A STUDY OF ECOLOGICAL SANITATION AS A WAY TO COMBAT URBAN WATER STRESS

(Date received: 19. 7. 2007)

Darrien Mah Yau Seng , Frederik Josep Putuhena , Salim Said and Law Puong Ling
Department of Civil Engineering, Faculty of Engineering, Universiti Malaysia Sarawak
Km-17 Kuching Samarahan Expressway, 94300 UNIMAS Kota Samarahan, Sarawak
E-mail: darrien_mah@yahoo.co.uk., fjputuhena@feng.unimas.my, ssalim@feng.unimas.my, puonglaw@feng.unimas.my

ABSTRACT

Water supply is one of the basic infrastructure requirements. Water treatment and supply are often granted a much higher priority than wastewater collection and treatment, despite the fact that wastewater deserves a greater emphasis due to the impact of its poor management has on public health. A new commitment to give wastewater the same priority as water supply is a very positive development. A pilot project of greywater ecological treatment is established in Kuching city since 2003. Such treatment facility opens up an opportunity of wastewater reclamation for reuse as secondary sources of water for non-consumptive purposes. This paper aims in exploring the potential of the intended purposes in the newly developed ecological treatment project. By utilising the Wallingford Software model, InfoWorks WS (Water Supply) is employed to carry out a hydraulic modeling of a hypothetical greywater recycling system as an integrated part of the Kuching urban water supply, where the greywater is treated, recycled and reused in the domestic environment. The modeling efforts had shown water saving of more than 50% from the investigated system reinstating that the system presents an alternative water source worth-investing in an urban environment.

Keywords: *Ecological Sanitation, Greywater, Kuching City, Recycling, Urban, Water Supply*

1.0 BACKGROUND

Kuching is the capital city of the Sarawak State in Malaysia. The authorised water supplier, Kuching Water Board abstracts freshwater sources from upstream Sarawak River to supply clean water to 580 000 population. Though Sarawak River system, where more than 97% of freshwater abstraction for Kuching city, is fortunately rich in its reserve and hydrology, this advantaged physical environment is increasingly challenged when placed in the context of the dynamic social environment of Kuching city. Being the capital city of the Sarawak State, Kuching city is the fastest growing area placing great pressure on the water supply and has seen a rapid growth in water demand.

Effectively managing its demand and supply requires a sustainable approach that manages the natural resource together with community demands, both consumptive and uses, and not forgetting also the environment needs. The local practiced water supply management still focuses on strategic direction and priorities revolved around water supply, infrastructure, water reticulation and management of water storages. Sustainable water supply into the future would embrace the concept of Integrated Water Resources Management (IWRM) where the new challenge requires a very different response.

The current water uses are construed along the lines of a one-time use of water, draining them into the sewer and back into Sarawak River as wastewater sink. The system is conceptualised as a flow-through system (see Figure 1). Little attention is placed on the safe management on the huge volumes of wastewater.

To cater for a change for sustainable and ecologically efficient use of water supply, water resources and wastewater management must come together in addressing the water cycle under the IWRM processes. Diversifying the supply options is one way to reduce dependency on sole sources of supply [1]. In order to decrease the pressure on the finite water resources, wastewater need not be throwing away after one time use but can be prompted for reclamation of household wastewater. Recycling and reuse of wastewater can be a water source for non-consumptive purposes where lesser quantities of potable water are used for purposes other than drinking. This lowers water supply costs, as potable water is expensive in treatment costs and the needs of storage facilities management.

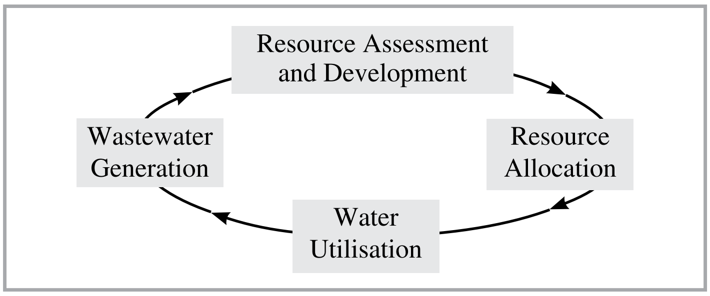

Figure 1: Schematic of local water resources management

Much of the water used in daily life ends up as wastewater. Greywater is produced when water is discharged from household appliances and water using fixtures such as shower, baths, washing machines, kitchen and laundry sinks. It excludes water discharged from toilets and urinals (black water). Rough estimate in a water-conserving household in Germany, for example, approximately 60 liters of greywater are generated per person daily [2]. Presently, the wastewater from households in Kuching is partly treated. Only the black water undergoes a partially treatment in septic tanks before the overflow being discharged to the storm water drains. The greywater is released untreated to the storm water drains which runs into Sarawak River. Therefore the water quality of drains, streams and rivers in Kuching are highly polluted. Greywater contains a number of bacteria that may include disease causing organisms.

It also contains a number of pollutants including organic matter, nutrients, salts and detergents. However, it is possible to collect and reuse greywater as it can be treated to a less health-hazardous standard. Since greywater is generated directly in every household in just about equal volumes every day independent of the weather, it presents a constant resource.

There are financial, environmental and health considerations involved in wastewater treatment. Kuching city is generally flat, low-lying with only small possibilities for gravity piping. In addition large part of the city is deep peat, which may decompose due to draining effect of the sewers and thus may lead to breaking sewers and rising mains. A centralised sewer management with sewer piping is therefore not in favour considering the local conditions. Ecological Sanitation (Ecosan) facilities are considered as an alternative to centralized wastewater system. Kuching city did not practice water recycling. Treated greywater can be used as processed water for flushing for toilet, for watering the garden and for cleaning.

2.0 ECOLOGICAL SANITATION

In June 1999, the State Government of Sarawak, in collaboration with the Danish Cooperation on Environment and Development (DANCED), initiated the Sustainable Urban Development Project in Sarawak. The project was based on the wish to enhance sustainable urban development in Kuching city and other urban centers in Sarawak. Kuching city was selected as key project area to implement an Urban Environment Management System (UEMS) [3]. It was decided to focus on two prioritised issues as a starting point. River quality and solid waste management were selected as the areas of concern. Ecological Sanitation (Ecosan) system is a cost-effective effort in part of the UEMS initiatives [4] devised to take care of household greywater.

