Aquatown water safety plan

Worked example

An extract of a water safety plan to support implementation of the guidance presented in the *Water safety plan manual: step-by-step risk management for drinking-water suppliers (second edition)*

World Health Organization

IWA
the international water association

INTRODUCTION

This worked example provides a hypothetical water safety plan (WSP) for the water supply in the fictitious Aquatown. It should be used in conjunction with the guidance provided in the Water safety plan manual: step-by-step risk management for drinking-water suppliers, second edition (WHO & IWA, 2023). The worked example aims to support implementation of water safety planning across all 10 modules in the manual.

This is not a full WSP. It is heavily abbreviated and is not comprehensive. It should be read and used as a tool to understand how water safety planning works in practice. The example should inform the development of a context-specific WSP tailored to the local water supply.

Not all hazards, hazardous events, control measures and validations relevant to the water supply – or their justification – are included. Where there is more detail that is not included in this abbreviated example, it is shown as "……".

CONTEXT

Aquatown is located in the tropics, in a country that has an emerging economy. Despite recent improvements in living and health standards, Aquatown has substantial lower-income populations, many of whom live in informal settlements. Aquatown Water Services (ATWS) is the water supplier to Aquatown.

Aquatown's water supply has surface water and groundwater sources. The region is experiencing the effects of climate variability and change, and these effects are likely to be exacerbated in the future. There are some concerning trends in the reliability of source water already apparent.

This worked example is an abbreviated version of the Aquatown WSP. It illustrates:

- application of water safety planning in a realistic scenario;
- the linkages between all modules in water safety planning, including identifying hazards and hazardous events, conducting risk assessments, implementing improvement plans and conducting operational monitoring;
- how water safety planning is a continuous cycle, highlighting the WSP development, operation, verification and review phases; and
- potential reporting formats (in an abridged form).

As every WSP is developed to suit its own unique context, the Aquatown WSP is illustrative only and should not be indiscriminately used for the development of a system-specific WSP.

Some commentaries from the WSP team are shown

"We hope you find our commentary helpful as you prepare and implement your own WSP.

*Sometimes we describe **how** we did a particular task. Or we might explain **why** we did something or highlight other points of interest."*

Aquatown WSP team

MODULE 1: WSP TEAM

Stakeholders

Table 1.1 shows an extract of a summary of the stakeholder identification process conducted as part of the initial WSP development.

"One of the early tasks the ATWS leadership group undertook when selecting the WSP team was to identify the stakeholders. We used simple stakeholder mapping."

TABLE 1.1 • SUMMARY EXTRACT OF THE STAKEHOLDER IDENTIFICATION PROCESS

WATER SUPPLY STAGE	STAKEHOLDER	RELEVANCE TO THE WSP	POINT OF CONTACT	INTERACTION WITH WSP TEAM
Source	Department of Forestry	Manages forestry in catchment	Chief forestry officer for region	Annual meeting, and ad hoc support
	Department of Religious Affairs	Operates place of worship in catchment	Local chief official	Meeting before annual religious festival
	Farmer representative	Farming in catchment	Farmers Association chairperson	Guidance on catchment farming activities; to be included on WSP team
	Department of Environment	Oversees raw water data (flow and water quality), setting of environmental standards and regulations to control contamination	Principal regional officer	Twice-yearly briefings, and ad hoc support
	National Meteorological Office			Ad hoc support on technical issues for risk assessment
…	…	…	…	…
Treatment and distribution	Aquatown Municipal Council	Owns and operates the water supply	Aquatown mayor	Scheduled monthly update meetings and informal meetings as required
Customers	Householders	Responsible for household water storage and any subsequent treatment	Complaints and Billings Section of ATWS	Quarterly reports
	Nongovernmental organization (NGO)	Works with people living with HIV/AIDs in Aquatown	NGO coordinator	Annual meeting or as required
	Schools, institutions and local businesses	Individual representatives	Not applicable	Informal meetings
Regulatory	Ministry of Health	Sets and regulates national drinking-water quality standards, including annual reports on ATWS compliance. Responsible for public health, especially related to drinking-water; has expertise in the event of incidents or disease outbreaks. Undertakes water sampling and testing independently of ATWS.	ATWS Water Quality Manager and Aquatown Municipality Health Department	Annually regarding compliance reporting unless incident or serious non-compliance issue arises
…	…	…	…	…

"Before the WSP, we had no interaction with this stakeholder."

WSP team

An extract of the WSP team table is given in Table 1.2.

"Team members shown with [a] formed the core team and met more often than the other members."

TABLE 1.2 • EXTRACT OF THE WSP TEAM TABLE

JOB TITLE	SKILLS, KNOWLEDGE AND EXPERTISE RELEVANT TO WSP	ROLE IN WSP TEAM	CONTACT DETAILS
ATWS Operations Manager[a]	Operations, including water treatment	• Team leader • Coordination with all external stakeholders • Operational monitoring	
ATWS General Manager[a]	Senior management of ATWS; long-term knowledge of the water supply, including operations management	• Adviser • Emergency response coordinator	
Water Delivery Manager[a]	Abstraction of both surface water and groundwater sources and water treatment	• Operational monitoring related to catchments, abstraction and treatment • Liaison with catchment authorities	
Network operations and maintenance representative[a,b]	Day-to-day water network operation; customer in-house practices	• Network risk management and operation linkages • Emergency response planning	
Water Treatment Operator[a,b]	Day-to-day treatment operations	• Water treatment risk management and operation linkages • Emergency response planning	
ATWS Water Quality Officer[a]	Water sampling, laboratory testing and reporting	• Operational monitoring and reporting involving sampling and testing, and reporting on verification programme	
ATWS Planning and Design Engineer	Planning and design of water services	• Adviser • Liaison with design expertise as required	
Farmers Association Chairperson	Farming operations in catchment	• Liaison with farming operations in catchment	
Aquatown municipality Public Health Officer	Health (especially waterborne diseases)	• National health expertise liaison as required • Emergency response planning	
Senior officer of ATWS Complaints and Billings Section[c]	Customers and customer practices	• Regular reporting on customer feedback, especially related to water quality and service levels • Liaison with the NGO coordinator working with informal settlements • Customer service surveys	
…	…	…	

"Contact details, including emergency contact numbers, were added for all team members. This is very important in the case of an emergency!"

[a] Core WSP team member.
[b] This role rotates to provide opportunity over time for several maintenance staff to be part of the WSP.
[c] This group waAs subsequently renamed and given a new focus – see Module 7.

Several external stakeholders supported the WSP team as expert advisers for targeted risk assessments and improvement planning, as shown in the Table 1.3.

TABLE 1.3 • EXTERNAL ADVISERS TO THE WSP TEAM

JOB TITLE	SKILLS, KNOWLEDGE AND EXPERTISE RELEVANT TO THE WSP
Chief Forestry Officer for the region (Department of Forestry)	Catchment risks associated with forest management in the catchment
Climate Forecast Officer (National Meteorological Office)	Hazards and hazardous events, and assessment of risks related to climate change
NGO coordinator	Experiences of informal settlement communities
National university microbiological and water quality specialist	Microbiology and water quality

MODULE 2: SYSTEM DESCRIPTION

Intended users and uses

ATWS provides a single product: potable water. The water is abstracted from surface water and groundwater sources, treated, and delivered to customers to meet the water quality objectives set by the national health authority and other service-level requirements. The water quality objectives are captured in the national drinking-water quality standards. The intended uses and users of the water supply are given in Table 2.1.

