Naval Facilities Engineering Systems Command

Naval Facilities Engineering Systems Command Hawaii

Water Quality Surveillance and Response System

JOINT BASE PEARL HARBOR-HICKAM

August 30, 2023

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ACRONYMS AND ABBREVIATIONS

DOH	Department of Health, State of Hawai'i
DW	Drinking Water
EDMS	Electronic Data Management System
JBPHH	Joint Base Pearl Harbor-Hickam
LTM	Long-Term Monitoring
NAH	Navy Aiea Halawa
Navy	Department of the Navy, United States
SCADA	Supervisory Control and Data Acquisition
SDWB	Safe Drinking Water Branch, Department of Health, State of Hawai'i
SRS	Surveillance and Response System
TPH	Total Petroleum Hydrocarbons
UM	JBPHH Public Works Department Utilities Management Department
VOC	Volatile Organic Compound

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1. Introduction

This document describes the Joint Base Pearl Harbor-Hickam (JBPHH) Water Quality Surveillance and Response System (SRS). The JBPHH drinking water (DW) system supplies water for potable and other uses at JBPHH, nearby Department of Defense installations, and adjacent communities outside of the Department of Defense fence line. The JBPHH DW system draws groundwater from the Pearl Harbor aquifer via the Navy's Waiawa, Aiea-Halawa (NAH), and Red Hill shaft (well) sources.

The JBPHH DW Long Term Monitoring (LTM) Plan, developed jointly by representatives of the Hawai'i Department of Health (DOH), the Navy, the United States Army, the Environmental Protection Agency (EPA) and a team of technical and subject matter experts, and published in June 2022, provides direction on State requirements for the reactivation of the NAH shaft.

The DW LTM Plan, which discusses the State of Hawaii's requirements for reactivating the JBPHH shafts includes the requirement for the implementation of a Water Quality Surveillance and Response System. The principal requirement is that "*The Navy shall ensure that its current drinking water source(s) are protected from future contamination and implement a Water Quality Surveillance and Response System (SRS). The SRS is a framework designed to support monitoring and management of distribution system water quality.*"

The two primary features of the SRS are an early warning system and that the Navy provide an effective response to a deterioration in water quality. This system will include continuous monitoring of water quality parameters at the shafts in addition to the ongoing sampling throughout the distribution system through LTM. At the shafts, the DW LTM Plan discusses the implementation of an online program which monitors water at the entry point to the distribution system. The DW LTM Plan states that the monitoring system must be "fully functioning" (as in installed and tested) prior to water from the sources entering the water distribution system.

This SRS is a framework designed to support monitoring and management of the JBPHH distribution system water quality and outlines how the Navy will implement an early warning system to quickly detect and then effectively respond to a deterioration in water quality. Having a mechanism in place for early detection and response will help mitigate the impact of potential future contamination, enhancing the resiliency of drinking water system and provides a level of assurance to those who consume the water on a daily basis.

2. Design Goals

This SRS is intended to monitor for contamination incidents, specifically those involving volatile organic compounds (VOCs) and total hydrocarbons (TPH). These compounds were chosen as an indicator for the presence of fuel based on the DW LTM Plan. Providing early warning of these contaminants can significantly mitigate the impact that they have on the drinking water system, those who consume it, and operational mission for the units located at JBPHH.

3. Performance Objectives

Performance objectives and their associated metrics provide a measurable indicator of how well an online monitoring system is operating. As one of the primary goals for this system is to mitigate the impact of future contamination incidents, the performance objectives considered for this system is sustainability and information reliability.

3.1 SUSTAINABILITY

Sustainability is defined as the degree to which benefits derived from this system justify the cost and continued operation and maintenance. This will be evaluated by:

- Consequences avoided by early detection of, and response, to contamination incidents. In the event of a detection, review of lessons learned and ways for improving future responses will be evaluated.
- Increased confidence in water consumers, as measured by number of water complaints associated with fuel. Concerns with drinking water quality are currently tracked when a notification is made by a resident to either the DOH or the Navy Emergency Operations Center (EOC). Reviewing trends in this data can help inform if analyzers installed have had an impact on consumer confidence.
- System costs for installation and annual maintenance. Although there is no alternative for not having this system in place, it is important to capture costs associated with this system to provide transparency to leadership on cost versus benefits.

3.2 INFORMATION RELIABILITY

Information reliability is the degree to which information produced by an online monitoring program is of sufficient quality to support decision-making. UM personnel who work with the online monitoring program must be able to distinguish between typical water quality variability andchanges that indicate a more acute issue requiring a response action.

Data from the SRS will be transferred to EDMS as a secure location for data sharing. SDWB will maintain access to EDMS and any data provided by the SRS.

In context of this SRS, information reliability will be characterized by:

- Number of false positives per month.
- Number of false negatives per month.
- Timeliness of data transfer to EDMS.

4. System Resources

In order to maximize the effectiveness of this system, data will be considered from all available resources including but not limited to:

- Regulatory compliance data. The LTM program is in the process of collecting thousands of data samples across the water distribution system. This information will be used to help establish a baseline for the anticipated level of any contaminants.
- Customer complaint records. Both the DOH and Navy maintain records of customer complaints regarding water quality. Evaluating both the number of complaints and the specific concerns will help to understand existing conditions in the water system and if there are any trends over time.
- Organic Expertise. Both the resident knowledge of the UM personnel who operate the water distribution system on a daily basis and as-built drawings for the system provide an invaluable resource for informing locations of analyzers and how to react in the event of a potential contamination incident.

- Hydraulic modeling. An existing contract to develop a hydraulic model for the water distribution system can also help to inform future analyzer locations and recommended courses of action to minimize the effect of a contaminant in the system.

5. Monitoring System Design

The initial concept for this system is to initially capture data for drinking water originating from the Navy Aiea-Halawa shaft. Additional analyzers will augment the system to provide an operational screening tool for drinking water originating from the Waiawa shaft and Red Hill shaft in accordance with the DW LTM Plan.

5.1 Implementation Team

The following personnel will be key stakeholders in the design, implementation, operation, and maintenance of the OWQM-DS.

- NAVFAC Public Works Department JBPHH Utilities Management Director: Overall responsibility for the installation, maintenance, and daily operation of the online analyzers. Other areas of responsibility include:
  - Management of 24 hour, 365 day operation of potable water systems.
  - Planning, maintenance, testing, and operation of SCADA systems which control potable water distribution.
- NAVFAC Public Works Department JBPHH Public Works Officer (JB4): Responsible for providing products and services of Utilities Management Department in order to meet the operational mission of JBPHH and tenant commands. In the event of a contaminant detection, provides timely notification to Red Hill EV OIC.
- Red Hill EV OIC: Primary point of contact with regulatory agencies, specifically the DOH SDWB in the event of a contaminant detection. Ensures proper implementation of DW LTM Plan including transfer of SCADA data from online analyzers to the Electronic Data Management System (EDMS).

5.2 Monitoring Locations

In accordance with Section 9 of the DW LTM Plan, this SRS plan will be used to detect potential contaminants from the Navy's 3 existing drinking water shafts as well as any future sources. Two main requirements for selecting analyzer locations include being able to isolate the source of the contaminant (ie, which shaft) and ready access to remote terminal units (RTUs) which facilitate access to the water distribution SCADA system.

- NAH shaft: Enclosure (#1) identifies the location for this analyzer in the vicinity of NAH. This location will monitor drinking water only from NAH and is isolated from drinking water from the Waiawa shaft via a check valve downstream of it. A contaminant detection at this analyzer will be able to pinpoint the NAH shaft as the source of this contaminant informing corrective measures necessary.
- Waiawa shaft: Once a suitable location is identified this plan will be updated.
- Red Hill shaft: Once a suitable location is identified this plan will be updated.

The first analyzers installed will be located based on the experience and recommendation of the UM Department using historical knowledge of the water distribution system and as-built drawings for suitable locations. In late 2022, a hydraulic modeling contract is anticipated to be complete which will provide more insight into optimal locations for installing analyzers.

5.3 WATER QUALITY PARAMETERS

Contaminants of interest for this SRS plan are volatile organic compounds (VOCs) and total hydrocarbons (TPH). These are intended to be indicators of fuel contamination in the drinking water system. Enclosure (#1) provides the product specifications for the particular analyzers to be used. Analyzers have a detection range between 0-1000ppb with calibration centered at 200ppb. Although the action level for TPH is 266ppb, the concentration at which a response will be triggered is significantly lower, at 100ppb. The intent for this is to provide a proactive response prior to contaminant levels presenting a danger for health.

Currently, an in-line analyzer pilot study (Appendix B) is being conducted at the Red Hill shaft to validate the accuracy, sensitivity, and determine the appropriate calibration parameters. This work is being conducted as part of a joint effort with our UM Department with the verification sampling done though our current Drinking Water contract. The performance information collected from the pilot study will help inform the ultimate design and are integral in determining the final procedures which will be included in the Final SRS report.

5.4 MONITORING STATION

All online analyzers will be connected to the existing SCADA infrastructure that monitors the JBPHH water distribution system. This system is monitored 24/7 at a control center located at the Waiawa shaft.

5.5 DATA SHARING

Data from this system will be transferred to EDMS as a secure location for data sharing. SDWB will maintain access to EDMS and any data provided by the SRS. At a minimum, data will be collected and transferred to EDMS on a monthly basis.

6. System Implementation

All online analyzers will be connected to the existing SCADA infrastructure that monitors the JBPHH water distribution system. This system is monitored 24/7 at a control center located at the Waiawa shaft. The information gained from pilot study at Red Hill will determine the upper and lower alerting thresholds of the system. These thresholds will be used to create the response procedures that will need to be taken. A period of training both on the system operation and the response procedures, followed by preliminary operation will precede the system becoming fully operational. Once the system is fully functioning and is approved by the SDWB, alerts will be investigated as they are generated. The transition from preliminary operation to real-time operation will be clearly communicated to both regulators and Navy personnel with a role in alert investigations.

Potential future upgrades to the system could include conductivity and temperature sensors. These instruments can provide useful information needed for source tracking

6.1 TRAINING AND PRELIMINARY OPERATION

Following installation of the first analyzer at NAH, UM will ensure water distribution system operators are familiar with the readout from analyzers, how to troubleshoot, and the alert detection SOP. A period of preliminary operation is anticipated to allow personnel to practice their responsibilities in a training environment before transitioning to real-time operation. As the analyzers are a system that is new to this water distribution system, this period will be critical to enabling an effective response once the system is considered operational. Until UM staff are fully trained and ready to assume real-time operation of the system, it will not be considered fully functioning and there will be no notification requirements to DOH in the event of a detection.

6.2 Sustained Operation

Periodic training will performed as needed to ensure all staff who operate this system are familiar with it. Periodic reviews of SOPs, documentation procedures, and response notifications will also help to continually develop and improve this plan.

7. References

EPA. April 2018. Online Source Water Quality Monitoring for Water Quality Surveillance and Response Systems.

Drinking Water Long-Term Monitoring Plan, Joint Base Pearl Harbor-Hickam Public Water System #HI000360 and Aliamanu Military Reservation PWS #HI0000337 O'ahu Hawai'i. June 2022.

Red Hill Pilot Study - KECO 204P Oil / Hydrocarbons in Water Analyzer Validation

July 28, 2023

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The Working Principals and Calibration of the KECO Model 204 VOC-In-Water Analyzer

EPA

Online Water Quality Monitoring in Distribution Systems

The KECO 204P Analyzer and MS 1200 Analyzer

Background:

Company	Analytical Systems-KECO	Multisensor Systems
Model	204P-GP-G2	MS 1200 and MS 1700
Website	www.LiquidGasAnalyzers.com	https://www.multisensorsystems.com/ms-products/oil-in-water-analyzer/
Permit Fulfillment	LTM Plan SRS	NPDES permit under the RSHRMP regulations

There are currently 10 analyzers installed in the Red Hill GAC system; nine (9) MS 1200 Oil in Water Analyzers and one (1) MS 1700 Oil in Water Analyzer to monitor water pumped from the Red Hill shaft that is filtered through the GACs, and subsequently discharged into Halawa Stream to fulfill the NPDES permit under the RSHRMP regulations. The contractor, Vectrus, is currently operating these inline analyzers via 24-hour surveillance and exceedance-response when Total Petroleum Hydrocarbons (TPH) is detected over 200ppm. The MS 1200 captures low level concentrations while the MS 1700 captures higher levels of contamination.

The currently installed MS 1200s measure headspace gases from a sample tank using Henry's Law where the concentration of gases in the headspace is proportional to the concentration of the substance in the water. Accordingly, the measurement of the gas provides a reliable technique to measure the concentration of the substance in the sample water. The volatile components in the water are then passed into the headspace above the water where they are trapped until equilibrium is reached. A sample of the headspace gases are subsequently passed across sensors that respond to the VOCs to be analyzed.

The Joint Base Pearl Harbor Hickam (JPHH), Public Works (PW) Department has purchased KECO inline analyzers which monitor for DRO and GRO. Typically, EPA approved analyzers monitor water quality, not specifically DRO or GRO. As such, the KECO in-line analyzers purchased by JBPHH require pilot testing for accuracy and precision to ensure a reliable early detection system is in place.

With the installation and validation of the KECO units, the objective is not to replace the MS 1200 and MS 1700s, but rather, to supplement the early detection system by having the KECO analyzers in-line of the MS units to establish accuracy through verification sampling at Red Hill. Additionally, to be functional on a flow of water that is not connected to the distribution system and reducing the risk of total TPH false positives.

The DW LTM Plan states that the monitoring system must be "fully functioning" (as in installed and tested) prior to water from the sources entering the water distribution system. Once deemed fully functional, the KECO inline analyzers will be an integral component of an early warning system at Red Hill and other Navy shafts to ensure the Navy's drinking water sources and where water is distributed are protected from future contamination. The inline analyzer pilot study will characterize the new KECO analyzers prior to implementation into the JBPHH water distribution system which is the first step in satisfying the requirement of the LTM Plan which states that the monitoring system must be "fully functioning".

The KECO Volatile Organic Carbon (VOC) In-Water Analyzer analytically quantifies total hydrocarbons and total volatile organic compounds in water using KECO's Sample Transfer Stripper exclusive membrane technology and tin oxide sensor. A total of 14 KECO 204P analyzers are currently on the island of Oahu and are ready to be installed and validated with the purchase of the "Startup and Commissioning" service from The KECO Company. Upon successful installation of the new KECO 204P analyzers, significantly improved sensitivity, exceedance-detection response time, and other important parameters will be in to protect the JBPHH Drinking Water System.

