# WATER SAFETY PLAN COST ANALYSIS: EXPLANATION BUILDING WITH CASE STUDIES IN THE WESTERN PACIFIC REGION

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# ABSTRACT

ZAI KANG CHANG: Water Safety Plan cost analysis: explanation building with case studies in the Western Pacific Region
(Under the direction of Jamie Bartram)

Unsafe water remains a significant public health threat in high and low income countries. The World Health Organization promotes Water Safety Plans (WSPs) as the most effective means of consistently ensuring the safety of a drinking-water supply. Currently, there is a lack of information relating water suppliers to expected costs and benefits of WSP implementation. Costing practices are adapted from food quality management studies and adapted to six water suppliers from the Western Pacific Region. The explanation building procedure is used to develop understanding of relationships between water supplier characteristics and WSP implementation costs. The results indicate costs associated with WSP implementation are expected to be low for developed water suppliers, however, for less developed water suppliers, the high variability in costs indicates further studies may not improve *a priori* estimation of costs and these suppliers may require ongoing technical and financial assistance to achieve a safe water supply.

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# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

**DWD -** Dasmariñas Water District

**DWQM** – Drinking-water quality monitoring

**DWSA** – Drinking-water supply agency

**(US) EPA** – (United States) Environmental Protection Agency

**HACCP** – Hazard Assessment and Critical Control Points

**HUE -** Thua Thien Hue Water Supply & Sewerage Company

**ISO** – International Organization for Standardization

**K-A -** Koror-Airai Public Water Supply

**MYD -** Maynilad Water Services, Inc.

**PKE -** Pakse Provincial Water Supply State-Owned Enterprise

**SOP** – Standard operating procedure

**WHO** – World Health Organization

**YVW -** Yarra Valley Water, Ltd

# 1 Introduction

## 1.1 Water safety and health

The overarching understanding on water, sanitation, hygiene and health is clear. Populations where these qualities are lacking or poor suffer from adverse health outcomes. Globally, the disease burden from water, sanitation and hygiene (WaSH) is estimated to be 4.0% of all deaths and 5.7% of the total disease burden (Prüss et al.). Poor WaSH conditions result in an estimated 94% of diarrhea incidence (Prüss-Üstün and Corvalán) which is significant considering diarrheal diseases are responsible for an estimated 2.46 million deaths nearly all occurring in low and middle income countries (World Health Organization). The costs of the burden of disease extends past their immediate health effects and has economic consequences through the cost of treatments and lost time at work and school. While there is a degree of uncertainty in the exact number of deaths and disease burden, the magnitude of the figures make WaSH issues one of the greatest health threats to populations.

While in 2008 there were an estimated 5.82 billion people using improved water supplies (World Health Organization/UNICEF), it is understood that using an improved water supply does not necessarily guarantee safe water. Typically thought of as a health issue in lower income countries, threats to safe water exist in populations other than those without improved access. In areas with piped connections, illegal connections, utility staff errors, and breaks in the distribution system are examples of potential sources of not only revenue loss, but contamination and public health threats. Losses from non-revenue water are particularly prevalent among utilities in developing countries, with as much as a third of production being lost in the form of physical and revenue losses (The World Bank). Other utility indicators point to management failures in matching output quality to desired quality. In developing countries service quality is generally seen as poor (Briscoe and Garn). These characteristics make it difficult for utilities to maintain financial sustainability. Utilities must find ways to maintain both financial responsibilities and the responsibility to provide safe water to the public.

Conditions threatening the safety of the water supply are greatest in lower- and middle-income countries; however, larger utilities in wealthier settings are not immune. Large microbial and chemical contamination events occur in higher-income countries as illustrated by the 1998 Sydney Cryptosporidium outbreak or the Milwaukee and Walkerton outbreaks (Hrudey and Hrudey) detailed further by Hrudey (2006). Rural settings of developed countries are also susceptible to unsafe water supply.

Globally, the provision of safe drinking-water is a necessary, but often insufficient condition for alleviating the incidence of diarrheal disease. One of the first evidence-based public health interventions began with John Snow and the epidemiological study of the Broad street pump, since then it has been established that improvements to water supply offer an effective means of reducing the incidence of diarrheal diseases and other waterborne illnesses (Esrey et al.). Improving the availability of safe water for drinking, sanitation and hygiene is fundamental to the development process with benefits extending across many sectors in addition to health.

## 1.2 Drinking-water quality management based upon end-point monitoring

A safe and consistent drinking-water supply is a necessity for public health, economic prosperity and basic societal development. Where a centralized management of drinking-water quality exists, there are roles for water quality monitoring such as surveillance agencies or drinking-water supply agencies (DWSAs) or both. Guidelines from the WHO suggest an authority independent from the water supplier be responsible for surveillance through periodic audit and/or verification testing while DWSAs remain continually responsible for the quality and safety of the water they produce (World Health Organization). DWSAs and surveillance agencies perform direct monitoring by sampling and analyzing drinking-water quality to verify the quality of the water produced. In many parts of the world, the water sector monitors end-point water quality relative to drinking-water quality standards to manage water safety. Drinking-water quality management systems relying on end-point monitoring, test drinking-water quality at some point after any treatment of the raw water. Under this management scheme, water quality samples not meeting defined standards, trigger corrective action in response. While end-point monitoring is critical in verifying the system of quality control measures, these types of methods alone for the control of microbiological quality of drinking-water are inadequate (Howard). Compliance with drinking-water quality standards does not ensure water safety because corrective actions are triggered only after human exposure has occurred. Errors in the operation or flaws in the design of some components of the water supply system may exist undiscovered and have yet to contribute to a contamination event. Monitoring, even when consistently performed by both the surveillance and drinking-water supply agencies, does not prevent outbreaks, rather indicates only after the exposure has occurred (World Health Organization and Swedish Institute for Infectious Disease Control). Risk management approaches seek to identify and manage the risks to safe water supply before they result in a hazardous event. Therefore, international thinking on management of drinking-water quality is moving towards taking a preventative, risk-management approach to water supply.

## 1.3 Water Safety Plans and Risk Management

Given the largely environmental nature of diarrhea and other water-borne diseases, it is understood that environmental pathways such as drinking-water systems should be the target of health interventions. Understanding the environmental pathways in the context of water quality management is critical for not only providing safe water, but providing it consistently. While it is impractical to suggest that supplied water should present zero risks to health, interventions for water utilities should focus on managing the risks to providing safe water.

The World Health Organization (WHO) presented Water Safety Plans (WSPs) in 2004 in the third edition of the *Guidelines for Drinking-water Quality* as "the most effective means of consistently ensuring the safety of a drinking-water supply…". The Water Safety Plan is a comprehensive risk management approach that provides a template for DWSAs to assess and manage risks of drinking-water contamination found in the catchment, treatment systems and distribution networks in an integrated manner. In specific applications, elements of a WSP may already exist as a part of a water supply agency's operational procedures. WSPs are a conceptual approach to producing safe water, therefore, adaptation of the concepts is necessary in application and the specifics of the resulting plan will be unique. This is reflected in practice by the variety of existing WSPs that are publicly available. While these differences exist, the WHO (World Health Organization) suggests all WSPs should maintain the following three essential components:

(1) system assessment to determine if the water supply system can deliver safe water;

(2) Identifying control measures in the water supply system to control identified risks. Each control measure will have a means of operational monitoring that will ensure that any deviation from performance limits will be detected in a timely manner; and

(3) The management plans describing normal operation and incident conditions and documenting the system assessment and other water safety plan outputs.

The WHO also prescribes a specific methodology for the creation of a WSP. The key steps in this process are presented in **Figure 1**.

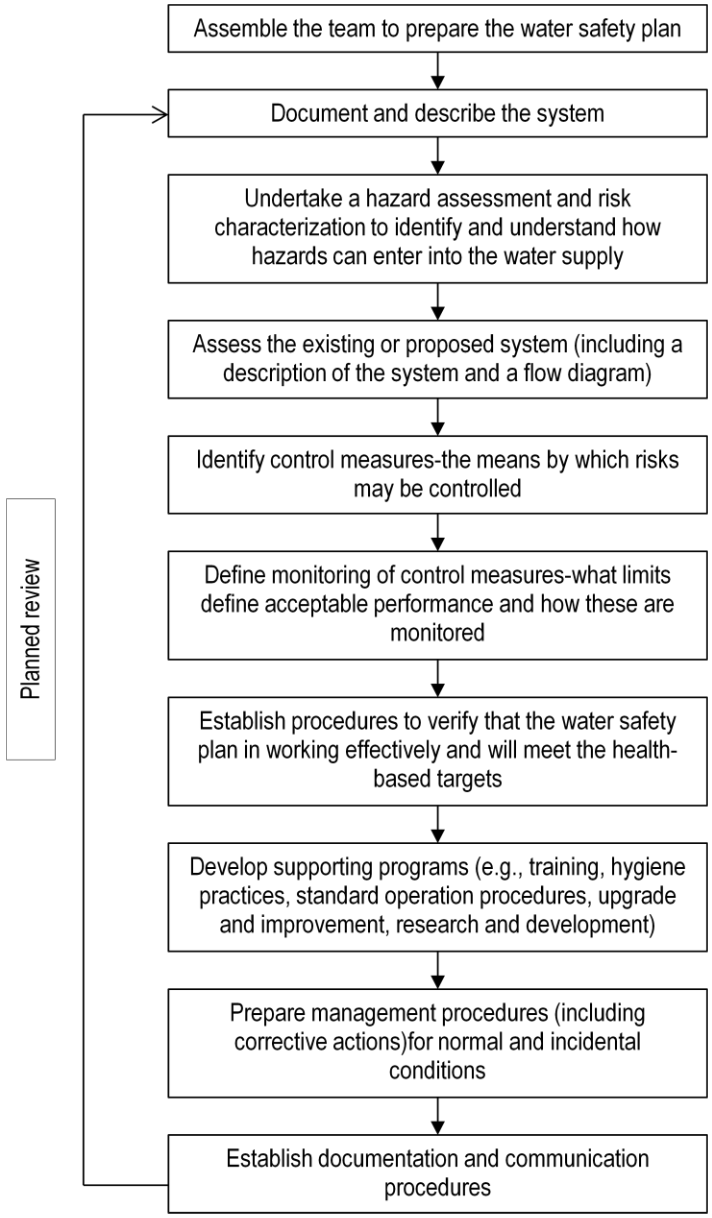


**Figure 1: Key steps in the development of a water safety plan. Adapted from WHO, 2011.**

The approach is to encompass the four stages of the water supply: catchment, treatment, distribution and customer plumbing systems forming a holistic approach to drinking-water quality management. Further details on the implementation procedure can be found in the many publicly available guides.

WSPs have been developed from a history of risk and quality management systems and HACCP (hazard analysis critical control point) system. Developed in the 1970s and used in the food industry the full HACCP procedure is formalized in detail by the Codex Alimentarius Commission in 1993. HACCP implementation is comprised of a series of step processes designed to help assess and manage the risks to the safety of the supplied product. The key steps are taken from the Codex (CAC (Codex Alimentarius Commission)) as follows:

1. Assemble a HACCP team
2. Describe the product
3. Identify the intended use of the product
4. Construct a flow diagram of the production process
5. Confirm the process flow diagram
6. Conduct a hazards analysis.
7. Determine Critical Control Points (CCP).
8. Establish critical limits.
9. Establish a system to monitor control of the CCP.
10. Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.
11. Establish procedures for verification to confirm that the HACCP system is working effectively.
12. Establish documentation concerning all procedures and records appropriate to these principles and their application.

The HACCP system has been implemented throughout the world in the food industry (Ropkins and Beck) and its economic impacts have been well studied (Crutchfield et al. and Antle). Thoughts on applying the HACCP system to drinking-water supply were first published by Havelaar in 1994 and are implicit in earlier documents from WHO (Bartram, Fewtrell and Stenström). The overarching goals of HACCP and WSP show many similarities: to assess the water supply system, conduct hazard analysis, establish plans for monitoring the risks (at the critical control points) and create a plan for the continuation of risk management. While commonalities exist, WSPs strive to assess and manage risks through a large number of interventions, while the HACCP system primarily focuses on hazards at the control points. Managing risks to water safety include managing both the probability of the hazard and the severity of its consequence. However, in practice, both approaches have been adapted and implemented to fit the needs and capacities of the DWSAs, resulting in a spectrum of water safety strategies.

Relevant to both of these systems are the idea of total quality management and management system standards such as the ISO 9000 and ISO 14000 series. The ISO 9000 series creates three standards for quality management that fulfills the quality requirements of the customer, meets regulatory requirements, enhances customer satisfaction and achieves continually improvement throughout operations (International Organization for Standardization). The three standards included in **Table 1**. It specifies how management operations are to be conducted with the goal of reducing non-conformity of the product (Buttle). There is overlap between the ISO 9000 series and the system description, system assessment, verification establishment and management procedure preparation steps in the WSP implementation process. The ISO 14000 series is a management tool, when met, enable an organization to identify and control the environmental impact of its activities, products or services; continually improve its environmental performance, and implement a systematic approach to setting and achieving environmental objectives and targets (International Organization for Standardization). ISO 17025 *General requirements for the competence of testing and calibration laboratories* specifies the requirements for competence to carry out test such as drinking-water quality testing. It creates specifications on sampling and testing but is also used to develop management systems for quality, administrative and technical operations (International Organization for Standardization). When employed in water supply agencies, both systems create management environments or prescribe actions that overlap with those identified by both HACCP and WSPs.

**Table 1: ISO 9000 series of quality assurance standards**

| Standard | Description |
|---|---|
| ISO 9001 | Standard for quality assurance in design, development, production, installation and servicing |
| ISO 9002 | Standard for quality assurance in production and installation |
| ISO 9003 | Standard for quality assurance in final inspection and test of product or service |

## 1.4 Barriers to WSP implementation

Current uptake of the WSP methodology worldwide is uncertain, however, WHO estimates that pilot projects exist in 17 countries, WSPs are implemented in a number of supplies in 28 countries and WSPs are required in regulations in eight countries (World Health Organization). The United States Environmental Protection Agency (U.S. EPA) summarizes the incorporation of HACCP concepts into regulations of seven countries, two of which are not included in the WHO estimates (Environmental Protection Agency).

While utilities desire to systematically manage risks and provide a consistent supply of safe water to their consumers, due to resource constraints, it is necessary for decision makers, from the drinking-water supply agency to the Ministry level authorities, to evaluate the efficiency of implementing WSPs.  One portion of this evaluation should weigh the benefits and costs of such actions.

In a field that is largely practitioner-led, qualitative descriptions of WSP benefits to utilities have been documented extensively in countries including Australia (Jayaratne and Smith), Iceland (Gunnarsdottir), South Africa (Viljoen).  The intended beneficiaries of water safety plans are primarily the consumers; however, there are numerous benefits for DWSAs as well (Martel et al. and World Health Organization).  Martel (2006) presents a HACCP guide for water distribution system in which it is recommended that the organization identify goals and expected benefits of HACCP.  It is readily understood that benefits gained from WSP implementation will depend upon the characteristics of the DWSA.  While information on benefits to DWSAs exists, it has yet to be organized in a systematic way to aid understanding of the relationship between benefits and DWSA characteristics.

Literature regarding WSP cost information is generally lacking.  The Martel (2006) and Gerber (2010) studies were the only examples of costing case studies for WSPs available to the researcher. A WHO report to the European Commission suggests there is limited evidence to support the consensus that the WSP-type approach is cost effective and that effort should encourage utilities to development arguments of cost effectiveness (World Health Organization).  While general cost types are known, there is a lack of understanding of implementation costs and justifying these costs to funding bodies with the purported benefits (*Costs and Benefits of Implementing Water Safety Plans - DWSPs*).  Expressed need for WSP cost information has largely come from donors, practitioners and advocates and has been identified as an important data need in conferences where water safety plans have been discussed (Godfrey). Furthermore, costs of implementing WSPs will vary widely between DWSAs. The motivation of the DWSAs to implement WSPs will be based upon its prior perception of costs and benefits. Understanding relationships between DWSA characteristics and resulting costs and benefits can improve the ability for individual DWSAs to predict cost and benefit estimations.