TABLE 2.1 • INTENDED USES AND USERS OF THE WATER SUPPLY

Intended use	The water supplied is intended for general use for ingestion, personal bathing and laundry. Foodstuffs may be prepared from the water.
Intended users	ATWS provides water to the entire general population of Aquatown, including the population living in the town's informal community. The intended users do not include those who are significantly immunocompromised, or industries or institutions with special water quality needs. These excluded users are advised to provide additional point-of-use treatment.

Boundary of WSP

The boundary of the WSP begins at the catchment, and includes all treatment, distribution and storages operated by ATWS.

For customers with piped connections and continuous (24/7) supply, the WSP ends at the customer's meter or in-house plumbing connection point.

For all other customers, including customers served by intermittent supply, yard taps and public tap stands, the WSP extends to include the user's premises.

"These limits go beyond the formal limits of legal responsibility of ATWS in providing its water services.

This was done because:

- *significant areas of Aquatown have intermittent water services, which means that household storage is needed; and*
- *the low-income areas rely extensively on public tap stands, where water is collected in small containers for transfer to other household storage tanks.*

*We want to minimize water quality risks to **all** consumers. We, and the Municipal Council, see this as part of ATWS's customer charter commitments to Aquatown's residents and visitors."*

Detailed system information

General information on the supplier and water supply

Aquatown is the second largest town of its state. ....

The water supplier is Aquatown Water Services (ATWS). ATWS is part of the Engineering Services Department of the Aquatown Municipal Council.

The ATWS staff breakdown is given in ....

General information summarized in the system description includes water supply coverage, population and customer category details (with special consideration of equity issues), unaccounted-for water, water demand and production rates, and scale and limitations of water quality testing services.

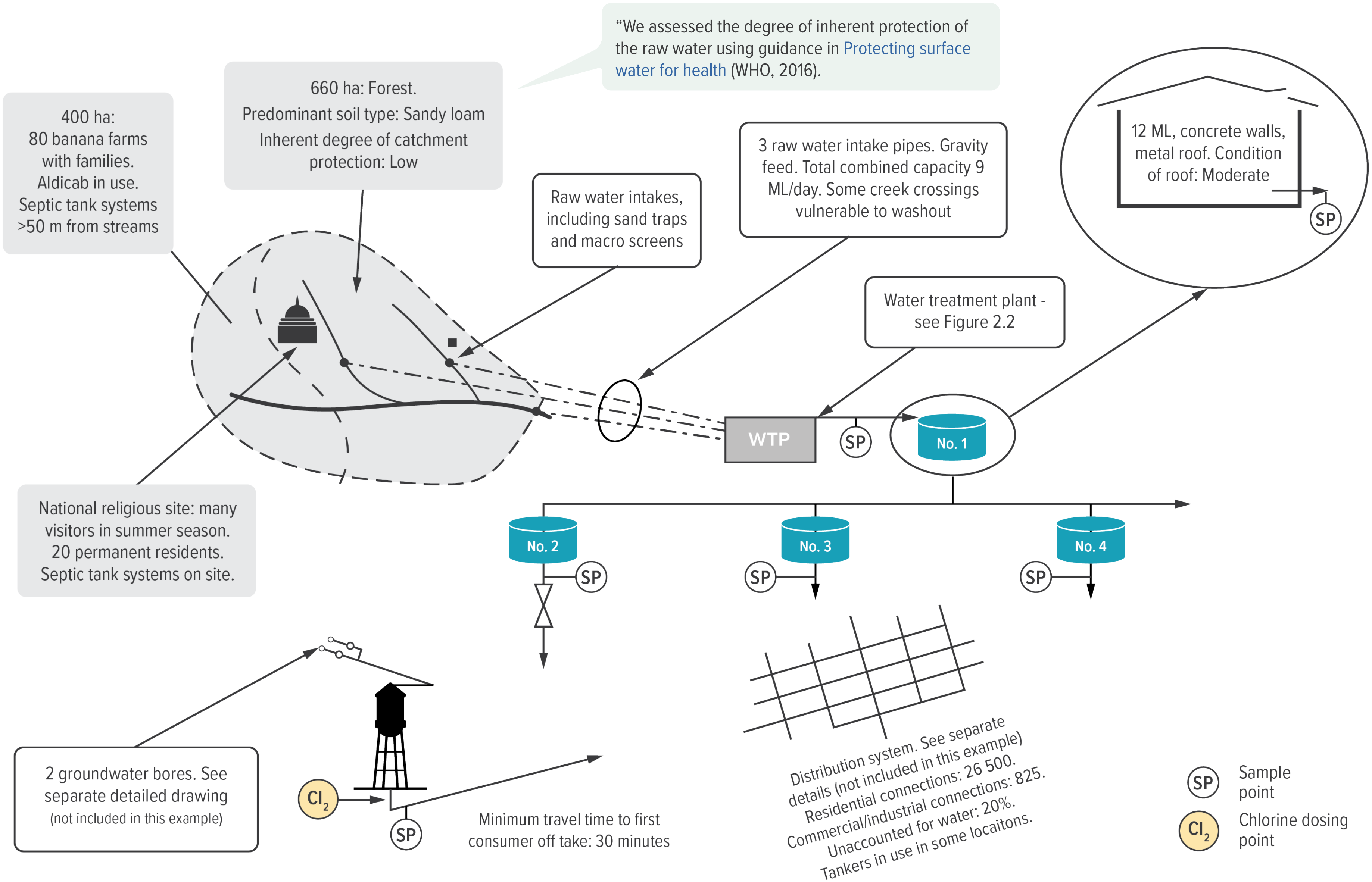
"We maximized the use of diagrams and tables to keep the text minimal, while not leaving out important details."

"Aquatown has an annual religious festival that has significant implications for demand and services in some months, so it was important we understood this."

See Fig. 2.1 for an overview of the water supply. Fig. 2.2 shows a detailed schematic of the water treatment plant, and Fig. 2.3 shows a schematic of a typical user premises.

