# Water Safety Plan Manual

## Step-by-step risk management for drinking-water suppliers

World Health Organization

International Water Association

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IWA's Bonn Charter for Safe Drinking Water promotes the application of Water Safety Plans (WSPs) as expressed in the WHO Guidelines for Drinking Water Quality. (Revisions to the WHO Guidelines will be taken as revisions to the Bonn Charter in as much as the Bonn Charter refers to the Guidelines). IWA promotes WSPs with WHO through a formal project collaboration agreement and associated programme of work lasting through 2015, and through its membership of water utilities, research institutes, industry, and individual professionals. IWA's work spans the continuum between research and practice, covering all facets of the water cycle. IWA is a registered charity in England (Company registered in England No. 3597005 Registered Charity (England) No. 1076690).

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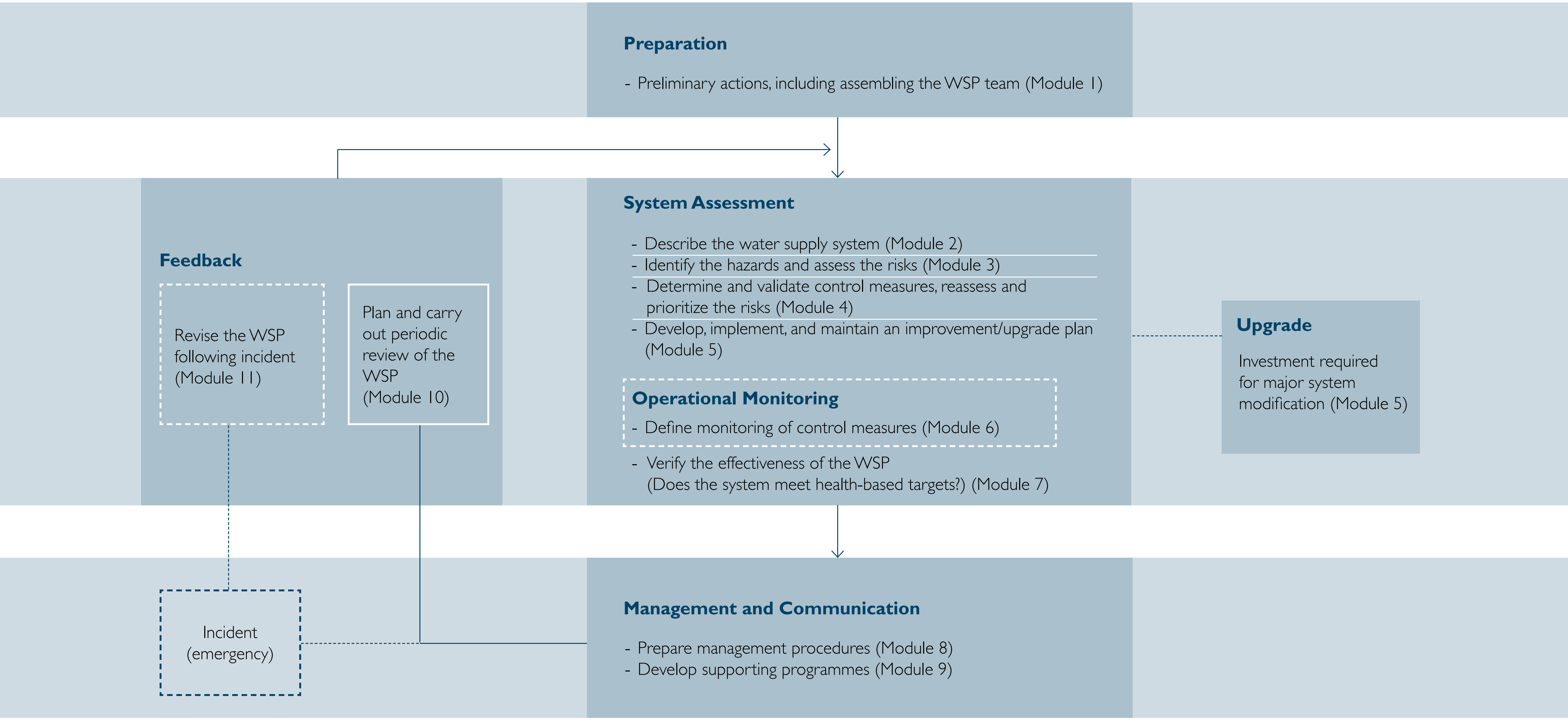
# How to develop and implement a Water Safety Plan

## A step-by-step approach using 11 learning modules



# Contents

# Introduction

*"The most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer. In these Guidelines, such approaches are called water safety plans (WSPs)".*

## Purpose of the Manual

The words above open Chapter 4 of the Third Edition of the WHO Guidelines for Drinking-water Quality (2004) and capture the philosophy of the WSP approach. The chapter describes the principles of the WSP approach rather than being a guide to their practical application. The aim of this manual is to provide that practical guidance to facilitate WSP development focusing particularly on organized water supplies managed by a water utility or similar entity.

## Points to consider when developing and implementing a WSP

The aim of a WSP is very straightforward:
*To consistently ensure the safety and acceptability of a drinking-water supply.*

The development and implementation of the WSP approach for each drinking-water supply is as follows:

- Set up a team and decide a methodology by which a WSP will be developed;
- Identify all the hazards and hazardous events that can affect the safety of a water supply from the catchment, through treatment and distribution to the consumers' point of use;
- Assess the risk presented by each hazard and hazardous event;
- Consider if controls or barriers are in place for each significant risk and if these are effective;
- Validate the effectiveness of controls and barriers;
- Implement an improvement plan where necessary;
- Demonstrate that the system is consistently safe;
- Regularly review the hazards, risks and controls;
- Keep accurate records for transparency and justification of outcomes.

**This systematic nature of the WSP strategy should never be lost** or forgotten during implementation. The great advantage of the WSP strategy is that it is applicable to ensuring the safety of water in all types and sizes of water supply systems no matter how simple or complex.

The WSP approach should be considered as a risk management strategy or umbrella which will influence a water utility's whole way of working towards the continuing supply of safe water. Significant risks that are not currently controlled need to be mitigated. This may involve short-, medium- or long-term steps for improvement. **The WSP approach should be dynamic and practical and not merely another operating procedure.** It should not be viewed as a vehicle for generating bureaucracy and paperwork. If it just ends up as a rarely-used folder labelled 'WSP' on a shelf, it is almost certainly not an effective approach.

**There is no one way to undertake the WSP approach.** The text in this manual shows how the strategy can be implemented, with examples showing what has been effective for some water utilities. What is important is that the WSP approach fits in with the way a utility is organized and operates, otherwise it will not be accepted within the organization. Developing the WSP approach may show that certain ways of working introduce, or do not properly control risks, in which case the utility should alter its way of working. It should not alter its way of working just to comply with a recommendation from a manual or to reflect another utility's methodology.

Implementation of the WSP approach requires both financial support and encouragement from senior management within a utility. There will be financial and resource requirements and these need to be addressed at the outset but there should also be the understanding that proper implementation of the **WSP approach can save money** and better target resources in the longer term.

**It is important that the WSP team has adequate experience and expertise** to understand water abstraction, treatment and distribution and the hazards that can affect safety through the supply system. For small utilities, additional external expertise may be helpful. The team is vital to getting the WSP approach understood and accepted by everyone connected with water safety in the utility and those outside.

**A WSP cannot be done solely as a desk study**. It must involve site visits to confirm the knowledge, information and schematics available to the utility. Site visits need to include input from those who work at the sites or within catchments and have detailed local knowledge that may not have been captured within the utility's records. Assessment, updating, compiling or rewriting standard operating procedures is an integral part of the WSP strategy. Ideally, all procedures should be labelled as part of the WSP strategy or way of working which helps to gain recognition and acceptance across the utility.

**The water utility will take the lead in the WSP approach but it should not do this in isolation**. It is a prime purpose of the WSP approach to identify that others have responsibilities towards ensuring the safety of water and for them to work with the water utility on risk reduction. Examples are agriculture and forestry workers, landowners, industry, transport, other utilities, local government and consumers. It is probably not necessary for representatives of all organizations to be included in the WSP team but they should be part of a communication network and aware of the impact of their contributions to the WSP effort. It is important that the WSP is subject to regular external independent audit. This will retain the confidence of all stakeholders.

There can be a tendency for the identification of hazards to be limited to thinking about those direct inputs to the water supply system impacting microbial and chemical parameters, as these are important in terms of compliance with water quality standards. However, the approach to ensure safe water must go much wider, with consideration of aspects such as potential for flood damage, sufficiency of source water and alternative supplies, availability and reliability of power supplies, the quality of treatment chemicals and materials, training programmes, the availability of trained staff, service reservoir cleaning, knowledge of the distribution system, security, emergency procedures, reliability of communication systems and availability of laboratory facilities all requiring risk assessment. This list is by no means exhaustive. **If a water utility considers that some of these areas fall outside of its WSP approach, then it does not have a comprehensive WSP strategy and has not fully understood the concept.**

The obvious controls for identified risks are physical barriers or processes within water treatment plants such as filtration and disinfection, but consideration and assessment of controls needs to be much wider. Agreements with farmers and industry on chemical usage, livestock controls, use only of trained staff, pumping regimes, visual inspection, auto-shutdown or turnout, audit of, or quality agreements with, chemical suppliers and plant manufacturers, could all be considered controls as long as they can be validated as effective and monitored to demonstrate that they continue to provide protection. Again, this list is by no means exhaustive. **Starting out on the implementation of the WSP approach does not mean that every existing control has to be re-validated but it does require the robustness of existing data and reports to be evaluated.**

It is important to assess risk before and after its control (or mitigation) where this exists because this will demonstrate that each hazard has been recognized and its control assessed for effectiveness. The risk assessment is likely to highlight a great many risks that are not considered significant to the safety of the water supply system. It is important, though, that all risks are clearly documented and understood by the utility. Even **more important is the need to prioritize and quickly put in place an improvement programme** where significant risks are identified.

Not all risks can be easily assessed using a methodology (e.g. a 'semi-quantitative' risk matrix), where a risk is estimated in terms of likelihood of the hazard occurring, and severity of the consequence should the hazard occur. Some risks do not lend themselves to be assessed via narrow definitions of likelihood (e.g. estimated occurrence is 'monthly') or consequence (e.g. estimated severity is 'moderate' public health impact). For example, potential negative feedback from consumers regarding issues that may not have a significant impact on health may be viewed as a significant risk to a utility's reputation and therefore should be addressed for the WSP. Sometimes, it may be more appropriate to assess risk in a simplified format (e.g. 'significant', 'non-significant' or 'uncertain') based on a group decision. **Whatever method is used, it is imperative that the risk assessment methodology is sufficiently clear and detailed to allow consistency.** This is a particular concern for a large utility, where the risk assessment is likely to be undertaken by many different people.

The complexity of the risk assessment depends on the complexity of the water supply system. Sophisticated water treatment equipment and processes viewed as controls for safe water production introduce their own potential hazards to a water supply system which will require detailed risk assessment. For example, an ozone and granular activated carbon system introduced as a control for organic contamination could generate hazards such as ozone emissions, bromate formation, biofilm growth, taste problems and contamination after regeneration. **The WSP approach needs to be included from the planning stage of any improvements or new arrangements for a water supply system.**

Compliance monitoring is an important part of the verification process to show that the WSP is working. It will show whether water at the point of compliance, which is often the consumers' tap, is meeting water quality standards; it does not make the water safe because by the time the results of compliance monitoring are available the water will have been drunk and used for other domestic purposes. Validation, to show that controls are capable of mitigating risks, and operational monitoring, to demonstrate that they continue to work effectively, are much more important tools in ensuring the safety of water because they focus on the processes that make water safe. **Operational monitoring is an integral part of the WSP approach.**

## Overcoming complacency

Many elements of the WSP approach are already incorporated in existing water utility good operating practice. However, fully implementing the WSP will require all utilities to take a fresh look at everything that can affect the safety of water. **Nothing should be taken for granted.** If barriers are in place and producing water of acceptable quality, is this because they are robust or through luck? The water utility that has no incidents or near misses and consumers that are happy with their safe water supplies is fortunate indeed, or maybe it is lacking the procedures and assessment it needs to identify problems. Open and transparent implementation of the WSP approach will increase the confidence of consumers and all other stakeholders in the safety of water supplies. Developing a WSP is not an end in itself, but a means to an end. A WSP is only useful if it is implemented and revised.

# Overview of the modules

**Points to consider when using the Manual**

The Manual is divided into 11 Modules, each representing a key step in the WSP development and implementation process. Every Module is divided into three sections: 'Overview', 'Examples and Tools', and 'Case Studies', as described below.

**Overview**

The overview section provides a brief introduction to the Module, including why it is important and how it fits into the overall WSP development and implementation process. It outlines key activities that should be carried out, lists typical challenges that may be encountered, and summarizes the essential outputs to be produced.

**Examples and Tools**

The examples and tools section provides resources which could be adapted to support the development and implementation of WSPs. These resources include example tables and checklists, template forms, diagrams, or practical tips to help a WSP team address specific challenges. These are often example outputs and methodologies adapted from recent WSP experiences.

**Case Studies**

Case studies present lessons-learned from real-life experiences. They are intended to make WSP concepts more concrete and to help readers anticipate issues and challenges that may arise. The descriptions were drawn from WSP initiatives in Australia, the Latin American and the Caribbean region (LAC), and the United Kingdom. These experiences are presented as three distinct case studies. The insights gained through the development of these 'composite' WSPs are likely to apply to other water systems that share a similar profile. A general description of the water supplier and the context within which the WSP was developed and implemented is provided in the following pages.

## CASE STUDY 1: AUSTRALIA

### Profile
Organized urban piped water supply systems in Australia.

### Introduction
These WSPs were undertaken almost entirely by the urban water utilities themselves without significant external agency support. Most water utility employees were familiar with the use of systematic risk assessment and management systems, and of management systems generally, due to previous requirements to implement occupational health and safety and environmental management systems. In addition to this, most utilities had some kind of generic management system in place, such as ISO 9001. The WSPs drew to varying degrees on these management systems in place, and on food safety management systems, such as HACCP and ISO 22000. The WSPs were driven initially by a desire by utilities to adopt good practice, and more recently by a desire to conform to the Australian version of the WHO WSP, being the Framework for Management of Drinking Water Quality (Australian Drinking Water Guidelines 2004).

### Population served
The populations served ranged from around 50,000 to over 4 million.

### Water sources
Water was supplied from a combination of surface and groundwater sources. In most cases, there was considerable unregulated low intensity agricultural activity within the catchment, such as cattle grazing; there was also rural residential habitation. Sewage systems existed in some catchments and others included on-site sanitation with varying degrees of oversight.

### Treatment processes
Treatment processes typically consisted either of chlorine disinfection only, or of direct or conventional filtration and chlorination. Surface water sources from protected catchments were typically treated by chlorination only and those from impacted catchments by conventional coagulation/flocculation/sedimentation, filtration and chlorination. Chloramination was commonly applied to maintain residual in many systems. Groundwater sources were typically treated by aeration and chlorination. Treatment processes were well-operated.

### Delivery point
Households received water directly to their homes through internal plumbing systems. The cities were predominantly connected to the municipal water system with reliable continuous pressurization so that storage in household tanks was virtually absent.

### Water quality standards
Water quality standards were set out in the Australian Drinking Water Guidelines, which are very similar to the WHO Guidelines for Drinking-water Quality. Testing and reporting against guidelines was well established, particularly for *E. coli* or thermotolerant coliforms.

### Quality of service
Water service to taps was continuous and water quality standards were met almost continually. There were no recorded waterborne disease incidents during the period of WSP development and implementation. Point-of-use treatment was not required, although this was sometimes used by consumers for aesthetic reasons to remove chlorinous tastes and odours.

### Resource constraints
Systems were operating on full cost recovery with government dividends being paid. The utility recovered all costs associated with maintaining water quality and quantity.

### Condition of infrastructure
The systems described were well maintained with low leakage rates reflecting the focus on water savings in these relatively dry Australian settings. Systematic asset management systems were in place to repair and replace assets to keep failure rates under control.

## CASE STUDY 2: LATIN AMERICA AND THE CARIBBEAN (LAC)

### Profile
Organized piped water supplies operating under significant resource constraints in Latin America and the Caribbean.

### Introduction
These WSPs were initiated as part of a multi-agency effort for which external technical advice and seed funding were provided to promote WSP demonstration projects in the LAC region. Project site selections were made by drinking-water utility managers and senior government officials, primarily within the Ministry of Health. Although some water utility employees were familiar with the WSP approach, they did not have a formal process of preventive risk management and believed that they did not have the expertise or resources to carry out the process.

### Population served
The populations served by the utilities ranged from 30,000 to 120,000.

### Water sources
Water was supplied from a combination of surface and groundwater sources. In all cases, there was considerable unregulated industrial activity within the watershed, such as mining, forestry, or road construction. Municipal sewerage systems did not exist; hence excreta was treated in poorly maintained septic systems or deposited directly into source waters.

### Treatment processes
Between one and five treatment plants served each community. Surface water sources were treated by conventional treatment techniques: coagulation/flocculation/sedimentation, filtration and chlorination. Groundwater sources were treated by aeration, filtration and chlorination, or in some cases, chlorination alone. In all cases, treatment processes were not operated optimally due to poorly trained operators and financial constraints.

### Delivery point
Most households received water directly to their homes. Others had yard taps, and some used shared community taps or storage sites. In each case, there were parts of the city that were not connected to the municipal water system, or had unauthorized and clandestine connections. Storage in household storage tanks was common due to inconsistent service.

### Water quality standards
Water quality standards were often poorly defined, or were inconsistent, with some agencies using environmentally-based targets and others using health-based targets for the same system. In some cases, WHO's health-based guidelines were adopted without adaptation to local conditions and constraints, making standards unrealistic and therefore of little value. In all cases, there were no active enforcement programs.

### Quality of service
Water service to taps was intermittent. In some areas, households routinely experienced eight hours or more per day without service and periods of low pressure were the norm in a majority of homes. Water quality was consistently out of compliance with regulatory standards; secondary treatment within the home was common.

### Resource constraints
Systems were not operating at cost recovery even with government subsidies. The utilities could therefore not afford to maintain a sufficient supply of chemicals, adequate equipment maintenance, or the high energy cost of pumping 24 hours a day.

### Condition of infrastructure
The systems described were characterized by aging treatment infrastructure, leaking distribution system pipes with as much as 70% loss, and decrepit storage tanks in the distribution system that had been taken off-line, affecting pressure and ability to meet demand. In all cases, capital improvements were needed in order to achieve desired water quality and consistency of service.

## CASE STUDY 3: UNITED KINGDOM (ENGLAND AND WALES)

### Profile

Privately-operated organized piped water supplies in England and Wales.

### Introduction

This case study, written by a regulator of drinking-water quality, describes some of the benefits and challenges faced by private water suppliers introducing WSPs in England and Wales. The regulator encouraged water companies to implement WSPs following the publication of the third edition of the WHO Guidelines for Drinking-water Quality in 2004, with its advocacy of the WSP approach. Impetus for WSP implementation was given by the regulator stating that drinking-water improvement schemes for the next five year investment programme would only receive regulator support if they were identified through WSP methodology.

The case study focuses on areas where the regulator viewed WSP methodology as weak or incomplete, in order to be most helpful to suppliers starting out on WSP implementation. Experiences should not be taken to reflect the experiences of all suppliers, as some companies developed good WSP methodologies from the outset.