# 2 Objective

The objective of the research is to provide perceived benefits and costs of WSP implementation to DWSAs and surveillance agencies and to improve the ability of the agencies to estimate *a priori* the cost of WSP implementation. The second objective of the research is achieved by providing evidence to answer the following questions.

(1) What are the relationships between DWSA characteristics and benefits and costs of WSP implementation?

(2) What are the dominant types of WSP implementation costs?

# 3 Scope of costs and benefits

Decision makers undertake costing exercises to identify how best to allocate their scarce resources. To establish the costs of WSP implementation, the following steps were taken to establish the scope of costs and benefits:

1. specify the alterative projects,
2. decide which groups have standing, and
3. identify impacts of the project.

Decisions makers choose an intervention among a set of alternatives. The intervention (the WSP) has already occurred, therefore, the study is considered as an *ex post* analysis and compares the impacts of the activity against a situation without an intervention. In the case that WSPs add to an existing cost to the utility, such as staff time, then the marginal increase in costs will be calculated. In economics, this is called a "with-and without-" analysis[1]. All monetary values presented are the costs incurred with WSP implementation relative to the costs incurred without WSP implementation.

Standing is a term used to describe the people to whom the costs and benefits accrue. To assess total costs, the analyst would have to include anyone impacted by the intervention. Theoretically, this can include many people outside of the consumers, DWSAs, governments funding the DWSAs (for public utilities) to include all of society. DWSAs and surveillance agencies were the groups chosen to have standing, therefore, costs will be financial costs (to the DWSA or surveillance agency) as opposed to economic costs (to all of society). A financial analysis of costs to the aforementioned agencies is more relevant for DWSA managers and some surveillance agencies than an analysis of costs to all society. The primary beneficiaries of WSPs are consumers. Their benefits are well recognized and will not be included. The focus of the study is water utilities rather than community supplies. The scope is chosen for several reasons: to limit the variability in the observed costs of WSP implementation, accessibility of information, and the prevalence of cases to study.

The impacts of WSP implementation are any changes in activities resulting directly from the development and implementation of the WSP. The cost of WSP development and implementation is the monetary value of any new activities or the marginal value of any change of existing activities directly resulting from the WSP. Similarly, the benefits are perceived advantages of WSP implementation accrued to the DWSAs and surveillance agencies. If activities called for by the WSP were already performed under another management strategy such as ISO 9001 then that activity is not considered a cost of the WSP. Where the WSP calls for renewed emphasis on an already existing program, the incremental increase in effort or funding to the program is considered to be the

[1] "With- and without" analysis compares the costs and/or benefits of the system with and without the intervention to determine the net value of the effect of the intervention. The researcher identifies and monetizes the impacts of the intervention ('with' - scenario) relative to an alternative scenario in which the intervention is not undertaken (Asian Development Bank. *Handbook for the Economic Analysis of Water Supply Projects.*, 1999. Web.

attributed cost. Water Safety Plans are to be a continually adapting management plan; therefore, no WSP can be described as 'fully' implemented. The scope of activities considered in the research does not include planned projects or activities that have yet to be budgeted. Though some utilities may not count staff time at training or additional workload for a salaried employees as a monetary expense, this information is calculated for two reasons: 1) additional time spent, or used for WSP activities may be accounted for by other utilities that attempt to estimate the potential cost of WSP implementation 2) the research characterizes the total costs of WSP implementation.

In some cases, water suppliers obtain technical assistance from aid agencies, government agencies and non-governmental organizations such as the WHO at no expense to the DWSA. There is value in these resource costs and they will be included and noted separately. This is done to attempt to capture the cost of WSP implementation for those suppliers that may not be able to obtain the no-cost technical assistance from these entities. Costs of the facilitation of WSP activities by the WHO and other global actors are diluted across many beneficiaries and are not included.

The cost of HACCP (herein described as WSP) system implementation is also studied.

# 4 Methods

## 4.1 Participant selection

The objective of the research is to understand costs and benefits as they accrue to DWSAs and surveillance agencies. To accomplish this it is necessary to collect information from participants with firsthand experience in developing and implementing WSPs. This includes drinking-water supply agencies and surveillance agencies. In order to maximize the coverage of information collected, all relevant agencies from which information was readily accessible were included. Solicited agencies were chosen primarily based on whether there was experience implementing WSPs.

This study includes case studies from countries with a variety of levels of gastrointestinal illness due to water supply. WSPs that have been developed are at various levels in the implementation process. The case studies are from the WHO Western Pacific Region: Australia, Lao PDR, Palau, the

Philippines, and Vietnam. The six DWSAs involved in the study include: Yarra Valley Water, Ltd (YVW) in Melbourne, Australia; Pakse Provincial Water Supply State-Owned Enterprise (PKE) in Pakse, Lao PDR; Koror-Airai Public Water Supply (K-A) in Koror, Palau; Maynilad Water Services, Inc. (MYD) in Manila, Philippines; Dasmariñas Water District (DWD) in Cavite, Philippines; and Thua Thien Hue Water Supply & Sewerage Company (HUE) in Hue City, Vietnam. The Western Pacific Region has eleven countries with implemented WSPs: Australia, Fiji, Niue, Palau, China, Japan, Lao PDR, New Zealand, the Philippines, Singapore, and Vietnam and an active regional WSP community. This was critical to data collection efforts as the required data comes primarily through practitioners directly involved in WSP implementation.

The selection of WSP included in this research is not meant to be representative of WSPs found globally; rather they were chosen to give deeper insight into the relationship between DWSA characteristics and perceived benefits and accrued costs.

## 4.2 Data collection

A set of data requirements was developed to identify all the data necessary to understand the WSP costs and benefits of specific DWSAs and surveillance agencies. A summary of the data requirements are organized by category in **Table 2**. There are several data requirements per requirement categories.

**Table 2: Purpose and example questions by data requirement category**

| Data requirement category | Purpose | Example question |
|---|---|---|
| 1. General participant information and perceptions | Gain information to describe the participant and understand the perceived advantages and disadvantages of WSP implementation | What are the perceived advantages of WSP implementation? |
| 2. General DWSA/Surveillance agency data | Gain information to understand basic characteristics. | What organizations perform bulk water distribution? |
| 3. General cost parameters | Gain cost parameters to estimate cost of the drinking-water quality monitoring program and WSP. | What is a representative staff salary for those working on drinking-water quality monitoring? |

| | | |
|---|---|---|
| 4. Pre-WSP Drinking-water quality monitoring program costs | Gain information to be used to estimate the cost of the drinking-water quality monitoring program in place before the WSP. | What is the number of drinking-water quality samples taken before the WSP implementation? |
| 5. General WSP information | Gain information to describe the WSP's implementation. | Were any management systems in place before the implementation of the WSP? |
| 6. WSP Initial development costs | Gain information to estimate the cost of the initial development of the WSP. | What were the resources used to develop the WSP? |
| 7. Change in drinking-water quality monitoring activity | Gain information to estimate any change in the cost of drinking-water quality monitoring resulting from the WSP. | Has there been a change in the annual costs of drinking-water quality monitoring since the WSP implementation? |
| 8. Cost of activities directly related to WSP implementation | Gain information to estimate the costs associated with WSP implementation. | Have there been or will there be any capital improvements resulting from the WSP? |

This study undertakes a case study approach to accounting costs of WSP implementation. The case study is a research strategy which focuses on understanding the dynamics present within individual settings (Eisenhardt). Data collection for this project took two forms: literature review and qualitative research methods. Data was collected through different and independent sources to increase the validity and retest reliability of the analysis. The strengths and weaknesses of the sources of evidence used in this study are included in **Table 3**.

**Table 3: List of the strengths and weaknesses of the primary sources of evidence. Adapted from Yin, 1994.**

| Source of evidence | Strength | Weakness |
|---|---|---|
| Documentation | • Stable – can be reviewed repeatedly<br>• Unobtrusive – not created as a result of the case study<br>• Exact – contains exact names, references and details of an event<br>• Broad coverage – long span of time, many events, and many settings | • Ability to retrieve-can be low<br>• Biased selectivity if collection is incomplete<br>• Reporting bias – reflects (unknown)bias of author<br>• Access – may be deliberately blocked |
| Interviews (and questionnaires) | • Targeted – focuses directly on case study topic<br>• Insightful – provides perceived causal inferences | • Bias due to poorly constructed questions<br>• Response bias<br>• Inaccuracies due to poor recall<br>• Reflexivity – interviewee gives what interviewer wants to hear |

The primary advantage of using multiple sources of evidence is the development of converging lines of inquiry- a process of information triangulation that is likely to be more convincing and accurate than information collected from a single source (Yin). All information sources were compared with each other to verify consistency. Where discrepancies between information sources existed, the researcher followed up with the participant or created a best estimate. Usage of best estimates is noted in the results.

All relevant data were organized by country and compiled into separate Microsoft Word documents. Information transferred to the Microsoft Word documents was referenced to maintain a chain of evidence.

A portion of the data collection was conducted from the WHO Pacific Regional Office in Manila, Philippines. Communication with participants in Lao PDR and Vietnam were administered through the WHO country offices.

Much of the data was collected through qualitative research means, only collected documents and background and literature review documents will be referenced.

4.2.1 Background and literature review.

In all countries studied, a desk-based academic and gray literature review was performed to collect background information. While the academic literature review employed standard techniques the gray literature review included the following resources:

(1) legislative databases such as ECOLEX,

(2) country pages of international water-related organizations such as the Secretariat of the Pacific Community, the World Health Organization, and AusAID..

(3) web pages of relevant ministries- often ministries of health, environment, or water supply and,

(4) trade magazines such as the International Water Association's Water21.

The review returned documents such as national drinking-water quality standards, water legislation, articles from academic journals, stakeholder mission reports, water supply agency operating procedures, water safety plans, relevant standards documents and country and sector reports from various relevant and reputable organizations. Where searches revealed more than one version of a document, the more recent version was used. This was not always possible to determine as not all documents maintained dates. The review gathered information on WSP implementation projects in the WHO Western Pacific Region, background information on the selected countries' water sectors; resource valuation data, utility characteristics and relevant drinking-water quality monitoring cost parameters for DWSAs, regulators and surveillance agencies. Particularly relevant information was found in water safety plans, mission reports, drinking-water quality standards, advocacy material, conference notes and academic journal articles.

#### 4.2.2 Lessons learned from piloting research methods and research ethics

Collecting data from multiple sources requires that each data collection method be used with skill in order to maintain information triangulation (Yin). To prepare, pilot projects were completed prior to the data collection period. The purpose of the first pilot was to develop and refine qualitative research methods while the purpose of the second was to validate the content of the inquiries. The pilot projects gave insight into several strategies for the qualitative research methods used in the research.

The first pilot project provided experience with general qualitative research methods in foreign context-settings. Questionnaires and interviews can suffer from several sources of bias. Several strategies were used to control the effect of biases. First, standardized questionnaires were used to control the expression of the inquiry. Secondly, the researcher sought verification by asking the participants to provide reference documents for their responses. Third, the solicitation stated the participant would remain unidentified throughout the data collection process and afterward. Lastly, the objectives of the study and output were clearly stated so as to reduce the possibility of the perception that anything could be gained from responding inaccurately.

These procedures were implemented for questionnaires and interview methods and piloted with the Australian water company, Yarra Valley Water. The focus of this second pilot was to test the content of the questionnaire and interview. This exercise proved useful as Yarra Valley Water is a world-leader in risk-based management and has previously engaged in a costing exercise. Gaps in the required data were uncovered during the pilot and were subsequently adapted to reflect the insight gained from the pilot work. During the study, cost values depended upon the information from the participants directly involved in the implementation; therefore, designing a comprehensive approach to the qualitative research methods was critical.

The research involved human subjects and therefore approval from the University of North Carolina Office of Human Research Ethics (study number: 11-1022) was obtained. This process resulted in a research plan that took precautions to preserve the privacy of the identities of research participants and to remove information linking participants to the provided information. These precautions were included throughout the data collection process.

4.2.3 Standardized questionnaires

Where data requirements were not satisfied through the background and literature review, the researcher contacted individuals in relevant regulatory agencies, ministries, utilities, and other organizations working in the field such as the World Health Organization. These potential participants were solicited through a scripted email or voice communication. Initial solicitations contained language assuring potential participants that they would remain unidentified and unlinked to any provided information. The objectives of the study and the output were clearly stated here so as to reduce the perception that anything could be gained from responding inaccurately. Positive responses to the solicitation were interpreted as agreements to participate in the research and were followed up by a description of the study and an email questionnaire or voice interview. Questions were developed to fulfill the data requirements (**Table 2**) and were arranged to create a default questionnaire. Where possible, a background and literature review was performed and each questionnaire was adjusted to be appropriate for the participant. A list of definitions was attached with the questionnaires to help ensure a common understanding. A copy of the goals, default questions, and definitions used in the research is included in **Appendix 1A, 1B, and 1C**.

The questionnaire was emailed to participants in the Microsoft Word document format. Where the meanings of responses were unclear, the researcher followed-up via email or phone call. Being static documents, the questionnaires were used to serve as the initial point of correspondence for follow up necessary to capture greater resolution of the data.

Data on benefits were collected through open-ended questions and were supplemented by secondary sources. The open-ended question to participants regarding perceived benefits of WSP was phrased as "advantages of WSPs" as opposed to "benefits of WSP". All elicited responses can be considered benefits of WSP. The open-ended question to participants regarding perceived challenges was phrased as "disadvantages of WSPs"; however, all elicited responses were disadvantages or difficulties in implementing WSP rather than disadvantages of WSP concepts. The results will be presented as challenges in implementing WSPs.

#### 4.2.4 Semi-structured interviews and site visits

Direct communication with participants of the research was designed to gain information about the most relevant activities and costs and gain in-depth understanding of the cost components. During the data collection period, data requirements were adjusted to respond to new information from the participants. Changes in the data collection during the study is acceptable in the given research because the nature of the research is to understand each case individually in as much detail as is feasible (Eisenhardt).

Utility-specific costing data were also collected through site visits, paper documents and interviews. Interviews were performed by e-mail, voice and in-person. All of the in-person interviews and a majority of the data collection were conducted during the summer of 2011 from the WHO Pacific Regional Office in Manila, Philippines. Participants from Australia, Palau, and the

Philippines were interviewed by phone and email. All interview questions asked during the interview are based off of the questions referred to in the questionnaire. Similar to the questionnaire, the varied nature of the types of data obtained necessitated the use of semi-structured interviews.

During the site visits, the researcher requested documentation on any information provided by the participant during the interview.

Staff at WHO country offices acted as translators and investigators in Vietnam and Lao PDR. The objective of the research and issues to be investigated was reviewed thoroughly by phone conversation with staff members in Lao PDR while the staff in Vietnam received text of the research objectives. Staff members at both country offices were familiar with background information regarding WSPs and their respective participants.

## 4.3 Cost calculation

### 4.3.1 Approach

Costs were initially organized into two groups: non-recurring and recurring. Non-recurring costs refer to costs not expected to occur again e.g., staff time spent during the development of the WSP. The cost of the WSP development consists of staff time and other resources spent (on consultants, etc.) by either the DWSA or surveillance agency in documenting the system, assessing the hazards, creating process documents, etc. These costs are not expected to recur. Recurring costs refer to continuous resource inputs e.g., the cost of annual training sessions. Recurring costs or cost savings are sustained changes in resource expenditures by the water utility or surveillance agency due to findings from the WSP.

Some cost information is directly used in the analysis while costing information such as the number of hours spent or costs per test are used in conjunction with costing parameters such as salaries and number of tests taken to develop cost estimates. Where costs were not provided directly by the participant, estimates were made using the other sources of evidence previously described. Unknown costs were treated as having zero values.

All DWSAs in the study except Yarra Valley Water obtained technical assistance from aid agencies, government agencies and non-governmental organizations such as the WHO at no expense to the DWSA. The value of these resource costs are included and noted separately. This is done to attempt to capture the cost of WSP implementation for those suppliers that may not be able to obtain the no-cost technical assistance.

All cost information was organized by country into a Microsoft Excel document. The cost calculations described below were performed within the spreadsheet. All monetized values should be seen as an approximate value within a range of estimates rather than a precise value.