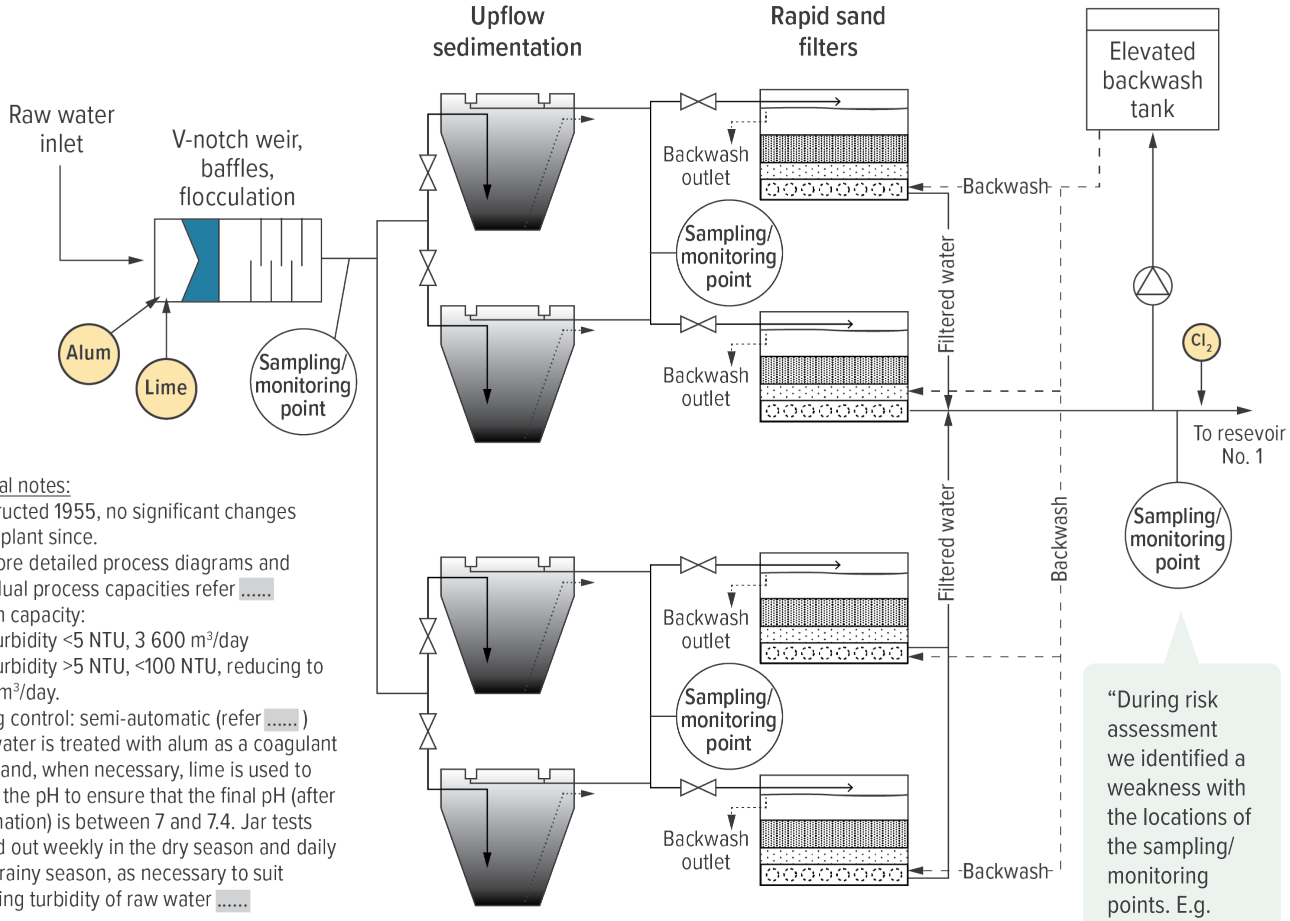
"We used simple in-house software packages to prepare these figures and sketches. We found this style adequate, apart from some treatment processes where process flow diagrams were used.

As there are many ways to show and sketch a system, you need to adopt drawings that best suit your needs and capabilities."



ha: hectare; ML: megalitre; SP: sample point; WTP: water treatment plant.

Fig. 2.1. Aquatown water supply system diagram (extract only)

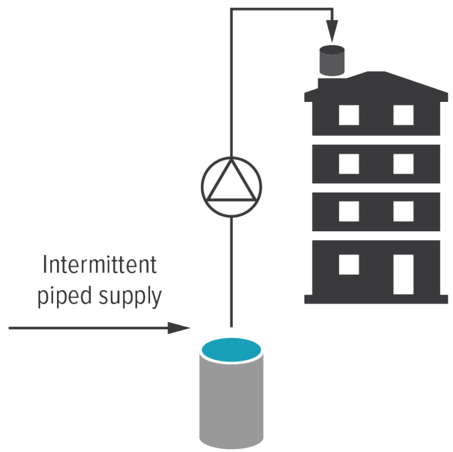


General notes:
Constructed 1955, no significant changes to the plant since.
For more detailed process diagrams and individual process capacities refer ......
Design capacity:
with turbidity <5 NTU, 3 600 m³/day
with turbidity >5 NTU, <100 NTU, reducing to 2900 m³/day.
Dosing control: semi-automatic (refer ......)
Raw water is treated with alum as a coagulant agent and, when necessary, lime is used to adjust the pH to ensure that the final pH (after chlorination) is between 7 and 7.4. Jar tests carried out weekly in the dry season and daily in the rainy season, as necessary to suit changing turbidity of raw water ......

"During risk assessment we identified a weakness with the locations of the sampling/ monitoring points. E.g. See Risk Assessment Item T8".

Fig. 2.2. Water treatment plant schematic

"Figure 2.3 shows how houses with intermittent supply typically transfer and store water."



Some tanks are burried (masonry construction), and some are on-ground (poly/plastic). Tank covers are frequently not in use.

Fig. 2.3. Schematic of a typical three-storey household with rooftop storage tanks

"For the purposes of this worked example, only abbreviated notes of our system description are given here."

Surface water catchment and abstraction

This information included pertinent details, with some graphics and analysis of catchment area, soil types and land use in the catchment; farming practices and chemical pesticides in the catchment; and raw water quality, including seasonal changes, source protection measures, and intake and abstraction details.

Groundwater

This information included pertinent details, such as aquifer type, safe yield, extraction, depth of groundwater, groundwater quality, and source protection measures to protect the bore and groundwater.

Climate and climate change impacts

This information summarized pertinent climate information, such as rainfall patterns (including trends and seasonal analysis). It also included results of national climate change projections relevant to the surface water and groundwater sources, including impacts on water quantity and quality.

Water quality required

....

"The WSP document presented the water quality that ATWS is required to deliver to customers in an annex, but highlighted here the key parameters and conditions for ease of reference."

Water treatment plants

This information included the treatment plants for both surface water and groundwater.

As far as possible, these were presented in diagrammatic form using simplified process diagrams (see Fig. 2 as an example) and graph format, especially showing treatment plant performance data.

"We were keen to understand vulnerabilities of the treatment process. So we were interested in issues like design capacity, historical performance records of production and quality, chemical dosing practices, operational controls and procedures, operational monitoring, staff capacity, training and limitations."

Distribution system

This information included details about:

- *post-treatment storage (e.g. type, size, roofing, access points/openings, maintenance);*
- *the pipe network (overview);*
- *the pipe network's condition, pressure regimes, and extent and scope of intermittency;*
- *service for residents of the informal areas – especially vulnerability related to the public tap stands;*
- *the extent of use and controls for the trucked-in water service (i.e. water tanker trucks);*
- *the condition of the sanitation services especially in the intermittent service areas (see commentary); and*
- *records of water quality in the distribution system.*

"Much of this information was presented in the flow diagrams.

With regard to water carting services, ATWS has two potable water tanker trucks but also uses additional private contractors when required.