For the first three years of WSP implementation the regulator gave guidance and advice on development. The regulator made a point of not specifying detailed WSP methodology, in order to ensure that companies developed their WSPs in a way that fitted in with how each company operated, an important consideration given the diversity in water companies under the regulations.

Compliance monitoring was initially viewed as the main WSP verification stage. However, additionally from the beginning of 2008, the hazard identification and risk assessment elements of the WSP framework were made regulatory requirements and WSPs began to feature in the regulator's audit programme.

### Population served

The populations served by individual utilities ranged from 2,500 to 8.5 million consumers.

### Water sources

Approximately 70% of supplies originated from surface water sources, 30% from groundwater sources. Twenty-six water companies supplied 15,750 million litres a day of mains water to a population of 53.6 million people through a distribution network of 338,500 km. There were 4,520 service reservoirs and 1,690 water supply zones.

### Treatment processes

The case study covered 1,220 water treatment works, with a range of processes, encompassing conventional coagulation/flocculation/sedimentation, filtration and chlorination, and increasingly, technologies such as GAC (granular activated carbon), membranes, ozonation and UV light, to deal with emerging risks. Many groundwater sources were still treated by disinfection only.

### Delivery point

Households received water directly to their homes through internal plumbing systems, connected to the companies' water system with reliable continuous pressurization. Despite this, plumbed-in water storage within premises was common in England and Wales.

### Water quality standards

Water quality regulations were set out for England and Wales, in line with the European Union's Drinking Water Directive, which in turn reflect the WHO Guidelines for Drinking-water Quality. Water suppliers were subject to firm regulation from financial, drinking-water quality, and environmental regulators.

### Quality of service

Treated water quality as a whole was very good, generally 99.9% in compliance with European and national standards for drinking-water quality.

### Resource constraints

The water industry in England and Wales was privatized in 1989, which has resulted in improved investment by the water suppliers. It is a technically sophisticated and advanced industry.

### Condition of infrastructure

The systems described were well maintained, but leakage rates from the network are still a problem in some areas with aging mains.

Module 1

# Assemble the WSP team

## Introduction

Establishment of a qualified, dedicated team is a prerequisite to securing the technical expertise needed to develop a Water Safety Plan (WSP). This step involves assembling a team of individuals from the utility, and also in some cases, from a wider group of stakeholders, with the collective responsibility for understanding the water supply system and identifying hazards that can affect water quality and safety throughout the water supply chain. The team will be responsible for developing, implementing and maintaining the WSP as a core part of their day-to-day roles. It is essential that all involved play an active role in the development of the WSP and support the WSP approach. It is important that the WSP team has adequate experience and expertise to understand water abstraction, treatment and distribution and the hazards that can affect safety through the supply system from the catchment to the point of consumption. For small utilities, additional external expertise may be helpful. The team is vital to getting the WSP approach understood and accepted by everyone connected with water safety within and outside the utility. Therefore, an inclusive team that works with everyone within a utility and outside is likely to be far more effective than an exclusive team who impose their WSP approach on the utility. A vital early task of the team is to set out how the WSP approach is to be implemented and the methodology that will be used, particularly in assessing risk.

## Key actions

### Engage senior management, and secure financial and resource support

For successful implementation of the WSP, it is important that senior management support the process. This support is crucial to obtain support for changes in working practices, to ensure sufficient financial resources are available and to actively promote water safety as a goal of the organization. A clear case is needed to show that the adoption of a WSP is important and advantageous to the organization.

### Identify the required expertise and appropriate size of the team

Involving operational staff on the team will contribute to the success of the plan through facilitating its ownership and implementation. However, depending on the size of the utility, 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 the associated risks may be controlled. The team needs to have the authority to enable implementation of the recommendations stemming from the WSP.

### Appoint a team leader

A team leader should be appointed to drive the project and ensure focus. This person should have the authority and organizational and interpersonal skills to ensure the project can be implemented. In situations where required skills are unavailable locally, the team leader should explore opportunities for external support.

This can include use of benchmarking or partnering arrangements with other organizations, national or international assistance programmes and resources, such as the internet.

### Define and record the roles and responsibilities of the individuals on the team

It is important to divide responsibilities among the team members at the start of the process and clearly define and record their roles. For large teams it is often helpful to put together a table outlining WSP-related activities along with who will be responsible for carrying these out.

### Define the time frame to develop the WSP

The initial development of a WSP requires considerable time input. WSPs will increase the amount of time staff spend in the field inspecting the system yet reduce the reliance on the results of routine laboratory tests. The WSP approach enables the operators to get to know their system more effectively as they spend more time identifying and controlling risks instead of just analyzing risks. Once the WSP is established and the organization becomes familiar with the system the time input will decrease.

## Typical challenges

- Finding skilled personnel;
- Organizing the workload of the WSP team to fit in with the existing organizational structure and roles;
- Identifying and engaging external stakeholders;
- Keeping the team together;
- Getting the team to communicate effectively with the rest of the utility and other stakeholders.

## Outputs

Establishment of an experienced, multidisciplinary team that understands the components of the system, and is well-placed to assess the risks that may be associated with each component of the system. The team needs to understand the health and other targets which have to be achieved; and have the expertise to confirm, following an assessment, whether the system can meet the relevant water quality standards.

## Example/tool 1.1: Checklist of skills to be considered when identifying the required expertise for a large WSP team

- ☑ Technical expertise and operational system-specific experience;
- ☑ 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 management systems including emergency procedures;
- ☑ Understanding of the processes used to obtain and communicate the results of monitoring and reporting;
- ☑ Understanding the water quality targets to be met;
- ☑ Appreciation of the water quality needs of the users;
- ☑ Understanding of the practical aspects of implementing WSPs in the appropriate operational context;
- ☑ Understanding the impact of proposed water quality controls on the environment;
- ☑ Familiarity with training and awareness programmes.

## Example/tool 1.2: WSP team composition (from Melbourne Water, a large utility supplying water to 3.5 million people through separate retail companies)

| Job title | Work team | Expertise |
|---|---|---|
| Team Leader / Senior Engineer | Water Quality Planning | Water quality engineering |
| Water Supply Operator | Water Harvesting Team | Operations – Upper Yarra |
| 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 | Thomson Reservoir Team | Operations – Thomson Reservoir |
| Process Engineer | Operations – North Area | Water supply engineering |
| Water Supply Operator | Silvan Reservoir Team | Treatment plant operations |
| Water Supply Operator | Maroondah-Winneke Reservoir team | Sugarloaf Reservoir, Winneke Treatment Plant and Maroondah 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 |

**Example/tool 1.3: Different WSP team building approaches for larger and smaller systems**

Depending on the size of the water supply organization, and where organizations are responsible for multiple systems, it may be necessary to have more than one WSP working group, which report to a central team. The usefulness of this arrangement needs to be assessed at the commencement of the process, but may include: a core team; subordinate working groups that undertake particular aspects of the WSP (e.g. on 'catchment', 'source water', 'treatment' and 'distribution system'); and external team members and reviewers, which may comprise government agencies and independent experts. It is essential that each team uses the same methodology, particularly for assessing risks and is aware of what the other teams are doing.

Small utilities may often not have in-house water quality experts. However, such utilities should at least have the operators and management on the team and bring in health and water quality expertise from external sources. External sources could include agencies (e.g. the department of health, engineering and sanitation or natural resources) or consultants.

Examples of forms that can be used to record essential information when assembling the WSP team and starting the initial stages of the WSP are listed in Example/tool 1.4, 1.5 and 1.6.

### Example/tool 1.4: WSP team details form

The details of the WSP team and any subordinate teams should be documented as part of a utility's WSP methodology. This needs to be kept up to date as personnel and contact details change.

| Name | Affiliation | Title | Role in team | Contact Information |
|---|---|---|---|---|
| Sam Kariuke | Blue Water Supply | Water Supply Operator | Catchment Liaison Officer | 234-5678<br>kariuke@bluewater.com |
| Etc. ↓ | | | | |

## Example/tool 1.5: WSP resourcing plan form (example for a large utility)

While outsourcing work may be necessary when there is limited in-house expertise or capacity, it should be minimized as much as possible as in-house knowledge development will be impeded.

| Activity | Activity budget | Aspects sourced within the utility | Aspects sourced from outside the utility | Staff budget |
|---|---|---|---|---|
| Establishment of WSP team | US $5,000 | Project management and delivery | Facilitation and review | 1.5 Full-time equivalents (FTE) during development and implementation<br>0.5 FTE for ongoing maintenance |
| WSP working group(s) | US $30,000 each | Project management<br>Stakeholder liaison<br>Integration with existing systems | Technical support<br>Data assembly<br>Data analysis and presentation | 3 FTE during development and implementation<br>1 FTE for ongoing maintenance |
| Etc. ↓ | | | | |

## Example/tool 1.6: WSP stakeholder identification form

| Stakeholder name | Relationship to drinking-water supply issues | Key point | Point of contact in WSP team | Stakeholder point of contact | Interaction mechanism | Reference to contact details and record of interaction |
|---|---|---|---|---|---|---|
| Environment Protection Authority (EPA) | Regulate large polluting facilities | Affects catchment protection | Regulatory Liaison Officer | Regional Manager | Annual meeting | EPA file |
| Farming organization with land adjacent to catchment | Livestock raising and agricultural chemical use | Minimizes the introduction of microbial and chemical hazards to catchment | Catchment Protection Liaison Officer | Manager of Operations | Informal and scheduled meetings | Catchment stakeholder file |
| Chemical manufacturing plant | Point-source discharges to catchment | Adheres to industrial effluent standards | Regulatory Liaison Officer | Plant Manager | Annual meeting | Catchment stakeholder file |
| Etc. | | | | | | |

### Example/tool 1.7: Understanding the WSP commitment

A WSP represents a significant responsibility that is shared by all relevant employees within a water supply organization. Development and implementation is time consuming and requires significant resources. Implementation requires commitment at all levels within the organization. Maintenance of the WSP requires ongoing management attention to reinforce a culture of compliance with the requirements of a WSP. It may take several years to see all the benefits of WSP implementation, but experience has shown that the input and commitment is rewarded as the WSP leads to efficiencies and better understanding of the water supply system, including producing water of a quality that consistently meets the health-based targets.

### Case study 1: Australia

#### Field Experience 1.1 – roles of the WSP team

The WSP team was typically set up and led by a dedicated utility coordinating person. This person was usually a graduate engineer or scientist with several years or more experience working in water quality management. The coordinating person typically had titles such as 'Water Quality Manager', or 'Water Quality Coordinator', or more recently, the title 'Product Quality Coordinator' has been used to reflect an extension of their role to cover recycled water. Typically the WSP coordinating team was small, made up of just the coordinator, or the coordinator and one or a few support staff, being almost solely dedicated to creating and maintaining the WSP. The coverage of the full team extended to a dozen or more staff which typically included staff from operations, field maintenance and water supply planning who contributed to the work of the WSP team as a small part of their overall role.

#### Field Experience 1.2 – external parties

One or more stakeholders usually contributed to the WSP efforts. In most cases, the health authority that regulated the utility was involved in risk assessment workshops and in reviewing the plan. Often local government and catchment management agencies were involved in the plan. Bulk water suppliers, or retail utilities, were often involved in WSP development, represented by their retail customers or wholesale suppliers, respectively. Contractors, such as treatment or operations and maintenance contractors, were also typically involved in the utility's WSP development. However, the involvement of these external stakeholders and contractors was usually limited to review and workshop participation. Sometimes professional facilitators were contracted to help support the development of the plans, acting as coaches or mentors and providing technical support to the WSP coordinator, and general support to run workshops and help complete documentation.

### Case study 2: Latin America and the Caribbean (LAC)

#### Field Experience 1.1 – roles of the WSP team

A small 'initiating' group comprising external experts and a senior utility manager discussed the objectives and composition of the WSP team and agreed that it should serve two key functions. The first was to bring together people with expertise in water supply (e.g. abstraction, treatment and distribution), health, and environmental issues, to develop the WSP. Thus, a multidisciplinary Task Force was formed to provide this on-the-ground role. The second purpose of the team was to provide the political support and authority necessary to enable implementation of the recommendations that followed from the WSP. To this end, a Steering Committee comprising senior officials of the water utility, the Ministry of Health, and the regional Environmental Protection Agencies was formed to oversee and support the activities of the Task Force. Engaging senior officials from the start of the project proved essential for generating support to carry out tasks that required managerial or political authority, such as establishing water quality standards, introducing regulatory requirements, and dedicating financial or personnel resources.

#### Field Experience 1.2 – designating a WSP writer/coordinator

While the role of the WSP coordinator is ideally filled by water utility personnel, the utility was unable to commit full-time personnel to this time-intensive task due to resource constraints. Therefore the WSP team decided to engage a consultant to assume the role of the WSP coordinator, which involved planning and facilitating Task Force meetings, liaising with Task Force and Steering Committee members, identifying information gaps, providing technical expertise in water quality assessment, and writing the WSP document. A number of problems soon presented themselves, including the utility's hesitation to share potentially sensitive information about their operations; concerns about conflicts of interests in a small country where considerable overlap in professional spheres exists; and a reduced sense of utility investment and engagement in the WSP.

Personality conflicts also contributed to an ineffective team dynamic and progress was significantly hindered. A second consultant was ultimately engaged to replace the first and a senior utility manager assumed additional responsibility for WSP development. The increased role of the utility manager required relieving her of some other duties for the duration of the WSP development process, but it proved essential to increasing interagency collaboration and project momentum. The second arrangement was successful and underscored the importance of giving careful consideration to the designation of a WSP coordinator to avoid conflicts of interest and to ensure team cohesion.

## Case study 3: United Kingdom (England and Wales)

### Field Experience 1.1 – gaining commitment to adopt the WSP approach

Enthusiasm for the WSP approach was initially not universal within the industry and in some companies there was scepticism of its additional value to an advanced, well performing industry. However, other companies immediately viewed the approach as developing what they were already doing in risk assessment and risk management.

Some companies were uncomfortable using the term 'safety' in Water Safety Plan, because they felt consumers might perceive that the water may be unsafe. Therefore, these companies preferred to label their WSPs as 'Risk Management Plans' or similar, terms which the regulator viewed as appropriate alternatives, provided that the content was consistent with a WSP.

A short document explaining WSP methodology, how they were going to be implemented and what was expected to be achieved was seen as a necessary starting point to obtain board and senior management approval which was essential for the success of the project. A common experience among almost all water companies was that the time required for WSP implementation was significantly underestimated.

Paper-based WSPs restricted access within the company and therefore did not encourage staff ownership. For large water companies computer-based systems available to all staff through an intranet was much more successful. Such systems usually had the basic elements of the WSP for each water supply system laid out in a conventional manner and included links to all the associated procedures and other material. The best plans identified everything as part of the WSP. Issues with sensitive and security related matters were overcome by having restricted levels of access.

### Field Experience 1.2 – expanding the WSP team

In most companies, teams expanded from an initial small core group as appreciation of how wide the WSP approach covered was fully understood. In very large companies that covered a wide geographical area, sub-teams were set up that liaised with a central team. This worked well in getting company wide involvement.

External stakeholders have not yet been generally included as members of the WSP team. This probably results from understandable reticence about making sensitive information too readily available.

### Field Experience 1.3 – valuing WSP team members with fresh perspectives

Early in the implementation process, in some companies, responsibility for WSP development was given solely to the water quality manager or similar post. This meant that the water supply system was considered only by someone who thought they were already fully familiar with it and aware of all the hazards, risks and weaknesses so the fresh WSP approach was lost. Such individuals also tended to limit their thinking to hazards relating to compliance parameters (although this was not a problem confined to individuals) as this was their main area of experience. This meant that the wide umbrella WSP approach was missing from the beginning.

Module 2

# Describe the water supply system

## Introduction

The first task of the WSP team is to fully describe the water supply. Where utilities do not already have documentation of the water system, it is essential that field investigations are conducted. The objective is to ensure that subsequent documentation of the nature of the raw, interim, and finished water quality, and of the system used to produce water of that quality is accurate to allow risks to be adequately assessed and managed. While it is accepted that there may be some room for a generic approach to be taken where works are very similar, or where liaison with outside bodies remains the same for a number of water supplies, each supply must be assessed in detail on its own. Data should be gathered specifically for that supply, and all other steps taken leading to a WSP should be exclusive to that particular supply. Many utilities will already have extensive experience of their water system and hold relevant documentation. In this case, the WSP will simply require this to be systematically reviewed to ensure it is up to date and complete and checked for accuracy by a site visit.

## Key actions

A detailed description of the water supply system is required to support the subsequent risk assessment process. It should provide sufficient information to identify where the system is vulnerable to hazardous events, relevant types of hazards, and control measures. The following should be included in the description but it is not an exhaustive list, nor is every point relevant for each water supply system:

- Relevant water quality standards;
- The source(s) of water including the runoff and/or recharge processes, and if applicable, alternative sources in case of incident;
- Known or suspected changes in source water quality relating to weather or other conditions;
- Any interconnectivity of sources and conditions;
- Details of the land use in the catchment;
- The abstraction point;
- Information relating to the storage of water;
- Information relating to the treatment of the water, including the processes and chemicals or materials that are added to the water;
- Details of how the water is distributed including network, storage and tankers;
- Description of the materials in contact with water;
- Identification of the users and uses of the water;
- Availability of trained staff;
- How well existing procedures are documented.

A flow diagram should be developed which captures all the elements of the water supply system in sufficient detail. The flow diagram should be validated through on-site field checking and then used in the risk assessment process. Cross reference should be made to other documentation showing details such as maps with property boundaries, sewage treatment plants, septic tanks, industry and other potential sources of risk. A map of the supply areas should be checked. Referenced and dated copies of the validated flow diagram should be retained as part of the WSP. 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.

## Typical challenges

- Lack of accurate maps showing distribution systems;
- Lack of knowledge of land use / management in catchments;
- Lack of knowledge of industry and risks;
- Finding all government and local agencies with potential information or a role to play;
- Time required by staff to undertake fieldwork;
- Out-of-date procedures and documentation.

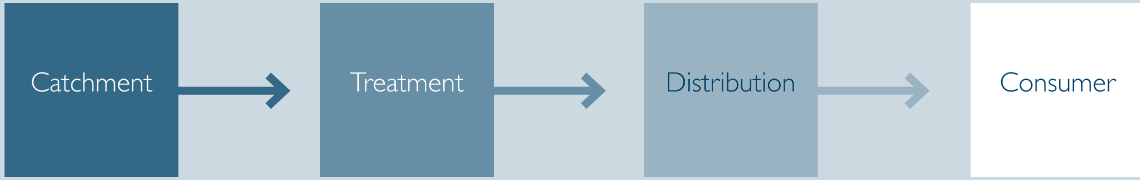
**Outputs**

1. A detailed up-to-date description of the water supply system, including a flow diagram.
2. An understanding of water quality currently being provided by the utility.
3. Identification of the users and uses of the water.

### Example/tool 2.1: Consider the basic arrangements of the water supply system to be assessed

The description should cover the whole system from the source to the end point of supply. Staff should be prepared to spend considerable time on this step. For example, undertaking the field assessment of a large water distribution system of more than 800 km of pipeline in Kampala, Uganda took 40 person days, while the assessment of a smaller network of 600 km took 15 days.

### Example/tool 2.2: Basic elements for describing the water supply system




Several other formats for a supply system are possible, for example, more than one source catchment feeding a treatment works; a distribution area receiving water from more than one treatment works; further dividing distribution into trunk main, service reservoir and network elements; and separately considering consumers as industrial and domestic users. The basic system must document all inputs and outputs even if they do not operate all the time.

