Training Workbook

on Water Safety Plans for Urban Systems

World Health Organization
Western Pacific Region

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Abbreviations

AusAID	Australian Agency for International Development
BAC	Biological activated carbon
CT	Contact time (chlorine)
GDWQ	Guidelines for Drinking Water Quality
HACCP	Hazard Analysis Critical Control Point
HOCl	Hypochlorous acid
ISO	International Organization for Standardization
MWSI	Maynilad Water Services, Inc
RABQSA	Registrar Accreditation Board Quality Society of Australasia
THMs	Trihalomethanes
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WPRO	Western Pacific Regional Office
WSPs	Water Safety Plans

Foreword

Every year, thousands of deaths due to diarrhea, cholera, typhoid and other gastrointestinal diseases have been attributed to poor water, sanitation and hygiene not just in this region but globally. Diarrheal diseases could be avoided if water suppliers would ensure the safety of drinking water from source to consumer. Guided by the national drinking water regulations, the health based targets of maximum allowable concentration for microbiological, chemical, physical and radiological parameters in drinking water could be achieved through the application of the multiple barrier approach to risk management in water supply. This is the overall principle and goal of Water Safety Plans.

This workbook is intended to be used for training within the Region emphasizing a systematic and preventive risk-based approach to avoid drinking water contamination towards improvement of public health. The strategy is to use multiple barriers so that if one barrier fails, the water stays safe. The intended users are possibly water supply practitioners at all levels especially water quality managers, operators, regulators, assessors, academics, consultants, NGOs, and international organizations.

WHO has introduced Water Safety Plan (WSP) in the 3rd Edition of the WHO Guidelines for Drinking Water Quality to provide a systematic approach for improving and maintaining drinking water safety. This training material is intended to provide participants with an understanding of the key concepts of the WSP and how to further communicate those concepts to others in future training sessions. The training should also provide a networking opportunity for WSP trainers to get together and discuss WSP training experiences with a view to maintaining a long-term network of mutual support to help facilitate WSP implementation.

The objective of this workbook is to serve as a guide to facilitate WSP development for an organized water supply that is managed by a water utility or similar entity. WSPs can be tailored differently for each specific water supply system. This workbook is generic and is not specific to any particular country. It is anticipated that trainers in each country would develop their own WSP training material which would be linked directly to country drinking water standards and implementing guidelines as well as being written in other appropriate languages.

The workbook is intended to be used in a step wise fashion, to guide the user through each step in the development of a WSP. Each step has been described concisely in the body of the text with detailed examples to help illustrate what is involved at each step. A set of pro forma worksheets are given in Appendix A which, if completed for a specific system, will provide a first draft of a WSP. A sample WSP is also provided in Appendix B based on an actual WSP case study developed and implemented in the region. The draft Water Safety Plan should be revised accordingly as more information and experience is gained during its implementation.

The document is structured according to the WSP developed by WHO and draws from a worldwide body of practical experience. It begins with an introductory section designed to orient the user and facilitate the process of starting a WSP. The document addresses each WSP step and provides the following information: (a) what each step involves; (b) an explanation of each step including examples; and (c) examples of exercise sheets (Annex A) that can be used to complete the WSP.

The WSP book "Annette Davison, Guy Howard, Melita Stevens, Phil Callan, Lorna Fewtrell, Dan Deere and Jamie Bartram (2005) Water safety plans: Managing drinking-water quality from catchment to consumer" can be accessed from the Internet at:

www.who.int/water_sanitation_health/dwq/wsp0506/en/.

Another good resource is the WHO WSP Portal at:

www.who.int/wsportal/en/

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The Broader Context of a WSP: Water Safety Framework

This workbook provides practical guidance to water supply practitioners implementing WSPs in organized water supply entities and complements the broader WHO WSP monograph (Davison et al 2005) and WHO Guidelines for Drinking Water Quality 3rd Edition (GDWQ). This workbook should also assist supervisory and supporting organizations, such as regulators, auditors and surveillance authorities. Separate WHO projects are underway to develop resources for small, remote, low income and community water supplies where there is no organized water supply organization.

Access to safe drinking water is a basic need and is one of the most important contributors to public health. The GDWQ outline a framework for safe drinking water. This framework includes WSPs, which can be implemented by those responsible for supplying drinking water to help improve its safety of drinking water.

1.1 The problem: Why WSPs are needed

Traditionally there has been a curative approach to public health aspects of drinking water quality management. There has been a reliance on awaiting the results of water quality tests, or consumer perception regarding perceived health or aesthetic problems, before action is taken. This approach has met with some success, but is not sufficient to represent a preventive public health protection strategy.

A major limitation of the traditional curative approach is that water quality results are only available after exposure has taken place. For example, a waterborne disease outbreak in 2000 in Walkerton, Canada caused seven deaths and around 2,300 became ill due to *E. coli O157:H7* and *Campylobacter* contamination of the drinking water supply. Test results were not responded to until after consumers had been exposed to contamination. Another flaw in the curative approach is that not all contaminants can be reliably monitored. For example, a waterborne disease outbreak in 1993 in Milwaukee, USA, made around 400,000 people ill due to the presence of *Cryptosporidium*. The water supplied at the time met all US and international drinking water standards but the causative pathogen could not be readily detected through testing. Even today, few laboratories are able to test for any more than a relatively small number of pathogens and toxicants and most contaminants do not have standards.

WSPs are now being adopted worldwide to better protect public health by reducing endemic waterborne disease and preventing outbreaks. A preventive approach involves making sure that water quality never becomes unsafe so that reliance is not placed on reactive, curative responses based on water quality tests and customer perceptions of poor water quality. WSPs provide a comprehensive framework for assuring the quality of water through systematic assessment and management of health risks.

1.2 Training needs for WSP implementation

WSPs are not intuitively understood by all water supply professionals and their stakeholders, such as their health regulators. The WSP approach represents something of a paradigm shift in water safety management. Furthermore, the jargon words found in WSPs are often not clear even to native speakers of the original WSP texts, and are usually misunderstood following translation, causing further confusion. Simply reading WSP texts has been found to be an inadequate means of communicating some of the important WSP concepts.

A successful means of communicating WSP concepts has been the use of training workshops involving:

- lectures describing each concept, one step (or groups of steps) at a time from an experienced WSP practitioner;
- illustration of each concept using examples from a model WSP;
- the completion of exercises by small work groups, with access to a trainer during the exercises, whereby groups consider how to apply WSP concepts to their own, (or an example), water supply system;
- feedback given by the groups to help motivate good work by the groups and to allow understanding to be assessed; and
- coaching and facilitation support, if required, in the implementation of the WSP after the training.
- This training of trainer workshop will provide an example of the WSP training process as well as helping to highlight key areas that require special attention.

1.2.1 Resource materials

With respect to WSP training resource material, the key points are listed below.

- Training materials must be written in simple, common language, wherever possible. Most of the jargon words found in WSPs are not clearly understood even to native speakers of the original WSP material. Therefore, where possible, jargon words should be avoided, and if jargon is used, the terms should be clearly explained.
- Examples are essential. The best way to communicate most WSP concepts is through the use of examples from real or case study WSPs. However, examples should be kept brief in the main training material, and just illustrative, to avoid breaking the flow of the material. Furthermore, examples must be clearly just that, just examples. Each WSP has unique aspects and trainees need to understand that they need to develop their own WSP, and not simply copy others' examples, unless directly applicable.
- A separately prepared, full, example WSP in the local context is helpful and should be provided if available. However, the example WSP must be a good example otherwise it will only cause confusion. Many WSPs are of poor quality when first produced and may need significant modification before using as a training example. However, modified examples of real WSPs are useful, and one is provided with this course.

- All example material should be relevant to the context. The technologies illustrated in the example, the language used and standards and guidelines referred to should ideally be appropriate for the trainees' own systems. Within the Western Pacific Region, examples from advanced water supplies in major cities of developed regions are likely to appear irrelevant to lower income areas and are not at all comparable with any community supplies. The use of such 'high technology' examples is likely to lead trainees to feel that they cannot achieve the WSP requirements.

1.2.2 Common misunderstandings

Common errors that are made in understanding WSPs, and that need special attention during training, are listed below.

- It is difficult for traditional water supply practitioners to shift away from thinking about water quality laboratory testing as the focus of 'monitoring' in the supply of water. In fact, within WSPs, 'monitoring' is mostly focused on the operation of processes and systems, not on water quality laboratory testing. In contrast, under WSPs, the laboratory testing is primarily confined to the 'verification' testing of water. However, in some cases, laboratory testing is undertaken as part of validation, investigative baseline monitoring and some types of operational monitoring. It is vital that these different types of monitoring are understood and communicated to trainees.
- Often operational process limits are incorrectly expressed with reference to drinking water quality standards. The drinking water quality standards define what the process must achieve, but not how the process should be monitored and what the operational parameters of the process should achieve. For example, disinfection is designed to achieve no detectable bacterial faecal indicators. However, the process monitoring would involve achieving chlorination concentration and time goals, not microbial quality objectives.
- Participants often feel that they cannot implement a WSP because their system is not good enough. It is important to emphasise two things here. Firstly, systems can be improved over time and the WSP can be implemented now, to help provide the best quality water possible from the existing water supply system, while seeking to make improvements. Secondly, the WSP is an excellent context in which to present requests for further resources to improve water quality. Many entities now request or even require a WSP before they will provide funding for new works and research.

1.2.3 Training approach

With respect to the training approach, the areas that need special attention are listed below.

- It is essential that trainers allow participants to test their understanding using group work. Trainers should work with the groups during the group work. The group work forces trainees to test their own personal understanding in a small group of their peers. If this group work is not undertaken, participants are likely to lose interest after an hour or so and stop absorbing any new information. The subject matter of WSPs is not particularly interesting in its own right.

- Field visits are useful during the training, ideally after the main concepts have been taught. This allows participants to think about how to apply those concepts to a real system. Trainees can inspect catchments, review treatment processes and storages, inspect records and think about how risks might arise and how they are managed.
- Workshops should finish with a discussion on how to apply WSPs. Once the concepts are understood, the participants should think about how they will implement their own WSPs in their own context. Issues to consider include reviewing what is in place now (a gap analysis) and how gaps will be filled (an implementation plan).
- Trainers should be themselves expert in water quality as well as in WSPs. Expertise in both areas is required to maintain credibility and accuracy during the training. If such expertise is not found in one individual, training teams can be used. WSPs are quite similar to ISO 9001, ISO 22000 and HACCP management systems, and it may be possible to take a water quality and safety expert and combine them in a training team with a management systems expert. Similarly, it may be possible to bring in trainers from outside of the immediate area to fill skills gaps. After a number of training events, it is likely that trainers will be able to work in smaller teams or alone to provide the training.
- Ideally, groups should be formed around specific water supply systems. This allows the trainees to test their understanding against their own system rather than trying to understand another system. Another benefit of trainees using their own system is that when they return to their workplace they can use what they have learned, and some of their documented examples from the group work, to make an immediate start on their own WSP.
- Groups should provide feedback to the other groups. This peer review process helps with mutual learning as well as ensuring that trainees pay attention to the task. Therefore, the feedback process strongly encourages and motivates. Furthermore, the trainer can review understanding and can sensitively provide feedback.

1.3 Context: A Framework for Safe Drinking water

The WHO's water safety framework comprises five key elements of which the WSP encompasses elements 2 to 4, as illustrated in Table 1-1. Within the context of the WHO water safety framework, the GDWQ provide a range of advice on microbial, chemical, radiological and acceptability aspects.

As stated in the GDWQ, there are many microbial and chemical constituents of drinking water that if consumed, can adversely impact human health. Detecting these constituents in raw water and water delivered to consumers is possible but is generally slow, complex and costly. All these factors impact on a supplier's ability to detect water quality problems and therefore, are of limited use to the consumer and the community in general in terms of protecting public health at an operational level. Monitoring requirements within the WSP are therefore targeted at key points within a multiple barrier water supply system and for key characteristics to maximize the assurance of water quality as it is delivered to the consumer. Microbial testing results, and the use of other parameters that may have slow turn around times, are used within a WSP as verification of water quality to confirm that the multiple barriers are actually working as planned.

1.4 Health-based targets

The setting of health-based targets is a prerequisite to developing a WSP, as shown in Figure 1-1 and Figure 1-2. The health-based targets define the benchmark that needs to be achieved by the water supply (Table 1-2). Health-based targets support development of water safety plans and provide information with which to evaluate the adequacy of existing installations and assist in identifying the level and type of inspection and analytical verifications appropriate. Full details of health-based targets are in GDWQ Chapter 3.

Figure 1-1. Interrelationship of elements of the WHO's Guidelines for Drinking Water Quality in ensuring drinking water safety.

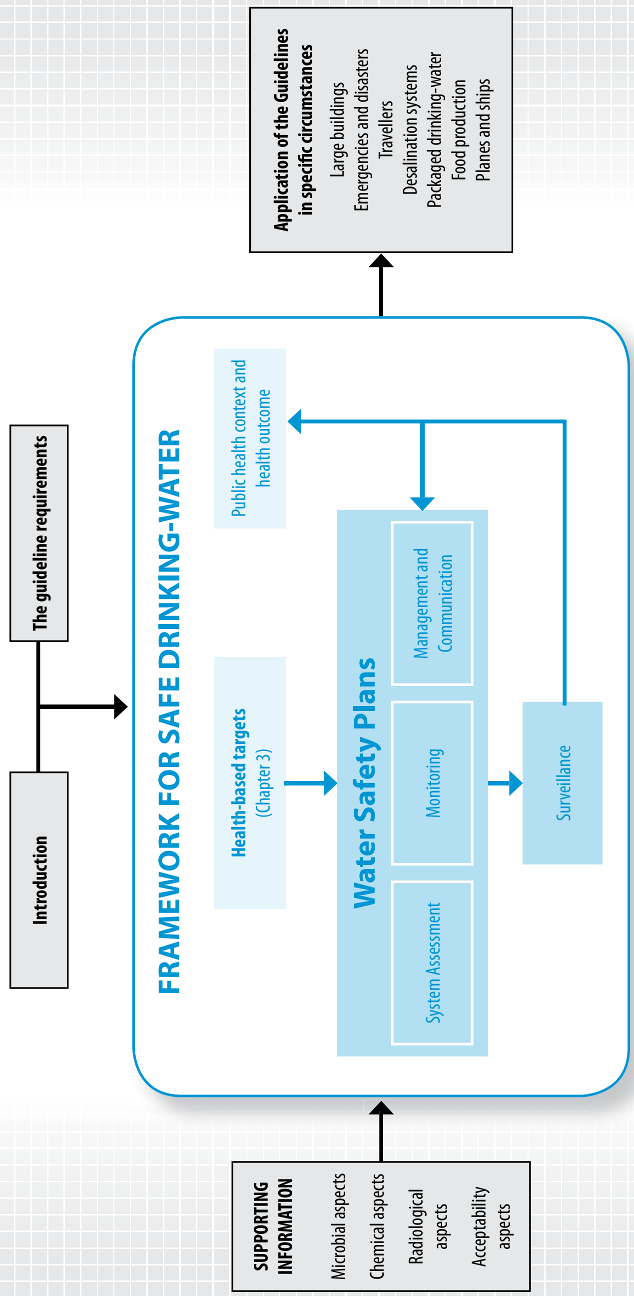


Table 1-1. The WHO's Framework for Safe Drinking Water.

Component		Requirements
1: Setting Health-based Targets	▶	Targets are based on an evaluation of health concerns and need to be set at a tolerable level for the community (e.g. are risk-based and can be coordinated with national guidelines, standards or WHO guidelines).
2: System Assessment	▶	An assessment is conducted to characterize the water supply system, assess risks and to determine whether the drinking water supply (from source through treatment to the point of consumption) as a whole can deliver water that meets the health-based targets).
3: Operational Monitoring	▶	Monitoring of the control measures in the drinking water supply that are of particular importance in securing drinking water safety. Monitoring at multiple points within the system, rather than relying on end-product monitoring, provides the supplier with assurance that unsafe product does not end up with the consumer.
4: Management Plans	▶	Management plans are set up and consist of: Documentation of the system assessment Monitoring plans including normal and incident operations, upgrades, improvements and communication
5: Surveillance	▶	A system of independent surveillance verifies that the above components are operating properly and effectively.

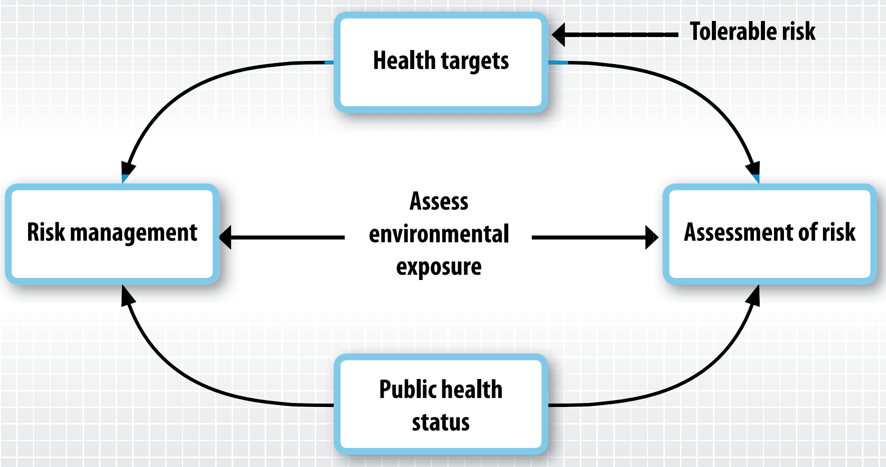


Figure 1-2. Simplified harmonized risk-based water cycle management framework showing health-based targets (based on Bartram et al, 2001).