### 4.3.2 Accounting for inflation and local currencies

All monetized values are presented in 2009 international dollars. Cost information was received by participants in the local currency units during the year of the expense; therefore, adjustments are made to account for inflation and convert local currency to international dollars. Given the year the fixed costs were incurred, all costs were converted to real terms using a GDP deflator. The GDP deflator is a price index of all goods produced domestically and measures changes in the price level of GDP relative to real output. It is used to adjust for inflation. All local currency units were converted to international dollars using purchasing power parity exchange rates.

Currency is typically deflated using either the Consumer Price Index (CPI) or the Gross Domestic Product deflator (Boardman et al.). The Consumer Price Index is a commonly used as a deflator being expressed as a ratio of the cost of purchasing a standard basket of goods in a particular year to the cost of purchasing the same or similar basket of goods in a base year. The GDP deflator works on a similar principle, but reflects broader prices of goods and services in the economy, including the public sector (Boardman et al.). The GDP price deflator is the broadest-based measure of inflation and was chosen because the impacts of the project affect the public sector and not just consumers. GDP deflators for the study countries are sourced from the World Bank (World Bank). A GDP deflator is the ratio of the GDP in current local currency to GDP in a constant local currency.

To inflate or deflate dollars into 2009 dollars, the nominal dollars are multiplied by the ratio of the GDP deflator of the year the analyst would like to inflate or deflate to and the GDP deflator of the same year as the nominal dollars. For example, if 1999 dollars were converted to current 2009 dollars the following formula would be applied:

$$Current\ dollars_{1999} * \left(\frac{GDP\ deflator_{2009}}{GDP\ deflator_{1999}}\right) = Current\ dollars_{2009}$$

All currencies were converted to 2009 international dollars, and were then converted to international dollars using purchasing-power parity (PPP) exchange rates to enable cross-country comparison. 2009 international dollars were used because this was the most recent year for which there was information on PPP exchange rates. PPP is "the number of currency units required to buy goods equivalent to what can be bought with one unit of the currency of the base country or with one unit of the common currency of a group of countries. The PPP may be calculated over all of GDP, but also at levels of aggregation, like capital formation" (United Nations). The PPP exchange rate is the number of units of local currency required to purchase similar, quality adjusted, goods and services as one unit of currency in a reference country. The use of PPP assumes the existence of the same goods in both economies and covers all of GDP to include both traded and non-traded goods. Monetary values of different currencies can be made comparable by either market exchange rates of purchasing power parity exchange rates. Expounding on the reasons for choosing one over the other is outside of the scope of this research. However, PPP was used primarily because market rates are relevant only for internationally traded goods and because local labor was one of the largest costs, PPP was thought to be more suitable.

PPP conversion factors are ratios of local currency units to international dollars and were sourced from the World Bank (World Bank). Following the example above, the use of PPP conversion factors can be seen in the following formula:

$$\mathit{Local\ current\ dollar} \div \left(\frac{\mathit{Local\ current\ dollar}}{\mathit{International\ dollar}}\right) = \mathit{International\ dollars}$$

4.3.3 Staff time costs

All staff time costs were derived from received or estimated salaries of staff and units of time spent. In calculating time costs occurring over past time intervals, salaries were assumed to remain the same in real terms. The salaries were multiplied by staff hours spent to derive a total staff time cost. Cost figures from before 2009 were then inflated to 2009 local currency units and converted to international dollars.

Recurring costs were collected in terms of annual costs in local currency. These figures were assumed to remain constant and were converted into international dollars.

4.3.4 Capital costs

Capital goods are defined in this research as physical inputs lasting more than a year. Capital costs require sustained operation and maintenance inputs to maintain functionality. Operation and maintenance costs are simulated by a recurring cost equivalent to 3% of the total paid price of the capital. Where financing mechanisms are used to pay off large capital costs these costs are annualized over the lifespan of the capital. The annual payments are calculated using the equation below. The annualized costs presented here should not be used for long-term projections because it is understood the annual costs are subject to change and these changes are likely to occur before the end of the lifetime of the capital improvements.

Annual payments for paying off capital are calculated using the following equation:

$$\mathit{Payment} = \mathit{Amount\ of\ loan} * \mathit{Capital\ Recovery\ Factor},$$

where, $\mathit{Capital\ Recovery\ Factor} = \frac{r(1+r)^N}{[(1+r)^N - 1]}$

and
N = lifespan of capital good
r = interest rate

The capital goods found in the study DWSAs range from large projects such as establishing intakes and pipe-laying to smaller ones including purchasing of monitoring equipment. The lifespan of the capital good was based on the lifespan estimates of water supply equipment published by the New Zealand Ministry of Health (Ministry of Health) in **Table 4**. The weighted-average interest rate used in the analysis is 5%.

**Table 4: Lifespan estimates for water supply equipment. Adapted from the New Zealand Ministry of Health, 2007**

| **Equipment** | **Normal lifespan** |
|---|---|
| Buildings, concrete or steel structures, buried pipes | 50-100 years |
| Pumps, valves, switchboards and similar equipment | 15-20 years |
| Instruments and controls | 10-15 years |

### 4.3.5 Activity costs

Activity costs include any other non-labor and non-capital costs associated with a given activity. For example, increased cleaning solution costs are activity costs expected to follow from increased tank cleaning activities. Efforts were made to include all associated costs of activities. It is noted where this was not possible or costs were otherwise not parsed.

## 4.4 Analysis

The methods used in the analysis draws from case study methodologies and analogous costing studies found in the HACCP and food industry literature. The collected data were divided into categories in preparation for analysis (**Figure 2**).

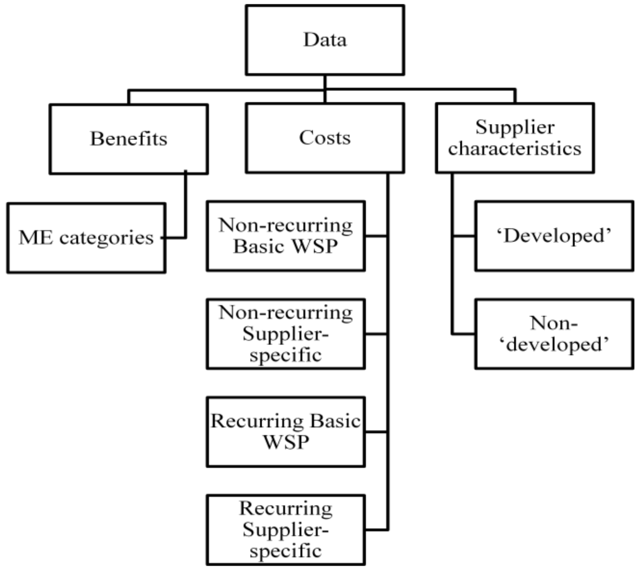

**Figure 2: Data were categorized into categories. Benefits were divided into theoretically mutually exclusive categories.**

### 4.4.1 Developing benefit categories

Currently, there is no method for organizing benefits. The benefit categories used in this research are based on the primary or initial point in the system where the benefit was detected. This is relatively similar to categorizing benefits according to 'source of benefit' which is suggested in a FAO report regarding methods for evaluating cost and benefits of food quality systems (Krieger, Schiefer and da Silva). **Table 5** lists the benefit categories and example benefit types. Martel et al. (2006) organizes nine benefits from five case studies by water quality, operations and business performance. The United States Environmental Protection Agency combines a list of benefits from the water and food sector into the following categories: improvements in public health protection, improved regulatory compliance demonstration of due diligence, improvements in water system processes, improved understanding of risks and risk management, improvements in employee skills, and improvements in work processes (Environmental Protection Agency).

**Table 5: Benefit categories developed based on the perceived benefits of the participants**

| Benefit category | Description |
|---|---|
| Improved core functions | Improvements to the functions immediately necessary for the provision of water. |
| Improved ancillary functions | Improvements to the functions that increase the efficiency or effectiveness of the core functions. |
| Improvement enabler | An effect resulting in the opportunity for further improvement of other benefit categories. |
| Motivation, morale and assurance | An effect resulting in increased motivation, morale and self-assurance of the safety of the supplied water. |
| Improved water supply/quality indicators | Improved rates of water supply indicators e.g. pressure, chlorine residual, indicator organisms, etc. |
| Financial | Improvement creating immediate financial opportunity or stability |
| Community perception and relationship | Improvements in the quality of the community's perceptions of and relationships with the DWSA. |

### 4.4.2 Developing cost categories

Cost categories were developed based on cost types found to be important in HACCP costing literature. Maldonado et al. ordered the importance of different costs of implementing HACCP based on survey responses from enterprises in the Mexican meat industry. Cost types are listed here in decreasing importance: investment in new equipment, external consultants, staff time in documenting system, structural changes to plant, managerial changes and staff training (Maldonado et al.). A similarly designed study of the UK dairy processing sector included the same cost types; however, the order of importance was different from the Maldonado study. HACCP cost types are organized into "pure process control aspects" and costs of "specific interventions" (Jensen, Unnevehr and Gomez; Roberts, Buzby and Ollinger). Krieger, Schiefer and da Silva (2007) similarly categorize food quality system costs by 'system induced' and 'process dependent'. System refers to the food quality management system. Analogous cost categories in this research are Basic WSP and DWSA-specific costs. Basic WSP costs isolate the costs thought to be universal and essential to all WSPs: training, auditing and monitoring. These can alternatively be thought of as the costs of quality assurance. The DWSA-specific costs describe the cost types thought to be highly variable among DWSAs, both in the specific activity and magnitude of cost. DWSA-specific costs types are control measures, operational monitoring, supporting programs, and capital improvements. Although these cost types describe activities that are universal to all utilities, considered here are new activities (control measures, operational monitoring, etc.) due to the WSP implementation. DWSA-specific costs are largely costs of *achieving* water assurance and represent costs of activities or expenditures that are required to provide a consistent and adequate supply of safe water.

**Table 6: Cost categories adapted from those used in HACCP costing studies of the food industry**

| Cost category | | Cost type | Example costs |
|---|---|---|---|
| Non-recurring | Basic WSP | Staff time | System mapping, plan hazard assessment, documentation |
| | | Drinking-water quality monitoring | Change in sampling frequency of bacteriological parameters |
| Recurring | | WSP training | Costs to external trainer, staff time costs |
| | | Auditing | Costs to external auditor, staff time costs (for internal audits) |
| Non-recurring | DWSA-specific | Control measures | Watershed protection program, augmented treatment processes, tank cleaning |
| | | Operational monitoring | pH, chlorine residual, pressure monitoring, human/animal access monitoring |
| Recurring | | Supporting programs | Water quality research, public awareness programs, non-WSP training |
| | | Capital improvements | Maintenance of capital, additional infrastructure |

Basic WSP and DWSA-specific activities each have costs that occur once, or periodically. Costs are separated in this manner because they represent different units of analysis. The cost categories and associated cost types and examples are included in **Table 6.**

### 4.4.3 Developing DWSA groups

DWSAs incur different types and magnitudes of benefits and costs from implementing WSPs based on their respective context and characteristics. DWSAs were split into two groups, ‘developed’ and non-‘developed’ to characterize these differences. The inclusion of a DWSA in the ‘developed’ group depended upon two characteristics: a measure of efficiency and a measure effectiveness. Efficiency is measured by number of connections per 1000 employees, a commonly used benchmark for efficiency among utilities. An effective water supply is one that supplies an adequate amount of safe drinking-water on a consistent basis. Effectiveness is measured based on whether the DWSA maintains total quality management system. The DWSA characteristics used to determine the DWSA groups are listed in **Table 7**.

**Table 7: Measures of efficiency and effectiveness used to determine the DWSA categories.**

| DWSA | Employees/1000 connections | Other QM system in place |
|---|---|---|
| YVW[1] | 0.846 | ISO 9001, ISO 14001 |
| MYD[2] | 2.26 | ISO 9001, ISO 14001 |
| K-A | 5.30 | None |
| DWD | 6.75 | None |
| HUE | 8.24 | ISO 9001, ISO/IEC 17025 |
| PKE | No data | None |

[1]Scope of operations does not include abstraction or primary treatment and includes wastewater distribution.
[2]Scope of operations includes wastewater management.

On this basis, Yarra Valley Water and Maynilad were included as 'developed' DWSAs. **Appendix 2B** contains a table listing other key characteristics of the DWSAs.

4.4.4 Case study analysis: explanation building procedure

Data analysis of case studies consists of examining, categorizing, or otherwise recombining the evidence to address the initial purpose of the study. Yin (1994) identifies four dominant analytic techniques to analyze case studies: pattern-matching, explanation building, time-series analysis and program logic models. Explanation building is a specific form of pattern-matching that analyzes the case study data by building an explanation about the case or cases (Yin). Explanation building is a hypothesis-generating process that takes an iterative approach to develop a set of causal links, or an explanation, about the phenomenon under research. An initial proposition is constructed based on theory or previous evidence. The proposition is used to compare an empirically based pattern with the predicted one (William M.K.). Where the theoretical statement is not consistent with the pattern of findings among the cases, it is revised and compared again with the findings. Explanations for why the proposition does or does not match the data are created using the previously gathered contextual information (e.g. high costs were due to many research undertakings). Repeated comparisons among the data produce numerous explanations that create an explanation framework that is true among all cases and addresses the study question. A conceptual model of the process is seen in **Figure 3**. This technique allows for the initial hypothesis of the research to be different from the final explanation. The goal of this process is not always to answer the initial proposition, but to develop the idea for further study (Yin).

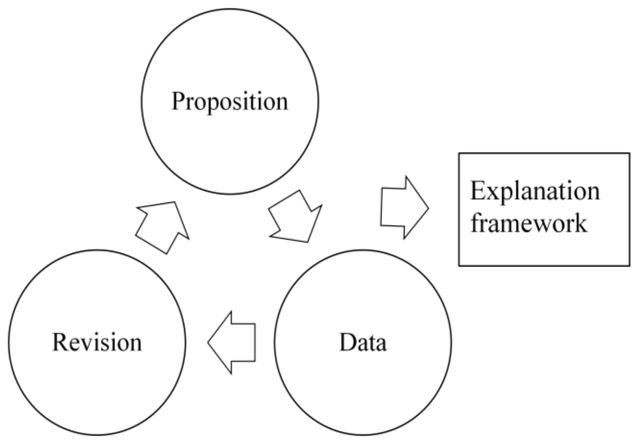


**Figure 3: A conceptual model of the explanation building procedure.**

In this research it is used to develop a framework to explain the cost compositions of DWSAs. To fulfill the purpose of the research two propositions are examined: 1.) more ‘developed’ DWSAs are expected to incur lower costs from WSP implementation compared to non-‘developed’ DWSAs and 2.) the total cost of drinking-water quality monitoring (DWQM) is expected to decrease as a result of WSP implementation. The second proposition is a specification within the first. The DWQM costs are a portion of the WSP implementation costs and are analyzed simultaneously with the first proposition. The analysis of benefits is similar to the 1$^{st}$ proposition for costs: more ‘developed’ DWSAs are expected to incur fewer benefits from WSP implementation compared to non-‘developed’ DWSAs.

Comparisons between the proposition and the data make use of patterns across the case studies, groups of case studies or other data category. The types of possible comparisons are seen in **Figure 4**.