### Example/tool 2.3: A good water system flow diagram

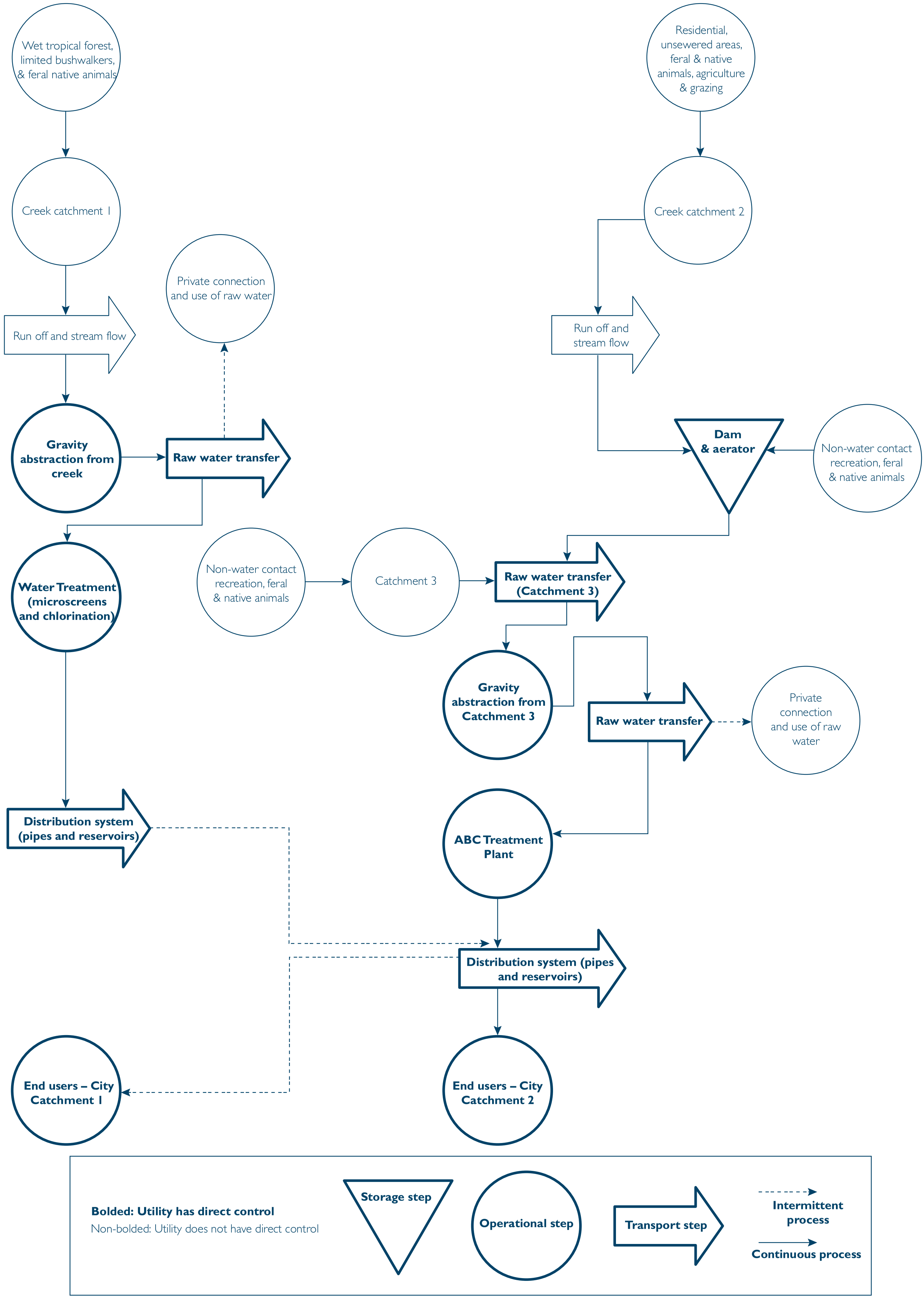
An accurate flow diagram of the water supply system from catchment to point-of-use greatly helps the identification of hazards, risks and current controls. It will help identify how risks can be transferred to consumers and where they are or can be controlled. It is vital to take the flow diagram out on site to check its accuracy and local knowledge is an important input. For simplicity and consistency, standard engineering flow diagram symbols can be used (see Example/tool 2.5). For large systems it may be helpful to divide the flow diagram for each or some of the basic elements (catchment, treatment, distribution, and consumer) into discrete sections. Discrete flow diagrams could be produced, for example for more than one source in the catchment, for different treatment streams and service reservoirs, and trunk mains and network mains in distribution.

### Example/tool 2.4: Intended uses and users of the water

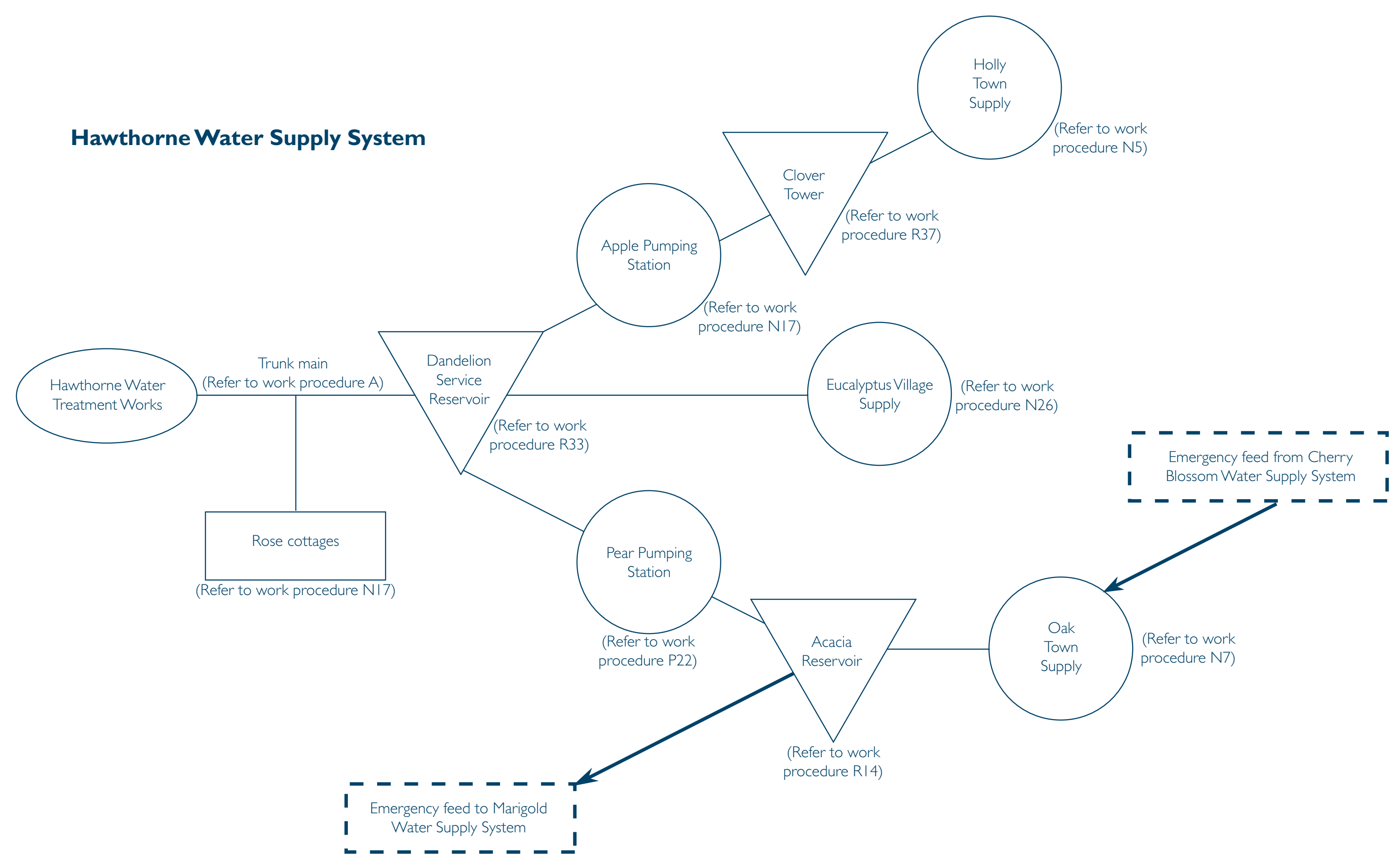
Suitable uses may be specified in regulations. For example, the European Drinking Water Directive covers water intended for human consumption which is defined as water intended for drinking, cooking, food preparation and food production.

| Intended use | Intended users |
|---|---|
| The water supplied is intended for general consumption, personal hygiene and clothes washing. Foodstuffs may be prepared from the water. | Water is provided to the general population.<br><br>The intended consumers do not include those who are significantly immunocompromised or industries with special water quality needs. These groups are advised to provide additional points-of-use treatment. |

**Example/tool 2.5: Checked system process flow diagram.** Note that a separate flow diagram would be produced for the water treatment plant to show the steps involved in treatment. (e.g. coagulation, flocculation, sedimentation, filtration, clearwell storage, and chemical addition points such as alum and pH adjusters, any upfront oxidants, chlorine for primary disinfection, and if necessary, additional chlorine for desired residual, finished water pH adjustment, etc.).



### Example/tool 2.6: Basic distribution system diagram, referencing more detailed procedures and diagrams as necessary



## Case study 1: Australia

### Field Experience 2.1 – the flow diagram

Most utilities already had extensive system diagrams including geographic information system (GIS) data for their catchments, asset locations and distribution network. Most utilities also had process flow and hydraulic system diagrams for their assets. However, few had the type of theoretical flow diagram typically used for WSPs. Therefore, most utilities developed one or more additional flow diagrams to support their WSPs. Most utilities developed one overarching flow diagram and many then developed specific flow diagrams for each treatment plant and for each distinct water supply system. The flow diagrams were generally developed using common generic software, but many also used specialized flow diagram software.

### Field Experience 2.2 – describing current water quality

Most utilities undertook water quality data analysis as part of the risk assessment phase of their WSP development. Water quality was typically plotted showing time series graphs of results against date, usually illustrating guideline values on the plots. Tables were usually prepared to summarize water quality statistics and compared with guideline values. This data was used to help inform the utility of what hazards might be present at levels of concern. Additional, or special water quality testing was usually not required to complete the WSP, although investigative sampling was often flagged as an action for improvement in the future.

### Field Experience 2.3 – describing the system

System descriptions were typically brief and summary in nature. Detailed system descriptions, such as reports used for design and operation, were referenced for full details, with the WSP just providing summary details. As a result, the WSP system descriptions were usually quite brief and were aimed at the key audience: the WSP team.

## Case study 2: Latin America and the Caribbean (LAC)

### Field Experience 2.1 – the flow diagram

The WSP team found the flow diagram to be a useful tool for describing the system and referred to it frequently throughout the WSP development process. Rather than using the standard engineering flow diagram symbols, the team opted for an alternative schematic to represent the water supply system in an intuitive way because these were seen to be more easily interpreted and user friendly. The schematic showed all surface and groundwater sources and a detailed description of treatment processes, including coagulation/flocculation/sedimentation, filtration, clearwell storage and all chemical addition points, and directional arrows with pipe diameters to indicate flow through the distribution system. This level of detail made the diagram a useful tool to facilitate understanding and discussion of the system being assessed. Additional maps of the watershed and distribution network were also useful visual guides.

### Field Experience 2.2 – describing current water quality

A key component of the system description is an assessment of the current quality of treated and delivered water. Water quality testing and a review of monitoring records collected by the water utility and the health department showed that finished water was consistently not meeting water quality standards, revealing discrepancies between perceived and actual water quality. These discrepancies were particularly important to consider when evaluating the effectiveness of existing control measures and in assessing the risk presented by the identified hazards (Module 4). For example, if the belief that chlorination at the water treatment plant was sufficient to maintain water quality throughout the distribution network had not been disproven through a current water quality assessment, increased chlorine dosing would not have been identified as a critical corrective action to prevent microbial contamination. Because subsequent steps of the WSP rely and build upon information gathered in the system description, it was important that the system description accurately reflected current conditions.

### Field Experience 2.3 – conducting a household survey

Problems with inconsistent service and uncertainty about water quality led many community residents to store or treat water in the home. To better understand the impact of point-of-use practices, a Household Water Use and Health Survey was conducted that included questions about household water sources, household storage and treatment practices, consumer perceptions, satisfaction and health concerns. Water from household taps was tested for chlorine residual and some samples were also tested for microbial contaminants. The household survey found that storing water in household tanks and drinking-water containers was associated with increased contamination; identified areas with inconsistent or no service; found that most water reaching the taps was not chlorinated; and revealed that water-associated health impacts and costs were major community concerns. Such information served to inform the water utility about consumers' experiences and priorities and informed the Ministry of Health of health concerns and the need for public education.

### Field Experience 2.4 – selecting appropriate regulatory standards

In order to determine whether regulatory standards for chemicals and disinfection were being met, it was first necessary that all agencies involved in monitoring agree upon which standards should be targeted. At the start of the WSP process, target levels for some chemicals were set so low that they could not be expected to be reached even within an optimized system. Agencies differed on whether they used the environmentally-based EPA, European Union or national standards, or WHO health-based standards. The agencies represented on the WSP team agreed to adopt a consistent set of criteria that ensured drinking-water safety and was also achievable given system capabilities. In the case of turbidity, the team determined that the system could not be expected to consistently reach the indicated target until considerable system improvements were made. Rather than remain in continual non-compliance, a step-wise approach was taken, in which intermediate targets were set with the understanding that standards would be modified in subsequent WSP revisions as improvements were made. This incremental approach to reaching target turbidity levels represented a realistic and proactive way of dealing with certain limitations within the system and provided a long-term plan for reaching compliance for this parameter.

## Case study 3: United Kingdom (England and Wales)

### Field Experience 2.1 – field checking system descriptions

The water treatment works and distribution systems were already reasonably well documented using flow and engineering diagrams. A lot of information was already available on catchments, from companies' own investigations and regulatory requirements in respect of pesticides, nitrate and *Cryptosporidium*. The main challenge was the time and workload required to take existing and desk reviewed system diagrams out on site to check their accuracy and obtain input from catchment and site technicians and operators. This exercise paid dividends in that the review often revealed small errors or provided information previously not available centrally.

### Field Experience 2.2 – incorporating existing water supply data into the WSP

Generally companies had very good information on their distribution systems and maintained sophisticated GIS systems and records of large industrial users and sensitive users such as hospitals and schools. Such systems and records, being already in place were not always immediately included in WSP development.

Module 3

# Identify hazards and hazardous events and assess the risks

## Introduction

In practice this Module, together with Module 4 (determine and validate control measures, reassess and prioritize the risks), and Module 5 (develop, implement and maintain an improvement/upgrade plan), are usually carried out concurrently. For clarity, each of these is being presented as a separate step as they involve a number of activities. In essence these steps constitute the system assessment which identifies the potential hazards and hazardous events in each part of the water supply chain, the level of risk presented by each hazard and hazardous event, the appropriate measures to control the identified risks, and confirmation that standards and targets are met.

Module 3, the first step in this process, should:

- Identify all potential biological, physical and chemical hazards associated with each step in the drinking-water supply that can affect the safety of the water;
- Identify all hazards and hazardous events that could result in the water supply being, or becoming, contaminated, compromised or interrupted;
- Evaluate the risks identified at each point in the flow diagram previously prepared.

## Key actions

### Identify the hazards and hazardous events

For each step of the validated process flow diagram, the WSP team is required to assess what could go wrong at what point in the water supply system in terms of hazards and hazardous events. Hazard identification involves site visits as well as desk studies. Visual inspection of aspects such as the area surrounding abstraction points and elements of treatment may reveal hazards that would not have been identified through desk studies alone. Hazard identification also requires assessment of historic information and events, as well as predictive information based on utility data and knowledge of particular aspects of the treatment and supply systems. The team should consider factors that could introduce risks that are not readily obvious, for example the siting of a water treatment works in a flood plain (where there was no record of flooding) or the age of pipes in a distribution system (old pipes could be more susceptible to pressure fluctuations than new ones). Identification of 'influencing' factors like these will require the WSP team to think laterally and widely. A number of hazards and hazardous events may occur at any step in the water supply system.

### Assessment of risk

The risk associated with each hazard may be described by identifying the likelihood of occurrence (e.g. 'certain', 'possible', 'rare') and evaluating the severity of consequences if the hazard occurred (e.g. 'insignificant', 'major', 'catastrophic'). The potential impact on public health is the most important consideration, but other factors such as aesthetic effects, continuity and adequacy of supplies, and utility reputation should also be considered.

The aim should be to distinguish between significant and less significant risks. The best way of carrying this out is to draw up a simple table in order to systematically record all potential hazardous events and associated hazards, together with an estimation of the magnitude of risk (see Example/tool 3.8). When starting the risk assessment process, utilities should draw up detailed definitions of what they mean by 'possible', 'rare', 'insignificant', 'major' etc. These definitions should enable the risk assessment to avoid being too subjective. Of crucial importance is the need to define in advance the definition or risk matrix score that identifies 'significant' risk. The information that will inform the risk assessment will come from the experience, knowledge and judgment of the utility and the individual team members, industry good practice and technical literature. When data is insufficient to determine whether a risk is high or low, risks should be considered significant until further investigations clarify the assessment.
The risk assessment should be specific for each drinking-water system because each system is unique.

**Hazards and hazardous events**

Hazards are defined as: Physical, biological, chemical or radiological 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. For example, heavy rainfall (hazardous event) may promote the introduction of microbial pathogens (hazards) into source water.

## Typical challenges

- The possibility of missing new hazards and hazardous events. Since a risk assessment provides a 'point in time' picture of the system, the risk assessment should be reviewed on a regular basis in order not to miss new hazards and hazardous events.
- Uncertainty in assessment of risks due to unavailability of data, poor knowledge of activities within the water supply chain and their relative contribution to the risk generated by the hazard or hazardous event.
- Properly defining likelihood and consequence with sufficient detail to avoid subjective assessments and to enable consistency.

## Outputs

1. Description of what could go wrong and where in terms of hazards and hazardous events.
2. Assessment of risks expressed in an interpretable and comparable manner, such that more significant risks are clearly distinguished from less significant risks.