The KECO 204P analyzer has a 99% typical uptime and has proven on-line reliability. This analyzer operates with a Sample Transfer Stripper which separates the hydrocarbons and VOCs from the liquid sample to gas phase while the hydrocarbon VOC solid state sensor quantifies hydrocarbons and VOCs in the gas phase. The transfer read-out then electronically assembles a digital reading from sensor for user display and interaction. The analyzer also includes a temperature controller which regulates temperature inside the analyzer enclosure/ cabinet.

Table 1: Technical Comparison of KECO 204P vs MS 1200

	KECO 204P			**MS 1200**			**MS 1700**		
Parameter	**Operational Requirements**		**Notes**	**Operational Requirements**		**Notes**	**Operational Requirements**		**Notes**
	Min	**Max**		**Min**	**Max**		**Min**	**Max**	
Working Temp: Ambient	1°C (33°F)	55°C (131°F)	Operating without ext. cooling/heating. PPB range may require temperature controlled building.	0°C (32°F)	40°C (104°F)		0°C (32°F)	50°C (122°F)	Higher temperature available.
Working Temp: Water	**(not listed)**			1°C (33°F)	40°C (104°F)		1°C (34°F)	40°C (104°F)	
Storage Temp:	0°C (32°F)	70°C (158°F)		**(not listed)**			**(not listed)**		
Sample Detection Rate / Sampling Period	3 min	6 min	3-6 min after initial hydrocarbon contamination reaches the analyzer	10 min	120 min	User Selectable. High concentrations may limit the minimum time period allowed	**(not listed)**		
Resolution	<1 ppb	50 ppb	App. Dependent	**(not listed)**			**(not listed)**		
Repeatability	-3%	+3%		-2%	+2%	200 ppb sample measured using standard 1.5 L solution (water plus Toluene dissolved in DMSO) in glass 2.5 L Winchester type bottle using magnetic stirrer at 20°C / 68°F	**(not listed)**		
Accuracy	-3%	+3%	May be improved significant near points of interest including ppb level concentrations.	-10%	+10%		-15%	+15%	At 10 ppm at 20°C
Validation Period			Calibration is performed at factory and values set in the control electronics with is a factory setting.	6 Months		Using Validation Kit available from Multisensor Systems or Authorized Distributor	**(not listed)**		
Detection Range	0 ppm 0 ppm 0 ppm 0 ppm 0 ppm	1 ppm 10 ppm 50 ppm 100 ppm 500 ppm	(By wt.). Customer specified (contact factory).	1 ppb	3,000 ppb	Most applications focus on the 1-200 ppb range	1 ppm (1,000 ppb)	100 ppm (100,000 ppb)	Measured against Toluene standard. For calibration using other compounds contact Multisensor Systems.
Analysis	Continuous			Continuous			Continuous		
Analog Output	4mA	20mA	"4 to 20" means that current is output in a range between 4 mA and 20 mA.	4mA	20mA	Scalable to range required, max load 900Ω	4mA	20mA	Scalable to range required, max load 900Ω
Supply Voltage	110 V AC	220 V AC		90 V AC	240 V AC	50 Hz or 60 Hz	**AC Version:** 90 V AC **DC Version:** 10 V DC	**AC Version:** 240 V AC **DC Version:** 15 V DC	50 Hz or 60 Hz
Field Calibrations	Virtually never required.			**(not listed)**			**(not listed)**		
Weight	~ 45 kg (100 lbs.)			25 kg (55 lbs.)			**Instrument**: 5 kg (11 lbs.) **Sampling System**: 12 kg (26.4 lbs.)		
Dimensions	609.6 X 609.6 X 304.8 mm (2 X 2 X 1 ft.)			1170 X 490 X 300 mm (46 X 19.2 X 12 inches)		Mounted on 2 separate PVC backboards.	**Instrument:** 300 X 200 X 132 mm (11.8 X 7.8 X 5.2 inches) **Sampling System:** 570 X 490 mm (22.4 X 19.2 inches)		
Service and Consumables	**(not listed)**			Air Filters: Every 6 Months Air Pump: Every 12 Months			Air Filters: Every 6 Months Air Pump: Every 12 Months		

The new KECO analyzers will need to be characterized against a known quantity, the inline analyzers currently in use in the Red Hill Granular Active Carbon (GAC) system (MS 1200 and MS 1700), and lab data to validate accuracy prior to implementation into the Long-Term Monitoring (LTM) Plan System Surveillance Response System (SRS).

The objective of the pilot study is to ascertain the KECO Analyzer sensitivity, response time, appropriate calibration concentrations, effectiveness, and other important parameters to protect the Drinking Water System. This includes defining the standard of "fully functioning" for the KECO units. Moreover, due to the lack of EPA approved SRS that address TPH as the primary Contaminate(s) of Concern (COC), the comprehensive goal of the pilot study is to verify the KECO units before they are installed elsewhere in the JBPHH drinking water system.

Per the DOH approved Drinking Water Long-Term Monitoring Plan (DW LTM), the need for an improved system of early detection in-line analyzers is outlined to support the SRS. The principal requirement is that "The Navy shall ensure that its current drinking water source(s) are protected from future contamination and implement a Water Quality SRS. The SRS is a framework designed to support monitoring and management of distribution system water quality." The intent is to validate the accuracy of the KECO units so they can be installed at various locations within the JBPHH drinking water distribution system as an early detection system for TPH that may enter the system.

Since water from the Red Hill shaft will not be entering the drinking water distribution system in the foreseeable future, the proposed location of the pilot study will be ran while water is flowing through the GAC to be discharged into the Halawa Stream. Once deemed fully functional, the inline analyzers will be an integral component of an early warning system to ensure the Navy's drinking water sources are protected from future contamination. The inline analyzer pilot study will characterize the new KECO analyzers prior to implementation into the JBPHH water distribution system which is the first step in satisfying the requirement of the LTM Plan which states that the monitoring system must be "fully functioning".

Implementation of Pilot Study:

The MS 1200 Oil in Water Analyzers are installed, calibrated, and currently operating at Red Hill. The analyzers are located at the influent (1 MS 1700 and 1 MS 1200), mid-line (4 MS 1200), and effluent lines (4 MS 1200) of the GAC system.

(b) (3) (A)

[redacted]

Image 1: Current GAC/Analyzer Layout

It is important to note a new GAC system will be constructed within the next six months according to Vectrus. This pilot study should accommodate to the amount of space and possible VOCs in the air that may affect the results. The KECO 204P inline analyzers will be installed at the influent line, before the GACs, next to the MS 1200 and MS 1700.

(b) (3) (A)

[redacted]

Image 2: Proposed New GAC/Analyzer Layout

KECO Volatile Organic Carbon (VOC) In-Water Analyzer shall be installed, calibrated and verified, and tested at Red Hill. The location of the analyzer should be placed next to the MS 1200 for a side-by-side comparison. The KECO Company does not perform the installation, however the Engineering Firm, Beavens, has successfully worked with KECO to install the 204P inline analyzers.

MS 1200	**KECO 204P**
	
Image 3: MS 1200 Retrieved from: https://www.multisensorsystems.com/ms-products/oil-in-water-analyzer/	Image 4: KECO 204P Retieved from: https://liquidgasanalyzers.com/product-category/type/liquid-analyzers/
	
Image 5: The MS 1200 shed situated between two GACs	Image 6: The MS 1200 located in the shed
	
Image 7: Example of the KECO 204P	Image 8: Secondary view of the KECO 204P

Startup and Commissioning of the KECO Analyzers – Calibration and Validation

After the installation of KECO 204P, it will need to be validated. A subject matter expert shall work with KECO Company and Vectrus to perform tests and conduct a statistical analysis. The KECO Company offers the purchase of the "Startup and commissioning" service. The Company can then perform a site visit to confirm all installations are correct, start the analyzers, and lastly, perform the initial test(s) to validate the accuracy of the analyzer described further below:

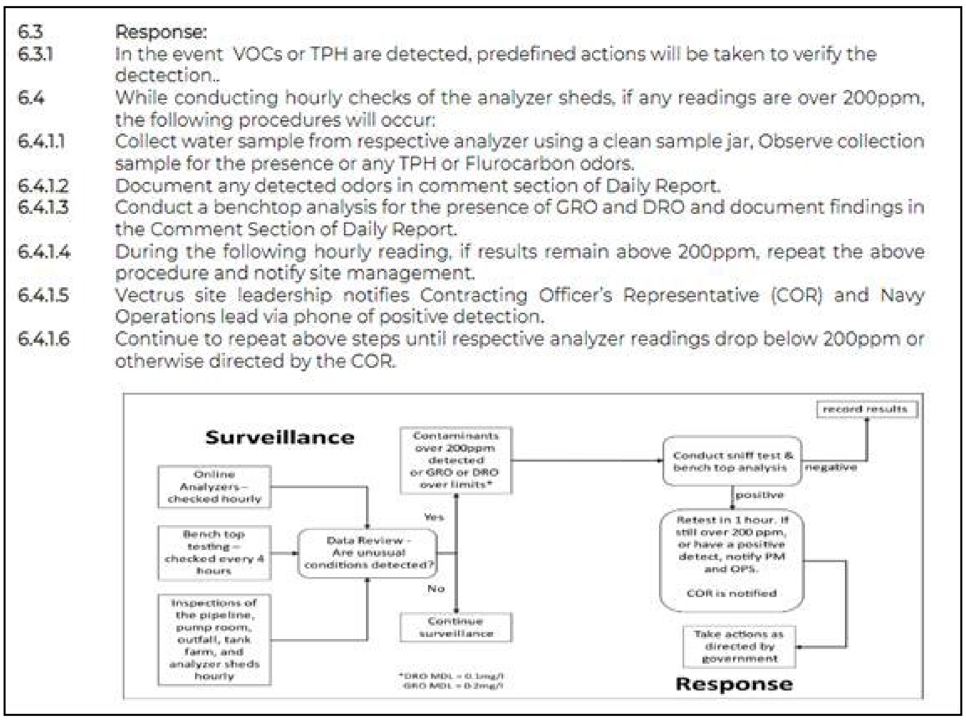
1. **"Bump" Test**: The bump test procedure utilizes the permeation tube inside of the analyzer. The tube provides qualitative results where water flows through permeation tube, a little bit of hydrocarbons are permeated into the water inside of the tube, when the perm tube is activated, water is routed to sample transfer stripper, where hydrocarbon are quantified and exit though sample drain. This tests the machine's ability to quantify TPH by using the sample transfer stripper.
2. **Known Concentration Spike Test**: Water spike with a known concentration of TPH is ran through the analyzer. The same TPH spiked water is also sent to a certified laboratory for analysis. The results are compared.
3. **Custom Test(s)**: The startup and commissioning service team is flexible and depending on the parameters that the client wishes to test, they can devise a method that is appropriate.

Along with the appropriate tests outlined above, the results will be compared to validated lab data which will be collected simultaneously.

Early Detection System - Determination of Alarms

Upon successful installation, calibration, and validation of the KECO Analyzers, they will be integrated into the SRS system and serve as a method of early detection of TPH exceedances. This will be determined with the percent error margin and the Incident Specific Parameter (ISP) of TPH. The alarm system is planned to have detections in the “green zone”, “yellow zone”, and “red zone” which will initiate various responses.

Image 9 is a current detection response for the MS 1200 and MS 1700 analyzers that Vectrus uses to fulfill the NPDES under the RSHRMP regulations. Table 3, shows an example of updated SRS for the KECO analyzers to support the LTM Plan SRS.



6.3 Response:

6.3.1 In the event VOCs or TPH are detected, predefined actions will be taken to verify the dectection..

6.4 While conducting hourly checks of the analyzer sheds, if any readings are over 200ppm, the following procedures will occur:

6.4.1.1 Collect water sample from respective analyzer using a clean sample jar, Observe collection sample for the presence or any TPH or Flurocarbon odors.

6.4.1.2 Document any detected odors in comment section of Daily Report.

6.4.1.3 Conduct a benchtop analysis for the presence of GRO and DRO and document findings in the Comment Section of Daily Report.

6.4.1.4 During the following hourly reading, if results remain above 200ppm, repeat the above procedure and notify site management.

6.4.1.5 Vectrus site leadership notifies Contracting Officer's Representative (COR) and Navy Operations lead via phone of positive detection.

6.4.1.6 Continue to repeat above steps until respective analyzer readings drop below 200ppm or otherwise directed by the COR.

Image 9

Example of Updated Surveillance and Responses

Zone	Range	Response
Green	0-50 ppb	Continue work as normal
Yellow	50-250 ppb	Monitor data closely
Red	>250 ppb	Inform COR and collect a sample for lab analysis

Table 3

Installation of Inline Analyzers at Joint Base Pearl Harbor – Hickam

Upon purchase of the, “Startup and Commissioning” service, KECO comes on site, ensures that all installations are correct, start up the analyzers, and perform the initial test(s) to calibrate and validate the analyzers previously described in *Overview of the Pilot Study*.

Once the KECO units have been deemed “fully functional” via the pilot study and validation tests, they will be installed across the JBPHH water distribution system, which has been strategically chosen by Utilities Management (UM) as seen in Map 1 & 2. In the future, once the water treatment plant at Red hill is operational, the KECO 204P will be installed after the GAC trains as an SRS for the distribution system.

JBPHH WEST SYSTEM

(b) (3) (A)

[redacted]

JBPHH EAST SYSTEM

(b) (3) (A)

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Enclosures

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Drinking Water Long-Term Monitoring Plan

Drinking Water Long-Term Monitoring Plan

Joint Base Pearl Harbor-Hickam Public Water System #HI0000360 and Aliamanu Military Reservation PWS #HI0000337 0' ahu, Hawai' i

June 2022

Approved by:

Kathleen Ho

Jun 16, 2022

Kathleen S. Ho Date
Deputy Director for Environmental Health
State of Hawaii, Department of Health

Acknowledged by:

Corine Li

June 29, 2022

Corine Li, P.E. Date
Manager, Drinking Water Program
U.S. Environmental Protection Agency, Region 9

Approved by:

ENG.SHERRI.R.12 29438936 Digitally signed by ENG.SHERRI.R.1229438936
Date:2022.07.1319:32:42-10'00'

Sherri R. Eng, N45 Date
Environmental Director, Navy Region Hawaii
By Direction of the Commander
PWS #Hl0000360

Approved by:

SUZUKI.RHONDA .L S.1275028912 Digitallysignedby SUZUKI.RHONDA.L S.127S028912
Date:2022.07.1914:35:06-10'00'

Rhonda L. Suzuki, P.E. Date
Deputy Director, Directorate of Public Works
U.S. Army Garrison Hawaii
PWS #Hl0000337

This Drinking Water Long-Term Monitoring (DW LTM) Plan was prepared by the State of Hawaii Department of Health, the United States Navy (Navy) for Joint Base Pearl Harbor-Hickam (JBPHH) Public Water System (PWS) #HI0000360, and the United States Army (Army) Aliamanu Military Reservation (AMR) PWS #HI0000337 .