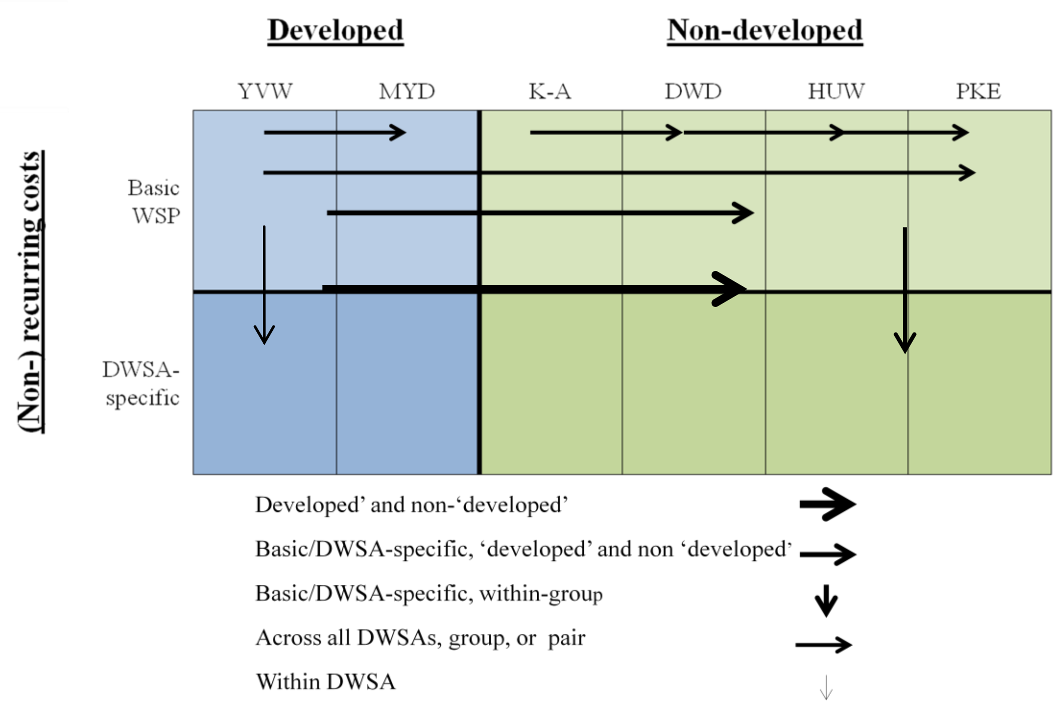


**Figure 4: Diagram of the types of comparisons made in the explanation building procedure.**

Cross-case pattern searching techniques suggested by Eisenhardt (1989) are used to evaluate the propositions. The four cost categories (non-recurring Basic WSP, non-recurring DWSA-specific, recurring Basic WSP and non-recurring DWSA-specific) are applied to the 'developed' and non-'developed' DWSAs groups. Information from within-DWSA group, across DWSA group and within DWSA comparisons is also used in the explanation building process. Patterns between the cost types and magnitudes and the DWSA groups are assessed and explanations are given.

# 5 Results

## 5.1 Perceived benefits of WSP implementation

Benefits collected from the participants YVW (Yarra Valley Water), MYD (Maynilad), K-A (Koror-Airai), DWD (Dasmariñas Water District), HUE (Thua Thien Hue Water Supply & Sewerage Company), PKE (Pakse Provincial Water Supply State-Owned Enterprise) are listed by benefit type (**Table 9**). Commonly perceived benefits include: Improved record keeping, documentation and formalization of procedures and activities; more focused monitoring and reporting; systematic identification and prioritization of risks and control measures; improved understanding of the distribution system, and potential factors affecting water quality; risk mitigation; and assurance to DWSA of water quality. A more complete description of the benefits is included in **Appendix 2C**.

**Table 8: Table of benefits types with benefit categories**

| YVW | MYD | K-A | DWD | HUE | PKE | Benefit type | Benefit category |
|---|---|---|---|---|---|---|---|
| X | X | | | | | Reduced water quality incidents | Is |
| X | | | | | | Reduced chlorinator failures | Cf |
| X | | | | | | Reduced plant down time | Cf |
| X | | | | X | | Improved maintenance of positive system pressure | Is |
| X | | | | | | Enhanced backflow and cross-connection prevention | Af |
| X | | | | | | Improved information database | Af |
| X | X | | X | | | Improved record keeping, documentation and formalization of procedures and activities | Af |
| X | | | | | | Improved senior management involvement | Ie |
| X | | | | | | Improved communication within the utility | Ie |
| X | | | | | | Improved communication with other stakeholders | Cp |
| X | | X | X | | | More focused monitoring and reporting | Af |
| X | X | | X | | | Systematic identification and prioritization of risks and control measures | Ie |
| X | X | | X | | X | Improved understanding of the distribution system, and potential factors affecting WQ | Ie |
| X | | | | | | Non-reliance upon end-product testing | Ie |
| X | | | | X | X | Risk mitigation | Af |
| | | | | | X | Better asset management | Fi |
| | | X | | | X | Improved regular maintenance (lower op costs) | Af |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | X | Improved operational monitoring capability | Af |
| | | | | X | X | Safe water benefits to consumer | Sw |
| | | | | X | X | Improves relationship/image with community | Cp |
| | | | X | | X | Demonstrating to community | Cp |
| | | | | | X | Decreases in water turbidity | Is |
| | | | | | X | pH consistently within standards | Is |
| | X | | | | | Improved water quality | Is |
| | X | | | | | Sound economic practices | Fi |
| | X | | | | | Provides contingency plan | Af |
| | X | | | | | Improved response time to failures | Af |
| | | X | X | X | | Assurance to DWSA of water quality | Am |
| | | | X | | | Identifies opportunities for capacity building | Ie |
| | | | X | | | Places renewed emphasis on NRW program | Fi |
| | | X | | | | Improved financial opportunities | Fi |
| | | X | | | | Improved diligence of staff | Am |
| | | X | | | | Adherence to SOPs | Cf |
| | | | | X | | Clean water to attract tourists | Other |
| | | | | X | | Continuous supply | Is |
| | | | | X | | Control of source water pollutants | Af |
| | | | | X | | Prevention of post-treatment recontamination | Cf |
| | | | | X | | Improved residual chlorine results | Is |

Note: Abbreviations used in **Table 9.**

| **DWSAs** | | **Benefit categories** | |
|---|---|---|---|
| **YVW** | Yarra Valley Water | **Cf** | Improved core functions |
| **MYD** | Maynilad Water Services, Inc. | **Af** | Improve ancillary functions |
| **K-A** | Koror-Airai Public Water Supply | **Ie** | Improvement enabler |
| **DWD** | Dasmariñas Water District | **Am** | Assurance, motivation and morale |
| **HUE** | Thua Thien Hue Water Supply & Sewerage Company | **Is** | Improved water quality indicator |
| **PKE** | Pakse Provincial Water Supply State-Owned Enterprise Champassack | **Fi** | Financial |
| | | **Cp** | Community perception and relationship |

The benefits for surveillance agencies (the Philippine Department of Health - PDoH, the Environmental Quality Protection Board -EQPB and the Hue City Preventive Medicine Center – HuePMC) were not analyzed, and are included in **Table 10**.

**Table 9: Benefits perceived by surveillance agencies.**

| **PDoH** | **EQPB** | **HuePMC** | |
|---|---|---|---|
| X | | | Proactive means of risk reduction |
| X | | | Reduced regulatory avoidance |

| | | | |
|---|---|---|---|
| X | X | | Stakeholders have uniform plan fostering collaboration |
| X | | | Potentially reduces number of compliance parameters |
| X | | X | Safe water for public health |
| | X | | Creates compliance plan |
| | X | | Assists (DWSA) in obtaining support from lending institutions |
| | X | | Demonstrates greater focus on protecting water |

## 5.1 Costs of WSP implementation

An accounting approach was used to study WSP implementation costs in six DWSAs in Australia, Lao PDR, Palau, the Philippines and Vietnam and four surveillance agencies. A summary of costs to DWSAs itemized by WSP step is included in **Appendix 2A**. Cost summaries for the surveillance agencies were not developed as some of the recorded costs were directly attributable to WSP implementation. Detailed costing for DWSAs and surveillance agencies are included in **Appendix 2C**. A summary of costs itemized by cost category are included in **Table 11** and are presented as costs per connection in **Table 12**.

**Table 10: Cost categories for all six case studies presented in international dollars**

| | YVW | MYD | K-A | DWD | HUE | PKE |
|---|---|---|---|---|---|---|
| Basic WSP non-recurring | 72,890 | 74,650 | Unknown | 14,010 | 16,560 | 2,740 |
| Basic WSP recurring | 41,290 | 2,420 | Unknown | 660 | 32,200 | 1,220 |
| DWSA specific non-recurring | 0 | 0 | 138,33 | 8,390 | 60,360 | 1,880 |
| DWSA specific recurring | 51,610 | 0 | 10,400 | 19,060 | 2,247,580 | 13,170 |
| **Total non-recurring** | 72,890 | 74,650 | 138,330 | 22,400 | 76,920 | 4,620 |
| **Total recurring** | 92,900 | 2,420 | 10,400 | 19,720 | 2,279,780 | 14,390 |

**Table 11: Cost categories for all six case studies in international dollars per connection**

| | YVW | MYD | K-A | DWD | HUE | PKE |
|---|---|---|---|---|---|---|
| Basic WSP non-recurring | 0.106 | 0.0796 | Unknown | 0.141 | 0.112 | 0.0309 |
| Basic WSP recurring | 0.0602 | 0.0026 | Unknown | 0.0066 | 0.218 | 0.0125 |
| DWSA specific non-recurring | 0 | 0 | 29.3 | 0.0844 | 0.408 | 0.0192 |

| | | | | | | |
|---|---|---|---|---|---|---|
| DWSA specific recurring | 0.0752 | 0 | 2.20 | 0.192 | 15.2 | 0.134 |
| **Total non-recurring** | 0.106 | 0.0796 | 29.3 | 0.225 | 0.520 | 0.0502 |
| **Total recurring** | 0.135 | 0.0026 | 2.20 | 0.199 | 15.4 | 0.147 |

## 5.2 Relationships between DWSA characteristics and WSP implementation benefit and cost types

The explanation building procedure was used to develop understanding about the relationship between the DWSA characteristics and the types of benefits and costs incurred during WSP implementation. The procedure results in an explanation framework presented here as a narrative. The narrative describes evidence for the DWSA costs of WSP implementation. Regarding costs, inherent in these results are the relative magnitudes of the cost types.

### 5.2.1 Benefits of WSPs

Benefits were organized into benefit categories and analyzed for patterns. A pattern does not readily emerge after comparing the data with the proposition.

### 5.2.2 DWSA-specific costs

An initial comparison of the total (non-recurring and recurring costs) with the DWSA groups does not reveal a readily identifiable pattern. The proposition was revised to incorporate the different types of non-recurring and recurring costs. Subsequent analysis applied the explanation building technique to the cost categories adapted from HACCP costing studies (Basic WSP and DWSA-specific). ‘Developed’ DWSAs are found to incur lower DWSA-specific (non-recurring and recurring) costs compared to non-‘developed’ DWSAs. DWSAs in the ‘developed’ group incur lower costs compared to non-‘developed’ DWSAs for DWSA-specific costs.

5.2.3 Basic WSP, non-recurring costs

Basic WSP, non-recurring costs capture the one-time cost of activities thought to be necessary to develop WSPs and implement its core functions. The ratio between the highest and lowest values in international dollars per connection is 4.6 – the lowest of all four cost categories (**Table 13**). These costs are found to be the most predictable of all cost types for developed and non-'developed' DWSAs. Comparison across DWSA groups reveals no pattern supporting the proposition that more 'developed' DWSAs will incur lower Basic WSP, non-recurring costs. Explanation for the consistent costs is found in the composition of the cost category. Staff time and WSP training make up the majority of the Basic WSP non-recurring costs for all DWSAs and are the most prevalent cost types in all cost categories.

**Table 12: Ratio between the costs of the highest and lowest DWSAs in each cost category.**

| | |
|---|---|
| Basic WSP non-recurring | 4.6 |
| DWSA-specific non-recurring | 1,526 |
| Basic WSP recurring | 84.5 |
| DWSA-specific non-recurring | 202 |

5.2.4 DWSA-specific, non-recurring costs

The original proposition holds when comparing the DWSA-specific, non-recurring costs across DWSA groups. There are no DWSA-specific, non-recurring costs for the 'developed utilities because many of the WSP 'findings' were already put in place by other programs and systems such as the Business Planning program at YVW and the ISO 9001 management systems at YVW and MYD.

For the non-'developed' group, the DWSA-specific costs vary significantly. Within the group, costs range from \$0.0192/connection for PKE to \$29.3/connection for K-A. DWSA-specific costs vary significantly among the non-'developed' DWSAs. An explanation for the variation is found by examination of the DWS-specific cost types. Cost types comprising the DWSA-specific costs include supporting programs and capital expenditures. These costs are shown alongside the Basic WSP costs in **Figure 5**.

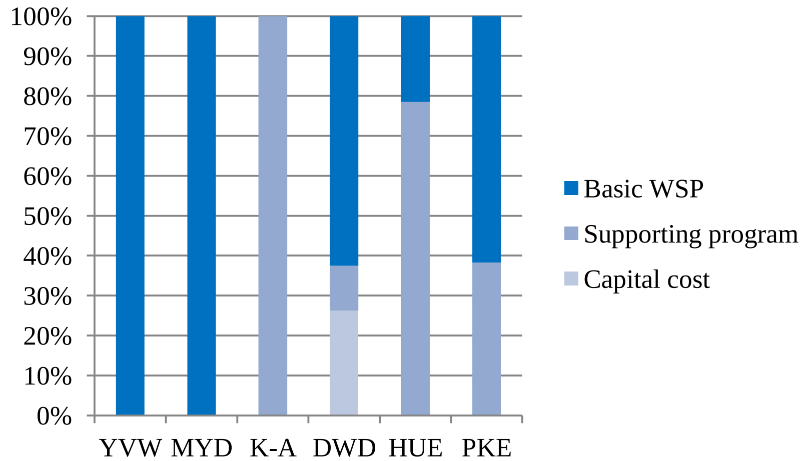


**Figure 5: The percent contribution of Basic WSP and DWSA-specific costs to non-recurring costs. The DWSA-specific costs of non-'developed' DWSAs consisted of supporting program and capital costs.**

5.2.5 Basic WSP, recurring costs

The Basic WSP, recurring costs varies widely across all DWSAs. This pattern does not support the proposition. The source of the variation is determined by the degree to which Basic WSP activities are implemented rather than the level of 'development' of the DWSA (**Figure 6**).

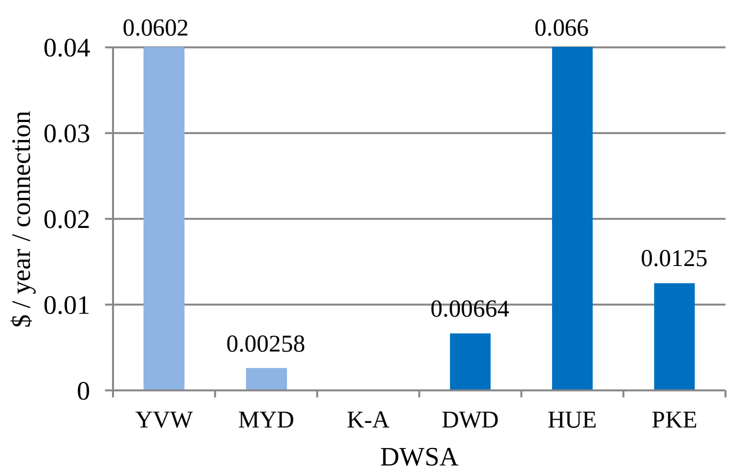


**Figure 6: Basic WSP recurring costs by DWSA. Significant variation exists among both 'Developed' and non-'developed' DWSA.**

YVW incurs Basic WSP costs due to staff time, training, and auditing. YVW staffs a HACCP coordinator who allocates 10% of their time to plan maintenance along with 10 other staff allocating 5% of their time throughout the year. Ongoing training costs include payment to a trainer as well as staff time costs of being trained. YVW audits their HACCP plan externally by hiring a third-party auditor (as per regulations) twice a year as well as internally using staff time. Additionally, annual reviews of the HACCP plan cost YVW additional staff time. MYD's Basic WSP costs are composed of annual external audits and biennial internal audits. Both are indicated to audit the WSP and the ISO 9001 together. MYD currently has no plan maintenance or training activities. The within-group difference between YVW and MYD is explained by the difference in the degree of implementation of Basic WSP activities. This pattern holds throughout all other DWSAs as indicated the Basic WSP costs. HUE has both WSP training and external auditing costs and PKE has training costs for a trainer and staff time. HUE's DWQM costs due to WSP implementation are $17,000 and account for roughly the half of the Basic WSP costs. After removing this cost, HUE's Basic WSP costs/year/connection are still more than 10 times higher than MYD and five times higher than DWD which does not have an auditing or training schedule. **Table 14** enumerates the number of Basic WSP cost types incurred by each DWSA.