## Example/tool 3.1: Typical hazards affecting a catchment

| Hazardous event (source of hazard) | Associated hazards (and issues to consider) |
|---|---|
| Meteorology and weather patterns | Flooding, rapid changes in source water quality |
| Seasonal variations | Changes in source water quality |
| Geology | Arsenic, fluoride, lead, uranium, radon<br>Swallow holes (surface water ingress) |
| Agriculture | Microbial contamination, pesticides, nitrate<br>Slurry and dung spreading<br>Disposal of dead animals |
| Forestry | Pesticides, PAHs - polyaromic hydrocarbons (fires) |
| Industry<br>(including abandoned and former industrial sites) | Chemical and microbial contamination<br>Potential loss of source water due to contamination |
| Mining (including abandoned mines) | Chemical contamination |
| Transport – roads | Pesticides, chemicals (road traffic accidents) |
| Transport – railways | Pesticides |
| Transport – airports (including abandoned airfields) | Organic chemicals |
| Development | Run-off |
| Housing – septic tanks | Microbial contamination |
| Abattoirs | Organic and microbial contamination |
| Wildlife | Microbial contamination |
| Recreational use | Microbial contamination |
| Competing water uses | Sufficiency |
| Raw water storage | Algal blooms and toxins<br>Stratification |
| Unconfined aquifer | Water quality subject to unexpected change |
| Well / borehole headworks not watertight | Surface water intrusion |
| Borehole casing corroded or incomplete | Surface water intrusion |
| Flooding | Quality and sufficiency of raw water |

### Example/tool 3.2: Typical hazards associated with treatment

| Hazardous event (source of hazard) | Associated hazards (and issues to consider) |
|---|---|
| Any hazard not controlled / mitigated within the catchment | As identified in catchment |
| Power supplies | Interrupted treatment / loss of disinfection |
| Capacity of treatment works | Overloading treatment |
| Disinfection | Reliability<br>Disinfection by-products |
| By-pass facility | Inadequate treatment |
| Treatment failure | Untreated water |
| Unapproved treatment chemicals and materials | Contamination of water supply |
| Contaminated treatment chemicals | Contamination of water supply |
| Blocked filters | Inadequate particle removal |
| Inadequate filter media depth | Inadequate particle removal |
| Security / vandalism | Contamination / loss of supply |
| Instrumentation failure | Loss of control |
| Telemetry | Communication failure |
| Flooding | Loss or restriction of treatment works |
| Fire / explosion | Loss or restriction of treatment works |

## Example/tool 3.3: Typical hazards within a distribution network

| Hazardous event (source of hazard) | Associated hazards (and issues to consider) |
|---|---|
| Any hazard not controlled / mitigated within treatment | As identified in treatment |
| Mains burst | Ingress of contamination |
| Pressure fluctuations | Ingress of contamination |
| Intermittent supply | Ingress of contamination |
| Opening / closing valves | Reversed or changed flow disturbing deposits<br>Introduction of stale water |
| Use of unapproved materials | Contamination of water supply |
| Third party access to hydrants | Contamination by backflow<br>Increased flow disturbing deposits |
| Unauthorized connections | Contamination by backflow |
| Open service reservoir | Contamination by wildlife |
| Leaking service reservoir | Ingress of contamination |
| Unprotected service reservoir access | Contamination |
| Security / vandalism | Contamination |
| Contaminated land | Contamination of water supply through wrong pipe type |

## Example/tool 3.4: Typical hazards affecting consumer premises

| Hazardous event (source of hazard) | Associated hazards (and issues to consider) |
|---|---|
| Any hazard not controlled / mitigated within distribution | As identified in distribution |
| Unauthorized connections | Contamination by backflow |
| Lead pipes | Lead contamination |
| Plastic service pipes | Contamination from oil or solvent spillage |

### Example/tool 3.5: Deciding which method of risk assessment is most appropriate

The risk assessment process can involve a quantitative or semi-quantitative approach, comprising estimation of likelihood/frequency and severity/consequence (see Example/tool 3.6, 3.7 and 3.8), or a simplified qualitative approach based on expert judgment of the WSP team (see Example/tool 3.9 and 3.10). A small water supply system may only require a team decision, whereas a more complex system may benefit from a semi-quantitative risk prioritization approach. In any case, it is beneficial to record the basis of the decision to act as a reminder to the team and/or auditor or reviewer as to why the decision was taken.

### Example/tool 3.6: Semi-quantitative risk matrix approach (from Deere et al., 2001)

| | | Severity or Consequence | | | | |
|---|---|---|---|---|---|---|
| | | **Insignificant or no impact - 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 |

| | | | | |
|---|---|---|---|---|
| **Risk score** | <6 | 6-9 | 10-15 | >15 |
| **Risk rating** | Low | Medium | High | Very high |

All risks should be documented in the WSP and be subject to regular review even when the likelihood is rare and the risk rating is low. This avoids risks being forgotten or overlooked and provides the water utility with a record of due diligence should incidents occur.

### Example/tool 3.7: How to calculate the risk using the matrix

| **Event** | **Loss of network integrity through illegal connections results in the ingress of pathogens.** |
|---|---|
| **Severity of event and basis for score** | 5 – Public health impact including disease and potentially death. |
| **Likelihood of event and basis of score** | 2 – Plumbing controls are in place, but are ineffective - at least two outbreaks have occurred from illegal connections in the past 5 years. |
| **Score** | 5 x 2 = 10 high risk |
| **Outcome** | Risk requires prioritizing for action, including reviewing the current controls and whether new control(s) could be implemented (see Module 5). |

### Example/tool 3.8: Output of hazard assessment and risk assessment using semi-quantitative approach

| Process step | Hazardous event (source of hazard) | Hazard type | Likeli-hood | Severity | Score | Risk rating (before consideration of controls) | Basis |
|---|---|---|---|---|---|---|---|
| Source (groundwater) | Cattle defecation in vicinity of unfenced wellhead causing source of potential pathogen ingress in wet weather | Microbial | 3 | 5 | 15 | High | Potential illness from pathogens from cattle, such as *Cryptosporidium* |
| Source | Cocktail of pesticides from agricultural uses | Chemical | 2 | 4 | 8 | Medium | Potential introduction of toxic chemicals which could lead to concentrations in finished water above national standards and WHO Guideline values |
| Source | Potential for informal solid waste disposal | Microbial and chemical | 1 | 1 | 1 | Low | Potential for hazardous waste plus rainfall event causing contamination to water supply is low |
| Storage tank | Unroofed reservoir allows birds to congregate and defecate in treated water | Microbial | 2 | 5 | 10 | High | Potential illness from pathogens such as *Salmonella* and *Campylobacter* |
| Treatment | No back-up power supply | Microbial and chemical | 2 | 5 | 10 | High | Potential loss of treatment and pumps/pressure |
| Distribution | Leaks on trunk main and distribution system | Microbial | 5 | 3 | 15 | High | Leaks are a potential source of microbial pathogens and contribute to high % of unaccounted for water |

### Example/tool 3.9: Simplified risk assessment based on expert judgment of the WSP team

An alternative to scoring risks based on the likelihood and severity of consequences model, is to undertake a simplified risk assessment process, drawing on the team's judgment. Risks may be ranked as 'significant', 'uncertain', or 'insignificant', based on an assessment of the hazards/hazardous events at each step in the process. Following this, and as explained in Module 4 and 5, it will be necessary to determine whether risks are under control, through which control measures, and when necessary, identify and put in place an improvement programme, which may require short-, medium- and long-term mitigation measures. It is critical to document which events need urgent attention. The NZ MoH (2005) defines 'urgent attention' as those things that can happen frequently and/or could cause significant illness. The descriptors below can be used to capture this information.

### Example/tool 3.10: Definition of descriptors for use in simple risk prioritization

| Descriptor | Meaning | Notes |
|---|---|---|
| Significant | Clearly a priority | The risk should be considered further to determine whether additional control measures are required and whether a particular process step should be elevated to a key control point in the system. It is necessary to validate existing control measures before defining whether additional control measures are required. |
| Uncertain | Unsure if the event is or is not a significant risk | The risk may require further studies to understand if the event is really a significant risk or not. |
| Insignificant | Clearly not a priority | Note that the risk will be described and documented and will be revisited in future years as part of the WSP rolling review. |

### Example/tool 3.11: Prioritizing and documenting risks for urgent action or regular review

Any hazard scored for risk as 'high' or 'very high' or 'significant', should have in place, or requires urgently, validated controls (or mitigation measures). Where controls are not in place, an improvement programme should be drawn up. Any hazard classified as 'moderate' or 'low risk' should be documented and kept under regular review. Controls for 'high' or 'very high' risks may also mitigate other risks.

### Example/tool 3.12: The necessity of working with stakeholders

Identification of a hazard does not mean the water company is responsible for the cause. Many hazards are naturally occurring or the result of agricultural or industrial activity. The WSP approach requires water utilities to work with other stakeholders to make them aware of their responsibilities and the impact that their actions have on the utility's ability to supply safe drinking-water. The WSP approach promotes dialogue, education and collaborative action to remove or minimize risks.

## Case study 1: Australia

### Field Experience 3.1 – identifying threats to water quality

Usually two-day workshops were convened for each major water supply system and involved the full WSP team with one or more external experts, stakeholders and facilitators. The process of hazard identification and risk assessment was usually carried out on day one. Control point determination and specification was usually carried out on day two. Hazardous events were typically listed for each process step identified in the flow diagram. For each hazardous event, the hazards arising were considered and risks were scored against two factors: likelihood and consequence. Likelihood was usually expressed as a frequency of anticipated occurrence. Consequence was usually expressed in terms of population size (small-large) and severity of effect (operational-aesthetic-health). The workshops typically involved brainstorming exercises, review of water quality data and consideration of a range of what-if scenarios. Most utilities assessed risks assuming that the current control measures were in place and working normally. Some utilities assessed each risk twice: both with and without considering the effect of the current controls in place. Most utilities used a risk assessment ranking matrix that was based on their corporate risk assessment system which was often used for environmental, occupational health and safety and other types of risk assessment, too.

### Field Experience 3.2 – limitations of the semi-quantitative approach to risk assessment

The semi-quantitative approach was relatively easy to apply in Australia because it formed the basis of the Australian and New Zealand Risk Management Standard (1995, 1999, 2004) and was very familiar to most industry professionals. However, there was always difficulty forming agreement on risks. In particular, it was common for the same stated risk to have more than one connotation: a low likelihood of a severe consequence and a high likelihood of a minor consequence. For instance, the risk of dirty water contamination was both likely but minor (sporadic dirty water complaints with no health implications are quite common) and rare but severe (major dirty water events that compromise disinfection are serious but not common). Therefore, it was necessary to set out very clearly what each risk was. Another limitation of the scoring system was that health consequences were typically not differentiated between short-term acute and established effects, such as pathogen infections, and long-term theoretical effects, such as disinfection by-product effects. Therefore, the risk ranking tended to overstate the importance of some chemical related health risks of relatively low or even questionable significance as compared with microbial risks.

## Case study 2: Latin America and the Caribbean (LAC)

### Field Experience 3.1 – identifying threats to water quality

A two-day workshop was convened to carry out the process of hazard identification and risk assessment. Hazards in the watershed, treatment process, distribution system, and household were identified by Task Force members through brainstorming exercises and through a review of water quality monitoring site visits and household survey reports. The most critical threats identified were institutional, including a lack of operator training, a lack of system accountability to ensure routine monitoring and a lack of standard operating procedures. Physical hazards identified through brainstorming, such as the introduction of sewage and gasoline, while important, were found to be largely hypothetical. The more critical physical threats, such as a lack of chlorine and the presence of thermotolerant coliforms in delivered water, were identified through a review of the monitoring and survey reports of existing conditions and practices.

Because of the range of possible hazards at each step of the water supply chain, the multiple factors considered in assigning risk, and the relative and subjective nature of the scoring process, the input of stakeholders with varied expertise and experience was important for minimizing bias by any single agency perspective. It also improved the accountability of those agencies and facilitated the appropriate assignment of responsibility for corrective actions identified to address the risks.

### Field Experience 3.2 – limitations of the semi-quantitative approach to risk assessment

Initially a semi-quantitative approach following WHO's WSP risk scoring matrix (chapter 4 of the Guidelines) was employed. Considerable confusion and disagreement arose, however, over some hazards that did not always lend themselves to quantitative ranking and led to time-consuming discussions of hypothetical situations. In many cases, assignment of severity and likelihood was inconsistent. The severity of sewage effluent from cesspool emptying, for example, was ranked high, while the severity of sewage effluent from on-site absorption pits was ranked low, resulting in vastly different priority assignments, even though likelihood was ranked the same. Participants also found it difficult to exclude consideration of existing control measures when assessing risk, further contributing to frustration in the preliminary ranking process. WSP team members found that the resulting rankings did not reflect priorities and therefore decided to switch to a more intuitive approach and to delay priority ranking of risks until after control measures had been considered (see LAC Field Experience 4.1).

## Case study 3: United Kingdom (England and Wales)

### Field Experience 3.1 – broadening the application of risk assessment

The initial process for many companies was to restrict hazard identification and risk analysis to those that related directly to compliance parameters. Issues such as flooding, power supplies, security, emergency responses, telemetry, communications and IT systems, although well documented within company procedures, were not considered as part of the WSP, often because they were not under the direct control of the WSP team lead or members (usually from the operations or scientific divisions of a company). Gradual development of the WSP approach demonstrated the need for wider application but this area remains a problem.

Many companies had applied risk assessment techniques to their operations, assets and financial systems for many years and had risk registers. Sometimes ownership of the risk register was not covered by the WSP team so that, for example, a waterborne outbreak of illness did not feature in the WSP because it already featured in the company's risk register. Widening WSP application is still a challenge in some companies.

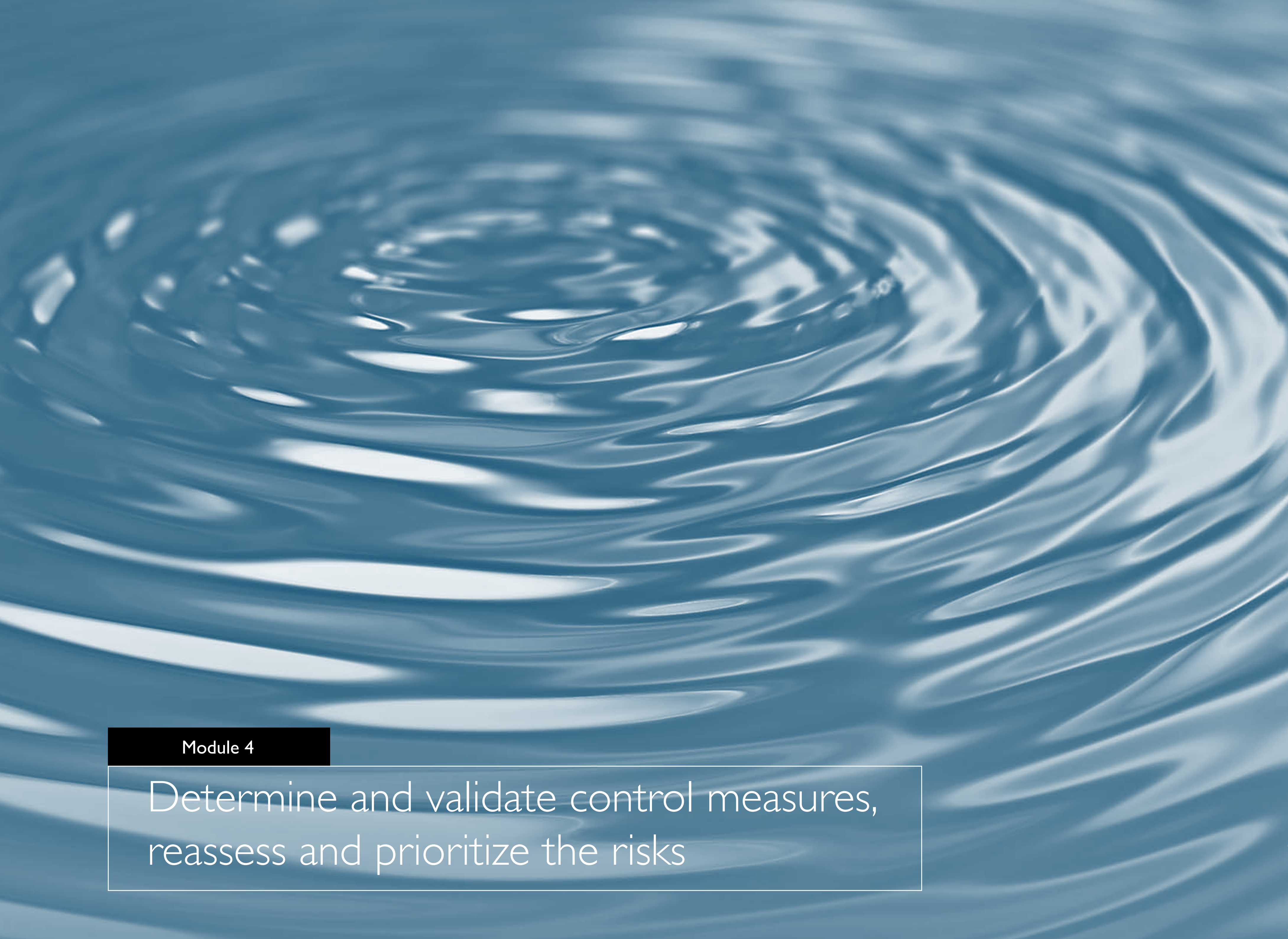
### Field Experience 3.2 – tailoring the risk scoring matrix to fit the supplier

Most companies found the 5x5 risk matrix from Chapter 4 of the third edition of the Guidelines useful for scoring and prioritizing risks. Some changed the scoring ratio because they considered it was easier to separate high, medium and low risks. The use of a basic non-scoring 3x3 risk matrix (high, medium and low) was not found to be very helpful because most risks ended up in the medium category and then had to be reprioritized. Many companies found it useful to supplement the basic definitions in the Guidelines with further explanations to help with consistent assessment, particularly where more than one team was carrying out assessments. An example is shown below but it is important that each company works out its own methodology rather than copy other examples.

| | | | | Consequence | | | | |
|---|---|---|---|---|---|---|---|---|
| High risk ≥20<br>Medium risk 10-19<br>Low risk <10 | | | | Wholesome water<br>Insignificant<br>1 | Short term or localised, not health related non compliance or aesthetic<br>Minor<br>2 | Widespread aesthetic issues or long term non compliance not heath related<br>Moderate<br>4 | Potential long term heath effects<br>Major<br>8 | Potential illness<br>Catastrophic<br>16 |
| Likelihood | Has not happened in the past and it is highly improbable that it will happen in the future | Most unlikely | 1 | 1 | 2 | 4 | 8 | 16 |
| | Is possible and cannot be ruled out completely | Unlikely | 2 | 2 | 4 | 8 | 16 | 32 |
| | Is possible and under certain circumstances could happen | Forseeable | 3 | 3 | 6 | 12 | 24 | 48 |
| | Has occurred in the past and has the potential to happen again | Very likely | 4 | 4 | 8 | 16 | 32 | 64 |
| | Has occurred in the past and could happen again | Almost certain | 5 | 5 | 10 | 20 | 40 | 80 |

### Field Experience 3.3 – addressing risks within consumer premises

It was noticeable that many WSPs did not identify consumers or consumer organizations as WSP stakeholders. Hazard identification and risk assessment of consumer premises was a weak area in most WSPs and it is true that there is a limit to what water companies can achieve although they do have powers of inspection. Water storage within premises is common in England and Wales and is a source of hazards but is an area where water companies have little control. A good example of co-operation within the water industry was an education package for consumers setting out what they can do to protect the safety of their water supplies in areas such as hygiene, plumbing and preventing back syphonage. Companies were aware that this is an area that requires handling carefully as there is a danger of scaring consumers away from drinking tap water.



Module 4

# Determine and validate control measures, reassess and prioritize the risks

## Introduction

Concurrently with identifying the hazards and evaluating the risks, the WSP team should document existing and potential control measures. In this regard, the team should consider whether the existing controls are effective. Depending on the type of control, this could be done by site inspection, manufacturer's specification, or monitoring data. The risks should then be recalculated in terms of likelihood and consequence, taking into account all existing control measures. The reduction in risk achieved by each control measure will be an indication of its effectiveness. If the effectiveness of the control is not known at the time of the initial risk assessment, the risk should be calculated as though the control was not working. Any remaining risks after all the control measures have been taken into account, and which the WSP team consider unacceptable, should be investigated in terms of additional corrective actions.

Control measures (also referred to as 'barriers' or 'mitigation measures') are steps in the drinking-water supply that directly affect drinking-water quality and ensure the water consistently meets water quality targets. They are activities and processes applied to reduce or mitigate risks.