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FIGURES

TABLES

APPENDICES

2. Acronyms and Abbreviations

µg/L	micrograms per liter
AECOM	AECOM Technical Services, Inc.
CDC	child development center
CDH	child development home
COC	chain of custody
CTO	contract task order
DBP	disinfection byproducts
DOC	dissolved organic carbon
DOH	State of Hawaii, Department of Health
DW	drinking water
EAL	Environmental Action Level
EDMS	Environmental Data Management System
EPA	United States Environmental Protection Agency
HCl	hydrochloric acid
HNO_3	nitric acid
HPC	heterotrophic plate count
IDWST	Interagency Drinking Water System Team
JBPHH	Joint Base Pearl Harbor-Hickam
LOD	Limit of Detection
LOQ	Limit of Quantification
LTM	Long-Term Monitoring
MCL	Maximum Contaminant Level
MDL	method detection limit
MDV	medical, dental, and veterinary clinics
mg	milligram
mL	milliliter
NAVFAC	Naval Facilities Engineering Systems Command
POC	point of contact
PWS	Public Water System
QC	quality control
RAR	removal action report
SAP	sampling analysis plan
SDWB	Safe Drinking Water Branch, State of Hawaii, Department of Health
SOP	standard operating procedure
TAT	turn-around time
TOC	total organic carbon
TPH	total petroleum hydrocarbons
U.S.	United States
VOA	volatile organic analysis

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3. INTRODUCTION

This Drinking Water Long-Term Monitoring (DW LTM) Plan (Plan) was developed jointly by representatives of the State of Hawaii, Department of Health (DOH), the Navy, the Army, and a team of technical and subject matter experts. This Plan is designed to fulfill the post advisory requirements stated in the Sampling Analysis Plan (SAP) titled *Drinking Water Sampling Plan for JBPHH, Oʻahu, Hawaiʻi, Addendum 3, Version 10, dated February 25, 2022 (DOH 2022)* and the 19 Removal Action Reports (RAR) for each zone established for Joint Base Pearl Harbor-Hickam (JBPHH) Public Water System (PWS #HI0000360) and the Aliamanu Military Reservation (AMR) PWS (PWS #HI0000337). For the purposes of this Plan, PWS #HI0000360 and PWS #HI0000337 will be considered a single distribution system divided into zones (System). Adoption of this document by the signatories formalizes the agreements detailed in this Plan for the remainder of Long Term Monitoring. During the period between the amendment of the zone and the adoption of this document, the System has complied with DW LTM section as generally described in the previously signed SAP and as directed by SDWB.

On November 20, 2021, an unknown quantity of petroleum, a hazardous substance, was released into the Red Hill Shaft. Both the Navy and DOH received complaints of a chemical or fuel odor and taste to the drinking water served by the System that serves approximately 93,000 consumers. On November 29, 2021, DOH issued a public health advisory recommending Navy water system consumers to avoid using the water for drinking, cooking, or oral hygiene. The water distribution system was divided into 19 manageable zones where systematic remedial action was conducted to remove petroleum contamination from the system through comprehensive flushing of the water distribution lines and premise plumbing. In order for DOH to amend its public health advisory, evidentiary benchmarks were developed, which included (among other things) sampling for indicators of contamination and response by-products as well as cross-connection surveys to understand the potential for contaminants to spread through the System. Within the SAP, a preliminary construct of a long-term approach to monitor and ensure the safety of the System is presented. Elements of the SAP approach is incorporated into this Plan. The basic elements of this Plan requires the Navy and Army to:

1) Sample the source, distribution lines, and houses/buildings for an additional 24 months to February 2024 to ensure that the drinking water does not exceed EPA drinking water standards, DOH drinking water standards and Incident Specific Parameters (ISPs);
2) Conduct the requirements and conditions included in the RAR of each zone; and
3) Ensure that its current drinking water source(s) are protected from future contamination.

The sampling portion of this Plan was initially drafted by AECOM Technical Services, Inc. (AECOM) under Comprehensive Long-Term Environmental Action Navy V, contract task order (CTO) N6274222F0106, to support the sampling of the System. DOH modified the initial draft to its final form, in collaboration with the Navy and Army.

This Plan supersedes the DW LTM section of the previously signed SAP. The surveillance metrics are applied to ensure that the water is safe to drink, meets all State and Federal drinking water standards and continues to be non-detectable or below the designed incident specific limit for petroleum and other response by-product contamination. DW LTM Round 1 has already been completed for all zones and DW LTM Round 2 is partially complete. The sampling for these rounds were conducted under the previously signed SAP. Therefore, these “DW LTM Rounds” are not subject to the additional sampling requirements presented in this Plan. However, all DW LTM Rounds performed after this Plan has been signed/adopted will be subject to the requirements of this Plan. The Plan will be implemented in two phases as further described below.

- *0-3 Months After Initial Drinking Water Sampling:* Samples will be collected pursuant to the Plan every month from 5% of the houses/buildings in a zone, with a minimum of 5 houses/buildings sampled in each zone. All schools, child development centers (CDCs), child development homes (CDHs), medical, dental, and veterinary (MDV) clinics, and distribution system sample locations (also referred to throughout this document as fire hydrants, hydrants, hydrant locations, or distribution samples, or similar) previously sampled in Step 4 of the Red Hill response are to be sampled in each of the first 3 months (See Table 2). The 0-3 months phase will result in samples collected from a total of 15% of the houses/buildings in each zones during the 3-month period.
- *4-24 Months After Initial Drinking Water Sampling:* Samples will be collected pursuant to the Plan during four periods from 10% of the houses/buildings in each zone. Four periods will be separated as three 6-month periods and one 3-month period to reach 24 months. All schools, CDCs, CDHs, MDV clinics, and distribution system sample locations previously sampled in Step 4 of the Red Hill response are to be sampled in each of the 6-month and 3-month periods (See Table 2). The 4-24 month phase will result in samples collected from a total of 40% of the houses/buildings in each zone.

Building facilities to be included in the effort include high public health risk entities, such as schools, CDCs, CDHs, and MDV clinics.

Unless otherwise noted, all samples will be analyzed as listed in Table 5 of this Plan, aka "Compliance Monitoring."

Schools, CDCs, CDHs, MDV clinics, and distribution samples do not count towards the percentage of houses/buildings sampled in each round.

4. DW LTM SAMPLING PURPOSE AND IMPLEMENTATION

4.1 PURPOSE

The DW LTM is a surveillance tool intended to continuously ensure that the water is safe to drink, meets all State and Federal drinking water standards and is free of petroleum and response by-product contamination. A single water sample will be collected from each of the houses/buildings and fire hydrants selected for sampling in the zone. If the tap water results collected from all the representative houses/buildings that were sampled comply with Table 5 of this Plan, then it will be confirmed that the drinking water in the area remains safe to drink.

If the drinking water results collected from any of the sampled representative houses/buildings and fire hydrants do not comply with Table 5 of this Plan, go to Section 8 of this Plan (Response to a Detection or an Exceedance).

4.2 IMPLEMENTATION

This Plan will be implemented through drinking water sampling and completion of the conditions identified in the RAR as listed in Section 6 of this Plan.

4.2.1 0-3 Months After Initial Drinking Water Sampling

In the first three months[1], DW LTM samples will be collected every month from 5% of the houses/buildings[2] in a zone, with a minimum of five houses/buildings sampled in each zone (Table 2 of this Plan). These houses/buildings will be geographically distributed throughout the zone to provide spatial coverage along the water supply line and will not be the same houses/buildings that were sampled in Step 4, unless otherwise agreed upon by SDWB. New houses/buildings will be sampled to achieve more robust spatial/geographic coverage.

Drinking water samples shall be collected from the taps in these houses/buildings and analyzed for parameters listed in Table 5 using EPA Methods 524.2, 525.2/525.3, 200.8/245.1, supplemented with 8015 (Total Petroleum Hydrocarbon-Diesel (TPH-D) and TPH-Oil (TPH-O)), 8260 (TPH-Gasoline (TPH-G)), total organic carbon (TOC), and 8021 for Free Chlorine (field test).

Distribution system sample locations will be sampled and analyzed for parameters listed in Table 5.

Additional details on the 0-3 months sample site selection process are provided in Section 5.1 of this Plan and in Appendix A, Standard Operating Procedure (SOP) 3 for Scheduling and Sample Site Selection. The 0-3 month phase will collect samples from a total of 15% of the houses/buildings in each zone. **Wherever there is a conflict between the SOP and this Plan, this Plan governs.**

Within each sampling round, the Navy shall collect one (1) sample at the Entry Point to Distribution (EPD) from the Waiawa Shaft and analyze for the constituents shown in Table 1.

[1] For planning purposes, it was assumed that all the zones would start the 0-3 Month phase simultaneously, however in actuality the DOH advisory for each zone was amended in a staggered procession creating different DW LTM start dates per zone.

[2] House and building sampling shall ensure the ratio of houses and buildings sampled are proportional to the proportions in each zone; however, repeat samples from houses and buildings over the duration of DW LTM sampling shall be minimized. Additionally, and not included in the percentage calculation, all schools, CDCs, CDHs, MDV clinics and hydrant locations will be sampled in each period of the long-term monitoring (a total of 7 times).

In accordance with Section 5.1 of this Plan, the Navy shall provide a schedule and location of these samples to SDWB[3] for SDWB review and approval at least 1 week before the collection of these samples and will provide customer notification of this sample collection. SDWB may collect splits and/or stratified samples at these locations.

4.2.2 4-24 Months After Initial Drinking Water Sampling

Beginning in month 4 of this Plan, 4 additional sampling periods will be completed. There will be three (3) 6-month periods followed by a single 3-month period. During each of these four (4) periods, samples will be collected from 10% of the houses/buildings in a Zone (Table 2 of this Plan). [4] These houses/buildings will be geographically distributed throughout the area to provide spatial coverage along the water supply line and will not be the same houses/buildings that were sampled in Step 4. As much as possible, new houses/buildings should be sampled to achieve more robust spatial/geographic coverage.

Drinking water samples will be collected from the taps in these houses/buildings and analyzed for parameters listed in Table 5 using EPA Methods 524.2, 525.2/525.3, 200.8/245.1, supplemented with 8015 (TPH-D, TPH-O), 8260 (TPH-G), TOC, and 8021 for Free Chlorine (field test).

Distribution samples will be sampled and analyzed for parameters listed in Table 5.

Additional details on the 4- to 24-months sample site selection process are provided in Section 5.1 of this Plan and in Appendix A, SOP 3 Scheduling and Sample Site Selection. The 4-to-24-month phase will collect samples from a total of 40% of the houses/buildings in each zone. **Wherever there is a conflict between the SOP and this Plan, this Plan governs.**

In accordance with Section 5.1 of this Plan, the Navy shall provide a schedule and location of these samples to SDWB[5] for SDWB review and approval **at least 1 week** before the collection of these samples and will prepare customer notices of this sample collection. SDWB may collect splits and/or stratified samples at these locations.

[3] The schedule shall be provided to SDWB in PDF format for map(s) of prospective/actual sampling locations and Excel format for chart of prospective sampling locations.

[4] House and building sampling shall ensure the ratio of houses and buildings sampled are proportional to the proportions in each zone; however, repeat samples from houses and buildings over the duration of DW LTM sampling shall be minimized. Additionally, and not included in the percentage calculation, all schools, CDCs, CDHs, MDV clinics and hydrant locations will be sampled in each period of the long-term monitoring (a total of 7 times).

[5] The schedule shall be provided to SDWB in PDF format for map(s) of prospective/actual sampling locations and Excel format for chart of prospective sampling locations.

TABLE 1 ENTRY POINT TO THE DISTRIBUTION SYSTEM SAMPLING

Analytical Method	Analyte	CAS_RN	DOH / EPA MCL (µg/L)	DOH EAL (µg/L)	Incident Specific Parameter (µg/L)	Method Detection Limit (µg/L)
524.2	1,1,1-Trichloroethane	71-55-6	200/200	11	11	0.5
524.2	1,1,2-Trichloroethane	79-00-5	5/5	5	5	0.5
524.2	1,1-Dichloroethylene	75-35-4	7/7	7	7	0.5
524.2	1,2,4-Trichlorobenzene	120-82-1	70/70	70	70	0.5
524.2	1,2-Dichlorobenzene	95-50-1	600/600	10	10	0.5
524.2	1,2-Dichloroethane (EDC)	107-06-2	5/5	5	5	0.5
524.2	1,2-Dichloropropane (DCP)	78-87-5	5/5	5	5	0.5
524.2	1,4-Dichlorobenzene	106-46-7	75/75	5	5	0.5
524.2	Benzene	71-43-2	5/5	5	5	0.5
524.2	Carbon tetrachloride (CTC)	56-23-5	5/5	5	5	0.5
524.2	Chlorobenzene	108-90-7	100/100	25	25	0.5
524.2	cis-1,2-Dichloroethylene	156-59-2	70/70	70	70	0.5
524.2	Dichloromethane (aka methylene chloride)	75-09-2	5/5	5	5	0.5
524.2	Ethylbenzene	100-41-4	700/700	7.3	700	0.5
524.2	Styrene	100-42-5	100/100	10	10	0.5
524.2	Tetrachloroethylene	127-18-4	5/5	5	5	0.5
524.2	Toluene	108-88-3	1000/1000	9.8	1000	0.5
524.2	trans-1,2-Dichloroethylene	156-60-5	100/100	100	100	0.5
524.2	Trichloroethylene (TCE)	79-01-6	5/5	5	5	0.5
524.2	Vinyl Chloride	75-01-4	2/2	2	2	0.3
524.2	m,p-Xylenes	1330-20-7	10000/10000	13	10000**	0.5**
524.2	o-Xylenes	95-47-6	10000/10000	13	10000**	0.5**
525.2	1-Methylnaphthalene	90-12-0	—	10	2.1	
525.2	2-Methylnaphthalene	91-57-6	—	10	4.7	
525.2	Naphthalene	91-20-3	—	17	12	
525.2	Benzo[a]pyrene	50-32-8	0.2/0.2	0.06	0.06	0.02
525.2	Di(2-ethylhexyl)ph Di(2-ethylhexyl)phthalate (DEHP aka BEHP)	117-81-7	6/6	3	3	0.6
200.8	Antimony	7440-36-0	6	6	6	0.4
200.8	Arsenic	7440-38-2	10	10	10	1.4
200.8	Barium	7440-39-3	2000	220	220	2
200.8	Beryllium	7440-41-7	4	0.66	0.66	0.3
200.8	Cadmium	7440-43-9	5	3	3	1
200.8	Chromium	7440-47-3	100	11	11	7
200.8	Copper	7440-50-8	1300	2.9	2.9	50
200.8	Lead	7439-92-1	15*			1
245.1	Mercury	7487-94-7	2	0.025	0.025	0.2
200.8	Selenium	7782-49-2	50	5	5	2
200.8	Thallium	7440-28-0	2	2	2	0.3
EPA Approved	Total Organic Carbon (TOC)	TOC	—	—	2000	1500—
8260 PCHG 8015 PCHD 8015 MOIL	JP-5 as Combined Total Petroleum Hydrocarbons (TPH)-Gasoline, Diesel, and Oil Ranges[2] [Incident Specific Parameter]	PCHG PCHD MOIL	Not Applicable	266	266	GRO, DRO, ORO = 50
8021	Chlorine, Free (Field Test)	CHLORINE	—	—	4000	—

Table 1 Notes:

Method Detection Limit is the limit that determines when an analyte can be detected (either the LOD or the MDL). Detections above this level and below the Method Reporting Level (MRL or LOQ) are deemed "detected" and will be qualified as estimated (J).
* Action Level for Lead.
** 10,000 ug/L is the MCL for Total Xylenes.
MCLs: DOH regulatory constituents
DOH EALs: Table D-1a. Groundwater Action Levels (Drinking Water, Surface Water <150 meters) (DOH 2017). https://health.hawaii.gov/heer/files/2019/11/HDOH-EAL-Surfer-Fall-2017.xlsx; Volume 2 Appendix 1, Section 6.6.

