Planning for sustainable urban water systems in adapting to a changing climate – a case study in Can Tho City, Vietnam

A synthesis of key findings and implications for the local context

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Executive summary

The *Climate Adaptation through Sustainable Urban Development Project* was a research initiative supported by the Research for Development Alliance (RfD Alliance) between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Agency of International Development (AusAID) of Australia. The focus of the project was to put into practice sustainable urban development principles to adapt to climate change. In this we report we summarise the case study of the project in Can Tho City, Vietnam. Specifically, the project investigated the use of Integrated Urban Water Management principles to improve the planning of urban water services as a means to enhance the resilience of the city to climate change. The project demonstrated an approach that is effective in building local capacity for communities in the Mekong Delta to adapt their water systems to a changing climate.

This report provides a summary of major findings and achievements of the project. More detailed information can be found in the project publications listed in the end of this report.

The project was undertaken over two years from October 2010 to November 2012. The project had three focus areas, which were to: understand the current context for urban water service provision in Can Tho, including the implications of future strategic plans and climate change on the sector; develop strategic adaption plans with the City; and demonstrate a range of approaches through case studies. More detail of each of these focus areas are presented in this report.

The research was underpinned by the development of strong partnerships with local organisations and departments, and also the involvement of local research partners.

Recommendations

The research team provides the following recommendations to the city, with a view to assisting the city in the development of sustainable and adaptive urban water systems.

- The urban water adaptation plans, developed in this project in collaboration with CSIRO, should be further developed to seek support from the central government or donor organisations for implementation.
- An integrated and collaborative approach should be applied to planning urban water services that considers the implications of strategies across sectors. The process can be facilitated by the assessment tools developed in this project.
- In the development of urban water services:
  - Prioritise improved sanitation: this was shown to reduce the impact of urban pollutants on water sources and improve public health outcomes. The project found that providing a combination of centralised and decentralised wastewater infrastructure is the most suitable and cost effective approach for improving access to adequate sanitation.
  - Apply the assessment framework, demonstrated in the project by Can Tho University, in the planning and design of urban water services: this considers life cycle costs, environmental impacts and institutional capacity.
  - Define more clearly the institutional arrangements for peri-urban areas of the city, where there is lack of clarity on planning and management responsibilities. Institutional capacity also needs to be developed for improved water services in these peri-urban areas.
  - Improve the maintenance of urban water infrastructure to ensure more reliable supply of water safe for drinking. There is also the need for renewal of aging and degraded water supply pipe network.
  - Encourage household behavioural changes to improve sustainability of urban water services. In particular, reduce the disposal of solid waste to urban waterways and foster more efficient water use.
  - Consider rainwater as an auxiliary fit for purpose water source in peri-urban areas outside of the areas serviced by piped water.

There is the potential to build upon the work undertaken in this project by considering the potential next steps of research for development (RfD) which would build the city's capacity toward more adaptive and sustainable development.

The RfD opportunities include:

- integrate research findings into the implementation of the current city master plan
- consider opportunities for replicating and scaling up the research that applies climate adapted water services in different community contexts
- build further capacity for local institutions in undertaking integrated assessment of urban services for achieving multiple objectives
- research into the broader system interactions in developing communities that are resilient to climate change, for example, climate-water-energy-food nexus
- design sewerage systems for the Mekong Delta to maximise resource recovery, and minimise energy demand and greenhouse gas emissions.

Synthesis

The *Climate Adaptation through Sustainable Urban Development Project* investigated the use of Integrated Urban Water Management principles to increase the resilience of the urban water sector to climate change. The study used Can Tho City, Vietnam as its case study, to provide important insights into challenges and approaches for how the city can continue to grow in a sustainable manner. The study has demonstrated an approach that can build local capacity for communities in the Mekong Delta to adapt their urban water systems to climate change impacts.

Throughout this study, local stakeholders were actively involved through a sequence of workshops and meetings, which ensured that the solutions were relevant to Can Tho City. The framework of the project can be used in other locations, where the engagement with the local stakeholders would provide solutions for these other locations.

The initial phase of the study focused on understanding the local context and engagement with the local stakeholders. A water needs assessment workshop was the first step in the project (Moglia et al. 2010) which defined key issues relevant to the Can Tho City urban water system. Key issues were categorised as follows: aquatic ecosystems, infrastructure condition, groundwater systems, access to services, water quality and flooding. The definition of these thematic areas during the workshop created a shared language to explore urban water issues with stakeholders and in the study team, and helped to focus the research on critical local issues.

The workshop themes also formed the basis for a sector review that sought to understand the institutional context, identify data sources and data gaps, and crystallize the critical dilemmas facing the city (Neumann et al. 2011). Based on the data gaps identified, two sets of surveys were conducted to further understand the local context. The first survey comprised a 1,200 household survey related to issues of water access, water quality, groundwater issues and flooding issues (Neumann et al. 2013), while the second survey used qualitative interviews focused on poorer households (Carrard et al. 2012). Using data supplied from stakeholders and the survey results, a Water Needs Index was applied to the city, which identified the diverse needs to be addressed in improving water services across the city (Moglia et al. 2012a).

These initial activities provided a picture of the urban water system in Can Tho City. The Water Needs Index showed that the urban water sector was highly fragmented, as some areas had access to improved water services and sanitation while other areas lacked any form of basic access to improved water services. Moreover, infrastructure condition and water quality were also highly variable across the city. Furthermore piped water access was often problematic due to issues of intermittent supply, poor pressure, and relatively poor water quality, which meant that the water supply could not always be considered safe. Those households who use community groundwater systems for their water supply had a significantly lower rate of reported illness. However, groundwater resources in some areas showed signs of pollution and/or a declining water table. Further groundwater investigations are needed to assess sustainable extraction rates and groundwater quality before community groundwater systems can be scaled up. Improved treatment techniques and management practice are also needed, as the perception of survey participants was that the supplied water from the community groundwater systems is often turbid and coloured.

It was found that many households draw from multiple sources and tend to match water source to intended use. Decisions on the choice of water source are influenced by what is available, what is affordable, and the observed or perceived quality of different sources. However, the survey showed that the use of multiple sources of water leads to higher reported rates of illness. The reported rates of illness were also higher when households stated that their water source was of poor quality or that their household lacked adequate sanitation.

The interviews with poorer households revealed that they are acutely vulnerable to climate change impacts. Many of those interviewed had experienced flooding in their house on a regular basis, supplemented their diet with locally caught fish (from river or paddy fields), and tended to struggle to pay their water bill and thus relied on surface water for household use. This means that water service options and scenarios have specific impacts for poorer households, and these should be considered in urban water planning.

A key dilemma for the city is that there is extensive pollution of waterways because of a lack of wastewater treatment, and because of endemically poor or missing solid waste management. Pollution of waterways seems to be exacerbated in conditions where flow is restricted, or in dry seasons which have been observed to become longer in recent years.

After the critical dilemmas and challenges facing the city had been identified, the next step was to identify strategies that could be used to address the problems. A set of strategic adaptation options was identified in a stakeholder workshop. The stakeholders discussed strategies that were subsequently refined based on the desired and unintended impacts, implementation pathways and project risks associated with the identified strategies.

The strategies identified for the improvement of the urban water sector ranged from household measures to large-scale infrastructure projects. At the household scale, options included the use of rainwater tanks in peri-urban areas (although this was limited by rainfall seasonality) and the promotion of behavioural change to reduce solid waste disposal into surface waters and reduce the use of hanging toilets or other ad hoc toilet facilities. In terms of municipal infrastructure, options included the upgrading of the water supply pipe network to improve supplied water quality; the linking of water treatment plants in different districts to improve reliability; and the installation of decentralised wastewater treatment systems for residential and/or industry clusters.

In analysing the identified strategies, cause and effect diagrams were developed to identify the desired impacts and the factors contributing to the likelihood of achieving these impacts. This process challenged pre-conceived notions amongst the stakeholders and allowed them to think about the implementation pathways for different options. The same process also highlighted those individuals and organisations that have important roles and responsibilities in any potential implementation. For example, solid waste management cannot be introduced without considering affordability of collection services, awareness, household habits, and a process for treating the waste, etc. The linkage of water treatment plants in different districts to improve reliability was found to have a very low likelihood of achieving desired goals; even in best case scenarios. Furthermore, we can analyse at a small scale (ward level) what combinations of strategies can be used to address the particular local dilemmas of that ward.

The workshops set the project context and identified possible solutions to urban water issues. Analysis of the strategies highlighted a lack of systems thinking amongst planners and local stakeholders; and this means that important opportunities for improved urban water management may be missed. Furthermore, solutions are often a result of a narrow focus in singular issues, short term goals or without consideration of what is required in order to ensure successful implementation 'from cradle to grave'. Given the problems with infrastructure planning, a demonstration case study was undertaken to explore sustainable options for water and sanitation services in a peri-urban case study area.

A conceptual design and planning exercise was used to assess the sustainability of different water supply and wastewater servicing options, ranging in management scale from household to City departments. The purpose was to build the local capacity to identify suitable options for water and wastewater servicing in peri-urban areas that consider cost effective solutions, environmental impacts, service levels, community expectations and suitable institutional arrangements to manage and maintain the system. During the final workshop, participants were presented with the water servicing options and their performance in terms of life cycle costs, BOD loads and greenhouse emissions to inform the selection of a preferred option. However, stakeholders were also challenged to consider the implementation of strategies. As a result stakeholders chose an option that was a compromise between cost, environmental outcomes and likelihood of successful implementation given institutional capacity.

Furthermore, the project included a demonstration of rainwater harvesting to evaluate likely rainwater quality and the use of rainfall to augment water supply. It found that whilst rainwater can provide a good source of water during parts of the year, reliability of supply during the drier times of the year would be limited.

In summary, the project demonstrated that the water supply system in Can Tho City is highly fragmented, and that a 'one size fits all' solution may not be adequate to address all the issues. It was apparent from the survey and sector review that different areas of Can Tho City need different approaches for the provision of water supply infrastructure, which will improve access to safe and adequate water supply services across the community. Other locations, not only in Vietnam but in several developing countries, are likely to face the same fragmentation problem with the management of urban water services, although the issues will be specific to the location. However, the framework developed as part of this project can be easily applied to other locations, provided two important considerations of this project are met.

First, there is a need for strong engagement with local stakeholders, through workshops, meetings and interviews. This ensures that local stakeholders have a buy-in in to the project and solutions, and also ensure that the developed solutions are suitable and acceptable. This project developed strong collaborative partnership between research partners (CSIRO, UTS, and CTU) and the key relevant stakeholders in Can Tho, in particular the Climate Change Coordination Office (CCCO), the Water Supply and Sewerage Company (WSSC), the Department of Agriculture and Rural Development (DARD) through its Centre of Rural Clean Water and Environmental Sanitation, and the Department of Natural Resources and Environment (DONRE).

Second, there is a need for capacity building in the local institutions. This is necessary to allow them not only to participate in the discussion, but also to maintain any systems that are implemented as part of the project. Local capacity building also helps improves institutional capacity for planning and maintaining the urban water systems. This project had a strong focus on capacity building, which included hands-on training of staff from the College of Environment and Natural Resources of Can Tho University, both in Australia and in Vietnam. Also a training workshop was conducted for 30 staff from local stakeholders on the outcomes of the project; and items were developed (Map Book, publications, report, models and data sets) that can be usefully applied in urban planning.

The outputs of this project revealed how the city can improve urban water management, which will increase resilience to climate change impacts and assist in managing the effects of urban growth. A number of adaptation strategies identified for Can Tho could be implemented; the strategy to install rainwater for peri-urban households has been explored in more detail with on-site demonstration. In some cases, further exploration is needed before strategies can be confidently implemented; and in other cases, implementation would require funding and further training.

Can Tho City stakeholders have provided consistent support to the project since its inception in October 2010. Over the course of the project, a large number of city's department and agencies, with a growing level of interest and enthusiasm, have contributed to the project significantly through actively participating workshops and interviews; as well as providing data, information and valuable advice. In September 2012, the project outputs were presented to the city in the Summary Workshop where, through a survey, a high proportion of the participants gave strong recognition of all project outputs as useful for the city's adaptation action plan. Currently, the relevant agencies (CCCO, WSSC, DARD, and DONRE) are considering the inclusion of the project outputs into their action plans as well as realising the benefits from the system thinking and the integration approach that has been introduced by the project. The local research partner - the College of Environment and Natural Resources of Can Tho University, has actively built a new RfD capacity, and as such have started to use the new knowledge learnt from the project in training local stakeholders, and teaching students – the next generation of the city and the region.

It is highly likely that several of the identified adaptation strategies can be widely implemented across Vietnam and in the region, but care must be taken to ensure they are suitable to local conditions and that institutional arrangements are met: this can be done through assessments and pilot studies such as those developed in this project.

The Climate Adaptation through Sustainable Urban Development Project

The Climate Adaptation through Sustainable Urban Development Project was a research initiative supported by the RfD Alliance of CSIRO and AusAID that focussed on how to bring sustainable urban development principles into practice, as an effective means of adapting to climate change. The project investigated the use of Integrated Urban Water Management principles to improve the planning of urban water services, through which to enhance the resilience to climate change of Can Tho City, Vietnam.

Background

Can Tho City is the main regional urban centre in the Mekong Delta, Vietnam, with a population of around 1.2 million people. Can Tho is undergoing rapid urbanisation: currently 60 percent of the population lives in urban areas, and by 2030 this is projected to be 70 percent with a projected population of 1.7 million. The economy of the city is still currently based on agriculture and aquaculture, but there is also a rapid transition towards a regional service centre and an industrial city. The whole region is characterised by flat terrain with a dense waterway network, which is essential to people's livelihoods. Water is central to everyday life and underpins the local economy, including agriculture, aquaculture, transport, and tourism (Neumann et al. 2011).

The city has nine districts (Figure 1), including five urban districts (Ninh Kieu, Bith Thuy, O Mon, Cai Rang, and Thot Not), and four rural districts (Vinh Thanh, Thoi Lai, Phong Dien, and Co Do). One of the features of Can Tho City is that the landscape of the city includes a combination of different land uses, i.e. old urban, new urban, peri-urban, and rural areas (Figure 2). Such a mix of landcapes exists even within the most urbanised district of Ninh Kieu. Water service provision greatly varies among these areas: ranging from reticulated water supply and sanitation services in the urban areas to no services for many rural areas.