Once again, bearing in mind the intermittent service areas and the diverse users in these areas, we were seeking to understand vulnerability related to the pipes when they are under low or no pressure during the day."

Customers' premises

Metered connections

Details of connections with continuous supply are shown in ....

For properties with intermittent supply (see Fig. 3), water is fed from the system to a ground-level plastic/poly tank or a buried masonry tank. From this tank, water is pumped to rooftop storage tanks and for distribution to the ....

This also described typical in-house treatment of water by consumers (i.e. point-of-use systems).

Low-income/informal living areas

Collected water is ....

These containers are transported to the house by ....

Point-of-use treatment is ....

"Being conscious that the residents of these areas are generally more vulnerable than others, we needed to understand how the water is collected, stored, treated and used in these localities."

Current delivered-water quality

Graphs and analysis of the raw and treated water quality in the previous 24 months indicate that ....

"The data for the analysis were from both ATWS and Ministry of Health historical data."

Persistent problems observed by the WTP team

Intermittent supply is ....

The water treatment plant is sometimes operated above its capacity as a result of demands greater than its capacity. As a result, ...

Free chlorine residual results below the target levels are observed ....

Insufficient reliable water quality data are available for the distribution network downstream of the service reservoirs to allow a complete understanding of the quality of the water that customers receive.

The low-income/informal areas have a more vulnerable population. The poor condition of the standpipes and the intermittent supply mean that their water quality ....

The water tanker trucks used to deliver trucked-in water are not well managed, and ....

Anecdotal evidence suggests that, during the religious festival, the health department reports increases in waterborne illnesses (e.g. diarrhoea).

Most dirty water complaints are in the low-income/informal areas and in the network served by Service Reservoirs 2 and ....

"Summarizing the persistent problems was a very helpful exercise for us. It increased our understanding of the water supply and informed the risk assessment in other modules."

Confirm system information accuracy

This section summarized how the information was collected and how the accuracy of the information was confirmed.

"Our record of older pipe assets was poor, so we supplemented the information we had with that of existing line operation staff and a recently retired plumber who 'knew the system in his head' to capture and record our pipe network.

Getting reliable and accurate pipe network drawings is likely to be an ongoing project."

"After we completed our desktop description, we divided the WSP team and went with staff on-site to confirm or, in some cases, correct our understanding of the water supply.

The treatment plant engineer used the original design data and compared this with the available raw and treated water data."

MODULES 3 AND 4: IDENTIFICATION OF HAZARDS AND HAZARDOUS EVENTS, AND RISK ASSESSMENT

"This section is related to Modules 3 and 4.

Refer to Table 3/4.1, which presents an extract of the risk assessment. The risk assessment took some time to complete. We focused on one component of the water supply at a time (e.g. surface water catchment, groundwater abstraction). We initially brainstormed hazards and hazardous events using the WSP team's expert judgement, and then cross-checked this against examples of generic threats for water supplies. We also had discussions with field staff, stakeholders and selected experts.

This extract reflects some of the particular issues facing our water supply, including climate change impacts, service areas with intermittent supply and low-income/informal housing areas, and the system's dependency on water trucking services."

"For the initial cycle of WSP development, the WSP team decided not to undertake a dual-stage (raw and residual) risk assessment, and used a single-stage approach instead (residual risk only). However, in the first review of the WSP, the team did undertake raw risk assessments for some hazardous events – refer to the comments in Module 10."

Validation of existing control measures

"Existing control measures were validated using the informal judgment technique (as discussed in section 4.2 of the Water safety plan manual, second edition (WHO & IWA, 2023)).

We chose this because we lacked a lot of specific validation data, and it seemed the most suitable for the initial cycle of WSP development, based on the WSP team's limited experience. However, during future rounds of WSP development, and as the team's capacity builds, the WSP team intends to do more robust validation of select control measures it is deemed necessary."

Risk matrix

The risk matrix and definitions used are presented below.[1]

LIKELIHOOD AND SEVERITY DEFINITIONS

LIKELIHOOD RATING	LIKELIHOOD DESCRIPTION	DEFINITION
1	Highly unlikely	Not expected or will probably not occur. Has not been observed in the field. No water quality data or other relevant data confirm occurrence.
2	Unlikely	May occur in exceptional circumstances. Has not been observed in the field. No water quality data or other relevant data confirm occurrence.
3	Possible	Could occur, but not often. Has been observed occasionally in the field. Limited water quality data or other relevant data confirm occurrence.
4	Likely	Expected to occur in many circumstances. Recurrent but not frequent occurrence. Has been observed occasionally in the field. Confirmed by water quality or other relevant data.
5	Almost certain	Expected to occur in most circumstances. Occurs frequently. Has been observed regularly in the field. Confirmed by water quality data or other relevant data.

"Risk matrices often describe the severity in terms of 'treated' water quality.

Undertaking the risk assessment for the first time, we found it difficult to address hazardous events at the source stage (i.e. untreated water) using severity definitions that relate to treated water.

So we thought it would be helpful to use separate severity definitions for the source stage (i.e. untreated water) and other downstream stages of the water supply (i.e. treated water)."

[1] Additional examples of risk matrices for consideration may be found at https://wsportal.org/resource/wsp-manual-supplementary-tool-module-4-examples-of-risk-assessment-matrices/.

LIKELIHOOD AND SEVERITY DEFINITIONS

SEVERITY		DEFINITION	
RATING	DESCRIPTION	AT SOURCE STAGE	AT OTHER DOWNSTREAM STAGES OF THE WATER SUPPLY (WATER TREATMENT PLANT, DISTRIBUTION/STORAGE, USER LEVEL)
1	Insignificant	Insignificant impact or consequence on quantity or quality of untreated water at the intake (abstraction) point, and little impact on operation of other parts of the water supply.	Insignificant impact on treated water quality or quantity. Insignificant impact on service delivery or normal operations. Insignificant impact on customer trust.
2	Minor	Minor impact or consequence on quantity or quality of water at intake point (e.g. requiring minor adjustments to treatment plant operations to maintain normal supply for short durations).	Minor (non-health related) impact on treated water quality for a small percentage of customers. Minor impact on water quantity. Some manageable disruptions to service delivery or normal operations. Minor corrective action required for service delivery. Slight rise in customer complaints. Minor impact on customer trust.
3	Moderate	Moderate impact or consequence on quantity or quality of water at intake point (e.g. requiring adjustments in dosing and backwashing to treatment plant operations to maintain supply for extended durations).	Moderate (non-health) impact on treated water quality for a small percentage of customers. Moderate impact on water quantity. Some manageable disruptions to service delivery or normal operations. Corrective action required for service delivery. Appreciable rise in customer complaints. Moderate negative impact on customer trust.
4	Major	Major impact or consequence on: • water quality at intake point (e.g. significantly compromised ability of the treatment plant to meet required standards, resulting in major disruption to normal operation); or • available quantity of water (e.g. production quantities significantly reduced, supply of water interrupted for short periods); or • an extensive duration of these negative consequences for an extended duration (e.g. several days or weeks).	Treated water quality (non-health) impact for a large percentage of customers. Potential long-term health effects from consuming the drinking-water. Major impact on water quantity. Water supply is significantly compromised, with abnormal operation requiring extra level of monitoring. Large number of customer complaints. Considerable negative impact on customer trust.
5	Catastrophic	Very serious impact or consequence on water quality or quantity at intake point (e.g. the water supply would be unable to meet required standards for either quality or quantity, emergency water supply arrangements).	Significant treated water quality impact for a large percentage of customers. Potential illness or death from consuming the drinking-water. Breach of regulatory requirement or major investigation by regulator, with regulatory sanctions or prosecution likely. Significant impact on water quantity. Litigation by customers likely. Failure of system operation and considerable levels of additional monitoring. Very large number of customer complaints. Significant loss of customer trust.

