drainage process. Besides that, it is also considered as an efficient source of water since it can be delivered faster to serve area due to the closeness of their location to the fields compared to the water from the dam which takes couple of days to reach the fields.

In order to realize this, several recycling pump stations have been installed on the site. Starting from the first launching of the recycling pump project in 1982 under the 4th Malaysian Plan, many new recycling pump sites have been introduced (refer Figure 4.2).

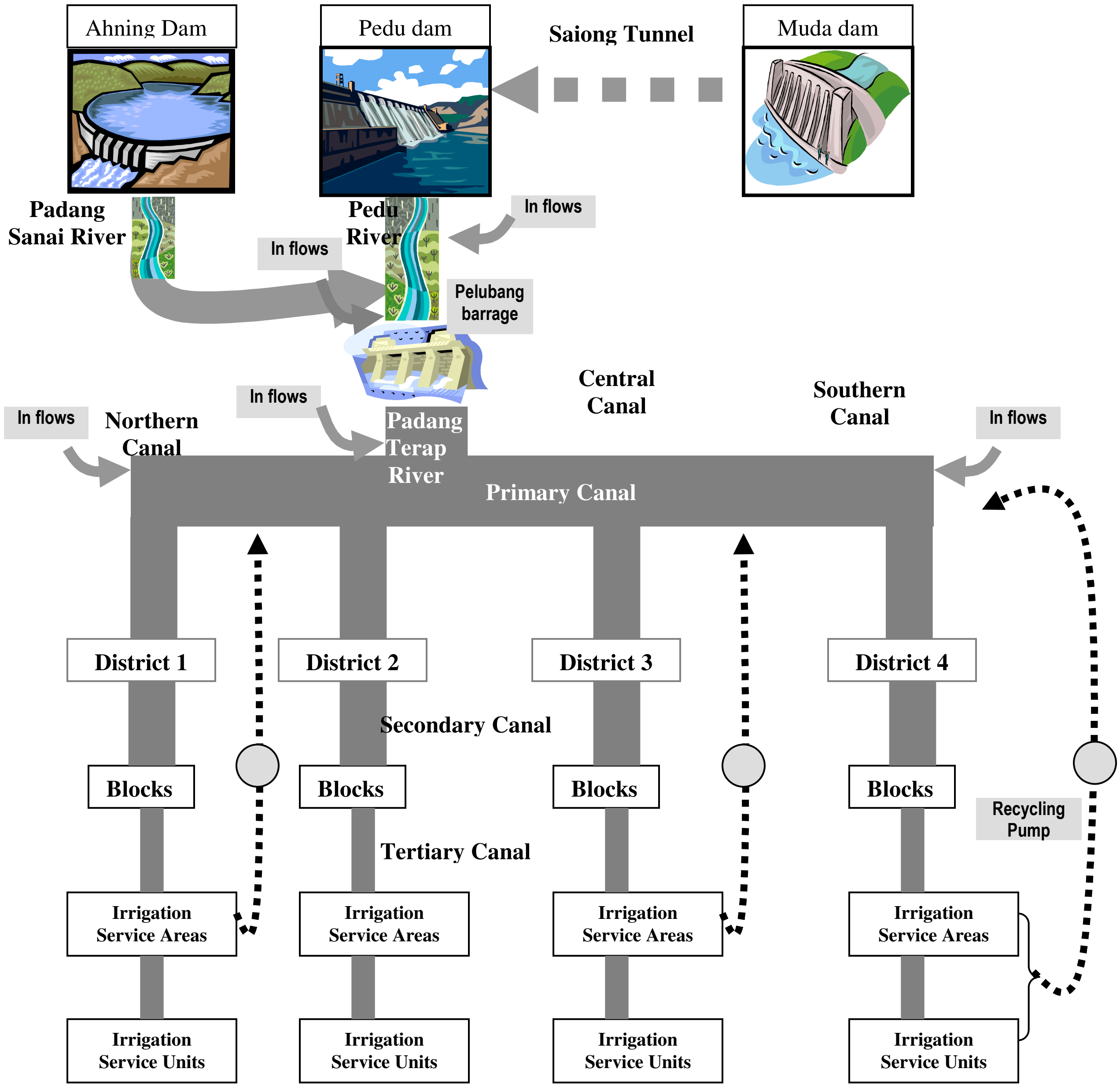

Figure 4.2: Recycling Pump Station in 4 Districts Irrigated by Muda, Pedu, and Ahning Dams

4.3 The Water Level Control Method

The function associated with the MADA central control is to make decision regarding the water level control that should be supplied to the filed site. This also includes the need to fulfil specific water demand from farmers other than the standard allocated amount of water. The decision making process is based on several parameters either calculated or measured from the field or canal.

The central control component located at the MADA headquarters in Ampang Jajar will collect data periodically in order to perform the calculation needed to make decision. The general formula used to calculate

$$D_{I+1} = D_t + I_t - ET_t - SP_t + Re_t$$

D_{I+1} = calculated water depth
SP_t = Sea Page – obtained from study
I_t = Irrigation (the rate of water consumption in the district)
ET_t = Evaporation
D_t = Current water depth
Re_t = Rainfall rate

With HyperMuda prototype, the D_{I+1} is automatically calculated. After the integration with MADA databases, Re_t and D_t can be obtained from the existing Telemetry database, whereas data for I_t and ET_t can be obtained from a few operating servers used by various support system at MADA such as PPK, AIS, and SPA.

4.4 The Water Supply Chain Infrastructure and Administration Structure

The overall management of the Muda area irrigation systems is done by MADA. MADA is made a statutory body under the Ministry of Agriculture in 1970. MADA structures the organizational structure for managing the Muda irrigation project into hierarchy of offices and different level of geographical units. At the highest level is MADA headquarters currently located at the Ampang Jajar, Alor Setar. The headquarters manage main structures in the Muda irrigation system such as the dams and headworks. Central to its function is to make decision regarding water control – i.e. the provision of water for fulfilling the needs of farmers through out the irrigation structure.

In order to facilitate the irrigation management, the whole Muda area is divided into four main districts, namely district 1, 2, 3 and 4. Each district will have a district engineer office headed by a district engineer assisted by a deputy district engineer, technicians, irrigation inspectors (IIs), irrigation overseers (IOs) and line operators (LOs). Each II is given the task to oversee several IOs under them. The IOs in turn will have several LOs under them. Each district office will receive instructions directly from the control center. The district engineer office is generally given the tasks to handle various irrigation and drainage facilities under each area. Figure 4.3 explains the hierarchy of administration in the secondary and tertiary level systems.