1.5 Water Safety Plan

The steps to be undertaken in a WSP are illustrated in Figure 1-3. In summary, a WSP:

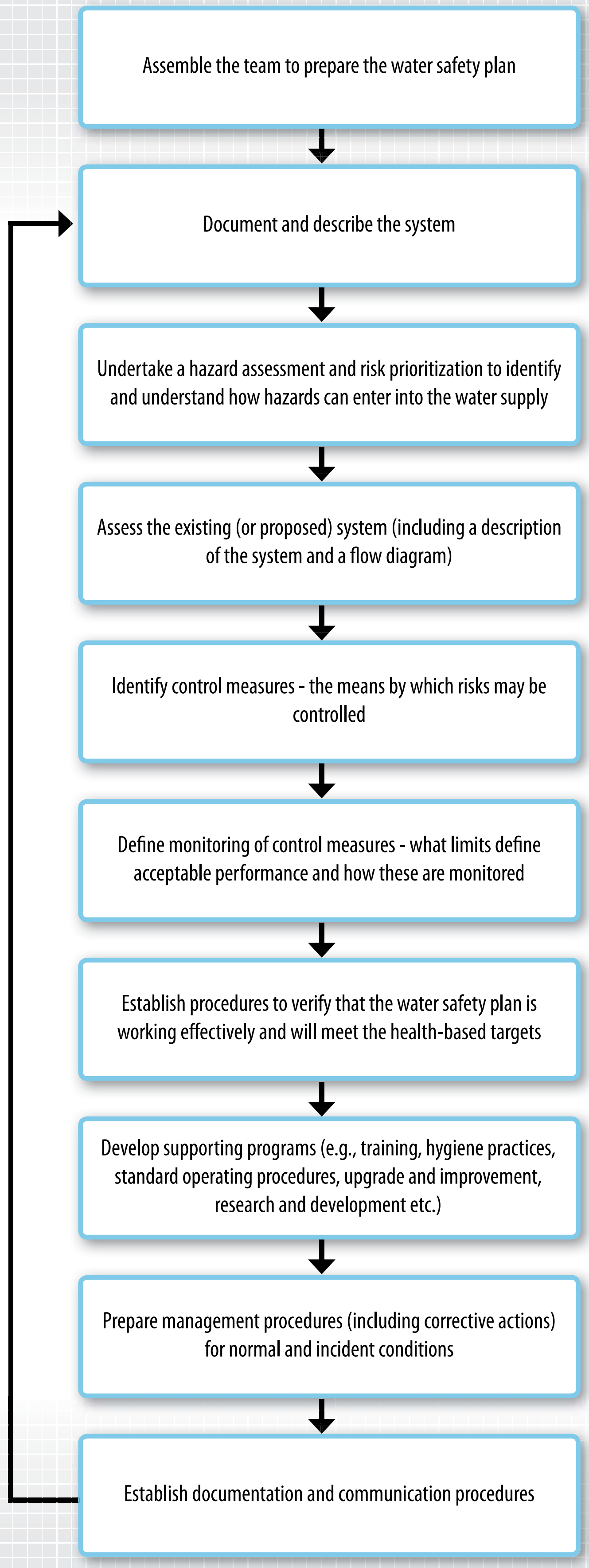
> *"…provides for an organized and structured system to minimize the chance of failure through oversight or lapse of management and for contingency plans to respond to system failures or unforeseen events." (GDWQ).*

Table 1-2. What health-based targets mean to the water supplier

Type of Target	Nature of target	Typical applications	Assessment	Interpretation by water supplier for WSP
Health Outcome				
Epidemiology based	Reduction in detected disease incidence or prevalence	Microbial or chemical hazards with high measurable disease burden largely water-associated	Public health surveillance and analytical epidemiology	These will need to be translated by the water supplier into water quality, performance or technology targets.
Risk assessment based	Tolerable level of risk from contaminants in drinking water, absolute or as a fraction of the total burden by all exposures	Microbial or chemical hazards in situations where disease burden is low and cannot be measured directly	Quantitative risk assessment	
Water Quality				
	Guideline value applied to water quality	Chemical constituents found in source waters	Periodic measurement of key chemical constituents to assess compliance with relevant guideline values.	These can be directly interpreted for chemical constituents that have their effects through chronic exposure and that can be readily monitored. For other chemicals and for microbial constituents, these will need to be translated by the water supplier into either performance or technology targets
	Guideline values applied in testing procedures for materials and chemicals	Chemical additives and by-products	Testing procedures applied to the materials and chemicals to assess their contribution to drinking water exposure taking account of variations over time.	
Performance				
	Generic performance target for removal of group of microbes	Microbial contaminants	Compliance assessment through system assessment and operational monitoring	These can be applied directly by the water supplier in terms of the system design specification whereby technologies are selected based on their ability to meet the performance targets.
	Customized performance targets for removal of groups of microbes	Microbial contaminants	Individual assessment would then proceed as above reviewed by public health authority	
	Guideline values applied to water quality	Threshold chemicals with effects on health which vary widely (e.g. nitrate and cyanobacteria)	Compliance assessment through system assessment and operational monitoring	
Specified technology				
	National authorities recommend specific processes to adequately address constituents with health effects (e.g. generic/model water safety plans for an unprotected catchment)	Constituents with health effect in small municipalities and community supplies	Compliance assessment through system assessment and operational monitoring	These can be applied directly by the water supplier through compliance with technology requirements.

Source: Davison et al 2005

Figure 1-3. Water Safety Plan steps (WHO 2004).



1.6 References

Bartram, J., Fewtrell, L. and Stenström, T. A. (2001) Harmonised assessment of risk and risk management for water-related infectious disease: an overview. In Water Quality: Guidelines, Standards and Health – Assessment of risk and risk management for water-related infectious disease. (eds L. Fewtrell and J. Bartram), pp. 1-16, World Health Organization, IWA Publishing, London, UK.

Davison, A, Howard, G, Stevens, M, Callan, P, Fewtrell, L, Deere, D and Bartram, J (2005) Water Safety Plans Managing drinking-water quality from catchment to consumer. Geneva: World Health Organization. WHO/SDE/WSH/05.06

WHO (World Health Organization) (2004). Guidelines for Drinking-water Quality. Third Edition.

CHAPTER

2 Before Starting: Foundations of WSP

2.1 Roles and responsibilities

The process of development, implementation and maintenance of a WSP is primarily the role of the water supply organization but generally requires support and involvement from a number of supporting and regulatory organizations. Therefore, prerequisite steps before beginning the WSP process include:

- **Identify the organization leading the WSP process**
- **Gain commitment from other key organizations**

Responsibilities for the WSP need to be clear and documented. They include those listed below.

- Where a single water supply organization is primarily responsible for managing a water supply system, that organization will lead the WSP for that system.
- Where multiple water supply organizations are collectively responsible for different components of a water supply system, a joint working group or committee might be identified as the entity with the overall responsibility for leading the WSP for that system. Alternatively, each water supply organization might take the lead for the component of the water supply system for which they are responsible.
- The authority responsible for regulating water quality will typically need to be formally engaged in the process to confirm the health-based targets and other target criteria, such as customer service standards. In addition, the water quality regulator will need to commit to auditing and surveillance roles. The auditing role may be undertaken directly by the regulator or there may be a requirement for independent, third party audits.
- The authorities responsible for regulating and/or managing source water quality, customer plumbing, water treatment and consumer management and use might also need to be involved to undertake relevant aspects of the WSP for those water supply system components.

2.2 Resource (staff) commitment

The critical requirement is that all those organizations responsible for the water supply system from catchment to tap are involved, and are committed to improving the controls in their part of the system. If a WSP is to be implemented and maintained in practice, two essential prerequisite steps are:

- **Commit to WSP implementation and maintenance**
- **Identify and allocate the resources (staff effort) required**

Experience shows that successfully developing, implementing and maintaining a WSP within an organization requires a firm high-level commitment to the WSP and the allocation of adequate resources. A WSP represents a significant responsibility that is shared by all relevant employees within a water supply organization. Examples are listed below.

- Experience has shown that WSP development and implementation takes many months and requires significant resources. Even a third party can document a WSP relatively readily. However, implementation of a WSP within an organization requires genuine and strong commitment at all levels within that organization. At least one person within the water supply organization needs to be fully dedicated to coordinating the WSP development and implementation process. Numerous additional employees will need to provide timely, significant and substantive inputs to the process to make it work.
- Experience has shown that WSP maintenance requires ongoing management attention to reinforce a culture of compliance with the requirements of the WSP. At least one person within the water supply organization needs to have the role of internal supervision to ensure that the WSP is being implemented in practice. A person with sufficient authority needs to enforce compliance. It may take several years until clear benefits emerge from WSP implementation, such as improved process control and water quality, and a degree of culture change may be required.

2.3 WSPs for multiple systems

For water supply organizations with multiple water supply systems, choosing one system as a pilot will facilitate development and implementation of the WSP and the two recommended prerequisite steps are:

- **Precisely identify distinct 'water supply systems'**
- **Decide how systems will be grouped for WSP(s)**

An important early decision that a water supply organization must make is how to structure its WSP(s) to ensure that all systems are most efficiently encompassed. Where a water supply organization is responsible for managing a single system, a WSP will be developed for that system. However, a complication arises where a water supply organization is responsible for managing many water supply systems. There are three ways for a water supply organization to structure WSP(s) for multiple systems:

- A single WSP can encompass all systems within one plan.
- Several WSPs can be created with each plan covering one system or a group of related systems.
- A combination of the above, whereby a single high-level WSP overarches a series of subordinate system-specific WSPs.

In practice, where a water supply organization is responsible for multiple systems, a WSP for one distinct system is often developed as a 'pilot' before moving on to encompass other systems. Once the pilot WSP has become well enough developed, other systems are encompassed through an extension of the WSP program. It may also be the case that the catchment or the reservoir is managed by another agency other than the water supplier.

2.4 Preliminary assessment of system capability to meet targets

Before progressing to the full development of a WSP, it recommended that the following two steps are completed:

- **Describe health-based targets in relevant terms**
- **Assess system capability to meet health-based targets**

A preliminary analysis is undertaken to examine the capability of the water supply system to deliver water of the desired quality based on the health-based targets. To complete this step, the water supply organization should undertake the actions listed below.

- Confirm the health-based targets with the relevant regulatory organization.
- Express health-based targets in terms that are relevant, such as water quality objectives, process capability requirements and/or technology requirements.
- Assess the existing (or proposed) system for the presence of any required technologies, system process capabilities or evidence of compliant water quality performance in both routine and peak event conditions.
- Formally document whether or not the water supply system appears *prima facie* capable, if operating according to specification, of producing water of the desired quality.

If a system is not confirmed as being capable of meeting the health-based targets, the water supply organization may need to investigate what additional control measures and subsequent validation data are required. The WSP should still be developed to ensure that the best possible water quality is delivered at all times from the existing (or proposed) water supply system. However, there needs to be a formal recognition by the relevant health authority that the system for which the WSP is being developed is not capable of meeting the health-based targets and that upgrading or improvement may be required.

There are several techniques that can be used independently, or together, to perform system assessment and examples are given in Table 2-1.

Importantly, the preliminary system capability assessment must consider capability under both routine and event (such as during wet weather events) conditions.

Table 2-1. Assessment of system capability to meet health-based targets.

Type of Target	Tools and supporting information	Example
Health Outcome	*Quantitative risk assessment (QRA) modeling*	*QRA modeling is used to re-express 'health outcome' health-based targets in terms of finished water quality requirements for microbial hazards. The water supply organization then reviews source water contamination to establish hazard concentrations in raw water. Performance targets are then developed based on the requirement to reliably reduce hazard concentrations in the raw to the required level in the water supplied to consumers during both routine and peak event conditions. The system capability assessment is then based on comparing system performance capability with performance requirements, as described two rows below.*
Water Quality	*Guideline concentrations for health-related constituents*	*For chronic-acting chemical constituents, the water supply organization compares long term monitoring with guideline values to establish whether or not the 'water quality' health-based targets are being achieved under both routine and event conditions. For acute-acting chemicals, and for microbial constituents, water quality values are translated into either performance or technology targets and system performance capability is assessed as described in the two rows that follow.*
Performance	*Performance characteristics and validation data on the removal of groups of microbes and chemicals by water supply system process steps*	*The water supplier assesses the capability to meet the required 'performance' health-based targets. Knowledge of system capability is obtained from both local validation data and literature-derived technology performance information. System capability assessment is based on comparing the collective performance of the multiple barriers in the system with performance requirements under both routine and event conditions.*
Specified technology	*Knowledge of the functional presence of technologies within the water supply system*	*The water supplier assesses the presence within the system of the required 'technology' health-based targets. System capability assessment is based on comparing the functional presence of the required technology in the system with specified requirements under both routine and event conditions.*

2.5 References

WHO (World Health Organization) (2004). Guidelines for Drinking-water Quality. Third Edition.

CHAPTER

3

System Assessment

In this section, the key WSP steps to be worked through are:

- Assemble the team to prepare the Water Safety Plan
- Document and describe the system

Commencement of the WSP process involves gaining an understanding of the water supply system and its context that can affect water quality and safety throughout the supply chain. To achieve this understanding, it is necessary to undertake the steps listed below.

- Bring together a team with sufficient experience, expertise and capacity.
- Understand the source of water and what risks may impact on the source.
- Know what criteria or health-based targets have to be achieved.
- Confirm whether the current system is capable of meeting the required criteria (more comprehensively than that preliminary assessment of system capability described at Section 2.4).

3.1 Assemble the team to prepare the WSP

Team members

Typically, the team might include:

- managers;
- engineers (operations, maintenance, design and capital investment);
- water quality control staff (microbiologists and chemists); and
- technical staff involved in day-to-day operations.

This step involves assembling a team of individuals and stakeholders with the collective responsibility for identifying hazards that can affect water quality and safety throughout the water supply chain. In general the team will be a working party or taskforce that is collectively responsible for developing, implementing and maintaining the WSP as a core part of their day-to-day roles. However, with the probable exception of one or more coordinating and resource personnel, most members of the team will not be 100% committed to WSP duties but will also continue with their normal duties. Team members need to collectively possess the skills required to identify hazards as well as to understand how these hazards may be controlled. In addition, the team needs to have the authority to ensure the implementation and management of controls so that the WSP can be implemented in practice.

Given the above, it is vital for the success of the WSP development and the team dynamic that a range of people are included. In setting up the team, the following checklist points will need to be considered to ensure that an appropriate team mix is achieved:

- ☑ technical expertise and operational system-specific experience required to develop the WSP;

- ☑ capacity and availability to undertake the WSP development, implementation and maintenance;
- ☑ organizational authority to report through to the relevant controlling authorities, such as the Executive of an organization, or leaders of a community;
- ☑ understanding of the organizational and people management systems and processes that turn plans into actions and that communicate the results of monitoring and reporting;
- ☑ understanding the health based targets to be met;
- ☑ general appreciation of the water quality needs of the end users;
- ☑ understanding of the practical aspects of implementing WSPs in the appropriate operational context;
- ☑ appreciation of the regulatory and policy environment of the organization; and
- ☑ familiarity with training and awareness programs.

Depending on the size of a water supply organization, and where organizations are responsible for multiple systems, it may be necessary to have multiple WSP sub-teams, which report to a central overarching team. The usefulness of this arrangement needs to be assessed at the commencement of the process but may include:

- a core team;
- subordinate teams that undertake particular aspects of the WSP, such as a 'catchment', 'source water', 'treatment' and 'distribution system' sub-team and if necessary, where treatment aspects are complicated and varied for instance, it may be advantageous to have separate treatment teams; and
- external team members and reviewers (incorporating government agents and independent experts).

3.1.1 Recording information

Information on the team needs to be recorded (facilitates demonstration of due diligence and communication) and include:

- ☑ name;
- ☑ affiliation;
- ☑ title;
- ☑ role in WSP; and
- ☑ contact information.

WSP Example 3-1. WSP team composition (illustrative example from Melbourne Water).