## Key actions

### Identify the controls

Existing control measures should be determined for each of the identified hazards and hazardous events. Missing controls (i.e. those that are needed, but are not in place to mitigate hazards) need to be clearly documented and addressed, as explained below.

### Validate the effectiveness of the controls

Validation is the process of obtaining evidence on the performance of control measures. For many controls validation will require an intensive programme of monitoring to demonstrate the performance of a control under normal and exceptional circumstances. This should not be confused with operational monitoring, which shows that the validated control continues to work effectively. The efficacy of each control measure should be determined at its point in the water supply system rather than in isolation as the performance of one control can influence the performance of subsequent controls. If a control has been in place for some time, a utility may have sufficient operating data to give it confidence that further validation monitoring is not required.

Technical data from scientific literature or data from studies at pilot drinking-water treatment plants may be helpful in the validation process, but care must be taken to check that the circumstances described or piloted are the same or very similar to the risks that have been identified as requiring controls. Validation may also be carried out by seeding challenge organisms or chemicals and determining the effectiveness of removal or inactivation, although this is not a procedure that should be used when water is going into supply. Validation of controls will involve a variety of methodologies. For example, validating buffer distances and fencing in a catchment may be carried out through catchment sanitary surveys to ensure minimal risk of microbial pathogens entering a water intake; and an alternative power source, supplied through an on-site emergency generator, may be validated by demonstrating that it switches on when power is lost, and that it has sufficient power output to run the required process.

During operations, it is critical to monitor the effectiveness of validated controls against pre-determined targets or 'critical limits' (see Module 6 on Operational Monitoring). These targets may be expressed as upper and/or lower limits. For example, if a control measure is 'maintenance of continuous chlorine residual', a critical limit might be expressed as water meeting a 0.2-0.5 mg/l residual chlorine level, pH 6.5-7 and turbidity <1 NTU.

### Reassess risks, taking into account the effectiveness of controls

The risks should be recalculated in terms of likelihood and consequences taking into account the effectiveness of each control. Control measures must be considered not only for their longer-term average performance, but also in light of their potential to fail or be ineffective over a short space of time. It is important that significant risks that do not have controls are highlighted as remaining significant risks in that water supply system. The determination of the appropriate missing controls is critical and is discussed in Module 5.

### Prioritize all the identified risks

Risks should be prioritized in terms of their likely impact on the capacity of the system to deliver safe water. High priority risks may require system modification or upgrade to achieve the water quality targets. Lower priority risks can often be minimized as part of routine good practice activities.

As per Module 5, an upgrade or improvement plan should be developed to address all uncontrolled and prioritized risks. Upgrade plans should identify who is responsible for the improvements, together with an appropriate time frame for implementation of these controls.

Examples of controls include short-term mitigation measures (e.g. advice notices and restricting output or not using a particular source); and medium- and long-term mitigation measures (e.g. improving community consultation activities; catchment measures, such as covering of water storages; treatment improvements, such as enhanced coagulation and filtration; and other capital investment projects).

### Typical challenges

- Identifying staff responsibilities in terms of who will undertake the field work to identify the hazards and determine the control measures;
- Ensuring appropriate controls are identified that are cost-effective and sustainable;
- Uncertainty in prioritizing the risks due to unavailability of data; poor knowledge of activities within the water supply chain and their relative contribution to the hazard type generated by the hazardous event as well as the risk score of the event.

### Outputs

1. Identification of the controls.
2. Validation of the effectiveness of the controls.
3. Identification and prioritization of insufficiently controlled risks.

## Example/tool 4.1: Typical control measures associated with hazards at a catchment

| |
|---|
| Restricted access to catchments |
| Water utility ownership and control of catchment land |
| Stock fencing |
| Moving stock away from river access at calving / lambing times |
| Codes of practice on agricultural chemical use and slurry spreading |
| Moving farm operations away from sensitive locations |
| Planning controls |
| Agreements and communication with transport organizations |
| Communication and education of catchment stakeholders |
| Industrial effluent standards and volume controls |
| Raw water storage |
| Ability to close intakes (time of travel information) |
| River biology – indicator of diffuse or point source contamination |
| Covering and protecting springs |
| Ability to use good alternative water sources when hazards affect one source |
| Continuous monitoring of intake and river |
| Site inspections |
| Regular internal inspections of wells and boreholes |

## Example/tool 4.2: Typical control measures associated with hazards at treatment

| |
|---|
| Validated treatment processes |
| Alarmed operating limits |
| Stand-by generator |
| Automatic shut-down |
| Continuous monitoring with alarms |
| Trained staff (operator competency) |
| Purchasing policy and procedure |
| Fencing, locked premises, intruder alarms |
| Communications back-up |

### Example/tool 4.3: Typical control measures associated with hazards at a distribution network

| |
|---|
| Regular reservoir inspections (external and internal) |
| Cover open service reservoirs |
| Up-to-date network maps |
| Known valve status |
| Purchasing policy and procedure |
| Mains repair procedures |
| Trained staff (operator competency) |
| Hygiene procedures |
| Hydrant security |
| Non-return valves |
| Pressure monitoring and recording |
| Protected pipes |
| Fencing, locked hatches, intruder alarms for service reservoirs and towers |

### Example/tool 4.4: Typical control measures associated with hazards at consumer premises

| |
|---|
| Property inspections |
| Consumer education |
| Plumbosolvency control |
| Non-return valves |
| Advice to boil / not use the water |

## Example/tool 4.5: Critical limits and actions relating to microbial hazards

| Hazards and hazardous events | Examples of control measures | Critical limit target | Critical limit trigger for action |
|---|---|---|---|
| Microbial hazards from contamination of a service reservoir | Ensure inspection covers remain in place<br>Ensure ventilators and cable ducts are secured against vermin entry | Inspection covers locked in place and vermin-proofing intact | Inspection covers not in place or unlocked or damage to vermin-proofing |
| Microbial hazards from contamination of a source water reservoir | Protection of catchments from stock and human habitation<br>Fencing stock from catchment streams and watercourses | Only permitted development or activity in catchment and stock fencing intact | Any non-permitted development or activity in catchment and any damage to stock fencing |
| Chemical, microbial and physical hazards overwhelming treatment capability | Cessation of source water abstraction during high contamination periods, e.g. after storms | Rain event, flow rate and turbidity monitoring within normal range | Rain event, flow rate and turbidity monitoring outside of specified range |
| Chemical cyanotoxin hazards from algal bloom in source water reservoir | Mixing of storages to reduce cyanobacteria | Mixing system operating when required | Failure of mixing system and stratification forming |

## Example/tool 4.6: Validation information capture format

| Item validated | Validation | Reference |
|---|---|---|
| Chlorine residual critical limit values | Australian Drinking Water Guidelines state that a Ct of 15 is required to control bacterial pathogens which require the minimum specific chlorine concentrations at the specified measurement points in peak day demand flows. | *Australian Drinking Water Guidelines* (1996 and 2004). National Health and Medical Research Council. |
| Filtered effluent critical limit values | Systems that filter must ensure that the turbidity goes no higher than 1 NTU and 0.3 NTU for conventional or direct filtration in at least 95% of the daily samples in any month. | US EPA National Primary Drinking Water Regulations (2002) |
| Critical limits for underground travel time in riverbank filtration | Site and depth of wells should ensure minimal travel times of the water in the ground of 30 days (as shown from a two year observation programme run with a sequence of observation wells) to ensure elimination to < 1 μg/L of toxins even during prolonged cyanobacterial blooms with > 1000 μg/L of toxins in the river. | Internal report documenting analysis of two years' worth of data in observation and production wells. |
| Critical limit for turbidity at outlet of each single rapid filtration unit | Research programme run by five utilities over a two year period showed *Cryptosporidia* oocysts to remain below detection limit if the filters are operated to meet this critical limit for turbidity. | Project report of joint research programme. Analytical method had to meet performance target for result to be accepted. |

### Example/tool 4.7: Validate controls before prioritizing risks for mitigation

Risks can only be reassessed and prioritized following validation of control measures. Initial validation of controls can be carried out through intensive monitoring, unless controls have proved their effectiveness over time. If it is clear that the system needs to be improved to achieve the relevant water quality objectives, an upgrade/improvement plan should be developed and implemented.

### Example/tool 4.8: Maintaining consistency in reassessing and prioritizing risks

☑ Decide on a consistent risk assessment methodology upfront, as done in Module 3;

☑ Be specific about what the hazard is in terms of:

- Likelihood of the hazard occurring, taking into account effectiveness of controls;
- Consequence of the hazard occurring;
- Probability that it will affect the safety of the water supply; and
- Where and when it can occur.

### Example/tool 4.9: Establishing cut-off points to prioritize risks

The WSP team needs to establish a cut-off point, above which the reassessed risks will require further action and below which they will be kept under review. In Example/tool 3.6, a score of 6 is taken as the cut-off point, but in addition, any risk that includes a catastrophic consequence rating should be documented and kept under review even if the likelihood is rare. Classifying the risk from low to very high can be rather subjective but should help to prioritize where the most urgent action is required.

### Example/tool 4.10: Output of hazard assessment and determination and validation of control measures

| Hazardous Event | Hazard Type | Likelihood | Severity | Risk | Control measure | Efficacy of control measure | Basis |
|---|---|---|---|---|---|---|---|
| Cattle defecation followed by rainfall | Microbial (pathogens) | 3 | 5 | 15 | Filtration of water<br>Boil water advisory if filtration fails (corrective action) | Protozoa controlled by filtration validated by manufacturer's data on pore size and testing for oocysts | Waterborne disease outbreaks seen in similar situations |
| Etc. | | | | | | | |

### Example/tool 4.11: Dealing with uncertainty in scoring of risks

The uncertainty of risk scoring for each of the hazards and hazardous events can be addressed by further investigations which can be added to the WSP.

| Step | Catchment |
|---|---|
| Event | Leaching from sites such as disused cattle, landfill or contaminated sites and run-off of water soluble compounds (e.g. pesticides) into the source water. |
| Basis | While the dilution factors are significant, there is no monitoring data available and no barriers in place for this hazard. If pesticides are present in high concentrations, there could be potential health risk. |
| Possible investigations to reduce uncertainty | 1. Undertake a sanitary survey with special focus on pesticide usage and dip site locations, particularly those in the proximity of spray from pesticides.<br>2. Undertake pesticide monitoring at the source intake during normal and event conditions. |
| Practicality of investigation | 1. High practicality but low cost and could be combined with other studies being undertaken by other stakeholders.<br>2. High practicality but high cost. |
| Output | The WSP team recommends which of the above options to undertake, by whom, at what time, and at what cost. |

## Example/tool 4.12: Risk prioritization and reassessment

| Hazard | Hazardous event (source of hazard) | Likelihood | Severity | Score | Risk rating (see table 3.6) | Example control measure | Validation of control measure | Reassessment of risk post-control |
|---|---|---|---|---|---|---|---|---|
| Microbial | Inadequate disinfection method | 3 | 4 | 12 | High | Improve disinfection method (longer-term).<br>Minimizing ingress of contamination to system and lengthening reservoir detention times (short-term). Fitting alarms triggered by low disinfectant level. | Alarms effective and demonstration of consistent removal of indicator organisms under range of operating conditions. | Low with appropriate operational monitoring. |
| Chemical | Formation of disinfection by-products at levels that exceed Guideline values | 3 | 3 | 9 | Medium | Reducing water age through tanks downstream where possible in periods of low water demand. | Consistent reduction in disinfection by-products under range of operating conditions. | Low with appropriate operational monitoring. |
| Microbial | Less effective disinfection due to elevated turbidity | 4 | 4 | 16 | Very high | Improve clarification and filtration processes (longer-term).<br>Fitting alarms triggered by low disinfectant level. | Alarms effective and demonstration of consistent removal of indicator organisms under range of operating conditions. | Low with appropriate operational monitoring. |
| Microbial | Major malfunction/ failure of disinfection plant | 2 | 5 | 10 | High | Chlorination plants refitted for equipment and process reliability of 99.5%.<br>Fitting alarms triggered by low disinfectant level. | Alarms effective and demonstration of consistent removal of indicator organisms under range of operating conditions. | Low with appropriate operational monitoring. |
| Microbial | Reliability of disinfection plant less than target level of 99.5% | 3 | 4 | 12 | High | Defined band widths for chlorine dosing linked to alarms. | Alarms effective and demonstration of consistent removal of indicator organisms under range of operating conditions. | Low with appropriate operational monitoring. |
| Microbial | Failure of UV disinfection plants | 3 | 4 | 12 | High | Alarms in place for power outages. | Alarms triggered under a range of operating conditions. | Low with appropriate operational monitoring. |

| Hazard | Hazardous event (source of hazard) | Likelihood | Severity | Score | Risk rating (see table 3.6) | Example control measure | Validation of control measure | Reassessment of risk post-control |
|---|---|---|---|---|---|---|---|---|
| Microbial | Low chlorine residual in distribution and reticulation systems | 4 | 4 | 16 | Very high | Set point designed to achieve established target chlorine residual to achieve microbial standards at consumer premises linked to alarms. | Alarms effective and demonstration of consistent removal of indicator organisms under range of operating conditions. | Low with appropriate operational monitoring. |
| Microbial | Power failure to disinfection plant | 2 | 5 | 10 | High | Dual power source. | Supplies confirmed to come from different generating sources. Automatic switching shown to be triggered under a range of operating conditions. | Low with appropriate operational monitoring. |
| Physical, chemical, microbial | Contamination of dosing chemicals or wrong chemical supplied and dosed | 2 | 4 | 8 | Medium | On-line monitoring controls.<br>Laboratory analysis certificate from supplier. | Intensive audit of suppliers. Alarms triggered under a range of operating conditions. | Low with appropriate operational monitoring. |
| Chemical | Over or under dosing from fluoridation plants | 3 | 3 | 9 | Medium | Plants have alarms on high and low levels with dosing cut-offs on high levels. | Alarms triggered under a range of operating conditions. | Low with appropriate operational monitoring. |
| Chemical, physical | Over or under dosing of lime for pH correction | 3 | 3 | 9 | Medium | Plants have alarms on high and low pH with dosing cut-offs on high pH. | Alarms triggered under a range of operating conditions. | Low with appropriate operational monitoring. |
| Physical | Failure of pumps | 4 | 3 | 12 | High | Pressure measurement triggering back-up pumps. (Not in place.) | No controls in place. | High - priority for mitigation. |
| Chemical | Nitrate exceeds compliance standards | 3 | 2 | 6 | Medium | Blending with low-nitrate source from another water supply. (Alternative source itself has rising levels of nitrate and is subject to other demands.) | Unreliable long-term control. | Medium - keep trend under regular review and propose alternative mitigation scheme. |

## Case study 1: Australia

### Field Experience 4.1 – using a qualitative approach to assessing controls

In most cases, actual performance of controls in the removal of contaminants, and actual source water concentrations of hazards, were not defined. Rather, a qualitative, 'gut feel' approach was used to rate the adequacy of controls based on operator experience. Reliable, telemetered, automated engineered controls, such as treatment plants, were often classified as critical control points. Less directly controlled control measures, such as backflow prevention strategies and catchment management actions, were sometimes classified as critical control points but were more usually classified as supporting programs or just control points. There was often great difficulty in coming to agreement as to what should constitute a critical control point rather than a control point and some utilities did not use the term critical control point at all (consistent with WHO WSP and NZ MoH guidance). In general, however, there was good agreement as to which controls were important and needed to be actively managed.

### Field Experience 4.2 – areas of uncertainty

There were significant uncertainties in estimating the effectiveness and value of some catchment and distribution system controls. There was often a reluctance to rely on catchment controls due to difficulties with measuring and enforcing controls in practice. There was also difficulty in having confidence as to the effectiveness of catchment controls, other than total exclusion of people, agriculture, industry and development, which was practiced in some catchments. In general, if activities were allowed in the catchments, it was assumed that treatment was required regardless of the way that the activities were managed. A good example of this was that many source waters that feed disinfection-only treatment systems prohibit recreational activity in catchments and dams because there is not confidence that these activities can be managed to low enough levels to avoid excessive contamination. Another area of concern was disinfectant residual maintenance in distribution systems. Most utilities targeted residual maintenance to water tanks, which are obvious points of possible ingress, but most did not target residual disinfection to all taps, relying instead on low leakage rates and reliable pressurization combined with sanitary repair procedures.

## Case study 2: Latin America and the Caribbean (LAC)

### Field Experience 4.1 – using qualitative operator knowledge and experience to inform risk assessment

Through discussion of the hazards, existing control measures, the effectiveness of the control measures, and 'gut feelings' about the relative importance of the hazards, the team came to consensus on the prioritization of risks. Because the water supply system was recognized as 'risky' a comprehensive pre-control risk assessment was not done. Postponing assessment of risk until after consideration of existing control measures and their effectiveness reduced the time spent on evaluating the risk of hazards for which good control measures were in place and allowed for the inclusion of additional variables, such as the feasibility of preventing the hazard. For example, theft of chlorine tanks resulting in no chlorination, which had occurred in the past, was ranked low in the semi-quantitative approach, while contamination due to residential and industrial activities along the 13-mile intake canal was ranked high. The qualitative approach considered the ease with which the problem of stolen tanks could be corrected (lock boxes), and thus ranked it higher than addressing the multitude of threats that existed along the expanse of the intake canal. This showed that prioritization of risks can be easily influenced by how readily they are mitigated. In this example, although locking the boxes was obviously an improvement, the much higher risk of the quality of the source water should have still remained a top priority.

### Field Experience 4.2 – considering the effectiveness of control measures

In preparing the system description, the WSP team found that there were standards and protocols that were not always carried out as indicated. For example, chlorination was described as part of the standard operations for the water treatment plant; but at the time of the WSP development, a chlorinator had not yet been connected. Routine water quality monitoring was carried out as indicated, but there was no system of review or communication of results. Thus, even though control measures were indicated, they were shown to be minimally or not effective. The evaluation of current system operations as described in LAC Field Experience 2.2 proved helpful for understanding the effectiveness of the control measures and instances in which revising existing control measures or establishing new control measures were needed.

## Case study 3: United Kingdom (England and Wales)

### Field Experience 4.1 – assessing risk before and after controls

An area that the regulator has encouraged, which had been included in some but not all methodology, is the assessment of risks before and after controls. The reason for this is that it is important to know how many risks can affect the water supply system if no controls were in place. This in turn leads to the clear consideration of the effectiveness of each control under normal and abnormal conditions. Having to prove the reasons for the reduction in risk pre- and post-control is a powerful tool for confirming the validity of risk assessment criteria, scoring and effectiveness of controls.

### Field Experience 4.2 – validating control measures

For a mature industry, identification and validation of controls was sometimes seen as a less important step because companies considered that they had so much data and information that the effectiveness of controls was self evident. However the WSP approach does encourage re-evaluation of the use of such data.
Validation of catchment initiatives such as animal management and pesticides and fertilizer usage is a challenge because it is not always a clear measurement and they require the involvement of catchment stakeholders as well as the water company.
The effectiveness of the WSP approach is now seen to be in the interest of the industry and regulator. For example, the WSP approach was effective in validating UV disinfection units, which have recently been allowed for use as a treatment measure for *Cryptosporidium*.
There was confusion about the meaning of the terms validation and verification and these sometimes appeared interchangeable although understanding has improved as the WSP approach has become more widely implemented.