**Table 13: Number of Basic WSP activities/cost types by DWSA. Cost totals correlate with the number of Basic WSP activities, or the degree of implementation.**

| Basic WSP cost type (recurring) | YVW | HUE | PKE | DWD | MYD | K-A |
|---|---|---|---|---|---|---|
| Staff time | X | | X | X | X | Unknown |
| DWQM | | X | X | | | Unknown |
| WSP training | X | X | | X | | Unknown |
| Auditing | X | X | | | | Unknown |

This evidence suggests the proposition should be reformulated to: Basic WSP, recurring costs are determined by the degree to which Basic WSP activities are implemented rather than the level of 'development' or the DWSA.

5.2.6 DWSA-specific recurring costs

The non-‘developed’ DWSA-specific recurring costs are higher than those of the ‘developed’ group. This pattern supports the original proposition. Further within group comparison shows that for the non-‘developed’ group, the DWSA-specific costs are larger than the basic WSP costs and form the majority of the recurring costs (**Figure 7**). The ratio of the DWSA-specific to Basic WSP costs/connection is 28.9, 69.7, and 10.8 for DWD, HUE and PKE respectively. DWSA-specific costs are also highly variable. The recurring costs are composed of capital costs, operational monitoring and supporting programs. This pattern indicates that total recurring costs in non-‘developed’ DWSAs are sensitive to DWSA-specific activities, predominantly operational monitoring and capital costs.

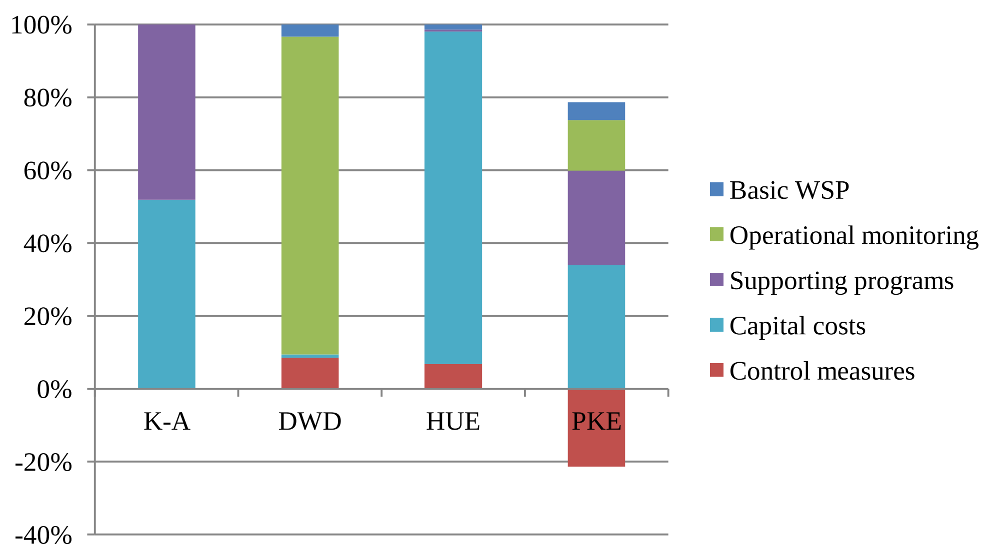


**Figure 7: Recurring costs for non-'developed' DWSAs primarily consist of capital and operational monitoring costs.**

5.2.7 DWQM costs

HUE and PKE experienced increases in DWQM costs as a result of WSP implementation. There were no cost changes in DWQM programs at YVW, MYD and DWD. MYD had indicated they were currently testing at or above the level required by the Philippine National Standards for Drinking Water. DWD noted changing their DWQM program because of the Philippines National Standards for Drinking Water and saw no reason to change the sampling frequency. However, DWD changed the location of sampling points based on information learned in the system description step of the WSP. There is no data regarding changes in DWQM costs due to WSP implementation at K-A. There is no discernable relationship between WSP implementation and changes in DWQM costs.

# 6 Discussion

## 6.1 Results

Benefit types received from participants in this study were similar to those identified in the literature. This work attempted to organize the benefits based on the primary or initial point in the system where the benefit was detected and discern patterns between the benefit categories and the development of the DWSA. No pattern readily emerged which suggests the benefits may be specific to characteristics other than those identified by the DWSA categories ('developed' and non-'developed'). Perceived benefits are also thought to be different depending upon the type of respondent (e.g. water quality manager, technician, CEO). The basis for the categorization of benefits was primarily developed by the researcher as there was little organization of the benefits applying directly to WSP/HACCP in water supply. It is recognized that the development of a pattern is highly dependent upon the information gained from the participants. Benefits can be intangible and not countable. They apply to an aspect of a system and can propagate subsequent benefits identified at other parts of the system making it difficult to quantify discrete 'benefits'. The understanding of any patterns is highly dependent upon the conceptual basis of the categories.

The Martel case studies of five 'developed' water utilities in Australia (one of which is YVW) are comparable to YVW and MYD. The within-group ('developed' DWSAs) explanation for cost patterns in initial development costs was not consistent with the findings of this research. Cost differences resulted from the extent to which external service providers were used and the degree to which WSP steps were already completed prior to the formal beginning of WSP development. Cost pattern explanations for recurring Basic WSP costs, however, were consistent with the findings of this research. The costs of Basic WSP are very low considering annual total operations and maintenance expenditures of YVW, MYD, K-A and DWD. DWSA-specific costs have been difficult to estimate concretely in the food industry precisely because of its context dependence. These results validate the application of costing categories and techniques from HACCP studies in the food industry to WSP studies.

MYD and DWD, at the time of the study noted WSP improvements were not executed. MYD's WSP includes several capital improvements that had yet to be completed at the time of the research (**Appendix 2C**). DWD indicated funding for larger capital improvements and technical capacity were obstacles to the implementation of a non-revenue water program and internal training and auditing programs respectively. A preliminary evaluation of HACCP implementation in Iceland shows limited resources as a challenge to implementation of auditing functions (Gunnarsdottir). This suggests that financial and technical capacities limit the implementation of both Basic and DWSA-specific implementation costs. However, the developed DWSAs in the Martel study found that the benefits of HACCP outweighed its costs and continued to be audited and registered each year (Martel et al.). While WSPs may identify and prioritize investment areas requiring large capital inputs, DWSAs may find it difficult to mobilize the proper resources to address them. This consideration is more relevant for non-'developed' DWSAs as the findings show DWSA-specific capital, supporting program and operational monitoring costs are significantly larger than Basic WSP costs and account for a majority of the recurring costs of WSP implementation. Predicting DWSA-specific costs for individual non-'developed' DWSAs may prove to be difficult given the variable nature of these costs.

Lastly, WSP implementation was not found to change DWQM costs for either DWSA group. DWSAs at which DWQM costs did not change cite adequate monitoring and regulatory reasons for maintaining DWQM sampling frequencies. The reasons for increases in DWQM costs at HUE and

PKE were not obtained. DWQM costs did increase for two surveillance agencies: the Preventive Medicine Center in Hue and the Environmental Quality Protection Board. At the Hue PMC, the baseline sampling frequency and the sampling frequencies after flooding increased. At the EQPB in Palau, the sampling of chemical parameters increased while the sampling frequency for microbial parameters did not change. The analysis for the chemical sampling is done by a non-EQPB laboratory and is relatively expensive for EQPB. Previously, chemical sampling was not performed, but because the WSP emphasized the need to monitor, it is budgeted to occur.

## 6.2 Limitations

Limitations on the results of the research stem from data quality, case selection and determining the definition of a WSP cost.

Relative to the other case studies, sources of evidence from PKE and HUE were limited. Convergence of multiple sources of evidence is important in qualitative research to improve the validity of the data. Cost explanations in these DWSAs were limited and the costing results should be interpreted with caution.

A majority of the selected case studies were involved in an ongoing WSP program under the WHO. Although there was significant diversity in the level of 'development' of DWSAs, the selected cases may not support analytic generalization of the results. Costing results for individual DWSAs should be interpreted relative to the other DWSAs in the study.

The factors determining when and to what extent DWSA's implement WSP findings are unknown. MYD and DWD at the time of the study noted several WSP improvements that were not executed. MYD's WSP includes several capital improvements that have yet to be completed (**Appendix 2C**). The 'cost of WSP implementation' is dependent upon the definition of each term in this phrase. The researcher interpreted 'implementation' to mean activities or improvements for which resources have been spent or budgeted at the time of data collection. This definition does not account for those projects that have yet to be completed.

Furthermore, these results may be biased toward the explicitly WSP-related costs such as those included in the Basic WSP category. DWSA-specific costs are predominantly activities that are regularly performed by the DWSA, it may be more difficult to parse these costs from regular operation, whereas the Basic WSP costs may be easier to identify. Detailed financial information of the DWSAs may contain such information, but may not be feasible to obtain.

## 6.3 Areas of future research

Further research may seek to improve or standardize the conceptual basis for the benefit categories used to analyze the data. To further explore the relationship among the benefits, one may categorize the benefits as Basic WSP and DWSA-specific in a manner similar to the costs. However, this would require a strong conceptual basis that may be adapted from other qualitative fields of research. The types of perceived benefits are also expected to vary based on the position of the research participant in the DWSA (water quality manager, technician, and CEO, etc.), future qualitative studies may benefit from performing focused interviews with participants at different levels of each DWSA. Similarly, future studies will benefit from a variety of sources of evidence using multiple qualitative research approaches. The quality and number of sources of evidence should be consistent across each DWSA.

The results from this research provide a more refined system of hypotheses for understanding WSP implementation costs. This can be used as a basis for further inquiry into the relationship between DWSA characteristics and WSP implementation costs. The creation of more comprehensive or alternative group of DWSAs may refine the resolution of results. Future studies should endeavor to create a case selection strategy with a strong analytical basis. The case studies should be analytically representative and cost results should be compared to validate or refute existing cost hypotheses.

Further analysis may reflect on how to account for the degree to which DWSAs have performed the activities or findings of the WSP. The degree of implementation will clearly affect the cost magnitudes. For this reason, a more extensible study should have a means of accounting for the various levels of implementation for both Basic WSP and DWSA-specific costs. This is made difficult because WSPs are evolving documents and should be continuously identifying areas of improvement. Amount of time passed since the ‘implementation’ of the WSP may be a proxy for degree of implementation. An alternative measure of the degree of implementation may be relative to the original WSPs schedule of improvements.

Improvements such as WSPs have the potential to increase society’s welfare; therefore, a more complete analysis would include costs and benefits of groups outside of DWSAs and surveillance agencies. For decision makers seeking to expand those with standing to include more groups, an economic analysis of costs and benefits should be the chosen method of study. The financial costing performed in this analysis can be used as a precursor to such a cost-benefits analysis. These results provide insight into the relationships between DWSAs and costs. This provides a theoretical basis upon which larger scale quantitative studies can base their costing assumptions. Analogous HACCP

studies in the food industry have quantified costs and benefits of quality management regulations at larger scales in (Antle and Crutchfield et al.) and produced guides for doing so in (Krieger, Schiefer and da Silva) and (MacDonald, J. M. and Crutchfield, S.). Significant lessons can be learned from the quantitative approach of performing cost-benefit analyses for HACCP regulation.

# 7. Conclusion

Improving the availability of safe water for drinking, sanitation and hygiene is fundamental to public health and the development process. Water Safety Plans present a risk management system to effectively provide safe water. The application of the plan will result in different types of benefits and costs depending on the characteristics of the drinking-water supply agencies (DWSAs). Currently, there is a lack of information relating DWSAs and expected costs and benefits of WSP implementation. This research presents cost analysis case studies of WSP implementation in DWSAs of reticulated systems from Australia, Lao PDR, Palau, the Philippines and Vietnam. Costing practices are adapted from HACCP costing studies from the food industry to illustrate the types and magnitudes of WSP costs. A case study data analysis procedure called explanation building is used to develop an explanation framework for the relationship between DWSAs and WSP costs. This research contributes to the very small body of empirical WSP cost studies; provides an evidence base to improve WSP cost estimations and future studies; and validates the adaptation of select HACCP costing practices to WSP costing studies.

The results show no readily understandable pattern in the types of benefits accruing to different types of DWSAs. Among the case studies, drinking-water quality monitoring costs are not found to be influenced by the implementation of WSPs. One-time development costs of a quality assurance program such as a WSP are generally low and predictable regardless of level of development of the supplier. However, costs of maintaining quality assurance will vary depending on the degree to which the basic water safety plan activities have been implemented. The costs of achieving water safety are low for developed DWSAs on account of the existing programs that have implemented appropriate measures to achieve an adequate and consistent supply of safe water. Less developed DWSAs experience large and highly variable capital and operational monitoring costs that are fundamental to achieving safe water supply. These results further indicate future study in the relationship between DWSA characteristics and costs may not improve the WSP implementation costs of individual, less developed DWSAs because of the inherent variability in these costs.

DWSAs may require initial technical input to implement quality assurance programs; however developing DWSAs may require ongoing financial and technical resources to execute the activities and physical improvements necessary to achieving a safe water supply. For larger scale studies of the cost and benefits of WSPs, these findings suggest potential lessons to be learned from analyses performed in the food quality management sector.

# APPENDIX 1A: Brief introduction to project

## DO NOT DISTRIBUTE

## Questionnaire: Cost analysis of drinking-water quality management plans and traditional end-point monitoring

***Goal***

The goal of the project is to develop information about the costs associated with the initial development and maintenance of Water Safety Plans and traditional end-point drinking-water quality monitoring programs.

***Executive summary of research***

While monitoring is critical in verifying the system of quality control measures on the whole, these types of traditional methods alone for the control of microbiological quality of drinking-water are inadequate (Howard). Drinking-water quality management plans such as Water Safety Plans, Hazard Assessment and Critical Control Points (HACCP), and Public Health Risk Management Plans are examples of effective means of providing safe water and are being or have been implemented throughout the Asia Pacific region. There is very little information in the published literature regarding the costs to water supply agencies and surveillance monitoring agencies of implementing and maintaining such drinking-water quality management plans (DWQMPs) in comparison to traditional, end-point drinking-water quality monitoring. Information regarding the change in costs to both water supply agencies and surveillance agencies may be useful information for decision makers considering the adoption and implementation of drinking-water quality management plans.

***Notes***: Often times it is difficult to capture the complexity of the answer in written text, therefore, it is our belief that a telephone or Skype interview will make this exchange of information more efficient. If you are willing and available to be interviewed by voice, please contact Kang Chang (kchang8@email.unc.edu) to arrange a suitable date and time.

Data provided by individuals will provide data to characterize the country as a whole and will not be linked to individuals providing data.

For any questions regarding terminology, please see the list of definitions below.

Do not feel pressure to provide a response to each question. A response of 'I don't know' is useful information and is not discouraged.

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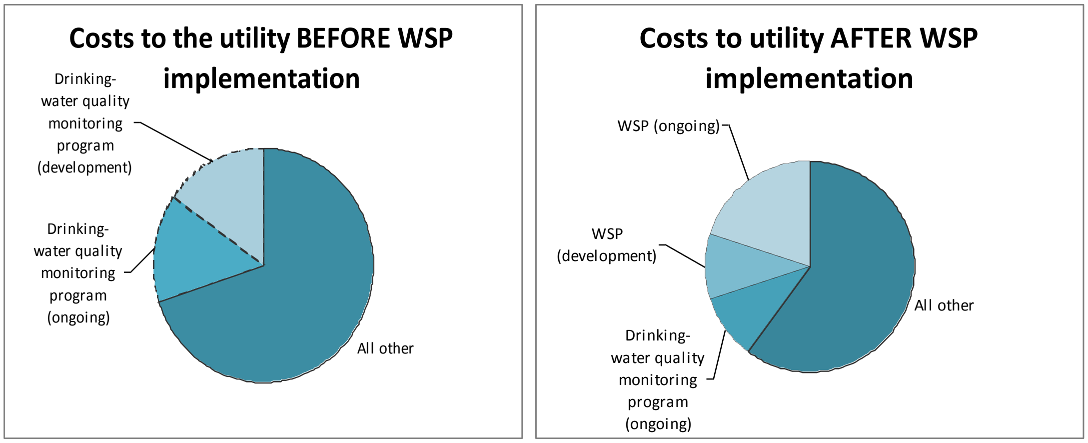
# APPENDIX 1B: Questionnaire template

Below is a graphical overview of the types of costs of interest to this study.