5. DW LTM SAMPLING OPERATIONS

DW LTM sampling operations are executed by three Navy core teams and further detailed in the subsections below:

- Sampling preparation, supply inventory and management, and sample shipping operations
- Field sampling operations
- Chemists, data managers, and data quality control (QC) managers

Sampling operations, including field operations, sample scheduling and tracking, site notification, sample preparation, sample shipment, and sample transportation to the laboratory are outlined in detail in Appendix A, SOP 4.

5.1 SAMPLE SITE SELECTION

The quantity and locations of samples will be identified through the guidance in this section as well as discussed in Appendix A, SOP 3. The number of samples by zone, monitoring phase, and by month are summarized in Table 2. Zone, neighborhood, and address information for all associated schools, CDCs, CDHs, and MDV clinics are presented in Table 3.

5.1.1 Scheduling and Sample Site Selection

The Navy will propose to SDWB the selected sampling sites for review **at least 1 week** in advance of commencement of sampling, unless an alternate schedule is approved by DOH. Failure to meet this requirement may delay DW LTM sampling schedules. The Navy will issue notices to building occupants and residents. This process is further discussed in Appendix A, SOP 3 of this Plan. Procedures for site selection are detailed in Appendix A, SOP 3 Scheduling and Sample Site Selection.

DW LTM sample sites will be preferentially selected proximal to locations where there were exceedances during the previous sampling round(s).

MDV clinics and compromised communities (i.e., Long-Term Facilities, Retirement Communities, Independent Communities, Residential Care Home) which service vulnerable populations shall be included/listed in the DW LTM as priority building sampling locations. No compromised community facilities are currently connected to the System.

TABLE 2 ESTIMATE OF THE NUMBER OF SAMPLES BY ZONE AND BY MONTH OR MONITORING PERIOD

Zone Name	Zone	Residences[1]	Non-residences[1]	CDHs[2]	CDCs[3]	Schools[4]	MDVs[5]	Distribution (Hydrants) [6]	Total Buildings	Samples (M0-M3)[7]	Samples (M4-M24)[8]
Pearl City Peninsula	A1	635	32	1	-	-	-	6	667	41	74
Ford Island	A2	411	112	3	1	-	-	10	523	42	68
Iroquois Point	A3	1,459	33	-	-	2	-	8	1,492	93	168
McGrew/Halawa	B1	227	38	-	-	-	-	2	265	16	29
Sub Base	C1	-	183	-	2	-	4	6	183	24	33
Hale Alii, Marine Barracks, Hospital Point	C2	32	126	-	-	-	1	7	158	16	24
Shipyard Hospital Point	C3	6	137	-	-	-	-	2	143	10	17
Hale Moku Hokulani	D1	508	74	-	2	1	-	6	582	45	74
Hickam Hale, Na Koa Officer Field Area, Onizuka Village	D2	1,577	224	-	1	1	2	11	1,801	111	201
Earhart Village	D3	912	115	-	6	4	1	8	1,027	93	144
Hawaii Air National Guard	D4	0	148	-	-	-	1	2	148	11	18
Makalapa	E1	89	63	-	1	1	-	4	152	19	27
NEX Moanalua Terrace	F1	752	91	-	1	1	2	8	843	60	102
Catlin Park, Maloelap, Doris Miller, Halsey Terrace, Radford Terrace	F2	1,435	59	2	2	-	-	14	1,494	95	170
Camp Smith	G1	10	49	-	-	-	-	1	59	4	7
Aliamanu Military Reservation (AMR)	H1	918	12	2	4	-	-	3	931	60	106
AMR	H2	230	1	2	-	-	-	3	230	17	29
AMR	H3	379	-	-	-	-	-	3	379	22	41
Red Hill Housing	I1	135	6	-	-	1	-	1	141	14	21
	Total	**9,715**	**1,503**	**10**	**20**	**11**	**11**	**105**	**11,218**	**793**	**1,353**

Resamples, Field Duplicate (FD), Trip Blank (TB)	15%
Samples / Team / Day	5
Working Days / Month	20

	Samples (M0-M3)	Samples (M4-M24)
Samples/Month	793	226
Resamples	119	34
Samples/Month	**912**	**260**
Samples/Day	46	13
# Teams	10	3

	M0-M3	M4-M24	Total
Total # anticipated samples	2,736	6,224	8,960

Footnotes:

1. Samples will be taken from 5% of houses/buildings in each of the first 3 months; samples will be taken from 10% of houses/buildings for each period of sampling from Month 4-24 (three 6-month periods; one 3-month period).
2. One sample will be taken from each CDH each sampling period and will not be included as part of the houses/buildings percentage. Quantities subject to change based on resident participation in CDH program.
3. Two samples will be taken from each CDC each sampling period and will not be included as part of the houses/buildings percentage.
4. Five samples will be taken from each School each sampling period and will not be included as part of the houses/buildings percentage.
5. One sample will be taken from each Medical/Dental/Veterinary clinic each sampling period and will not be included as part of the houses/buildings percentage.
6. One sample will be taken from each hydrant each sampling period; samples collected from hydrants previously sampled in Step 4.
7. Samples required per month in Phase 1 (Months 0-3).
8. Samples required per period in Phase 2 (Months 4-24); three 6-month periods and one 3-month period.

TABLE 3 LOCATION INFORMATION FOR SCHOOLS, CDCS, CDHS, AND MEDICAL, DENTAL, & VETERINARY (MDV) CLINICS

Zone	Neighborhood / Bldg. Description	Category
A1	Pearl City Peninsula	CDH
A2	BLDG 350 - Ford Island CDC	CDC
A2	Ford Island	CDH
A2	Ford Island	CDH
A2	Ford Island	CDH
A3	Iroquois Point Elementary	School
A3	Iroquois Point Preschool	School
C1	BLDG 1655 - Pier Side CDC	CDC
C1	BLDG 679 - Armed Services YMCA	CDC
C1	BLDG 1535 – Medical Clinic/SARP – Pearl Harbor	MDV
C1	BLDG 1407 – Naval Station Pearl Harbor Dental & Navy Branch Health Clinic	MDV
C1	BLDG 1514 – Navy Medical Readiness Clinic (MRC)	MDV
C1	BLDG 584 – CNSG MIDPAC Clinic	MDV
C2	BLDG 1750 – Pearl Harbor Navy Shipyard Environmental (Occ. Health) Clinic	MDV
D1	Kids Cove 24/7 CDC	CDC
D1	Center Drive CDC LE	CDC
D1	Pearl Harbor Kai Elementary School	School
D2	Hickam Elementary	School
D2	Hickam Harbor CDC	CDC
D2	BLDG 559H – 15th Medical Group & Hickam Pharmacy	MDV
D2	BLDG 554H – Occupational Health Clinic	MDV
D3	Hickam Main CDC	CDC
D3	Hickam West CDC	CDC
D3	Trinity "Missionary" Baptist Church	CDC
D3	Pearl Harbor Church of Christ	CDC
D3	BLDG 1330 - Hickam Youth Center	CDC
D3	Hickam School Age Center	CDC
D3	Chester Nimitz Elementary School	School
D3	Holy Family Catholic Academy (Holy Trinity School)	School
D3	Assets School	School
D3	Mokulele Elementary School	School
D3	BLDG 1864H – Public Health Command – Pacific Veterinary Clinic	MDV
D4	BLDG 3365H – Clinical Lab – Epidemiology	MDV
E1	BLDG 80 - Montessori Center	CDC
E1	Hale Keiki School	School
F1	Pearl Harbor Elementary	School
F1	Moanalua Pre-School - Kama'aina Kids	CDC
F1	Hook Orthodontics, Moanalua Shopping Center	MDV
F1	Pearl Family Dental Care, Moanalua Shopping Center	MDV
F2	Catlin School Age Children	CDC
F2	Peltier CDC	CDC
F2	Halsey Terrace	CDH
F2	Doris Miller	CDH
H1	BLDG 1783 - AMR CDC	CDC

Zone	Neighborhood / Bldg. Description	Category
H1	BLDG 1782 - AMR Child Youth Services Center	CDC
H1	BLDG 1795 - AMR Youth Activities Center	CDC
H1	Rim Loop	CDH
H1	Bougainville	CDH
H1	BLDG 1875 - AMR YMCA	CDC
H2	Skyview	CDH
H2	Skyview	CDH
I1	Red Hill Elementary School	School

5.1.2 Alternate Sample Sites and Event Changes

Alternate sample site locations may be required for instances such as, but not limited to:

- High ambient photoionization detector (PID) reading
- Vacant location with no water or stagnant water
- Loose pets
- No key available from facility maintenance
- Ill resident in home
- Unaccompanied minor in home
- Continued missed appointments by tenant
- Tenants unwilling to support sampling
- Other unsafe conditions

In these instances, an alternate sample location and event change is required. Sampling teams have the capability to reprint labels in the field and update field logs to accommodate sample location changes. Procedures for selecting an alternate site, adjusting sample labels and chain of custody (COC) forms, and creating an EDMS event change is presented in Appendix A, SOP 3 Scheduling and Sample Site Selection. Sample sites and event changes will be documented to include the reason why a location was not sampled.

5.2 Field Sampling Operations

Field staff are responsible for collecting samples each day according to assignments prepared by the scheduling team. Field staff begin their day at the sample staging area to receive their assignments and sample collection kits. The sampling teams end their day at the sample staging area to return the sample collection containers so they can be prepared for transport to the analytical laboratories.

5.2.1 Field Sampling Team Staffing and Schedule

Field sampling operations are controlled by a senior operations manager, with assistance from a deputy operations manager. Each sampling team will consist of two (2) staff, a vehicle, and a sampling kit.

Prior to sampling, the field team will inspect all supplies and consumables to ensure that they are acceptable for use. DW LTM sample collection procedures are detailed in Appendix A Drinking Water Sample Collection SOPs (SOP 1A and SOP 1B).

5.2.2 DOH Field Oversight Team

The DOH field oversight team shall be provided with Defense Biometric Identification System (DBIDS) access to JBPHH to randomly inspect the field sampling and/or sampling operations for quality assurance. The Navy and Army must provide base access to DOH personnel engaged in this oversight. Upon receipt of the sampling plan, if DOH representatives desire to inspect, DOH shall submit for DBIDS installation access to allow for a week of processing. The Department of Defense must either provide DOH staff or DOH contractor with DBIDS credentials, for the duration of the DW LTM, or escort upon request.

5.3 CHEMISTRY AND DATA MANAGEMENT

A team of chemists and data managers will track and verify the laboratory data as it is uploaded into EDMS. Dedicated staff and redundant chemist lab coordinators will focus on communicating with each lab. Lab coordinators serve as the primary liaison with the water quality labs, and their daily contact with the labs results in quicker lab processing of samples.

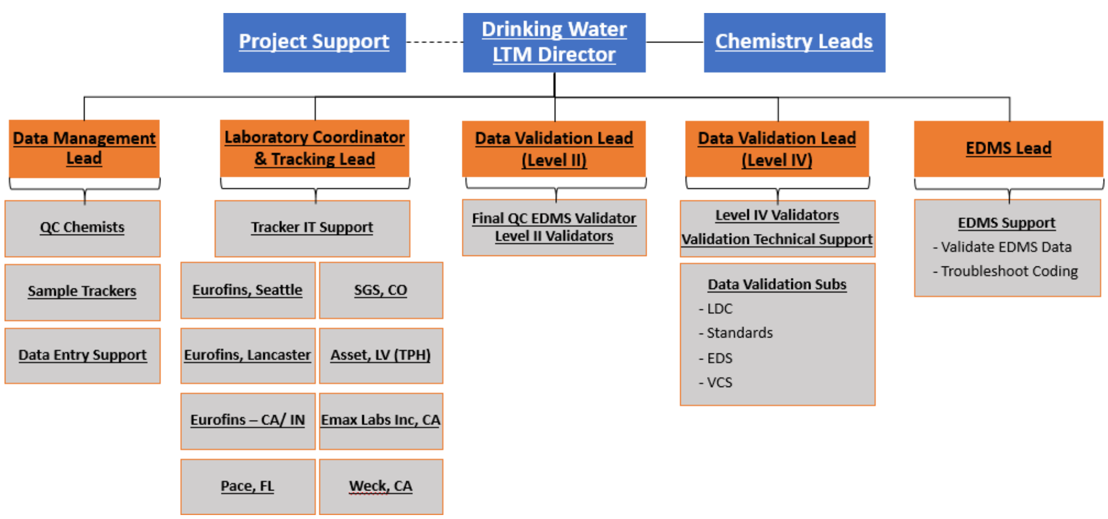
Lab coordinator responsibilities are listed below:

1. Coordinate with the lab
2. Act as the lab point of contact (POC)
3. Input samples status into tracker
4. Check that the lab uploaded data
5. Review initial lab data

Additional dedicated staff will serve in support and back-up roles for each of the lab coordinators, in many cases assigning people from the labs or other time zones, to promote full-time coordination.

The team of chemists and data managers is presented in Figure 1.

FIGURE 1 CHEMISTRY TEAM



5.3.1 Laboratory Analytical

Analytical laboratories are currently under contract to provide an expedited turn-around-time (TAT) on sample analytical results. However, there may be instances when the requested TAT is exceeded and will have to be individually managed.

Table 4 below lists, for each analyte group, the sample containers, preservatives, and applicable hold times as required by SW-846 and state and federal drinking water methods. All analytical required supplies, sample containers and preservatives, and shipping supplies will be provided by the analytical laboratory.

