WEB BASED SYSTEM TO SUPPORT NRW MANAGEMENT: A STUDY ON PERLIS WATER MANAGEMENT

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Abstract: *Perlis, the smallest state in Malaysia is one of the states that suffers high amount of non-revenue water although the water authority has taken actions in controlling non-revenue water. Major problems encountered by the authority are to identify the source and location of non-revenue water. This has resulted in poor water services to affected areas and bad impression to the management team. This study endeavors a web-based system to support non-revenue water management. The system has been designed by including all manual functionalities as well as the authority new requirements. The system records data such as meter reading from all distribution points. The testing shows that the system functionalities are 100% error free with the gathered real data provided by the water authority. The system also managed to calculate the amount of non-revenue water at each zone. This report will benefit the water authority especially in locating the zone with high amount of non-revenue water.*

Keywords: *non-revenue water, web-based system, perlis, water management*

INTRODUCTION

Water encourages agricultural activities, industrial activities, homes and outdoors activities. Water is used daily at residential, commercial or industrial, agriculture, power generation and many others (Mayer, 2004). In economic sector, water demand comes from all types of economic activities such as heavy industrial activity (e.g: steels industry, concrete production, car manufacturing, and etc.), small and medium industries (e.g: food production, craft industry, and etc.), and other activities (e.g: food stalls, coffee shop, and etc.). In contrast to it usage, water harvesting should not exceed the level which could cause negative impact to the environment. Water storage either underground or surface storage should be maintained to ensure the sustainability of its usage.

Many organizations have been set up to organized and monitored global water management. Examples of these organizations are International Water Management Institute (IWMI), Bristol Water Holdings Group, The International Water Association (IWA), World Water Council (WWC), and International Water and Sanitation Centre (IRC). In every country, a specialized institution either runs by the government or private, managed the water resources and supplies. These water institutions either global or local institutions play an important role in managing the water resources, supply and demand. IWMI for example, has launched a long-term research program to improve the conceptual and empirical basis for analysis of water in major countries of the world. The output of the research has been reported in IWMI research report (Seckler *et al.,* 1998) and reviewed in series of IWMI annual reports.

NON-REVENUE WATER

During the last decade studies have been made in the understanding and modeling of water loss components. Despite some encouraging success stories, the majority of water supply systems all around the world continue to experience high level of water losses, many of which are almost certainly higher than their economic level. The presence of water leakage in the water distribution systems has resulted in the shortage for the demand of water. Shortage of water becomes worst when there is disaster cause by mother's nature. In Southeast Asia for instance, the draught caused by the El-Nino weather phenomenon during 1997/1998 has also demonstrated that the water demand of many cities has reached critical levels.

Water lost from the many public water utilities is also known as non-revenue water (NRW). This is due to poor water distribution network facilities and management, which resulted in a negative impact on the utilities. There is no general terminology for NRW. It is sometime categorized as the amount of water put into the supply systems that bring no revenue to the supply authority. IWA defined NRW as the difference between the System Input Volume and Billed Authorized Consumption (Liemberger, 2001). System Input Volume is the annual volume input to that part of the water supply system to which the water balance calculation relates. Authorized Consumption is the annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so, for residential, commercial and industrial purposes. The IWA standard water balance and terminology is shown in Figure 1.

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
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Figure 1: IWA Standard International Water Balance and Terminology
(NRW and its components shaded grey)

PERLIS WATER MANAGEMENT

Perlis, one of the smallest states in Malaysia, experienced high level of NRW. NRW control has been given high priority by the Malaysian Federal Government beginning from the Sixth Malaysian Plan. In the Seventh Malaysia Plan for example, the government spent more than RM500 million for rehabilitation of water supply system. The effort did reduce the amount of NRW in all states, but the figures are still high. NRW figures for all the states in Malaysia are estimated to be around 25% to 48%, with the exception of Penang, which is about 20%. However, the national target for NRW in all states is around 25% (BW Perunding, 2000).