The sustainability of the water systems in Can Tho City, including both the physical systems of water service provisions and the water environment, is under pressure (Neumann et al. 2011). This is due to challenges such as rapid urbanisation and industrialisation and also from the likely impacts of climate change. Such impacts include salinity intrusion and pollution of the waterway network. Currently the main issue is inadequate physical infrastructure resulting in limited access to clean water and sanitation, frequent flash floods in urban areas, and increasing pollution in waterways.

To deal with such a complex system of water and sanitation services and environment, the research team used the integrated urban water management (IUWM) principles (Maheepala et al. 2010). This provides state of the art integrated assessment methodologies and participatory processes for engagement with stakeholders to assist the strategic planning and development of urban water systems that are sustainable for the specific conditions of Can Tho City. The aim of IUWM is to plan, design and manage the overall water cycle – the management of water supply, stormwater and wastewater – in a coordinated manner. This helps to minimise the impact on the natural environment, maximise the city's contribution to economic development, and engender overall community well being and improvement. The use of IUWM allows the development of realistic, effective and feasible strategies for improving water management, water supply and sanitation for households and industry. This should form a key element of the city's climate adaptation strategy as well as provide a pathway to achieve sustainable urban growth. It will also enhance the capacity of the local communities to adapt to many future challenges, including climate change.

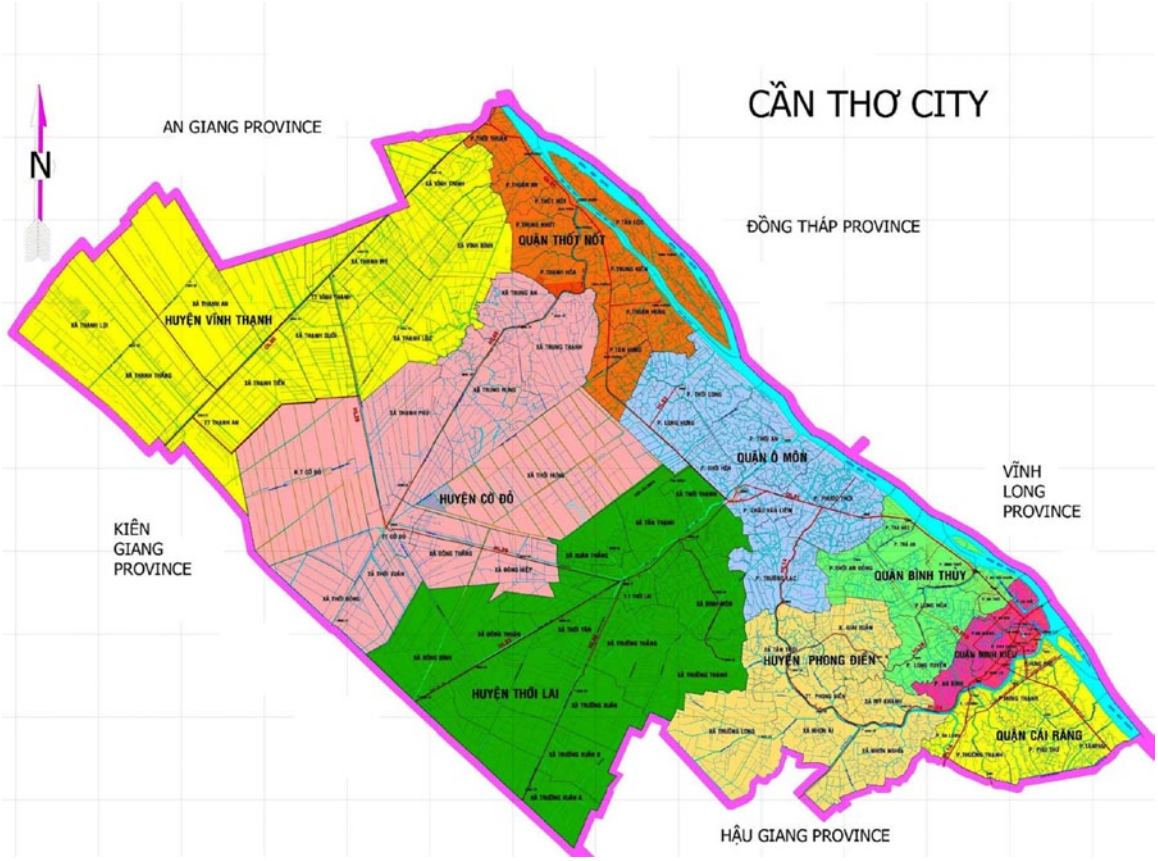


Figure 1. Can Tho City administrative map (Can Tho DONRE, 2008)

Figure 2. Can Tho City's landscapes

Project Focus Areas

The project has three focus areas, as depicted in Figure 3:

1. **Understanding** – Together with local stakeholders, we developed a detailed understanding of the local urban water context, the likely influence of planned future urban development, and the regional climate change impacts on local water resources and the environment. This involved workshops, literature and data reviews as well as extensive householder surveys.
2. **Strategic Planning** – We established a portfolio of effective, feasible and action-supported strategic options for adaptive and sustainable urban water management in Can Tho City. The strategies were supported with science-based outcomes from integrated system assessments of the effectiveness and feasibility of the options. This involved engaging stakeholders through workshops with key stakeholders, institutional and scenario analysis, risk and multi-criteria assessments.
3. **Demonstration** – We conducted trial and pilot testing in the local context for key options which were identified as no-regret adaptation measures. The options selected for demonstration were rainwater harvesting systems, and the design of water service provision in peri-urban areas. The main purposes of these demonstrations were to: provide a local example as an evidence-based practice of IUWM; and to develop the Research for Development (RfD) capacity for in-country stakeholders to be able to assess and implement solutions for providing adaptive and sustainable water services that are appropriate to the opportunities, challenges and limitations of the region.

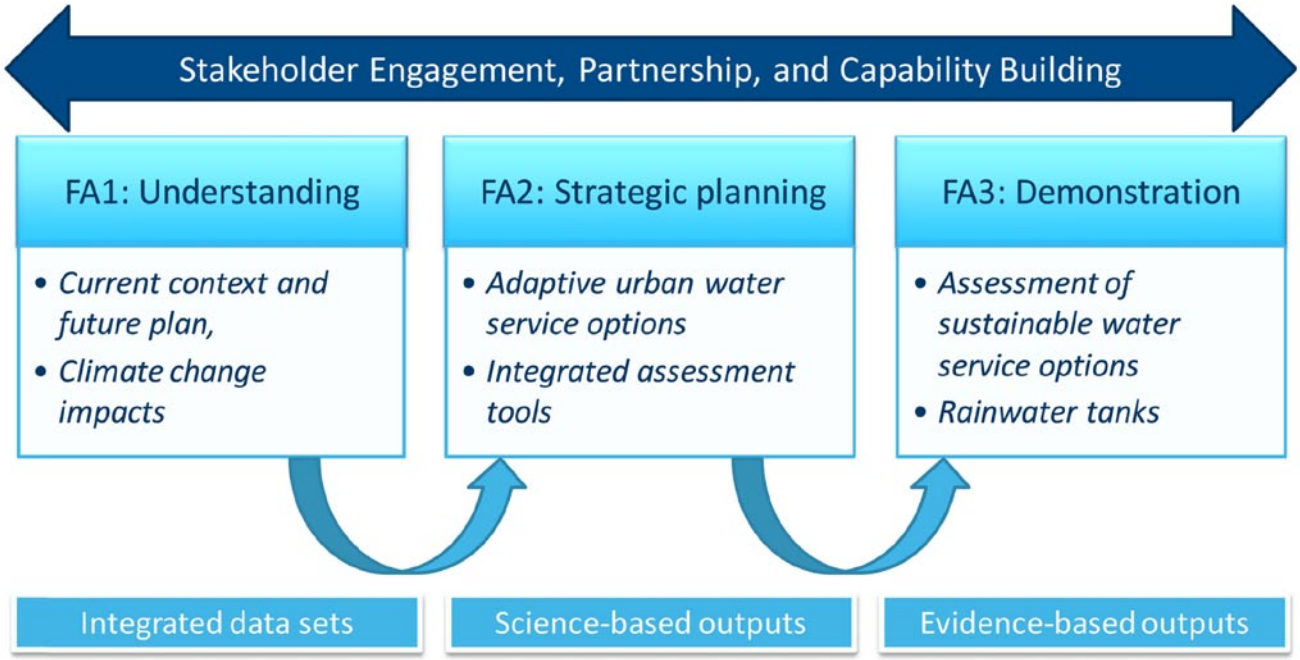


Figure 3. The Focus Areas (FAs) of the project

The three focus areas aimed to provide the city with evidenced-based options for future development of urban water systems. They also provided the city with integrated data sets for use in planning for improved urban water services in Can Tho, and for informing future research.

Engaging and developing partnerships with key water and urban stakeholders in the city underpinned activities across all three focus areas. This engagement was an important component of building the capacity for research and development by local research partners and stakeholders. A participatory approach with workshops and interviews was used throughout the study to ensure local knowledge was incorporated in the research and that key stakeholder organisations had a sense of ownership of project outcomes.

Figure 4 presents the components of the three focus areas, which will be described in the following chapters.

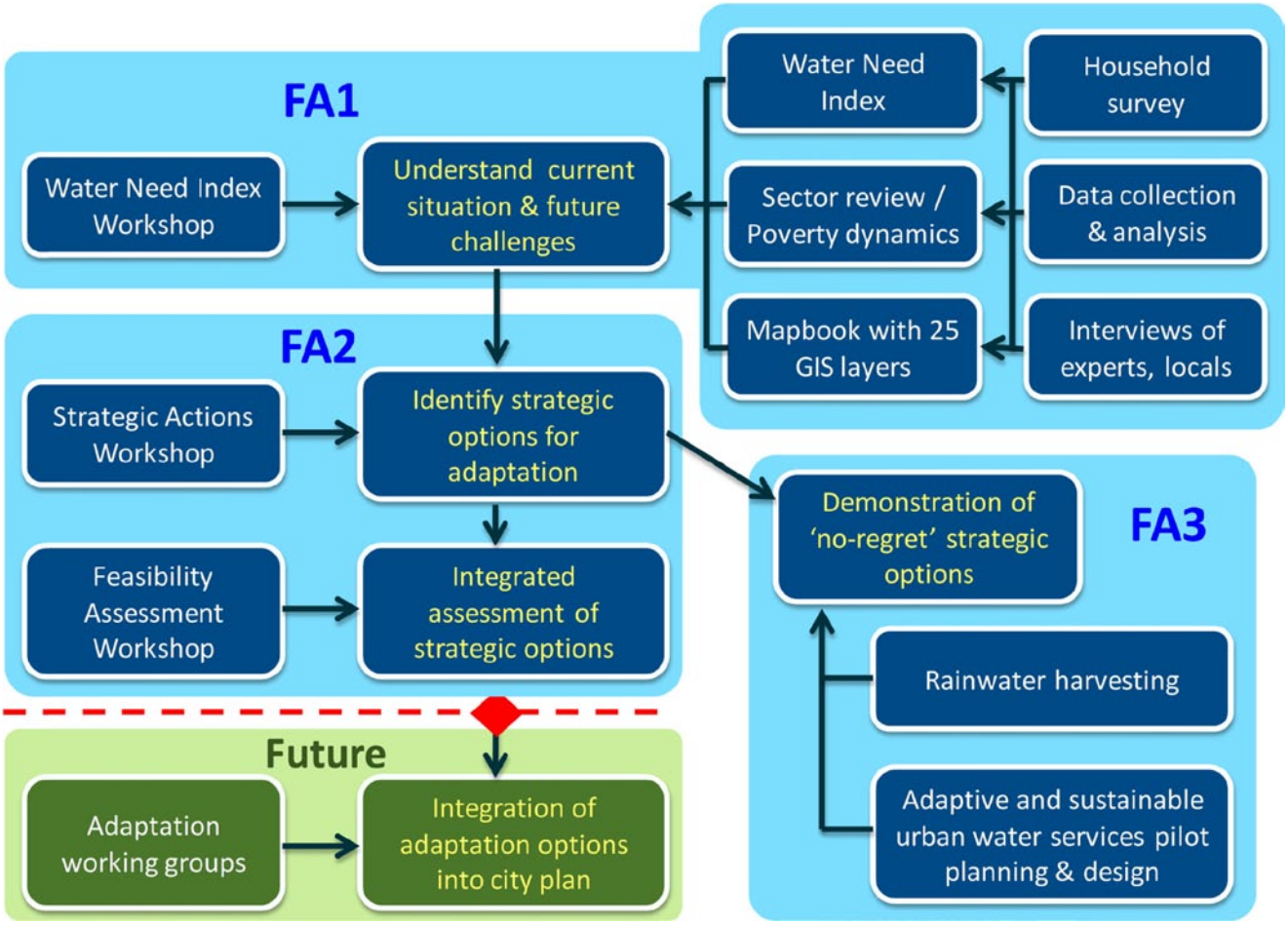


Figure 4. Components of the Focus Areas and their relations

Achievements

Over the two years from October 2010 to November 2012, the project has:

- Developed a detailed understanding with a tool for spatial representation of the local context and issues. The knowledge and the tool developed have been used to assist the city's stakeholders and the research team to co-develop strategic actions to improve the city's water services. This will also assist the local water management to identify critical urban water challenges and target segments of the community most vulnerable to the impacts of climate change for actions. The research team completed the following.
  - An extensive survey of households on issues of urban water services and climate change: this provided a good understanding of the interplay between level of access to water services and socio-economic data across Can Tho City. Analysis of the survey revealed that households on the peri-urban fringe have the poorest access to adequate water supply and sanitation, leading to adverse impacts in terms of health outcomes and economic opportunities.
  - An extensive sector review of the urban water system in Can Tho and related environmental management challenges. This review helped understand the institutional context, identify available data sources, and assess the Water Needs across the urban landscape.
  - An analysis of the poverty dimensions of water and sanitation, and climate vulnerability for Can Tho City. This highlighted that poor households, which have to actively manage their water systems, are particularly vulnerable to the likely impacts of climate change.
- Co-developed with stakeholders a set of strategic adaptation options for the sustainable development of the city's water system, and analysed the desired and unintended impacts, implementation pathways and project risks associated with the developed strategies. This set of strategic options will assist the city in planning and investment decisions to improve the city's water services, environment, and people livelihood.
- Undertook two demonstrations to undertake detailed assessment of adaptation options, through with providing hands-on training to local research partners to be able to assess and implement sustainable water services that are appropriate to the local context. The demonstrations include the following.
  - Rainwater harvesting systems that provided an understanding of rainwater quality and trialled cost effective options for improving quality of water harvested from roofs. It implemented pilot rainwater systems at the household scale, and for a university building. Rainwater tanks would be a suitable adaptation option to augment water supply in Vietnam where pollution, drought and salinity intrusion are critical issues for local water resources.
  - Sustainable planning and design options for water and sanitation service in a peri-urban pilot area, considering life cycle costs, environmental impacts and institutional capacity. This provides the city with a very practical tool for sustainable development of its water services.
- Developed and/or improved the local capacity for climate adaptation in the urban water sector through developing a:
  - Map Book that includes 25 GIS-based maps depicting current issues and challenges in the urban water systems and environment of the city
  - new RfD capacity for the local research partners and stakeholders on integrated urban water system engineering and management
  - strong collaborative partnership between research partners (CSIRO, UTS, and CTU) and the key relevant stakeholders in Can Tho, in particular the Climate Change Coordination Office (CCCO), the Water Supply and Sewerage Company (WSSC), the Department of Agriculture and Rural Development (DARD) through its Centre of Rural Clean Water and Environmental Sanitation (CERWASS), and the Department of Natural Resources and Environment (DONRE).