TABLE 4 SAMPLE CONTAINERS, PRESERVATIVES, AND HOLDING TIMES

Parameter	Analytical Method	Container	Preservative	Holding Time
Volatile Organic Compounds	524.2	3 x 40 mL Glass VOA	0.5 mL HCl (Unchlorinated); 25 mg Ascorbic / 3 drops HCl (Chlorinated)	14 days
Synthetic Organic Compounds	525.2/ 525.3	2 x 1 L Amber Glass	525.2 2 mL HCl (unchlorinated); 45 mg Sodium Sulfite / 2 mL HCl (chlorinated) 525.3 Ascorbic Acid, EDTA, KH2Citrate	14 days
Metals	200.8/245.1	250 mL Poly	1 mL HNO_3, pH<2	6 months /28 days
JP-5 (Total Petroleum Hydrocarbon [TPH], Diesel/Oil Ranges)	8015	2 x 1 L Amber Glass	0.5 mL HCl	14 days
JP-5 (TPH-Gasoline Range)	8260	3 x 40 mL Glass VOA	0.5 mL HCl	14 days
Total Organic Carbon (TOC)	EPA Approved	3 x 40 mL Glass VOA	Acidify to pH < 2 with H2SO4 or H3PO4 immediately after collection and cool to ≤ 6°C, but not frozen.	28 days
Chlorine, Free (Field Test)	8021			
Haloacetic Acids (HAA5)	552.2/552.3	2 x Amber Glass	Ammonium Chloride	14 days
HPC	SM9215B Pour Plate/SM9215E SimPlate	125 ml or 150 ml Plastic Bottles		24 hours

Note: All samples will be chilled to < 6°C.

Table 5 of this Plan presents the analytical methods and associated analytes, action levels, and method detection limits (MDL) along with regulatory standards, including the Federal and State Maximum Contaminant Levels (MCL) for drinking water and SW-846 analytical methods, respectively. Any updates of these parameters will be provided in addendums to this document.

COC documentation will be maintained for samples during all phases of sample collection, transport, and receipt and internal transfer within the laboratory.

5.3.2 Data Quality

Field QC samples will be collected during each sampling event to include field duplicates, field reagent blanks, and trip blanks. Field duplicates will be collected at a frequency of 10% the number of the normal samples and field reagent blanks, and trip blanks will be collected daily for each sampling event in accordance to the procedures described in Naval Facilities Engineering Systems Command (NAVFAC)

Pacific Environmental Restoration Program Project Procedure III-B, *Field QC Samples* (Water, Soil) (Navy 2015) and as specified in the respective drinking water methods.

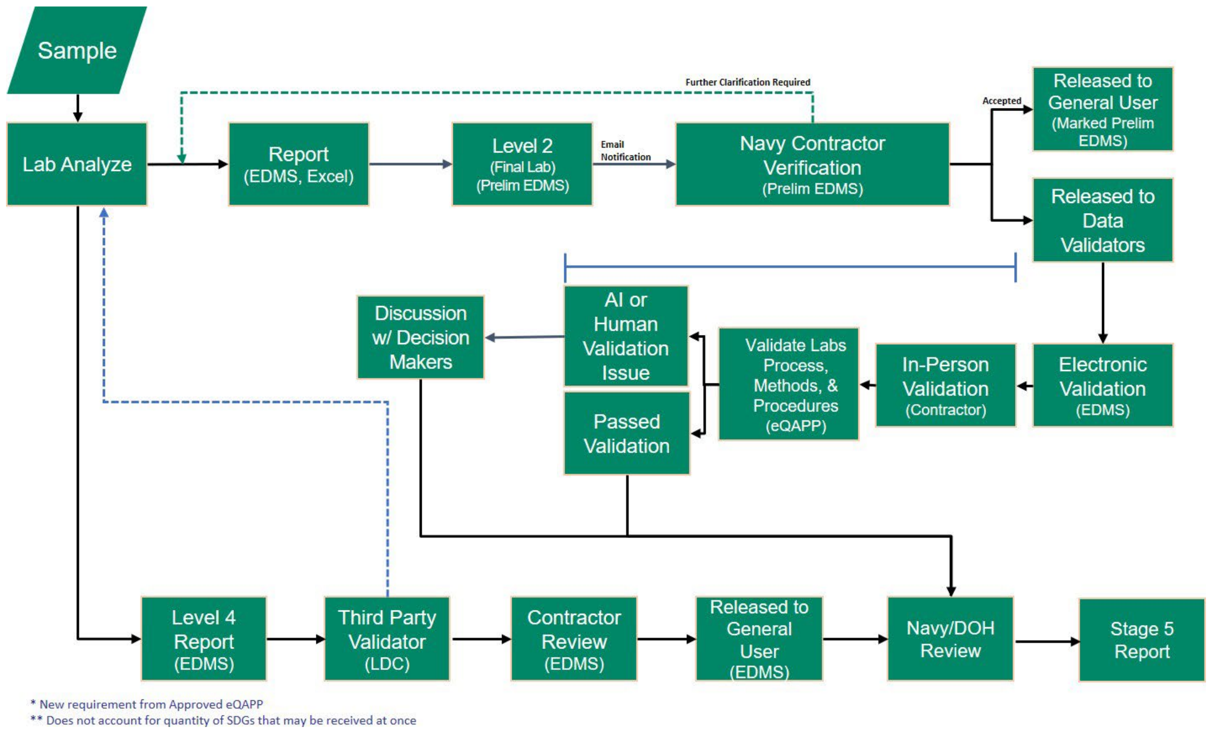
The analytical laboratory will report non-detected results to the method detecting limit. Detections between the method detection limit (MDL) and the method reporting limit (MRL) are detections and should be flagged as estimated (J).

Level 2 and Level 4 data packages will be provided by the laboratory for all DW LTM samples that are collected according to the schedule in Figure 4. Ten percent of the drinking water compliance samples will undergo Level 4 data validation by an independent validator (i.e., the validator will be independent of the laboratory who performed the analyses). This percentage of samples requiring Level 4 validation is per zone and period and may be increased depending on the number, type, and severity of corrective actions that are identified by the data validator; however, the percentage per zone in each period can fluctuate to accommodate the number of samples collected. The remaining samples will undergo Level 2A data validation.

5.3.3 Laboratory Data Review Process

Figure 2 illustrates the laboratory data analysis and validation process. As shown in Figure 2, once lab data is entered into the EDMS and verified, Level 2 and Level 4 validation efforts start. Level 2A validation includes both a computerized validation and manual review and validation by chemists. Both processes generally act together to produce the Level 2A validation in a timely manner. However, as is the case with any laboratory analyses, some samples will not pass this QC step and will be singled out for further discussion with the Navy/Army Team. A record of the discussion and decision must be memorialized and submitted to DOH. Level 4 validation is a separate process that starts with the labs providing Level 4 data packages, reports that are hundreds or thousands of pages long. Those packages are validated by a data validator contractor, an independent third-party validator, and further reviewed for approval by the Navy/Army Team.

FIGURE 2 LAB DATA REVIEW PROCESS FLOWCHART



5.4 PRESENTATION OF DATA

Data must be uploaded to EDMS and be available in a comprehensive, full system view, as well as per zone. All field sample results associated with the DW LTM program shall also be included in EDMS.

The following is an excerpt from page 1 of the Interagency Drinking Water System Team – Data Management Plan, dated January 24, 2022:

> *"This Site-Specific Data Management plan (SSDMP) is intended to provide guidance for data collection and subsequent data management activities associated with the activity detailed below. The data collection and management practices identified in this plan are designed to ensure data integrity and consistency throughout the response activity. The SSDMP is not intended to be all encompassing regarding data management. Additionally, this document is intended to be updated as data management practices change. If there is a substantial change in activity or phase of the response, i.e. necessitates a new sampling plan, a new SSDMP should be written or updated upon written agreement with all parties involved.*
>
> *Data collected under this SSDMP only applies to the emergency response related to the November 20, 2021 release of a mixture of jet fuel/water into the Red Hill Shaft and subsequent transport to the Joint Base Pearl Harbor-Hickam (JBPHH) drinking water distribution system. Only data obtained after the Drinking Water Sampling Plan was signed by the Interagency Drinking Water System Team (i.e., Navy, Army, Hawaii Department of Health [HDOH], and United States Environmental Protection Agency [EPA]) on December 14, 2021 will be included in this SSDM. Historical Data and data from other events that are not associated with the Red Hill/JBPHH Drinking Water System Site (as defined herein) will not be included in the site-specific*

database without prior written consensus of the signees of the Interagency Drinking Water System Team (IDWST).

All validated (Level 2 or Level 4, as appropriate) drinking water data/information that is collected/developed under this plan is subject to Uniform Information Practices Act (HRS 92F) and the Freedom of Information Act (FOIA).[1] *All members of this team will have equal access to the data and management of access/permissions to the database management system. The IDWST Communications Plan(s) will identify the process and schedule to approve release of data. All Approvals/Disapprovals will be documented in the daily IDWST Meeting Minutes or IDWST Decision Memos. All members are allowed to access and download data from the system at any point.* ***Data is owned by the individual agency that submitted the data.*** *However, all data in the EDMS/database will be shared with all parties of the IDWST without restriction. [emphasis added]*

This SSDMP is an Evergreen document—meaning that it is intended to be updated/modified, as necessary, to fulfill the mission of the IDWST. All revisions/edits of this plan require prior approval of the signees of the IDWST (or their designees), which will be documented in the daily IDWST Meeting Minutes."

[1] *The US EPA has guidance documents for environmental data verification and data validation which can be generally summarized by the following levels of data quality:*
Level I Data Validation: Verification is made to confirm that analytical methods, analytes, and reporting levels are consistent with project objectives as well as applicable state and federal regulations.

- *Level II Data Validation: In addition to a Level I data validation, these data are reviewed to verify that supporting QA/QC are of a level of quality necessary to support sample results.*
- *Level III Data Validation: In addition to a Level I and II data validation, these data undergo a detailed review to ensure reported results have valid laboratory procedures and documentation underpinnings. This includes all evaluations that are not derived exclusively from raw instrument data.*
- *Level IV Data Validation: These data undergo full review and evaluation of a complete Data Validation Package (DVP) according to DQO/QAPP specific criteria, and National Functional Guidelines. This level of review includes all summaries, and raw data associated with the data package, and ensures the highest level of defensibility.*

6. Removal Action Report Conditions

As stated in *DOH's Guidance on the Approach to Amending the Public Health Advisory, Addendum 1,* dated February 12, 2022, "*DOH's priority is to protect the public health of the people of Hawaii. The guidance is based on "lines of evidence" (Table 1 [of the referenced guidance]) that must be met before DOH will amend the health advisory and issue notices that the water can be used for drinking. The Navy must also commit to following the [DW] LTM of system water quality for this incident under the IDWST Drinking Water Sampling Plan, as amended.*" References made to "Memo" in Sections 6.1 – 6.3 refer to the memorandum for record provided in the identified sections of the RAR submitted by the Navy to the IDWST for each zone. These RAR provided the framework for the lines of evidence used by DOH to amend each zone per the previously stated guidance.

In connection with DOH's amendment of the Public Health Advisory, prospective actions were required for certain Zones. Those conditions and, where appropriate, the steps for fulfilling them are set forth in this Plan.

6.1 Tank Cleaning

In accordance with the RAR, Section 2a.5 Memo, dated February 26, 2022:

> *…regarding the Water Storage Facilities and Water Source for Zones A1, A2, A3, B1, C1, C2, C3, D1, D2, D3, D4, G1, E1, F1, F2, H1, H2, H3, and I1, "the inspection of the water storage tanks will be conducted in accordance with American Water Works Association (AWWA) Standard for Inspecting and Repairing Steel Water Tanks, Standpipes, Reservoirs, and Elevated Tanks by personnel with the requisite qualifications outlined in this AWWA standard. The planned work is scheduled to be completed before the end of this calendar year." See also Section 2a.5 Memo Enclosure (3) for the Memorandum for Record, dated 25 February 2022, regarding Inspection, Maintenance, and Cleaning of Potable Water Tanks.*

The above commitment will be fulfilled with successful completion of this Plan.

6.2 Cross Connection Control Federal Fiscal Year 2022 Survey

In accordance with the RAR, Section 1c.1 Memo, dated March 7, 2022:

> *The Navy has committed to the funding and performance in FY2022 of a comprehensive cross connection control survey of the entire JBPHH water system per the December 2021 AH Engineers & Scientists Water Quality CAT Memorandum.*
>
> *Comply with the COMNAVREG HAWAII INSTRUCTION 11330.2D, dated 19 Sep 2016, Backflow Prevention and Cross-Connection Control Program.*

The above commitment will be fulfilled with successful completion of this Plan.

6.3 Closed Inactive Underwater Interconnections or Distribution Lines

6.3.1 Closed Inactive Underwater Distribution Line - Secured

The currently inactive underwater distribution line at JBPHH Bishop Pt-Iroquois Pt (Zone D2 – Zone A3) is closed and secured. In accordance with the RAR, Section 2a.5 Memo Enclosure (5), dated 25 February 2022:

> *The interconnection was secured on 05 Dec. 2021 by closing the gate valve on each end (shore) of the interconnection. The water between these valves has not moved since then. When we bring this section back online, the process will be as follows....*

1. *Secure two additional valves (126 and 130 at West Loch). See Enclosure (1).*
2. *Open valve 128 (currently shut) at West Loch*
3. *Open valve at Hickam that is currently shut*
4. *Open and flush from hydrant no. 64 at West Loch, located between valves 126 and 128.*
5. *Flush transmission line for 6-8 hours to the sanitary sewer.*
6. *Flushing, chlorination and testing of the transmission main will follow ANSI/AWWA C651-05:*
7. *Disinfecting Water Mains.*
8. *Collect first sample for bacteriological testing after flushing.*
9. *Collect second sample (at least 24 hours after first sample) for bacteriological testing.*
10. *Open valves 126 and 130 and valves on Bishop Point, completing the loop.*

In accordance with the mentioned Memo, when reactivating this underwater distribution line, the Navy shall fulfill this commitment with the successful completion of this Plan.

6.3.2 Closed Inactive Underwater Distribution Line - Broken

The inactive underwater transmission line, at Ford Island-Hospital Point (Zone A2 – Zone C3) is broken. As described in the RAR, Section 2a.5 Memo Enclosure (4), dated 22 February 2022, the 24-inch underwater crossing was damaged by a contractor who drilled through the casing and pipe. **Design of the repairs to remedy the broken line is subject to review and approval by DOH under Hawaii Administrative Rules (HAR) §11-20-30.**

6.4 Lead and Copper Monitoring

Lead and Copper Rule monitoring will continue under normal SDWB regulatory authorities.