NRW percentage in Perlis was estimated to be 43.8% in the year 2000 and a reduced in percentage to 39.2% was observed in 2001. However, the percentage has increased in 2002 to 40% and 41.6% in 2003. The operating costs of the water authority were about 12.3, 12.4, 12.9, and 13.7 millions while the total revenues were about 11.1, 12.8, 12.7, and 12.9 millions for the 2000, 2001, 2002, and 2003 respectively. The authority is currently operating at a loss and they knew that there is a great loss of water in the distribution system.

The management of treated water for domestic and non-domestic in Perlis is handle by the Perlis Water Work, which is the government water authority. Clean water is obtained from three main sources i.e MADA canals, Timah Tasoh dam and underground water. Water is treated at the treatment plants before being sent through pipes to storage or supply tanks. From the tanks, the water is then distributed to all consumers around Perlis. There are cases where the treated water is being stored in several tanks before reaching the consumers. However, there is also a case where the treated water is directly pumped from the treatment plant to the consumers. This occurred in the Semadong consumer area where treated water reaches the consumer directly from Air Semadong treatment plant.

Consumers are charged or billed based on the amount of water consumed and the amount is record by a meter. The reading is done on a schedule basis. The total water billed is a source of revenue to the State Government. Perlis water distribution system covers the rural and urban area and it is anticipated that 99% of the state population is being served. Figure 2 shows the existing Perlis water distribution system.

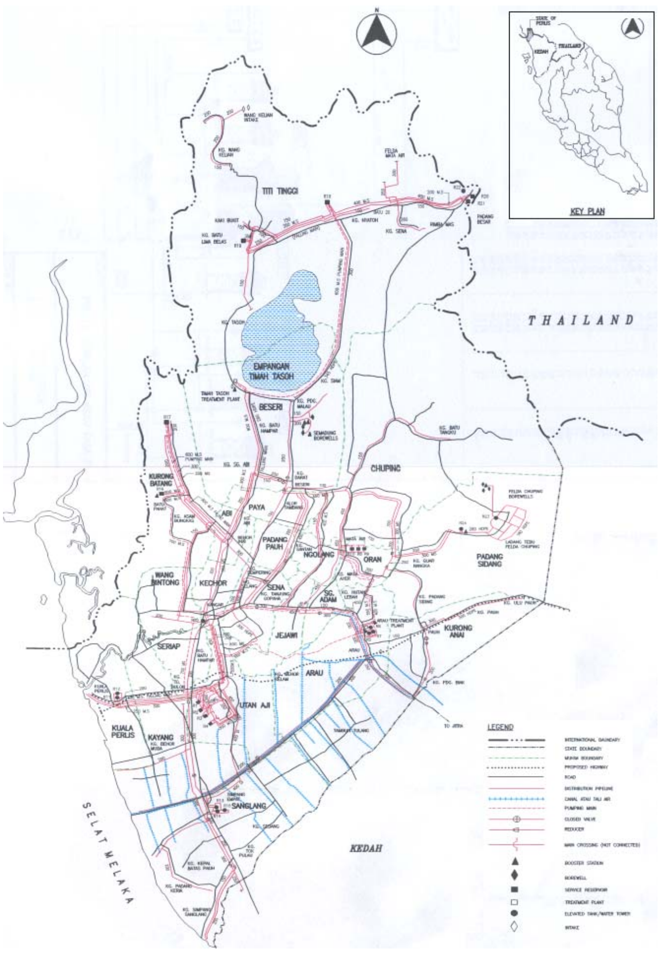

Figure 2: Existing Perlis Distribution System

WEB-BASED NRW MANAGEMENT

Efforts have been made by the Perlis Water Work department to reduce the NRW figure to an acceptable level. The first was to hire a consultant company to redesign the water distribution network, which includes the suggestions on the types of pipes to be used. This has been implemented and the state was able to reduce NRW figure by 10%. Another consultant company was hired to study on water shortage and to give suggestion on building new water treatment plants and as a result, the treatment plants are now being designed. Despite these efforts, NRW figures are still high.

Locating the area of water loss as well as identifying the amount of loss is the first step in solving the problem. However, the water authority cannot identify the location and magnitude of the water loss due to the absence of a complete water distribution system model as well as lack of staff to handle NRW issues and problems. Moreover, there is no measuring equipment to measure the amount of water that is flowing through the water supply tanks to various consumer zones.