The buildings in Sarawak and in generally all Malaysian houses, the black water channels are separated from the greywater channels. This facilitates a source separating Ecosan system. The quantity and quality of greywater can be controlled at the household level [5]. Based on this, Ecosan project in Kuching city is targeted at lowering the nutrient loads in waterways and reducing the pollutant loads in our rivers. It makes sense in the case of Kuching city where water abstraction and wastewater dumping are practically done on the same Sarawak River system.

Sarawak River is deteriorating in terms of water quality because of pollution by being too close contact to raw sewer. Existing conventional septic systems and available resources are often inadequate to deal with the associated public health issues arise, and contributing to the escalation of ecological problems. A significant change is needed in the manner in which sanitation is broadened to include ecological alternatives. The philosophy of Ecological Sanitation is based on the concept of human excreta and wastewater as a valuable resource to be recovered and recycled, rather than as a waste product to be disposed of [6]. Ecosan systems enable the recovery of nutrients from human faeces and urine for the benefit of agricultural, thus helping to preserve soil fertility, assure food security for future generations, minimise water pollution and recover bioenergy. They ensure that water is used economically and is recycled in a safe way to the greatest possible extent for purposes such as irrigation or groundwater recharge. This concept is very similar to the IWRM principles where wastewater is re-integrated as a major component in water cycle. Countless efforts in all over the world are trying various ways of wastewater recycling and reuse.

Experiences of Ecosan approach in different regions have showcased the successful reuse of treated wastewater from constructed wetlands or wastewater treatment ponds. In Peru, for example, the wastewater from the city of Chiclayo (84 000 m^3/a) is lead into a treatment pond before continuing on to irrigate 2000 ha of rice fields.

In the Philippines, a model constructed wetland is more robust and more performant than conventional models, as it uses a regional plant variety. The wetland treats the wastewater from 715 households in a poor settlement, uses the treated water from the wetland to irrigate green areas in the town and is an integral part of the ambitious environmental program of the city of Bayawan.

In the south east of Damascus, Syria, another model constructed wetland in the village of Haran Al-Awamied adopted the technology to the local climatic conditions implementing the sanitation and irrigation project, whilst retaining very good cleaning and disinfection results. The use of untreated wastewater from the existing gravity sewers for irrigation is common. The specific purpose of the Ecosan project in Haran Al-Awamied is therefore to make use of wastewater for irrigation hygienically safe and to make best use of its fertilising effect.

The three cases above, which are projects implemented by the German Development Cooperation (as documented by [7]), involve the ecological treatment of high strength wastewater (combination of black and greywater). The nutrient rich water discharged from the constructed wetlands or wastewater treatment ponds are hygienically safe for agricultural reuse purposes. However, Ecosan application to date on wastewater reuse in domestic environment is rare.

The uniqueness of the model project in Kuching city only involves the treatment of lower strength greywater. A structure of constructed wetlands with integrated aerobic filter using the Norwegian technology and sizing [8] is adopted in the pilot facilities in Taman Hui Sing, Kuching. The size is considerably suitable for the urban environment, about 2.5 m x 4 m in area. A 3D depiction of such structure is showcased in Figure 2. The pilot device connects to nine households of single-storey detached houses with an average of five persons per household. Greywater from the kitchen, shower and washing machine is channeled to the Ecosan facilities. Rainwater from the roof is drained to the system as well. The greywater is treated through the Oil and Grease Tank, then pumped to and sprayed on the Vertical Biofilter and later the Horizontal Biofilter. Currently, black water is transported to a sludge treatment plant. In future, black water will be fed to a biogas plant to sterilise and produce energy and fertiliser without allowing any overflow to the natural waterways.

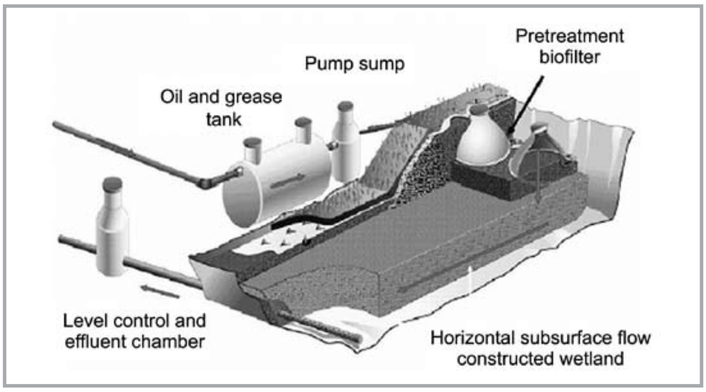

Figure 2: Graphical of ecological sanitation design

Baseline monitoring and sampling results indicated a high efficiency of the pilot system. The project is under constant supervision and observation to check any irregularities in the operation. The average values for treated greywater show more than 90% removal of BOD, COD, TSS and ammonia [8]. The effluent meets the WHO drinking water requirements with respect to nitrogen (<10mg N/I) [8]. Levels of indicator bacteria meet the European swimming water standards [8]. After treatment, the water is discharged as surface water to the storm water drains.

In Kuching city, the pilot greywater Ecosan project has been operating at Taman Hui Sing for four years (since 2003) with excellent results. The treated greywater is however released back to river system as treated wastewater without reusing them though the treated water is of good quality. It is quite a waste to throw away the good resources. The quality of the effluent from the Ecosan system is suitable for a number of discharge and reuse options [9]. Such treatment facilities open up the potential of greywater reclamation for reuse as secondary sources of water for non-consumptive purposes.

3.0 MODELING OF ECOSAN SYSTEM

Reuse of treated greywater facilitates water savings exceeding 50% [10]. Non-consumptive water reuse has an excellent and well-documented performance track records, which to date have featured no documented health problems, strong public acceptance and good regulatory compliance [10]. In order to evaluate a recycle system, the modeling process of using a mathematical representation of the real system is commonly performed. By using network simulations, which replicate the dynamics of a proposed system, problems can be anticipated and solutions can be evaluated before time, money and materials are invested in a real-world project.