Focus Area 1: Understanding current context water service provision, future plan, and climate change impacts

Research in Focus Area 1 (FA1) contributed to a detailed understanding of context and challenges for water services and environment of Can Tho City, as well as an understanding of stakeholders' objectives and priorities.

Figure 4 depicts the main components included in the FA1. The information developed was essential to inform the analysis of water management strategies conducted in the Focus Areas 2 and 3.

Problem definition for the city's water system

The Water Needs Index Workshop was the first project workshop and was held in October 2010 (Figure 5). The workshop provided the foundation for the project for subsequent activities by:

1. creating a frame of reference, i.e. defining the dimensions of the city's water system, and using these as the common language among stakeholders to facilitate effective communication

BOX 1

Focus Area 1 (FA1) started with the Water Needs Index Workshop to enable the project to develop a detailed understanding of the city's water systems including: the physical water service systems, the socio-economic context, and the environment, and the possible climate change impacts.

Detailed knowledge of the city's water system was obtained through various activities including:

- a top-down approach via a workshop, data collection from stakeholders, and a comprehensive water sector review
- a bottom-up approach through extensive household surveys and interviews with local people and experts.

FA1 has produced the following outputs.

- An introduction of systems thinking, which encouraged local stakeholders to depart from traditional 'silo' management to a more integrated thinking and collaborative approach.
- Large integrated data sets on various aspects of the city's water systems, which have been utilised by the local stakeholders for management and further research and development.
- Results from an extensive 1,200-household survey, which assisted the city to explore strategic actions to improve water services to appropriately target segments of the community most vulnerable to the impacts of climate change.
- A Water Needs Assessment: a quick assessment, which provided a spatial representation of issues in each ward of the city, assisting local water management to identify and target the most vulnerable areas for actions.
- A Map Book of 25 GIS maps on current issues and challenges to the city's water systems, which is an effective tool for communication and data sharing between local institutions and international agencies.
- An analysis of poverty dimensions of water, sanitation and climate vulnerability in Can Tho City.

2. providing an initial qualitative description of the Can Tho water system, identifying key data and information sets available, and the owners of the data
3. providing active engagement with stakeholders and enabling critical dialogue that supported discussion on the planning and design of alternatives for integrated urban water management and the future scenarios.

A key concern for the city's water sector is the impacts of climate change and rapid urbanisation. Workshop participants explored the impacts of these drivers of change on the city's water issues according to six different dimensions which are referred as the Water Risk Index (WRI) or Water Needs Index (WNI). The six dimensions and their explorations are:

(A) Aquatic Ecosystems – pollution of local waterways, changes in flow conditions due to the effects of upstream countries' development (hydropower dams, deforestation etc)

(F) Flooding – changes in frequency and intensity in different land use areas, and the influencing factors (tidal, rainfall, and lack of infrastructure etc), as well as the consequences of flooding (river bank erosion, damage to housing and impacts on public health)

(G) Groundwater – the use of monitoring data that indicated receding groundwater levels due to over-exploitation, and concerns about groundwater quality

(I) Infrastructure – a range of operational problems (leakage, low pressure, blockages, energy inefficiency), difficult demand-supply balance, the inadequacy of treatment plan capacity, and the problem of illegal connections

(W) Water and Sanitation Access – socio-economic factors that influences access to adequate services

(Q) Water Quality – current issues of inadequate sanitation, excessive uses of fertilisers and pesticides, pollution due to industry, as well as disparities between urban and rural populations.

Participants defined the thematic areas through facilitated discussion, providing definition of concepts and a common language. Whilst there was consensus that all themes are inter-connected, the theme of *water quality* was perceived to be the most important dimension, and *groundwater systems* the least important.

Figure 6 presents the city's 'hot spots' of water issues identified by the local stakeholders in terms of the six dimensions (Figure 7). It identified that there are some particular areas of concern:

- peri-urban areas with high population densities had significant concerns related to inadequate water and sanitation access and insufficient infrastructure
- industrial zones near the river had problems related to groundwater, flooding, lack of infrastructure, inadequate water and sanitation access, and poor water quality
- highly urbanised areas had a combination of problems related to water quality, inadequacy of infrastructure, and intense pollution impacting on aquatic ecosystems.

Figure 5. WNI Workshop (October 2010)

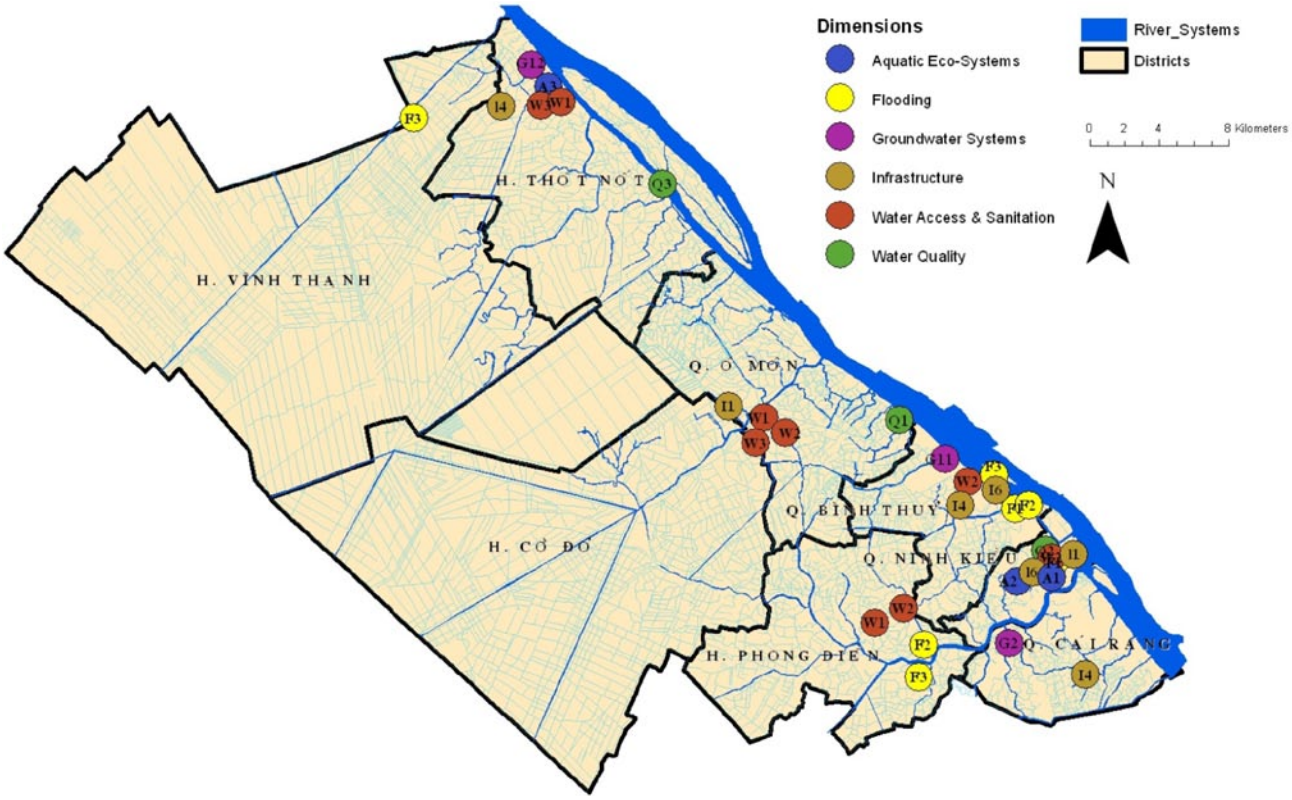
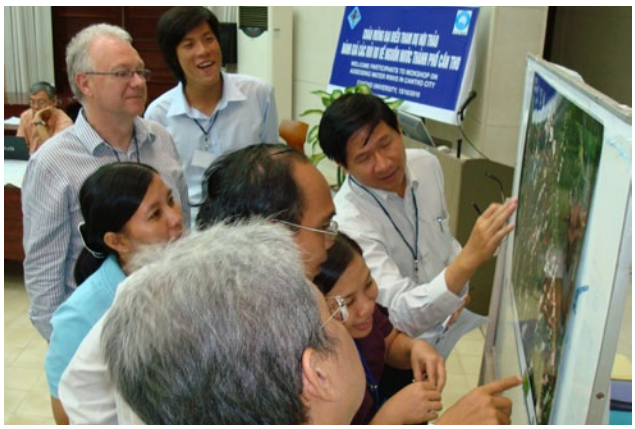


Figure 6. Geographically referenced issues for WRI dimensions

(Note: This is a reproduction of where participants noted locations for demonstration and illustration purposes, and hence may be considered an approximation in terms of location)

The deliberation process introduced to the city's stakeholders, for the first time, a systems thinking approach via the consideration of the six Water Need Index dimensions and their interactions. This encouraged local stakeholders to move to a more integrated approach and away from the traditional 'silo' management view where elements of the urban water systems are considered and managed in isolation to other elements. The process helped to highlight the benefits of improved collaboration and communication between sectors, department and organisations.

More details of this Workshop were presented in Moglia et al. 2010. The workshop initiated an extensive literature search and data collection effort led by the in-country research partner - the College of Natural Resources and Environment of Can Tho University. It was followed by a detailed sector review of the Can Tho City's water systems conducted by the CSIRO team. The review was presented in a report by Neumann et al. (2011).



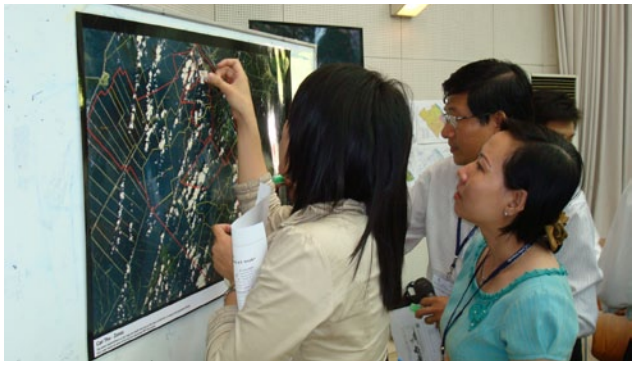


Figure 7. Identifying hot-spots of water issues

Household Survey

The research team conducted a survey of 1,200 households in different areas. The survey aimed to understand the concerns and issues related to household access to water and sanitation services, rapid urbanization and perceptions of the potential future impacts of climate change. This is the largest and the most comprehensive survey ever conducted in Can Tho City on water issues.

The 1,200 households surveyed were selected from a subset of urban wards in Can Tho. The wards surveyed were chosen through discussions with local experts on the basis of obtaining a reasonable representation of old urban (well established urban areas), new urban (newly built urban areas), and peri-urban wards. Rural areas were not included in this survey, as it was focused on urbanization and water supply issues. The survey consists of 48 questions for six categories.

1. Baseline information on socio-economics
2. Access to water and sanitation
3. Water quality perceptions and health impacts
4. Cost and ability to pay for water services
5. Levels of service and willingness to pay
6. Climate change impacts and adaptation.

The surveyed wards were then grouped according to their access to piped water supply:

- ***(P) Piped*** wards were located in urban areas where most households had access to water supplied by the Water Supply and Sewerage Company (WSSC)
- ***(M) Mixed*** wards where some households had access to WSSC piped water, but source significant proportion of households had no access to WSSC
- ***(NP) No Pipe*** wards where households had no access to piped water supply from WSSC.

The grouping of the wards was used to structure the analysis of survey results to understand the characteristics of households with and without adequate water access, and the impact on health outcomes and their perceptions of pertinent water supply and sanitation issues.

The results of this extensive survey, as well as other data, have been used to create a spatial representation of the city's water issues via the use of a Water Needs Index (Moglia et al. 2012a). The Water Needs Index can be used by the relevant water authorities of the city in establishing strategic actions to improve water services that appropriately target segments of the community in need and/or most vulnerable to the impacts of climate change. The results of this survey is reported in Neumann et al. 2012.