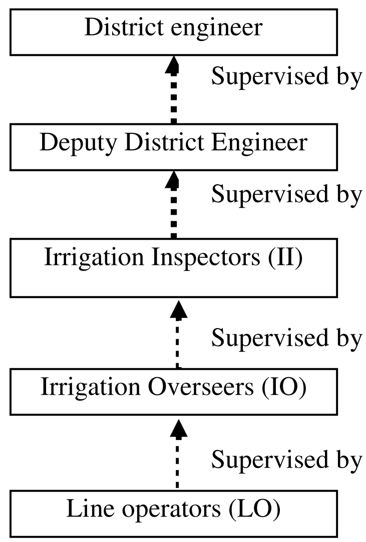

Figure 4.3: The Hierarchy of Administration in the Secondary and Tertiary Level Systems

Each district is furthermore divided into irrigation blocks. The irrigation blocks are mostly rectangular shaped area of 200 to 810 ha by size. The whole Muda area is currently divided into 110 irrigation blocks. The blocks are irrigated through the secondary canals and secondary system facilities. Each irrigation block will be assigned to an LO. Each block is further divided into 6 to 10 irrigation Service areas (ISA) covering area of 80 to 200 ha each. Each ISA is further divided to 5 to 6 irrigation Service Unit (ISU) with the size of 15 to 25 ha each. The ISA level and below are watered by a tertiary system.

In short, the responsibility for the operation of the whole irrigation system is divided between MADA as the central authority and the farmers as the customers. MADA provides major facilities or the primary systems, which include the dams, main rivers support services, the secondary system, and the tertiary system off-take. The parts that are beyond the tertiary system off-take, fall under the responsibility of the farmers. The farmers themselves carry out the responsibility through the establishments of different level of committee. There are currently two levels of committee namely the ISA committee and the ISU committee. The ISA committee member is generally consists of all the leaders of the ISU Committee. Figure 4.4 shows the hierarchy of responsibilities in the management of the Muda irrigation system.

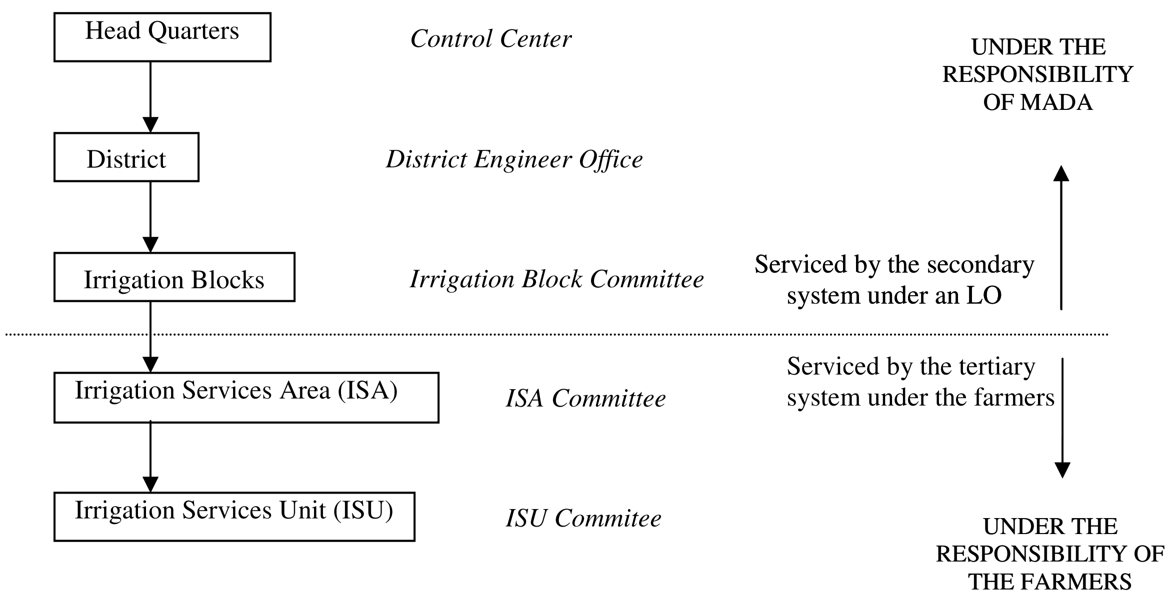

Figure 4.4: The Hierarchy of Responsibility in the Management of the Muda Irrigation System

4.5 Summary

It is deemed necessary to understand the administrative structure, the water supply chain infrastructure and their relationship with all actors in the irrigation process in order to come out with user requirements and task analysis for system development. This chapter provides analysis and discussion on the running of the system and the whole system. The tasks performed by MADA and performed by users in the tertiary system in order to manage the irrigation network were analysed to enable the formation of HyperMuda task and user analysis.

This chapter serves as an important input to Chapter 5 and 6, because we can identify all the necessary data and user model for the various type of users as depicted in Figure 4.3 and 4.4. This chapter basically fulfil the user requirement, task analysis, user analysis, which enable us to formulate a design for the HyperMuda database as well as its GUI.

CHAPTER 5

DESIGNING HYPERMUDA DATABASE

This chapter will cover the processes involved in designing HyperMuda database. Input for data is obtained from the user and task analysis carried out in Chapter 4. In designing the database, two main activities involved namely constructing conceptual model, and transforming the model into relational schema.

The main aim in developing the conceptual model is to build the conceptual representation of the database and its relational schema. Building the conceptual representation includes identifying the important entities, relationships, and attributes of the data whereas building the relational schema includes designing the relations between data attributes. Relational schema aims at translating the conceptual representation into the logical structure of the database. The outcome of these three activities is also described in this chapter.

5.1 Conceptual Database Design

Based on analysis described in the previous chapter, the following data flow diagram has been captured (Figure 5.1). From the diagram, we can identify the relevant initial entities. These entities contain significant information that needed to be stored and maintained by technical (super) user of the HyperMuda.