Job title	Work team	Expertise
Team Leader Senior Engineer	Water Quality Planning	Water Quality Engineering
Water Supply Operator	Water Harvesting Team	Operations
Process Support – Service Delivery	Operations – North Area	Water Treatment Specialist
Water Supply Operator	Westernport Area Team	Operations – distribution/treatment
Section Leader Water Treatment	Treatment Systems	Treatment plant asset management
Operations Contractor	Operations – South Area	Water supply engineering
Water Supply Operator	Reservoir Team	Operations
Process Engineer	Operations – North Area	Water supply engineering
Water Supply Operator	Reservoir Team	Treatment plant operations
Water Supply Operator	Reservoir team	Reservoir area
Principal Scientist	Water Quality Planning	Microbiology
Section Leader Headworks	Operations	Catchment operations
Scientist from retail water company	Retail Water Company	Water quality specialist/chemist
Engineer from retail water company	Retail Water Company	Water quality engineering (distribution)
Engineering manager from retail water company	Retail Water Company	Water quality planning

NB: as mentioned above (section 3.1), the use of sub-teams should be considered to pay specific attention to areas such as source water, treatment and distribution with these sub-teams reporting back to the core WSP team.

3.2 Describe the System

Documentation of the nature of the water quality and of the system used to produce water of that quality is important to ensure that hazards and risks are adequately assessed and managed.

3.2.1 Describe the Water Supply System and Water Quality Requirements

A detailed description of the water supply should include:

- the source of water including the runoff and/or recharge processes;
- if the water is stored or treated anywhere and how;

- what is added to the water;
- how the water is distributed; and
- a water quality specification for each type of water produced.

A detailed description of the water supply system is required to support the subsequent risk assessment process. Pertinent information on the system should be assembled and made readily available for use during that process. The description should include:

- ☑ sufficient information to identify relevant types of hazards and controls;
- ☑ regulatory water quality requirements;
- ☑ chemicals or materials that are added to the water; and
- ☑ customer water quality requirements and expectations.

WSP Example 3-2. Process description.

Step	Process description	Reference for details
Water source	Surface water as supplied by the bulk supplier. Catchment includes intensive agriculture and urban development and requires extensive treatment.	GIS layers and reports
Water treatment	Filtration, ozonation, biological activated carbon treatment and chlorination to meet the objectives of the appropriate health authority requirements as specified in water treatment plant design and operations manuals and contractor specifications. Treatment chemicals are added.	Plant process and instrumentation diagrams Treatment chemicals register
Distribution	Piped and pumped reticulated distribution as shown in system GIS and printed system diagrams.	System maps and GIS layers
Storage after treatment	Covered service reservoirs as shown in system GIS and printed system diagrams.	System maps and design drawings
Any special controls required?	Quality of chemicals and materials used in the production and delivery of the product.	Contracts specifications for supplies
Water quality requirements?	Current version of the National Guidelines or Standards and special requirements if stipulated by the Health Authority.	National Guidelines or Standards and Health Authority Internet sites

WSP Example 3-3. Water quality specification.

The organization provides one product, which is described as potable water. The water will be received from a bulk water supplier and/or abstracted from rivers and groundwater and delivered to customers to meet the water quality objectives set by the Health Authority. The water quality objectives are captured in the prevailing National Drinking Water Standards. Disinfection and fluoridation chemicals are supplied by approved chemical manufacturers and form part of the delivered product. Quality agreements are in place in relation to treatment chemicals received from manufacturers and bulk water received.

3.2.2 Identify the range of uses and users of water

The objective of this section is to identify the range of uses of the water supplied by the organization and the intended consumers of the water including:

- uses of water (this may include some or all of the following - drinking, cooking, bathing, laundry, washing utensils);

- what education and training has been provided to the community regarding the use of the water supply, including specific messages;
- identifying whether there are particularly vulnerable groups within the user population who have specific water quality requirements; and
- can the technology satisfy all the demands placed upon it in relation to quality and quantity, including consideration of vulnerable groups?

This information is essential if risks are to be subsequently identified within the context of the actual use of the water. Specifically, water supply organizations should consider the following:

- ☑ primary intended use of the water and the users that can carry out that use;
- ☑ accepted additional uses and associated users;
- ☑ uses to which the water should not be put;
- ☑ groups that should not use the water for its primary intended uses;
- ☑ vulnerable human populations; and
- ☑ sensitive residential industrial, commercial and medical water uses.

WSP Example 3-4. Intended uses and users of the water.

Intended Use	Intended Users
The water supplied is intended for general consumption by ingestion. Dermal exposure to waterborne hazards through bathing, laundry as well as inhalation from showering and boiling are also exposure routes for waterborne hazards. Foodstuffs may be prepared from the water.	The organization provides water to the general population. The intended consumers do not include those that are significantly immunocompromised or industries with special water quality needs. These groups are advised to provide additional point-of-use treatment. Fish and amphibians may be intoxicated by the chlorine and chloramine present in the water.

3.2.3 Construct a flow diagram

It is important to capture the elements of the water supply system in sufficient detail to enable the accurate assessment of risks and identification of control measures. The objectives of this step are therefore:

- to conceptually understand the water supply process through building a process flow diagram;
- to identify the linkages, water flow direction and responsibilities in the water supply process; and
- to go over how to take the process flow diagram 'out of the office' and verify it on site.

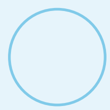
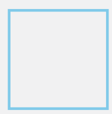
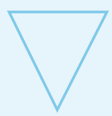
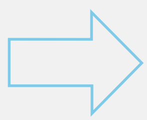
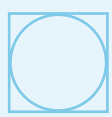
A good conceptual flow diagram greatly facilitates the identification of hazards, risks and controls as it allows:

- identification of pathways by which hazards can be transferred to consumers; and
- identification of "critical control points" on the flow diagram at the conceptual level even if they cannot be identified as specific points in time and space.

The flow diagram should be high level and conceptual. To avoid duplication, cross reference should be made to other documentation covering finer details (depending on the complexity of the system and if available) such as maps showing properties, sewage treatment plants and other potential polluters and customers.

For simplicity and consistency, standard flow diagram symbols are generally used (Table 3-1) to construct the flow diagram although for smaller systems, narrative descriptions may suffice (NZ MoH 2005).

Table 3-1. Process flow diagram symbols.

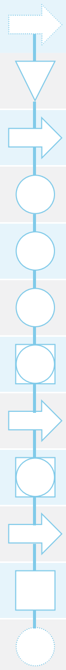
Flow Diagram Symbol	Definition of Symbol
	Operation: Indicates when there is an operation or group of operations that result in intentional change in the water.
	Inspection: Represents an inspection or decision, for example, water supply is examined or is verified.
	Storage: Where water is stored.
	Transport: Occurs when the water is moved from one place to another.
	Combined activity: Indicates activities performed either concurrently or by the same operator at the same location. Any combination of symbols may be used. Example shown indicates a combined operation and inspection.

Not all process steps are the responsibility of the water supply organization. However, it is important to record who has primary responsibility as this information will impact on the choice and efficacy of control measures.

For simple systems, showing the order of each step is sufficient to indicate the direction of water flow through the system. However, for more complex systems it may be necessary to indicate the water direction with the use of arrows.

For an accurate representation of the system and identification of hazardous events, it is essential that the flow diagram is taken "out of the office" and verified. Signed copies of flow diagrams should be prepared after field verification and the diagram is retained as part of the WSP.

WSP Example 3-5. Verified process flow diagram.

Code	Step	Description	Responsibility
W1		Catchment	Multiple stakeholders
W2		Primary storage	Utility
W3		Bulk water transfer (gravity)	Utility
W4		Setting/clarification	Utility
W5		Filtration	Utility
W6		Ozone/BAC	Utility
W7		Chlorination (HOCl)	Utility
W8		Distribution	Utility
W9		Booster chlorination (HOCl)	Utility
W10		Distribution	Utility
W11		Meter box	Utility
W12		Household use	Customer

System verified by: Barbara Ford **Authority:** System Manager **Date:** 25 October 2007

3.3 References

NZ MoH (New Zealand Ministry of Health) (2005) Small Drinking-water Supplies. Preparing a Public Health Risk Management Plan. Drinking-water Supplies. Ministry of Health, Wellington. ISBN 0-478-29618-5

CHAPTER

4

Hazard Identification & Risk Prioritization

In this section, the key WSP steps to be worked through are:

- **Undertake a hazard identification and risk prioritization**
- **Identify additional control measures required**

The objectives of this step are:

- to consider all aspects of the supply system (including the catchment and source waters and make reference the flow diagram for treatment and distribution);
- to identify all potential biological, physical and chemical hazards that are associated with the drinking water supply;
- to identify the hazardous events that can result in hazards gaining entry to the water supply "What could happen here or what could go wrong here?";
- to identify the control measures currently in place; and
- to determine the risk potential of each hazardous event at each process flow step.

4.1 Hazard identification & risk prioritization

4.1.1 Identify potential hazards

For each step of the verified process flow diagram, the team is required to assess what could go wrong to introduce hazards (Table 4-1) through hazardous events. An example output is given in WSP Example 4-1. Further guidance on hazards and hazardous events can be found in WHO (2004), Howard (2002) and online at www.moh.govt.nz.

4.1.2 Determine existing control measures

Control measures ('barriers to contamination') that are currently in place need to be captured at each process step and for each hazard/hazardous event identified above (section 4.1.1).

The control measure information allows the organization to assess the existing (or proposed) system and determine if there are risks that are high, and consequently, need further treatment to be reduced to a tolerable level (AS/NZS 4360:2004; NZ MoH, 2005a).

Similarly, if control measures are planned for implementation, such as improved treatment works, it is acceptable that they are also considered as part of the existing system at this stage.

Hazards and Hazardous Events

Hazards are defined as:

- physical, biological or chemical agents that can cause harm to public health.
- Hazardous events are defined as:
- an event that introduces hazards to, or fails to remove them from, the water supply.

Control Measure

Any action or activity that can be used to prevent, reduce or eliminate a water supply quality/safety hazard to a tolerable level.

Control measures may take the form of:

- preventing contaminants (hazards) gaining access to the water;
- removing hazards from the water;
- inactivating pathogens in the water; and
- maintaining the quality of the water during distribution (NZ MoH, 2005a).

Preventive approaches within the catchments are a wiser investment than a treatment facility to remove the hazard or contaminant. Control measures should be recorded against each of the identified hazards and hazardous events.

Table 4-1. Examples of hazards and their control measures.

Hazards	Examples of Control Measures
Microbial (M) *Examples:* *bacteria, viruses, protozoa*	▪ Protection of catchments from farm animals and human habitation. ▪ Fencing out of farm animals from catchment streams and watercourses. ▪ Exclusion of juvenile animals from catchment source areas. ▪ Cessation of source water abstraction during high contamination periods, e.g. after storms. ▪ Mixing of storages to reduce cyanobacteria. ▪ More reliable treatment through introducing duty and standby systems. ▪ Maintenance of continuous system pressurisation to prevent ingress. ▪ Hygienic line maintenance and repair procedures. ▪ Backflow prevention devices.
Chemical (C) *Examples:* *disinfection by-products, chemical impurities, cleaning agents, pesticides, naturally occurring chemicals such as arsenic and fluoride*	▪ New procedures/equipment for dosing of chemicals. ▪ Chlorine optimisation study to reduce trihalomethanes (THMs). ▪ Removal of precursors to reduce THMs. ▪ Isolating system from potential spills. ▪ Quality Assurance system for chemical suppliers. ▪ Backflow prevention for key industries. ▪ New liners/materials for pipes and reservoirs.
Physical (P) *Examples:* *sediment particulates, corrosion products*	▪ Increased cleaning of mains. ▪ Replacing unlined pipes and fittings. ▪ Flocculation or filtration treatment steps. ▪ New maintenance Standard Operating Procedures to avoid unnecessary resuspension of materials. ▪ Practices to avoid reversal of flows.

4.1.3 Prioritise risks

Risk Definition

Risk is:

The likelihood of identified hazards causing harm in exposed populations in a specified timeframe including the magnitude of that harm and/or the consequences (GDWQ)

Because a number of hazardous events may occur at any one step, it is important to decide whether any of these events present a significant risk and need to be elevated for action. A risk assessment process is therefore required to prioritise the events.

The risk assessment process can involve a quantitative or semi-quantitative approach (estimation of Consequence/Likelihood and Frequency/Severity) or a simple team decision to rule hazardous events in or out. Further direction can be found in AS/NZS 4360 (2004) and other supplementary texts including Deere and Davison (2005), WHO (1999), WHO/FAO (2003) NZ MoH (2005b).

A relatively small water supply system may only require a team decision approach to rule events in or out (section 4.1.3.1). A more complex system may benefit from a semi-quantitative risk prioritization approach. In either case, it is beneficial to record the basis (WSP Example 4-1) of the decision as this acts as a reminder to the team and/or an auditor or reviewer, on why a particular decision was taken at the time. Past water quality monitoring data would be helpful in identifying the risks.

The following checklist for risk prioritization can be used to help direct thinking.

- ☑ Decide on a consistent risk assessment methodology upfront;
- ☑ Be specific about what the risk is in terms of:
  - risk of a specific event;
  - leading to a specific hazard;
  - reaching a specific and problematic concentration; and
  - at a specific point in time and space.
- ☑ Treat control measure failure as a separate hazardous event in its own right and with its own likelihood and consequence.

The following sections detail the risk prioritization methods that can be used.

4.1.3.1 Risk Prioritization Method 1: Simple Team Decision

This method involves using the team's judgement to:

- assess the hazardous event/s at each step in the process;
- determine whether they are under control; and
- document whether those events need urgent attention.

The NZ MoH (2005) defines 'urgent attention' as those things that happen a lot and/or could cause significant illness. The descriptors listed in Table 4-2 can be used to capture this information.

Table 4-2. Simple risk prioritization.

Descriptor	Meaning	Notes
Significant	Clearly a priority	The risk should be considered further by the team to define whether additional control measures are required and whether a particular process step should be elevated to a key control point in the system.
Uncertain	Requires further consideration by the team	The risk may require further studies to understand if the event really is a significant risk or not. An example of an uncertain risk includes endocrine disruptors for which it is suggested that a watching brief be kept.
Insignificant	Clearly not a priority	Note that the risk will be described and documented as part of a transparent and diligent process and will be revisited in future years as part of the WSP rolling review

WSP Example 4-1. Output of hazard assessment and simple risk prioritization.

Process Step	Hazardous Event	Hazard Type	Control Measures Current and/or Planned	Risk	Basis
Source (Groundwater)	Cattle defecation in vicinity of unfenced wellhead causing source of potential pathogen ingress in wet weather	M (pathogens) and C (nutrients)	None existing for this hazardous event	S	Public health issues from pathogens from cattle including Cryptosporidium and E. coli 0157; contamination of water from nitrogen and phosphorus compounds from faeces

4.1.3.2 Risk Prioritization Method 2: Semi-quantitative Approach

The AS/NZS 4360:2004 Risk Management Standard gives some guidance on the use of semi-quantitative risk assessment. This approach has been adapted by various people for application in the water sector (NZ MoH, 2005; Davison et al, 2003; Stevens et al, 2004) (Figure 4-1).

The team needs to determine a cut-off point, above which hazards will require further attention and below which they will be considered in future iterations. In the example below (Figure 4-1), the score of 6 is generally taken as the cut-off point with the exception of "Rare" and "Catastrophic" which although it has a score of 5, is also included.

For each event, 'Risk' is calculated by multiplying 'Likelihood' by 'Severity', the results recorded (WSP Example 4-2) and those hazardous events with scores at the cut-off or above are investigated further in terms of reducing their risk.

Figure 4-1. Example risk matrix.

Risk Factor Matrix:		Severity or Consequence				
		Insignificant No impact / not detectable Rating: 1	**Minor** Compliance Impact Rating: 2	**Moderate** Aesthetic Impact Rating: 3	**Major** Regulatory Impact Rating: 4	**Catastrophic** Public Health Impact Rating: 5
Likelihood or frequency	**Almost Certain** Once a day Rating: 5	5	10	15	20	25
	Likely Once a week Rating: 4	4	8	12	16	20
	Moderate Once a month Rating: 3	3	6	9	12	15
	Unlikely Once a year Rating: 2	2	4	6	8	10
	Rare Once every 5 years Rating: 1	1	2	3	4	5

Source: Deere et al, 2001

WSP Example 4-2. Output of hazard assessment nd semi-quantitative risk prioritization.

Process step: Catchment

Hazardous Event	Hazard Type	Likelihood	Severity	Risk	Control Measures	Basis
Sewage spill during large storm transporting pathogens to reach unacceptable concentrations at the surface water abstraction point	Microbial (pathogens)	2	5	10 Significant	Pollution control in source water catchment Filtration of water Disinfection of water Boil water advisory	Waterborne disease outbreaks have arisen from pathogens from sewage including *Cryptosporidium* and viruses during similar scenarios

4.2 Identifying additional or improved control measures

All significant risks identified through the risk assessment process need to be further investigated to ensure that the risk is reduced to a tolerable level especially after control measures are in place. In the examples above (WSP Example 4-1 and WSP Example 4-2), both hazardous events have been elevated to 'Significant' because control measures are either not in existence or not effective. Through the risk assessment process, it has become clear that the system needs to be modified to achieve the relevant water quality objectives, and therefore reduce risk to a tolerable level.