This study revealed the complexity of identifying the NRW sources. The solution applied is by grouping the consumer into several NRW zones. The water flows are measured at several points. These readings can be used in determining the losses, which include the quantity and the location. To simulate the model a computerized system that is similar to the current manual systems is design and develops.

A Perlis NRW system is design and develop under on WWW based application. The system consists of two main components: client and server sides (Figure 3). The clients, particularly the intranet and Internet users communicate with the server through the web pages. Intranet users accessed the server directly through Local Are Network (LAN) connection, while Internet users accessed the server through the Internet. The server uses Windows 2003 platform, which support dynamic web pages, embedded with Active Server Page (ASP) and VB.net scripts. These scripts connect the users with the SQL database, which store the information on Perlis water system.

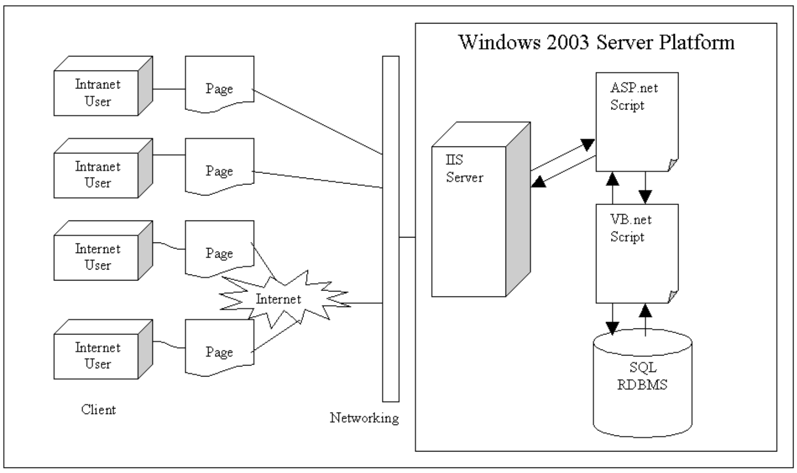

Figure 3: Overview of System Architecture

The main user of the system is the Perlis water authority officer. Even though the system was design with dynamic WWW capability and global access, the users are restricted for certain officers who have right to the data. Hence, the system prototype is equipped with password protection. Figure 4 shows the main interface of the system prototype.

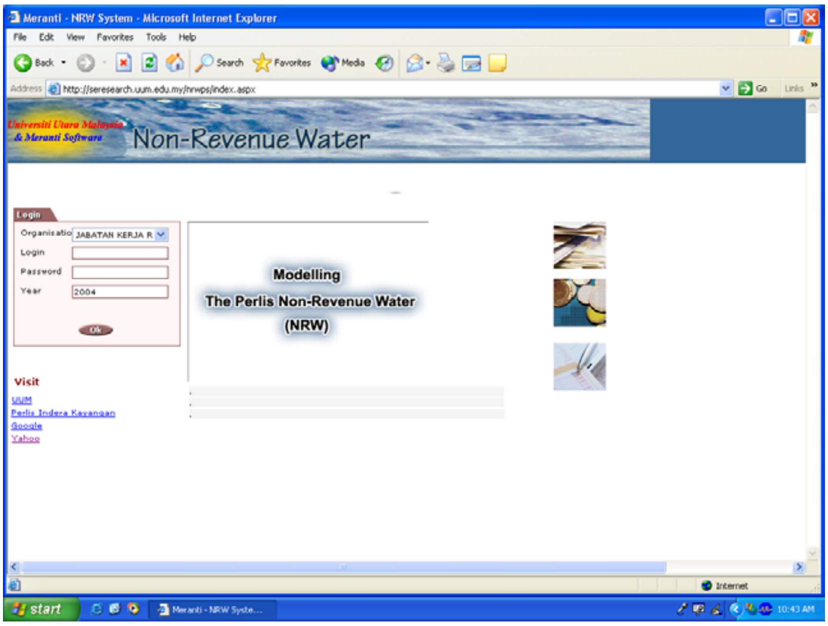

Figure 4: Main Interface

Once login, users may view a list of menus that comprises of file, parameter, data entry, calculation, simulation, report and help (Figure 5).