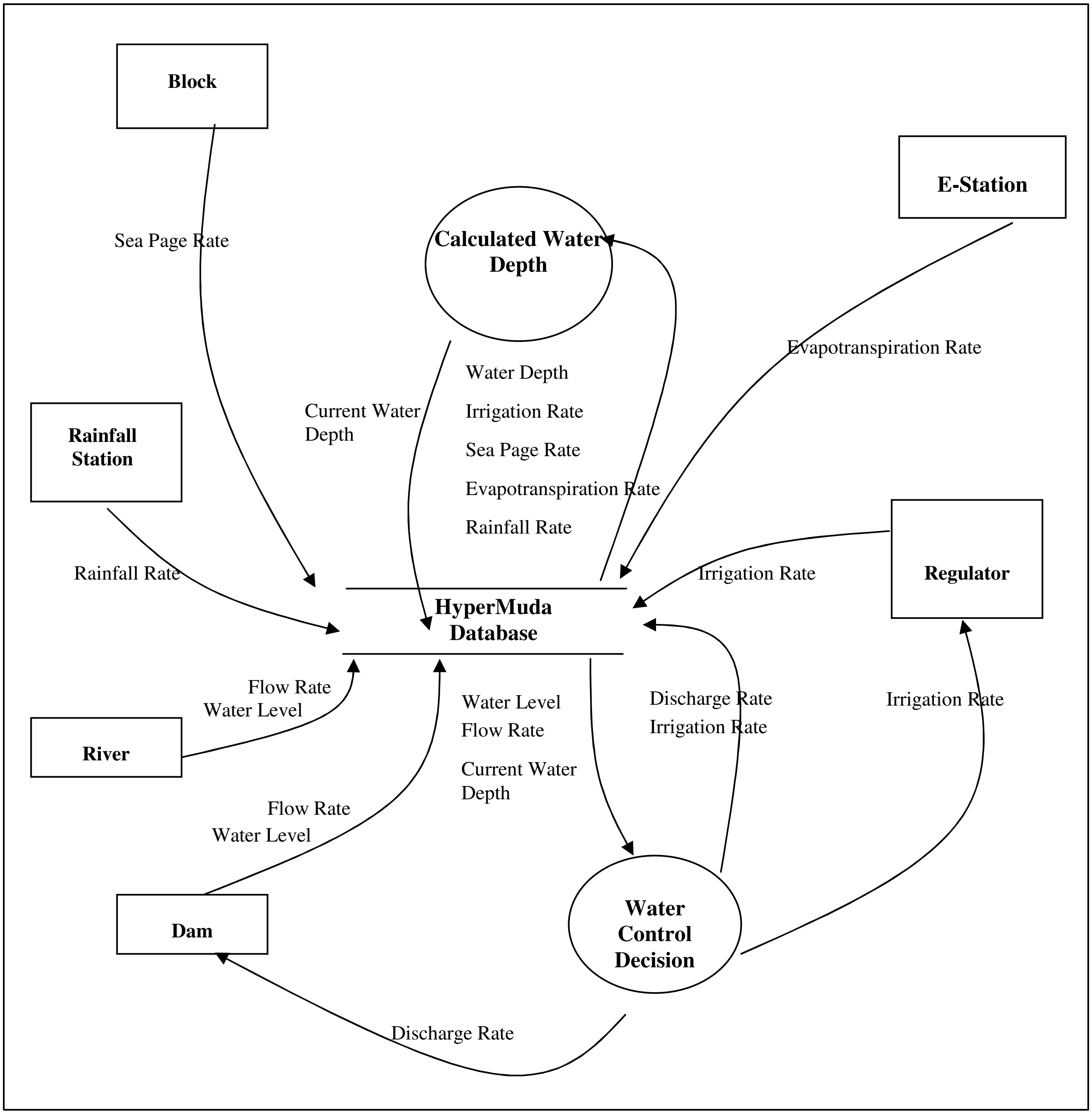

Figure 5.1: Dataflow Diagram for the HyperMuda

The first step in building a conceptual model is to define the main objects that the users are interested in (Connolly & Begg, 2004). These objects are entity types for the model. One method of identifying entities is examining the results obtained from analysis phase. From the data flow diagram in Figure 5.1, the extracted main data that support the process in water control decision are Evapotranspiration Rate, Sea Page Rate, Irrigation Rate, Rainfall Rate, Water Depth, Water Level, Flow Rate, and Discharge Rate. All of the these data are dynamic, where the value will change daily and should be measured and calculated every day by the officer at MADA and staff at location involved. After the main data have been identified, they are clustered together according to the source and location of the data.

We also performed analysis on supported data in printed form provided by MADA and as a result we manage to identify additional attributes that we later add to the related entity. These are static attributes where the data remain unchanged unless the top management of MADA decides to change it. Beside investigating and analysing the documents, observation to the daily operation performed in MADA for water control decision was also done. This way, we managed to discover more entities and attributes to be used in HyperMuda. Table 5.1 shows the entire entities and attributes after combining results from Chapter 4, document analysis, and observations.

Table 5.1: Entities for HyperMuda

Entities	Attributes
Dam	DamName, Width, WaterLevel, DischargeRate, FlowRate
River	RiverName, WaterLevel, FlowRate
Rainfall Station	Station#, RainfallRate
E-Station	Station#, EvapotranspirationRate
Regulator	RgName, Upstream, Downstream, Gate1, Gate2, Gate3, IrrigationRate
Block	Block#, BName, Width, WaterDepth, SeaPageRate
Off-take	OffName, Upstream, Downstream, Gate1, Gate2, Gate3, IrrigationRate
Recycling Pump	RpName, NoOfPump, WaterLevel

The next step done was investigating the relationships that exist between these entities. Typically, relationships are indicated by verbs or verbal expressions. For example: Dam *flows_through* River; Block *irrigate_by* Off-take; Block *has* Rainfall Station

Having identified the relationships, we must also determine the multiplicity of each relationship. Multiplicity constraints are used to check and maintain data quality (Connolly & Begg, 2004). These constraints are assertions about entity occurrences that can be applied when the database is updated to determine whether or not the updates violate the stated rules of the organization. It is frequently easier to visualize the relationship and multiplicity using Entity Relationship Diagram. Figure 5.2 shows the conceptual scheme that consist all the entities and attributes involved and the key attributes called primary key in italic.