Hydraulic modeling of a centralised, large scale treatment system and reuse of its effluent is largely available in the literature for the purpose of irrigation and industry. A decentralised in nature on-site small scale recycling system is not common in records. In the present works, modeling of the Ecosan to investigate the possibility of reusing the treated greywater as an integrated part of the water supply system is made possible with the assistant of the Wallingford Software model, InfoWorks Water Supply (WS) software. The modeling approach is tested on a medium system in Tabuan Jaya Phase 4. Such modeling is beneficial in understanding the appropriate analysis methodology for designing the water supply/recycle systems. At the same time, the model shall be used as a model-project to adapt the methodology to local conditions and to allow for replication of the small system to a larger system elsewhere.

The Tabuan township (see Figure 3) is the sub-urban satellite towns of Kuching city, located about 5 km away from the city center. Tabuan Jaya is one of the residential areas that have a standing establishment of over 20 years. The housing estate is most accessible by using the Wan Alwi Road, one of the main roads that connecting Kuching city to Kota Samarahan. The Kuching Water Board trunk water main was laid along side of Wan Alwi Road branching from Simpang Tiga to supply clean water to Kota Samarahan and Siburan (16th mile Kuching – Serian Expressway) areas. The consumers of Tabuan Jaya are tapping clean water from the same trunk water main.

Tabuan Jaya is surrounded by the Tabuan River that formed a triangulated-shape delta. There are three bridges (see Figure 3), which are (1) the bridge connects to Foo Chow Road, (2) the bridge connects to Tabuan Desa, and (3) the bridge connects to Tabuan Desa Indah. The water supply pipelines do not cross the river for the first two bridges, however pipeline crossing is observed at the third bridge supplying water to Tabuan Desa Indah. For modeling purpose, the pipeline is assumed to stop at the third bridge making Tabuan Jaya an isolated system to accommodate investigations. The current work only concentrates on the northern-end Tabuan Jaya Phase 4 (see Figure 4).

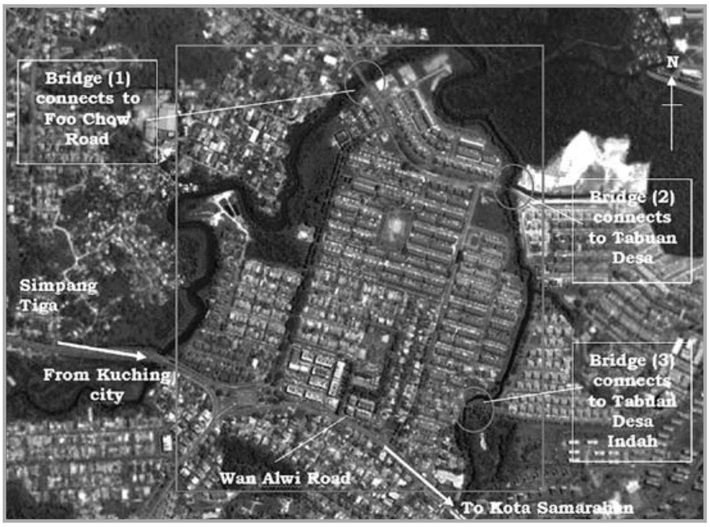

Figure 3: Satellite imagery of Tabuan Jaya[1]

Figure 4: Satellite imagery of Tabuan Jaya Phase 4[1]

Note: [1]Farmosat (Taiwan) Imagery of 2.5 m resolutions taken in September 2005 use with permission of the ICT unit, source Chief Minister's Department

Further analysis of the Tabuan Jaya housing estate with Geographical Information System tool would enhance the appropriate analysis of fitting the domestic scale Ecosan system into the urban water supply network.

4.0 GEOGRAPHICAL INFORMATION SYSTEM

In recent years, considerable interest has been focused on the use of GIS as a decision support system, particularly in the context of holistic approach of water resources management is indeed a great challenge and an important milestones. Providing the responsible agencies with a comprehensive

GIS model, the system conditions, if presenting visually on a geographical data, it facilitates proper planning of urban water supply facilities.

Figure 5: Tabuan Jaya cadastre map shapefiles[2] with building footprints

Note: Official Digital Kuching Cadastre Maps of Sarawak Land and Survey Department Use with permission of the Sarawak State Secretary

The requirement of maps in terms of contents, quality and accuracy vary from organisation to organisation. Comprehensive maps are required for planning and execution by engineering water supply works. For water supply works, to show a concept for distribution system and layout of plots in a local plan, in an urban area, a 1:2000 large scale map is adequate. The 1:2000 ratios cadastre map shapefiles of Kuching city (see Figure 5), maintained and updated till 2002 by the Sarawak Land and Survey Department, is sourced to develop the intended GIS system. The shapefiles contain the following information:

- Block and Lot Numbers
- Street Names
- Lot Lines- Water Bodies
- Lot Dimensions
- Building Footprints
- Contour and height in mass points

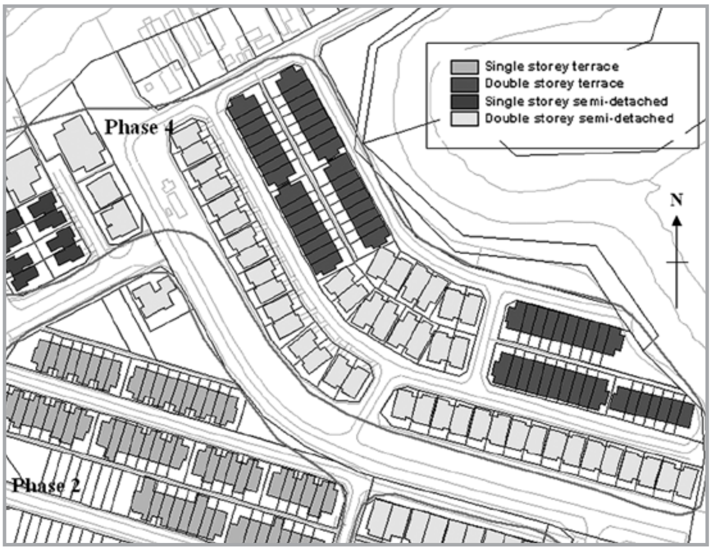

Figure 6: Housing typology in Tabuan Jaya Phase 4

A city transforms its environment and landscape hauled by the momentum of development activities. The expansion of the built-up areas and the transformations resulted in land surfaces and valley reshaped into domestic, enterprises and institutions, eventually leading toward urbanisation. This also has posed serious implications on the freshwater resources in the region. A city like Kuching requires a large input of freshwater. By mapping the urban land uses, breaking down to domestic, commercial, industry and public institutions in different layers to provide a full picture in one integrated system, it is easy to view and interrogate.