Some key results

Households surveyed in Can Tho differed significantly in terms of income, education, house ownership and types of dwelling. Households in wards that relied on Piped water had significantly higher incomes than households surveyed in Mixed or No Pipe wards. In Piped wards 45 percent of households earned more than 4 million VND (about 200 AUD) per month, with the figure dropping to 22 percent and 19 percent for households in the Mixed and No Pipe wards respectively. The higher socio-economic status of households in Piped wards was also reflected in level of education completed, with nearly 50 percent of households having someone who had completed senior secondary school or higher, while in Mixed and No Pipe wards only 25 percent of households had senior secondary school or higher completion rates. While most households have access to flush toilets, a significant proportion of household in the Mixed (23 percent) and No Pipe (34 percent) groups reported inadequate sanitation facilities such as hanging toilets or open defecation.

The degrees of urbanization and socio-economic differences between the groups clearly influence the water sources used within households, as shown in Figure 9. In the highly urbanized, higher socio-economic status wards (Piped group) the main water source for all uses is piped water, while a more diverse set of water sources is used by the other two groups of households (Figure 8).

For the Piped group 75 percent of respondents classified their source(s) of drinking water as fine, however only 43 percent for the Mixed group and 38 per cent for the No Pipe group classify their water as fine. Rainwater seems to be consistently ranked as a reliable and fine source of water quality, while surface water appeared

Figure 8. Multiple sources of water use

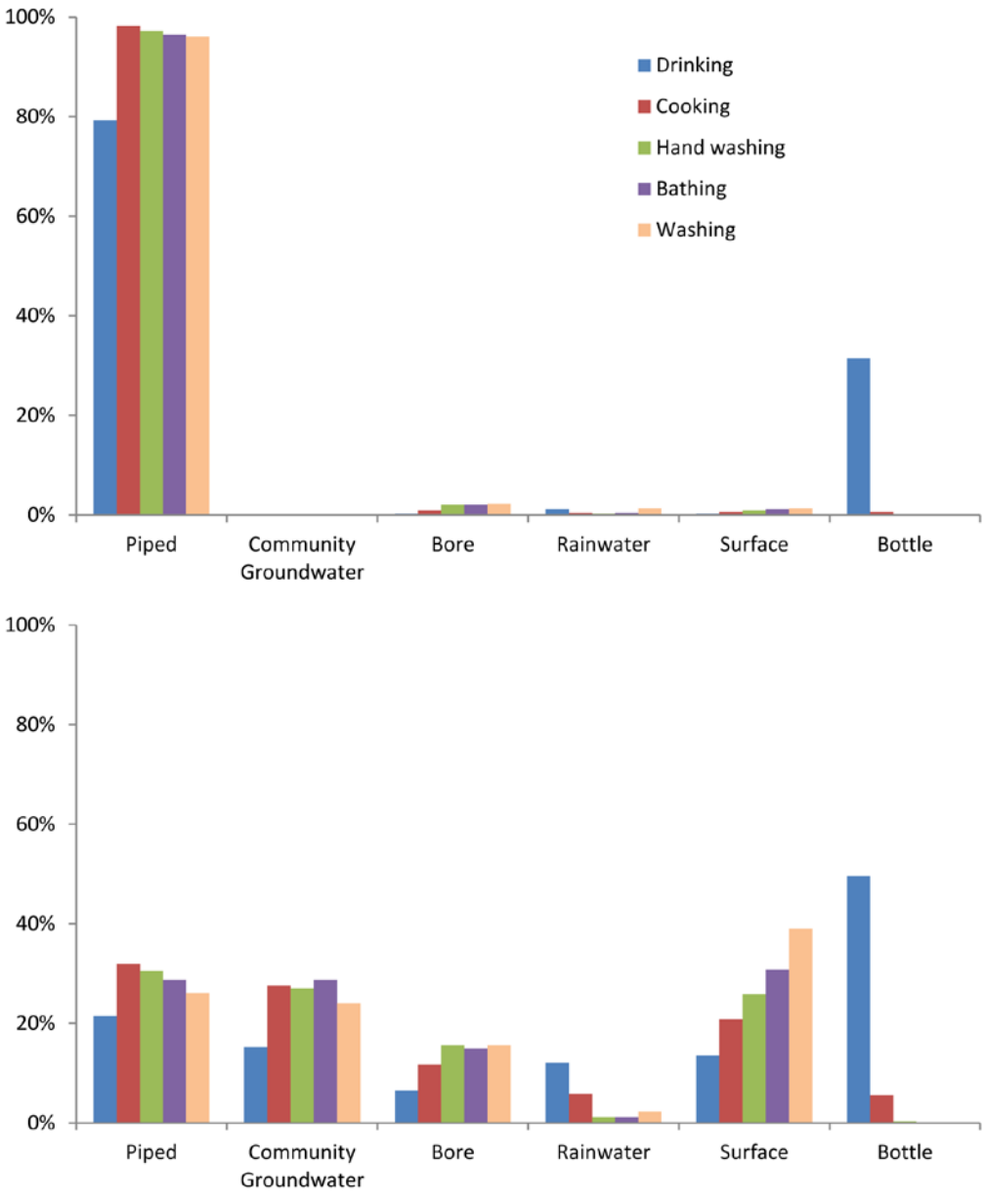


Figure 9. Proportion of Piped (top) and Mixed (bottom) households using different water sources for different end uses

the most problematic in terms of quality and reliability. In all groups, the majority of households treat their water prior to drinking, as shown in Figure 10. For the Piped group, treatment mainly consists of disinfection, while for the Mixed and No Pipe groups (which report poorer quality) households also perform sediment removal.

In total, 97 households (8.1 percent) reported that a household member had suffered from an upset stomach (nausea, vomiting, cramps and/or diarrhoea) over the last six months, which is similar to an estimated value of 8.4 percent per person from the World Bank in 2008 (see Neumann et al. 2012). (However, it should be noted that the survey asked about illnesses for any member of the household, while national figures are illness reported per person.) Examination of the data at the ward level (sub-district) indicated that the established urban ward of Chau Van Liem in O Mon district (Piped group) had the highest proportion of reported illness (38 percent). The infrastructure in this ward was considered old and limited, and had been identified by local stakeholders as having a serious lack of clean water access and sanitation infrastructure (Moglia, 2010) and it may be one of the factors in the illness rates.

The rates of reported illness were evaluated for trends relating to seven factors including: income; type of septic system used; solid waste collection method; water treatment strategy; toilet type; source of drinking water; and perceptions of water quality. The factors that were found to have statistically significant trends relating to the Rate of Reported Illness were source of drinking water, toilet type and water quality. Importantly,

- in all groups, households that use more than one water source (unless they use piped water and bottle water only) have a *higher* incidence on illness
- there are *higher* rates of illness in households in the Piped group which have poor self-reported quality of drinking water or poor sanitation practices such as open-defecation or use of hanging toilets
- households in the Mixed groups which rely on community groundwater schemes showed significantly *lower* rates of illness.

Households were also asked what they considered to be the most important local water-related issue for them over the next 10 years, with the most significant responses shown in Figure 11.

For all groups, the issue that ranked highest was pollution of surface water, reflecting that many respondents believed surface water quality had significantly worsened in the last 10 years and may continue to do so. However, there were significant differences across groups, with the least urbanized Mixed and No Pipe groups more concerned with water quality, whereas in the highly urbanized Piped group, only 40 percent of the households considered that surface water pollution was problematic. This group also had the highest proportion of residents who reported that there are no problems in particular or that they 'don't know or don't care about it'.

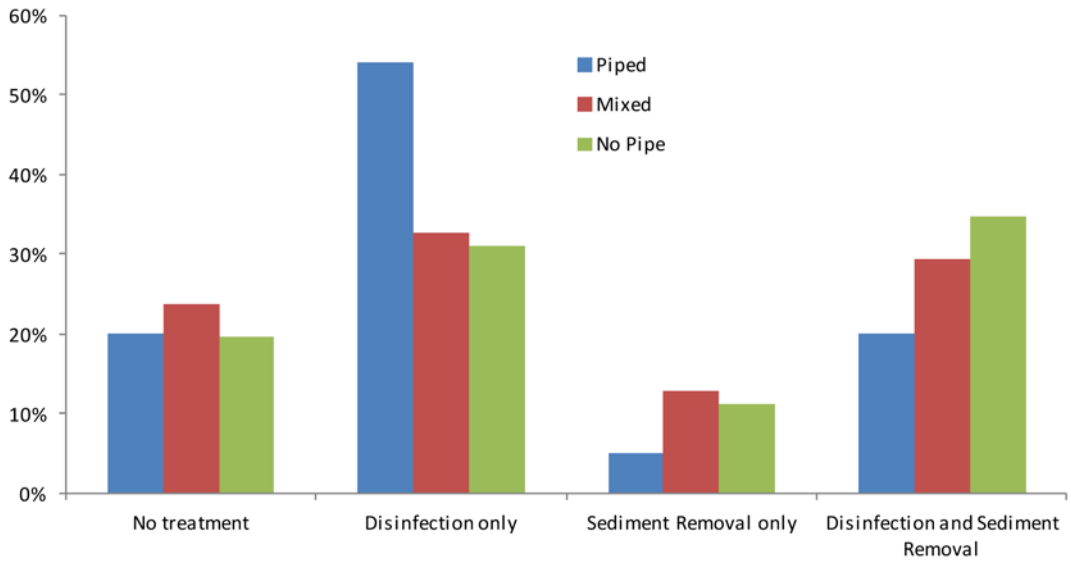
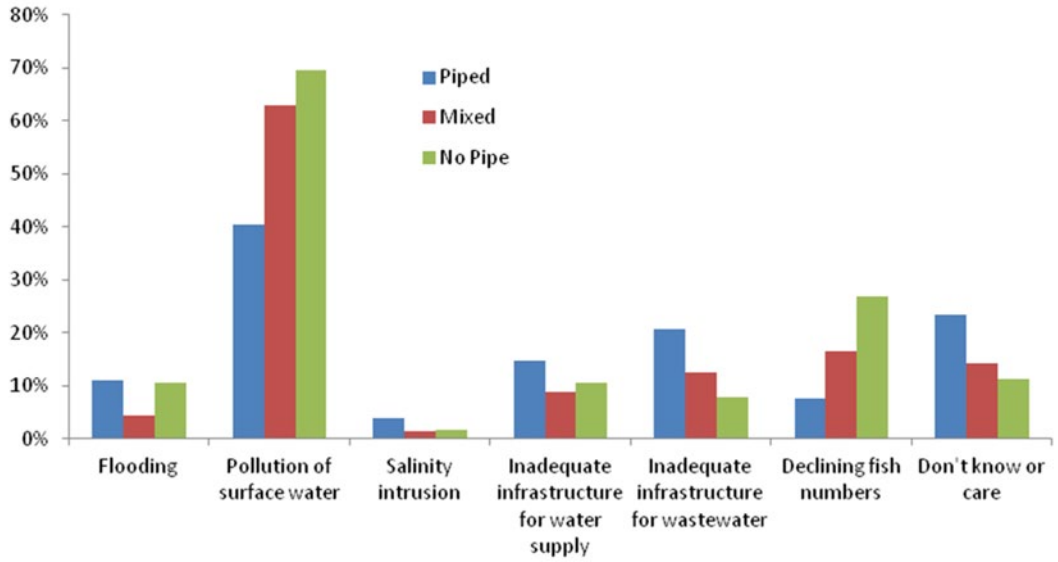


Figure 10. Proportion of households in different groups which apply different treatment types

Figure 11.
Proportion household perceptions of important future local water-related issues



In terms of infrastructure, the highest number of households that indicated there was inadequate infrastructure for water supply and sanitation came from the Piped group, which had the highest rates of urbanization. In contrast, the groups with lower urbanization rates were less preoccupied with infrastructure and more concerned with environmental indicators such as water quality and fish numbers, which is likely to be linked to the more rural setting and livelihoods.

As well as highlighting the need to provide water supply and sanitation infrastructure, these results also highlight the importance of the maintenance of the current infrastructure. Wards with poorly maintained infrastructure or problems in the quality of the supplied water had higher rates of illness that most likely can be mitigated by better infrastructure maintenance. In areas where infrastructure for water supply was minimal, community groundwater schemes appear to be a suitable solution for the provision of water of suitable quality.

The use of multiple water sources by households was the consistent factor in high reported rates of illness and therefore these households have to match water sources to applications depending upon quality, availability and cost. Therefore it is critical to extend the coverage of water supply infrastructure to more households so that they have sufficient water for drinking as well as for secondary uses.

Poverty Dynamics

The Institute for Sustainable Futures analysed the poverty dynamics of water and sanitation services and climate vulnerability in the city using the government data on poor households, the results of the household survey, and 23 more detailed interviews with low income households in O Mon and Thot Not districts (Figure 12).

Poverty dynamics in Can Tho

Recent official data indicates that poverty rates are falling so that overall in the city only six percent of households were classified as officially poor in 2010. However there is a significant variation between the urban districts, with Ninh Kieu having the lowest rate of householder poverty (one percent) but eight percent of households in O Mon are officially classified as poor. Data from the survey conducted for this project suggests that these figures may underestimate the extent of poverty particularly if we include 'non-income' dimensions related to living standards.

According to official data, 59 percent of households classified as poor in urban districts live in 'dilapidated' dwellings. The survey data indicates over 50 percent of households in the two lowest income groups of Can Tho, and nearly 47 percent of all households in Chau Van Liem live in temporary or semi permanent housing.

Sources of income for poor households are typically seasonal, sporadic and unreliable. Most households included in the qualitative study reported experiencing stress with key concerns identified as health, income, food, education, ability

to cope with flooding, and overall quality of life. The majority of households interviewed lived over or near to waterways, occupying marginal land vulnerable to seasonal or longer term climatic changes and weather events.

Access to infrastructure and water related behaviour

In urban districts, 27 percent of poor households had no access to water services in 2008 (the Water Supply and Sewerage Company's figure for the city overall is 20 percent). The rate differs between districts, with only two percent of poor households in Ninh Kieu lacking access while the figure in other urban districts is between 30-40 percent.

Most households in the qualitative study used multiple sources of water, matching the source with intended purpose. While piped water (when available) was identified as the main source for non-drinking purposes, interviewees used river water for at least some purposes (for example washing) to save on water bills. For poorer households the assessment of affordability is also influenced by whether they meet official criteria which makes them eligible for registration and payment of tariffs by the city.