5 × 5 RISK ASSESSMENT MATRIX

Likelihood		SEVERITY: Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Highly unlikely	1	1	2	3	4	5
Unlikely	2	2	4	6	8	10
Possible	3	3	6	9	12	15
Likely	4	4	8	12	16	20
Almost certain	5	5	10	15	20	25

RISK SCORE (likelihood × severity)	RISK LEVEL
≤5	Low
6-11	Medium
≥12-24	High
≥25	Severe

GENERAL RISK PRIORITY GUIDELINES

Low risk	*Clearly not a priority* Actions may be taken as part of routine operation to manage the hazardous event. Actions should be considered in the future, especially when changes take place or as part of the WSP review process.
Medium risk	*Medium priority* Attention is required in operation, and/or possible improvements related to the hazardous event should be made in the medium and long terms to continue minimizing risks.
High risk	*Priority* Actions need to be taken to mitigate the risk from the hazardous event. Possible options should be documented (as part of the improvement plan) and implemented based on priorities and available resources.
Severe risk	*Clearly a priority* The risk from the hazardous event is severe enough that action is clearly a priority. This means checking short-term options to mitigate acute consequences and examining alternative water resources.

TABLE 3/4.1 • EXTRACT FROM THE RISK ASSESSMENT TABLE

				Are existing control measures effective?					Risk with controls in place			
Ref No.	Process step	Hazardous event (X happens because of Y)	Hazard type	Existing control measure	Validation notes	Yes	No	Uncertain	Likelihood	Severity	Risk score	Risk level
...	...	...	...	...	...	...	...	...	...	...	...	⋮
...	...	...	...	...	...	...	...	...	...	...	...	⋮
C5	Surface-water catchment	Poorly treated domestic wastewater from septic tank installations in the catchment seeps into surface water and reaches intake (X) due to overflows (Y)	M	None	Not applicable				3	3	9	Med
C6	Surface-water catchment	Reduced quantity available for drinking-water purposes (X) due to increased competing demands between Aquatown water supply and farming irrigation needs (Y)	Q	Regulations limiting water extraction for farming use	Historically, existing regulations have been adequate but, in reduced rainfall and run-off scenarios, regulations may not be adequately managed because they are based on percentage of flows, not volumes of water extracted			✓	3	4	12	High
C7	Surface-water catchment	Decreased source water yield (X) due to long-term reduced rainfall (Y)	Q	None	Not applicable				3	5	15	High
C8	Surface-water catchment	Reduced water availability per capita (X) due to increased demand driven by population growth (Y)	Q	None	Not applicable				3	5	15	High
C9	Surface-water catchment	Contamination of the raw water with agrichemicals (specifically aldicarb) (X) because of suboptimal on-farm management practices (Y)	C	Farming regulations	Poor practices have been observed and noted by the Department of Environment		✓		2	4	8	Med
C10	Surface-water catchment	Mobilization of accumulated sediment and nutrients and sudden influx into raw water source (X) caused by rainfall after excessive drought/dry periods (Y)	M, A	None	Not applicable				4	4	16	High

TABLE 3/4.1 • EXTRACT FROM THE RISK ASSESSMENT TABLE CONTINUED

				Are existing control measures effective?					Risk with controls in place			
Ref No.	Process step	Hazardous event (X happens because of Y)	Hazard type	Existing control measure	Validation notes	Yes	No	Uncertain	Likelihood	Severity	Risk score	Risk level
C11	Groundwater abstraction facilities	Local surface run-off contaminated by animal waste contaminates the bore (X) due to animals grazing near the abstraction facilities, combined with inadequate protection of surface run-off entering borehole (Y)	M	Concrete apron casing around bore head, borehole sanitary seal, and some fencing	Sanitary seal is only flush with ground level. Fencing is broken or gates are left open.		✓		3	4	12	High
C12	Groundwater abstraction facilities	River water floods groundwater abstraction sites (X) due to intense run-off/flooding events (Y)	M, P, Q	Site is located well above historic or predicted 100-year flood levels	...	✓			1	5	5	Low
...	...	...	...	...	...	...	...	...	...	...	...	⋮
...	...	...	...	...	...	...	...	...	...	...	...	⋮
T4	WTP for surface water: coagulation and flocculation	Particles not removed (X) due to dosing equipment breakdown (Y)	M, A	Routine maintenance schedule for the dosing system – pumps and lines, probes and meters, electronics	Spot checks indicate poor compliance with maintenance schedule, with some operators reporting resource limitations impacting maintenance. Not every dosing pump has a back-up (standby) pump.		✓		2	4	8	Med
T5	WTP for surface water: coagulation and flocculation	Particles not removed (X) due to dosing rates set incorrectly or inappropriately (Y)	M, A	Operator training following experience	Weakness in consistency noted in field visits			✓	3	4	12	High
T6	WTP for surface water	Poor performance of the whole treatment process (X) due to failure of the power supply and inadequate power supply back-up (Y)	M, A	On-site back-up generator	Generator has insufficient capacity to continue with normal operations, and fuel source is limited		✓		3	4	12	High

TABLE 3/4.1 • EXTRACT FROM THE RISK ASSESSMENT TABLE CONTINUED

Ref No.	Process step	Hazardous event (X happens because of Y)	Hazard type	Are existing control measures effective? Existing control measure	Validation notes	Yes	No	Uncertain	Risk with controls in place Likelihood	Severity	Risk score	Risk level
T7	WTP for surface water: sand filters	Compromised removal of particles (X) due to sand filter bed not being completely fluidized during filter backwashing (Y)	M, A	Operator manually managed	Historically, has not been noted as a problem, but sudden changes in flow rates through the filters have been occasionally observed			✓	3	3	9	Med
T8	WTP for surface water: sand filters	Protozoa contamination arising from poor performance of one filter (X) because of an inability to determine individual filtered water turbidity readings from each filter (Y)	M	Filtered water sampling point at common manifold	Can only sample and analyse combined filtered water turbidity. Chlorination is not effective for most protozoa.		✓		3	5	15	High
T9	WTP for surface water: chlorination	Insufficient free chlorine residual in water at the exit point of the treatment plant (X) because the dose controller's set point has been incorrectly calculated (Y)	M	Adjustments by the operator to calculate and select the dose controller set point, and periodic manual checks of free chlorine concentration, especially during periods of water quality variability	...	✓			2	5	10	Med
T10	WTP for surface water: chlorination	Ineffective chlorination (X) because turbidity is above the target level (Y)	M	Coagulation, flocculation and filtration before chlorination	...	✓			3	5	15	High
...	...	...	...	...	...	...	...	...	...	...	...	⋮
...	...	...	...	...	...	...	...	...	...	...	...	⋮