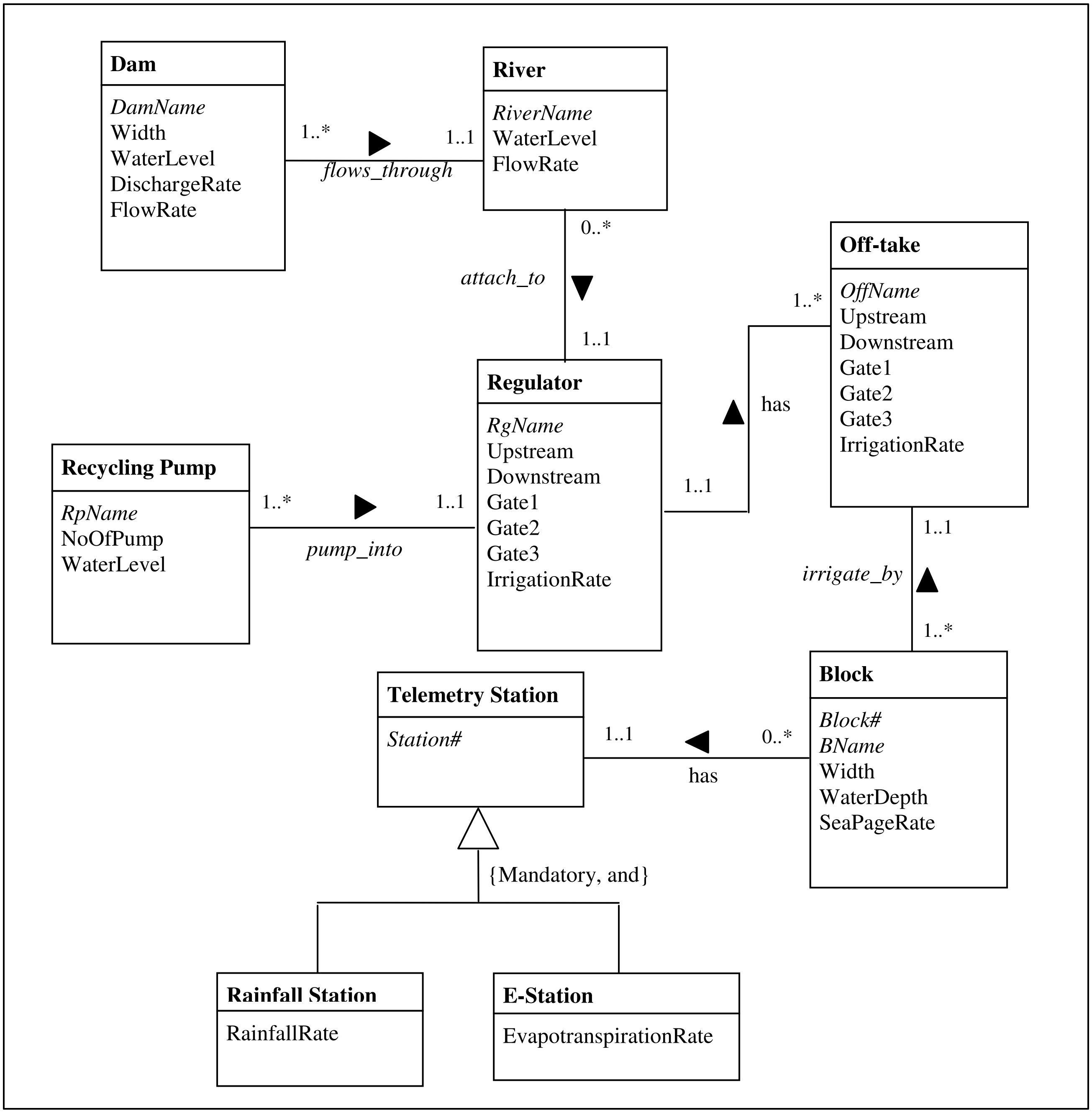

Figure 5.2: Entity Relationship Diagram

The Entity Relationship Diagram in Figure 4.2 shows that: (a) Water from a few dams flows through one river; (b) Water from zero or many rivers attach to one regulator; (c) One regulator has many off-take; (d) Many blocks are irrigated by one off-take; (e) One or many blocks have one telemetry station; (f) One telemetry station must be a rainfall station or e-station and sometimes it can function as both; (g) Many recycling pumps will pump water into one regulator.

5.2 Logical Database Design

The design of logical databases involved transforming the conceptual model. According to Kroenke (2004), the transformation process starts by removing features that cannot be represented directly in the relational model such as many-to-many relationships. Relational schema should be validated using the rules of normalization to ensure it is structurally correct and it supports the transactions given in users' requirements specification. Finally integrity constraints should be added into the relational schema.

The relational schema for HyperMuda is designed in line with the guidelines given by Kroenke (2004). The schema is shown in Figure 5.3. The relation has its full set of attributes together with the primary key and foreign key to show integrity constraints involved.

Dam(DamName, Width, WaterLevel, DischargeRate, FlowRate, RiverName)

Primary Key DamName

Foreign Key RiverName **references** River(RiverName)

River(RiverName, WaterLevel, FlowRate, RgName)

Primary Key RiverName

Foreign Key RgName **references** Regulator(RgName)

Regulator(RgName, Upstream, Downstream, Gate1, Gate2, Gate3, IrrigationRate)

Primary Key RgName

Recycling Pump(RpName, NoOfPump, WaterLevel, RgName)

Primary Key RpName

Foreign Key RgName **references** Regulator(RgName)

Off-take(OffName, Upstream, Downstream, Gate1, Gate2, Gate3, IrrigationRate, RgName)

Primary Key OffName

Foreign Key RgName **references** Regulator(RgName)

Block(Block#, BName, Width, WaterDepth, SeaPageRate, OffName, Station#)

Primary Key Block#, BName

> **Foreign Key** OffName **references** Off-take(OffName)
> **Foreign Key** Station# **references** Rainfall Station(Station#) and E-Station(Station#)
>
> **Rainfall Station**(Station#, RainfallRate)
> **Primary Key** Station#
>
> **Rainfall Station**(Station#, RainfallRate)
> **Primary Key** Station#
>
> **E-Station**(Station#, EvapotranspirationRate)
> **Primary Key** Station#

Figure 5.3: Relations that Represent the Logical Data Model for HyperMuda

The final diagram that represents the entire merged logical data model is drawn based on the relation above. The resulting diagram shows only the primary keys and foreign keys for HyperMuda is shown in Figure 5.4.