Below is an overview of the purpose of each of the sections of the questionnaire

| **Section of the questionnaire** | **Purpose** |
|---|---|
| 1. General information and perceptions | Gain information to describe the utility and understand the perceived advantages and disadvantages of WSP implementation and traditional end-point monitoring. |
| 2. General utility data | Gain information to develop basic characteristics of the utility. |
| 3. General cost parameters | Gain cost parameters to estimate cost of the drinking-water quality monitoring program in place before the WSP. |
| 4. Pre-WSP Drinking-water quality monitoring program costs | Gain information to be used to estimate the cost of the drinking-water quality monitoring program in place before the WSP. |
| 5. General WSP information | Gain information to determine the WSP's scope. |
| 6. WSP Initial development costs | Gain information to estimate the cost of the initial development of the WSP. |
| 7. Change in drinking-water quality monitoring activity | Gain information to estimate any change in the cost of drinking-water quality monitoring activity before and after the WSP. |
| 8. Cost of activities directly related to WSP implementation | Gain information to estimate the costs associated with WSP implementation. |

## 1. General information and perceptions

**Purpose**: Gain information to describe the utility and understand the perceived advantages and disadvantages of WSP implementation and traditional end-point monitoring.

1. Please select the choice the best describes you. Select all that apply.
    a. A representative of a: i. Water utility/supplier, ii. Water utility regulator, iii. Water quality surveillance organization, iv. Community water management, v. standard setting organization, vi. Water-related government agency, vii. Other: (please list)
    b. What is the name of the organization you represent?
    c. I am able to share information about drinking water quality monitoring as it relates to: i. Urban water systems, ii. Community or rural water systems, iii. Regulations, iv. Standards, v. WQ Analysis

2. What are the perceived advantages of WSP implementation?

    i. Is there any quantifiable evidence for any of the above statements (e.g. compliance rates, etc.)?

3. What are the perceived disadvantages of WSP implementation?

4. What are the perceived advantages and disadvantages of traditional end-point monitoring?

5. What are the reasons why the utility implemented the WSP?

## 2. General utility data

**Purpose:** Gain information to develop basic characteristics of the utility.

6. What is the number of connections, daily produced volume, and type of service provided (distribution only or treatment and distribution)?

7. What percentage of the source water is:
    a. ground water (%):
    b. surface water (%):

8. What organizations perform treatment, management of the distribution system, drinking-water sampling, analysis, management, or other functions involved in water supply?

| **Function** | **Organization** |
|---|---|
| Bulk water supply | |
| Treatment | |
| Distribution | |
| Water quality analysis | |
| Other | |

## 3. General cost parameters

**Purpose:** Gain cost parameters to estimate cost of the drinking-water quality monitoring program in place before the WSP.

9. What is the current number and type (managers, lab technicians, samplers etc.) of staff involved in drinking-water quality monitoring?

| **Number of Staff** | **Type of staff** | **Annual salary** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

10. What is the per-test cost (please specify currency) for the most frequently used methods of analysis?

| | | **Types of costs included in the per-test cost figure (Please check with an 'X' all that apply)** | | | | |
|---|---|---|---|---|---|---|
| **Name of method of analysis** | **Cost per test (Specify currency)[1]** | Consumables | Staff time | Private Lab rate | Laboratory operation and maintenance | Other (please describe below) |
| 1. | | | | | | |
| 2. | | | | | | |
| 3. | | | | | | |
| 4. | | | | | | |
| 5. | | | | | | |

a. Please describe the "Other" type of cost included in the per-test cost figure:

## 4. Pre-WSP Drinking-water quality monitoring program costs

**Purpose**: Gain information to be used to estimate the cost of the drinking-water quality monitoring program in place before the WSP.

11. What is the average total, annual budget of the utility?

12. If this has changed since the implementation of the WSP please estimate this change.

13. What was the total, annual cost of the drinking-water quality monitoring program before the implementation of the WSP?

14. What is the number of drinking-water quality monitoring samples that were taken previous to the implementation of the WSP?

[1] If cost per test values are not given, please indicate the units of the provided cost figure.

If this has changed after the implementation of the WSP please estimate this change or provide the number of samples taken before and after WSP implementation.

## 5. General WSP information

**Purpose**: Gain information to determine the WSP's scope.

15. Were there any management systems in place (ISO 9001, etc.) before the implementation of the WSP (Yes/No)?

    a. Name of the system:
    b. Scope of the system:
    c. Start date of the implementation (MM/DD/YYYY):

16. What were the beginning and end dates (MM/DD/YYYY) of the WSP development?

17. When did the WSP implementation begin (MM/DD/YYYY)?

18. To what degree has the WSP been implemented (Completely, nearly all steps, about half of all steps or a few of the steps)?

## 6. WSP initial development costs

**Purpose**: Gain information to estimate the cost of the initial development of the WSP.

19. Please describe the WSP team (the number of participants, their respective organizations).

| **Number of participants** | **Organization** |
|---|---|
| | |
| | |
| | |
| | |
| | |

20. Please describe the resources used to develop the WSP (time of staff, hours spent, monetary resources for consultants etc.)?

21. Please give an estimate of the annual salary of any or all of the participants.

## 7. Change in drinking-water quality monitoring activity

**Purpose:** Gain information to estimate any change in the cost of drinking-water quality monitoring activity before and after the WSP.

22. Has there been a change in the annual costs or activities of the drinking-water quality monitoring since the implementation of the WSP (Yes/No)? If so, please describe the

changes to the monitoring program (eg. Changes in number of samples taken, changes in staff hours, other):

## 8. Cost of activities directly related to the WSP implementation

**Purpose**: Gain information to estimate the costs associated with WSP implementation.

23. Has there been any change in the activities performed by staff (operational monitoring, supporting programs, etc.) due to the WSP implementation? If so, please describe while including estimated annual costs (please specify currency) and/or time spent and whether the activity represents an increase, decrease, no change or unknown change in costs

| **Additional activity** | **Description of annual cost (dollars, time, other)** | **Cost compared to pre-WSP: "Increase", "decrease", "no change" or "unknown"** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

24. Have there been any new hires e.g. champion or coordinator, technical specialist, etc. as a result of the WSP implementation (Yes/No)?

    a. If yes, please describe annual salary (please specify currency) and percentage of time allocation to WSP activities.

25. Have there been, or will there be any capital improvements resulting from the WSP? If yes, please describe the improvement(s) and the total estimated costs (please specify currency).

26. Please estimate the annual cost of staff training resulting from the WSP?

27. Please describe the annual costs of any auditing activities.

28. Please describe any other costs to the utility for WSP implementation and maintenance.

Thank you for completing the survey. The information you provide is critical in helping other countries understand the costs associated with implementing drinking-water quality management programs. If applicable, please attach any relevant documents that are referenced in the provided answers.

Sincerely,

Kang Chang

Graduate Research Assistant, The Water Institute at UNC
UNC Gillings School Of Global Public Health
Department of Environmental Sciences and Engineering
Chapel Hill, North Carolina, USA

# APPENDIX 1C: Definitions

All definitions were adapted for the purpose of this questionnaire and were not intended to be used otherwise.

Adapt- Adjust, accommodate and or modify a method, practice or ideology to the local conditions.

Adopt- Receive and or acquire methods, practices, or ideologies created by others and take them on as your own.

Develop a WSP- Adopt and adapt a WSP methodology to the local water supply system.  The creation of the water safety plan itself.  Development of a WSP is a primarily the creation, formalization, and collation of the documents necessary to produce a water safety plan. The WSP can be developed throughout all of the water supply or only in a part of it.

Drinking-water Quality Management Plan (DWQMP)- A general term for the types of approaches that seek to assesses and manages risks to drinking-water quality.  This can include good management practices such as HACCP as well as Public Health Risk Management Plans.

Drinking-water quality monitoring- This term will only refer to the actions directly involved in monitoring the quality of the drinking-water.  This involves sampling (transportation), analysis and reporting of results.  This definition does NOT include operational monitoring of control points such as inspecting infrastructure integrity or monitoring source protection measures such as fences.

Drinking-water samples (samples)- This term refers to samples taken after any treatment process. These samples should reflect the quality of the water being consumed and can be taken from any site after the treatment plant up until the consumer's tap.

Hazard Analysis Critical Control Points (HACCP)- HACCP is a management tool used to evaluate the hazards and establish systems of control that focus on prevention of hazardous events rather than reacting to hazardous events measured in the product inspections.

Implement a WSP- To put in place a functioning WSP or act upon the activities described in the water safety plan.  The level of implementation will depend on the number of steps made functional within the specific WSP.

ISO 9001 – Specifies the requirements a quality management system.  Goals of the standard are to produce products that meet customer, regulatory and other requirements and aim to enhance customer satisfaction.  This standard is created by the International Organization for Standards.

Operational water quality monitoring- the conduct of planned observations or measurements to assess whether the control measures in a drinking-water system are operating properly" (WHO, 2004). This form of monitoring is typically conducted by the drinking-water supplier and will vary in nature and frequency based on the characteristics of the system being monitored i.e. an urban piped systems compared to a rural surface water abstraction. Results should be recorded, but do not have to be in order to be considered operational water quality monitoring.

Supporting program- A supporting program is an action or series of actions important to ensuring drinking-water safety, but is not directly affecting the quality. Examples of supporting programs include: developing protocols for the use of chemicals and materials in drinking-water supplies, using designated equipment in installation, sanitary surveys and repair of infrastructure, training and educational programs for personnel involved in activities affecting water quality. Characteristics of these programs include risk avoidance and recovery, comprehensive assessment, critical limit monitoring, recordkeeping, verification/audit and update/improvement.

Surveillance water quality monitoring- The World Health Organization defines drinking-water supply surveillance as "the continuous and vigilant public health assessment and review of the safety and acceptability of drinking-water supplies" (WHO, 1976). It is further described as complementary, not a replacement, to the quality control function of the drinking-water supplier (operational water quality monitoring). Authorities responsible for surveillance may be public health ministries or related agency. It is also referred to as compliance monitoring. Activities involved in Surveillance water quality monitoring can include sanitary inspections, direct assessment water quality monitoring, and operational monitoring data audits. For the purpose of this project, our definition of surveillance monitoring will not include operational monitoring data audits.

Method of analysis, or test method- Specifications for the detection and enumeration in water of culturable microorganisms. Should at least include specifications for culturing, inoculation, incubation, examination, and enumeration of organisms. Examples of test methods include the ISO 9308-1:2000 – Water quality – Detection and enumeration of Escherichia coli and coliform bacteria – Part 1: Membrane filtration method and EPA Method 1604: Total Coliforms and Escherichia coli in Water by Membrane Filtration Using a Simultaneous Detection Technique (MI Medium). The term can also refer to generic methods of analysis such as membrane filtration method or most probable number method. Can also be referred to as analytical methods and/or techniques.

Water Supply Agencies-

1. A public or private entity who owns and/or operates a (public) water system

2. A public or private entity who owns and/or operates only the distribution aspect of water supply.

Water supply system- The entities, actions and infrastructure necessary to collect, treat, store, and distribute potable water from source to consumer.

# APPENDIX 2A: Cost estimates summary

| | YVW | MYD | K-A | DWD | HUE | PKE |
|---|---|---|---|---|---|---|
| ***Basic WSP*** | | | | | | |
| Staff time | | | | | | |
| *non-recurring* | 18,364 | 58,538 | three months | 6,815 | 14,991 | 2,757 |
| *recurring* | 22,254 | 701 | - | 328 | - | -[1] |
| Change in DWQM | | | | | | |
| *non-recurring* | - | - | Unknown | - | Yes, unknown | - |
| *recurring* | - | - | Unknown | - | 16,948 | 1,221 |
| WSP training | | | | | | |
| *non-recurring* | 54,522 | 16,112 | - | 7,195 | 1,568 | 275 |
| *recurring* | 4,423 | - | - | 332 | 12,227 | - |
| Auditing | | | | | | |
| *non-recurring* | - | - | - | - | - | - |
| *recurring* | 14,609 | 1,714 | - | - | 3,026 | - |
| ***DWSA-specific*** | | | | | | |
| Control measure | | | | | | |
| *non-recurring* | - | - | - | - | - | - |
| *recurring* | - | - | - | 1,680 | 155,075 | (5,374) |
| Operational monitoring | | | | | | |
| *non-recurring* | - | - | Unknown | - | - | - |
| *recurring* | - | - | Unknown | 17,205 | Yes, unknown | 3,493 |
| Supporting program | | | | | | |
| *non-recurring* | - | - | 138,333 | 2,517 | 60,357 | 1,883 |
| *recurring* | 51,613 | - | 5,000 | - | 13,316 | 6,523 |
| Capital maintenance | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *non-recurring* | - | - | - | 5,871 | - | - |
| *recurring* | - | - | 5,396 | 176 | 2,079,189 | 8,531 |
| Basic WSP non-recurring | 72,886 | 74,650 | - | 14,010 | 16,558 | 2,736 |
| Basic WSP recurring | 41,287 | 2,415 | - | 660 | 32,201 | 1,221 |
| DWSA specific non-recurring | - | - | 138,333 | 8,387 | 60,357 | 1,883 |
| DWSA specific recurring | 51,613 | - | 10,396 | 19,061 | 2,247,580 | 13,173 |
| **Total non-recurring** | 72,886 | 74,650 | 138,333 | 22,397 | 76,916 | 4,619 |
| **Total recurring** | 92,899 | 2,415 | 10,396 | 19,721 | 2,279,782 | 14,394 |
| External WSP non-recurring costs | Unknown | 4,758 | 8,970 | - | 972 | 2,944 |
| External WSP recurring costs | Unknown | 2403[3] | 3,000 | -[3] | -[2] | Unknown |

Note: All costs can be converted into the local currency unit by multiplication of the given figures by the following 2009 PPP exchange rates: 1.55 for Australian dollars, 27.13 for Philippines pesos, 8,260.51 Vietnamese dong, 1 for U.S. dollars, and 4,093.67 for kip.

[1]Costs are also incorporated into the recurring maintenance costs

[2]Costs of PMCs not included

[3]Costs represent DoH staff time. It is split between Maynilad and Dasmariñas Water District.

# APPENDIX 2B: DWSA characteristics

| DWSA | Class | Employees/ 1000 connections | # of connections | NRW (%) | Average production (1000 $m^3$/day) | QM system | WSP development | WSP implementation date |
|---|---|---|---|---|---|---|---|---|
| YVW[1] | State owned corporation | 0.846 | 685,918 (2009) | 13 | 116,000 | Yes | Yes | 1999 |
| MYD[2] | Private corporation | 2.26 | 937,578 (2011) | 50 | 2,149 | Yes | Yes | 2007 |
| K-A | Government department | 5.30 | 4,721 (2009) | 42 | 15.141 (capacity) | No | Yes | 2009 |
| DWD | State owned enterprise | 6.75 | 99,346 (2011) | 25 | 70.659 | No | No | Ongoing |
| HUE | State owned enterprise | 8.24[3] | 147,836 (2011) | 15 | 134.4 | Yes | No | 2007 |
| PKE | Government department | No data | 98,000 (2010) | Under 20 | 12.795 | No | Yes | 2006 |

[1]Scope of operations does not include abstraction or primary treatment and includes wastewater distribution.
[2]Scope of operations includes wastewater management.
[3]Number of employees and number of connections are from 2005.

# APPENDIX 2C: Results of individual case studies

## 1. Yarra Valley Water, Ltd. (YVW) Melbourne, Australia

Yarra Valley Water was established under the State Owned Enterprises Act 1992, as a state-owned company. It operates under a water and sewerage license in the northern and eastern suburbs of Melbourne. YVW employs 580 employees (2011) to perform distribution of water and wastewater services (Yarra Valley Water). YVW purchases bulk water that come entirely from surface water sources. The daily distribution of 116 million cubic meters of water (Yarra Valley Water) to the estimated 685,920 connections (2009) is managed under several management systems: ISO 9001 certified in 1995, ISO 14001 certified in 1996 (Martel et al.) and standard operating procedures, general operation manuals and documented quality procedures established in 1999. Yarra Valley Water also maintains a Business Planning process that identifies potential large cost items. Sources of investment funds consist of both internally and externally generated funds including deposits with banks, accounts receivable and payable, short and long term borrowings with the Treasury Corporation of Victoria (TCV) and leases. Annual operations and maintenance costs in 2010 were $84,733,165 and total capital expenditure over the last five years is $678,090,500 (Yarra Valley Water).