The survey data indicates that 81 percent of households overall use 'improved sanitation' facilities as defined by WHO/UNICEF but only just over 60 percent of respondents in the lowest income group have access to this standard of facility. Of the 23 households included in the qualitative study, 21 used hanging fishpond toilets. However for many households investing in sanitation facilities is not a priority (unlike water) and their willingness to use financing opportunities can be limited where they are concerned about repayments.

Social vulnerability

Poor households are particularly vulnerable to the impacts of climate change predicted for Can Tho.

The proximity of dwellings to waterways and their poor structural quality means significant exposure to any increase in flooding. Reported impacts of flooding included poor health (respiratory and skin disorders), reduced mobility and loss of income (particularly for those relying on rice or fish industries).

Many households noted worse local environmental conditions, such as degraded water and river environment quality or a decline in fish numbers. For both employment and also food, the majority of households interviewed were dependent on local resources. This includes households eating locally caught or grown fish and vegetables, and those trying to get an income from selling local crops or produce.

For the full analysis of poverty dynamics in Can Tho City see Carrard et al. (2012).

Water Need Index

The Water Needs Index (WNI) methodology is an effective approach for rapid interdisciplinary assessment of the current status of an urban water system. The approach has been proved to be an effective tool to provide information for the decision making processes of planning and development in many places (Sullivan 2002; Sullivan and Meigh 2003; Alexander, Moglia et al. 2010; Alexander, Moglia et al. 2011).

To understand the current status of the water system across the urban landscape in Can Tho City, the WNI method has been applied to each ward of the five urban

Figure 12. Interviews of poor households in O Mon and Thot Not

districts. The choice of indicators for each the WNI occurred through a process that involved the national and international research teams and local stakeholders, based on the data collected as part of the sector review, as well as the data from the household survey. The indicators chosen for assessment of each WNI dimension defined in the WNI Workshop were:

- **(W) Water and sanitation access** – relating to households and other customers access style to water and sanitation services
- **(Q) Quality of accessed water** – relating fit for purpose water supply quality, measured using health impacts
- **(A) Aquatic ecosystems** – relating to the health of river and other freshwater eco-systems and surface water quality
- **(F) Flooding** – relating to damages from floods, effectiveness of protection measures, and frequency of flood occurrences
- **(I) Infrastructure performance** – relating to issues such as leakage, inadequate pressure, adequacy and condition of storages, and occurrences of infrastructure breakages
- **(G) Groundwater issues** – relating to over-extraction of groundwater, pollution of groundwater, protection measures and salinity intrusion.

The overall status of the water systems in each ward was represented by the ward overall WNI, which is a weighted sum of the WNI dimensions. The weighted factors used were from the evaluation of the importance of WNI dimension conducted in the WNI Workshop. The result is in Figure 13, where colours indicate the overall WNI score in different wards. Wards with a higher score (for example, in green) means that they have a better water system than wards with a low score (for example, in red). The cause for a low overall WNI score can relate to any of the WNI dimensions. For example, an area in the central Ninh Kieu district gets a low overall score because of very poor surface water quality (low A), whilst in other areas the low overall score is more to do with poor access levels (low W) and health impacts (low Q). Details of the WNI assessment were presented in Moglia et al. 2012a.

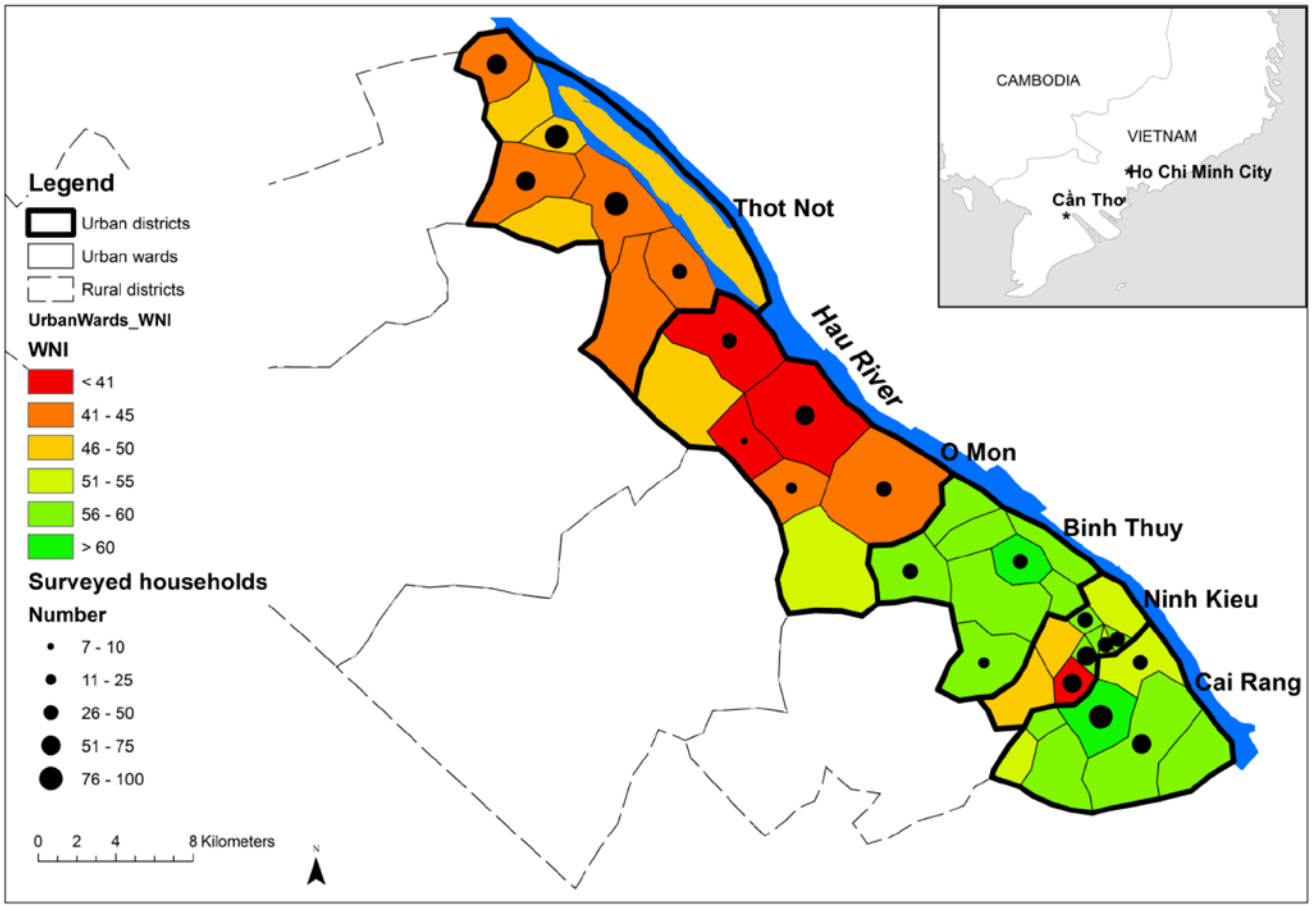


Figure 13. Application of the WNI in Can Tho City

This is an effective and quick spatial assessment, providing a spatial representation of critical issues in each ward of the city, assisting local water management to identify and target the most vulnerable areas for action.

It also noted that the local stakeholders may be unaware of issues in certain areas, due to their limited knowledge about parts of the city with which they were unfamiliar. These blind spots are likely to exist because of the inherent social and economic structures in the city, and may entrench existing inequalities relating to water and sanitation access as well as indicating different environmental management practices.

Adopting the WNI assessment framework would be useful to the city in the future. It would:

- provide a common language, co-generated with stakeholders and experts, to discuss the nature of the inter-connected aspects of the urban water system
- allow for rapid assessments of water needs in a diverse urban landscape and so guide investment in water related infrastructure and strategic options
- provide shared assessments based on collaboration between agencies and departments which increases the legitimacy of identified actions.

Map Book

The project developed a Map Book that includes 25 GIS-based maps depicting current issues and challenges in the urban water systems and environment of the city.

The project had collated a large amount of secondary data and information on the current situation for the Can Tho City urban water system. In addition, the survey of 1,200 households had generated a significant amount of information on relationship between access to water services and socio-economic indicators. There was a need to ensure that information made available from this project was summarised and provided in a form that can be easily accessible and could inform decisions by local stakeholders. Visualisation of the data with maps provides a way to present complex data and relationships simply, which enables more intuitive and rapid interpretation than data embedded in large report or spreadsheets. There has been significant interest from local departments in the Map Book as it will provide them with a useful reference that summarises some the key issues for urban water management in Can Tho, and highlights the spatial variability in access to services and water quality. The Can Tho University research team developed 25 maps using the base data from local departments and previous projects, as well as the primary data developed during this project.

The Map Book presents information across four main themes, which were:

- social economics
- surface and ground water quality and quantity
- water supply and sanitation infrastructures, current and planned
- spatial analysis of households' access and satisfaction of current services.

Figure 14 provides an example of maps developed for the Map Book (Trung et al. 2012).

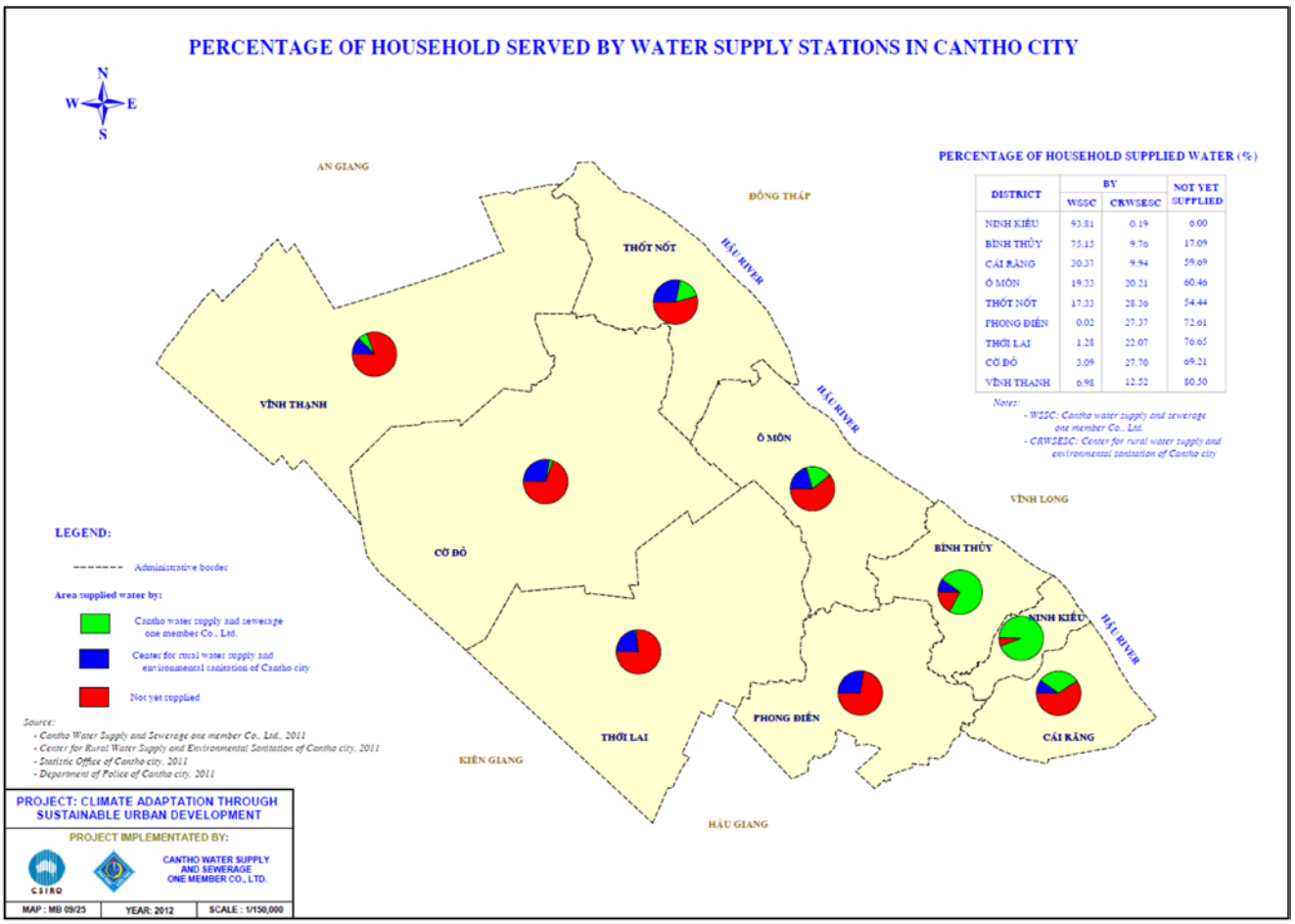


Figure 14. An example of maps from the Map Book

Focus Area 2: Strategic Planning for the City

Research in Focus Area 2 (FA2) aimed to identify strategic options to plan for the sustainable development of the city's water system in a changing climate. The main components included in FA2 are depicted in Figure 4.

A set of strategic options was established through an interactive engagement process between the research team and stakeholders, and was also assessed for their effectiveness and feasibility to provide science-based evidence to facilitate the implementation.

Strategic options

The Strategic Action Workshop was held in October 2011 (Figure 15) to identify possible strategies that help sustainable urban water management and climate adaptation. The CSIRO team suggested a number of options for consideration by the participants, based on the understanding of the local context, and the known best practice around the world. The stakeholders played the central role in establishing and evaluating strategic options. Through this facilitated interaction, and a follow-up survey, eighteen alternative options were identified.

BOX 2

Focus Area 2 (FA2) was a strategy establishment process with two workshops, expert interviews, and integrated assessments.

- The Strategic Actions Workshop was a strategy identification process: stakeholders played a central role in identifying, evaluating, and ranking strategic options for development of the city's water systems. CSIRO facilitated the process and suggested a number of options based on world best practice and also on the understanding of the local context.
- The Feasibility Assessment Workshop was to enable the stakeholders to identify key criteria for the strategic options – considering the associated risk factors – to be successfully implemented. Based on the results, CSIRO performed an integrated assessment of the identified options using Bayesian Network (which is a science-based artificial intelligence technique).

As a result, the FA2 has produced the following outputs.