This information needs to be recorded against the relevant hazards and hazardous events on the worksheet and can subsequently be used to develop an 'Action Plan' (WSP Example 4-3) for improving drinking water quality.

WSP Example 4-3. 'Action Plan' for identifying and addressing system improvements.

Issue Identified		Action Required	Procedures or Records?	Responsibility	Time Frame	Signed Off By
No.	Issue					
1	Wellhead is unprotected	Liaise with landholder and fence-off buffer zone around wellhead.	Catchment inspection records	Catchment officer	Within three months	Signature here
		Protect wellhead by building secure premises	Work schedule	Manager Water Supply System	Within one year	Signature here

If system modification is required, control measure options will need to be considered at an economic, environmental and social level to ascertain suitable technologies and interventions for the situation (especially if capital works are identified) and to generate balanced outcomes for the community.

4.3 References

AS/NZS 4360:2004 Risk Management Standard. 3rd Edition. Standards Australia and Standards New Zealand. ISBN 0 7337 5904 1

Davison, A., Howard, G., Stevens, M., Callan, P., Kirby, R., Deere, D. and Bartram, J. (2003) Water Safety Plans. Protection of the Human Environment. Water, Sanitation and Health. WHO/SDE/WSH/02.09.

Deere, D., Stevens, M., Davison, A., Helm, G. and Dufour, A. (2001) Management Strategies. In Water Quality: Guidelines, Standards and Health – Assessment of risk and risk management for water-related infectious disease. (Eds. J. Bartram and L. Fewtrell) pp. 257-288, World Health Organization, IWA Publishing, London, UK.

Deere, D.A. and Davison, A.D. (2005) The Ps and Qs of Risk Assessment, Water, October 2005 pp 38-43

Howard G (2002). Urban water supply surveillance — a reference manual. Water, Engineering and Development Centre/Department for International Development, Loughborough University, UK.

NZ MoH (New Zealand Ministry of Health) (2005a) A Framework on How to Prepare and Develop Public Health Risk Management Plans for Drinking-water Supplies. Ministry of Health, Wellington. ISBN 0-478-29627-4

NZ MoH (New Zealand Ministry of Health) (2005b) Small Drinking-water Supplies. Preparing a Public Health Risk Management Plan. Drinking-water Supplies. Ministry of Health, Wellington. ISBN 0-478-29618-5

Stevens, M., Howard, G., Davison, A., Bartram, J. and Deere, D. (2004) Risk management for distribution systems. Chapter 7 In Safe Piped Water: Managing Microbial Water Quality in Piped Distribution Systems. Edited by Richard Ainsworth. ISBN: 1 84339 039 6. Published by IWA Publishing, London, UK.

WHO (World Health Organization) (1999). Principles for the assessment of risks to human health from exposure to chemicals. Environmental Health Criteria: 210. World Health Organization.

WHO (World Health Organization) (2004). Guidelines for Drinking-water Quality. Third Edition.

WHO (World Health Organization)/FAO (Food and Agriculture Organization of the United Nations) (2003). Hazard characterisation for pathogens in food and water: Guidelines.

CHAPTER

5

Operational Monitoring to Support Risk Management

In this section, the key WSP steps to be worked through are:

- **Define monitoring of control measures**
- **Develop corrective actions**

For operational monitoring, it is useful to have both target and action levels. Target levels are often related to national drinking water quality standards, such as zero E. coli, but not necessarily so. In the water resource section a target may relate to, for example, no landfills or housing projects within the watershed. The action levels are those, if breached, at which the pre-established corrective procedures come into force.

The type and number of control measures will vary for each system and will be determined on the type and frequency of hazards and hazardous events associated with that system. Monitoring of control measures is essential to support risk management by demonstrating that the control measure is effective and that if a deviation is detected, that actions can be taken in a timely manner to prevent health-based targets from being compromised. 'Monitoring' may also comprise verification and validation monitoring but these will be dealt with in the following chapter and this chapter specifically focuses on operational monitoring of control measures.

5.1 Operational monitoring and selection of operational control parameters

Operational Monitoring

Operational monitoring assesses the performance of control measures at appropriate time intervals.

Intervals may vary widely – for example, from on-line control of residual chlorine to quarterly verification of the integrity of the plinth or concrete base surrounding a well (GDWQ).

Operational monitoring is the act of conducting a planned sequence of observations or measurements, to assess whether the control measures applied at a point in the system are achieving their objectives. Effective monitoring relies on establishing:

- what will be monitored;
- how it will be monitored;
- where it will be monitored;
- when it will be monitored;
- who will do the monitoring.

In most cases, routine operational monitoring will be based on simple surrogate observations or tests, such as turbidity or structural integrity, rather than complex microbial or chemical tests.

Examples of Operational Monitoring Parameters

Measurable:

- chlorine residuals;
- pH; and
- turbidity

Observable:

- integrity of fences or vermin-proofing screens (GDWQ).

In defining operational monitoring, consider the following checklist and see WSP Example 5-1:

- ☑ Have limits been defined for the control measure?
- ☑ Can the parameter be measured in a timely fashion (monitoring needs to be in line with the speed with which the barrier can fail – critical processes would ideally be on-line, less critical processes could be monitored monthly for instance)?
- ☑ Can corrective actions be implemented in response to the detected deviations?
- ☑ Has the list of hazardous events and hazards been checked against monitoring to ensure that all significant risks can be controlled?

For some control measures, it may be necessary to also define 'critical limits' outside of which confidence in water safety would be lost. Deviations from these critical limits usually require urgent action and may involve immediate notification of the local health authority (GDWQ).

5.2 Establish corrective action for deviations that may occur

Corrective Action

Action to be taken when the results of monitoring at a control point indicate a loss of control.

Corrective actions, along with monitoring, form the control loop to ensure that unsafe drinking water is not consumed. Corrective actions should be specific and pre-determined where possible to enable rapid action. By ensuring that a contingency is available in the event of an operational limit being exceeded, safety of supply can be maintained (Stevens et al, 2004). In devising corrective actions within WSPs consider the following checklist and WSP Example 5-1.

- ☑ Have corrective actions been documented properly including assigning responsibilities for carrying out the actions?
- ☑ Are people correctly trained in carrying out corrective actions?
- ☑ Are the corrective actions effective?
- ☑ Is there a review process in place for analysing corrective actions to prevent recurrence of the need for a corrective action?

WSP Example 5-1. Operational monitoring and corrective action example.

Process Step/ Control Measure	Operational Limit	Monitoring					Corrective Action
		What	Where	When	How	Who	
Source/ control of development in catchment	< 1 septic tank per hectare and none within 30 m of stream	Local government planning approvals	Local government offices	Annually	On site at local government office	Environmental officer from Ministry of Environment	Meet with landholder to explain risks and get septic system relocated
	Fencing out of all juvenile cattle from riparian areas	Farm management practice audits	Ministry of Agriculture	Annually	On site at Ministry of Agriculture	Environmental health officer from Ministry of Health	Meet with farmer to explain risks and install fences
Treatment/ chlorination at water treatment plant	Chlorine concentration leaving plant must be between 0.5- 1.5 mg/l	Disinfectant residual	At entry point to system	Every four hours	Chlorine test kit	Water quality officer	Issue boil water notice until chlorinator fixed

5.3 Incidents and emergencies

Most corrective actions are relatively routine and are capable of being handled by automated systems and/or trained system operators. However, if the corrective action does not bring the system back under control, or if some unforeseen event occurs, it is possible that water quality and safety could become compromised. Under such circumstances a major response is required to prevent potentially significant health impacts. Such broad responses are often termed 'incidents' or 'emergencies'. To prepare for such events, predetermined water quality incident and emergency response plans should be developed to set up a response framework. A checklist for incident and emergency response aspects of WSPs follows.

- ☑ Are people correctly trained in carrying out emergency and incident response, including undertaking mock water contamination incidents?
- ☑ Are there mechanisms for rapidly notifying at risk groups to prevent ingestion of potentially contaminated water? This may include hospitals, dialysis patients, schools and nursing facilities.
- ☑ Are there mechanisms for rapidly notifying local health authorities at any time of day or night?
- ☑ Are alternative water supply arrangements in place?
- ☑ What will be done with any potentially contaminated water and how will normalcy be restored?

5.4 References

Stevens, M., Howard, G., Davison, A., Bartram, J. and Deere, D. (2004) Risk management for distribution systems. Chapter 7 In Safe Piped Water: Managing Microbial Water Quality in Piped Distribution Systems. Edited by Richard Ainsworth. ISBN: 1 84339 039 6. Published by IWA Publishing, London, UK.

CHAPTER

6 Verification

In this section, the key WSP steps to be worked through are:

Establish procedures to verify that the water safety plan is working effectively and will meet the health-based targets

The objective of this step is:

- to build a body of evidence that water produced by the water supply system is compliant with the water quality objectives;
- to confirm that the WSP is being implemented in practice as it was designed to be; and
- to confirm that the critical limits and other important values are appropriate for controlling the identified risks so that the system is capable of producing water fit for intended uses.

6.1 Establish verification

Verification

Involves:

- water quality monitoring;
- internal and external audit of operational activities;
- consumer satisfaction; and
- validation of system capability.

Having a formal and systematic process for verification of the WSP ensures that responsibilities are outlined and personnel assigned. Verification involves three activities that are undertaken together to provide a body of evidence that the WSP is working effectively and will meet the following health-based targets:

- water quality monitoring;
- internal and external auditing of operational activities;
- consumer satisfaction; and
- validation of system capability.

An example of a verification schedule is given in WSP Example 6-1.

6.1.1 Water quality monitoring

Water quality monitoring, and potentially other tests, need to be used to build up an ongoing body of evidence of compliance with the water quality targets. The purpose of water quality verification is primarily about confirmation of water quality targets. Therefore, the water supply organization should be expecting to find results from verification monitoring that are consistent with the water quality targets. Corrective action plans need to be developed to respond to, and understand the reasons for, any unexpected results. Monitoring frequencies for verification need to be commensurate with the level of confidence required by the water supply organization and its regulatory authorities. Monitoring frequencies for microbial verification are often quite high, not less than monthly, often weekly and up to once per working day (see also Table 4.5 of the GDWQ).

For microbial water quality verification, indicator organisms generally provide conservative subjects for such monitoring and do not represent excessive cost as compared with pathogens. Monitoring of pathogens is unnecessary if more numerous and resistant indicators can be shown to be below target concentrations. The most widely used verification system is to monitor *E. coli* or thermotolerant coliforms at representative points in the water distribution system.

For chemical water quality verification, indicators are not generally used and chemicals are monitored directly. Most chemical hazards are unlikely to occur at acutely hazardous concentrations and verification frequencies might be less frequent than for microorganisms, often quarterly and sometimes biennially. Ideally, long term monitoring and/or detailed and verified knowledge of source water inputs are used to tailor verification monitoring to only test for chemicals that have a reasonable probability of occurring in the specific water supply system.

6.1.2 Internal and external auditing

A WSP is of little value if it is only a document or statement of intentions. The practical implementation of the WSP in practice is of vital importance if water safety and quality risks are to be controlled. An important aspect of maintaining the practical implementation of a WSP is to undertake rigorous audits. Auditing can involve internal, external peer review, regulatory and independent external auditors. The auditing can have both an assessment and a compliance checking role. For example, auditors will identify opportunities for improvement such as areas where resources are insufficient, plan requirements are impractical or where training or motivational support is required for staff. Auditing frequencies for verification need to be commensurate with the level of confidence required by the water supply organization and its regulatory authorities. Typically, WSP internal auditing is from daily to monthly whereas external WSP audits are generally from every six months to triennial.

6.1.3 Consumer satisfaction

It is important that consumers are using the safe, managed water supply rather than less safe alternatives. Verification includes checking that consumers are satisfied with the water supplied.

WSP Example 6-1. Example verification information capture format.

Activity	Description	Frequency	Responsible Party	Records
Water quality monitoring	E. coli is monitored in finished water samples in all zones at tap sites	At least weekly	Laboratory of Ministry of Health	Water quality database
Calibration program audit	Calibration records are audited at all sites for instruments that monitor key control points.	At least quarterly	Auditor from Ministry of Health	Audit records

Validation

Validation is required where assumptions or statements are made in the development of the WSP with particular attention being given to why particular critical limits were chosen.

6.1.4 Validation of system capability

Validation involves verifying that the operational and critical limits and other values that have been chosen are appropriate for controlling the identified risks. Validation is the process of using empirical evidence from pilot and full-scale operation of the system, water quality testing, published technical literature and documented expert judgement. There are several items that receive attention during validation.

- the basis for the risk prioritization;
- the justification for the values set for operational and critical limits identifying the basis on which the limits are believed to enable control of the identified risks;
- the practicality of the monitoring regime and corrective actions; and
- the evidence to show that the overall system design and operation is capable of consistently delivering water of the specified quality to meet the health-based targets (described above as part of preliminary assessment of system capability under Section 2.4).

An example of what might constitute validation evidence is given in WSP Example 6-2. Validation may also include system specific studies, for instance, performing pathogen budgeting exercises in catchments to validate implemented control measures such as buffer distances and fencing.

WSP Example 6-2. Example validation information capture format.

Item validated	Validation	Reference
Chlorine residual values for pH, temperature, time and free chlorine concentration.	USEPA provide specific CT requirements for inactivation of Giardia from catchments containing possible sewage and animal contamination sources which are expressed in terms of minimum chlorine/time/pH/temperature envelopes.	USEPA Disinfection Guidance.
Maintaining system pressure	Hydraulic modelling and system design to ensure no areas of low pressure below 15 m head during peak flow	Hydraulic system design and modelling report.

6.2 Generic management systems and certification

The WSP guidance provides a tailored system for guiding the systematic assessment and management of risks to drinking water quality. There are many parallels between the WSP and the generic management system standards, such as ISO 9001, ISO 22000 and HACCP.

The WSP should be applied to all water supplies and is tailored, and designed, specifically for that purpose. The generic management systems can be applied to water supplies too, but are not tailored to water and can be applied to virtually any good or services (ISO 9001) or any food or food chain components (ISO 22000 and HACCP). The generic management system standards can be used to gain 'certification' of conformance with the principles and criteria of the standard. Certification involves a registered certifying auditor undertaking an audit of the water supply organization and reporting conformance with the relevant standard. The auditor would be registered with a registration body (such as RABQSA) and would either operate independently, or would work for an auditing and certification firm.

It is perfectly reasonable to implement a WSP without drawing from, or using, any of the generic management systems. In fact, the WSP was developed with the relevant aspects of the generic management systems kept in mind and so already includes those that are of value. However, the converse is not true: it is not sensible to implement a generic management system standard without fully conforming to the WSP guidance. The generic management systems specifically promote adoption of good industry and sectoral practices as part of their compliance requirements. The WHO GDWQ, and the WSP, are international best practice benchmarks for drinking water quality management. Therefore, not implementing a WSP could be seen as nonconformity against a generic management system standard as applied to safe drinking water supply.

6.3 References

WHO (World Health Organization) (2004). Guidelines for Drinking-water Quality. Third Edition.

CHAPTER

7

Supporting Programmes and Management Procedures

In this section, the key WSP steps to be worked through are:

- **Develop supporting programmes**
- **Prepare management procedures for normal and incident conditions**

The delivery of safe water through a WSP involves managing people and processes and this is generally achieved through programmes known as Supporting (or in some instances Prerequisite) Programmes.

In addition, actions to be undertaken in operating the system according to the WSP need to be captured in the form of management procedures, such as standard operating procedures.

7.1 Supporting programmes

Supporting Programmes

Organization-wide programmes that are required to support the delivery of safe quality water by the organization and any contractors used.

Supporting Programmes are those activities that indirectly support water safety and are also essential for proper operation of the control measures.

Supporting Programmes cover a range of activities including calibration, preventive maintenance and hygiene and sanitation as well as legal aspects such as a programme for understanding the organization's compliance obligations. Due to the increasing demands on organizations in terms of business aspects and the production of many water 'products' (drinking water, recycled water, etc) (Davison and Deere, 2005; Davison et al, 2004), it is essential that organizations understand their liabilities and have programmes in place to deal with these issues. Examples of types of Supporting Programmes are provided below (Table 7-1).

The organization should use the examples (while not intended to be exhaustive) as a guide and assess the programmes it currently has in place and any gaps that need to be addressed including:

- updating of existing programmes; and
- development of new programmes.

As mentioned in the following section (Chapter 8), it is important to ensure that version control on the programmes is clearly marked to ensure that staff follows the most current procedures.

Table 7-1. Types of Supporting Programmes that could be included in the WSP.

Program	Purpose	Examples
Calibration	To ensure that critical limit monitoring is reliable and of acceptable accuracy.	Calibration schedules. Self-calibrating equipment.
Preventive maintenance	To ensure that malfunctions of important processes are minimized and storages and assets are in good working order.	Maintenance program. Tank cleaning program.
Hygiene and sanitation	To prevent organization (and contractor) plant, personnel and equipment from introducing hazards to the water.	Divers using fully contained suits. Pipe sections stored capped.
Training and awareness	To ensure organization (and contractor) personnel understand water safety and the influence of their actions.	WSP training. Competency requirements. Induction training.