TABLE 3/4.1 • EXTRACT FROM THE RISK ASSESSMENT TABLE CONTINUED

Ref No.	Process step	Hazardous event (X happens because of Y)	Hazard type	Is this control measure effective?					Risk with controls in place			
				Existing control measure	Validation notes	Yes	No	Uncertain	Likelihood	Severity	Risk score	Risk level
D11	Distribution: service reservoirs	Inadequate disinfection (X) due to flow short-circuit from the inlet to the outlet (Y)	M	Design of pipe inlet and outlet in storages. Intermittent supply operation helps to ensure that tanks are filled before demand.	...	✓			2	4	8	Med
D12	Distribution: service reservoirs with metal roofing	Microbial contamination (X) from entry of birds and small animals or faeces through faults and gaps in roofs or hatches, overflow pipes or air vents (Y)	M	Asset inspection / maintenance program including repair of faults or gaps and maintenance of chlorine residuals	No known incidents	✓			2	4	8	Med
D13	Distribution: concrete service reservoirs	pH increases in concrete tanks (X) due to excessive detention time (Y)	A	Short retention times	Tests indicate that pH of water exiting storages is within acceptable limits	✓			2	3	6	Med
D14	Distribution: service reservoirs	Stored water is contaminated (X) by unauthorized access and associated vandalism (Y)	M, C, A	Fencing, 24/7 caretakers and gates	...	✓			1	5	5	Low
D15	Distribution: service reservoirs	Growth of algae or biofilms (X) from inadequate cleaning (Y)	M, A	None	Frequency of cleaning: no programme in place, and some tanks have not been cleaned in 10 years	Not applicable			4	3	12	High

TABLE 3/4.1 • EXTRACT FROM THE RISK ASSESSMENT TABLE CONTINUED

				Are existing control measures effective?					Risk with controls in place			
Ref No.	Process step	Hazardous event (X happens because of Y)	Hazard type	Existing control measure	Validation notes	Yes	No	Uncertain	Likelihood	Severity	Risk score	Risk level
D16	Distribution: piped network	Survival of pathogens and growth of opportunistic pathogens (X) due to lack of residual chlorine (Y)	M	Maintaining chlorine residual	...	✓			4	4	16	High
D17	Distribution: piped network	Ingress of contamination into pipes (X) due to unsanitary repair and maintenance practices (Y)	M, A	Some practices informally followed	...		✓		3	4	12	High
D18	Distribution: piped network	Contaminated water is drawn into the pipes (X) because of low or no pressures in the pipes for extended periods due to intermittent operation of pipe network (Y)	M, A	None	Not applicable				5	4	20	High
D19	Distribution: piped network	Disruption of supply (X) due to pipe bursting/breaks (Y)	Q	Design specification, pipe stocks, asset register, purchasing from accredited suppliers	Pipe breaks are common		✓		5	4	20	High
D20	Distribution: piped network	Contamination of water by turbidity, offensive odours, scales, etc. (X) from internally corroded pipes (Y)	A	Pipes replaced after breaks and internal corrosion identified as cause of breakage	Control measure does not actively prevent problem based on historical customer complaints and asset inspection		✓		5	3	15	High
D21	Distribution: piped network	Inequitable pressure/flow distribution (X) due to intermittent operation (Y)	Q	No current control	Not applicable				5	4	20	High

TABLE 3/4.1 • EXTRACT FROM THE RISK ASSESSMENT TABLE CONTINUED

				Are existing control measures effective?					Risk with controls in place			
Ref No.	Process step	Hazardous event (X happens because of Y)	Hazard type	Existing control measure	Validation notes	Yes	No	Uncertain	Likelihood	Severity	Risk score	Risk level
D22	Distribution: piped network	Contamination (X) from illegal (and substandard) connections (Y)	M, A	Regulations	Enforcement is poor, and anecdotal evidence of low-level corruption by some staff		✓		5	5	25	Severe
D23	Distribution: piped network	Elevated disinfection by-products (X) due to long network detention times (Y)	C	No current control	Detention times in system are low, and source water is not high in organics				2	2	4	Low
D24	Distribution: piped network	Contamination (e.g. debris, soil or groundwater) enters an open main (not capped) when in the repair trench (X) because of poor repair procedures (Y)	A	Experienced staff conducting repairs	Complaints about dirty water after pipe repairs are sometimes received by complaints department		✓		3	3	9	Med
…	…	…	…	…	…	…	…	…	…	…	…	⋮
…	…	…	…	…	…	…	…	…	…	…	…	⋮
D31	Distribution: tanker	Cross-contamination of water tanker contents from other uses of the tanker (X) because the tanker is not properly cleaned and disinfected before use (Y)	M, C, A	Cleaning carried out by water tanker operators	Water supplier's tankers are reserved for drinking-water, and tankers are used frequently. Spot checks indicated that, when tanker operation is outsourced (e.g. high number of visitors in town), cleaning by some operators is inadequate. This has been confirmed by some spot checks and some water quality tests.		✓		4	4	16	High
D32	Distribution: tanker	Water transferred from the tanker direct to users or to local storage tanks becomes contaminated (X) because the connection hoses have not been disinfected by the water hauler before delivery (Y)	M	None	Not applicable				3	4	12	High

TABLE 3/4.1 • EXTRACT FROM THE RISK ASSESSMENT TABLE CONTINUED

				Are existing control measures effective?					Risk with controls in place			
Ref No.	Process step	Hazardous event (X happens because of Y)	Hazard type	Existing control measure	Validation notes	Yes	No	Uncertain	Likelihood	Severity	Risk score	Risk level
U3	User's premises: household	Deterioration of water quality (X) due to inadequate maintenance of household water storage tanks (Y)	M, A	None	Not applicable				5	2	10	Med
U4	User's premises: household	Loss of water availability in overall system (X) due to overflowing household tanks (X)	Q	Regulatory requirement to have automatic float valves on all household water storage tanks	It is common to see household water storage tanks overflowing		✓		5	3	15	High
U5	User's premises: household	Collected water for informal settlement households is microbially contaminated (X) due to unsanitary hoses connected to the public tap stand (Y)	M	None	Not applicable				3	3	9	Med
U6	User's premises: household	Water becomes contaminated by children at home (X) because open containers are used to transport water from public tap stand and/or household storage (Y)	M	None	Not applicable				4	3	12	High
U7	User's premises: household	Drinking-water is chemically contaminated by leaching (X) due to use of substandard material in building plumbing (Y)	C	Building regulations	Little enforcement of regulations. Older installations pre-dating existing regulations are not covered.		✓		3	2	6	Med
…	…	…	…	…	…	…	…	…	…	…	…	⋮

A: acceptability hazard; C: chemical hazard; M: microbial hazard; Q: quantity-related hazard; R: radiological hazard.

MODULE 5: IMPROVEMENT PLANNING

Prioritizing actions for improvement

A risk score of 6 (i.e. medium, high or severe risk) is taken as the cut-off point, above which improvements must be undertaken.