6.5 Flushing Plan

The development of a comprehensive, working hydraulic model; a valve inventory and maintenance program; and a flushing plan is a necessary component of a large, regulated water system's continuous obligation to ensure a safe, compliant and reliable supply of drinking water to its customers. During normal operations, routine flushing can significantly improve aesthetic water quality and help restore consumer trust in water quality at their taps.

Both the Navy and Army PWS, previous to the emergency, did not have: 1) an established routine flushing plan; 2) a complete inventory of valves in good working order, and 3) possessed a completed hydraulic model. These tools and practices can help the JBPHH PWS quickly respond to future contamination events in an efficient manner.

DOH acknowledges that the execution of these critical components of a water system's management and operations may extend beyond the time frame of the Plan's 24 months and can therefore be addressed under DOH Safe Drinking Water Act (SDWA) jurisdiction.

6.6 Water Response Team Operation

The Water Response Team Operation was turned over to the Joint Base Pearl Harbor-Hickam Public Works Department for action on April 1, 2022, incorporating requirements within their steady state operations. While the DW LTM is ongoing, calls and correspondence from customers of the water system will be received with a continued focus on providing timely response on system flushing and testing for TPH.

6.7 Condition of Removal Action Report for Zone D2

Hickam Officers Club, Building 901H, in Zone D2 is located at 2000 Signer Boulevard, Honolulu, Hawaii 96818. Samples taken at the facility on January 16 and January 18, 2022, exceeded the Maximum Contaminant Level of five (5) parts per billion or 0.005 mg/L of methylene chloride (also known as dichloromethane). This building has been closed for renovations as of April 2022. DOH is requiring the Navy to conduct the following as stated below to ensure that public health is protected:

1. Continue the isolation of the facility from the distribution system through a backflow preventer or by securing a valve to ensure that the source of the contamination would not impact the rest of the JBPHH Public Water System;
2. Maintain “RESTROOMS CLOSED” signs and prevent use of water;
3. Conduct an assessment, workplan, and implementation of locating and removing the source of methylene chloride;
4. Prior to the initiation of the renovations, develop and implement a health and safety plan for worker safety to include, but not be limited to, handling, protection from and potential health effects of methylene chloride;
5. Sample and analyze for Volatile Organic Compounds to include methylene chloride at same locations[outdoor spigot with no aerator];
6. Report the sample results to DOH;
7. Conduct further corrective actions as needed;
8. Notify and provide documentation to DOH once the corrective actions have been completed; and
9. Only reopen the facility following DOH approval.

6.8 Condition of Removal Action Report for Zone G1

Several residential homes in Zone G1 (Camp Smith) exceeded DOH’s TOC ISP set at two (2) parts per million (ppm) during Stage 4. Although there are no health-based standards for TOC, it is important for DOH to evaluate TOC in water distribution systems when levels are at or above DOH’s ISP. TOC can also be an indicator of other issues within a water distribution system that can impact drinking water quality and potentially public health. In addition, TOC analysis is used as a marker of the possible presence of regulated disinfection byproducts. TOC are naturally occurring organic molecules found in water and when elevated levels of these organic molecules come in contact with chlorine, disinfection byproducts can be formed. These disinfection byproducts do have health-based standards and if not monitored and managed effectively, could exceed regulatory Maximum Contaminant Levels. Investigating TOC levels are appropriate management controls when operating a water system. Therefore, due to the cluster of elevated TOC results found at locations 2133, 2151, 2165, and 2173 Baugh Road and 739, 749, 751, 755, 761, and 763 Anderson Road at a range of 7.22 – 12.6 ppm, DOH is requiring Navy to complete the following investigative procedures within 75 calendar days after amendment of this zone and in chronological order as stated below:

1. Perform a cross-connection survey representing the above cluster of buildings;
2. Sample for TOC at same locations identified above;
3. Sample for free chlorine at same locations identified above;
4. Re-flush according to the building flushing plan;
5. Sample for TOC at same locations identified above; and
6. Sample for free chlorine at same locations identified above.

Because TOC was detected above four (4) ppm, the public water system must analyze for the additional parameters listed in COA 2 for TOC in Section 8.2.2.

7. DW LTM SCHEDULE

Actual start dates for DW LTM were determined by the staggered amendment of the public health advisories in each separate zone; however, the schedule below assumes that months 1-3 of the DW LTM in all zones will begin on day zero and be repeated day zero +30 and day zero +60. It is assumed that Months 4-24 of the DW LTM will occur in all zones beginning in June 2022. Sampling during the six- month blocks may be, as practicable, spread out across the block to equalize the workload from month to month. The schedule is subject to change with the approval of DOH.

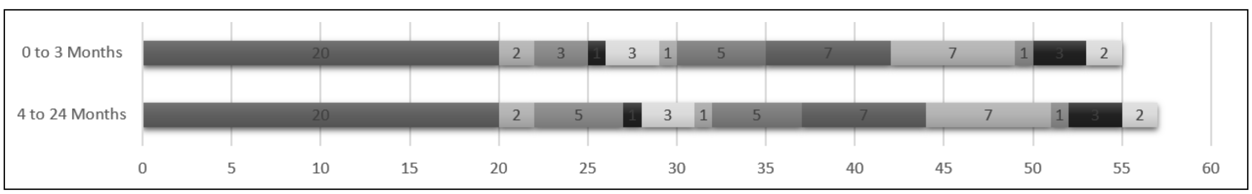
FIGURE 3 0-24 MONTHS DW LTM SCHEDULE

1 Mar '22 Sample 5%	2 Apr '22 Sample 5%	3 May '22 Sample 5%	4 June '22 Sample 1/4th	5 July '22 Sample 1/4th	6 Aug '22 Sample 1/4th	7 Sept '22 Sample 1/4th	8 Oct '22 Analysis & Reports	9 Nov'22 Analysis & Reports	10 Dec '22 Plan & Schedule	11 Jan '23 Sample 1/4th	12 Feb '23 Sample 1/4th
13 Mar' 23 Sample 1/4th	14 Apr '23 Sample 1/4th	15 May '23 Analysis & Reports	16 June '23 Sample 1/4th	17 July '23 Sample 1/4th	18 Aug '23 Sample 1/4th	19 Sept '23 Sample 1/4th	20 Oct '23 Analysis & Reports	21 Nov'23 Analysis & Reports	22 Dec '23 Plan & Schedule	23 Jan '24 Sample 1/2nd	24 Feb '24 Sample 1/2nd

The subtasks and assumed days to complete are presented in Figure 4.

FIGURE 4 0-24 MONTHS DW LTM SUBTASKS AND ASSUMED BUSINESS DAYS TO COMPLETE

DW LTM Subtasks	Sampling	Sample Shipping	Laboratory Analysis	Lab Results (Level II Package)	Level II Data Validation	Level II Packages Available to Navy/Army	Navy/Army Data Review	Lab Results (Level IV Package)	Level IV Data Validation	Level IV Available to Navy/Army	Stage 5 Report	HI DOH Review	Total Duration
0 to 3 Months	20	2	3	1	3	1	5	7	7	1	3	2	55
4 to 24 Months	20	2	5-10	1	3	1	5	7	7	1	3	2	57-62



8. Response to a Detection or an Exceedance

8.1 Sample Result Exceedance Data Package

In the situation where the monitoring identifies an exceedance of the parameter limits defined in Table 5, the System will provide DOH an information package on the sample of concern. The information package will include, but not be limited to:

1. Notify SDWB via sdwb@doh.hawaii.gov within 24 hours of receipt of a report of an exceedance from the laboratory (preliminary, DO NOT wait until level 2 validation is complete);
2. Provide location address and Zone;
3. Field crew notes (which shall be scanned daily and posted to EDMS);
4. Select information from the Sample Tracker Spreadsheet (or its replacement when the tracker is moved to EDMS); and

Proceed to Section 8.2 for the COA scenarios that the System will execute within five (5) calendar days of reporting the exceedance. The schedules and milestones within this section are subject to change with the approval of DOH.

8.2 Next Steps after Detection or Exceedance

Following receipt of data indicating a detection or an exceedance, System will comply with the applicable COA provided in this section. Four (4) COAs were developed to cover the following scenarios:

- Distribution System (i.e., Hydrant) Exceedance
- House/Building Exceedance
- Distribution System or House/Building Detection of BTEX[6] Less than MCL
- Detection of Other Analytes at Concentrations Less than the MCL

Please note that SDWB reserves the right, as the regulatory authority to modify specific COAs/requirements as warranted by the scenario. Contingent on where (distribution system or building) and what analyte was detected/exceeded, an associated COA is applied. A list of analytes and the associated COA is provided in Table 5. The schedules and milestones within this section are subject to change with the approval of DOH. SDWB will notify the Navy/Army to request site access, should SDWB decide to collect samples for any of the following COAs. The Navy/Army must provide access within 7 calendar days.

8.2.1 COA 1 – Distribution System (i.e., Hydrant) Exceedance

This COA is for all analyte exceedance reported within a water distribution system at a hydrant during DW LTM. The Navy must inform SDWB regarding actions to be taken prior to each step below.

1. Notify SDWB via sdwb@doh.hawaii.gov within 24 hours of receipt of the lab report (lab preliminary, DO NOT wait until Level 2 validation is complete);
2. Provide SDWB an information package consisting of items 1-5 in Section 8.1;
3. Navy will identify a minimum of 2 bracketing hydrant points in addition to the original exceedance location (3 total); Flush each hydrant sufficiently to bring fresh water from the nearest mainline junction;

[6] BTEX stands for benzene, toluene, ethylbenzene, and xylene. These are four specific compounds found in the Total Petroleum Hydrocarbons – Gasoline Range (TPH-g) category. BTEX chemicals are used in many products including JP-5.

4. Re-Sample;
5. Analyze for the method(s) specified for each exceeded analyte(s), instruct lab to report all Table 5 contaminants for the specified method(s); and
6. If result of re-sampling of initial hydrant is above AL, but results from bracketed samples are below AL, repeat sampling of initial hydrant for analyte(s) in question
7. Refer to "Remedial Actions" for different re-sampling result outcomes for the associated response.

For TOC exceedances, in addition to the above, the Navy shall:
1. Analyze for TOC/dissolved organic carbon (DOC), HPC, DBP, and chlorine residual.

8.2.2 COA 2 – House/Building Exceedance

This COA is for all analyte exceedance reported within a house/building premise plumbing during DW LTM. The Navy must inform SDWB regarding actions to be taken prior to each step below.

1. Notify SDWB via sdwb@doh.hawaii.gov within 24 hours of receipt of the lab report (lab preliminary, DO NOT wait until Level 2 validation is complete);
2. Provide information package items 1-5 in Section 8.1;
3. Provide additional investigator information with 24 hours of a reported exceedance to include the following items, pending availability:
   a. Available plumbing as-builts; and
   b. Maintenance records for the subject facility or residence;
4. Notify house/building tenant of the exceedance and provide a recommendation regarding water use.
5. If the Navy/Army suspects the contaminant of exceedance originated from the fixture, the Navy/Army may elect to: 1) replace the fixture if indicated by analyte detected (i.e., lead/copper [consult with DOH for other analytes]); 2) sample[7]; 3) flush for a minimum of 15 minutes; and 4) re-sample, as practiced in prior exceedances during the emergency response. Notification must be provided to SDWB prior to executing this option. If the post flush confirmation sampling results do not exceed MCLs/DOH Screening Levels in Table 5 then the COA may stop at this step. If the post flush confirmation sampling results exceed MCLs/DOH Screening Levels in Table 5, proceed to step 6. If Step 5 is not implemented, then proceed to step 6.
6. The Navy/Army will direct sampling for the original fixture location plus a minimum of one additional interior fixture in the subject building.
7. The Navy/Army will consult with DOH to determine if bracketed sampling (i.e., sampling one house upstream and one house downstream of the subject home) is required based on Steps 1 – 7. Re-sample without pre-flushing.
8. Analyze for the method(s) specified for each exceeded analyte(s) from Table 5, instruct lab to report all contaminants for the specified method(s).
9. Refer to "Remedial Actions" for different re-sampling result outcomes for the associated response.
10. Once the Navy verifies that the exceedance is cleared with validated laboratory data, the Navy will notify the tenant and DOH that the house/building can resume water use with no recommended restrictions.

[7] Pre-flush sampling may be skipped with DOH approval.

For TOC exceedances, in addition to the above, the System shall analyze for TOC/DOC, HPC, DBP, and chlorine residual.

8.2.3 COA 3 –Distribution System or House/Building BTEX Detection Less than the MCL

This COA 3 is for BTEX detected at concentrations greater than those listed below, but less than the MCL, for all locations whether it be within the premise plumbing of a house/building or at a hydrant for a water distribution system. Refer to Table 5 for select analytes applicable to COA 3, if detected.

Analytes	Target Detection Level (ppb)
Benzene	0.5 *
Ethylbenzene	30 ǂ
Toluene	40 ǂ
Xylenes	20 ǂ

*: The common minimum reporting level for EPA method 524.2
ǂ: denotes the gross contamination level

1. Notify SDWB via sdwb@doh.hawaii.gov within 24 hours of receipt of the lab report (lab preliminary, DO NOT wait until Level 2 validation is complete);
2. The Navy must collect sample as applicable for building or hydrant location:
    a. House/Building – First flush collection according to SOP 1B in Appendix A;
    b. Hydrant – Flush hydrant sufficiently to bring fresh water from the nearest mainline junction;
3. Re-sample at original hydrant/fixture;
4. Analyze for the method(s) specified for each detected analyte(s), instruct lab to report all Table 5 contaminants for the specified method(s); and
5. No further action needed if the result is either non-detected or remains below the MCLs. If an exceedance is now present, proceed to COA 1 or 2 as applicable.

8.2.4 COA 4 – Detection of Other Analytes at Concentrations Less than the MCL in Distribution System

This COA is for any analyte detected in the distribution system meeting all of the following criteria:
    a. Below, MCL, ISP, and AL;
    b. Does not meet COA 1;
    c. Does not meet COA 2; and
    d. Does not meet COA 3.

Refer to Table 5 for select analytes applicable to COA 4, if detected.

1. Notify SDWB via sdwb@doh.hawaii.gov within 24 hours of receipt of the lab report (lab preliminary, DO NOT wait until Level 2 validation is complete); and
2. For detections of VOCs in distribution samples
    a. Flush hydrant sufficiently to bring fresh water from the nearest mainline junction;
    b. Re-sample at original hydrant;
    c. Analyze for the method(s) specified for each exceeded analyte(s) from Table 5, instruct lab to report all contaminants for the specified method(s);

d. If the re-sample result:
   i. Exceeds the MCL, then proceed to COA 1.
   ii. Is Detected but does not Exceed the MCL, then SDWB will require quarterly sampling at that location as stipulated under HAR §11-20-12(f)(11)(A). Under SDWB, quarterly sampling at those locations will be required by the System until the sampling requirement is removed by SDWB during this period covered by the LTM Plan.
   iii. Is Not Detected, then no additional sampling is required during this event.