By using the ESRI ArcView software, the model calculated a total of 123 units of domestic houses in the Tabuan Jaya Phase 4 housing estate, where the residential area contains 59 units of double storey terrace, 10 units of single storey semi-detached and 54 units of double storey semi-detached houses. The distribution of the housing typology is shown in Figure 6.

The most important step towards an efficient water and wastewater management is the generation of reliable base data through the conversion of existing data into a newly developed integrated information system. What is lacking and the main focus to customise the sourced cadastre into water supply applications require the adding of the following to the existing GIS:

- Water Mains
- Customers' Information

With GIS software - ESRI ArcView in combination with InfoWorks WS, these features are extracted from existing Kuching Water Board records, plotted, overlaid in different layers, statistical analysis carried out on them and conducting spatial searches. Customising "Customers' Information" particularly the water use data and "Water Mains" are discussed in the subsequent sections. Water supply operations are becoming increasingly data-intensive. GIS approach finds its role as an effective tool to help water managers in planning and developing the water supply management and should be envisaged on this bigger picture.

Urban development and analysis of spatial and temporal water consumption are effectively and efficiently done with the help of GIS. Having regards that water withdrawal is practically done in a customer's property, which is a variety of land uses (e.g. residential or non-residential). Data on these urban land uses and water consumption patterns, in which are two different sets of data easily be collected, integrated into one single analyses system and stored within a GIS model for easy maintenance. Such an integrated analyses and monitoring system based on GIS and database management technologies provide an understanding of the current water demands and the application of available technologies, in the case of this work, domestic-scale Ecosan recycle system as an alternative urban water source to the specific problem of rising water demands.

5.0 WATER CONSUMPTION PATTERNS

Although Kuching Water Board makes a large number of flow measurements, such as those at customer meters for billing and at treatment plants for production monitoring, data on usage change over time is sadly practically none existence in records. A true picture of daily variation is very important and no effort should be spared on this. The temporal variations in water usage for municipal water systems typically follow a 24-hour cycle called a diurnal demand pattern.

Developing a diurnal curve for a specific customer require more information than can be extracted from typical billing records. More intensive data collection methods are needed to portray the time-variant nature of the demands. Manually reading a customer's water meter at frequent intervals is undertaken to gather the required field data. The field investigation is carried out in the months of no obvious festive celebration, non-school holiday season and drier months of April-March (2007) to collect at least 6 days water use of random samplings. As one might expect, weekend usage patterns often differ from weekday patterns. The current investigation is carried out during weekdays (from Monday to Thursday), exclusive of weekends (Friday to Sunday) at random sampling of households according to their property types.

For this study, housing typology is chosen as sampling criteria of household water as the household water using habits and behaviors are not known. Zhang and Brown [11] reported that housing typology is one common sampling criteria for developing countries in the absence of more detailed user characteristics. It is assumed that customers in the same property category use water in a similar pattern, but in different quantities [12]. These data are later analysed to normalise the profiles.

InfoWorks WS expresses demand by using a constant baseline demand multiplied by a dimensionless demand pattern multiplier at each time increment. The water demand for each customer is calculated using the formulas:

$$\text{Water Demand } i = \text{Q base} \times \text{Mult } i \qquad \text{(Equation 1)}$$

where Q base = base demand

Mult i = dimensionless multiplier at i^{th} time step

$$\text{Mult } i = \frac{\text{Q}i}{\text{Q base}} \qquad \text{(Equation 2)}$$

where Qi = demand in i^{th} time step

The baseline demand is often chosen to be the average daily demand. The series of demand pattern multipliers models the diurnal variation in demand and can be reused at nodes with similar usage characteristics [13]. Figures 7 to 9 illustrate the investigated customer diurnal curves for the Tabuan Jaya Phase 4 residential area. Generally, three peak hours are observed among the domestic users. Water use rate in the evening is higher than the usage during the day. However, it is interesting to find out that each sub-categories exhibit different tendency of water usage during the morning, noon and evening peak hours. No reason is available to explain the observations due to the absent of detailed consumer characteristics.