YVW developed a HACCP plan with external consultants and was HACCP 9000 certified in 1999 (Martel et al.). The perceived benefits and challenges of the WSP are included in the table below: Information on benefits includes that published in Martel (2006) and Jayaratne (2008).

| Perceived benefits | Perceived challenges |
| --- | --- |
| • Reduced water quality incidents, chlorinator failures, and plant down time.<br>• Improved understanding and maintenance of positive system pressure.<br>• Enhanced backflow and cross-connection prevention. | • None identified. |

| | |
|---|---|
| • Improved (information) databases and record keeping, improved senior management involvement, and communication within the utility and between the utility and external.<br>• More focused monitoring and targeted reporting.<br>• Systematic identification and prioritization of risks and control.<br>• Improved understanding of the distribution system.<br>• Non-reliance upon end product testing<br>• Risk mitigation | |

The costs of the WSP implementation are included the table below:

| | |
|---|---|
| Total non-recurring implementation costs | $72,890 |
| Total recurring implementation costs | $92,800 |

| **Basic WSP** | % of non-recurring costs | Costing parameter | % of recurring costs | Costing parameter (annual) |
|---|---|---|---|---|
| Staff time | 25% | 720 | 24% | 1,280 |
| DWQM costs | 0% | | 0% | |
| Auditing | 0% | | 16% | 56 hours |
| Training | 75% | N/A | 4% | 200 hours |
| **DWSA-specific** | | | | |
| Control measures | 0% | | 0% | |
| Operational monitoring | 0% | | 0% | |
| Supporting program | 0% | | 56% | 1 hire |
| Capital costs | 0% | | 0% | |

The initial development of the HACCP plan took an estimated 720 hours from one HACCP coordinator working full time for three months and 24 HACCP team members working part time. 80 additional hours of staff time are spent undertaking annual reviews of the plan. Costs for training on HACCP principles are combined with the costs of technical advice from external consultants and documentation of procedures. Since the development of the plan there are HACCP plan maintenance costs of 1,200 hours per year involving the HACCP coordinator and 10 other staff. HACCP awareness training costs YVW a total of 200 hours per year to train 20 staff. YVW conducts internal audits of the plan that cost YVW 56 hours annually.

DWSA-specific costs include enhancing the existing backflow prevention program by hiring a backflow prevention officer.  Capital costs incurred through the program were recognized before HACCP implementation and therefore not included.

Two program improvements have been proposed as a result of HACCP implementation, but have yet to be approved are further improvements to the backflow prevention program, estimated at $64,500 and a tank maintenance program improvement estimated at $193,550.  The following programs were identified through HACCP, but were not given cost estimates:  tank inspection and maintenance program, improved spot chlorination method, improved storage area security procedures, equipment calibration program, treatment chemical handling procedures, and incident and emergency management protocols (Jayaratne).  To obtain monetary values in local currency, multiply the given international dollars by the 2009 PPP exchange rate of 1.55.

## 2.  Department of Health, Victoria, Australia

The Drinking Water Regulatory Unit of the Department of Health enforces compliance with the Safe Drinking Water Act and its subsequent regulations.  The Department of Health develops the Act and its regulations and administers all of its aspects.  In addition to other requirements, the Safe Drinking Water Act 2003 requires suppliers to prepare and implement plans to manage risks in relation to drinking water and some types of non-potable water (Ministry of Health).  Significant resources from the Ministry of Health were invested in developing this legislation, only a portion of which concerns WSPs.  The portion of the cost of developing and administering the Act attributable to WSPs cannot be parsed, therefore, all costs related to developing and administering the Act are presented below with this understanding.  The Act requires water suppliers and water storage managers to pay an administrative levy to the DoH to cover the administrative costs associated with the Act.  To obtain monetary values in local currency, multiply the given international dollars by the 2009 PPP exchange rate of 1.55.

**Adapted from the Department of Health, Victoria, Australia** (Department of Health)

| **Activities** | Description | Cost |
|---|---|---|
| Development of The Safe Drinking Water Act (2003) | Preparation for legislating WSPs as a requirement | $603,270 |
| **Administering the Act** | | |
| 2004-2005 | Costs include salaries, indirect costs, operating costs, communication and education and research and development | $454,000 |
| 2005-2006 | Additional costs of IT development | $635,100 |
| 2006-2007 | None | $623,970 |
| 2006-2007 | Development of the Auditor Certification program. Independent auditors are certified in order to audit HACCP. | $4,460 |
| 2007-2008 | None | $659,040 |
| 2008-2009 | None | $671,030 |
| 2009-2010 | None | $603,210 |
| **Total** | | $4,254,080 |

The DoH played a significant role in the implementation of WSPs at the utility level throughout Victoria. Since 2004 the activities of the DoH have shifted largely from implementing the Act to greater involvement in surveillance or ensuring compliance with requirements of the legislation.

## 3. Provincial Water Supply State-Owned Enterprise Champassack (Pakse), Pakse, Lao People' Democratic Republic

Pakse is the capital town of the Champassack province. The Provincial Water Supply State-Owned Enterprise (PNP) Champassack is responsible for the water supply throughout the province including Pakse. The water supply facilities at Pakse are under the management of PNP Champassack and perform all functions of water supply from abstraction to distribution including analysis of drinking-water quality samples. Pakse draws 100% of its source water from the Mekong River. The 98,000 (2010) connections are supplied by two treatment plants employing conventional treatment systems to produce an average of 12,795 cubic meters per day. There were no quality management systems in place prior to WSP implementation.

The Provincial Department of Communications, Transport, Post and Construction began the development of Lao PDR's first WSP with the establishment of the Pakse WSP team in May of 2006 (PNP Champassack). Funding assistance was provided by the Australian Government Overseas Aid Program, AusAID to WHO for technical assistance. Other ministries were active in collaborating with Pakse during the plan's development. Implementation of the plan began later in 2006.

The perceived benefits and challenges of the WSP are collected by the DWSA are included in the table below:

| Perceived benefits | Perceived challenges |
|---|---|
| • Better asset management- identified the need for regular maintenance which results in lower operational costs.<br>• Better understanding of water supply system, how to monitor risks; how to mitigate; identify need to replace pipes, valves and old water meters.<br>• Providing safe water reliably is a long term benefit to the customer.<br>• Improved image of the company – demonstrating to the community that the company was making changes for the benefit of the people of Pakse.<br>• Water turbidity in some areas has dropped from 17.2 with NTU to just 0.66 NTU, while pH is consistently within MOH guidelines (Gherardi 33). | • Initially, it costs money which may require utilities to take on undesirable financial risks.<br>• No previous experience with anything like WSPs. |

Costs of WSP implementation are included in the tables below.

| | |
|---|---|
| **Total non-recurring WSP implementation costs** | $4,920 |
| **Total recurring WSP implementation costs** | $14,390 |

| **Basic WSP** | % of non-recurring costs | Costing parameter | % of recurring costs | Costing parameter (annual) |
|---|---|---|---|---|
| Staff time | 56% | 1,680 hours | Portion of maintenance | N/A |
| DWQM | 0% | 168 hours | 8% | Budget increase |
| Training | 6% | | 0% | |
| Auditing | 0% | | 0% | |
| **DWSA-specific** | | | | |
| Control measures | | | | |

| | | | | |
|---|---|---|---|---|
| *tank cleaning* | 0% | | -37% | Decreased frequency |
| Operational monitoring | 0% | | 24% | Increased sampling frequency |
| Supporting program | | | | |
| *Maintenance* | 0% | | 36% | Increased frequency |
| *Training* | 0% | | 10% | 480 hours |
| *research and upgrades* | 36% | Translation of WSP documents | 0% | |
| Capital costs | 5% | Unburying 61 valves | 59% | Installation of 402 meters, 350m pipe |

Seven staff members on the WSP team are estimated to have spent a total of 1,680 hours on developing the plan. Staff members of Pakse participated in a three day, WHO-led training at the PNP Champassack totaling to 168 hours of staff time. Many of the training documents had to be translated to Lao, making up 36% of non-recurring costs. This cost was considered to be DWSA-specific as not all DWSAs will incur this expense. Capital costs small enough to have been covered by internally generated fund in the year they were expensed included the unburying of 61 valves. Valves were buried due to construction of roads and houses and were excavated so as to be made operational.

Recurring costs for staff time are partially accounted for in the maintenance costs and were not parsed. The change in the drinking-water quality monitoring program was mostly due to a budget increase. Sampling frequency has not changed, but the number of chemical parameters has increased from 11 to 15. The only cost savings recorded in this study was the decreased frequency of sedimentation tank cleaning and filtration tank inspection, cleaning and refilling. The frequency of sedimentation tank cleanings decreased from six to four times per year while filtration tank control measures were decreased from two to one time per day. Operational monitoring of turbidity, pH, residual chlorine, and total chlorine increased from once to twice a week and has become more regular. The number of sampling points has also increased. Increased maintenance costs result from a greater focus on consistent preventative maintenance. These efforts included regular cleaning of screens and filters, building up stocks on spare parts (World Health Organization), placing locks on tanks, and excavating wells. Recurring training costs involve 20 staff for three days a year for a total of 480 hours. Annualized capital and maintenance costs include unburying of valves and installing household water meters and 350 meters of pipeline. Cost items not monetized include: the replacement of damaged valves and construction of concrete chambers around all unburied valves.

The value of the WHO-sponsored training for the PNP Champassack is estimated to be $2,940 for two staff spending over eighty hours. Three members of the WSP were senior staff representatives of the following provincial government bodies: Department of Communications, Transport, post and Construction, Department of Health, and the Office of Science, Technology and Environment. They were estimated to committing 5% of their time over the development period for a total of 240 hours. Other meetings with the water regulator, the Water Supply Authority and other government representatives total to 60 hours of time.

The Ministry of Health is charged with performing surveillance monitoring on the water suppliers. Their activities have not changed as a result of the WSP implementation at Pakse.
To obtain monetary values in local currency, multiply the given international dollars by the 2009 PPP exchange rate of 4093.67.

## 4. Koror-Airai Public Water Supply, Palau

The Koror-Airai (K-A) Public Water Supply is owned and managed by the Ministry of Resources and Development. The Public Utility performs all water supply functions from abstraction to analysis of drinking-water quality samples(Dasmariñas Water District). Daily production capacity is 15,141 (as of 2006) cubic meters and is sourced entirely from surface water. As of 2009, water sent to the 3,009 connections (Asian Development Bank) has been conventionally treated (Nath, Mudaliar and Dengokl). No other management systems were found to be in place before the implementation of the WSP.

With assistance from AusAID, the WHO and the Secretariat of the Pacific Community (SOPAC), the Drinking-water Safety Plan National Steering Committee has compiled the water safety plan on behalf of the Republic of Palau's Ministry of Resources and Development. WSP development in K-A began in April of 2007 (Gerber 1) and lasted three months. K-A had spent funds on their improvement schedule by 2010. Operations and maintenance costs in 2009 were $2,542,000 (Gerber 1). The perceived benefits and challenges of the WSP are included in table below and include those from the Gerber study:

| Perceived benefits | Perceived challenges |
|---|---|
| • Maintaining a WSP was beneficial when securing financing from the Asian Development Bank.<br>• Benefit of peace of mind knowing that water is safe.<br>• Improved diligence of treatment plant staff. Notable improvement in inspections, monitoring, maintenance and following standard operating procedures. | • No data. |

The costs of the WSP implementation are included the table below:

| | |
|---|---|
| Total non-recurring WSP implementation costs: | $ 138,330 |
| Total annual WSP implementation costs: | $ 10,400 |

| **Basic WSP** | % of non-recurring costs | Costing parameters | % of recurring costs | Costing parameters (annual) |
|---|---|---|---|---|
| Staff time | No data | Three months staff time | 0% | - |
| Change in DWQM | No data | - | No data | - |
| WSP orientation training | 0% | - | 0% | - |
| Auditing | 0% | - | 0% | - |
| **DWSA-specific** | | | | |
| Control measures | 0% | - | 0% | - |
| Operational monitoring | No data | - | No data | - |
| Supporting programs: | | | | |
| *Training* | 0% | - | 0% | - |
| *Awareness program* | 7% | 1 program | 48% | 1 program |
| *Research* | 82% | 4 studies | 0% | - |
| *Leak detection program* | 11% | 1 program | No data | - |
| Capital improvements | 0% | - | 52% | Monitoring equipment |

Information regarding WSP development costs was not obtained from the utility. A program designed to increase public awareness of water conservation and watershed protection was established and required 7% of non-recurring costs. Studies made up 82% of all non-recurring costs and included the following: a demand management study, an investigation and survey of dam assets, investigation of options for augmenting storage of finished water, financial feasibility of back-up intake and/or storage system for droughts (Palau Water Safety Plan National Steering Committee). Resources necessary for the leak detection program made up 11% of non-recurring costs. The awareness program was estimated in Gerber's 2010 analysis to incur a cost of $5,000 for the first year of operation. The costs of maintenance and loan payment of capital were calculated to be 52% of recurring costs. Items on schedule of improvement that have yet to be implemented:

| Description of improvement |
|---|
| Improve land use/planning within drinking water catchment areas |
| Develop contingency/emergency plans for all risks |
| SOP to be designed for water supply |
| Provide justification for annual maintenance and operations funding |
| Construction of fences around storage tanks |
| Design of integrated Disaster Management Plan |
| Develop a monitoring schedule |
| Verifying and reviewing WSP |

External support for WSP development and implementation came from the Environmental Quality Protection Board of Palau, WHO and SOPAC. To obtain monetary values in local currency, multiply the given international dollars by the 2009 PPP exchange rate of 1.

## 5. Environmental Quality Protection Board (EQPB), Palau

The EQPB is established under Title 24 of the Environmental Quality Protection Act. It is responsible for promulgating and enforcing primary drinking water regulations. The EQPB has been involved in the development of the WSP in Koror-Airai. The activities of the EQPB have also been changed as a result of the WSP. It has trained staff on WSPs and increased drinking-water quality monitoring activity. Perceived benefits and challenges of WSP implementation are included in the table below.

| Perceived benefits | Perceived challenges |
| --- | --- |
| • Allow for all stakeholders to have a written and uniform plan outlining a common goal.<br>• The enforcement aspect – the WSP creates a plan for compliance purposes. Surveillance agencies can ensure that system operators are performing in accordance to the WSPs.<br>• Having the improvement schedule and budget helps to obtain assistance from lending institutions.<br>• Demonstrates a greater focus on protecting water | • Lack of funding. The utility now has a plan of improvements and know what needs to be implemented but they don't have funding to complete the plans. |

Costs incurred by EQPB for implementing the WSP at K-A are described in the table below.

| | |
| --- | --- |
| **Total non-recurring WSP implementation costs** | $ 8,970 |
| **Total annual WSP implementation costs** | $ 3,000 |

| **WSP implementation costs** | % of non-recurring | Costing parameter | % of recurring | Costing parameter |
| --- | --- | --- | --- | --- |
| Staff time costs | 70% | 550 hours | 0% | - |
| DWQM | 0% | - | 100% | Change in sampling frequency |
| Training | 30% | 40 hours | 0% | - |

Time spent by EQPB staff in the plan development includes one staff member at full-time and three other staff spending about 5% of their time for three months. Changes in DWQM include increased sampling frequency of chemical parameters. The sampling program for microbiological parameters did not change. One EQPB staff member underwent training with SOPAC for one week. External support from SOPAC and WHO came from individuals from each organization visiting for a four day period once a year for three years.

To obtain monetary values in local currency, multiply the given international dollars by the 2009 PPP exchange rate of 1.

## 6. Maynilad Water Services, Inc. Manila, Philippines

In 1997, Maynilad was established as a private concessionaire to take over operations in the West Zone of Metro Manila. Maynilad employs 2,123 employees to perform both wastewater and all water supply functions. 97.7% of the source water is from the Angat-Umiray-Ipo watersheds and 2.3% from deep wells (Maynilad Water Services). The 937,578 connections are supplied by two treatment plants, both of which are ISO 9001:2000 Quality Management System certified in October of 2006. In 2007, the environmental management systems of the treatment plants received ISO 14001:2004 certification. The two plants employ a conventional treatment system to produce an average of 2,149,000 cubic meters per day. Maynilad's annual operations and maintenance cost averaged over 2007-2009 are $165,798,200 and total capital expenditure averaged over the same period is $542,821,200 (Maynilad Water Services).