- A set of five preferred strategic options that can be used to plan for adaptive and sustainable development of the city's water systems in a changing climate.
- An integrated assessment tool for the options to evaluate their feasibility and benefits, which also can be used to provide integrated information for the city's development decision making. For example, it can provide the city with:
  - a road map of activities required to achieve a high likelihood of success in implementation of the strategic options
  - a method to determine importance, and thus the priority, of each activity in the implementation through sensitivity analyses
  - an approach to assist the city in planning and arranging institutional responsibilities in implementing a strategic options
  - a way to estimate the benefit of different portfolio of strategic options in different future scenarios on the different dimensions of the city's water systems.

The research team used stakeholder and expert judgments to evaluate the strategies against a number of criteria. We considered strategic options that have wide support among local stakeholders; achieve important social, economic and/or environmental goals; and that are practical and suitable in climate change scenarios. This allowed us to identify the following shortlist of strategic options:

1. rainwater tanks for households without access to adequate piped water supply
2. constructing pipelines to link water treatment plants in O Mon, Ninh Kieu and Thot Not so that the risk to supply intakes can be minimised and the reliability of supply can be improved
3. promoting behavioural change to reduce solid waste disposal into surface waters and reduce the use of hanging toilets or other ad hoc toilet facilities
4. cluster-scale wastewater treatment for industrial areas
5. decentralised wastewater treatment for residential areas.

These strategic options were analysed for their implementation feasibility, and likely positive and negative impacts on the urban water system performance.

Integrated Assessment of Strategic Options

Strategic options can be put into action to achieve improvements in the urban water system and to promote climate change adaptation. There are risks and costs involved with adopting the strategic options, and practitioners and planners need to evaluate whether the benefits would justify the investment. The planners also need to identify an implementation plan for the strategies to ensure that investments are targeted and to maximise the chances of achieving the desired goals. Without such careful procedures it is far too common that aid and development in the urban water sector would not deliver on its promises.

The research team has undertaken an Integrated Assessment of the strategic options by analysing the implementation pathway, as well as the likely positive and unintended negative impacts of adopting the strategic options. The assessment approach relies on a framework developed by CSIRO (see Moglia et al. 2012b) using Bayesian Network analysis and Subjective Logic. The data used in this framework was a combination of expert judgments of multiple individuals through interviews or surveys, and the available

Figure 15. Strategic Action Workshop (October 2011)

scientific information and data collected. The process was applied to the five shortlisted strategies to assess their feasibility and benefits.

Feasibility Assessment

Through the Integrated Assessment process, each option was described in a 'cause and consequence' diagram which shows the factors that are likely to influence whether the outcome will be successful. Figure 17 describes an example of a cause and consequence diagram, which were modelled into a Bayesian Network.

The model has been set up in the Bayesian Network sofware named Netica (http://www.norsys.com/netica.html). Figure 17 also shows probabilities for a scenario of implementing this strategy when the following conditions are in place:

- adequate treatment facilities for handing the waste
- availability of dumping site
- available collection service
- strong enforcement of the appropriate household habits
- low tariff so that poorer household can afford the service
- strategy is applied in poor parts of the city
- strong communication of the need for this strategy
- strong community champions
- adequate diffusion of the message.

This is a 'perfect scenario' as we find the strategy has a high likelihood of success. Changing any of the above conditions will reduce the likelihood of achieving a successful strategy. The simulation therefore represents an integrated approach to considering important factors that influence the outcomes.

The integrated assessment of feasibility has provided the city an effective tool to:

- develop integrated thinking for the stakeholders about how to successfully implement a strategic adaptation option
- develop a realistic and holistic implementation plan with a 'road map' of activities that need to be done to achieve a high likelihood of success
- undertake sensitivity analysis to determine importance or priority of each factor or activity
- identify roles and responsibilities required for successful implementation
- identify possible unintended consequence.

Figure 16. Feasibility Assessment Workshop (May 2012)

Benefit assessment

With a similar modelling approach using a Bayesian Network, the benefit assessment explored how the shortlisted strategic options will affect the Water Needs Index at a ward level. The WNI is used here as a common reference to measure the impacts of the strategic options.

Figure 18 shows an example of the assessment. The left spider diagram shows the current situation of the water systems of Thới Long, a peri-urban ward of the city. The right spider diagram shows the result of the assessment for the same ward, but with two strategic options implemented. The two strategic options were the introduction of a good sanitation access and a well-functioning solid waste management system to the ward.

From this integrated assessment of benefits the city has an effective tool to support a multi-criteria decision making process that it can used to estimate the benefit of the strategic options in different future scenarios on the different dimensions of the city's water systems. If the costs of strategies are also estimated, this can help the city to analyse which options are most cost effective and likely to help achieve the desired goals.

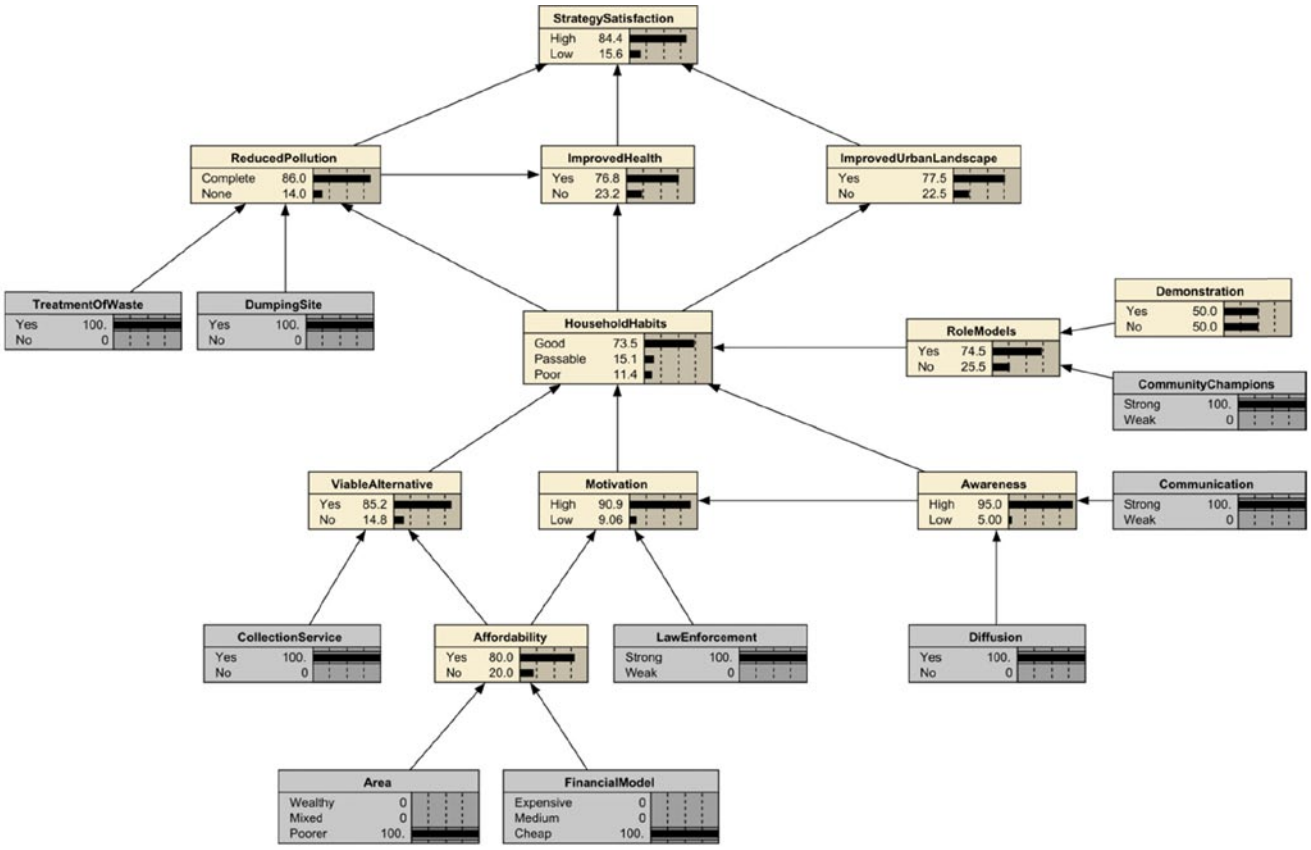


Figure 17. 'Cause and consequence' diagram for the solid waste management strategic option

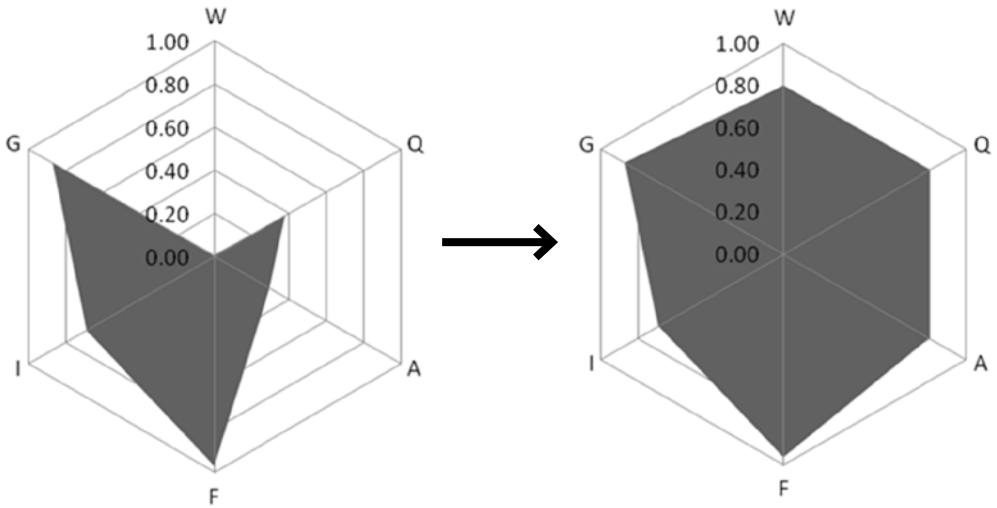


Figure 18. Example of modelled impact on WNI profile of Thoi Long ward (O Mon district). Left: current situation. Right: improvement with implementation of two strategic options

Focus Area 3: Demonstration of strategic options

The Focus Area 3 aimed to provide local examples of IUWM practice, as evidence-based outcomes of the project, through hands-on training to build research for development (RfD) capacity for local research partners and key stakeholders.

Rainwater harvesting

Rainwater harvesting was identified by Can Tho City stakeholders in workshops as a preferred local water source. Similarly the household survey also revealed that people in the community perceived this water source favourably in terms of quality. However there was a lack of data to validate the performance of rainwater tanks: in particular in terms of the water quality that could be expected, and understanding cost effective options for managing this water quality.

BOX 3

Focus Area 3 (FA3) considered local demonstrations of some identified strategic options that were considered to be 'no-regret' adaptation measures. These demonstrations aimed to provide stakeholders with local evidence-based examples of sustainable development practice. These local demonstrations, through their hands-on approach, have assisted in building the R&D capacity of local research partners and key stakeholders.

Two demonstrations have been conducted including the following.

- Development of rainwater harvesting systems to augment the supply for peri-urban and rural areas, where access to safe water is an urgent issue. The study focused on four aspects:
  - rainwater quality and 'first-flush' design
  - tank design and treatment techniques
  - rainwater tank volume and reliability assessment
  - risk of contamination due to local habits.
- Planning and design of decentralised sustainable water service provision for a peri-urban pilot site in Chau Van Liem ward - a 'hot-spot' of water issues identified by stakeholders and confirmed by the findings from the household survey. The analysis used a CSIRO award-winning sustainability assessment framework (Sharma et al. 2010).

The FA3 delivered the following tangible outputs.

- Locally suitable rainwater harvesting systems with two on-site demonstrations:
  - Can Tho University Campus for research and testing purposes
  - a household in a peri-urban area to trial cost effective treatment options.
- An option of water and wastewater service provision was accepted by the stakeholders (from the four options that had been planned and designed for the pilot areas). This provided a very practical exercise in which the local stakeholders were shown how to plan and design adaptive and sustainable water systems with a long-term view.
- A new RfD capacity for the local research partners and stakeholders was developed to support them to assess and implement sustainable water services that are appropriate to the local context.

There was also the need for demonstrations of rainwater tanks in different development settings. This could provide a practical example in Can Tho of how rainwater systems can be set up to maximise the yield and also manage the quality. Can Tho University, with the support of CSIRO, undertook the following practical activities to better understand and demonstrate rainwater harvesting in Can Tho.

- Testing of water quality for rainwater collected from different roof material types and in different urban settings. This sampling compared the quality of the initial water collected from a roof during a rainfall event with subsequent rainfall.
- Testing of water quality from rainwater storage to determine the impact of how the water is stored and withdrawn on water quality.
- A demonstration of a rainwater harvesting scheme and treatment system at a household in a peri-urban area of Can Tho (Figure 19).
- A demonstration of a rainwater harvesting scheme at the Can Tho University (Figure 19), where the rainwater was used to flush toilets.

Figure 19. Rainwater harvesting systems in Can Tho University campus (top) and a household in a peri-urban area (bottom)

Water quality testing found that (although the samples varied) collected rainfall did not meet standards for drinking water (TCVN 6187 – 1996 (ISO 9308 - 1990)) for total coliform contamination. This highlighted the importance of disinfection of rainwater prior to uses requiring direct personal contact, particularly if intended for drinking. It showed that disinfection is necessary prior to consumption. A definite effect was observed where the initial rainwater collected from the roof had the highest loads of contaminants, which could mean there is a build up of contaminants on roofs between rainfall events. This information was used in the design of trial treatment systems for the two demonstration rainwater systems.

The household rainwater harvesting demonstration trialled low cost treatment methods to improve the quality of water harvested. It was found that water quality significantly improved with use of a first flush device which removed the initial volume of runoff during a rainfall event. This treatment is a very low cost method to improve the quality of rainwater harvested.

The other treatment step was a sand filter which also improved water quality. Monitoring observed that quality deteriorated in the storage tank, which showed the potential for contamination to occur depending on how the rainwater is stored and accessed. Possible contamination sources for the rainwater in the tank were the removal of the tank cover, but also may be through the use of scoops or buckets.