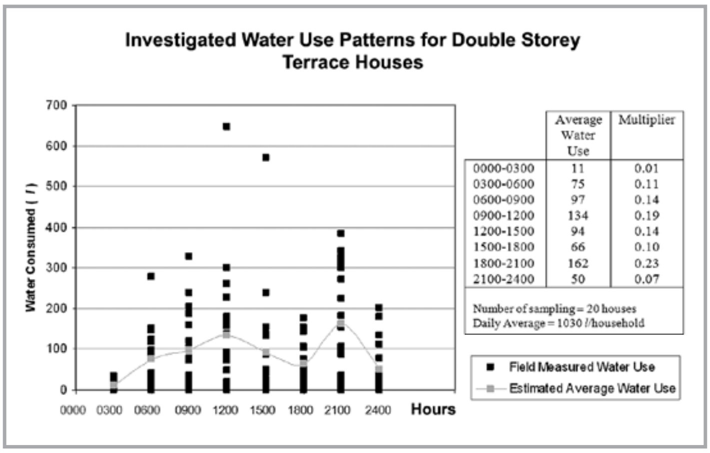

Figure 7: Water use patterns for double storey terrace houses in Tabuan Jaya

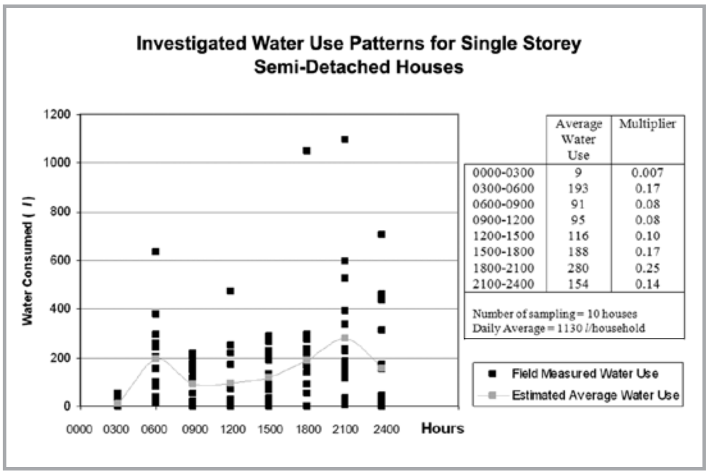

Figure 8: Water use patterns for single storey semi-detached houses in Tabuan Jaya

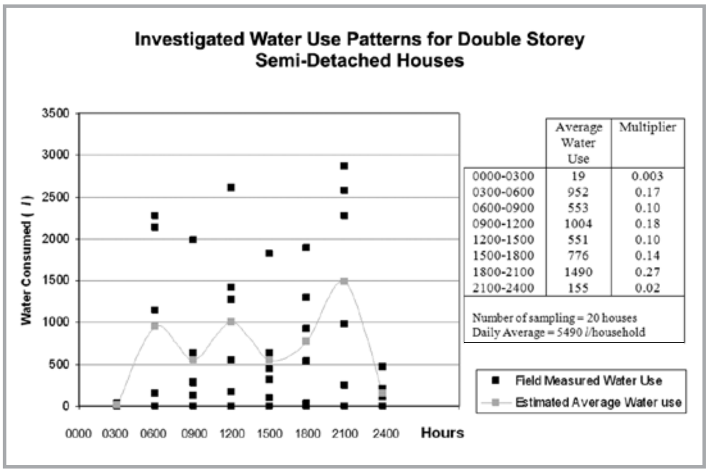

Figure 9: Water use patterns for double storey semi-detached houses in Tabuan Jaya

After consumption rates are determined, the water use is spatially distributed as demands, and stored in the ESRI ArcView model database. The wealth of spatial data generated is integrated into a common platform for water distribution systems via InfoWorks WS modeling system. This process is referred to as loading the model, where the water use data is assigned to model nodes.

6.0 INFOWORKS WATER SUPPLY (WS)

Access to geospatial database is important in supporting wise water supply management; however, water utilities planning require further information. Water distribution networks are basically hydraulic system. InfoWorks WS is one of the hydraulic solutions of an industrial standard JET (Microsoft Joint Engine Technology) Relational Database, WesNet flow simulation engine and Spatial Analysis tools, providing a single application that integrates water supply networks modeling for efficient planning and operation activities. InfoWorks WS integrates the existing ESRI packages into its own platform rather than replacing them, in which ESRI spatial attributes are used to facilitate hydraulic analysis and decision support processes related to supply region and distribution networks.

Modeling involves a series of abstractions. First, the real pipe networks in the system are represented in maps and drawings of those facilities. Then, the maps are converted to a model that represents the facilities as links and nodes. Another layer of abstraction is introduced as the behaviors of the links and nodes, the water use patterns and flows are described mathematically. The model equations are then solved, and the solutions are typically displayed on maps of the system or as tabular output. A model's value stems from the usefulness of these abstractions in facilitating efficient design of system improvements or better operation of an existing system. A flowchart of the modeling process is shown below:

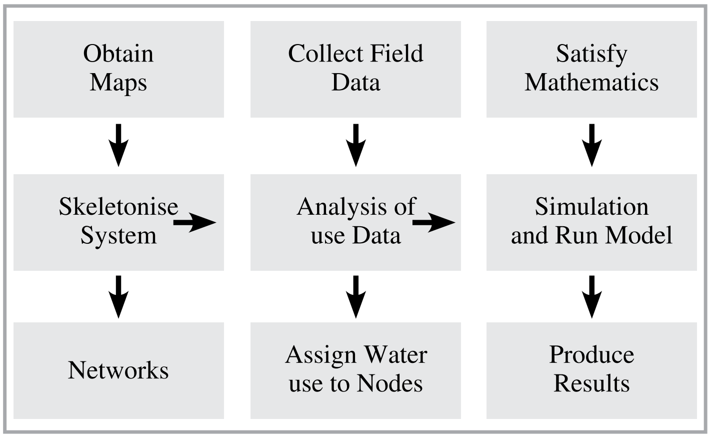

Figure 10: Flowchart of modeling process

Model-based simulation is a method for mathematically approximating the behavior of real systems. A water distribution system consists of a series of closed pipes carrying clean water, whereas the greywater system consists of closed collection pipes transporting the wastewater that the pipe material differs from the former. Both systems share the similarity hydraulically. The InfoWorks WS packages employed mathematics that covers the fluid properties, energy concepts due to frictions and most importantly the network hydraulic principles [13]. Such modeling theories are fundamental theories in engineering hydraulics and thereby not further discussed here.

The InfoWorks WS model is used to evaluate two scenario settings as in the subsequent sections.

7.0 CONVENTIONAL WATER SUPPLY SYSTEM MODELING APPROACH

This scenario is the existing settings of delivery potable water to the consumers. Therefore, well-developed methodology for the water supply network modeling is applied. The most commonly used empirical formulae for hydraulic water supply system is the Hazen- Williams formula. The Hazen-Williams formula for flow in pipes is given by

$$V = 0.849 C_H R^{0.63} S_f^{0.54} \qquad \text{(Equation 3)}$$

where the V is flow velocity (in m/s), CH is the roughness coefficient, R is the hydraulic radius (in m), and Sf is the slope of the energy grade line, defined by

$$S_f = \frac{h_f}{L} \qquad \text{(Equation 4)}$$

where h_f is the head loss due to friction over a length L of pipe.