8.3 Remedial Actions

This section provides response guidance post re-sampling results. Should the re-sample indicate either non-detect or below the exceedance levels, no further action is needed. Should the re-sample indicate continuing exceedance, an attempt to provide remedial action shall be made within 48 hours of preliminary re-sample results. If the re-sampled exceedance is at the:

- Original Location only – Re-flush house/building/hydrant only, investigate fixture or hydrant.
- Original Location and at the Additional interior fixture – Re-flush house/building only, investigate premise plumbing materials.
- Original Location and at the Bracketed samples – SDWB to direct further actions.
- Additional interior fixture only – Re-flush house/building only, investigate fixture.
- Bracketed samples only – SDWB to direct further actions.

8.4 Re-Sampling Method(s)

Table 5 provides re-sampling methods required for each detected or exceeded analyte. Analyze for the method(s) specified for each detected analyte(s). Instruct the lab to report all Table 5 contaminants for the specified method(s).

TABLE 5 LONG TERM MONITORING CONTAMINANTS AND COA FOR EXCEEDANCES/DETECTS

Contaminant	Chemical Abstracts Service (CAS) Number	DOH MCL[1] (µg/L)	DOH Project Screening Level (µg/L)	Method Detection Limits (µg/L)	Method Reporting Limits (µg/L)	Sampling Method	Re-Sampling Method(s)	Distribution COA	Building COA	Detection COA
From Table 2 of the Guidance										
JP-5 as Combined Total Petroleum Hydrocarbons (TPH)-Gasoline, Diesel, and Oil Ranges[2] [Incident Specific Parameter]	PCHG PCHD MOIL	Not Applicable	266	GRO, DRO, ORO = 50	GRO =100; DRO, ORO = 95	8260 PCHG / 8015 PCHD/O	8260 PCHG / 8015 PCHD/O / 524.2	1	2	4
Benzene	71-43-2	5	5	0.5	0.5	524.2	524.2	1	2	3
Toluene	108-88-3	1,000	1,000	0.5	0.5	524.2	524.2	1	2	3
Ethylbenzene	100-41-4	700	700	0.5	0.5	524.2	524.2	1	2	3
Xylenes (total)	1330-20-7 95-47-6	10,000	10,000	0.5	0.5	524.2	524.2	1	2	3
1,1,1-Trichloroethane	71-55-6	200	200	0.5	0.5	524.2	524.2	1	2	4
1,1,2-Trichloroethane	79-00-5	5	5	0.5	0.5	524.2	524.2	1	2	4
1,1-Dichloroethylene	75-35-4	7	7	0.5	0.5	524.2	524.2	1	2	4
1,2,4-Trichlorobenzene	120-82-1	70	70	0.5	0.5	524.2	524.2	1	2	4
1,2-Dichlorobenzene	95-50-1	600	600	0.5	0.5	524.2	524.2	1	2	4
1,2-Dichloroethane (EDC)	107-06-2	5	5	0.5	0.5	524.2	524.2	1	2	4
1,2-Dichloropropane (DCP)	78-87-5	5	5	0.5	0.5	524.2	524.2	1	2	4
1,4-Dichlorobenzene	106-46-7	75	75	0.5	0.5	524.2	524.2	1	2	4
Carbon tetrachloride (CTC)	56-23-5	5	5	0.5	0.5	524.2	524.2	1	2	4
Chlorobenzene	108-90-7	100	100	0.5	0.5	524.2	524.2	1	2	4
cis-1,2-Dichloroethylene	156-59-2	70	70	0.5	0.5	524.2	524.2	1	2	4
Dichloromethane (aka methylene chloride)	75-09-2	5	5	0.5	0.5	524.2	524.2	1	2	4
Styrene	100-42-5	100	100	0.5	0.5	524.2	524.2	1	2	4

Contaminant	Chemical Abstracts Service (CAS) Number	DOH MCL[1] (µg/L)	DOH Project Screening Level (µg/L)	Method Detection Limits (µg/L)	Method Reporting Limits (µg/L)	Sampling Method	Re-Sampling Method(s)	Distribution COA	Building COA	Detection COA
Tetrachloroethylene	127-18-4	5	5	0.5	0.5	524.2	524.2	1	2	4
trans-1,2-Dichloroethylene	156-60-5	100	100	0.5	0.5	524.2	524.2	1	2	4
Trichloroethylene (TCE)	79-01-6	5	5	0.5	0.5	524.2	524.2	1	2	4
Vinyl Chloride	75-01-4	2	2	0.5	0.5	524.2	524.2	1	2	4
Total trihalomethanes (TTHM) (sum of chloroform, bromoform, bromodichloromethane, and dibromochloromethane)		80	80	0.5	0.5	524.2	524.2	1	2	4
Total Haloacetic acids (five) (HAA5) (sum of mono-, di-, trichloroacetic acids and mono- and dibromoacetic acids)		60	60	1	1	552.2 / 552.3	552.2 / 552.3	1	2	4
Benzo[a]pyrene	50-32-8	0.2	0.2	0.0095	0.019	525.2 / 525.3	525.2 / 525.3	1	2	4
Di(2-ethylhexyl)phthalate (DEHP aka BEHP)	117-81-7	6	6	0.38	0.57	525.2 / 525.3	525.2 / 525.3	1	2	4
Antimony	7440-36-0	6	6	0.1	0.4	200.8	200.8	1	2	-
Arsenic	7440-38-2	10	10	0.5	2	200.8	200.8	1	2	-
Barium	7440-39-3	2000	2000	0.5	2	200.8	200.8	1	2	-
Beryllium	7440-41-7	4	4	0.15	0.3	200.8	200.8	1	2	-
Cadmium	7440-43-9	5	5	0.05	0.15	200.8	200.8	1	2	-
Chromium	7440-47-3	100	100	0.5	2	200.8	200.8	1	2	-
Copper [3, 5]	7440-50-8	1300	1300	0.5	2	200.8	200.8[4]	1	2	-
Lead [3, 5]	7439-92-1	15	15	0.13	0.5	200.8	200.8[4]	1	2	-
Mercury	7487-94-7	2	2	0.025	0.1	245.1	245.1	1	2	-
Selenium	7782-49-2	50	50	0.3	0.7	200.8	200.8	1	2	-
Thallium	7440-28-0	2	2	0.05	0.2	200.8	200.8	1	2	-

Contaminant	Chemical Abstracts Service (CAS) Number	DOH MCL[1] (µg/L)	DOH Project Screening Level (µg/L)	Method Detection Limits (µg/L)	Method Reporting Limits (µg/L)	Sampling Method	Re-Sampling Method(s)	Distribution COA	Building COA	Detection COA
From Table 3 of the Guidance										
1-methylnaphthalene	90-12-0	None	10	0.24	0.48	525.2 / 525.3	525.2 / 525.3	1	2	-
2-methylnaphthalene	91-57-6	None	10	0.24	0.48	525.2 / 525.3	525.2 / 525.3	1	2	-
Naphthalene	91-20-3	None	17	0.24	0.48	525.2 / 525.3	525.2 / 525.3	1	2	-
Total Organic Carbon (TOC) [Incident Specific Parameter]	TOC	None	4000	0.2	0.5	EPA approved method	EPA approved method	1	2	-
Chlorine, Free (Field Test)	CHLORINE	4000	4000	-	-	8021	8021	1	2	-

Notes:
1 CONTAMINANTS REGULATED BY THE SAFE DRINKING WATER BRANCH (updated 7/10/14) at https://health.hawaii.gov/sdwb/files/2014/07/MCL-Fct-2014-07-10.pdf
2 HIDOH, 2017, Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater – Hawaii Edition (Fall 2017): Hawai'i Department of Health, Office of Hazard Evaluation and Emergency Response. https://health.hawaii.gov/heer/guidance/ehe-and-eals/. HIDOH, 2022, Recommended Risk-Based Drinking Water Action Levels for Total Petroleum Hydrocarbons (TPH) Associated with Releases
3 Action Levels.
4 Analyze for the lead and/or copper, pH, alkalinity, calcium, conductivity, and temperature.
5 As a result of data collected during the first phase of LTM (Months 0-3), Lead and Copper samples will only be collected from residences, other buildings and the entry points to the distribution system during LTM Months 4-24.

9. Protection of Drinking Water Source(s)

DOH acknowledges that the execution of the items proposed in this section may extend beyond the time frame of the Plan's 24 months and the Navy's desire to maintain scope integrity relative to the response. However, this section is included in the DW LTM as a guide for requirements needed before returning closed sources to service. Additionally, certain items may be addressed under DOH SDWA jurisdiction pending further evaluation of both public water systems and the pending Sanitary Survey to be conducted by DOH in 2022.

The Navy shall ensure that its current drinking water source(s) are protected from future contamination and implement a Water Quality Surveillance and Response System (SRS). The SRS is a framework designed to support monitoring and management of distribution system water quality. This Plan outlines implementation of two components that enhance a drinking water utility's capability to quickly detect and respond to water quality issues. Early warning and effective response to a deterioration in water quality can prevent it from becoming a more serious problem.

Online (also known as inline) monitoring involves continuous monitoring of water quality parameters at storage tank inlets and other strategic locations in the distribution system. Data from these monitoring stations will be sent to a central information management system and analyzed to detect unusual water quality conditions. Performance objectives for the three (3) drinking water sources (i.e., Waiawa Shaft, Aiea Halawa Shaft, and Red Hill Shaft), as well as future sources, must be designed to report detections in the distribution system in the timeframes listed below and discussed to establish framework to detect contaminants of concern. The Navy shall base the system on EPA guidance Online Water Quality Monitoring in Distribution Systems:

https://www.epa.gov/sites/default/files/2018-05/documents/owqm-ds_guidance_042018.pdf.

Data from the System will be transferred to EDMS as a secure location for data sharing. SDWB will maintain access to EDMS and any data provided by the System. SDWB must be notified within 24 hours of the Navy's response to a detection above the action level. Alert notification procedure includes sending an email immediately to sdwb@doh.hawaii.gov for all exceedances or pattern deviations. In the case of a TPH exceedance, a phone call should be made to the HEER Office State On-Scene Coordinators at 808-586-4249 during office hours (Monday–Friday, 7:45 am–4:30 pm, excluding State holidays) and at 808-236-8200 after hours.

9.1 Waiawa Shaft

The Navy shall develop a proposal to establish and implement an online program for the Waiawa Shaft EPD. As the Waiawa Shaft has been proven to currently be adequately protected and meeting MCLs, the Navy is granted more time to develop continuous monitoring at this source. However, for efficiency, the Navy may choose to include the Waiawa Shaft in its engineering planning for the currently unapproved Aiea Halawa Shaft and Red Hill Shaft sources. (see below)

9.2 Aiea Halawa Shaft & Red Hill Shaft

An online program must be approved by SDWB, and fully functioning, prior to introducing water from these sources into the distribution system. Additional SDWB requirements may be required at the time of the request to re-activate the source.

10. Reporting and Meeting Schedule

10.1 Reporting to the Navy and DOH

A monthly DW LTM summary report which details the status of each zone will be provided to SDWB. Data included in the monthly report will be exported from EDMS and will, at a minimum, include the following:

- Houses and buildings sampled
- Number of samples collected
- Sampling phase (i.e., 0-3 Month, 6-Month, 3-Month and which 6-Month or 3-Month period, as appropriate)
- Sample sites that had exceedances and required resampling
- GIS map of sample sites with location IDs
- QC summary report
- Challenges incurred and recommendations for improvement
- Forward looking plan for DW LTM for the following month

The monthly DW LTM summary report will be submitted to SDWB by the 15th day of the month following the month that monitoring took place.

10.2 Reporting to Resident, Building Manager, and Public

10.2.1 Laboratory Results

With the receipt of the monthly Step 5 LTM laboratory reports, the Navy shall:

- Provide access to an electronic[8] copy of test results to the resident or building manager where sampling occurred. The electronic test results should be easily accessible using a code, address, or other means.
- Ask building managers or their representatives to post a notification in a common area of the sampled facility for a period of 30 calendar days that the results are available electronically. The electronic test results should be easily accessibly using a code, address, or other means.
- Post the laboratory reports on the https://jbphh-safewaters.org/ website.

https://Jbphh-safewaters.org/ may be converted to a static data and public information repository once the need for EDMS is complete for this response. EDMS is an environmental data management system, and its functions and features are necessary while data and lab reports are being uploaded and managed through the end of LTM. However, once all data have been validated and the full dataset is complete, the management of data will no longer be necessary, and a much more cost-effective data warehouse can replace the management functionality.

10.2.2 Press and Public Inquiries

The System shall be responsible for addressing inquiries/concerns from the public or press. The System must add SDWB and DOH Communications Office to media release distribution lists via email to sdwb@doh.hawaii.gov and doh.pio@doh.hawaii.gov, respectively.

Customer complaint surveillance monitors customer calls to identify unusual trends in water quality complaints. Calls associated with an unusual trend are further investigated to determine if they are

[8] Hardcopies shall be provided upon request of the resident or building manager where sampling occurred.

similar in nature and spatially clustered. Customers may often be the first to report loss of pressure, degraded water quality, waterline leaks, and much more.

The System will track complaints and develop a tool to specially evaluate clusters. These trends shall be identified by the System.

10.2.3 Public Notices as Required by DOH

Should the System be required to issue a public notice as required by HAR §11-20-18, they shall disseminate the notice upon consultation with DOH. It is the System's responsibility to ensure all affected consumers are notified. For each System, the appropriate method for issuing the public notice must be approved or suggested by SDWB. A copy of the draft public notice must be sent to SDWB for approval.

The area affected by the public notice is determined by the System and SDWB based on the location of the sampling points and the results of the routine and repeat sampling.

10.3 Key Stakeholders Meeting Schedule

SDWB will coordinate all DW LTM phase meetings with the stakeholders:

- Meetings with stakeholders to discuss DW LTM will, at DOH's discretion, be held monthly for first three (3) months of the DW LTM plan (e.g., April, May and June 2022).
- Meetings with key stakeholders to discuss DW LTM may be reduced to quarterly in January, April, July, and October of each calendar year 2023 and 2024.

The purpose of these meetings are to:

- Review schedules, data, deliverables and
- Discuss issues and possible modifications to DW LTM documents.

Attendees are DOH, and Navy and Army representatives. EPA may also be invited. The location of the meetings will be at the Uluakupu Bldg. 4, 2385 Waimano Home Road, Pearl City, Hawaii, 96782, (or other designated location determined by the DOH) and may include remote attendance as necessary or appropriate.