The demonstration of a rainwater harvesting scheme at the Can Tho University was able to provide a practical example of a rainwater harvesting system in a public building. Monitoring was also undertaken to answer research questions such as: the cost of implementation and pay back, reliability and rainwater yield, demand for non-potable application, and the impact on reducing piped water use.

As a result of this project we found that rainwater is highly valued as water source by households. The outputs from this project have developed the local understanding of likely water quality, and cost effective measures to improve quality. The two demonstration projects provided local examples of rainwater systems which raised awareness and also the local capacity to plan and implement these systems. While the monsoonal

climate, with pronounced wet and dry seasons, means the ability of rainwater systems to reliably supply water throughout the year is limited, rainwater can augment water supply, and reduce demand for groundwater abstraction. Advantages include: reduced reliance on groundwater extraction, relatively clean water source that with minimal treatment is suitable for non-drinking purposes and with disinfection for drinking, and reduced costs for water supplied from piped systems. Rainwater systems for households are mostly likely to be suitable in peri-urban areas where there is sufficient space for a storage tank, while for public buildings with large roof areas, such as schools, rainwater can significantly reduce demand for piped water and the associated tariffs.

More detailed information of this study and demonstration is given in Tuan et al. 2012 and Cook et al. 2012b.

Demonstration – Sustainable Water Service Provision Planning and Design

A conceptual design exercise was used to assess the sustainability of different water supply and wastewater serving options. The purpose was to build local capacity to identify suitable options for water and wastewater servicing in peri-urban areas that consider:

- the most cost effective option over the life cycle of system
- the need to minimise environmental impact
- the need to meet the community service requirements and expectations
- operation and maintenance that is suitable to community expectations and capacity of administration.

The approach implemented applied a sustainable urban development framework that can be used to support decisions to improve access to clean water and sanitation and manage the impacts of development and climate change.

The case study site selected was in the Chau Van Liem ward (Figure 20), which is located in the O Mon district, around 20 kilometres to the north of Ninh Kieu, the central district of the city. The site is on the fringe of the township, and just outside the area serviced by the WSSC. The current population is 760 people which is expected to increase to 1,440 people once all blocks are developed.

Chau Van Liem ward was identified by local stakeholders in a workshop as a 'hot-spot' of water issues: i.e. existing infrastructure was considered to be limited, and in poor condition. The survey found that in comparison to other wards surveyed, Chau Van Liem had the highest reported rates of illness (38 percent), which could be related to the poor access to adequate water services.

A survey found that households predominantly rely upon a community groundwater scheme for water supply, with smaller number of households having a household bore. Around two thirds of households use bottled water for drinking, which indicated that there was a lack of confidence in the quality of groundwater supplied. The reliance on bottled water for drinking imposes a cost burden on households, and disadvantages poorer households who don't have the means to pay for bottled water.

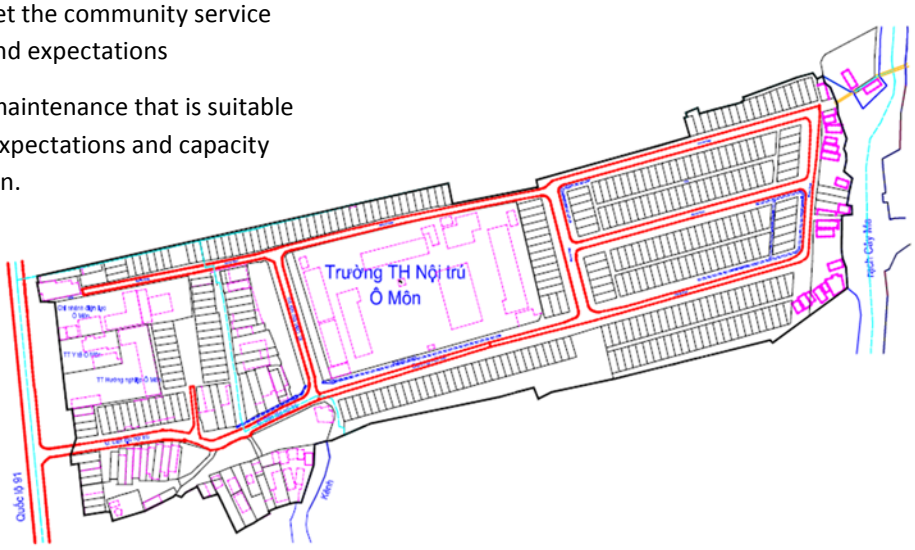


Figure 20. Pilot study area in Chau Van Liem ward

Figure 21 depicts the main steps in the assessment method. A key aspect of the method is the inclusion of stakeholder knowledge and values. Local expertise is important to establish the baseline data, and key criteria to value different options against. Stakeholder input is also important in evaluating the outcomes, as the quantitative analysis provides the evidence base that can challenge or validate pre-conceived ideas about the impact of different servicing options on sustainability objectives. Options were designed to explore the implications of managing urban water services at household, local and city levels in peri-urban areas. The exercise did not have the purpose of selecting a preferred option that will be implemented at Chau Van Liem but to build capacity for assessing options that considered:

- life cycle costs (capital and operating costs over full life cycle)
- environmental impacts
- suitability to local context (land area required, skills to maintain and operate).

It is possible that the best option for the Chau Van Liem case study may be a hybrid of the options assessed.

The specific quantitative metrics used for assessing scenarios were:

- life cycle cost (operational and capital costs)
- use of fossil fuels – energy demand
- GHG emissions for operational energy
- discharge of BOD and TN
- land footprint
- use of groundwater.

Also, an institutional assessment of options was undertaken to understand the management implications, local capacity to maintain and operate, and likely community acceptance. Table 1 summarises the four options assessed for the case study. The options were designed to operate at different levels of management, from household to city scale, and to explore the capacity to manage the systems at different levels. Wastewater treatment technologies were also selected for each option. For options A and D up-flow anaerobic sludge blanket was selected, dual chamber septic tanks with filtration were selected for the household scale in Option B, while for the cluster scale option (C) anaerobic baffled reactor was the selected technology.

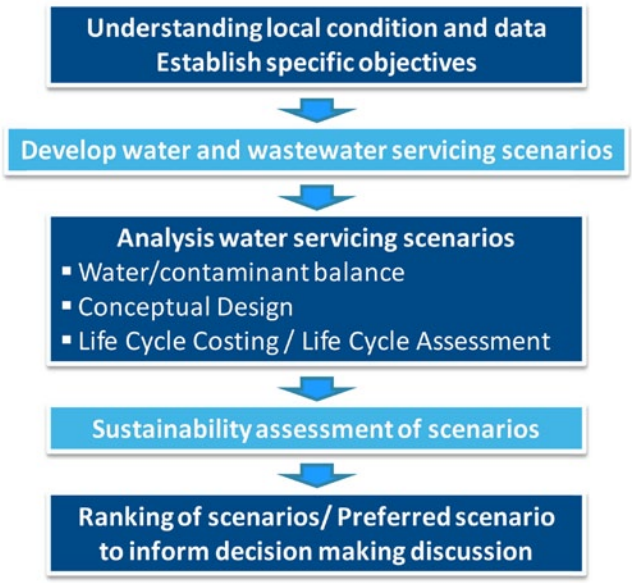


Figure 21. Sustainability assessment framework

The criteria for the selection of suitable wastewater treatment technology for Chau Van Liem were:

- low life cycle costs (capital and operating costs)
- wastewater quality to meet the standard (TCVN 6772: 2000)
- assurance of community safety and wellbeing
- land footprint
- implementation and maintenance requirements
- sustainability of the system
- environmental benefits.

Conceptual design of the options was undertaken by the research team at Can Tho University and included calculation of life cycle costs. The costs accounted for capital investment such as length of pipe material needed, trenching costs, pumps and plant costs. The costing also estimated the ongoing operating costs such as power requirements and labour for operation and maintenance. These costs were supplied from the WSSC.

Figure 22 depicts the capital and operating costs of different options for the water supply system. This demonstrated that the most expensive option in terms of capital costs may not be the most expensive option over the life cycle (which was assumed to be thirty years for this analysis).

Figure 23 shows the life cycle cost of options in net present value (NPV). NPV applies a discount rate to account for the time value of money, which means that all costs over the life cycle are discounted to the present value of money (that considers inflation and potential interest returns).

Table 1. Servicing options assessed for Chau Van Liem (CVL) case study, and relevant institutions for management

Servicing option	Water Supply	Sewage Collection System	Wastewater treatment and disposal
A – Improved base case	Upgraded community groundwater scheme (GWS)	Household septic tanks drain to collection drain, combined with stormwater flow	Development scale wastewater treatment plant. Effluent discharged to canal
Significant organisations	*Responsibility of Centre for Rural Clean Water and Sanitation (CERWASS)*		*Neighbourhood WWTP responsibility of community or of O Mon District*
B – Decentralised: Household scale	Rainwater harvesting and treatment at households for potable uses, back-up supply from upgraded GWS. GWS used for non-potable demands	Improved (dual chamber with filtration) septic system, before discharge to stormwater drains	Improved septic system to increase detention time to improve reduction of nutrients and organics. Septic discharge combined with stormwater, which drain to canal
Significant organisations		*Approval of new tank designs is likely to be required from O Mon District or City DOC depending on the scale*	
C – Decentralised: Cluster scale	Upgraded community groundwater scheme (GWS) with supply to GWS augmented by rainwater harvested from school roof	Two wastewater collection zones, separated from stormwater flows	Collection zones connected to two WWTP
Significant organisations	*The community scheme remains the responsibility of CERWASS. Responsibility for rainwater harvesting from the school is unclear. School is responsibility of Dept of Education: general security of school area and infrastructure responsibility of CVL*		*Options for responsibility for management and operations of WWTP likely to be either O Mon District or the city WSSC*
D – Centralised	Extension of the WSSC network to CVL for all uses, with upgraded distribution network	Wastewater collection system separate form stormwater	Treated WW discharged to canal
Significant organisations	*WSSC is responsible for investment and O&M of centralized systems WSSC is not currently designated with responsibility for this urban area*		*Single WWTP Options for responsibility for management and operations of WWTP likely to O Mon District or the city WSSC*

Figure 24 compares the options in terms of energy demand and related greenhouse gas emission. This shows that Option B, which has an energy passive wastewater system, is the least energy intensive. However, in considering suitability other criteria such as reliability, treatment efficiency and capacity to adequately operate and maintain must also be considered.

More detailed information of the study and demonstration is given in Cook et al. 2012a.

The options assessed were presented to a workshop with local representatives of departments and other organisations involved in managing water resources in Can Tho City. The workshop participants selected Option C – Cluster scale. This was not the cheapest

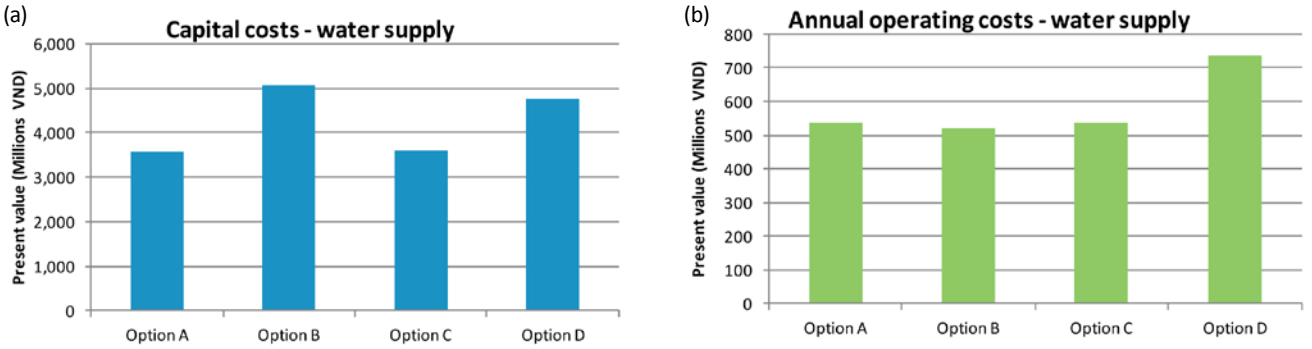
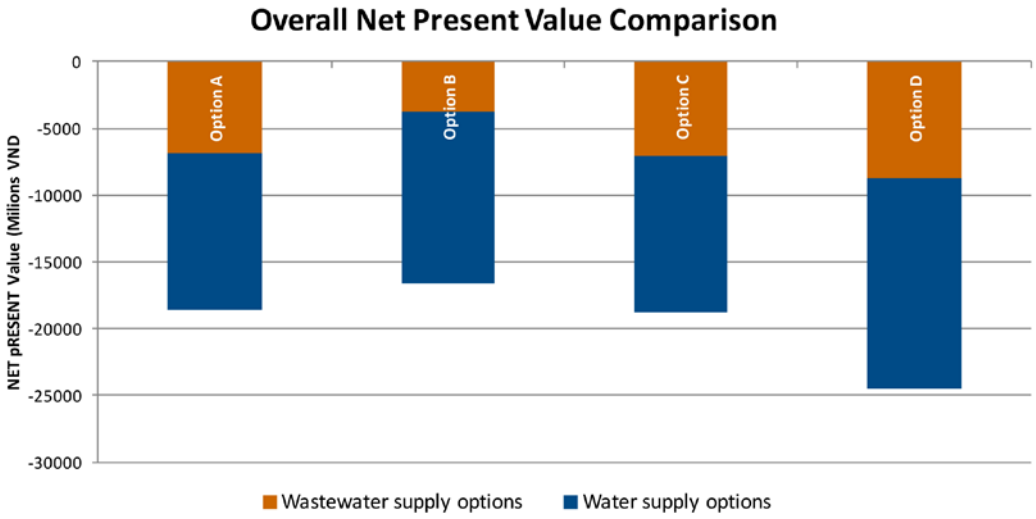


Figure 22. Life cycle cost assessment of options (a) capital costs, and (b) operating costs

Figure 23. Life cycle cost of option in net present values



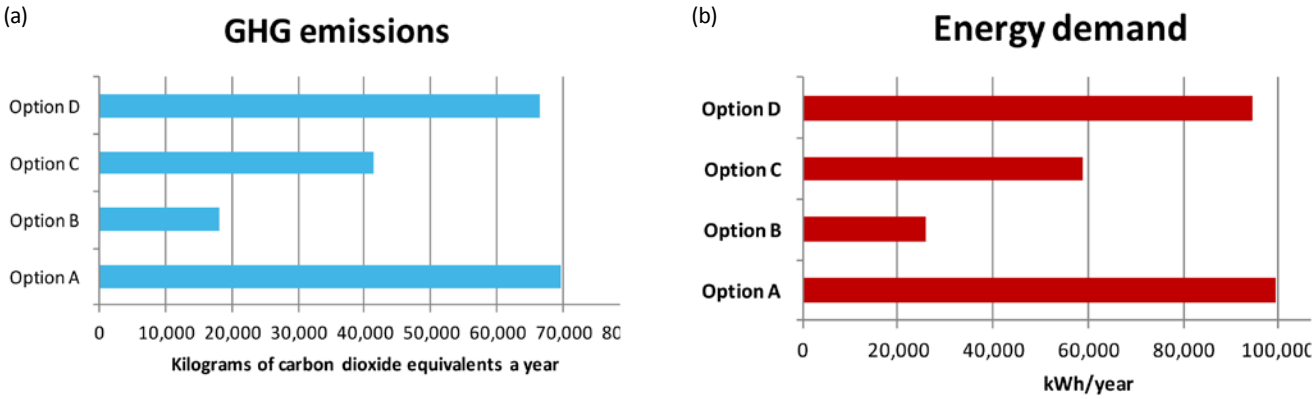


Figure 24. Comparison of options in terms of (a) energy related greenhouse as emissions, and (b) energy demand

option but it was a good compromise on costs, and the environmental impact assessed, and also was considered the most feasible in terms of institutional arrangements for ongoing operation and maintenance. The framework was useful to explore the overall sustainability outcomes of water servicing options, so a preferred option was not just selected on the initial capital investment required but also took account of life cycle costs, environmental impact and institutional arrangements. The latter is discussed more in the following section.