The network data the Kuching Water Board owned is in the traditional paper record drawings and graphics-only Computer-Aided Drafting (CAD) formats. The system map of the Tabuan Jaya residential area is only available in paper map form. Therefore the pipelines and related information are digitised and stored in the ESRI ArcView environment where they are added as thematic layers to the previously sourced GIS cadastre map. The customised GIS that combine graphics and data can assist in abstracting the topology data and general network parameters such as length and depth, for InfoWorks WS model building.

Tabuan Jaya water distribution system is a combination of looped and branched system. The Tabuan Jaya Phase 4 pipelines are solely in the form of Ductile Iron (DI) (see Figure 11). The main trunk along Wan Alwi Road is 400 mm Asbestos Cement (AC). From the main trunk, the flow is then distributed locally to the users through a series of progressively smaller pipes or mains. The pipeline size that mostly used is in the diameter of 150 mm (6''). The buildings being served are connected to the mains by small pipes called service lines or connections.

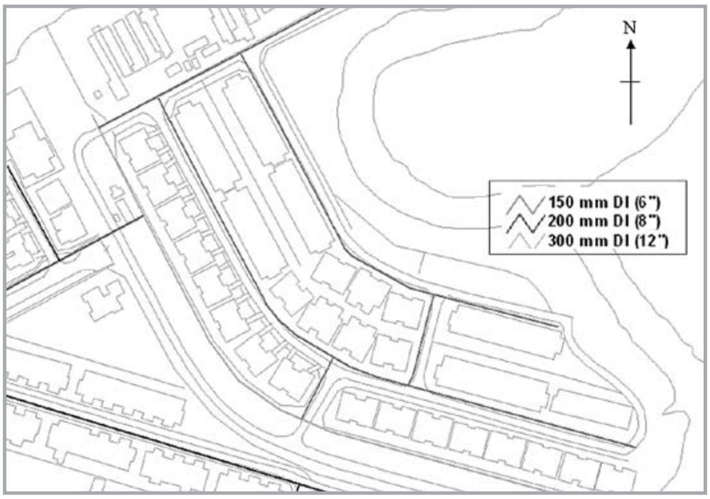

Figure 11: Pipelines network in Tabuan Jaya Phase 4

Values of C_H according to the used pipe materials are given in Table 1. These values are fed in the hydraulic model for flow computation.

Table 1: Water supply network pipe materials and roughness coefficient

Distribution Mains		Hazen-Williams Coefficient	Wave Celerity (m/s)
300 mm/ 12" 200 mm / 8" 150 mm / 6"	Ductile Iron (DI)	110 105 100	1400 1400 1400
Service Lines			
12 mm / 0.5"	Polyethylene (PE)	140	500

A network defines how the components of a water distribution system interconnected. Network data includes the traditional data mainly composed of two primary types-node and pipe data. A node represents the water system feature at specific location. Model uses link elements to describe the pipes conveying water from one node to another. Tabuan Jaya Phase 4 is intended to be modeled as a disconnected system where the trunk main is not necessary to be fully included. The Wan Alwi Road trunk main is modeled at the tapping points as water source Boundary Node to impose a requirement within the network that simulates flows entering the system.

Next is the process of selecting for inclusion in the model parts of the hydraulic network that have a significant impact on the behavior of the system. Attempting to include each individual service connection in a large system in a model could be a huge undertaking. However, the effort of capturing every feature of the small scale Tabuan Jaya system can not be spared to investigate the impact of greywater system to complete the important recycling loops in the domestic environment.

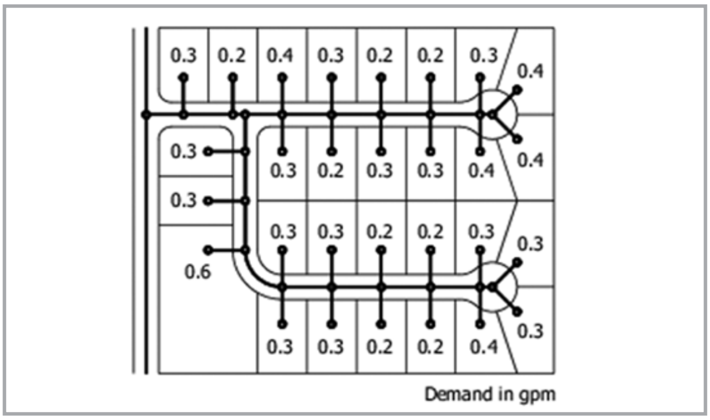

Figure 12: An all-link network

8.0 HYPOTHETICAL GREYWATER SYSTEM MODELING APPROACH

This scenario represents the hypothetical settings in additional to the conventional water supply system in which the treated effluent from the Ecosan facilities is purified, reclaimed and reused in the domestic environment. The greywater is to be transported to and forth by a series of closed pipes which share the similarity with the water supply network hydraulically. These 125 mm Polyethylene (PE) pipes are expected to be laid beside the storm water drains at the backyard of the consumer's houses. The Hazen-Williams formula is applied. They are also similarly represented as nodes and links in the hydraulic network.

Little is known about the household water use patterns. Metcalf and Eddy [14] reported that 60 – 90 % of the water consumed becomes wastewater. However, a study of the local wastewater characteristics [15] in two housing estates of Tabuan Jaya and Taman Satria Jaya reported a much lower rate. It was observed that the wastewater production is about 35 – 40 % of the water consumed, in which could be due to the internal leakage in the aging household pipes. Both Tabuan Jaya and Taman Satria Jaya have a standing history of over 20 years of establishment. Therefore, for the Ecosan modeling purposes in Tabuan Jaya, the water use patterns was presumably taken as greywater production is about 50% of water consumed, while human consumption is about 10%. The remaining 40% is assumed as the one-time uses that would be thrown away. The modeling assumptions are depicted in a schematic diagram as shown in Figure 13. These assumptions were treated as the embedded Control Data that defining the operational rules of the investigated network.