7.2 Management procedures

Management Procedures

The management plan needs to capture procedures for conditions of:

- normal operations; and
- incident and emergency operations.

Effective management implies definition of:

- actions to be taken in response to variations that occur during normal operational conditions;
- actions to be taken in specific 'incident' situations where a loss of control of the system may occur; and
- procedures to be followed in unforeseen and emergency situations (GDWQ).

Management procedures need to be documented alongside system assessment, monitoring plans, Supporting Programmes and communication procedures that are required to ensure safe operation of the system (GDWQ).

An incident/emergency response plan will typically cover the elements detailed in the following checklist:

- ☑ accountabilities and contact details for key personnel, often including several organizations and individuals are clearly stated;
- ☑ there is clear definition of trigger levels for incidents including a scale of alert levels e.g. when an incident is elevated to a boil water alert;
- ☑ there is clear description of the actions required in response to alerts;
- ☑ the location and identity of the standard operating procedures and required equipment, including backup equipment, are clearly detailed;
- ☑ relevant logistical and technical information is on hand and up to date; and
- ☑ checklists and quick reference guides have been prepared and are up to date.

Given the usual immediacy of emergencies, it is essential that the organization's staff is trained in the response procedures and that the training is up to date, including emergency scenario training with other agencies where appropriate.

Review of the emergency situation and response should also be carried out by the organization to ensure that if possible, the situation does not recur or if not possible, to review whether the response could have been handled better. Questions to be asked in a review include:

- What was the cause of the problem?
- How was the problem first identified or recognised?
- What were the most essential actions required?
- Water communication problems arose and how were they addressed?
- What were the immediate and longer-term consequences?
- How well did the emergency response plan function? (GDWQ).

7.3 References

Davison, A. and Deere, D. (2005) Risk Management & Due Diligence In The Water Industry. Water, May: 23-26

Davison, A.D., Pryor, E.L., Howard, G. and Deere, D. (2004) Duly diligent utilities. IWA World Water Congress & Exhibition, 19-24 September 2004, Marrakech.

WHO (World Health Organization) (2004). Guidelines for Drinking-water Quality. Third Edition.

CHAPTER

8 Documentation

In this section, the key WSP steps to be worked through are:

Establish documentation and communication procedures

Documentation

Provides proof of compliance. Facilitates demonstration of due diligence.

Documentation and records need to be retained to provide retrospective proof of compliance and to support due diligence requirements (Davison and Deere, 2005; Davison et al, 2004). In summary, the following points should be covered:

- document information pertinent to important aspects of water quality management;
- develop a document control system to ensure current versions are in use;
- establish a records management system and provide support in keeping records of activities; and
- periodically review documentation and revise as necessary.

There are many components for which records need to be kept and a review required. Examples of desired and useful records are provided by Stevens et al (2001) and adapted in Table 8-1.

Table 8-1. Examples of WSP records.

Requirement	Component
Must contain	An overarching WSP document
	WSP team information
	Description of the supply system, intended use and water quality requirements
	Process flow diagrams and including identifying control measures
	Operational monitoring procedures for control measures
	Hazard identification
	Contingency plans
Should contain	Supplier agreements for suppliers that are being relied upon to provide goods or services that influence water quality
	Detailed specifications for chemicals and materials used in the water supply system
	Job descriptions for those holding principal accountabilities for operating the water supply system
	Corrective action plans for deviations detected from operational monitoring
	Record-keeping requirements
	Validation data for control measures and for the system as a whole
	Procedures for verification and revision of the WSP
	An overarching water quality incident management plan
May contain	Operational manuals such as for line hygiene, preventative maintenance, and equipment calibration
	Job descriptions and accountabilities for all staff
	Training programme and records for all staff
	Findings and corrective actions from previous audits (including verification procedures)
	Consumer complaint policy and procedure

Source: Adapted from Stevens et al, 2004

8.1 Documentation

Documentation pertaining to the WSP should include the elements set out in the following checklist (GDWQ):

- ☑ description and assessment of the drinking water system including programmes to upgrade and improve existing water delivery;
- ☑ the plan for operational monitoring and verification of the drinking water system;
- ☑ water safety management procedures for normal operation, incidents (specific and unforeseen) and emergency situations; and
- ☑ description of supporting programmes.

In setting up documentation, it is preferable to interview staff to try and capture as much of their activity as possible rather than develop the documentation in isolation. This approach helps to foster ownership and eventual implementation of the procedures.

8.2 Records

Records are a necessary element of the WSP as they can be reviewed (through internal and external surveillance) to identify whether the WSP is adequate, and also to demonstrate adherence of the drinking water system to the WSP. The following checklist should be considered when developing records:

- ☑ Documents and records must be retained to provide an auditable system.
- ☑ Records need to include product identification, operational and critical limits and signatures.
- ☑ A system for capturing and recording completion of improvement actions is required.
- ☑ Corrective action records must correlate to monitoring records and include a description of the problem as well as record the method of contaminated water segregation and disposition.
- ☑ Records should be reviewed at appropriate intervals to identify any trends that may indicate the need for preventative action and/or review of the WSP.

8.3 Communication strategies

Effective communication strategies are essential for mitigating risk. Communication strategies (GDWQ) should contain the following elements:

- ☑ procedures for promptly advising of any significant incidents with the drinking water supply, including notification of the public health authority;
- ☑ summary information to be made available to consumers – for example, through annual reports and on the Internet; and
- ☑ establishment of mechanisms to receive and actively address community complaints in a timely fashion.

8.4 References

Davison, A. and Deere, D. (2005) Risk Management & Due Diligence In The Water Industry. Water, May: 23-26

Davison, A.D., Pryor, E.L., Howard, G. and Deere, D. (2004) Duly diligent utilities. IWA World Water Congress & Exhibition, 19-24 September 2004, Marrakech.

Stevens, M., Howard, G., Davison, A., Bartram, J. and Deere, D. (2004) Risk management for distribution systems. Chapter 7 In Safe Piped Water: Managing Microbial Water Quality in Piped Distribution Systems. Edited by Richard Ainsworth. ISBN: 1 84339 039 6. Published by IWA Publishing, London, UK.

APPENDIX

A Pro formas

A.1 Exercise Form 1: Water Safety Plan Core Team

Terms of reference:

Scope (what will be the geographical coverage, which systems will be covered)

Timelines (start, finish, interim milestones)

Objectives (WSP? HACCP? ISO 9001? Certification? Prototype? Pilot? Final? Demonstration?)

Roles

What role would you play in a WSP team?

Team details

Name	Organization/ Department	Job title	Role of person in WSP team	Contact details

A.2 Exercise Form 2: Product and process descriptions

Process step	Inputs	Description
Catchment, watershed or recharge area		
Nature of the consumers of water		
How the consumers will use the water		

A.3 Exercise Form 3: Flow diagram

Process step name	Symbol	Organization / department responsible
Key	Operation ○ Storage ▽ Transport ⇨	

A.4 Exercise Form 4: Hazard analysis

Process step:

Hazardous event (cause of contamination)	Hazard (contaminant of concern)	Control measure (to prevent contamination or remove it)	Severity (1 to 5) (consequence if event occurs)	Likelihood (1 to 5) (how often the consequence could arise)	Risk (1 to 25)

A.5 Exercise Form 5: Control points and monitoring

Process step:

Process monitoring (to confirm that the process is under control)	Critical limits (if critical limits are exceeded, corrective action is required)	Where to monitor	How to monitor	Frequency of monitoring	Who will monitor	Corrective action (Correction and longer term follow up in response to non-conformance)

A.6 Exercise Form 6: Verification

Verification activity	Location of activity	Type of activity (auditing, water quality testing, consumer assessment?)	Frequency of activity	Which organization/ department will undertake activity

A.7. Exercise Form 7: Gap Analysis against WSP requirements

Item that needs to be documented	Existing documentation and operational practices
Scope	
State which systems and sites are to be covered in the WSP	
State which issues are to be considered (Just one hazard? All health? Health and aesthetic?)	
Name the key contact person that is to be coordinating the WSP team(s)	
Decide if you'll have just one team or several WSP sub-teams.	
Identify who is on the team and their skills and roles including any external people.	
Product and use	
Identify water types provided (Potable water? Raw water?).	
Describe how the water is sources, treated, maintained, distributed and how consumers access the product.	
Identify all chemicals added including their form, type and source and any standards that they must conform with.	
Identify all materials that are used in the water supply assets, what is the source and what standards must they conform with?	
What is the water to be used for, by whom and will high risk groups be included (newborns, old people, AIDS patients, etc)	
Flow diagram	
Show main catchments, raw water storages, point of interface with raw water, any major storages, process steps (or rolled up process steps e.g. 'coag/floc/sed'), point where it becomes finished water then storage and distribution steps.	
Hazard analysis	
Consider hazards arising in the raw water, from each chemical input, at each process step and during distribution and storage. Include cause and hazard type. At least at the level of Microbial, Physical, Chemical, ideally more specific.	
Risks should be assessed in terms of probability of occurrence and severity with at least 1 to 3 scale for each and the overall risk is rated, at least as Low, Medium, High.	
Make sure the control measures are identified for each step.	
Identify the main control measures at which monitoring will take place for operational control.	
Document the operational procedures for the main control measures.	
Critical limits	
Identify the limiting operational values, at least identify the critical limits that must not be exceeded. Ideally identify other limits such as action, optimal operation or target levels too.	

Item that needs to be documented	Existing documentation and operational practices
Monitoring	
Identify how the main control measures will be monitored including What Where When (including frequency) How Who	
Document the monitoring procedures to be used for the monitoring of the main control measures.	
Corrective action	
Document the immediate correction to be used to provide the immediate fix or response if a critical limit is exceeded as detected by monitoring of each main control measure.	
Identify how water that may have become contaminated will be disposed of.	
Develop and test an emergency response procedure to handle water quality contamination incidents as efficiently as possible.	
Identify how alternative water will be supplied or provided in the event of a major failure.	
Record keeping	
Develop a systematic and searchable way of identifying the WSP records as distinct from general records.	
Assign accountability for accurate completion of all important WSP records.	
Ensure records are kept for the monitoring of all the main control measures.	
Ensure records are kept of the calibration and maintenance of equipment that is used to monitor the main control measures and key assets relevant to water quality protection.	
Ensure records are kept of any corrective actions taken including a root cause analysis before close out.	
Verification	
Document the validation of the critical limits at the main control measures.	
Have a regular audit of record keeping activities and other activities taking place at main control measures.	
Undertake water quality monitoring to verify the water being supplied.	
Audit the records of the corrective actions taken in response to nonconformances at the main control measures.	

Item that needs to be documented	Existing documentation and operational practices
Supporting Programs	
Implement a pest control program to keep vermin out of all facilities.	
Develop and comply with standard operating procedures for all working practices that involve working on the water supply system to ensure that hygienic work practices are adopted.	
Develop a quality assurance/quality control program for all inputs to the system such as chemicals and materials.	
Undertake a calibration and preventive maintenance program for equipment used to monitoring the main control measures and for the operational equipment used at the main control measures.	
Undertake regular staff training to ensure they are skilled to do their jobs and understand the risks associated with water quality.	
Ensure an awareness of regulatory issues related to water quality.	
Strive for compliance with good industry working practices and best practices in all issues related to water quality.	
Develop and use standard operating procedures for issues critically related to quality.	

APPENDIX

B Illustrative case study

Water Safety Plan

Illustrative Case Study - Maynilad Water Services, Inc, Manila, Philippines.

This work was supported by the World Health Organization Western Pacific Regional Office, Philippines Department of Health and Maynilad Water Services, Inc.

Case Study was based on 2007 version of the Water Safety Plan from Maynilad Water Services, Inc. Case Study paper prepared by Francisco A. Arellano, Maynilad Water Services, Inc., MWSS Compound, Katipunan Road, Balara, Quezon City, Philippines, frankie.arellano@mayniladwater.com.ph and Daniel A. Deere, Water Futures Pty Ltd, Sydney, Australia, dan@waterfutures.net.au.

Key words

MWSI, Maynilad Water Services, Inc., Manila; La Mesa Water Treatment Plant, Philippine National Standards for Drinking Water, Water Safety Plan, WHO Western Pacific Regional Office

Abbreviations

CPF	Common Purpose Facilities
DENR	Department of Environment and Natural Resources
DOH	Department of Health
GDWQ	Guidelines for Drinking Water Quality
HACCP	Hazard Analysis Critical Control Point
ISO	International Organization for Standardization
LGU	Local government unit
LP 1 & 2	La Mesa Water Treatment Plants 1 & 2
MMDWQC	Metro Manila Drinking Water Quality Committee
MSDS	Material Safety Data Sheet
MWCI	Manila Water Company, Inc
MWSI	Maynilad Water Services, Inc
MWSS	Metropolitan Waterworks and Sewerage System
MWSS-RO	MWSS Regulatory Office
NDCC	National Disaster Coordinating Council
NIA	National Irrigation Administration
NPC	National Power Corporation
NSC	National Security Council
NTU	Nephelometric Turbidity Unit
NWRB	National Water Resources Board
PNSDW	Philippine National Standards for Drinking Water
ppm	Parts per million
THMs	Trihalomethanes
WHO	World Health Organization
WPRO	Western Pacific Regional Office
WSPs	Water Safety Plans

Organizational commitment to the Water Safety Plan

Background

In February 2006 Maynilad Water Services Inc. (MWSI) made a commitment to the development of a Water Safety Plan (WSP) in 2007 in accordance with the World Health Organization (WHO) *Guidelines for Drinking Water Quality 2006*. The MWSI committed to developing a WSP covering all systems and operations.

In 2007 the Philippine National Drinking Water Standards (PNSDW) was revised which recommended the formulation of WSP by water service providers. The MWSI WSP was the first WSP developed in the Philippines and was developed through the collaboration of MWSI, the Department of Health (DOH) and the WHO, as a case study and pilot WSP for the Philippines.

This WSP commences from the source of water including watershed/catchment, up to the delivery point, its customers. The plan covers the water sources (watershed and catchment), surface water and groundwater, conveyance system, water treatment, pumps, reservoirs and distribution network.

Purpose of the WSP

The MWSI WSP sets out how MWSI ensures that safe drinking water is available to its customers, at all times through sound water supply practices. The WSP is used to help MWSI structure the following activities:

- Prevent contamination of the source of raw water.
- Develop programs to immediately respond to contamination scenarios.
- Operate treatment systems to provide safe quality water to the consuming public.
- Prevent re-contamination of water during distribution.
- Set the context for routine monitoring against a defined schedule to confirm water meets health-based standards set by DOH.
- Ensure that the desired water quality is met at all times at every stage of all its operation.
- Identify parties that are responsible for undertaking the above tasks.
- Predict events that may impair the quality of water and upset operations.
- Develop programs that will prevent the occurrence of events.
- Prepare plans to manage the impacts of the events.
- Implement control and monitoring programs to assess the WSP.
- Properly record and document procedures and outcomes.
- Conduct regular review and audits of the plan.
- Subject the plan to continual improvement.

Intended benefits

The adoption of the WSP and associated commitment of MWSI to the approach are expected to yield a number of important benefits:

- Developing and implementing a WSP requires a systematic and detailed assessment of MWSI processes and the prioritization of hazards and risks in all operations and facilities.
- Following the risk assessment, MWSI is required to establish the operational barriers to control hazardous events and set out contingency and mitigating measures to respond to adverse events.
- The WSP also provides an organized and structured system to minimize the chances of failure of its services caused by oversight, lapses in management decisions and identifies responsible parties.

This process increases the consistency with which safe water is supplied to MWSI's customers and provides contingency plans to respond to system failures and unforeseeable hazardous events and incidents that may impair operations. Overall, the anticipated advantages of the WSP can be summarized as having the following attributes:

- Improved compliance to water quality targets.
- Demonstration of the application of best practice to secure water safety.
- Improved consistency of water quality and safety.
- Improved ability to respond to crisis scenarios relating to water quality impairment.
- Potential cost savings from avoidance of incident and accidents.
- Improvements in asset management.
- More satisfied customers.

Development of the WSP

The WSP was developed in 2006 and 2007 by MWSI in-house. The formulation of the WSP consisted of the following activities:

- Documenting an organizational commitment.
- Organization of a WSP team.
- Assembling a system description of all the operations of MWSI.
- Development of process flow diagrams for the catchments, surface water, ground water, treatment plants and distribution networks.
- The assessment of risks to drinking water quality.
- The development of control measures to manage the identified risks.
- The specifications for those control measures to maintain risks under control.
- The development of a verification and surveillance schedule.
- Setting out the technical basis for the plan through the development of a validation schedule.
- Documenting the Supporting Programs that are required to support the effective operation of the control measures.
- Developing documents and record-keeping systems to support the WSP.

Each of the above points is discussed in this case study summary.