> *"This was our cut-off point so we would prioritize medium, high or severe risks over low risks, and to justify the improvement plans in budget submissions. Note that, in your WSP, you need to decide an appropriate basis where additional control (i.e. improvements) should be prioritized for action.*
>
> *An improvement was also considered where a loss of control would result in a public health risk."*

In addition, the WSP team used its judgement based on the general risk priority guidelines (See page 15).

Improvement plans

> *"The improvement plan number (IP no.) in Table 5.1 is matched to the row reference number in the risk assessment table (i.e. the first column in Table 3/4.1). This provided a clear linkage between the hazardous event and the improvement that addresses this risk.*
>
> *The improvement plan extract shows some examples of improvement for Aquatown. This extract shows the status 12 months after the WSP started, by way of illustration."*

TABLE 5.1 • IMPROVEMENT PLAN EXTRACT

IP NO.[a]	SPECIFIC IMPROVEMENT ACTION	ARISING FROM	RESPONSIBLE PARTY	DUE DATE (from commencement of the WSP)[b]	BUDGET (and source of funds)	STATUS (12 months after commencement of WSP operations)
…	…	…	…	…	…	…
IP C6	Work with stakeholders and government to develop a long-term strategy for demand management and water reuse, and investigate alternative water sources for the Aquatown water supply	High risk (risk score 12). Projected rainfall reductions and increased variability associated with climate change will make Aquatown's surface water source more vulnerable as the competition with farmers for water increases.	ATWS General Manager	3 years for review and final decisions	Low financial cost (no capital cost) but potentially high political cost. Source: AWTS strategic planning budget.	Review of options and implications 50% complete
…	…	…	…	…	…	…
IP T6-1	Replace single 3-phase power supply feed to treatment plant with dual supply	High risk (risk score 12) related to failure of plant when power supply is lost	ATWS Capital Works Manager	Within 18 months	Medium cost (around $500 000) anticipated. Source: ATWS capital budget.	Contract awarded. Current completion date is 6 months behind schedule due to import delays.
…	…	…	…	…	…	…
IP D15	Establish new process and standard operating procedures (SOPs) for storage tank maintenance programme, including cleaning	High risk (risk score 12) related to ingress of harmful microorganisms from leaky roofs and openings	ATWS Operations Manager	Within 12 months	No capital cost. Increase in annual operations cost by 1%. Source: ATWS operational budget.	Complete; SOP is now in operation
…	…	…	…	…	…	…
IP U5	Community advice, education and ongoing support to households on good hygiene practice	Moderate (risk score 9)	ATWS Equity Manager in conjunction with NGO	Within 6 months	Small cost to support NGO in its education campaign. Source: ATWS community engagement budget/ operational budget.	Initial programme complete; ongoing support planned for next 18 months

[a] The improvement plan number (IP no.) is matched to the row reference number in the risk assessment table (i.e. the first column in Table 3/4.1).
[b] Generic time frames are provided in this table for illustrative purposes. In practice, an actual date showed be provided in the improvement plan.

MODULE 6: OPERATIONAL MONITORING

Examples of some of the detailed operational monitoring plans are provided below.

"The operational monitoring number (OMP no.) in Table 6.1 is matched to the row reference number in the risk assessment table (i.e. the first column in Table 3/4.1). This provided a clear linkage between the existing control measure and the operational monitoring that must be conducted to confirm that this control measures is working as intended."

TABLE 6.1 • OPERATIONAL MONITORING PLAN EXTRACT

OMP NO.[a]	PROCESS STEP	CONTROL MEASURE	WHAT TO MONITOR	WHERE	WHEN	HOW	WHO	ACCEPTABLE LIMIT(S)	CORRECTIVE ACTION
OMP C11	Groundwater abstraction facilities	Inspection and maintenance programme for concrete apron casing around bore head, borewell sanitary seal, and some fencing	Fencing, and presence or evidence of stock near borewell. Damage to concrete cover.	At each borewell	Weekly minimum; if rain of more than 10 mm forecast within 3 days, before forecast rain days	Visual inspection	Groundwater pump operator	All fences and gates closed and no evidence of stock within 10 metres of each borewell. No damage to sanitary seal.	Repair concrete cover, fences and gates within 3 days. Contact stock owner immediately. Agree on ways to avoid in future and to remove any stock within zone. If stock were within 10 metres, check chlorination operation.
OMP T9	WTP for surface water: chlorination (chlorine dose controller)	Adjustments by operator to select dose controller set point and periodic manual checks on free available chlorine concentration, especially during periods of variability in water quality	Free chlorine residual concentration. Dose flow rate and dose calculation.	Downstream of storage before release to distribution	Continuous (online) monitoring or Four times daily	Chlorine analyser. Independent check of dose calculations.	Treatment plant operator	Free chlorine residual 1–1.5 mg/L. No dose calculation error identified.	Adjust controller set point. Recalculate dose rates and change settings. Train staff in dose calculations.
OMP T10	WTP for surface water: chlorination	Coagulation, flocculation and filtration before chlorination	Turbidity of filtered water before chlorination	Combined outlet of sand filters	Continuous (online) monitoring	Online turbidity analyser	Treatment plant operator	Turbidity <0.5 NTU	Identify cause, take appropriate remedial action as per SOP 013 and monitor closely.

TABLE 6.1 • OPERATIONAL MONITORING PLAN EXTRACT CONTINUED

OMP NO.[a]	PROCESS STEP	CONTROL MEASURE	WHAT TO MONITOR	WHERE	WHEN	HOW	WHO	ACCEPTABLE LIMIT(S)	CORRECTIVE ACTION
OMP D16	Distribution: piped network	Maintaining chlorine residual	Chlorine residual. pH.	Consumers' taps and public tap stands	Multiple samples per week as per sampling programme	Field kit	Water quality officer	Residual chlorine ≥0.2 mg/L to all customers. pH 7–8.	Adjust chlorine dose. Adjust pH. If persistent, investigate cause and take appropriate action as per SOP 069.
OMP D19	Distribution: piped network	Design specification, pipe stocks, asset register, purchasing from accredited suppliers	All pipe materials and values certified as safe for contact with drinking-water	ATWS contracts office At receiving sites (depots/ stores)	Before purchasing materials and on receipt. Annual review of records for compliance.	Check documentation, including certification of materials	Water quality officer/ procurement manager	All materials are suitable for contact with drinking-water and do not result in contamination of drinking- water. Pipe materials comply with quality requirements.	Do not accept unsuitable materials. If suspected that they have been installed, investigate appropriate options to rectify.
OMP D24	Distribution: piped network	Trained staff conducting pipe repairs	Free chlorine residual concentration and turbidity. Compliance with SOP 024.	At site of repair at hydrant or tap	At completion of pipe repair or installation of new main before main is returned to service	Field test kits	Pipe supervisor	Residual chlorine ≥0.5 mg/L. Turbidity ≤5 NTU.	Undertake addition flushing and disinfection, and repeat sampling
OMP D31	Distribution: tanker	Cleaning of tanker by water tanker operators	Free chlorine residual concentration of wash water and visual appearance check. Compliance with SOP 111.	On-site	Before putting tanker into service	Field test kits	Tanker supervisor	Residual chlorine of wash water ≥0.5 mg/L, left in tanker for 4 hours after spraying and visually clean	Repeat tanker cleaning

mg/L: milligram per litre; NTU: nephelometric turbidity unit; WTP: water treatment plant.