InfoWorks WS is not custom-made to model Ecosan facilities. Thereby, the elements are simplified and modified in the model. The Oil and Grease Tank and the Biofilters (combining both the vertical and horizontal) are modeled as two reservoirs, as shown in Figure 14.

The current modeling approach only matters the inflow and outflow of greywater in this system. Due to its on-site nature of Ecosan facilities, the loss of water is expected small. The water quality in the greywater system is not within the present scope. However, InfoWorks WS package supports the water quality modeling and one important event of risk modeling, where the propagation of bacteria species is possible to predict. Such information is lacking at the moment.

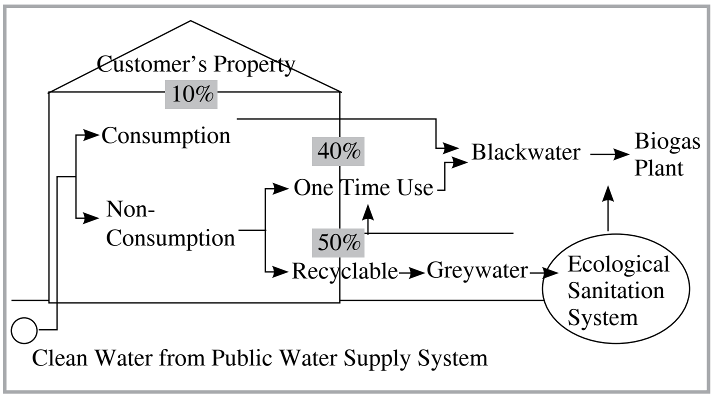

Figure 13: Schematic of single-house hypothetical integrated water supply system and ecological sanitation recycling system modeling

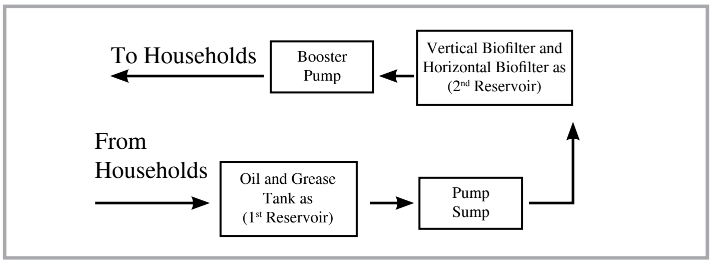

Figure 14: Schematic of the ecological sanitation elements modeling

9.0 SIMULATION ANALYSIS

The simulated water uses for the Tabuan Jaya Phase 4 are shown graphically in Figure 15 (for conventional networks) and Figure 16 (for networks with Ecosan) at one of the peak hours during noon. Lighter tone indicates a much lower water use while the darker tone indicates the opposite. Figure 15 shows an intense darker tone over the residential area. On the other side, Figure 16 shows a display a combination of light and dark tones, which imply that the water use is lowered with the inclusion of hypothetical Ecosan into the system.

The comparison of Tabuan Jaya Phase 4 isolated-system-wide water use rate (in l/s) of an average day is shown in Figures 17 (a) for conventional network and (b) for Network with Ecosan. The difference between the two graphs is significant that the peak hours at morning, noon and evening are lower during the scenario of greywater being recycled. The volume of water consumed for normal network is estimated as 0.14 M*l* per day for the system; while for recycle system, the volume of water consumed is estimated to decrease to only 0.09 M*l* per day for the system. The water saving is tremendously about 55%. Of course, such depictions are based on ideal conditions. Real time water uses are expected to be complex and difficult to predict. However, as the water use over the city has increased rapidly due to population expansion, the positive water saving prediction from the Ecosan greywater recycle system is encouraging.

The daily average water use rates for the different types of housing are predicted to reduce significantly. For the most water consuming Double Storey Semi-Detached category, the water use is predicted to drop 78%, from 5490 to 1185 *l*/household. For Double Storey Terrace category, water use is predicted to drop 23%, from 1030 to 798 *l*/household. For the Single Storey Semi-Detached category, the estimated water use drops 45%, from 1130 to 622 *l*/household.

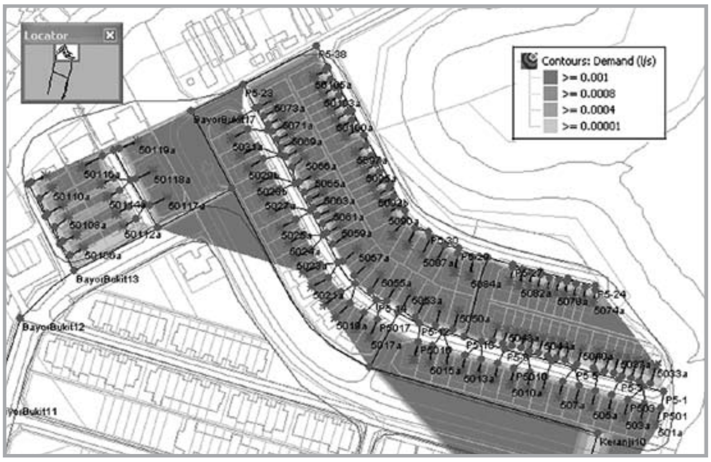

Figure 15: Conventional network at peak 1200 hour of average working day

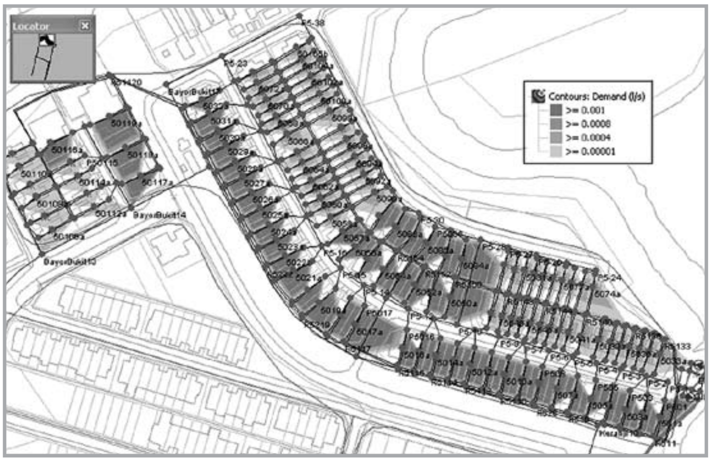

Figure 16: Network with ecological sanitation at peak 1200 hour of average working day