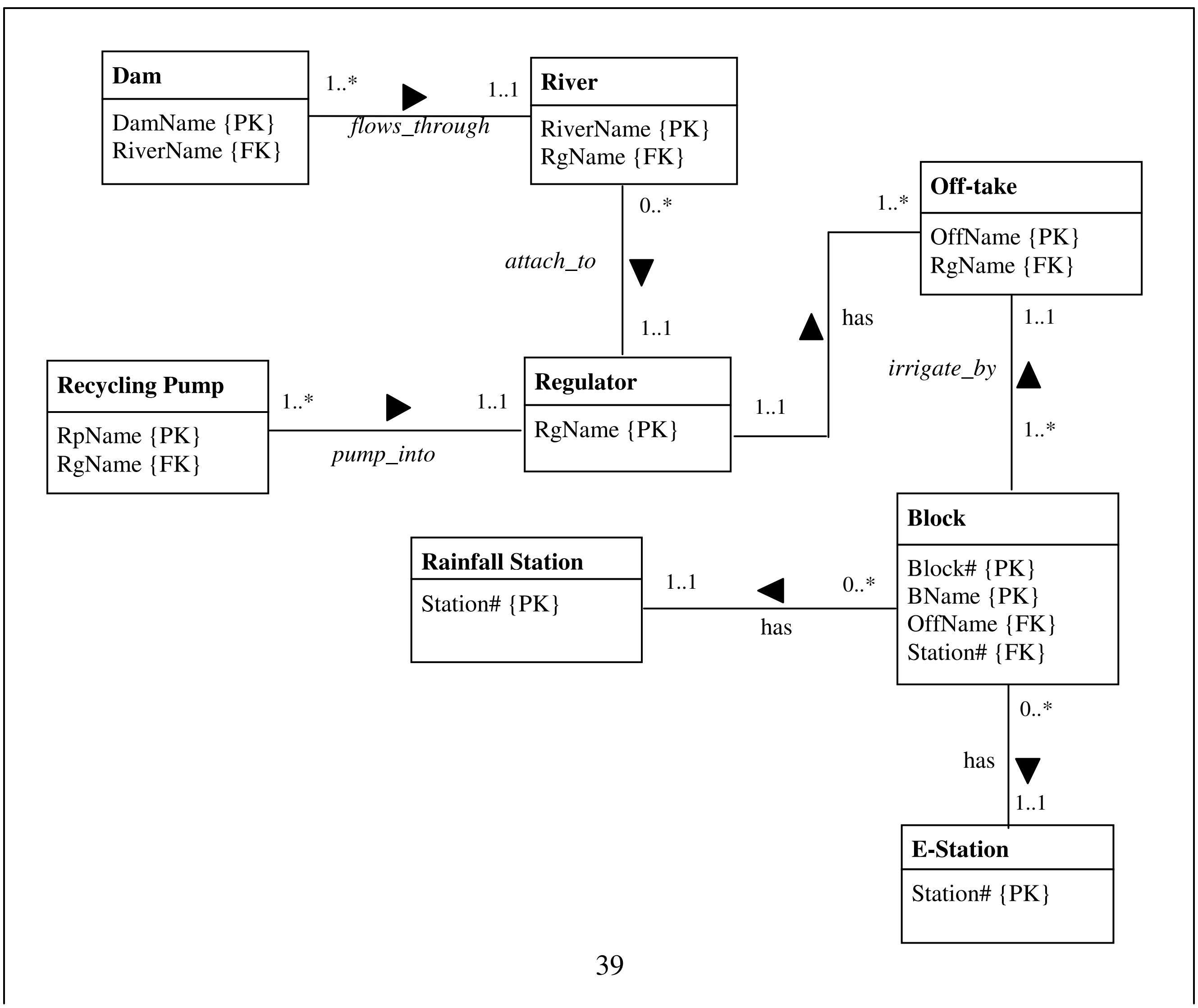

Figure 5.4: Logical Data Model for HyperMuda

5.3 Summary

The Discussion above has demonstrated the processes used in designing HyperMuda database. We began with analysing the data flow diagram, followed by the construction of entity-relationship diagram and transforming the diagram into a logical database model. Input for HyperMuda database design was collected in the form of entities and attributes. Eight entities and 34 attributes altogether were documented. The entities with their associated attributes are dams (attributes are: DamName, Width, WaterLevel, DischargeRate, FlowRate, RiverName), rivers (attributes are: RiverName, WaterLevel, FlowRate, RgName), rainfall stations (attributes are: Station#, RainfallRate), E-stations (attributes are: Station#, EvapotranspirationRate), regulators (attributes are: RgName, Upstream, Downstream, Gate1, Gate2, Gate3, IrrigationRate), blocks (attributes are: Block#, BName, Width, WaterDepth, SeaPageRate, OffName, Station#), off-take (attributes are: OffName, Upstream, Downstream, Gate1, Gate2, Gate3, IrrigationRate, RgName), and recycling pump (attributes are: RpName, NoOfPump, WaterLevel, RgName).

CHAPTER 6
DEVELOPING, TESTING, AND EVALUATING HYPERMUDA

6.0 Introduction

This chapter concentrates on the development of the HyperMuda prototype. Along the way, a series of white box and black box testing were performed in order to ensure that the development of the prototype achieve our stated objectives. The prototype development uses tools such as Macromedia Director, Microsoft Access, and Visio Technical for the network irrigation, databases, and GUI development. The prototype verification and validation involved extensive testing of the model to determine its accuracy in producing the correct output.

As we do not include the prototype evaluation in our scope, we proposed here the prototype evaluation process using real users. Procedures and methods for evaluating are put down here together with the test cases that should be used in evaluating the prototype with real users. The evaluation is strongly encouraged as it could determine the level of usefulness of the prototype. A controlled experiment based on predefined test cases should be performed before delivering this prototype to interested parties, such as MADA.

6.1 HyperMuda Design and Development

HyperMuda was developed using rapid prototyping approach, implementing the concept of adaptive hypermedia, in the field of irrigation. An adaptive hypermedia system reflects some features of the user in the user model and applies this model to adapt various visible aspects of the system to the user (Brusilovsky, 2001). We considered HyperMuda as an adaptive hypermedia prototype because it satisfies three criteria as elaborated by

Brusilovsky (1996). The criteria are (1) it should be a hypertext or hypermedia system; (2) it should have a user model, and (3) it should be able to adapt the hypermedia using this model. Even though HyperMuda is not a full-fledged hypermedia system, it has, to some extend, the three criteria listed above. Some may say that HyperMuda is not really adaptive, but rather adaptable. HyperMuda is a content-level adaptation prototype, which provides adaptive multimedia presentation.

We prepare a user model, which provides a representation for the information about each user. The basic *components* of our user model are organised into *contexts*. So, for example, all the components for our model of the user's knowledge of basic irrigation are in the basic-context. Within a context, a set of structural relationships is defined by a *view* (maps, photos, interactivity widgets, and text explanation). Where we have little information about a user, we can use a *stereotype* view. So, for example, if we only know that a user regards himself or herself as an irrigation expert, we use the irrigation-expert stereotype to define their knowledge of the irrigation concepts relevant to using this hypermedia prototype.

A series of unstructured interview was carried out in drafting the user model. A quick assessment of their relevant knowledge was collected, and it was used in sketching a view definition. This is also known as concept inventory interface. Using concept inventory interface, we developed three stereotype views, each one meant for beginners/novice user, intermediate/intermittent users, and expert/power users. At this stage, the users have to choose their view level from a menu provided. If they do not choose the level, then the default intermediate level will be set.