Figure 5: Main Menu

Figure 6 present the use case diagram for the system. Five actors and fifteen use cases have been identified to represent the functionality provided by the system. Tables 1, 2, 3, 4, and 5 depict the summary of use cases for the system.

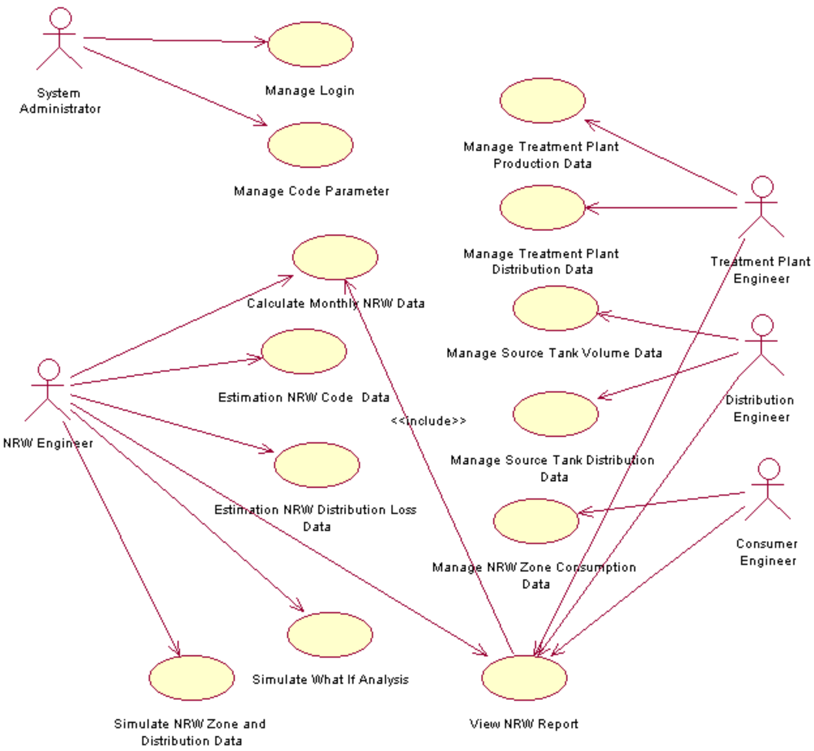

Figure 6: Use Case Diagram for Perlis treated water system

Table 1: Summary of Use Case for System Administrator

Use Case Name	Description
Manage Login	The system will create user name and password based on level identified. This use case can add, delete, edit and display user information such as username, password and user level. System user must use username and password combination which enter in this use case before enter to the main page of Perlis treated water system.
Manage Parameter	The system will create various parameters such as treatment plant, source tank, NRW zone, NRW code, treatment plant distribution, and source tank distribution. This parameter can be added, edited, and deleted depending on the environment of NRW system. System administrator must enter all the parameters before the system can be used.

Table 2: Summary of Use Case for Treatment Plant Engineer

Use Case Name	Description
Manage Treatment Plant Production Data	1. User will logon to the system with treatment plant engineer level authority. 2. User will select Treatment Plant Production from a Data Entry Menu. 3. User will select year and month from options of Plant Production Menu. 4. User will receive plant code and plant name of Plant Production Menu. 5. User will key in production data for each treatment plant display at the menu. 6. After do the data entry, user will press update button to save data in the system.
Manage Treatment Plant Distribution	1. User will logon to the system with treatment plant engineer level authority. 2. User will select Plant Distribution from a Data Entry Menu. 3. User will select year, month and treatment plant from options of Plant Distribution Menu.

Use Case Name	Description
Data	4. User will receive tank code and tank name from Plant Distribution Menu. 5. User will key in distribution data for each treatment plant display at the menu. 6. After do the data entry, user will press update button to save data in the system.