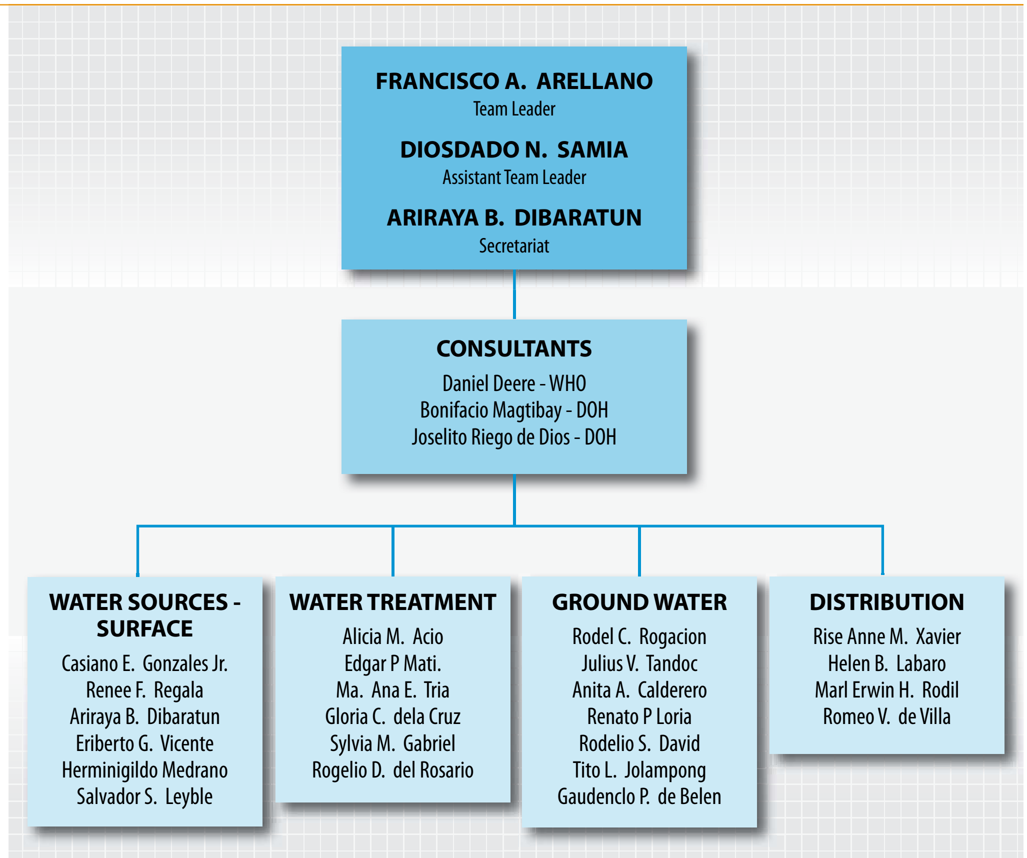
WSP Team

A WSP team was formed with representation from the full range of operating units within MWSI. The team was responsible for the assessment and the development of a model WSP for the entire system. The team participants and structure is given in Figure 1.

The full WSP team was divided into four main sub-teams covering particular specialist areas which were coordinated by a leadership team. The specialist teams undertook detailed work in their specialist areas and reported this through to the full WSP team. The leadership team undertook the task of assembling all information into the final WSP document.

Some WHO and DOH consultants were used to provide some assistance where required. Their role included training of WSP team members over a three day period and occasional review and comment on the WSP as it developed.

Figure 1. Overview of WSP team.



System Description

Overview

Maynilad Water Services Inc. (MWSI), based in Manila, is the largest water services provider in the Philippines and covers a service area of 540 km2 and supplies water to a population of over six million. The water is sourced from both a surface water catchment draining to a large reservoir dam and many ground water well fields. There are two water treatment plants for the surface water sources as well as numerous pumping stations, services reservoirs, a piped distribution network and consumers' plumbing systems.

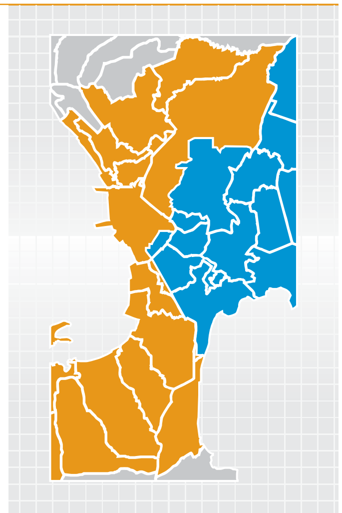


Figure 2. West (left hand side) and East (right hand side) Zone service areas for water supply in Manila. This case study refers to the West Zone area.

Organizational arrangements

Maynilad Water Services, Inc. (MWSI) is the private concessionaire which was awarded the exclusive right to take over the Metropolitan Waterworks and Sewerage System (MWSS, a government corporation) water supply and sewerage operations in the West Zone of Metro Manila. The west zone comprises 60% of the MWSS service population. This is a 25-year concession agreement, which commenced on 1st August 1997 and will last until 31st July 2022. Figure 2 shows the Manila service area which is divided into two operating zones: the East Zone managed by the Manila Water Company (MWC) and the West Zone which MWSI operates. Figure 3 shows in more detail the service area coverage of MWSI. Table 1 provides summary information on the MWSI coverage, customer base, water sources, facilities and distribution network.

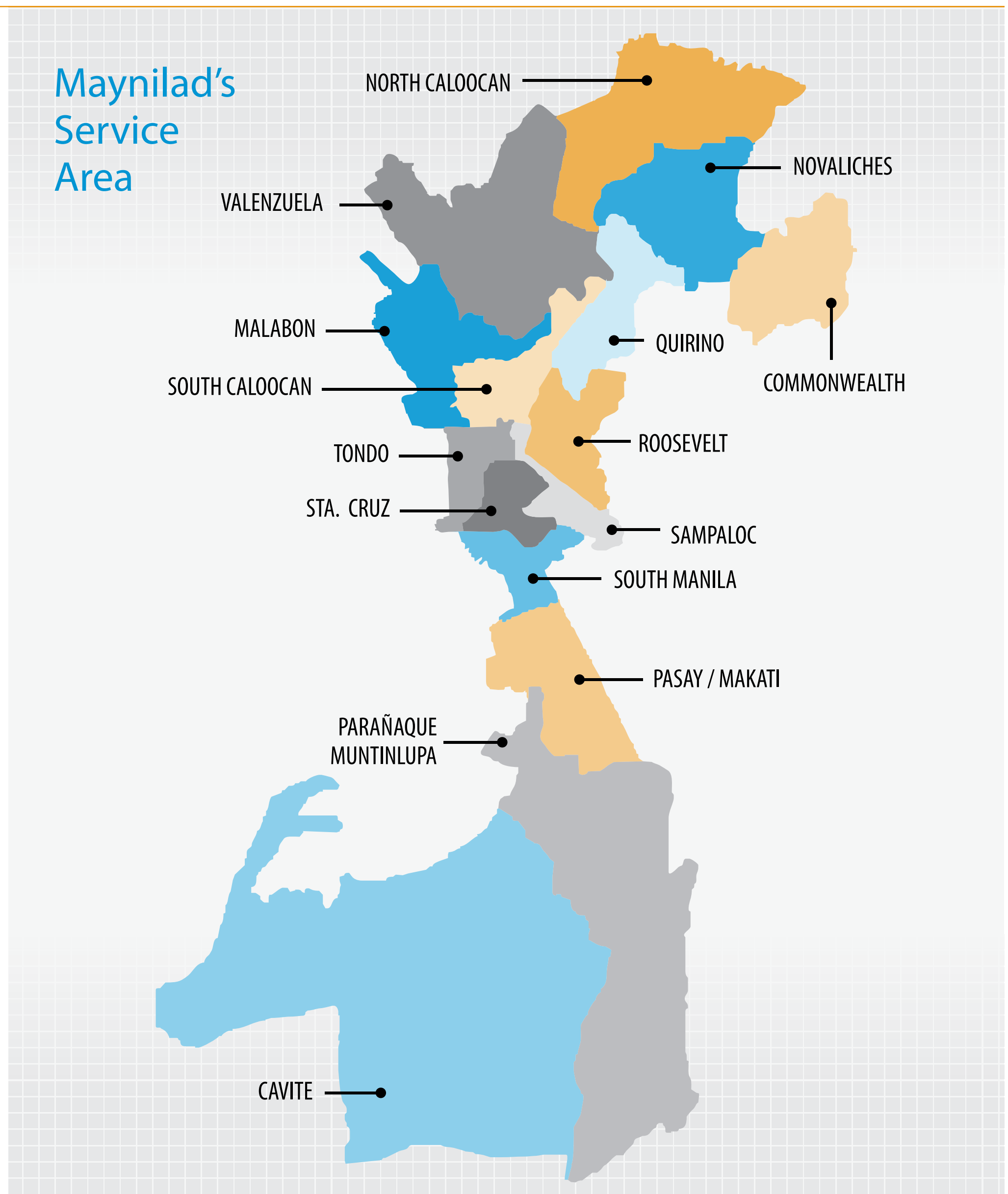


Figure 3. West Zone MWSI water supply area

Table 1. MWSI summary information.

Item	Value	Units
Source		
Water allocation for MWSS for supply to both MWSI and MWC from surface water Umiray-Angat-Ipo system	98 46.5 4,000	% m^3/s ML/day
Proportion of surface water allocated to MWSI	60	%
Water supplied from Angat Dam	37	m^3/s
Water supplied from Umiray River	9	m^3/s
Water supplied from Ipo Dam	0.5	m^3/s
Water sourced from ground water	2 0.5 40	% m^3/s ML/day
Number of deep production wells	64	Wells
Raw water tunnel conveyances	2	Tunnels
Raw water aqueducts	5	Aqueducts
Treatment		
Total surface water treatment plant peak capacity	2,550	ML/day
La Mesa Water Treatment Plant 1	1,650	ML/day
La Mesa Water Treatment Plant 2	900	ML/day
Distribution		
Number of distributions service reservoirs	10	Reservoirs
Number of distribution pumping stations	14	Pumping stations
Length of trunk distribution mains (150 to 3,200 mm diameter)	3,500	Km
Proportion of supply with 24-hour pressurization	65	%
Proportion of supply with less than 24-hour pressurization	35	%
Geographic area covered	540	km^2
Water quality monitoring sites in the distribution system	750	Sites
Customers		
Total service connections	630,000	Connections
Residential connections	580,000	Connections
Commercial/industrial connections	50,000	Connections
Population served	6,000,000	Persons

Water Sources

About 98% of Maynilad's raw water comes from the Umiray-Angat-Ipo system (Figure 4). The heart of the system is the Angat Dam, which is a multi-purpose dam intended for power, irrigation and urban water supply. The urban water supply of Manila is allocated 4,000 ML/d of water from this source of which 60% is allocated to MWSI.

Note that with the exception of the Ipo watershed (comprising less than 1% of total water sources) MWSI has no direct control over the quality of raw water:

- Umiray watershed is maintained by the Department of Environment and Natural Resources (DENR).
- Angat watershed is maintained by the National Power Corporation (NPC), the power generating company.
- Ipo watershed is maintained by the DENR, MWSS and the two concessionaires, MWSI and MWCI.

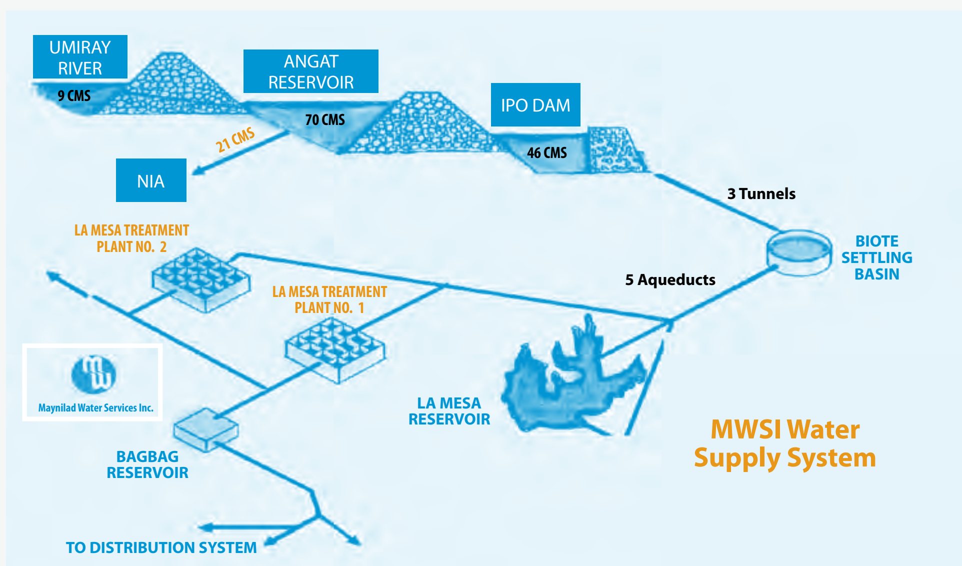
There are various stakeholders involved in the activities within the catchment area of the raw water sources. The surface water source is very vulnerable to the El Niño and La Niña phenomena. These impact both on quantity and quality of the available water.

The watershed areas of Angat Dam and the Umiray River are encroached by people entering the catchments for a range of reasons and by illegal loggers. These activities have resulted in mudslides and flash floods following heavy rainfall. The result, especially in the catchment of the Umiray River, has been incoming raw water turbidity exceeding 1,000 NTU and the presence of manganese that is dissolved by the floodwaters from the natural geological formations. In addition there are Dumagat indigenous tribes living in the catchment, providing a source of organic and microbial pollutants to the water sources.

From the Angat Dam, water flows to Ipo Dam through five auxiliary turbines. From Ipo Dam the water is diverted to a series of tunnel and aqueduct conveyance systems of about 24 km terminating at the La Mesa, Novaliches portal where the water is apportioned between MWC and MWSI. From the La Mesa portal, water is transported through open canals into the La Mesa Water Treatment Plants 1 & 2 (LP 1 and LP 2 respectively).

About 2% of MWSI's water is derived from the operation of 64 deep production wells. These wells serve a number of independent water supply areas including the southern part of Cavite and the private subdivisions in the northern part of the MWSI service area.

Figure 4. MWSI Water Supply System sketch map



Water Treatment

The West concessionaire MWSI has two treatment plants, La Mesa Water Treatment Plants 1 and 2 (LP 1 and LP 2 respectively). Both plants are ISO 9001:2000 Quality Management System certified.

LP 1 uses standard conventional coagulation-flocculation-sedimentation, rapid gravity dual media filtration and chlorine gas disinfection. It has no automation and minimal rehabilitation since its construction. It has only minimal electromechanical equipment and relies mostly on hydraulic properties of water to backwash its filters and on gravity to convey raw water from the source, into the plant and out into the distribution system.

LP 2 uses a coagulation-flocculation process and employs a pulsator clarifier for turbidity removal. The plan uses single media filtration and final disinfection by chlorination.
Both plants have the capability for pre- and intermediate-chlorination. Both plants use alum for coagulation, aided by polymers to enhance floc formation. pH is adjusted during coagulation using sulfuric acid or lime.
The groundwater undergoes disinfection only treatment, either using liquid chlorine or hypochlorite solution.

Distribution

The MWSI distribution system includes a Central Distribution System originating from La Mesa Water Treatment Plants 1 & 2 and small independent, distribution networks centered on the deepwells. Water is stored in 10 service reservoirs located around the supply area and is pressurized through 14 pumping stations.

To check the integrity of pipelines, gauging points are placed around the distribution system.

From the pumping stations, water flows through a network of primary, secondary and tertiary mains. The pipelines consist of various materials: asbestos cement, cast iron, concrete, steel, black iron, ductile iron and PVC and with sizes ranging from 50 mm to 3,200 mm. Water quality and quantity are monitored regularly. There are more than 750 monitoring points in the distribution network. The network is also capable of being dosed using on line chlorination.

The MWSI West Zone concession area covers a total area of 540 km^2 and consists of ten cities and one municipality in Metro Manila and one city and five towns in Cavite province. Approximately, 6 million people are fed water from the West Zone water supply.

Roughly 2 million West Zone residents also get their water from privately operated deepwells, private water dealers/vendors and illegal connections.

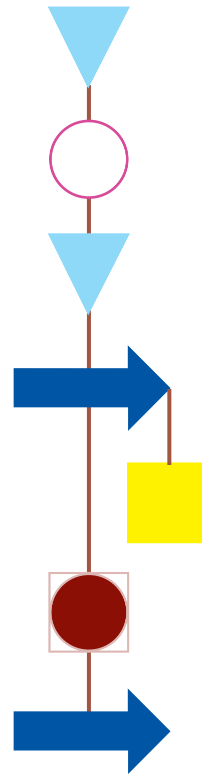
At the time of the privatization, there were only around 465,000 service connections in the West Zone. At present, MWSI has installed another 165,000 water service connections in the West Zone.

System flow diagrams

A series of system flow diagrams were developed covering the various parts of the MWSI system. An overview flow diagram is given in Figure 5. The more detailed system flow diagrams are given in Appendix 1.

Figure 5. System overview flow diagram.