Module 5

# Develop, implement and maintain an improvement/upgrade plan

## Introduction

If the previous step identifies significant risks to the safety of water and demonstrates that existing controls are not effective or are absent, then an improvement/upgrade plan should be drawn up. Each identified improvement needs an ‘owner’ to take responsibility for implementation and a target implementation date. The assessment may not automatically result in the need for new capital investment. In some instances, all that may be needed is to review, document and formalize the practices that are not working and address any areas where improvements are needed. In other cases, new or improved controls or a major infrastructure change may be needed.

Improvement/upgrade plans can include short-, medium- or long-term programmes. Significant resources may be needed and therefore a detailed analysis and careful prioritization should be made in accordance with the system assessment. It may be that improvements need to be prioritized and phased in.

Implementation of improvement/upgrade plans should be monitored to confirm improvements have been made and are effective and that the WSP has been updated accordingly. It should be taken into consideration that the introduction of new controls could introduce new risks to the system.

## Key actions

### Draw up an improvement/upgrade plan

Identify in the improvement/upgrade plan short-, medium- or long-term mitigation or controls for each significant risk, recognizing that other less significant risks can also be controlled by these measures.

### Implement the improvement/upgrade plan

Update the WSP, including recalculating risks taking into account the new control(s).

## Typical challenges

- Ensuring the WSP is kept up to date;
- Securing financial resources;
- Lack of human resources, including technical expertise, to plan and implement needed upgrades;
- Ensuring new risks are not introduced by the improvement programme.

## Outputs

1. Development of a prioritized improvement/upgrade plan for each significant uncontrolled risk.
2. Implementation of the improvement plan according to the planned schedule of short-, medium-or long-term activities.
3. Monitoring the implementation of the improvement/upgrade plan.

**Example/tool 5.1: A checklist of issues to be considered when developing an improvement/upgrade plan**

- ☑ Options for mitigating risks
- ☑ Responsibility for improvement programme (process owner)
- ☑ Financing
- ☑ Capital works
- ☑ Training
- ☑ Enhanced operational procedures
- ☑ Community consultation programmes
- ☑ Research and development
- ☑ Developing incident protocols
- ☑ Communication and reporting

### Example/tool 5.2: Drinking-water quality improvement/upgrade plan actions and accountabilities

| Action | Arising from | Identified specific improvement plan | Accountabilities | Due | Status |
|---|---|---|---|---|---|
| Implement measures to control *Cryptosporidium*-related risks. | *Cryptosporidium* has been identified as an uncontrolled risk.<br><br>Cattle defecation in vicinity of unfenced wellhead is a potential source of pathogen ingress, including *Cryptosporidium*, in wet weather.<br><br>Currently there is no confidence that these risks are adequately controlled. | Install and validate ultraviolet light treatment. Validation includes comparing theoretical treatment performance against that required to inactivate *Cryptosporidium* infectivity. | e.g. Engineer | e.g. Date the action should be completed by. | e.g. Ongoing, not started, etc. |
| Implement measures to control risks arising from agricultural pesticides introduced into the water supply. | Risk assessment process has identified a cocktail of pesticides from agricultural uses. Currently there is no confidence that these risks are adequately controlled. | Install ozone and granular activated carbon filtration within the water treatment plant.<br><br>These controls should be validated through intensive monitoring and shown to continue to work through operational monitoring. | e.g. Engineer | e.g. Date the action should be completed by. | e.g. Ongoing, not started, etc. |
| Review the need for, and if required, the options for, reducing the risks from viral and protozoan water quality contamination from sewage systems to reduce risks to acceptable levels. | Risk assessment process for pathogens risks arising from sewage systems. Currently there is no confidence that these risks are adequately maintained to acceptable levels by the control measures in place. | Develop additional sewage disinfection and downstream water treatment, including avoidance strategies as warranted. | e.g. Water quality officer | e.g. Date the action should be completed by. | e.g. Ongoing, not started, etc. |
| Etc. | | | | | |

## Case study 1: Australia

### Field Experience 5.1 – corrective actions to address inadequate chlorine dosing

In general, corrective actions in the event of critical limits being exceeded involved shutting down supplies until problems were fixed. Most systems had enough treated water in storage or alternative supply options, that it was possible to do this. However, some systems that would have difficulty shutting off supply had installed multiple duty and standby systems with automatic changeover to reduce the risk of untreated water being supplied. In general, treatment failure followed by an inability to provide an alternative supply or rely on stored treated water resulted in the issue of precautionary boil water advisories.

### Field Experience 5.2 – revising the capital improvement plan

Most WSPs identified the need for capital works to improve the reliability of systems and address vulnerabilities. Generally the Australian water supplies were able, under normal circumstances, to provide safe water, so most capital upgrades were aimed at reducing risks of process failures and improving overall system reliability. One of the major benefits of a WSP was the identified capital improvements, using the evidence obtained through the WSP as the driver, had a very high probability of being funded and given a priority. Prior to the use of WSPs there was often less clarity as to the real priority needs of the water quality investments. Furthermore, the WSP provided a justification for capital improvements to improve theoretical reliability and reduce risk. In the past there was more reliance on reacting only to the adverse events that actually occurred. Therefore, the WSP has helped to drive more proactive, preventive water quality planning.

## Case study 2: Latin America and the Caribbean (LAC)

### Field Experience 5.1 – corrective actions to address inadequate chlorine dosing

Several of the hazards identified through the household survey and the monitoring records led to a lack of chlorine residual in the distribution system. The risk associated with this was high and therefore corrective actions to optimize chlorine dosing were ranked among the highest priorities. The insufficient chlorine was associated with a lack of operator knowledge about appropriate dosing, a lack of routine monitoring of chlorine in the distribution system, a lack of communication of monitoring results to operators, and the perception that one source was clean and therefore required only minimal treatment. Corrective actions were proposed to address each of these contributing factors: a training program for plant operators was developed (see LAC Field Experience 9.1); a schedule was developed and sites were selected for routine monitoring along the distribution system (LAC Field Experience 7.1); a protocol for communicating monitoring results to plant operators was developed (LAC Field Experience 7.1); and water quality test results were presented to address misperceptions about the safety of water sources (LAC Field Experience 2.2). Corrective actions were highly detailed, and included responsible parties (process owners), specific tasks and target completion dates.

### Field Experience 5.2 – developing a consumer education program

The household survey revealed that a perception existed in the community that springs and a creek supplied water of high quality and could therefore be consumed directly, while water quality testing found the sources to be microbially contaminated. It also showed a lack of knowledge about effective point-of-use treatment and household storage methods to prevent contamination in the home. Corrective actions to address these hazards focused on designing and carrying out a consumer education program. Appropriate medias for communicating different messages, including radio and television public service announcements and posters, were developed jointly by the water utility and the Ministry of Health. Again, detailed action plans identified responsible parties, specific tasks and target completion dates.

**Field Experience 5.3 – revising the capital improvement plan**

Some capital improvement needs were identified through the system and hazard review. At the time of the WSP development, a plan for capital improvements, developed by the utility and sponsored by an outside donor, had already been proposed. The WSP team found that the improvements proposed by the plan did not necessarily reflect the priorities identified through the WSP process and were not based on a thorough needs assessment and risk analysis; thus, the plan had some important deficiencies. Identifying priority needs through the WSP allowed the team to provide input to the plan, to which the donor was responsive due to the team's ability to justify the proposed changes. The existing capital improvement plan was modified to address the priorities identified by the team, increasing its potential impact by making it an informed and recipient-driven process.

## Case study 3: United Kingdom (England and Wales)

**Field Experience 5.1 – targeting investment programmes**

The financial regulatory regime in place requires five-year investment programmes, with potential support from the regulator provided that investments were identified through WSP methodology. Implementation of WSPs provides the opportunity for a comprehensive risk based prioritized investment programme. Some companies were reluctant at first to share the outputs of risk analysis with the regulator even on an informal basis but this tendency has reduced with the need for the water quality regulator to approve improvement programmes to be put forward for funding. Risk assessment also highlights the need for good maintenance of assets, an area that has previously been difficult to justify for proper funding. There were a few examples of companies already being aware of investment requirements and trying to work these backwards into the risk assessment process. External audit of the improvement programmes should be able to identify flawed risk assessments.

**Field Experience 5.2 – prioritizing catchment initiatives**

Over the years water treatment has become more sophisticated and complex to deal with contaminated water sources. With little control over many catchments, water companies had little alternative. However, the WSP approach is now starting to give more priority to catchment initiatives with collaboration between water companies and catchment stakeholders. Such initiatives also require a more flexible approach from regulators because benefits are likely to take longer to achieve than through installing water treatment but they are likely to be more sustainable and have a lower carbon footprint.

Many companies had done a lot of liaison work in this area and some companies had very good links and communications with the environmental regulator which had a lot of information on catchments; in other cases these links were weaker but as a result of the WSP approach, were improving. Many companies had also undertaken initiatives with other catchment stakeholders, particularly with agriculture in respect to pesticides and fertilizer usage and animal grazing and breeding. In some cases these initiatives had lost impetus and the WSP approach was a way of re-invigorating them. For example, re-organization of the rail network had meant that some previous understandings on pesticides usage near water sources needed reinforcing. The WSP approach is helping involvement from other catchment stakeholders such as industry, forestry, road, rail and airport authorities but this is an area that water companies have found often requires a lot of work to raise stakeholder awareness and interest.

Module 6

# Define monitoring of the control measures

## Introduction

Operational monitoring includes defining and validating the monitoring of control measures and establishing procedures to demonstrate that the controls continue to work. These actions should be documented in the management procedures.

Defining the monitoring of the control measures also requires inclusion of the corrective actions necessary when operational targets are not met.

## Key actions

The number and type of control measures will vary for each system and will be determined by the type and frequency of hazards and hazardous events associated with the system. Monitoring of control points is essential for supporting risk management by demonstrating that the control measure is effective and that, if a deviation is detected, actions can be taken in a timely manner to prevent water quality targets from being compromised.

Effective monitoring relies on establishing:

- What will be monitored
- How it will be monitored
- The timing or frequency of monitoring
- Where it will be monitored
- Who will do the monitoring
- Who will do the analysis
- Who receives the results for action?

**Examples of operational monitoring parameters**
Measurable: Chlorine residuals; pH; turbidity.
Observable: Integrity of fences or vermin-proofing screens; stock density on farms in catchments.

Routine monitoring is usually based on simple observations and tests, such as turbidity or structural integrity, rather than complex microbial or chemical tests. For some control measures, it may be necessary to define 'critical limits' outside of which confidence in water safety would diminish. Deviations from these critical limits usually require urgent action and may involve immediate notification of the local health authority and/or the application of a contingency plan for an alternative supply of water. Monitoring and corrective actions form the control loop to ensure that unsafe drinking-water is not consumed. Corrective actions should be specific and predetermined where possible to enable their rapid

implementation. Monitoring data provide important feedback on how the water supply system is working and should be frequently assessed.

Regularly assessed monitoring records are a necessary element of the WSP as they can be reviewed, through external and internal audit, to identify whether the controls are adequate and also to demonstrate adherence of the water system to the water quality targets.

## Typical challenges

- Lack of sufficient human resources to carry out monitoring and analysis;
- Financial implications of increased monitoring, particularly on-line monitoring;
- Inadequate or absent evaluation of data;
- Changing the attitude of staff members who are used to monitoring in a certain way;
- Ensuring that resources are available to the operations department to carry out corrective actions.

**Outputs**

1. An assessment of the performance of control measures at appropriate time intervals.
2. Establishment of corrective actions for deviations that may occur.

### Example/tool 6.1: Checklist of factors to be considered when establishing a monitoring programme for the control measures

- ☑ Who will do the monitoring?
- ☑ How frequently will the monitoring be done?
- ☑ Who will analyse the samples?
- ☑ Who will interpret the results?
- ☑ Can the results be easily interpreted at the time of monitoring or observation?
- ☑ Can corrective actions be implemented in response to the detected deviations?
- ☑ Has the list of hazardous events and hazards been checked against monitoring or other appropriate criteria to ensure that all significant risks can be controlled?

* Note: often verification monitoring (see Module 7) will be the compliance monitoring required by regulatory or government bodies in which case parameters and monitoring frequencies will be specified as part of compliance.

### Example/tool 6.2: Corrective actions

A corrective action(s) should be identified for each control that will prevent contaminated water being supplied if monitoring shows that the critical limit has been exceeded. Such events may be: non-compliance with operational monitoring criteria, inadequate performance of a sewage treatment plant discharging to source water, extreme rainfall in a catchment, or spillage of a hazardous substance. Examples of corrective actions include the use of alarms and auto-shutdown mechanisms, or switching to an alternative water source during a period of non-compliance (allowing the operator time to bring the supply back into compliance). Risks associated with use of the alternative source should be identified and addressed within the overall WSP framework.

### Example/tool 6.3: Checklist of issues to consider for devising corrective actions

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

## Example/tool 6.4: Long- and short-term monitoring requirements and corrective actions

| Process step/Control measure | Critical limit | What | Where | When | How | Who | Corrective action |
|---|---|---|---|---|---|---|---|
| **Source: Control of development in catchment (example of long-term monitoring)** | <1 septic tank per 40 ha and none within 30 m of watercourse | Council planning approvals | Council offices<br>Site inspection | Annually | On site at council | Catchment/ Watershed Liaison Officer | Seek removal of septic system through planning tribunal |
| | Fencing out of all juvenile cattle from riparian or unfenced paddocks | Farm management practice audits | Dept of Agriculture<br>Site Inspection | Annually | On site at Dept of Agriculture | Catchment/ Watershed Liaison Officer | Meet with landholder in breach and discuss incentive programme |
| **Treatment: Chlorination at water treatment plant (example of short-term monitoring)** | Chlorine concentration leaving plant must be >0.5 and <1.5 mg/l | Disinfectant residual | At entry point to distribution system | On-line | Chlorine analyser | Water Quality Officer | Activate chlorine non-compliance protocol |
| **Etc.** | | | | | | | |

## Case study 1: Australia

### Field Experience 6.1 – identifying and monitoring critical control measures

Most control measures identified as 'critical' were assigned as 'critical control points' and were monitored against 'critical limit' criteria. In most cases, critical limits were monitored on-line with automated control in response to adverse results, and/or telemetry alarms being sent to 24-hour call centres and duty operators. In most cases such systems were in place prior to the use of WSPs, but WSPs provided a forum to review and upgrade these systems. Typically, the critical limits set related to filtered water turbidity, chlorine residual, post primary disinfection and maintenance of water pressure in distribution as measured indirectly by tank levels and pump pressures. In addition, many utilities formalized scheduled monitoring and inspection procedures for source waters and for assets such as water tanks. Procedures for sanitary working practices when repairing and installing water mains were often captured as key control measures and were sometimes classified as critical control points. Backflow prevention systems were usually given a renewed priority with WSPs and most utilities with WSPs had active programmes to enforce backflow prevention with various standards depending on the risk posed by the site being served with water.

### Field Experience 6.2 – operational monitoring of treatment processes

Operational monitoring of treatment processes was usually fully instrumented using on-line calibrated instruments linked to SCADA systems (a computer system used to monitor and control a process). Alarm levels were typically set to provide an early warning as well as an emergency trigger. Alarms usually called system operators to attend the plant and often started automated processes to stop supplying water into the treated water storage. In practice, the automated monitoring systems required a lot of work due to problems with selecting reliable instruments and reliable control systems. However, most utilities persevered until the systems were sufficiently reliable and are continuing to improve these systems into the future as their WSPs mature. Most systems were designed to have multiple triggers to avoid ever supplying untreated water. For instance, systems often automatically shut down or switched to standby systems, and usually there were early warning alarms that would provide time for problems to be fixed before they affected the customers.

### Field Experience 6.3 – operational monitoring along the distribution network

The process of maintaining continuous and quite high pressure to the whole distribution system at all times is well-established in Australian urban centres. Although taken for granted, the maintenance of positive pressure provides a highly effective water quality control which is monitored through water tank level sensors and pressure transducers at key points in the distribution network. Most systems have exceptionally reliable pressurization throughout the network with telemetered, SCADA linked alarms to alert system operators if pressures at any pump station or water levels at any service reservoir start to drop below critical levels. If areas of low pressure are identified through customer notifications, engineering or operational solutions are implemented as low or no pressure at customer supply points is not tolerated. In some isolated areas drought-related water restrictions led to unprecedented peak flows and low pressure events in elevated areas when all properties watered their gardens at once during restricted watering hours. Alternate odd and even property number watering arrangements have been used to alleviate this effect. Legally, the maintenance of sufficient pressure at all times is a service standard requirement of all large urban Australian water suppliers. Water tanks and pump stations are typically monitored regularly and are usually fully enclosed, roofed, secured and vermin-proofed. Disinfectant residual monitoring within the network is increasingly being automated but is not as reliably maintained and managed as pressure. Most distribution systems have significant proportions of the system that are routinely without an effective disinfectant residual. However, the reliable pressurization means that in most cases this is not considered a health issue and the situation is widely tolerated. Some systems with WSPs do not even provide a disinfectant residual and use UV-only disinfection. In very warm climates with long pipelines, disinfectant residuals are routinely monitored and maintained to prevent bacterial growth in the distribution systems. Testable backflow prevention devices that protect water supplies from high and medium hazard connections are usually tested annually and the utility usually keeps records of these tests and actively follows up failure to report successful test results.

## Case study 2: Latin America and the Caribbean (LAC)

### Field Experience 6.1 – identifying and monitoring critical control measures

For the key control measures that addressed the hazards identified in Module 3, a monitoring plan was established that indicated an acceptable operational range for each parameter, designated appropriate monitoring locations, established a schedule for frequency of monitoring, and assigned responsible parties. Corrective actions to be taken in the event that monitoring reveals a parameter to be outside of the acceptable range were also established. The monitoring of critical control measures (operational monitoring) facilitated the identification by plant operators and managers of probable causes of non-compliance that may be identified through compliance monitoring.

### Field Experience 6.2 – operational monitoring of treatment processes

The WSP team identified coagulation/flocculation/sedimentation, filtration and chlorination as critical control measures to be monitored. To gauge coagulation efficacy, regular measurement of turbidity at the outlet of the sedimentation basin was established. To monitor the efficacy of filtration, turbidity was again measured after filtration; and to gauge chlorine dosing efficacy, chlorine residual was measured at the point of entry to the distribution system. Monitoring at the plant was done by the utility plant operators and results were shared monthly with the utility managers, or immediately if found to be outside of established parameters. Prior to the WSP, these critical control measures were rarely measured or recorded. Because records were not reviewed and plant operators did not receive feedback, they saw little value in maintaining and submitting monitoring records. A schedule for distributing reports of utility operations from each of the treatment plants was established. Providing feedback increased plant operator accountability and adherence to protocol and informed them of any changes or concerns related to water quality.

### Field Experience 6.3 – operational monitoring along the distribution network

Insufficient water pressure within the distribution system caused by leaky pipes and unauthorized connections, led to inconsistent water service and the introduction of microbial and chemical contamination. Maintaining water pressure was therefore identified as a critical control measure. Pressure gauges were installed at strategic points along the distribution network, an operator monitoring and recording plan was established, and monitoring records were reviewed monthly by utility managers. This system of increased operator awareness and supervisory oversight improved accountability and adherence to protocol and ensured that operators were better informed of pressure conditions that required immediate corrective action.

### Case study 3: United Kingdom (England and Wales)

#### Field Experience 6.1 – developing a clear operational monitoring strategy

Operational monitoring was a normal and extensive part of the water companies' procedures and had been generally included and reviewed as part of the WSP implementation. A benefit of WSPs is that the methodology requires a clear operational monitoring strategy with defined responsibilities to consider its relevance to the safe production and distribution of drinking-water and for how it is programmed and assessed. This overcomes the tendency to carry out irrelevant tests.