Table 3: Summary of Use Case for Distribution Engineer

Use Case Name	Description
Manage Source Tank Volume Data	1. User will logon to the system with distribution engineer level authority. 2. User will select Source Tank Volume from a Data Entry Menu. 3. User will select year and month and tank volume from options of Tank Volume Menu. 4. The system will display tank code and tank description from Tank Volume Menu. 5. User will key in source tank volume in the system. 6. After data has been entered, user will press update button to save data in the system.
Manage Source Tank Distribution Data	1. User will logon to the system with distribution engineer level authority. 2. User will select Source Tank Distribution from a Data Entry Menu. 3. User will select year, month and zone distribution from options of Zone Distribution Menu. 4. User will receive tank code and tank name from Zone Distribution Menu. 5. User will key in zone distribution data for zone selected at the menu. 6. After data has been entered, user will press update button to save data in the system.

Table 4: Summary of Use Case for Other Actors

Use Case Name	Actors	Description
Manage NRW Zone Consumption Data	Consumer Engineer	1. User will logon to the system with consumer engineer level authority. 2. User will select Zone Consumption from a Data Entry Menu. 3. User will select year, month and press show button from options of Zone Consumption Menu. 4. The system will display zone code and zone name Zone Consumption Menu. 5. User will key in number of consumer and metered reading consumption for each zone cone. 6. After do the data entry, user will press update button to save data in the system.
Generate NRW Report	• NRW Engineer • Treatment Plant Engineer • Distribution Engineer • Consumer Engineer	1. User will logon to the system with user level authority. 2. User will select type of report from a Report Menu. 3. The system will display a report based on type of report selected by users. 4. The system also can export a data report to another file likes Excel, text file of flat files.

Table 5: Summary of Use Case for NRW Engineer

Use Case Name	Description
Manage NRW Code Estimation	1. User must estimate the magnitude and source of NRW Zone Loss. 2. User will logon to the system with NRW Engineer level authority. 3. User will select NRW Zone Estimation from a Data Entry Menu. 4. User will select year, month, zone and press show button at NRW Zone Estimation Menu. 5. The system will display calculated and percentage NRW loss. 6. User will key in the estimate amount losses by NRW code. 7. After data has been entered, user will press update button to save data in the system.
Manage Distribution Loss Data Estimation	1. User must estimate the magnitude and source of NRW Distribution Loss. 2. User will logon to the system with NRW Engineer level authority. 3. User will select NRW Distribution Estimate from a Data Entry Menu. 4. User will select year, month, zone and press show button at NRW Distribution Estimation Menu. 5. The system will display calculated and percentage NRW Distribution loss. 6. User will key in the estimate amount losses by NRW Distribution loss. 7. After data has been entered, user will press update button to save data in the system.
Calculate Monthly NRW	1. NRW Engineer must confirm that all the data entry for particular month key in to a system. 2. NRW Engineer enters username and password. 3. NRW Engineer select calculation menu from main menu. 4. NRW Engineer will select year, month and press start button to do monthly calculation. 5. The system must display "Calculation Finished" after this use case success.
Simulate NRW Distribution	1. NRW Engineer will logon to the system with NRW engineer level authority. 2. NRW Engineer will select Distribution NRW Simulation from a Simulation Menu. 3. NRW Engineer will select year, month and press show button from Distribution NRW Simulation Menu. 4. The system will display tank code, tank name, NRW percentage for tank distribution. 5. NRW Engineer can key in percentage of distribution simulation data and press show button to get an actual production, simulated production and total water metered reduction.
Simulate NRW Zone	1. NRW Engineer will logon to the system with NRW engineer level authority. 2. NRW Engineer will select Zone NRW Simulation from a Simulation Menu. 3. NRW Engineer will select year, month and press show button from Zone NRW Simulation Menu. 4. The system will display zone code, zone name, NRW percentage for each zone. 5. NRW Engineer can key in percentage of NRW change and press show button to get an actual production, simulated production and total water metered reduction.
Simulate NRW Combination	1. NRW Engineer will logon to the system with NRW engineer level authority. 2. NRW Engineer will select Combine NRW Simulation from a Simulation Menu. 3. NRW Engineer will select year and month and press show button from Combine NRW Simulation Menu. 4. The system will display both Distribution NRW simulation and Zone NRW simulation.
Simulate What If Analysis	1. NRW Engineer will logon to the system with NRW engineer level authority. 2. NRW Engineer will select What If Simulation from a Simulation Menu. 3. NRW Engineer will select year, month and press show button to display data production, metered consumption, and NRW percentage for selected year and month. 4. NRW Engineer can choose "What If Analysis" (Production, Consumption, and NRW Percentage) and press show button to receive a simulation data based on criteria selected.