Assessment of institutional capacity and poverty implications

An important component in considering options for their potential sustainability was to assess their implications for poorer households in the locality (poverty analysis) as well as the capacity of the organisations at the city and ward level to provide the management and administration that is required as well as using their technical knowledge.

The aim of this component of the research was to:

- identify socio-economic dynamics of water and sanitation services in the case study area of Chau Van Liem by reviewing what is known about poverty in the area using information about O Mon District and data from a survey of 154 households within Chau Van Liem undertaken by Can Tho University (CTU)
- document how issues of institutional capacity in Chau Van Liem, and Can Tho at the city level, can potentially affect the implementation or functioning of different water supply and sewerage servicing options in Table 1.

The research team identified the key institutional actors that would be responsible for the implementation of water supply and sanitation options explored for the Chau Van Liem case study as the:

- Centre for Rural Clean Water and Sanitation, part of the Department of Agriculture and Rural Development (DARD)
- Can Tho Water and Sewerage Supply Company (WSSC);
- two tiers of government: O Mon District and the Ward of Chau Van Liem
- Can Tho Urban Works Company Ltd.

Each of these organisations was interviewed by the research team for a semi structured discussion to elicit information about the most basic 'core issues' for a capacity assessment including:

- overall responsibilities of the institution
- their experience in managing or operating water or wastewater facilities
- the financial and personal resources available to them.

The capacity assessment, based on interviews, was an input into the consideration of which of the service options is likely to be viable and sustainable.

For the Cluster scale option, which was selected as the preferred option by stakeholders in the workshop, the upgrading of the community groundwater scheme would be under the existing institutional managerial and administrative arrangements of the Centre for Rural Clean Water and Sanitation. The additional requirements for improved water treatment and pipe network upgrade do not appear to be considerable however the viability would depend upon the specific improvements, as there is limited technical support currently available. This option also proposed harvesting rainwater from the school roof to augment supply to the development. The feasibility of this initiative would require the support and cooperation of the Department of Education, who does not have technical or administrative capacity in this area.

For the proposed decentralised waste water treatment plants, the institutional challenges are that O Mon District currently does not have the capacity to manage or administer services. Its primary role is contracting for maintenance of infrastructure hardware. The provider of that service on contract, the Urban Works Company, is a civil engineering maintenance provider, not a service manager.

Currently the Water Supply and Sewerage Company (WSSC) has no authority to provide water or sewerage services to this area of the District. There appear to be neither plans nor resources to extend sewerage facilities beyond the two urban districts closest to the City, and the WSSC does not yet have any expertise in managing decentralised facilities. Therefore, an implementation project of the service option would need a due support from the city government and relevant organisations (e.g. donors, developers) in developing management capacity and in arranging institutional responsibilities for the relevant local agencies. Details of this assessment were presented in Paddon et al. 2012.

Stakeholder engagement, partnership and capacity building

Engagement, partnering and capacity building with stakeholders were key elements of the project.

Stakeholder engagement and partnerships

Stakeholder engagement was a key process in the project. A participatory approach was used to engage and share the ownership of project's process and outcomes with the local research partner at the Can Tho University and other key stakeholder organisations. The participative nature of the project and active communication with the wider stakeholder community ensured social and political acceptance of the outcomes of the project. The ownership of the research for development was shared between research partners or transferred to the in-country partners.

Figure 25. CSIRO team with in-country research partners and key stakeholders

As depicted in Figure 4 (page 11), the stakeholder engagement process was coordinated through three workshops in which local stakeholders played a central role in deliberation of workshop outcomes. The process design, materials and facilitation of the workshops were provided collaboratively by CTU and CSIRO, to ensure they would be appropriate for the local context and expectations. The workshops were deliberately designed to be flexible to allow adjustment of the process and materials to adapt to situations and stakeholder reactions as they arose.

The result of this has been the formation of a strong collaborative partnership between research partners (CSIRO, UTS, and CTU) and the key relevant stakeholders in Can Tho (Figure 25), including the Climate Change Coordination Office (CCCO), the Water Supply and Sewerage Company (WSSC), the Centre of Clean Water and Rural Environmental Sanitation of the Department of Agriculture and Rural Development (DARD), the Department of Natural Resources and Environment (DONRE), the Department of Construction (DOC), and the Institute of Socio-economic Development Study (ISDS), Department of Health (DOH), and a number of local governmental offices.

Capacity Building

Training has been undertaken in a three-stage approach to ensure the adoption of the project's outcomes. The three stages were:

Stage 1: CSIRO conducted training for staff from Can Tho University (CTU) and key stakeholders in English in Australia. This included training for:

- staff from the DRAGON Institute of CTU in using CSIRO climate change downscaling data of the Mekong Delta – Melbourne, November 2010
- in-country research partners (CTU and CCCO) in undertaking the CSIRO Award-winning assessment framework of IUWM with associated software – Melbourne, Dec 2011 (Figure 26).

Figure 26. Training for in-country research partners (CTU and CCCO) in Melbourne, December 2011

The training has developed a sense of achievement and confidence for the project's partners who have gained a good insight of sustainable urban development and climate adaptation through field trips and lectures from leading CSIRO scientists in Australia. These have been greatly useful for the project in building up a team with mutual understanding and trust.

Stage 2: CSIRO provided hands-on training and technical support to CTU and key stakeholders, who have been actively leading the investigation, design, and implementation of the two project demonstrations (Dec 2011 to Sep 2012). This training stage has been done through frequent trips of the CSIRO team to Can Tho to work with CTU, and most importantly, with regular formal and informal communication between visits.

Stage 3: CTU conducted a training workshop for 30 staff from local stakeholders on the outcomes of the project in Vietnamese in November 2012 (Figure 27). The training included:

- extension of the GIS database with more spatial information of the city – this was based on the GIS database developed in the project that has been used to produce the Map Book (Trung et.al. 2012)
- CSIRO sustainability assessment framework for urban water service provisions and its application for the pilot peri-urban area in Chau Van Liem ward.

Figure 27. Training for local stakeholders on the outcomes of the project in Vietnamese (November 2012)

As the result of the Integrated Urban Water System Engineering and Management training a new RfD capacity has been developed for the in-country partners and stakeholders. The process of training has consolidated the knowledge and skills transfer as evidenced by the transition of the CTU's role from trainees to trainers. The three stage approach has also helped overcome the language difference, which was a barrier that often hindered the effectiveness of the training.

Stakeholder evaluation of the project outputs

An evaluation has been conducted in the Project Summary Presentation Workshop in September 2012 (Figure 28), where six key outputs of the project were presented to the key stakeholders of the project.

1. Household Survey and Water Needs Index (WNI)
2. Poverty Dynamics Analysis
3. Strategic Options for the development of the city's water systems
4. Map Book of 25 GIS layers of current issues and challenges of Can Tho City's water systems,
5. Rainwater Harvesting Systems
6. Sustainable Planning and Design of Water Service Provisions.

Workshop's participants were asked to evaluate each of the above outputs by answering three questions

1. What are the conditions for using this output? Without condition, or with further funding or training?
2. What are the conditions for up-scaling or replicating this output? Accepted and supported by the government or the people?
3. Is the output useful for the city's adaptation action plan in the next 10 years? 20 years?

The evaluation results are presented in Tables 2, 3, and 4.

Almost all participants responded that the outputs could be used for the city. They also provided the conditions that would be needed for deploying these outputs, as summarised in Table 2. The useability of 'Strategic Options', 'Map Book', 'Rainwater tanks', and 'Sustainable water services planning' appeared to depend on further funding or training. These outputs interested the stakeholders with their potential applications in the long term.

Table 3 presents the conditions for scaling up/replicating the outputs. Mostly it was thought that the government's acceptance and support were the most important condition, and people's acceptance and support only prevailed for the 'rainwater tank' output.

Table 4 presents the usefulness of the outputs to the city's action plan in the future. High percentages of the responses were obtained for the usefulness of the outputs in the next 10 years. The percentages of positive response were lower for the longer term of 20 years, due to the anticipated uncertainties about the future development and environment.

In summary, the local stakeholders have expressed a highly positive evaluation on all the project's outputs; all of which were thought to be practical, useful and in line with the needs and priorities of the city's urban water planning.

Figure 28. Project Summary Presentation Workshop in September 2012

Table 2. Useability of the project output

Outputs	Usable without condition	Useable with:	
		further training	further funding
Household Survey and WNI	48%	35%	14%
Poverty Dynamics	46%	27%	27%
Strategic Options	12%	29%	70%
Map Book	24%	59%	41%
Rainwater tank	37%	53%	47%
Sustainable water services planning	41%	47%	41%

Table 3. Conditions for up-scaling and replicating of the outputs

Outputs	Government's acceptance	People's acceptance
Household Survey and WNI	72%	65%
Poverty Dynamics	81%	61%
Strategic Options	70%	59%
Map Book	100%	35%
Rainwater tank	79%	95%
Sustainable water services planning	76%	18%

Table 4. Usefulness of the outputs to the city's adaptation action plan

Outputs	Useful for city's action plan in the next 10 years	Useful for city's action plan in the next 20 years
Household Survey and WNI	100%	48%
Poverty Dynamics	77%	46%
Strategic Options	83%	65%
Map Book	88%	58%
Rainwater tank	95%	84%
Sustainable water services planning	82%	65%

Publications from the project

Book / Book Chapter

Nguyen Hieu Trung, Minh Nguyen, Le Quang Tri (ed.) (2012) A Map Book of water system and environment of Can Tho City, Can Tho University Press (in review).

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Magnus Moglia, Minh Nguyen, Luis Neumann, Stephen Cook, Ashok K. Sharma (2012b) Framework for identification of and analysis of adaptation strategies in the urban water sector: and the case of Can Tho City, Vietnam (drafted)

Minh Nguyen, Nguyen Hieu Trung, Magnus Moglia, Luis Neumann, Stephen Cook, Ashok Sharma, and Xiaoming Wang (2012), Adaptive Sustainability for cities in developing countries – A Case Study in Can Tho city, Vietnam, (in preparation)

Stephen Cook, Luis Neumann, Dinh DA Tuan, Lam V Thinh, Ashok K. Sharma, Minh Nguyen, Magnus Moglia (2012a), Sustainable planning and design for water service provisions for a pilot peri-urban area of Can Tho city Vietnam, (in preparation)

Stephen Cook, Luis Neumann, Dinh DA Tuan, Nguyen X. Hoang, Ashok Sharma, Minh Nguyen, Magnus Moglia (2012b), A demonstration of rainwater harvesting systems for Mekong Delta of Vietnam - a 'no-regret' solution for safe water supply in a changing climate, (in preparation)

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Đinh Diệp Anh Tuấn, Lê Quang Trí, Nguyễn Xuân Hoàng, Nguyễn Hiếu Trung, Minh Nguyen, Stephen Cook, Luis Neumann (2012) Rainwater Harvesting: a Solution for Domestic Water in Rural and Coastal areas of Mekong Delta, Rural Development for Climate Change Adaptation in Coastal Areas of Mekong Delta Workshop, Ca Mau, September 2012 (in Vietnamese)

Minh Nguyen (2012) Climate Adaptation through Sustainable Urban Development: Vietnam Case Study. International Workshop on 'Urban Sustainability: Adapting to change', Makassar, Indonesia, April 2012.

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Alexander KS, Moglia M, Tjandraatmadja G, Nguyen M, Larson S, Trung NH, Barkey RA. 2011. Evaluation of Water Needs Index Case Studies. In Chan, F., Marinova, D. and Anderssen, R.S. (eds) MODSIM2011, 19th International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2011, pp. 2866-2877. ISBN: 978-0-9872143-1-7. http://www.mssanz.org.au/modsim2011/G3/alexander.pdf.

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Internal Reports

- UTS Report to CSIRO on Can Tho Water Sector Governance
- UTS Report to CSIRO on Can Tho Water End Uses in new urban area of Cai Rang District
- UTS Report to CSIRO on Can Tho Waste Water Infrastructure
- CTU Reports to CSIRO on Household and Stakeholder Surveys
- CTU Reports to CSIRO on Rainwater harvesting systems
- CSIRO Report on Strategic Action Workshop Oct 2011

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