DESCRIPTION	STEP	RESPONSIBILTY
Catchment (Angat Dam)		Multiple Stakeholder (NPC, DENR, MWSS, NIA, NWRB)
Natural and Human Activity		DENR, NPC, MWSS, NWRB
Primary Storage		Utility (NPC)
Transport (Gravity flow to Ipo, Bicti and Aqueducts)		MWSS, MWSI, MWCI, CPF
Legal and Illegal Connections		
Splitting of Raw Water Flow (Portal)		Common Purpose Facilities
Raw Water Transmission from Portal Weir to LP 1&2		Water Production, MWSI



Risk assessment

The risk assessment task was complicated by the fact that the source of the raw water for supply was not managed by MWSI. In addition, the operation covered a range of sources of water: surface and ground, two different treatment plants, an extensive bulk distribution system and a complicated network of urban distribution systems. The service coverage is geographically extensive and traverses a range of political boundaries.

The risk assessment involves completion of a hazard identification and risk assessment for the various process steps of MWSI operations as identified using the flow diagrams. The risk assessment employed a prioritization matrix centered around the analysis of the hazardous events that may impair water quality.

The systems were subjected to a risk analysis process as described in the WHO GDWQ:

- Identification of hazardous events and potential causes of contamination for each process step on the flow diagram.
- Types of hazards that could end (microbial, radiological, chemical, physical).

- Frequency/probability of occurrence of hazardous events.
- Severity of impacts if hazardous events occurred.

These last two parameters, frequency and severity of impacts, were quantified and risks were ranked and prioritized in a risk assessment matrix.

As part of the implementation of the WSP, a review of historical water quality problems was conducted by MWSI. Table 2 shows the most common water quality problems encountered by Maynilad, noting their potential hazards and causes, from source to distribution network.

An example of an extract from the completed risk assessment is given in Table 3 which describes part of the evaluation of MWSS surface water source.

Table 2. MWSI Typical Water Quality Problems, Potential Hazards and Causes.

Problems	Hazard	Causes
Raw Water	High turbidity High algal content Presence of manganese	Rainy days Dry season Long dry season and thermal stratification in dam
Distribution	Presence of coliforms and suspended solids	Low Water Pressure Illegal Connections Use of Booster Pumps System Leaks
Ground Water	Presence of fluoride	Naturally present in the source

Table 3. Extract from the MWSI WSP showing an example of the risk assessment.

Process	Hazardous Event / Cause of Contamination	Hazard	Control Measure	Likelihood	Severity	Risk
Catchment, Primary Storage	1. La Niña rain events	Physical (turbidity)	Reforestation	1	5	5
	2. Landslide, mudslide	Physical (turbidity)	Reforestation	1	5	5
	3. Clogging of tunnel	Supply shortage	Reforestation	1	5	5
	4. El Niño events	Supply shortage	Reforestation	1	5	5
	5. Contaminated runoff or turnover of dam	Chemical (manganese)	Installation of Manganese removal process	1	5	5
	6. Forest fire	Physical (color, taste, odor)	Security (forest ranger), LGU's, DENR coordination for preparedness	2	5	10
	7. Illegal Logging (denudation of watershed)	Physical (turbidity)	Vigilant monitoring and control DENR security Downstream Control	5	2	10
	8. Human Access (Dumagat Squatters)	Microbial (pathogens) Physical (turbidity)	Resettlement Education Downstream Control (chlorination and filtration)	5	2	10
	9. Security Threats (Terrorist Act)	Chemical (toxic substance)	Coordination of security to NSC and NDCC	1	5	5

Control measures and operational monitoring

The next step in developing the WSP was to assign control measures and operational monitoring strategies to the process steps. This required the evaluation of the current control points and monitoring requirements, considering the following elements:

- Water sources
- Treatment processes
- Distribution systems

For each process step, the required control measures, the operational target range and the critical limits were assigned to ensure operational efficiency and conformity to the health based standards of PNSDW. Documentation included the following elements:

- Specific points at which monitoring was to be undertaken.
- Methods and procedures used to conduct the analysis and monitoring.
- Required frequency of monitoring.
- Person responsible to conduct the monitoring.
- Corrections needed if the critical limits were not attained.

Table 4 provides an example of the control measures and operational monitoring identified in the MWSI WSP, in this case for the source water.

Table 4. Excerpts from the MWSI WSP showing Control Points and Monitoring for the water source

Process Monitoring Parameter	Operational Range and Critical Limits	Where to Monitor	How to Monitor	Frequency of Monitoring	Who will Monitor	Corrective Action
Transport-flow (Ipo Elevation)	100.0 to 100.8 m	Ipo Dam	Level Sticks/ Indicator	Hourly	Operator on Duty	Request for additional water releases or reduction at Angat
Transport-flow	Turbidity (30 NTU)	Ipo Dam	Turbidimeter	Hourly	Operator on Duty	Immediate Information to LMTP 1 & 2 by radio/cellular phone to avoid surprises (4-6 hrs travel time)
Security Patrols to avoid intrusion	Secured premises	Catchment area	Visual via foot patrol	Round the clock	Security guards	Strict compliance to security measures

Verification

Verification made use of objective methods, procedures and tests to audit processes and practices undertaken by MWSI and to test water quality throughout the water supply and particularly the distribution system. This verification was in addition to the regular monitoring activities undertaken for each operational process conducted by MWSI.

Verification activities were set out in terms of:

- identification of activity;
- location of monitoring points;
- specific type of analysis;
- frequency of analysis;
- required methods of analysis for contaminants;
- party responsible for the conduct of the analysis; and
- records and documentation needed.

Table 5 provides an example of verification, covering the distribution stage of the system.

Auditing

Internal and external auditing was undertaken as part of the MWSI ISO 9001:2000 quality management system and covered all aspects of water supply operation. At intervals following the implementation of the WSP there is a need to review the procedures and examine the records to ensure that activities are being carried out in accordance with the plan. Periodic auditing is used to achieve this outcome. An audit-based approach places responsibility on every unit involved to provide information regarding system performance against agreed indicators. Auditing has both an assessment and a compliance checking role. It gathers information on the level of conformance to the quality system as indicated in the WSP and to the ISO 9001:2000 standards for the water treatment plants, as well as the degree of compliance to regulatory requirements.

Aside from determining if the quality system is being effectively implemented, auditing obtains factual input for management decisions, determines if the company is at risk, identifies areas or opportunities for improvement, assesses individual performance, assists in identifying company staff training needs and improve communications and motivation of personnel.

Water quality testing

Some verification testing is undertaken by the MWSI Central Laboratory. In addition to the MWSI testing, independent surveillance is carried out at the source, treatment plant and in distribution. There is a multi-sector body created in Metro Manila which undertakes water quality testing surveillance verification. This body is called the Metro Manila Drinking Water Quality Committee. The committee is headed by DOH and consists of representatives from DENR, local government units, MWSS, Regulatory Office (MWSS-RO) and the two concessionaires. Split samples are collected from more than 750 monitoring points by two teams and the results are compared and reported monthly.

Any adverse test results are rapidly relayed to MWSI for action.

Table 5. Excerpts from the Verification Activity Plan citing the part on the verification process for the distribution system.

Activity	Location of Activity	Type of Activity	Frequency of Activity	Which org/ Department will undertake activity	Records
Microbial testing	Customers' Taps (regular sampling points)	Water quality testing	Daily	Central Lab, MWSS-RO	Database
Microbial testing	Surface water sources	Water quality testing	Semi-annual	Central Lab, MWSS-RO	Database
Microbial testing	Ground water sources	Water quality testing	Annually	Central Lab, MWSS-RO	Database
Microbial testing	Customers' Taps (regular sampling points)	Water quality testing	Monthly	Central Lab, MWSS-RO	Database
Physical and chemical testing	Surface water sources	Water quality testing	Semi-annual	Central Lab	Database
Physical and chemical testing	Ground water sources	Water quality testing	Annually	Central Lab	Database
Field activities	Along distribution network	Internal Audit	Anytime there is any field activity	Supervisors	Database
Leak detection	Along distribution network	Consumer Assessment	Regularly	Central lab	Records management systems
Customer satisfaction survey	Call Center	Monitoring of complaints	Daily	Customer Care, BusCenter, Zone, Central Lab	Database Records management systems
Instrument calibration	Central Lab Network	Internal Audit	Annual, before every use	ISO accredited Instrument. Supplier	Certificate/log book
Regulatory compliance	Customer taps Central Lab	External audit	Monthly	MWSS-RO, DOH	Monthly pronouncement, Audit Report

Validation

Validation was undertaken to document the technical basis underpinning the WSP. Reference information used for the validation included:

- scientific literature;
- trade associations;
- regulations;
- legislation historical data;
- professional bodies; and
- supplier warranties.

An excerpt from the validation schedule is given in Table 6 using the distribution system as an example.

In the validation step all the inputs from the above process are reviewed and compared to the available technical and scientific references. These are also benchmarked with the norms of the water industry and trade associations, regulatory and legislative measures, historical and statistical data, information from professional bodies and inputs from our suppliers and manufacturers. Table 6 provides portion of this activity covering the groundwater/deepwell operations. This includes the validation requirement and the reference used for each of the item being validated.

Table 6. Excerpts from the Validation Plan Citing the Distribution System as an Example

Items validated	Validation	Reference
Water quality targets – Physical/chemical – Microbial	Regulatory requirement MMDWQC	PNSDW
Customer satisfaction service Water availability (Pressure/Flow)	Regulatory requirement	Concession agreement
Laboratory Reagents	MSDS Standards for preparation	Standard methods for examination of water and waste water 20th edition
Operational Limits on different parameters – Pressure limits – Residual chlorine in distribution – Status of pipe network	Experience and/or expert judgment of staff	Decision is based on own monitoring results and MWSI judgment

Supporting Programs

Organization-wide supporting programs were developed as activities that are in place in support of the delivery of safe quality water. These activities do not directly affect water quality in the way that, for instance, treatment does. But the activities are valuable to help ensure no additional sources of potential hazards from the surrounding environment, the equipment used and the people handling the products themselves, including the employees and visitors to the facilities. Many of these programs covered a broad range of activities. An example of the types of supporting programs that MWSI uses is given in Table 7.

Table 7. Excerpts from the Supporting Programs Plan citing the groundwater source protection programmes as an example.

Issue	Purpose	Supporting program
Catchment protection is required using education and awareness activities for concerned communities and stakeholders.	To make sure that the water source is protected as much as practicable.	Formal liaison with government agencies that have control of the catchment.
Sprouting of communities within the water shed and vicinity of the treatment plants.	Increased population within the vicinity of the watershed/treatment plant would impair the quality of the water supply.	No communities should be allowed within the vicinity of plants and watersheds. They must be informed or educated that their presence and activities will impair water quality.

Record Keeping and Documentation

To support the WSP, a range of records is generated by MWSI. Examples include

- regular monitoring of process steps;
- reporting of corrective actions taken in response to deviations from critical limits;
- incident response reports; and
- other information relevant to the WSP.

The records are consistently maintained for future reference. The records management is used to provide evidence of compliance or adherence of the organization to the WSP, and the Quality Management System ISO 9001:2000 for water treatment in the Water Production Department.

Water Treatment had developed a document control system that involves version control processes, so that as documents are updated, the current revisions are made readily available when required and obsolete ones are retrieved and discarded or archived.

Documents are kept simple and as concise as possible with the level of detail in the procedures and work instructions being sufficient to provide assurance of operational control when performed by competent and well-trained operators.

The water treatment plant cross-references ISO 9001:2000 system documents with WSP documents to remove duplication.

A distinct records management system was established for LP 1 and LP 2. Records are retained and stored for a defined timeframe with a disposal schedule in specified storage areas that are accessible only to authorized personnel.

This system of recording and documentation fosters process and records ownership and encourages implementation of the procedures. In addition, it provides an auditable set of records for which review can be undertaken periodically.

As far as practicable, MWSI utilizes electronic media for recording and documentation. Most information and records are stored in this medium and some are backed up by hard copies.

Summary of Experiences

Constraints

Constraints identified in the implementation of the WSP included:

- MWSI service area is very wide;
- operations are numerous and complicated;
- several areas and steps of the operation are beyond the control of MWSI e.g. watershed, dam, raw water conveyance;

- different agencies are involved in several monitoring, verification and validation steps of the plan e.g. raw water, dam, water quality;
- treatment plant is ISO 9001:2000 certified but the other operations are not;
- some regulatory targets for water quality are not health based; and
- external documents from other agencies are not dependable and not readily available.

Above all, while the WSP covers all the operations of the water system, its implementation is restrained by the fact that water catchment and the source of raw water are beyond MWSI's direct control and responsibility This is the case in most water service providers in the Philippines. This is where the regulatory agencies can be drawn in as an oversight body for the successful implementation of WSP.

Opportunities

Opportunities from the WSP implementation experience included:

- linkages with the relevant external agencies have been established;
- most of the procedures were existing but have now been codified and documented;
- the need to revisit the WSP and determine if risk has been reduced after its implementation will provide for ongoing improvement;
- the need to involve consumer groups in the process will provide for additional consumer feedback;
- the use of document controller in record safekeeping will improve records management; and
- the use of the services of an external third party to audit implementation of the plan will provide additional transparency and input.

Importantly, the MWSI WSP has been used by Maynilad to help resolve problems not currently covered by its ISO 9001:2000 operational manual which was previously drafted. The ISO quality management system did not cover risk assessment and safety and emergency preparedness. This was limited to areas within the MWSI operational responsibility, and in particular the water treatment plant. The WSP thereby expanded and augmented the coverage beyond that of the ISO system.

Challenges

The key challenges ahead for the MWSI WSP include:

- incorporate the WSP in the entire MWSI business operational plan;
- ensure that all parties involved in the process assume ownership of the plan;
- integrate the WSP and ISO 9001:2000 Quality Management System particularly in the aspect of record, documentation, audit and review;
- incorporate in the plan the aspect of water quantity which impacts on quality;
- certain hazards cannot be avoided but can only be mitigated;

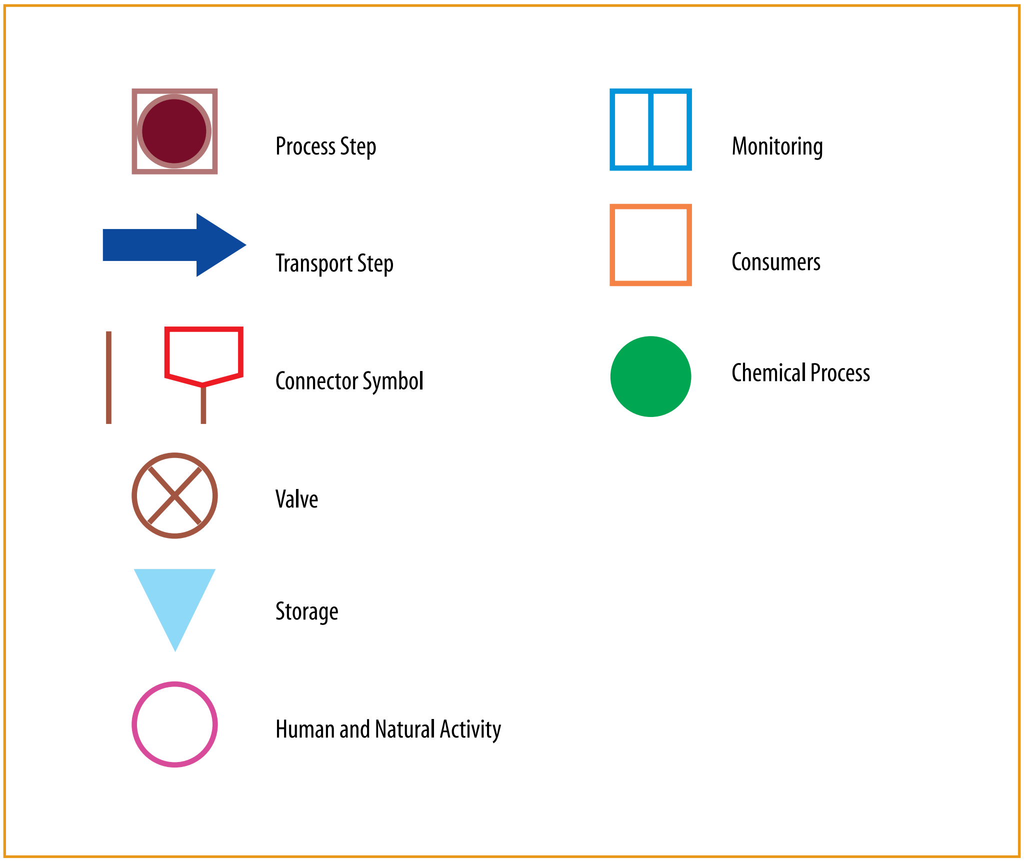
- emergency preparedness should include adjoining communities;
- certain parts of the plan are covered by National Security; and
- review the plan to ascertain the benefits arising from the formulation and implementation of the WSP.

In the longer term, the MWSI WSP is now being used to help support the adoption of WSPs by water service providers in the Philippines. The MWSI operations covers surface water that is quite typical for big water service providers in the region, and its ground water systems are quite typical for small water service providers.