The system workflow can be divided into four categories: code setup, data entry & calculation, data simulation, and report (Figure 7). Code setup is use to set and initialize the codes and basic parameters for treatment plant, supply tank, NRW zone, NRW code, distribution loss code, treatment plant distribution, and source tank distribution. These codes and parameters will be used in the data entry & calculation sections. In this section input data on treatment plant production and distribution, supply tank volume and distribution, and NRW zone consumption are gathered. Based on this data, NRW and distribution loss are estimated based on monthly basis.

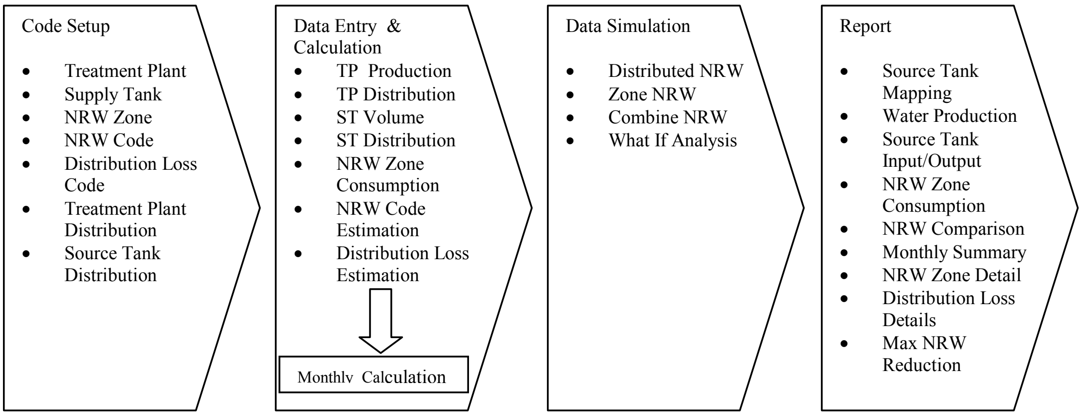

Figure 7: System Workflow

The system is validated to ensure that all data are valid and has the same result with the report published by Perlis PWD. Extensive testing is done by the researcher and user. The testing was performed based on water production, source tank distribution, zone consumption, NRW report, and NRW monthly summary report. To test the system, the actual data given by Perlis PWD was entered into the developed model. The output from the system is compared to ensure the accuracy of the data. The result shows that all reports are 100% accurate with the report produced by Perlis PWD.

CONCLUSION

The system developed is quite extensive. Currently, it support most of the functions performed in the conventional operation. The system also provides the function to calculate the NRW at specific locations. This function was not available before in the current conventional operation. It also utilized database utilities with extended graphical user interface (GUI). The system can assist users, typically water authority in report preparation and generation. The code and scripts embedded in the system may be easily modified and updated. In addition, the utilization of WWW architecture, Internet and intranet functionalities encourages other means of accessibility to the system.

REFERENCES

BW Perunding Sdn. Bhd. (2000). *Conceptual Design Report Vol. 2.* Jabatan Kerja Raya, Perlis

Liemberger, R. (2001). Performance Target Based NRW Reduction Contracts – A New Concept Successfully Implemented in Southeast Asia. *IWA 2nd World Water Congress*, Berlin October 2001.

Mayer, P. W. (2004). End Uses of Water Practical Data Collection, Analysis, and Utility. *Proceedings of International Water Demand Management Conference*, *May 30 – June 3, 2004*, Dead Sea, Jordan.

Seckler, D., Amarasinghe, U., Molden, D., Silva, R., & Barker, R. (1998). World Water Demand and Supply, 1990 to 2025: Scenarios and Issues. *Research Report 19*. Colombo, Sri Lanka: International Water Management Institute.