The user model was later used as a guideline for clustering various irrigation data obtained from MADA. These data of Muda irrigation network were gathered, clustered, and structured as shown in Figure 6.1 (The complete chart is provided in Appendix 1). The structure was then used as a basis for designing the HyperMuda navigation links.

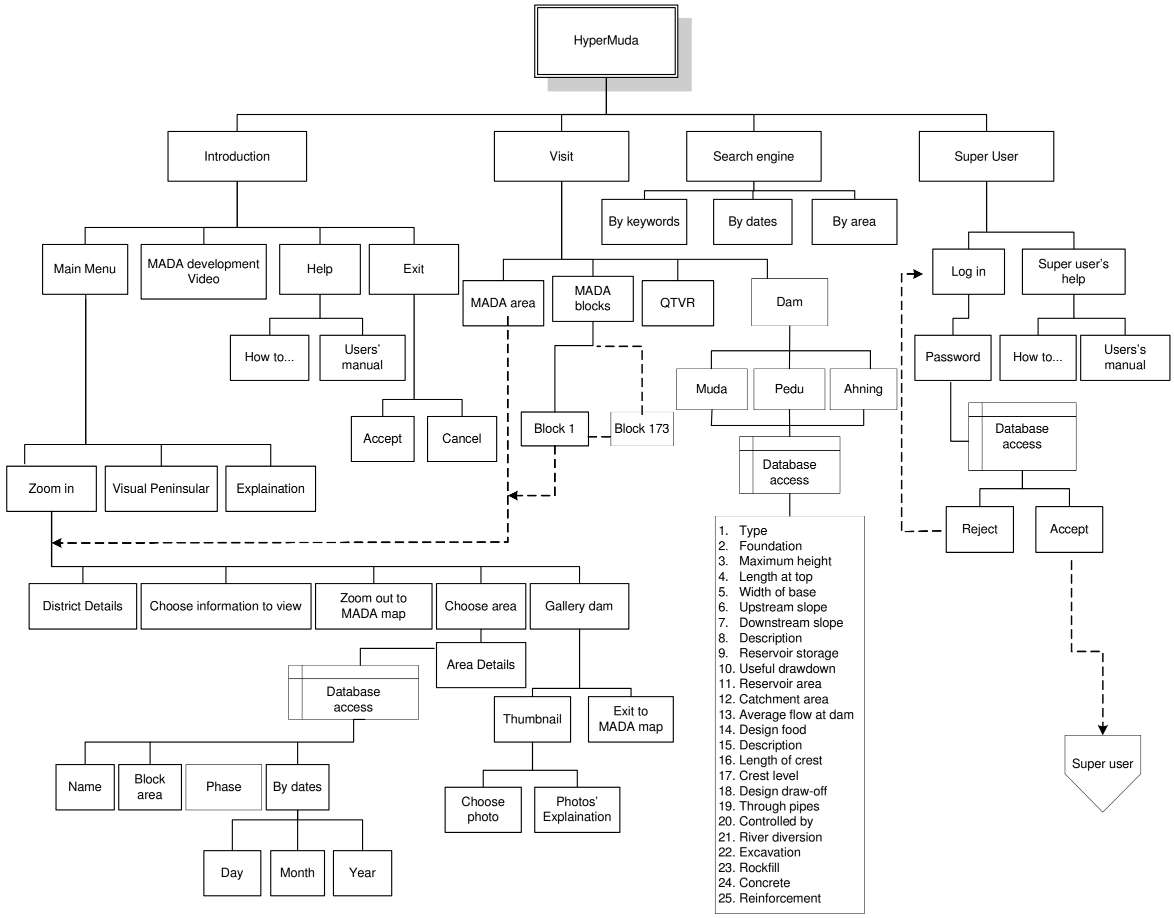

Figure 6.1: Clustered Data for Muda Irrigation Network

The following are the basic features of HyperMuda.

- Hypermedia on a PC platform: HyperMuda currently runs on the PC running Microsoft Windows. It can also be ported to Macs and Suns because it can afford a consistent application (i.e. Macromedia Director) across platforms.
- Multimedia User Interface: Utilizing multimedia database (supported by Macromedia Director) and traditional text database (supported by Microsoft Access), the graphical user interface (GUI) for HyperMuda was designed for ease of use. It does not impose any hypermedia theory and skill requirements.
- Hypertext/hypermedia (standalone on prototype): HyperMuda prototype provides links to various data, enabling rapid and easy cross-referencing and data retrieval via its hyperlinks and hypermedia ability (refer Figure 6.2).