[a] The operational monitoring plan number (OMP no.) is matched to the row reference number in the risk assessment table (i.e. the first column in Table 3/4.1).

Implementation of the operational monitoring plans

"Once the operational monitoring plans were agreed, we set about modifying and improving our day-to-day reporting systems to incorporate any new operational data. In some cases, little change was needed; for new monitoring, additional reporting mechanisms were required.

Staff were involved in the design of any new reporting mechanisms, and training was carried out to support implementation.

Reporting to the WSP team was by exception. The regular WSP team meetings reviewed data outside what is considered a normal range.

Monitoring results are reviewed twice weekly by the supervisor. Trending analyses are undertaken every 3 months to monitor performance of key control measures – for example, seasonal variations of treated water turbidity against raw water turbidity."

MODULE 7: VERIFYING WSP EFFECTIVENESS

Compliance monitoring

Compliance monitoring by the national health regulator continued in the same way as before the WSP.

Customer satisfaction programme

"Before the WSP, ATWS had a customer complaints team. During development of the WSP, this team was transformed to be an active customer communications team. Its role has become more important over time as a way of getting feedback from customers on ATWS's service.

After 18 months, the communications team undertook its first customer satisfaction survey, which included users in the low-income/informal areas.

The communications team has plans to develop a geographic information system to better track patterns and frequency of customer feedback, which will inform proactive maintenance activities in the distribution network."

WSP audits

"An external informal audit was carried out after 12 months operation of the WSP. The focus of this initial audit was providing advice. It was undertaken by an experienced WSP auditor from another city (i.e. independent of the ATWS's WSP team).

The auditor's report and assistance were greatly appreciated by the WSP team. For example, the audit highlighted that our operational monitoring on chlorine residuals needed improvement to better capture some dead-end areas of the network that experience low flow rates.

There is currently no regulatory requirement for WSP audits, but we have decided to undertake a formal external audit after 36 months of WSP operation."

MODULE 8: MANAGEMENT PROCEDURES

Standard operating procedures (SOPs)

"We undertook a review of our existing SOPs and emergency response plans to identify any existing gaps, existing management procedures that needed to be updated, or old SOPs that needed to be archived and taken out of circulation. We summarized the output of this exercise in Tables 8.1 and 8.2.

Our existing management procedures are stored in our electronic document management system, which can be conveniently accessed by operators on their field mobile devices. Hard copies are also available in the depots, at water treatment plants and at key assets throughout the network (e.g. distribution storage tanks)."

TABLE 8.1 • EXTRACT OF SOP DEVELOPMENT SCHEDULE

PROCESS STEP	SHORT DESCRIPTION OF SOPs TO BE DEVELOPED OR REVISED	TIMETABLE FOR DEVELOPMENT (FROM START OF THE WSP)
General	Response to customer complaints	18 months
Catchment	Fertilizer/pesticide application (to be prepared by Farmers Association, supported by ATWS)	18 months
	Waste management at religious cultural site in catchment (to be prepared by Department of Religious Affairs, with support from ATWS)	12 months
Treatment	Filter backwashing	12 months
	Jar test	12 months
Distribution	Tank cleaning (IP D6)	6 months
	Operating intermittent supplies	12 months
	Maintaining chlorine residual throughout the distribution system	12 months
	Pipeline repair procedures (IP D24)	12 months
Customer support	Customer reporting and follow-up procedures	12 months

Note: Details are not included in this example.

TABLE 8.2 • EXTRACT OF EMERGENCY RESPONSE PLAN DEVELOPMENT SCHEDULE

PROCESS STEP	SHORT DESCRIPTION OF EMERGENCY RESPONSE PLANS TO BE DEVELOPED OR REVISED	TIMETABLE FOR DEVELOPMENT (FROM START OF THE WSP)
General	Epidemic	18 months
	Cyber-attack on information technology system	
Catchment	Flood Bushfire	18 months
Treatment	Extended power failure	18 months
Distribution	Major backflow contamination event	18 months

Note: Details are not included in this example.

MODULE 9: SUPPORTING PROGRAMMES

Consumer outreach/education programmes

Apart from the improvement plan IP U5 (community advice, education and ongoing support to households on good hygiene practice), no additional outreach programmes have been planned at this stage. This will be kept under regular review.

Operator training and other supporting programmes

Planned supporting programme activities are summarized in the table below.

SUPPORTING PROGRAMME PLAN EXTRACT

PROCESS STEP OR GROUP	SHORT DESCRIPTION OF SUPPORTING PROGRAMMES TO BE DEVELOPED OR REVISED	TIMETABLE FOR DEVELOPMENT (FROM START OF THE WSP)
Operators	Training for operators on new SOPs	When new SOPs are developed
Supplier staff (general)	New staff orientation on WSP in induction	12 months
Contractor	Training on WSP approaches	9 months
Catchment	Research on transport and attenuation of agricultural chemicals used in catchment and possible impacts on raw water	24 months
Treatment	Calibration of online monitoring equipment	12 months
Distribution	Leak detection	12 months
	Water network hydraulic and water quality modelling	36 months
	Proactive mains cleaning	
Customer support staff	New customer complaint management software	When introduced

MODULE 10: WSP REVIEW AND UPDATING

Regular WSP team meetings

"Following adoption of the WSP, WSP team meetings were conducted initially every month for the first 6 months and then every 2 months thereafter. A regular agenda was soon developed to streamline the meetings. It included a dedicated agenda item for each meeting to review the operational monitoring data and actions taken on the improvement plans."

Planned and periodic review meetings

"We instituted a twice-yearly review of the WSP. This played a positive role in the ongoing monitoring, and some important improvements have been made over time as a result of this review."

Review after incident or near miss

"We are pleased to say that we've had no incidents or near misses since starting the WSP.

We continually try to think of 'what could go wrong', but know that it's quite possible for something unforeseen to occur, and recognise the importance of emergency preparedness as part of Module 8."

Postscript

"This is a quick note during the first external formal audit (36 months after starting our WSP).

Although it's great to have someone completely independent examine our WSP and our WSP operations, it's also a nervous time for us … The auditor is very experienced and thorough, but she is quite approachable and supportive … We know we'll learn a lot from the audit process.

For example, she's shown us some benefits of doing a dual-stage (raw and residual) risk assessment. This showed that, even without our existing control measure (which we've been monitoring for several years), the raw risk was very low. So all our efforts in having that control measure and monitoring it have not really gained very much. We will roll out the dual-stage risk assessment approach to other hazardous events gradually in the future!

We are still gaining experience with our WSP. Over the past 3 years, we have seen some real benefits – but that's another story …"

For more information, contact:

Water, Sanitation, Hygiene and Health
World Health Organization
20 Avenue Appia
1211 Geneva 27
Switzerland

gdwq@who.int

https://www.who.int/health-topics/water-sanitation-and-hygiene-wash