Module 7

# Verify the effectiveness of the WSP

## Introduction

Having a formal process for verification and auditing of the WSP ensures that it is working properly. Verification involves three activities which are undertaken together to provide evidence that the WSP is working effectively. These are:

- Compliance monitoring;
- Internal and external auditing of operational activities;
- Consumer satisfaction.

Verification should provide the evidence that the overall system design and operation is capable of consistently delivering water of the specified quality to meet the health-based targets. If it does not, the upgrade/improvement plan should be revised and implemented.

## Key actions

### Compliance monitoring

All the control measures should have a clearly defined monitoring regime validating effectiveness and monitoring performance against set limits. The water supply organization should expect 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. Verification monitoring frequencies will depend on the level of confidence required by the water supply organization and its regulatory authorities. The monitoring regime should include a review at intervals and at times of planned or unplanned changes in the supply system.

### Internal and external auditing of operational activities

Rigorous audits help to maintain the practical implementation of a WSP, ensuring that water quality and risks are controlled. Audits may involve internal review and external review by regulatory authorities or by qualified independent auditors. Auditing can have both an assessment and a compliance-checking role. The frequency of audits for verification will depend on the level of confidence required by the water supply organization and its regulatory authorities. Audits should be undertaken regularly.

### Consumer satisfaction

Verification includes checking that consumers are satisfied with the water supplied. If they are not, there is a risk that they will use less safe alternatives.

### Typical challenges

- Lack of capable external auditors for WSPs;
- Lack of qualified laboratories to process and analyse samples;
- Lack of human and financial resources;
- Lack of knowledge of consumer satisfaction or complaints.

### Outputs

1. Confirmation that the WSP itself is sound and appropriate.
2. Evidence that the WSP is being implemented in practice as intended, and working effectively.
3. Confirmation that water quality meets defined targets.

**Example/tool 7.1: Parameters that might be included in routine verification monitoring programmes**

For microbial water quality verification, indicator organisms are generally monitored. The most widely used verification system is to use the faecal indicator bacteria *E. coli* or thermotolerant coliforms at representative points in the water supply system. Other indicators may be more appropriate to verify that water is free from viral or protozoan faecal pathogens. Use of other tools, such as heterotropic plate counts, or *Clostridium perfringens* may be used for operational and investigative monitoring in order to better understand the water supply system.

Verification for chemical parameters is carried out by their direct measurement, rather than through the use of an indicator. Most chemical hazards are unlikely to occur at acutely hazardous concentrations and verification frequencies (often quarterly or sometimes biennially) might be less than those used for microorganisms.

Quantitative and qualitative taste and odour may be monitored to ensure the condition of the distribution network and consumer installations.

**Example/tool 7.2: Checklist of factors to be considered when establishing a routine verification monitoring programme. (A utility-led verification programme can provide an additional level of confidence, supplementing regulations which specify monitoring parameters and frequencies.)**

- ☑ Where appropriate, draw up a verification monitoring programme in accordance with regulatory requirements;
- ☑ Identify appropriate personnel to perform monitoring functions;
- ☑ Establish a system of communication between monitoring staff;
- ☑ Identify appropriate analysts;
- ☑ Ensure appropriate monitoring points are chosen;
- ☑ Ensure monitoring frequency is appropriate;
- ☑ Ensure results are interpreted and unusual or failing results are investigated;
- ☑ Establish a system to ensure the routine reporting of results to the appropriate regulator.

## Example/tool 7.3: Auditing the WSP itself and the implementation of the WSP

In addition to analysis of the water quality, verification should also include an audit of the WSP and of the operational practice to show good practice and compliance. Auditors will identify opportunities for improvement such as areas where procedures are not being followed properly, resources are insufficient, planned improvements are impractical, or where training or motivational support is required for staff.

When conducting audits, it is essential that the auditor has a detailed knowledge of the delivery of drinking-water and that procedures, not just records, are witnessed in person. Records may not always be factually correct and in some cases, equipment that has been shown to be working through the records may not be working in practice and can lead to unsafe water and waterborne disease outbreak.

## Example/tool 7.4: Checklist of factors to consider to ensure all appropriate information is obtained during an audit

- ☑ All feasible hazards/events are taken into account;
- ☑ Appropriate control measures have been identified for each event;
- ☑ Appropriate monitoring procedures have been established;
- ☑ Critical limits for each control measure are set;
- ☑ Corrective actions have been identified;
- ☑ A system of verification has been established.

## Example/tool 7.5: Operational monitoring and verification monitoring plan (from Jinga, Uganda)

| Unit process | Operational monitoring (see Module 6) | | | Verification monitoring | | |
|---|---|---|---|---|---|---|
| | **What** | **When** | **Who** | **What** | **When** | **Who** |
| Treatment works | On-line measurement<br>– pH<br>– Chlorine | Daily | Water treatment operators / Analyst | *E. coli* | Weekly | Analyst |
| | | | | Enterococci | Weekly | |
| | | | | Record audit | Monthly | |
| | Jar testing records | Weekly | | | | |
| | Turbidity | Daily | | | | |
| | Dosing records | Monthly | | | | |
| Distribution system | pH | Weekly | | *E. coli* | Monthly | |
| | Turbidity | Weekly | | | | |
| | Chlorine | Weekly | | Turbidity | Monthly | |
| | Sanitary Inspection | Weekly | | Enterococci | Monthly | |
| Etc. ↓ | | | | | | |

## Case study 1: Australia

### Field Experience 7.1 – compliance monitoring

Water utilities had typically made no significant changes to their verification monitoring as part of the introduction of WSPs. In general, this area was a strong focus of regulation in water supply for many decades prior to the advent of WSPs. Both monitoring of customer satisfaction and water quality testing were already well established processes, with data being publicly reported. WSPs have changed the focus to prevention and improved operational monitoring, but have not significantly affected verification monitoring. The major change has been to reposition customer complaint monitoring and water quality testing as 'verification monitoring'. Another effect of WSPs has been to recast verification testing as after-the-fact confirmation whereas in the past verification activities were often the focus of water quality management.

### Field Experience 7.2 – creating systems for internal and external auditing

One of the major changes introduced with WSPs has been the auditing of water quality management. Internal, and increasingly external, auditing is becoming commonplace with most Australian water utilities now being audited at roughly annual intervals by external auditors. Within the past year a new drinking-water quality management auditing system had been set up, together with a growing pool of specialist auditors. There has been some opposition to external auditing from many utilities but regulators are increasingly requiring it as part of their oversight roles.

### Field Experience 7.3 – selecting appropriate regulatory standards

Each jurisdiction (state and territory) has introduced or is developing a requirement for its major public water utilities to have WSPs. Victoria was the first through its Safe Drinking Water Act 2003 and other states have introduced or are introducing the same requirements through acts, regulations or licences. It is likely that by 2015 all public urban water utilities in all states and territories of Australia will have implemented WSPs that are subject to regulatory audit. The first regulatory audits took place in Victoria in 2008, allowing some time between the Act and the point at which compliance was required. Other states and territories are following this lead.

## Case study 2: Latin America and the Caribbean (LAC)

### Field Experience 7.1 – developing a compliance monitoring plan

When the utility's water quality monitoring records were collected and reviewed to assess the current state of the piped water supply (see LAC Field Experience 2.2), it became clear that the utility's protocol for testing, recording and reporting finished water quality was not consistently followed by operators. Lapses in data collection were common and the body of data that did exist had never been systematically compiled and reviewed to ensure compliance with water quality standards and to inform operational decisions. Additionally, the majority of samples had been processed at a remote laboratory and the results were never reported back to operators, denying them important feedback on plant operations. These deviations from protocol were attributed to the limited availability of personnel to perform the testing and analyse results; the cost of transporting samples to the remote laboratory; a shortage of necessary testing reagents; and a lack of accountability (both internal and external). The WSP team agreed that addressing these barriers should be given top priority as knowledge of the quality of water being produced is fundamental to safe water provision. The compliance monitoring plan was revised to include detailed guidance on data collection, recording, compilation and analysis, and operator feedback reporting. The revised monitoring plan also describes internal actions to be taken when results indicate non-compliance with water quality standards.

### Field Experience 7.2 – creating systems for internal and external auditing

When the WSP process began, there was no formal system in place for internal and external auditing of water quality or utility operations and management practices. The result was a lack of accountability within the utility and routine disregard for established procedures. To address these issues, the utility developed a plan to submit monthly water quality reports (created as part of the compliance monitoring plan described in LAC Field Experience 7.1) to senior management within the utility and to the Ministry of Health. This internal and external reporting of water quality records is expected to encourage consistent compliance monitoring and to facilitate regulatory oversight. In order to ensure that the other key procedures outlined in the WSP are also consistently followed, the utility worked with the Ministry of Health to develop an additional, more comprehensive internal and external WSP auditing plan. The more comprehensive plan involves semi-annual internal reviews with senior utility management and annual external reviews with the Ministry of Health. While the entire WSP is subject to review during these audits, the key focus areas are the standard operating procedures (including operational monitoring and compliance monitoring plans), operator training programs, and action plans to address high-priority hazards. In addition to improving adherence to established plans and procedures, these audits are expected to improve communication both within the utility and between the utility and the regulatory body.

## Case study 3: United Kingdom (England and Wales)

### Field Experience 7.1 – verification through compliance and audits

Generally, verification of the effectiveness of the WSP approach is through compliance with regulatory requirements for drinking water quality, treatment and use of chemicals and materials.

The regulator of drinking-water quality will be the WSP external auditor. It does not anticipate normally auditing a company's WSPs in their entirety but particular elements of the WSP will feature in its other audits including compliance assessment, sample audit trails, incident investigations, site inspections, consumer complaints and stakeholder liaison.

Module 8

# Prepare management procedures

## Introduction

Clear management procedures documenting actions to be taken when the system is operating under normal conditions (Standard Operating Procedures or SOPs) and when the system is operating in 'incident' situations (corrective actions) are an integral part of the WSP. The procedures should be written by experienced staff and should be updated as necessary, particularly in light of implementation of the improvement/upgrade plan and reviews of incidents, emergencies and near misses. It is preferable to interview staff and ensure their activities are captured in the documentation. This also helps to foster ownership and eventual implementation of the procedures.

## Key actions

Documentation of all aspects of the WSP is essential. Management procedures are the actions to be taken during normal operational conditions, and detail the steps to follow in specific 'incident' situations where a loss of control of the system may occur. Management staff have a responsibility to ensure procedures are kept up to date and in place to keep operators and management staff connected and involved, to make it easy for people to 'do the right thing', to provide adequate resources and to ensure that people are willing to come forward instead of withholding information for fear of reprisals. An efficient, regular review and updating cycle is also important.

If monitoring detects that a process is operating outside of the specifications of the critical or operational limits, there is a need to act to restore the operation by correcting the deviation. An important part of the WSP is the development of corrective actions which identify the specific operational response required following deviations from the set limits.

Unforeseen events/incidents or deviations may occur for which there are no corrective actions in place. In this case, a generic emergency plan should be followed. This would have a protocol for situation assessment and identification of situations that require activation of the emergency response plan. It is also important that near misses are assessed as they could be an indicator of a likely future emergency.

Following an emergency, an investigation should be undertaken involving all staff to discuss performance, assess if current procedures are adequate, and address any issues or concerns. Appropriate documentation and reporting of the emergency should also be established. Review of the cause of the emergency or near miss and the response to it may indicate that amendments to existing protocols, risk assessments and the WSP are necessary (see Module 11).

### Typical challenges

- Keeping the procedures up to date;
- Ensuring that staff are aware of changes;
- Obtaining information on near misses.

Example/tool 8.1 gives a general outline that can be used to start the development of a list of SOPs that would be typical for a water utility operation. It is impossible to list all the SOPs a facility would require due to the varying nature of the processes at each facility. The SOPs can be prioritized and once documented, additional SOPs can be developed as needed and added to the documentation. The SOP should be developed in a way that allows for revisions as required.

### Outputs

Management procedures for normal and incident/emergency conditions which address:

- Response actions;
- Operational monitoring;
- Responsibilities of the utility and other stakeholders;
- Communication protocols and strategies, including notification procedures and staff contact details;
- Responsibilities for coordinating measures to be taken in an emergency;
- A communication plan to alert and inform users of the supply and other stakeholders (e.g. emergency services);
- A programme to review and revise documentation as required;
- Plans for providing and distributing emergency supplies of water.

### Example/tool 8.1: Typical Standard Operating Procedures for a water utility

| Category | Sub-category | Standard Operating Procedure |
|---|---|---|
| **Facility operations overview** | General tasks/information | Daily rounds<br>Site security<br>Record keeping<br>Reporting procedures<br>Cross contamination prevention for operators |
| | Sampling | Sampling procedure |
| | Emergency response | Power failure |
| **Intake and pre-treatment** | Raw water | Valve operation<br>Screening |
| | Flow measurement | Meter calibration |
| | Pump operation | Switching duty pump operation<br>Increasing/decreasing pumping operation |
| **Dosing procedure** | | |
| **Disinfection procedure** | | |
| **Etc.** | | |

If monitoring detects that there is a deviation from an operational or critical limit, corrective actions need to be applied.

### Example/tool 8.2: Checklist of management procedures (or corrective actions) to deal with incidents

- ☑ Accountabilities and contact details for key personnel and other stakeholders;
- ☑ Clear description of the actions required in the event of a deviation;
- ☑ Location and identity of the SOPs and required equipment;
- ☑ Location of back-up equipment;
- ☑ Relevant logistical and technical information.

Quality control procedures should also be recorded for as many aspects of the WSP as possible. All measurements of control measures, for example, should be subject to appropriate quality control procedures, such as internal and external analytical control within laboratories. (Note that this could also be dealt with as a 'supporting programme'.)

**Example/tool 8.3: Checklist of characteristics and systems relating to people management which will facilitate ongoing success of the WSP**

- ☑ Choosing meaningful parameters on which to report;
- ☑ Having a well-defined and efficient failure reporting system;
- ☑ Including higher-level management in reporting so they are involved in events;
- ☑ Designing 'respected' audits that target likely areas of complacency that lead to adverse consequences;
- ☑ Observing the 'no blame' model where failure is shared by system participants;
- ☑ Having a widely accessible mechanism for presenting improvement opportunities, risk analysis and interpretation and for challenging existing practices;
- ☑ Ensure that all procedures are signed off at senior level. This is an important part of the continuous improvement mechanism.

**Example/tool 8.4: Emergency management procedures**

During an emergency it may be necessary either to modify the treatment of existing sources or temporarily use an alternative water source. It may be necessary to increase disinfection at the source or to additionally disinfect (e.g. rechlorinate) during distribution. Procedures for such an emergency situation should be documented.

**Example/tool 8.5: Checklist of key areas to be addressed in emergency management procedures**

- ☑ Response actions, including increased monitoring;
- ☑ Responsibilities and authorities internal and external to the organization;
- ☑ Plans for emergency water supplies;
- ☑ Communication protocols and strategies, including notification procedures (internal, regulatory body, media and public);
- ☑ Mechanisms for increased public health surveillance;
- ☑ Emergency procedure should be practiced regularly.

## Case study 1: Australia

### Field Experience 8.1 – developing standard operating procedures (SOPs)

In general, the Australian water supply industry was fairly informal with limited formal procedures and documentation. Therefore, most WSPs include some associated additional documentation. The lack of formality partly reflected the long careers and extensive experience of most water supply operators, making written procedures less important than the body of experience and hands-on training. In general, the procedures that have been developed for the Australian WSPs are concise statements of what is required to be achieved rather than detailed procedures for how to achieve those objectives. Generally, there is a reliance on training and operator experience and discretion rather than on following documented procedures. However, where large parts of utility operations are outsourced to contractors, most authorities have developed detailed procedures against which contractor activity can be measured and assessed.

## Case study 2: Latin America and the Caribbean (LAC)

### Field Experience 8.1 – developing standard operating procedures (SOPs)

The WSP team agreed that SOPs would be a critical focus area during the development of the WSP. The treatment plant operators and distribution system maintenance personnel had no reference document to inform and guide day-to-day operations. Operational guidance took the form of verbal instruction from supervisors and was often incomplete and poorly understood. The lack of thorough, clearly defined operating procedures was recognized as a major barrier to safe water provision and was also believed to adversely impact engagement and morale among utility personnel. Considerable time and energy was therefore invested in the development of SOPs. The utility's system-specific SOPs were created by adapting SOPs for another system in the region to the utility's own infrastructure, institutional framework, priorities and constraints. The SOPs contain information on key physical, chemical and microbial contaminants of concern and the role of each treatment process in their removal or inactivation. The SOPs also contain guidance on the optimization of treatment plant operations, such as determining the most effective pH and aluminum sulfate dose for coagulation; recognizing filter backwash and media replacement indicators; and ensuring sufficient chlorine dose and contact time for pathogen destruction. The control measure monitoring plan and the compliance monitoring plan (see LAC Field Experience 6.1 and 7.1) are also important components of the SOPs.

### Field Experience 8.2 – delaying emergency response plans due to resource constraints

The WSP team made the decision not to develop a formal incident/emergency response plan during the first iteration of WSP development in favor of focusing efforts elsewhere. Team members simply did not have sufficient time in their schedules to address each task recommended in the Manual in a meaningful way, so prioritization was necessary. Because the utility's operations were such that noncompliance with most water quality standards was the rule rather than the exception, the water system was effectively in a constant state of emergency. Consumers were under a continuous boil-water advisory and a system was in place to reinforce the ongoing advisory with additional public service announcements by the Ministry of Health whenever sampling revealed particularly poor water quality. While the WSP team members recognized opportunities to enhance the basic response plan, they determined that the water system would be best served by focusing limited resources on improving water quality.

As improvements to water quality are realized through WSP interventions and further experience, the utility will address gaps in the response plan during subsequent revisions of the WSP (see LAC Field Experience 10.1).

### Case study 3: United Kingdom (England and Wales)

**Field Experience 8.1 – revising procedures to incorporate WSP outputs**

Water companies already had good management and SOPs. The challenge was to modify these in line with the outputs of the WSP and to consider such procedures as part of the WSP.

Module 9

# Develop supporting programmes

## Introduction

Supporting programmes are activities that support the development of people's skills and knowledge, commitment to the WSP approach, and capacity to manage systems to deliver safe water. Programmes frequently relate to training, research and development. Supporting programmes may also entail activities that indirectly support water safety, for example those that lead to the optimization of processes, like improving quality control in a laboratory. Programmes may already be in place, but are often forgotten or overlooked as important elements of the WSP. Examples of other activities include continuing education courses, calibration of equipment, preventive maintenance, hygiene and sanitation, as well as legal aspects such as a programme for understanding the organization's compliance obligations. It is essential that organizations understand their liabilities and have programmes in place to deal with these issues.

## Key actions

- Identify the supporting programmes needed for implementing the WSP approach;
- Review, and as necessary, revise existing supporting programmes;
- Develop additional supporting programmes to address gaps in staff knowledge or skills that may impede the timely implementation of the WSP.

## Typical challenges

- Human resources;
- Equipment;
- Financial resources;
- Support of management;
- Not identifying procedures and processes as part of the WSP.

## Outputs

Programmes and activities that ensure that the WSP approach is embedded in the water utility's operations.

Supporting programmes include training of appropriate staff in all aspects of preparing and implementing the WSP, quality control procedures such as internal and external analytical quality control within laboratories, and research and development programmes to support long-term solutions.