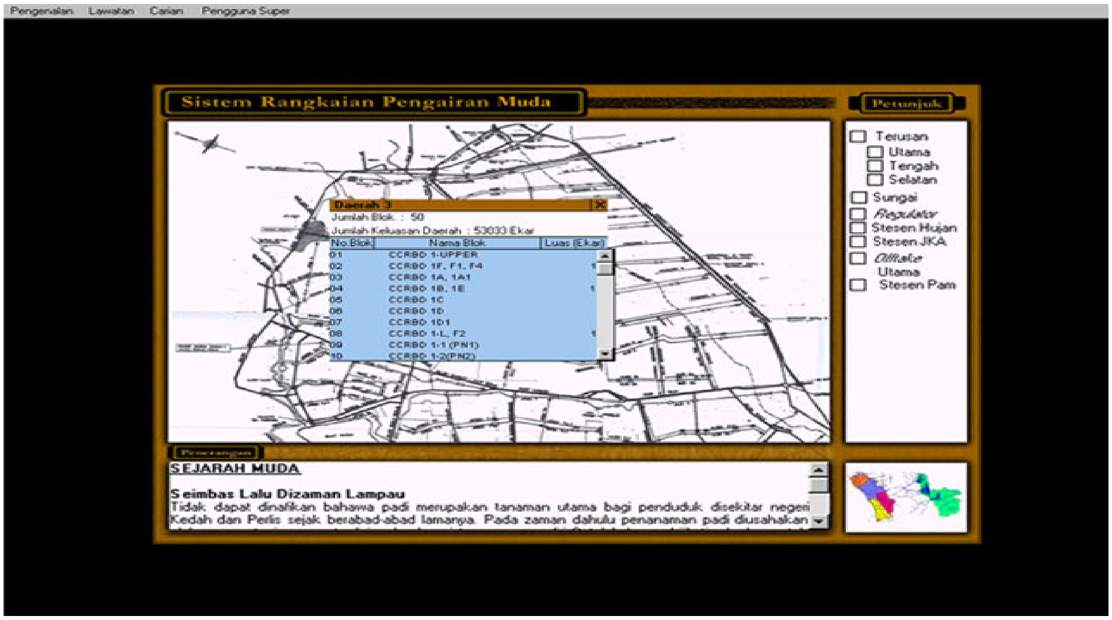

Figure 6.2: HyperMuda with its Hyperlinks and Hypermedia Ability

- User level selection: This feature is an additional one since our target is to generate an adaptive hypermedia prototype. This feature creates an adaptable feature of the HyperMuda. Current selections available are novice, intermediate, and expert users.
- Key measurement calculation: water depth (D_{I+1}) and water application efficiency (E_a) can be calculated using HyperMuda. Water depths are a function of sea page, water consumption rate, evaporation, and water depth. Application efficiency is a measure of how much of the water that is applied is actually retained in the target area. It is a function of the soil water status before irrigation, the depth (calculated depth as above) and the soil's water retention characteristic. The formula used by HyperMuda is inherited from Lincoln Environmental (2000):

  E_a = change in the volume of water stored in target area / the volume of water applied

- Text Search: Text search capability is also provided. The user can specify date and time searches in obtaining data for a certain attributes of irrigation such as regulators' opening, rainfall readings, and amount of water released to particular irrigated blocks. Users can traverse to the locations identified in the search by clicking the mouse on the item of interest.

- Photo search: More than 30 photographs were included in the prototype at the moment. It is still being added every time we receive new photographs from MADA. These are irrigation-related photographs, meant to introduce a variety of irrigation infrastructure, tools, and facilities to the users. Users can view the thumbnails as well as the actual images of those photographs.
- Reporting: Additionally, ordinary users can create reports whereas super user can create, add, delete, and perform other database management functions from within the HyperMuda environment (refer Figure 6.3).

Figure 6.3: Reporting Ability for Ordinary End Users

- Printing: Users can print information obtained from HyperMuda if they desire.

Having the features identified with the matching user model, we proceed with the design of databases, display widgets for the user interface, and the navigation structure of the overall HyperMuda key screens. The following sections will exclude database design because the design of the HyperMuda databases, its structure and the data flow diagram, as well as entity relationship diagram has been elaborated in Chapter 5.

6.1.1 HyperMuda Prototype Development Process

The method of development is divided into two, namely the database development and the GUI development. The integration of the two was done after the completion of both developments.

The development of all related databases is realised using Microsoft Access. The HyperMuda prototype is meant to be integrated with MADA's actual database (refer to Figure 1.3), therefore it is adequate to use a small-scale data set for the purpose of system testing. The development of GUI starts with collecting data for display widgets. The widgets identified for the GUI are windows for sections of HyperMuda display; the map of peninsular Malaysia, focusing on Kedah state; detailed maps of MADA area; detailed maps of MADA irrigation network, including the dams, rivers, canals (for both secondary and tertiary systems), and the irrigated blocks; interaction widgets including checkboxes, scrolls, hypertext links, buttons, data fields, and pull-down menus.

Whereas for the navigation, we use data categories that were clustered as in Figure 6.1, as a basis for navigation design and structure.

Combining both the display widgets and navigation structure, we produced the HyperMuda storyboard that acts as our blueprint for HypeMuda prototype development. The finalised storyboard can be viewed in Appendix 2.

The challenge we faced was integrating the two modules, i.e. the database (Appendix 3) and the GUI part of HyperMuda. This is due to the limitation of the tools that cannot retrieve data from database using a normal retrieval method, instead we must use a special module called DataGrip (www.datagrip.com).

6.1.2 White-Box and Black-Box Testing

Prototype testing was performed by the designer, researchers, and selected end-users throughout the design and the development process. During the test design phase we perform the black box testing, whereby we treated the prototype as a "black-box", i.e. we do not explicitly use any knowledge of the HyperMuda's internal structure. Basically this test aimed on testing the functional requirements of HyperMuda. We make sure that the features that we provided (listed in Section 6.1 above) function as expected.

White-box testing not only verifies that the basic unit of codes in Macromedia Lingo and Datagrip (class/function/procedure) behaves properly when appropriate input is given but also validates that unexpected inputs, such as invalid input of date for data searching, did not cause application crashes. This was done using exception handling in Lingo and DataGrip scripting. Our aim was to ensure proper design of the tests and the identification of all the mandatory test inputs to reap the advantages of white-box testing. We proceed with creating test plans to be reviewed. After reviewing the test plans, we design test procedures, including input data. Quality support at this stage includes, verification via walk-through, checking the algorithmic structure, and scripts of Lingo and DataGrip.

6.2 Procedures for Evaluating HyperMuda

As with other system, HyperMuda is also subjected to evaluation. In a nutshell, the process for evaluating HyperMuda is proposed in these order: (1) preparation of test cases and instrument for measurement; (2) perform a controlled experiment based on the test cases; (3) collect data using the instrument identified in (1); (4) conduct a debriefing session where a short survey can be carried out, and (5) analyse data collected in (3) and (4).

The evaluation focuses on users' experience goal, which is one of the main elements for adaptive system (Brusilovsky, 2002). The objectives for evaluating HyperMuda are as follows: (1) to identify whether users can navigate the system to find specific information needed; (2) to find out users' perception towards the system performance in specific tasks, and (3) to find out whether the information categorization in the system help fulfil users' task efficiently.

6.2.1 Test Cases and Evaluation Instrument

The test cases that we prepared were aimed at evaluating up to 95% of the available features in HyperMuda. There are five cases prepared for novice to intermediate user, and three cases prepared for expert users, or super users. The summary of test cases that should be used in the evaluation is detailed out in Table 6.1.