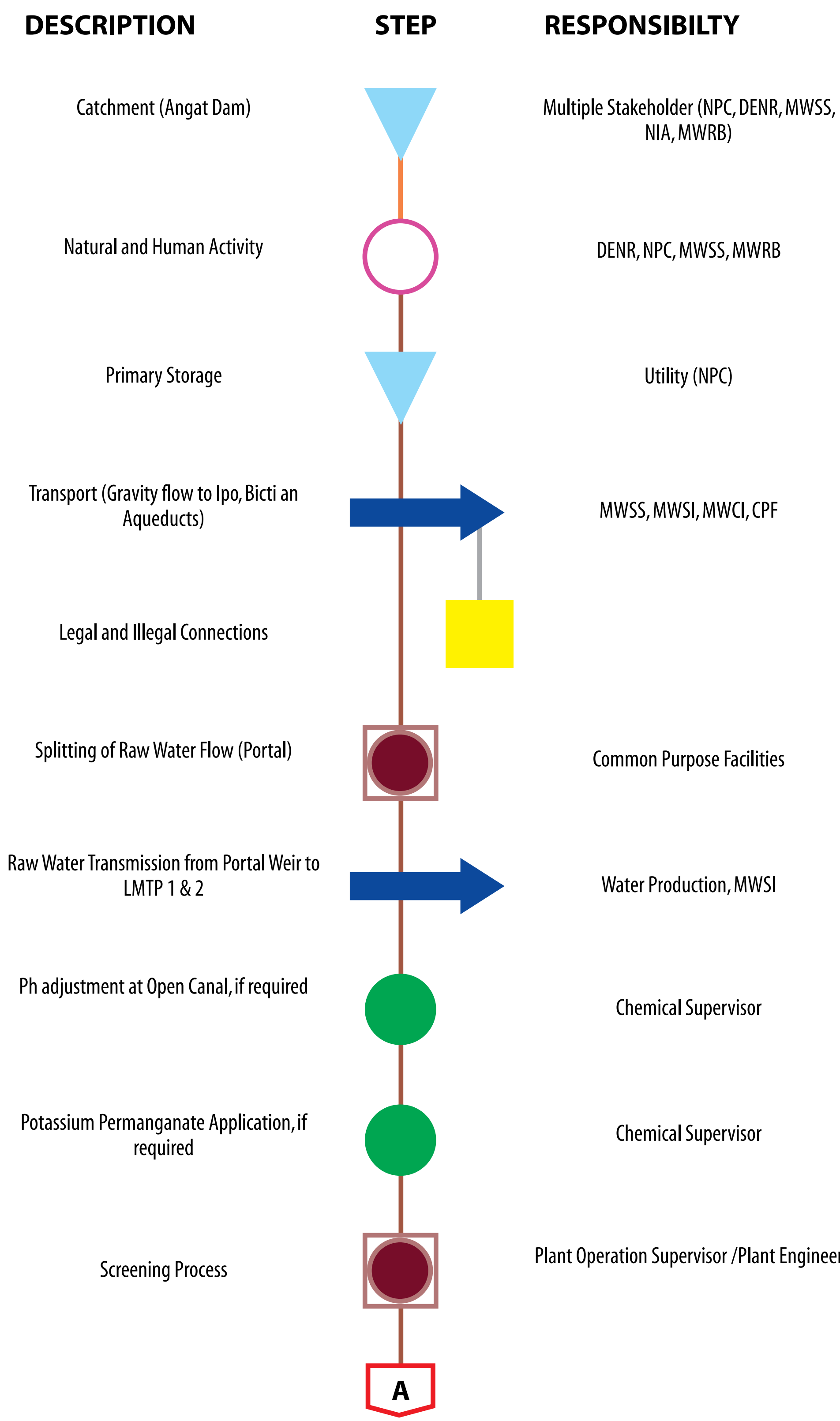
APPENDIX

1 System flow diagrams

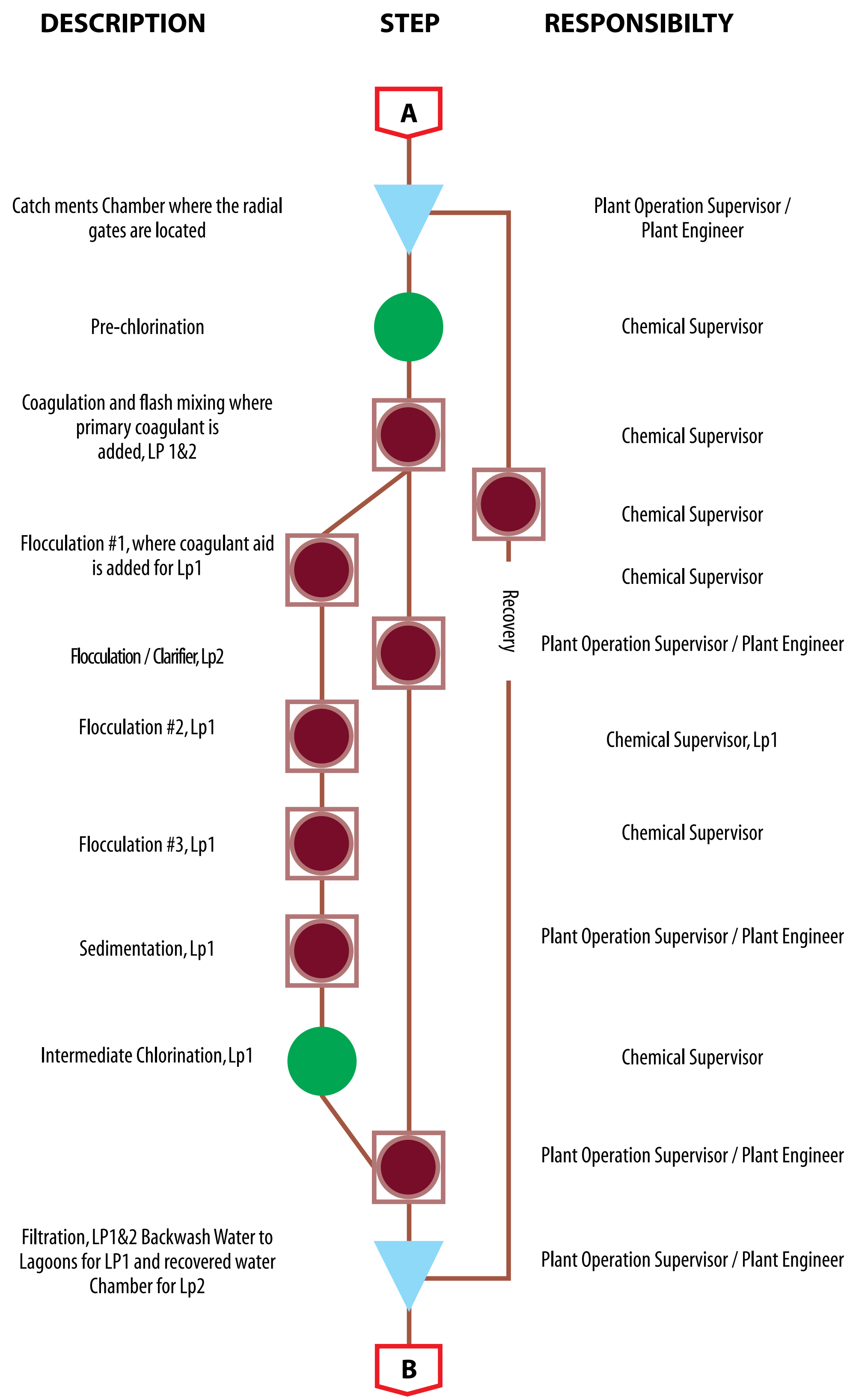
Flow diagram key



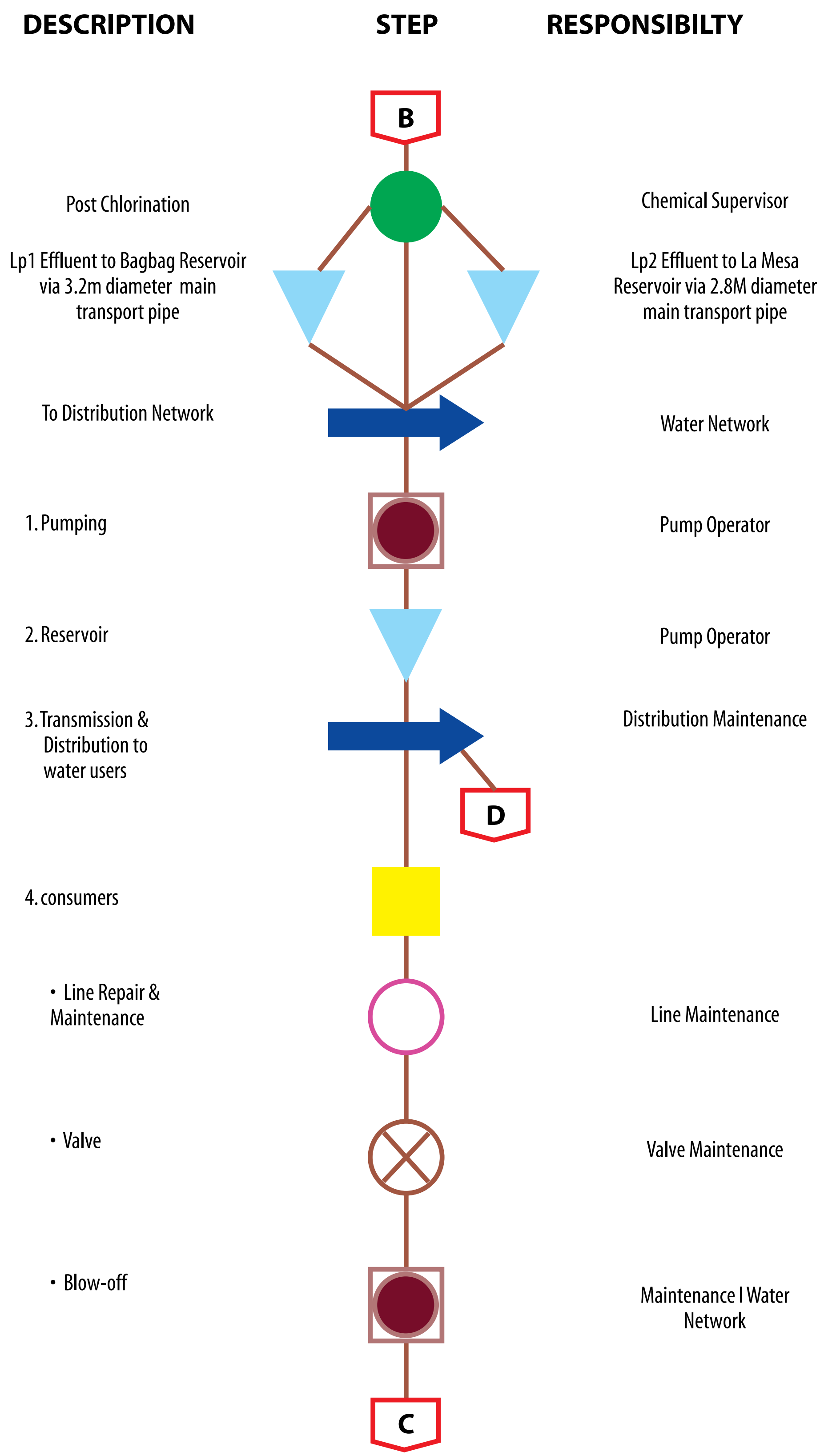
Surface water supply system flow diagram



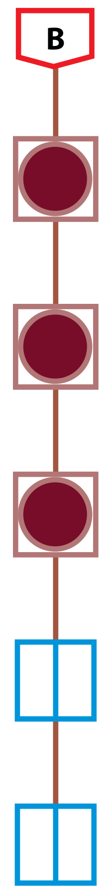
Surface water treatment system flow diagram



Surface water distribution system flow diagram



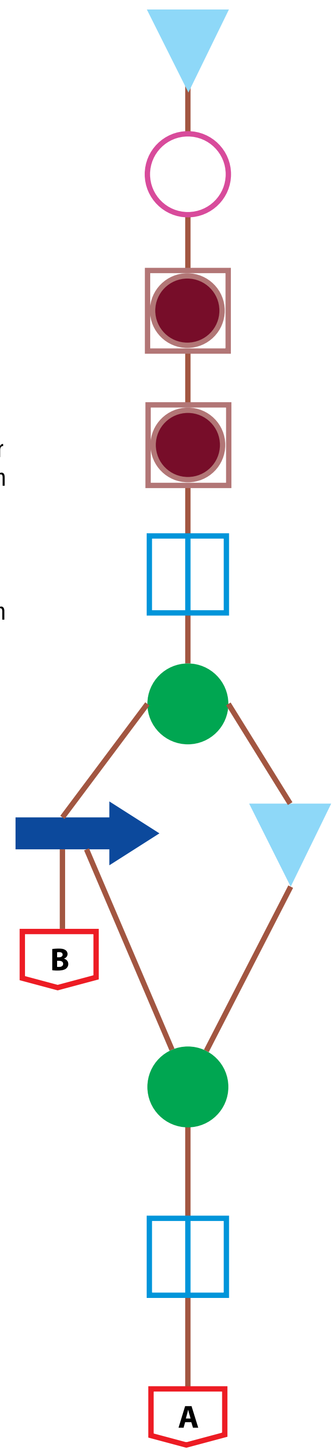
Distribution system flow diagram



DESCRIPTION	RESPONSIBILTY
• Air Valve	Maintenance I Water Network
• Gauging Points	Maintenance I Water Network
• District Meter	Maintenance I Water Network
5. Water Quality	Central Laboratory-Chemist/Water Quality
• Monitoring	Maintenance I Water Network

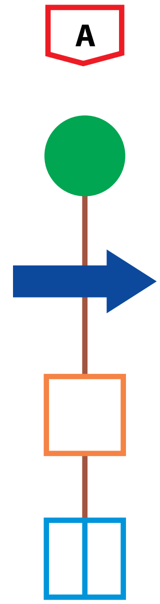
Ground water system flow diagram

DESCRIPTION		STEP	RESPONSIBILTY
Catchment	Well-water		Water Network
System Control Check-up			Pump Operator
Pre-operations			Pump Operator
Blow-off	Flushing out of stored water with sediments for 15 minutes at a minimum		Pump Operator
Meter Reading	Establish initial reading of meters for production quantification		Pump Operator
Monitoring	Of meter readings		Pump Operator
Preparation of Chlorine Solution	Prepare stock solution		Pump Operator
On-line	Allow water to go to distribution system. Direct pumping or to elevation water tank.		Pump Operator
Disinfection	Injection of Chlorine solution for disinfection		Pump Operator
Dosing			Pump Operator
Monitoring	Of dosing feed rate		Pump Operator



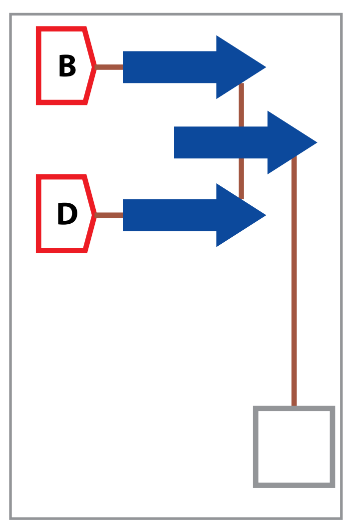
Ground water distribution system flow diagram

DESCRIPTION		STEP	RESPONSIBILTY
		A	
• Adjust Dose			Pump Operator
To Distribution	Through resorvior/ pumping stations		Water Network
To Service Areas	Consumers		Business Center
To Distribution	Of water quality in the distribution system		Central Laboratory/ MMDWQC



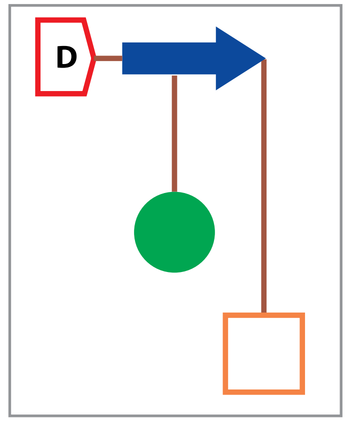
Distribution system flow diagrams for Paranaque City and Cavite Province where groundwater and surface water are mixed

DESCRIPTION		STEP	RESPONSIBILTY
Distribution	Groundwater distribution	B	Pump Operator
Distribution	Entry of surface water to the groundwater distribution system to augment water supply and achieve required water pressure (Business center determines the water demands of the area and decides on the mixing of surface and groundwater water supply)	D	Business Center
To Service Areas	Consumers		Business Center



Distribution system flow diagram for in-line rechlorination

DESCRIPTION		STEP	RESPONSIBILITY
Distribution	Surface water distribution		Water Network
On-Line Chlorination	Re-disinfection when residual chlorine falls below 0.3 ppm		Business Center
To Service Areas	Consumers		Business Center



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