### Example/tool 9.1: Reviewing existing programmes

In developing supporting programmes, it may not always be necessary to develop new programmes. Organizations should assess the programmes that are currently in place to identify any gaps that need to be addressed including updates of existing programmes.

All procedures should be documented and dated to ensure that staff follow the most recent version.

### Example/tool 9.2: Types of supporting programmes that could be included in the WSP

| Programme | Purpose | Examples |
| --- | --- | --- |
| Training and awareness | To ensure organization (and contractor) personnel understand water safety and the influence of their actions. | WSP training<br>Competency requirements<br>Induction training<br>Hygiene procedures |
| Research and development | To support decisions made to improve or maintain water quality. | Understanding potential hazards<br>Research into better indicators of contamination |
| Calibration | To ensure that critical limit monitoring is reliable and of acceptable accuracy. | Calibration schedules<br>Self-calibrating equipment |
| Customer complaint protocol | To ensure that customers are responded to if water quality questions are raised. | Call centre<br>Complaints training |
| Etc. | | |

## Case study 1: Australia

### Field Experience 9.1 – operator training programmes

In the past there have been limited formal training opportunities and requirements for water supply system operators and managers with most training being provided on the job. However, at present, regulators are driving more formalized training, competency assessments and qualifications and are working on developing training and assessment packages for the Australian water industry. WSPs invariably place a high prominence on training and experience as a supporting program, but to date, this has been typically relatively informal.

### Field Experience 9.2 – calibration and maintenance

Asset management programmes were typically well established within Australian urban water utilities. In general, key civil assets were well maintained and assessed. One area that has improved with the advent of WSPs is the maintenance of process assets and calibration of monitoring equipment. WSPs have driven more detailed review and often resulted in upgrades of how process assets are maintained and of how monitoring devices are calibrated and maintained.

## Case study 2: Latin America and the Caribbean (LAC)

### Field Experience 9.1 – developing an operator training programme

The utility did not have a formal operator training program and poorly trained operators were considered among the highest-priority threats to water quality. Training had not been offered in many years and considerable operator turnover had taken place since. Further, past training sessions had been conducted by external experts and in-house capacity had not been developed to address future training needs. The WSP team therefore developed an operator training program with a focus on sustainability. A senior utility manager was identified as the training lead and a number of utility personnel were selected as trainers. The training lead designed and conducted a 'training of trainers' course, drawing heavily from the material contained in the SOPs (see LAC Field Experience 8.1). An external consultant contributed additional expertise on optimizing system operations and effective troubleshooting techniques. The consultation and the utility's subsequent hands-on experience are expected to build sufficient capacity within the utility to preclude the need for external support in the future. Upon completion of the 'training of trainers' course, the trainers and the training lead designed the operator training course. The full operator training course will be held every three years and each time there is operator turnover. A simplified refresher course will be held annually.

### Field Experience 9.2 – improving surveillance monitoring

The WSP team identified surveillance monitoring as an important factor in safe water provision as it provides public assurance and demonstrates due diligence. A review of multiple years of surveillance monitoring records (performed as part of the existing conditions assessment described in LAC Field Experience 2.2) revealed that the Ministry of Health had not consistently performed monthly water quality sampling in the distribution system as required by protocol. On occasions when surveillance monitoring was carried out, findings were not shared with the utility. Instead, utility personnel learned of unacceptable surveillance results alongside their consumer base via public service announcements. The WSP team also learned that surveillance officers had never been formally trained in appropriate microbial sampling techniques, causing the utility to routinely challenge the validity of surveillance results and further contributing to poor relations between the utility and surveillance officers. To address these concerns, the surveillance monitoring plan was enhanced to include a system of timely communication of results with the utility as well as surveillance officer training on sampling techniques, appropriate sampling locations and key parameters of interest. Senior officials within the Ministry of Health were engaged in the surveillance plan improvement process to ensure follow-through and accountability.

**Field Experience 9.3 – increasing cost recovery**

Cost recovery was identified as a critical WSP focus area given that effective utility operation is contingent upon a sufficient revenue stream. Existing revenue was well below full cost recovery and even with government subsidies the utility did not have adequate funds to meet basic operational needs such as staffing, purchasing treatment chemicals and testing reagents, replacing filter media, and maintaining equipment. The utility was also unable to afford the high cost of pumping 24 hours a day – a constraint with major implications for water quality and consumer health. Daily breaks in service of eight hours or more made the water supply vulnerable to recontamination by creating routine low-pressure conditions in the distribution network and by giving consumers no option but to store water at home. Poor cost recovery was attributed in part to an ineffective system of billing and collections. Additionally, poor water quality and intermittent service affected consumers' willingness to pay for water (as evidenced by the household survey findings discussed in LAC Field Experience 2.3). The WSP team developed a plan to expedite the utility's ongoing efforts to revamp the billing system and created a public relations strategy to improve consumer-utility relations and increase willingness to pay.

### Case study 3: United Kingdom (England and Wales)

**Field Experience 9.1 – revising supporting programmes to incorporate WSP outputs**

This area was not a significant challenge for water companies as they already had good supporting programmes such as training programmes, hygiene procedures, ISO quality systems, accredited laboratories with internal and external quality control programmes and company and collaborative industry research and development. The challenge was to consider and include such supporting programmes as part of the WSP.

Module 10

# Plan and carry out periodic review of the WSP

## Introduction

The WSP team should periodically meet and review the overall plan and learn from experiences and new procedures (in addition to regularly reviewing the WSP through analysis of the data collected as part of the monitoring process). The review process is critical to the overall implementation of the WSP and provides the basis from which future assessments can be made. Following an emergency, incident or near miss, risk should be reassessed and may need to be fed into the improvement/upgrade plan.

## Key actions

### Keep the WSP up to date

Regularly reviewing and revising the WSP ensures that new risks threatening the production and distribution of safe water are regularly assessed and addressed. An updated, relevant WSP will maintain the confidence and support of staff and stakeholders in the WSP approach.

A WSP can quickly become of out of date through:

- Catchment, treatment and distribution changes and improvement programmes, which can impact on process diagrams and risk assessments;
- Revised procedures;
- Staff changes;
- Stakeholder contact changes.

### Convene regular WSP review meetings

The WSP team should agree to meet regularly to review all aspects of the WSP to ensure that they are still accurate. Local operator input or site visits may also be required as part of the review. Operational monitoring results and trends should be assessed. In addition to the regular planned review, the WSP should also be reviewed when, for example, a new water source is developed, major treatment improvements are planned and brought into use, or after a major water quality incident (see also Module 11). During the regular review meeting, the date of the next review should be established.

## Typical challenges

- Reconvening the WSP team;
- Ensuring continued support for the WSP process;
- Ensuring that where original staff have left the utility, their duties are maintained by others;
- Keeping records of changes;
- Keeping in contact with stakeholders.

## Outputs

A WSP that is up to date and continues to be appropriate to the needs of the water utility and stakeholders.

### Example/tool 10.1: When to review the WSP

A WSP should be reviewed immediately when there is a significant change of circumstances or a problem within the water supply chain. A WSP should also be reviewed from time to time, particularly taking into account the results of implementing the WSP. Any change made to the WSP as a result of a review should be documented.

### Example/tool 10.2: Example checklist for WSP review

- ☑ Notes of last review meeting;
- ☑ Notes of any interim review;
- ☑ Changes to membership of the WSP team;
- ☑ Changes in catchment, treatment, distribution;
- ☑ Review of operational data trends;
- ☑ Validation of new controls;
- ☑ Review of verification;
- ☑ Internal and external audit reports;
- ☑ Stakeholders communication;
- ☑ Date of next review meeting.

### Example/tool 10.3: Changes that can affect the WSP

A housing development increased demand for water within the Hawthorne Water Supply System. This led to a proposal that water from the Dahlia Water Supply System should be fed into the area. Yet the materials used in the piped distribution system of the Hawthorne System could not cope with the more aggressive water chemistry of the Dahlia Supply, leading to corrosion and leaching of metals. This situation could have been avoided if the WSP team had assessed the risks of such a change beforehand. The team would have needed to ensure that the process diagram for the 'joined-up' water supply system had been updated, and whether the risk assessment from the other water supplier was adequate, including data from operational monitoring, and consumer complaints.

## Case study 1: Australia

### Field Experience 10.1 – executive review of the WSP

Most Australian urban water utilities have at least one executive level water quality champion and they report on WSP implementation and outputs at the executive level. Audits of WSPs are typically reported to the utility executive. The WSP provides a useful framework for organizing and presenting water quality management actions in a form that assists executives to make strategic decisions on water quality management.

### Field Experience 10.2 – revising the WSP

Australian utilities maintain their WSPs as 'living documents' that are subject to ongoing change to capture improvements. Most WSPs are in fact version-controlled by having an intranet-based electronic version live on the web rather than a hard copy version. The WSPs typically undergo a major revision every couple of years with ad hoc revisions usually scheduled to coincide with audits or other milestones or major asset changes.

## Case study 2: Latin America and the Caribbean (LAC)

### Field Experience 10.1 – establishing a review committee for the WSP

The WSP team felt that a formal process of WSP review and revision needed to be established to ensure that the WSP is kept current and effective. Owing to the busy schedules of Task Force and Steering Committee members, long-term maintenance of the WSP was considered unrealistic without a clear plan outlining major review activities and identifying responsible parties. A Review Committee was formed and agreed to meet biennially following WSP development to revise the WSP to reflect progress on prescribed corrective actions and to address any shortcomings identified. In addition to scheduled biennial reviews, the Review Committee agreed to meet following any drinking-water-related incidents to revise the WSP as necessary to prevent recurrence.

### Field Experience 10.2 – revising the WSP following capital improvements

Several capital improvements were proposed as a result of the WSP. Structural or operational changes to the system can introduce additional risks, such as a lack of knowledge about operating new equipment or changing levels of disinfectants for a modified system. The Review Committee will revisit the WSP following structural improvements to assess and address any unforeseen hazards and update the WSP accordingly following any changes that are implemented. Similarly, as the capacity for improved water quality is realized through capital and operational improvements, standards will be revisited and may need to be modified, such as the step-wise standards established for turbidity, as discussed in LAC Field Experience 7.3.

## Case study 3: United Kingdom (England and Wales)

### Field Experience 10.1 – staying committed to the WSP approach

Companies that had many paper-based WSPs were challenged by the workload requirements to keep them up to date particularly where many improvements had been identified and implemented. Keeping the WSP initiative embedded in company operations was likely to be a challenge before the WSP risk assessment and risk management approach was made a regulatory requirement.

Module 11

# Revise the WSP following an incident

## Introduction

As outlined previously, to ensure that a WSP covers emerging hazards and issues, it should be reviewed periodically by the WSP team. A particular benefit of implementing the WSP framework is a likely reduction in the number and severity of incidents, emergencies or near misses affecting or potentially affecting drinking-water quality. However, such events may still occur. In addition to the periodic review, it is important that the WSP is reviewed following every emergency, incident or unforeseen event irrespective of whether new hazards were identified to ensure that, if possible, the situation does not recur and determine whether the response was sufficient or could have been handled better. A post-incident review is always likely to identify areas for improvement whether it is a new hazard or revised risk for the risk assessment, a revision for an operating procedure, a training issue or a communication issue, and the WSP must be revised to reflect the changes. In many cases, it will be necessary to include other stakeholders in the review. It is important that water suppliers, within their WSP, have procedures in place to ensure that the WSP team is made aware of the circumstances and details of all incidents, emergencies, and near misses.

## Key actions

- Review the WSP following an incident, emergency or near miss;
- Determine the cause of the incident, emergency or near miss and sufficiency of the response;
- Revise the WSP as necessary, including updates to supporting programmes.

## Typical challenges

- An open and honest appraisal of the causes, chain of events, and factors influencing the emergency, incident or near miss situation;
- Focusing and acting on the positive lessons learned, rather than apportioning blame.

## Outputs

1. Comprehensive and transparent review of why the incident occurred and the adequacy of the utility's response.
2. Incorporation of the lessons learned into WSP documentation and procedures.

**Example/tool 11.1: A checklist of questions to be asked following an emergency, incident or near miss includes**

- ☑ What was the cause of the problem?
- ☑ Was the cause a hazard already identified in the WSP risk assessment?
- ☑ How was the problem first identified or recognized?
- ☑ What were the most essential actions required and were they carried out?
- ☑ If relevant, was appropriate and timely action taken to warn consumers and protect their health?
- ☑ What communication problems arose and how were they addressed?
- ☑ What were the immediate and longer-term consequences of the emergency?
- ☑ How can risk assessment / procedures / training / communications be improved?
- ☑ How well did the emergency response plan function?

**Example/tool 11.2: Following an incident, emergency or near miss the following checklist may be useful to revise the WSP**

- ☑ Accountabilities and contact details for key personnel, usually including other stakeholders and individuals, are clearly stated;
- ☑ 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);
- ☑ Review whether the management procedures were appropriate for the incident and if not, revise accordingly;
- ☑ Standard operating procedures and required equipment, including back-up equipment, are readily available, and relevant;
- ☑ Relevant logistical and technical information is in hand and up to date;
- ☑ Checklists and quick reference guides have been prepared and are up to date;
- ☑ Does the risk assessment need revising?
- ☑ Do procedures/ training / communications need improving?
- ☑ Has the incident shown the need for an improvement programme?

## Case study 1: Australia

### Field Experience 11.1 – defining 'incident' and planning review and revision

Even prior to developing WSPs, Australian water utilities typically had incident and emergency response plans. Major water quality problems or threats to water quality typically constituted an 'incident', which was the term used to describe a major event. Agreed criteria were used to mark the start of an incident whereupon an incident management team was formed. The incident management team then managed the incident to minimize harm caused during the event and to return to normal operations as soon as possible. Most water quality incidents involved responding urgently to early warning and mobilizing sufficient resources to ensure that customers were not affected. Such incidents were usually managed internally by the utility. In a few cases, contaminated or inadequately treated water may reach customers. If contaminated or inadequately treated water reaches customers, then typically the incident involves the health department and customers are advised not to drink that water, or to boil the water. Water supplies are not usually shut off even if they may be contaminated. Water is required for sanitation and hygiene purposes, and most contamination events are not so severe that water supply should be terminated. Rather, water supply continues and people are asked to avoid or boil water before use, as a precaution. As a matter of course, following an incident there is a 'debrief' process in which the root cause of the problem is identified and the WSP changed to prevent a recurrence, if possible.

### Field Experience 11.2 – post-incident assessment

As an example, many WSPs triggered incidents due to disinfection system failures in their early stages. Prior to WSPs there was not necessarily a critical limit value set below which disinfection was considered suspect. However, with the advent of WSPs, disinfection critical limit values were set and these were breached from time to time. As a result of the root cause analysis following the incidents, many utilities changed their disinfection practices. Utilities introduced full or partial (focusing on vulnerable components) duty and standby systems to allow a change to the standby system in the event of a failure of the duty system. In some suppliers that desire high reliability, there are two independent standby systems to provide further back-up with one system at an independent downstream location. In many systems, automation was introduced to allow switchover to back-up systems and to provide an alert to operators. Treated water storage was augmented in many cases to allow systems to shut down and provide a window of a day or more to repair the systems without affecting customers. Utilities that would experience multiple incidents in the first years of the WSP implementation gradually moved to less than one incident per year through this improvement process.

## Case study 2: Latin America and the Caribbean (LAC)

### Field Experience 11.1 – defining 'incident' and planning review and revision

The WSP team defined an 'incident' as a violation of water quality that poses an acute or immediate threat to public health. At the time of WSP development, issues potentially satisfying this definition, such as microbial contamination in the distribution system, were commonplace and were largely the motivating factors for initially undertaking the WSP. Hazards such as these were identified as part of Module 3 and 4. The implementation of corrective actions, such as increased chlorine dosing and improved monitoring practices, are expected to address those problems. If post-implementation monitoring reveals recurrent microbial contamination, the Review Committee will meet to address weaknesses in the plan.

### Field Experience 11.2 – post-incident assessment

During the course of WSP development, an incident occurred in which chlorine gas was released into a residential area. Several failings in emergency mitigation and response procedures were identified, including a lack of monitoring of chlorine gas transfer; an unmanned duty station, which caused the leak to go unnoticed by the utility; a lack of prompt reporting to appropriate parties within the utility, to the EPA and to residents; a failure to evacuate appropriately; and a lack of provision of health officers to evaluate the incident. A post-incident evaluation by the utility and the EPA was subsequently conducted that addressed each of the failings and introduced protocol and enforcement procedures to the WSP to prevent the recurrence of such incidents.

## Case study 3: United Kingdom (England and Wales)

### Field Experience 11.1 – keeping emergency plans up to date

Water companies already had good emergency plans which are tested and kept up to date as part of normal procedures. Again, with such well established procedures, the challenge was to consider these as coming under the WSP umbrella.

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WHO Water Safety Plan portal – includes case studies, tools and other information on developing water safety plans: http://www.who.int/wsportal/en/, http://www.wsportal.org.

# Glossary

The following represents terms used in GDWQ and other documents such as Codex Alimentarius and other guiding materials used throughout this Manual.

| Term | Definition |
|---|---|
| Control (noun) (for instance control of water safety): | The state wherein correct procedures are being followed and criteria are being met. |
| Control (verb) (for instance control of a hazard): | To take all necessary actions to ensure and maintain compliance with criteria established in the WSP. |
| Control Measure: | Any action and activity that can be used to prevent or eliminate a water safety hazard or reduce it to an acceptable level. |
| Control Point: | A step at which control can be applied to prevent or eliminate a water safety hazard or reduce it to an acceptable level. Some plans contain *key* control points at which control might be essential to prevent or eliminate a water safety hazard. |
| Corrective Action: | Any action to be taken when the results of monitoring at the control point indicate a loss of control. |
| Critical Limit: | A criterion which separates acceptability from unacceptability. |
| Deviation: | Failure to meet a critical limit. |
| Flow Diagram: | A systematic representation of the sequence of steps or operations used in the production or manufacture of a particular water item. |
| HACCP: | Hazard Analysis and Critical Control Point. |
| Hazard Analysis: | The process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for water safety and therefore should be addressed in the WSP. |
| Hazard: | A biological, chemical, physical or radiological agent in, or condition of water, with the potential to cause an adverse health effect. Another word for hazard includes "contaminant". |
| Hazardous Event: | A process whereby a hazard/contaminant is introduced into a water supply. |
| Monitor: | The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a control point is under control or whether the water meets quality criteria. |
| Risk Assessment: | For the purposes of this Manual, risk assessment has the same meaning as hazard analysis. |
| Risk Score: | The score assigned to a hazard based on the risk analysis process. |
| Step: | A point, procedure, operation or stage in the water supply chain including raw materials, from primary production to final exposure. |
| Supporting Programmes/ Supporting Requirements: | The foundation activities required to ensure safe water including training, raw material specifications and general good water management practices. These programmes can be just as important as control points in controlling water quality risks but are used where application tends to cover long timeframes and/or broader organizational or geographic areas. Includes general organizational supporting programmes as well as specific programmes targeted to particular risks. |
| Validation: | Obtaining evidence that the elements of the WSP can effectively meet the water quality targets. |
| Verification: | The application of methods, procedures, tests and other evaluations, to determine compliance with the WSP, i.e. checking whether the system is delivering water of the desired quality and whether the WSP is being implemented in practice. |
| WHO: | World Health Organization. |
| WSP: | Water Safety Plan. |

World Health Organization

International Water Association

The most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer. In these Guidelines, such approaches are called water safety plans (WSPs).

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