Table 6.1: Summary of Test Cases

Case No.	Case Objectives	Specific Tasks to Achieve Case Objectives	Acceptable Time Frame with existing GUI (Max. in seconds)
1	To obtain general information about Muda irrigation area.	1. Show information about pool size, types, and water capacity related to the three dams in the reservoir. 2. Retrieve and show 4 pictures related to dams and irrigation (such as regulators, dams, barrage, syphon, aqua duck). 3. Retrieve general information of any one regulator, which controls the water supply rate. 4. Retrieve two maps of different districts. 5. Retrieve the area size and total number of blocks of every district in the Muda irrigation area.	60 90 90 30 90
2	To obtain data related to the calculation of water release rate.	6. Study previous data to get precise information about dry season for the purpose of calculating the amount of water to be released via the regulator as requested by the farmers. Information should include: a. Names of the months of dry season b. Duration of the dry season for year 2003 c. Water supply rate of the previous season.	 120 120 120
3	To obtain flood-related information	7. List down all the areas and blocks, which are frequently affected by flood. 8. Estimate the water supply level (in Cusec) of district 4 9. Estimate when flood is expected to happen in 2004.	120 120 180
4	To obtain river-related information	10. Name of two main rivers that supply water for irrigation to canals and blocks. 11. Name of the districts and blocks which use the water supply from those two rivers 12. Find out when (in month) is the highest amount of water needed to be pumped from one of those rivers.	90 60 180

5	To retrieve information related to water needed for domestic purposes	13. List down all JKA water pump centres along Central Canal and Southern Canal. 14. If JKA increases its water retrieval level, determine whether there will be increment in a. Water supply rate in the involving regulators b. Water pumping rate from the affected river	90 120 120
6	To change default password	15. Combination of alphabet and numeric data consisting of 8-16 characters.	180
7	To update rainfall database	16. Update yesterday's data for rainfall for all blocks in the District 1 because the data inserted contained errors. 17. Insert latest data of rainfall (today) for all blocks of District 3.	300 300
8	To produce a report for water usage in plantation for a particular district	18. a. Daily report b. Weekly report c. Monthly report d. Annual report e. Monthly report in bar chart form f. Produce a hard copy for each report	180 180 180 180 180 180

6.2.2 The Procedure for the Experiment

The experiment should be set up as follows. From a pool of novice-intermediate-expert users (say, from MADA) choose at random, five novice-intermediate users and five expert users. Place them in a lab where they can access the HyperMuda prototype. Start with some briefing regarding the purpose and the process of evaluation. Give them 15-minute ample time to get to know the prototype and get the hang of it. Each user should then be given one set of test cases. Request them to complete one case before trying another.

For each case, the users should obtain/retrieve the information needed as listed in Table 6.1 in order to achieve the evaluation objective. The objective for each case is achieved if at least 50% of the tasks were completed successfully within the acceptable time frame (Lincoln Environmental, 2000). The allocated maximum time is derived from the average time taken by real users during the prototype testing. However, this measurement should not be announced to the respondent, as we do not want them to feel depress or tense if they cannot complete the tasks within the maximum time frame.

Other than time, we can also consider other factors such as error rate, number of clicks, help accessed rate, and other accuracy measurement for evaluating HyperMuda. Data collected should be tabled according to user number, case number, tasks performed, and time taken by the said user. Based on the performance, we can later decide whether the cases' objectives are achieved or not. Performance of the novice users and expert users for task 1 to 18 should be evaluated and compared. The result will then serve as a basis for further enhancement of HyperMuda.

6.3 Summary

Our work with HyperMuda suggested that using a hypermedia-base system as a basis for finding information in a one-stop information center was possible and could be preferable. To a certain extend, a concept called adaptive hypermedia was implemented in HyperMuda since it was expected to be used by people with different knowledge. Implementing adaptation, HyperMuda would make it easy for people to find the information by indexing various Muda irrigation data based on the relationship among the data in the Muda irrigation network model that had been developed earlier.

As for its features, HyperMuda currently runs on the PC running Microsoft Windows. It utilized multimedia database (supported by Macromedia Director) and traditional text database (supported by Microsoft Access), which had been integrated with the graphical user interface (GUI) developed with Macromedia Director. The prototype provided links to various data, enabling data retrieval via its hyperlinks and hypermedia features. Text and photo search capability was also provided. Ordinary users could create reports whereas super users could perform other DBMS functions from within the HyperMuda environment.

The development of its database was realised using Microsoft Access and the development of GUI with Macromedia Director Lingo. The process began with collecting data for display widgets followed by designing the navigation structure, followed by combining both the display widgets and navigation structure, followed by designing the HyperMuda storyboard. The storyboard was then used as a blueprint for the actual implementation (coding and scripting) of HyperMuda. The final step was the integration of irrigation database with the HyperMuda GUI. Along the way, design test and system test were performed using black box and white-box testing.

A detailed procedure for evaluating HyperMuda were also proposed aiming at identifying its navigability in finding specific information, to find out users' perception towards the system performance in specific tasks, and to find out whether the information categorization in the system could efficiently fulfil users' task.

CHAPTER 7
CONCLUSION AND RECOMMENDATION

In this study we have attempted to identify major irrigation management systems' characteristics in order to design a unique one-stop irrigation management information system called HyperMuda. This chapter concludes the study in the summary section and suggests a few recommendations for future work in the recommendation section below.

7.1 Summary

Various uses of information systems to support decision-making in water resource planning and management have been highlighted by researches in their study on irrigation management. The information systems were used by managers thus enables them to plan future development.

MADA irrigation system provides water for paddy planting in the Muda area of Kedah. It covers the activities of the collection, storage and usage of water and distribution of water to various paddy fields through a massive network of canals. However, a one-stop centre where all the data on irrigation does not exist and this poses a problem for MADA in making fast decision.

The process of designing the HyperMuda database has resulted in identifying the entities and attributes that are required in developing the prototype. Eight entities that present, relate to dams, rivers and irrigation. Relationship between the entities is obtained from shared attribute between them.

Microsoft Access 2000 has been used in developing the database while Macromedia Director was used in developing the GUI of the prototype. Extensive testing of the prototype has been done in order to improve the prototype. Predefined test cases have been provided to be used for prototype evaluation involving end users.

7.2 Recommendations for Future Work

There are a number of issues which require further research:

1. Evaluation of the prototype by the end users will have to be performed based on the predefine test cases. Although extensive testing has been performed to improve the prototype, the evaluation stage will ensure that the prototype is usable and delivers what the end users expect.
2. The GUI of the prototype can be improved to provide more interactivity for the end users, specifically the main menu items, check box items in the main panels. The existing items are limited only to the compulsory first level items.
3. At the moment the search facility provided is based on dates. Search should be made possible by random keywords such as name of river, blocks, and canals.
4. Real database that can be integrated with MADA database will have to be implemented if the prototype is to be transformed into a full blown system.
5. The maps that are incorporated in the prototype can only be zoomed to only two or three levels. It would be better if the maps can be zoomed to the forth level which will be better for decision-making.
6. Some of the maps are being manually drawn and this does not represent the real image of the area. Incorporating digital maps will provide better display for the system.

As a final point, achievement of sustainable irrigated agriculture depends on better system design, as much as improved management. This will certainly require a combination of theoretical and fieldwork. Technology and expertise are available in our country to increase understanding and obtain the information that is needed for sustainable irrigated agriculture.

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