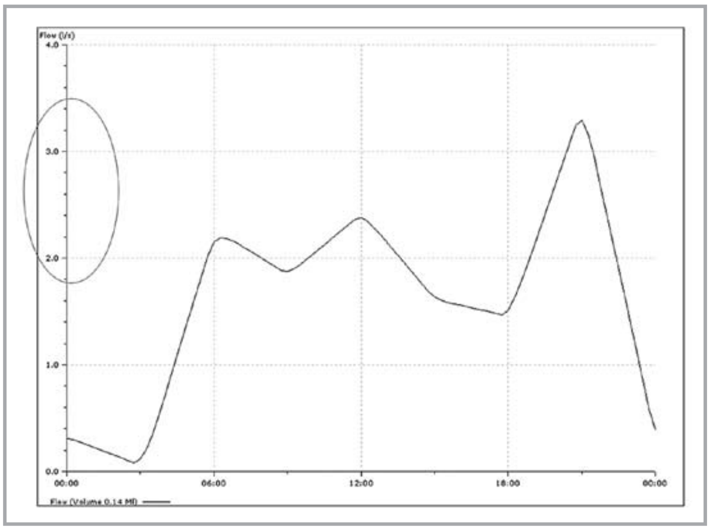

Figure 17 (a): Tabuan Jaya Phase 4 system wide conventional water use

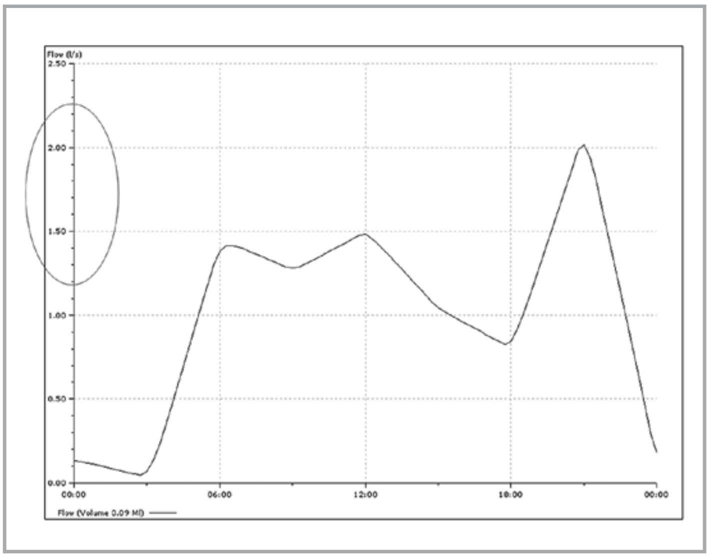

Figure 17 (b): Tabuan Jaya Phase 4 System wide water use with ecosan

The saved volumes of water can be a water source to be transferred to other systems. This has achieved the objective of water supply sustainability, indicating that the greywater recycling system is one investment worth trying in an urban environment. The investigated Ecosan system solves the wastewater problems in Kuching urban rivers to improve the river water quality, and at the same time, solves partly the water supply problems as a way to meet the water demand. The advantages of the integrated system are too great to ignore in an expanding city like Kuching city.

As mentioned earlier, storm water is directed to the Hui Sing pilot Ecosan system as well. However, the current applications of hydraulic water supply modeling to date do not have a readable capability to recognise rainfall as a water source format. Therefore, storm water is excluded in the modeling. With the intense rainfall in Kuching, with a mean monthly rainfall of about 200 to 300 mm in drier months and about 400 to 500 mm during wet seasons, the storm water appears to be a constant source. The storm water being drained to the Ecosan system, if recycled back to households, would compliment the water saving targets in addition to the recycled greywater.

10.0 CONCLUSIONS

Following the success of the first Ecosan pilot project at Taman Hui Sing, Kuching which was built in December 2003, the second Ecosan demonstration plant is launched in June 2005. This second pilot plant was aimed at assessing the feasibility of treating a combination of greywater and black water in a holiday resort, which is located approximately 20 km from the town of Sarikei, Sarawak.

Similar Ecological Sanitation approach is demonstrated in the management of oil and greases in food outlets in Bintangor River catchments, Kuching city. Another Ecological Sanitation approach was demonstrated in managing the sanitation facilities in two rural schools in Sarawak.

The existence of such facilities and its continued support financially is a dedication to commitment in ecological wastewater treatment by the State Government of Sarawak. As such, it is worth mentioning here that implementation of Ecosan will open up more opportunities for recycling and reuse of wastewater. This paper serves as an illustration of that Ecosan greywater recycling system is feasible that could be a start for further research into the field of wastewater reclamation to augment urban water supply.

ACKNOWLEDGEMENT

The authors acknowledge the financial support rendered by Universiti Malaysia Sarawak through the UNIMAS Fundamental Research Grant No. 02(75)/576/2006(09). The authors are thankful to Sarawak State Planning Unit (SPU), Sarawak ICT Unit (ICTU), Sarawak Land and Survey Department (L&S), Sarawak Natural Resources and Environmental Board (NREB), Sarawak Department of Irrigation and Drainage (DID) and Kuching Water Board (KWB) for their generous supports. ■

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PROFILES

ENGR. DARRIEN Y.S. MAH, Grad IEM
Ph.D. Candidate (Water & Environment)
Faculty of Engineering, UNIMAS
darren_maa@yahoo.co.uk.

PROF. FREDERIK JOSEP PUTUHENA
Professor of Water Resources
Faculty of Engineering, UNIMAS
fjputuhena@feng.unimas.my

PROF. SALIM BIN SAID
Professor of Water Resources
Faculty of Engineering, UNIMAS
ssalim@feng.unimas.my

ENGR. DR LAW PUONG LING, MIEM, P.Eng
Associate Professor (Environment)
Faculty of Engineering, UNIMAS
puonglaw@feng.unimas.my