With funding assistance from AusAID, the WHO and the Department of Health engaged Maynilad in 2006 to pilot water safety plans. Within a year, of consultation from local and international consultants, Maynilad developed a WSP. The perceived benefits and challenges of the WSP are included in the following table:

| Perceived benefits | Perceived challenges |
|---|---|
| • Improvement and consistency of water quality, better health (for consumers).<br>• Sound economic practice for the water suppliers.<br>• Systematic assessment and prioritization of hazards.<br>• Documentation of procedures and activities.<br>• Provides contingency plan to respond to system failures and unforeseeable events<br>• In a position to respond immediately to failures<br>• Collectively have developed an understanding of the factors affecting WQ. | • No ownership of the watershed. The watershed is a source of many problems (settlements, deforestation, security threats) yet Maynilad cannot manage identified hazards.<br>• Advantages were limited because many of the identified hazards were already being addressed.<br>• Development took longer than expected because staff worked on it in addition to regular work hours.<br>• Arranging meetings was also difficult due to differing schedules. |

The costs of the WSP implementation are included below:

| | |
|---|---|
| Total non-recurring WSP implementation costs | $76,040 |
| Total recurring WSP implementation costs | $2,420 |

| **Basic WSP** | % of non-recurring costs | Costing parameter | % of recurring costs | Costing parameter (annual) |
|---|---|---|---|---|
| Staff time | 78% | 8,100 hours | 29% | 120 hours |
| Change in DWQM | 0% | - | 0% | - |
| WSP orientation training | 22% | 1,910 – 3,190hours | 0% | - |
| Auditing | 0% | - | 71% | 1 audit |
| **DWSA-specific** | | | | |
| Control measures | 0% | - | 0% | - |
| Operational monitoring | 0% | - | 0% | - |
| Supporting programs: | 0% | - | 0% | - |
| Capital improvements | 0% | - | 0% | - |

All of the non-recurring costs incurred were due to staff time involved in developing the WSP. Twenty three staff members spent approximately 8,100 hours over eight months to develop the plan. WSP awareness training was conducted for all operational staff that is estimated to be between 30% - 50% of total staff. The resulting estimate of total time spent on awareness training ranges from 1,910 – 3,190 hours. The cost of the training consisted exclusively of staff time because Maynilad's previously trained staff took the responsibility of training the staff. Maynilad is estimated to spend 120 hours per year on auditing the WSP and ISO 9001: 2004 twice a year. Third party audits occurred once a year. Three external consultants spent approximately 120 hours each in the development of the WSP and their time was valued at $4,760. There were no changes in drinking-water quality monitoring (DWQM) or operational monitoring activities. Costs not included in the table above are of two types: those costs that have not been incurred and a project for which there was no cost information. The following capital improvements are either at the design stage or have cost estimations and forthcoming but were not complete during the time of the data collection:

| Description of capital improvement | Cost |
|---|---|
| An automated potassium permanganate facility within both treatment plants | $353,660 |
| Repair and reinstall caustic soda/lime application within both treatment plants including a grit remover | $353,660. |
| Rehabilitation of 24 filter units for one treatment plant | $1,237,820 |
| Backup pump at GW with liquid chlorinators | $176,830 |

Had the capital improvements been in place they would also have resulted in an annual maintenance cost of $63,660 throughout the usable life of the capital. A watershed protection program providing an indigenous community with a nursery was developed in response to the deforestation occurring in the watershed. An estimate of the cost of this program was not obtained from Maynilad; however, the program involves making payments to the indigenous community to plant trees to replace those that are illegally harvested. The program costs are not expected to be substantial.

Maynilad made several changes in activities such as changing the frequency of monitoring the catchment area; however, these costs were not estimated by the utility. Information on incremental changes made by the utility was not kept by the accounting staff at Maynilad. The additional activities were performed by salaried staff whose pay did not change as a result of the increase in workload. These marginal costs were not captured. Generally, the utility found it difficult to identify which activities were resulting directly from the WSP implementation because the WSP activities were similar to ongoing operations.

To obtain monetary values in local currency, multiply the given international dollars by the 2009 PPP exchange rate of 27.13.

## 7. Dasmariñas Water District, Dasmariñas, Philippines

Dasmariñas Water District (DWD) was created under Resolution No. 09-79 in 1979 as a state owned enterprise. DWD employs 671 employees to perform all water supply functions from abstraction to analysis of drinking-water quality samples (Dasmariñas Water District). 70,659 cubic meters are produced daily entirely from groundwater through the use of 116 deep wells, 72 elevated reservoirs and one ground reservoir. The water sent to the 99,346 connections is minimally treated with calcium hypochlorite as the groundwater meets the Philippine National Standards for Drinking Water. The company as a whole has no management systems in place before the implementation of the WSP with the exception of the laboratory which is accredited by the Philippine Department of Health. Prior to the WSP, DWD developed an internal system to harmonize existing policies and procedures for each staff position. Annual operations and maintenance costs are $13,458,800 and total capital expenditure over the last five years, from 2005 is $10,507,800 (SEAWUN and ADB). With funding assistance from AusAID, the WHO and the Department of Health have assisted DWD with the production of the WSP. DWD began the development in May of 2009 and the plan itself was being finalized in 2011 as elements of the plan were concurrently being implemented. The perceived benefits and challenges of the WSP are included in the following table:

| Perceived benefits | Perceived challenges |
|---|---|
| • Assurance to DWD and customers of the safety of water produced.<br>• Reaffirms DWD’s commitment to delivering safe water.<br>• Formalization of utility procedures to contribute to institutional knowledge.<br>• Identifies opportunity for skill development and promotes capacity building.<br>• Gives the organization a complete overview of the potential problems. Forced to search for problems and think about the problems not previously seen.<br>• Strengthens end-point monitoring by creating a more informed sampling program.<br>• Places renewed importance on NRW as a health threat. | • Developing documentation was mostly done by one person.<br>• Making the SOP took a lot of time even though some procedures were already documented.<br>• Increased workload for employees but not necessarily a commensurate increase in pay. |

The costs of the WSP implementation are included below:

| | |
|---|---|
| Total non-recurring WSP implementation costs | $22,400 |
| Total annual WSP implementation costs | $19,540 |

| **Basic WSP** | % of non-recurring costs | Costing parameter | % of recurring costs | Costing parameter (annual) |
|---|---|---|---|---|
| Staff time | 30% | 8,100 hours | 2% | 120 hours |
| Change in DWQM | 0% | - | 0% | - |
| WSP orientation training | 32% | 1,910 – 3,190hours | - | - |
| Auditing | 0% | - | 0% | - |
| **DWSA-specific** | | | | |
| Control measures | 0% | - | 9% | Quarterly cleaning |
| Operational monitoring | 0% | - | 87% | Chlorine and pH monitoring |
| Supporting programs: | | | | |
| *Training* | 7% | 2 courses | 2% | Budget for seminar |
| *Research and upgrades* | 4% | Update lab methods | 0% | |
| Capital improvements | 26% | One vehicle | <1% | Maintenance |

The staff time costs describe the costs of time spent at workshops, meetings, inspections, encoding data, researching, reviewing and producing the WSP. Twenty four DWD staff attended a workshop as part of the initial development of the WSP, spending a total of 1,152 hours. WSP total time costs for WSP meetings and inspection; data encoding, research review and production; and training on safety planning and emergency preparedness were 28 hours, 112 hours, and 440 hours. External consultants were not used throughout the implementation process. A gap in DWD's capabilities was discovered and trainings were held on safety planning and emergency preparedness. Other training costs included those from workshop fees, a water resource facility operator course, and production operator training. These costs include staff time as well. The laboratory's laboratory methods were updated with a new edition of the *Standard Methods for the Examination of Water and Wastewater*. An automobile was purchased to increase the ability of pump operators, supervisors and engineers to immediately respond to urgent situations. The recurring costs primarily consisted of staff time in performing increased operational monitoring tasks. The frequency of chlorine residual and pH monitoring were increased. Quarterly cleaning of elevated water tanks made up 9% of recurring costs. The annual budget includes a training seminar on WSP for well drillers, making up 2% of the recurring costs. As the DWD WSP is relatively new there were items on the improvement plan that were in the process of completion, but did not constitute a cost to the utility. These items are internal audits, development of an emergency response team, creation of a calibration program, installation of pressure gauges along distribution networks, implementation of training courses for pipe-laying and buried pipe installation, determination of status of all valves in the distribution networks and improvement of fire hydrant security. All capital improvements were already identified prior to the WSP. The non-revenue water program was previously identified as an area of capital improvement before the WSP but garnered renewed interest as the WSP highlighted its relationship to water safety. The renewed interest has yet to result in increased funds. There were no changes to the drinking-water quality monitoring costs, however, the sampling points were changed based on findings from the WSP. Sampling points were changed to residences closest to the pumping station and were positioned to include more zones. DWD recognized currently the highest cost of WSP implementation is in the documentation and development phase, however, it is predicted that implementing the improvement schedule will prove to be more expensive.

Minor additional costs due to staff were not captured because these hours accrued to salaried staff and an increase in labor did not represent a cost to DWD. To obtain monetary values in local currency, multiply the given international dollars by the 2009 PPP exchange rate of 27.13.

## 8. Department of Health, Philippines

The responsibilities of the Department of Health (DoH) include developing policies and providing technical input to DWSAs implementing WSPs. This work includes piloting and scaling up WSP implementation. Funding and additional technical assistance for this work is coming from the WHO. Since 2006, 5% of one staff member's time is spent on WSP related activities. Perceived benefits and challenges of WSP are included in the table below.

| Perceived benefits | Perceived challenges |
| --- | --- |
| • Proactive means of risk reduction allowing for prevention of contamination rather than its subsequent detection.<br>• Protection of consumers from contaminated drinking water.<br>• Fosters collaboration and understanding between surveillance agency and water utility to reduce conflict.<br>• Potential reduction in number of parameters to be sampled for compliance.<br>• Reduced regulatory avoidance by utility. | • Initial implementation will require new investment, which may be difficult for some.<br>• Some utilities may not see the importance of investing money in risk reduction.<br>• Limited technical capability and data to perform risk assessment (e.g. in the catchment area). |

To obtain monetary values in local currency, multiply the given international dollars by the 2009 PPP exchange rate of 27.13.

## 9. Thua Thien Hue Water Supply & Sewerage Company (HueWACO), Hue City, Vietnam

HueWACO was established in 1909 and is a state owned enterprise supplying urban areas of Hue province. HueWACO employs 525 employees (SEAWUN and ADB) to perform all water supply functions from abstraction to distribution and analysis of drinking-water quality samples. 98% of the source water is surface water and 2% from ground water. The 147,836 (2011) connections are supplied by 20 treatment plants that employ a conventional treatment system to produce an average of 134,400 cubic meters per day. HueWACO was ISO 9001:2000 certified in 2004 and a laboratory facility was ISO/IEC 17025:2005 certified in 2007. Annual operations and maintenance costs are $6,094,200 (SEAWUN and ADB).

With funding assistance from AusAID, the WHO and central and local government authorities piloted WSPs with HueWACO in 2007. By adjusting the ISO 9001:2000 certification, the WSP was completed before 2008 (Nguyen).

The perceived benefits and challenges of the WSP are included in the table below.

| Perceived benefits | Perceived challenges |
|---|---|
| • Management of risks and prevention of hazards and incidents.<br>• Ensure safe water quality and safe supply.<br>• Improve community health by reducing water-borne diseases.<br>• Improves relationship with the community.<br>• Clean water is a commodity to attract tourists<br>• Save time, effort and costs in preventing hazards and incidents that may affect community.<br>• Sufficient water pressure and continuous supply.<br>• Control and prevention of pollutants in water sources.<br>• Preventing post-treatment recontamination.<br>• Raising pressure and residual chlorine(Nguyen) | • Cooperation with many stakeholders at all levels is difficult when controlling source water risks.<br>• High costs due to implementing many control measures.<br>• Documents overlapping with ISO(Nguyen) |

Costs of WSP implementation are described in the tables below.

| | |
|---|---|
| **Total non-recurring costs** | $76,920 |
| **Total recurring WSP implementation costs** | $2,279,780 |

| **Basic WSP** | % of non-recurring costs | Costing parameter | % of recurring costs | Costing parameter (annual) |
|---|---|---|---|---|
| Staff time | 20% | 1,060 hours and meetings | 0% | - |
| DWQM costs | Yes, unknown | - | 0.74% | No data |
| WSP Training | 2% | No data | 0.54% | 88 staff, two trainings |
| Auditing | 0% | - | 0.13% | No data |
| **DWSA-specific** | | | | |
| Control measures | 0% | - | 7% | 3 measures |
| Operational monitoring | 0% | - | 0% | - |
| Supporting programs | | | | |
| *Source water protection* | 0% | - | 0.053% | 1 program |
| *Awareness program* | 0% | - | 0.27% | 1 program |
| *Research/upgrade* | 78% | Fees, 1 study | 0.27% | Water production and quality |
| Capital costs | 0% | - | 91% | Pipe replacement |

Five staff members of the WSP team spent a total of 1,060 hours to develop the WSP. Separate meetings regarding the establishment of the WSP team and a discussion on hazards also added to the initial development costs. An external consultant was not hired to support initial development. Changes in drinking-water quality monitoring resulted in non-recurring costs to HueWACO, but they were not monetized. Internal training workshops regarding the development of the WSP were conducted by staff. Research and upgrade costs include service fees for developing a WSP manual and a study on the changes in source water quality over time.

Drinking-water quality monitoring costs were attributed to the cost of analyzing samples at external institutions. Additional costs were noted, but are not included here, because they were not sufficiently described by HueWACO. Annual training on WSPs is administered by HueWACO staff to 88 other members twice per year. HueWACO pays for an annual external auditing fee. Control measure activities include the following: using activated carbon for de-odoring, using manganese sands for treating iron and manganese, and supplementing chlorine treatment. The source water protection supporting program consists of coordinating and meeting with other stakeholders to protect and monitor the source waters. HueWACO began a community awareness campaign using TV, newspapers, brochures, interactive games and visits to water treatment plants to raise awareness on water safety (Nguyen). The supplier annually executes research on water production and water quality. Annualized capital and maintenance costs are for the replacement of 100km of iron and low-grade steel pipes and annual or biennial distribution cleaning.

One representative from the local government was also a part of the WSP team. The development of the WSP was estimated to occur over the course of six months. To obtain monetary values in local currency, multiply the given international dollars by the 2009 PPP exchange rate of 8,260.51.

## 10. Thua Thien Hue Preventive Medicine Center (Hue PMC), Hue city, Vietnam

The Hue PMC is responsible for water quality and drinking-water quality. The PMC is to perform direct surveillance on the drinking-water quality produced by HueWACO, however, due to recent decreases in subsidies surveillance activities have moved to being audit-based. The PMC has been involved in WSP activities in the country and has identified safe water for public health as a benefit of WSPs. A perceived challenge to WSP implementation identified by the PMC is the 'high technology' that is required and high costs for drinking-water quality monitoring.

The PMC was represented by one staff member during the development of the WSP for HueWACO. Estimated time spent on the development is 5% of the staff member's time over the development period. The activities of the PMC have also changed as a result of the WSP. They have incurred the costs outlined in the table below.

| **Description** | **Cost** |
|---|---|
| Staff time in development of WSP | $200 |
| Water and sanitation inspection at source waters of water supply branches. Occurs twice a year. | $1,210 |
| Checking and monitoring water sources of households from provincial areas every month. | $12,110 |
| Random sampling and analysis of drinking-water. | $1,210 |
| Sampling and analyzing water after flooding. | $2,420 |
| Training course for provincial, district and commune levels on water and sanitation | $7,260 |
| Total recurring costs | $24,210 |
| Total non-recurring costs | $100 |

A program to audit WSPs was identified as a needed change in activities, but has not yet been created.To obtain monetary values in local currency, multiply the given international dollars by the 2009 PPP exchange rate of 8,260.51.

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