11. References

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Interagency Drinking Water System Team (IDWST). 2022. *Final Non-Residential Facility Flushing Plan Checklist and Standard Operating Procedures.* JBPHH, O'ahu, Hawai'i. January. https://www.cpf.navy.mil/Portals/52/Downloads/JBPHH-Water-Updates/20220104%20FINAL%20NON-RESIDENTIAL%20FLUSHING%20SOP.pdf?ver=S6-CBkQuZq1Z6LZ6BewCZQ%3d%3d.

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Appendix A:
SOPs

SOP 1A: Drinking Water Sample Collection for Headspace, Sheen Observation and Free Chlorine, Part A

Scope – The purpose of this SOP is to ensure the sample collection and observation process is performed in a consistent manner so the results can be comparable to other observations taken on base.

Procedure - Prior to the collection of drinking water samples, a headspace, sheen observation and free chlorine test must be performed.

- Pre-sampling preparation –
  - Clear sampling area of any potential volatile sources (hand soaps, dishwashing soap, hand soap, etc.) within the immediate vicinity of the tap/spigot and sample bottle staging area. Redon a new pair of gloves if it becomes contaminated.
  - Place several sheets of paper towels on a suitable flat surface such as a counter- top or the floor.
  - Place sample containers on the paper towels and conduct Part B – Pre-sampling preparation.
  - Remove aerator or backflow prevention device at sampling point, if present.

- Photoionization Detector –
  - Calibrate photoionization detector (PID). Take a PID reading in the vicinity of the drinking water sampling point (within 2 feet) and record the results on the Drinking Water Field Observation Form under “Ambient Room”. Record any presence of odor and note any potential sources of the odor. If “Ambient Room” PID reading is greater than 2.0 ppm, contact the Drinking Water field team supervisor(s).

- Sheen Observation –
  - Half-fill a clear, unpreserved 40-milliliter (ml) VOA vial with water from the drinking water sampling point. Avoid agitating the water inside the vial and close the vial tightly.
  - Lay the vial on a paper towel, on its side. Record initial sheen observation on the Drinking Water Field Observation Form under “Initial Sheen Observation.” Set a timer for 5 minutes.
  - After 5 minutes has elapsed, observe the surface of the water in the vial for sheen
  - or rainbow coloration. Record your observations on field form under “*Final Sheen Observation*”.
  - Once the analysis is concluded, the water can be discarded into the sanitary sewer (i.e. down the drain, if present). If no sheen is observed, the empty VOA vial can be reused at the next location. If a sheen is observed, dispose of the VOA vial with the discarded PPE.

- Quality control for Headspace and Sheen – In order to have consistency in the headspace and sheen analysis, it is critically important shake the 1L amber bottle for exactly 30 seconds and let the VOA vial rest for exactly 5 minutes. This way the results will be comparably with other teams collecting the same information. The vigorous shaking of the1L amber will out-gas volatile chemicals into the headspace of the bottle, if present. Similarly, letting the

VOA vial rest for 5 minutes, allows time for chemicals dissolved in the water to migrate out and float to the surface. Like oil and vinegar dressing separate inthe refrigerator, the oil floats to the top.

- Free Chlorine Analysis –
    - Review the Safety Data Sheet for the DPD Free Chlorine Reagent Powder Pillowsand ensure the proper PPE is in use (e.g. nitrile gloves and safetyglasses).
    - Power on the Hach DR300 coulometer and Start program 80 Chlorine F&T PP.
    - Set the instrument to low range by pressing the up arrow (triangle) button so the triangle is under **LR** (Low Range) on the instrument screen.
    - Rinse the Free Chlorine sample cell it with at least 3 volumes of the water from the sampling point. Similarly, rinse the sample cell cap.
    - Fill the sample cell to the 10 mL line and cap the sample cell. Clean the outsideof the sample cell with a lint free cloth.
    - Insert the sample into the cell holder ensuring the diamond mark on the cell is lined up with the triangle mark on the meter (facing themeter).
    - Place the instrument cap over the cell holder.
    - Push **ZERO** (Blue button on the left of the meter). The display should show 0.00.
    - Remove the cell from the meter. Carefully open the DPD Free Chlorine Reagent Powder Pillow and add the contents to the sample. Close the sample cell with the cap.
    - Invert the sample cell several times for 20 seconds to mix. A pink color will develop if chlorine is present.
    - Set a timer for 3 minutes.
    - While timing the mixture, clean the cell with a lint free cloth. Place the cell in the meter making sure the diamond on the cell is lined up with the triangle on the meter.
    - Press the green button with the check mark on the right side of the meter and record the results on the field form in mg/L.
    - If the screen on the meter is blinking, this indicates the Free Chlorine concentration is greater than 2.0 mg/L and a dilution of the sample is required.
    - Dispose the contents of the cell into the sanitary sewer (i.e. down the drain, if present). Rinse the cell and cap 3x with sample water.
    - Prepare a 1:1 dilution of the sample by decanting 50 mL of sample into a 100 mL beaker and add 50 mL of distilled water, swirl the mixture and decant into the 10mL cell to the 10 mL mark and repeat the analysis.
    - Take the reading from the meter and multiply the result by 2 and record on the field form.
    - If the analysis is still over range, prepare a 1:4 dilution by adding 25 mL of sample
    - to the beaker and 75 mL of distilled water. Multiply the results by 4 and record on the field form.

- Free Chlorine Analysis – Quality Control
    - Prior to analysis at the beginning of each working day, a calibration spec check reference sample should be analyzed.
    - Power up the meter.
    - Run a distilled water blank sample as described above.
    - Next insert the Spec Check reference cell in the meter and place the instrument cover over the cell.
    - Press the green button with the check mark to read the results and compare to the concentration value printed on the Spec Check cell.

If the concentration is outside the acceptable range, consult the operator's manual tomodify the instrument calibration. Repeat the Spec Check analysis.

SOP 1B: Drinking Water Sample Collection, Part B

Scope – The purpose of this SOP is to ensure the sample collection process is performed in a manner consistent with requests made by both EPA and Hawaii State Department of Health. The option to collect a sample from the first flush of water from a tap is a deviation of typical State and Federal requirements for the collection of drinking water samples for the generation of definitive-level analytical data.

Procedure - Once the headspace/sheen observations and free chlorine tests have been recorded according to Part A, samples can be collected for shipment to the designated analytical laboratory.

- Pre-sampling preparation - Place the cooler containing the sample containers to be filled next to the towel used in Part A. Check to ensure all required sample bottleware and preservatives are present in the sample kit. See Bottle Container Checklist (Part B). The 250 ml plastic bottle for metals contains the 1:1 nitric acid preservative, handle with caution. Do not rinse any of the bottles.
- First collect the samples for EPA Methods **524.2 VOCs** and **8015 TPH-g**.
    - Remove cap and tilt the vial so the flow falls on the interior surface of the vial, do not shake or agitate.
    - Fill almost to the top leaving a "U-shaped" concave meniscus at the top of the vial. Place cap on the vial, tighten and gently invert the vial several times to dissolve the solid ascorbic acid preservative.
    - For **524.2 VOCs**, remove the cap and add 3 drops of HCl using a dropper supplied by the lab. If the meniscus is not convex, add more sample until convex but do not overfill. Place cap on the vial, tighten and gently invert the vial several times to mix.
    - For **8015 TPH-g**, additional preservative is not required, remove the cap of the empty VOA vial and fill the vial until a convex meniscus is achieved. Place the cap on the vial and tighten. Once the vial has been sealed, turn the vial upside down and look for the presence of bubbles. If any bubbles are present greater than half the size on a pea, re-collect the sample. DO NOT add additional water. If there are no bubbles repeat the process until all the vials have been filled.

- Second collect the samples for EPA Method **5310 TOC**.
    - Remove cap and tilt the bottle so the flow falls on the interior wall of the bottle. Do not shake or agitate.
    - Fill the bottle 1 or 2 inches below the top (i.e. to the neck of the bottle).
    - Place the cap on the bottle and tighten. Gently tip the bottle to mix the preservative.

- Third collect the samples for EPA Method **525.2 SOCs** and **8015 TPH-d/o**.
    - Remove cap and tilt the bottle so the flow falls on the interior wall of the bottle. Do not shake or agitate.
    - For the **525.2 SOC** sample, fill the bottle 1 or 2 inches below the top (i.e. to the neck of the bottle). Add a vial of 1:1 HCl. Place the cap on the bottle, tighten and gently tip the bottle to mix the preservative.
    - For the **8015 TPH-d/o** sample, fill the bottle 1 or 2 inches below the top (i.e. to the neck of the bottle). Place the cap on the bottle and tighten. Gently tip the bottle to mix the preservative.

- Last collect the sample for EPA Method **200.8/245.1 Metals/Mercury**.
    - This bottle contains 1:1 HNO3, a corrosive acid that can cause serious injury, therefore when filling the bottle point the opening away from you prior to and during sampling.

- Fill the bottle 1 or 2 inches below the top (i.e. to the neck of the bottle). Place the cap on the bottle and tighten. Gently tip the bottle to mix the preservative.

Take note of any color or order associated with the sample and document. Complete the Chains of Custody (COC. Recode the date as Day/Month/Year (e.g. 15/02/2022) and time universal (military) time (e.g. 24:00). Affix the sample label to the bottles/vials, place the bottles/vial in bubble wrap or equivalent and then place in a zip lock bag. Transfer samples to a cooler containing ice.

SOP 3: Scheduling and Sample Site Selection

1. Purpose

This standard operating procedure establishes standard guidelines for the scheduling of the long-term monitoring (LTM) program for the Red Hill Drinking Water Sampling.

2. Scope

This procedure applies to the Red Hill Drinking Water Sampling performed in the NAVFAC Pacific Area of Responsibility.

This procedure shall serve as the reference for procedures on how to schedule the sampling events under the program.

3. Definitions

3.1 Drinking Water

Drinking water consists of Navy-supplied water within the Navy’s potable water system.

3.2 Geographical Information System (GIS)

GIS provides a database of coordinates and data associated with those coordinates. The data can be viewed in different formats and manipulated on maps and figures.

3.3 Environmental Database Management System (EDMS)

EDMS provides an interface to track samples from the sampling through laboratory analysis and validation. EDMS allows for laboratories to upload the electronic data deliverable directly to the system.

4. Responsibilities

The Project Manager is responsible for ensuring that this SOP is distributed to and understood by all sampling team members. The Project Manager is responsible for ensuring that all personnel involved in scheduling shall have the appropriate education, experience, and training to perform their assigned tasks, and be familiar with the requirements of the organizations requiring coordination.

The prime contractor QA Manager or Technical Director is responsible for ensuring overall compliance with this procedure.

5. Determination of Sampling Schedule, Quantity of Locations, and Event Generation

This section provides guidance on how the quantity and locations of samples will be determined.

5.1 Procedure

1. Determine if event is 0-3 month (5%) or 6-month (10%)
2. Determine number of hydrant, housing, buildings, CDCs, and schools to sample per zone.
   - All schools in each zone shall be sampled
   - All CDCs in each zone shall be sample

- For 0-3-month samples, 5% of the selected 5% of locations shall be non-residential
- For 6-month samples, 10% of the selected 10% of locations shall be non-residential
- In the event the zone is primarily non-residential, the overall percentage requirement shall be met using non-residential facilities.

3. Request most current list of vacant homes from the Navy. Avoid selecting vacant homes for sampling.
4. Request GIS figure for each zone showing which houses were sampled previously.
5. Following the same general spatial distribution of previous samples, pick new locations to add up to the required quantity. Try to sample previously unsampled homes that have filed a complaint.
6. Submit locations to GIS to generate a list of addresses.
7. Turn list of addresses over to EDMS contact who will:
8. QC the addresses and ensure addresses are standardized (e.g., Street vs. St.)
9. Match the addresses to the LOCID
10. Match the LOCID to the Sample ID for the Event
11. Generate Sampling Tracking Sheet for the zone
12. Generate Event in EDMS

6. Notification and Field Sampling Locations

This section provides guidance on how to notify the locations to be sampled and choosing a sampling point at the location. The Field Sampling SOP provides guidance on the field sampling procedures.

6.1 PROCEDURE

6.1.1 General Guidance

13. Sampling notification will involve coordination with primary, secondary, and individual levels of contact. The primary level of contact is the DoD branch (i.e., Navy, Air Force, Army, Marines). The secondary level is the housing management and Department of Education, and the individual level are school principals and facility managers.
14. Contact lists are included at the end of this SOP. Due to a high turnover rate of facility managers, this list shall be updated every time an entry is found to be out of date.
15. Sampling notification procedures within the Controlled Industrial Area (CIA) is covered in the Sample Site Notification SOP.

6.1.2 Notification Procedures

16. Primary Notification – notify the DoD branch POC that their residential and non-residential properties are scheduled to be sampled. Coordinate any necessary access and notifications through the Primary.
17. Secondary Notification – notify the housing management company for the area(s) that sampling is scheduled, and work with the management company to determine availability. Provide a list of houses to be sampled so that the company can prepare to assist. For schools

under Hawaii DOE jurisdiction, notify the DOE that sampling will be taking place prior to contacting the individual schools.

18. Individual notification – individual residents are not to be notified that their residence has been identified for sampling. Principals and heads of schools shall be contacted to coordinatea site walk to determine sampling locations and to agree on a time for sampling. Facility managers shall also be contacted to coordinate a site walk to determine sampling locations and to agree on a time for sampling.

6.1.3 Alternate Locations

Alternate locations may be required for instances such as, but not limited to:

- Elevated ambient PID reading
- No water
- Loose pets
- No key available
- Unaccompanied minor in residence
- Other unsafe conditions

To select an alternate location:

1. From initial sample location, pick a nearby home (to the immediate left or right is preferred).
2. Based on the new address, look up associated Location ID on the Coordinates and Elevationstable for the zone in EDMS.
3. Using the Location ID, match to the new Sample ID located on the Event Status Report tablein EDMS.
4. Use the new Sample ID on labels and COCs.
5. Send e-mail notification of all changed sample IDs to EDMS, GIS, laboratory trackingpersonnel, and any additional appropriate parties.
6. EDMS and GIS shall confirm sample IDs have been changed within their respective systemwithin 48 hours.

Appendix A:
Example COC Relinquishing/Receiving

COC#

CHAIN OF CUSTODY

Page 1 of 1

SGS

SGS North America Inc. - Wheat Ridge
4036 Youngfield Street
Wheat Ridge, CO 80033-3862
303-425-6021; 877-737-4521
FAX: 303-425-6854
www.sgs.com/ehsusa

Sampling Event:

Client/Reporting Information	Billing Information (If different from reporting)	SGS Job #
Company: AECOM	Company:	**Project Information**
Street: 1001 Bishop St., Suite 1600	Street:	PWSID or Project#: 60674414
City: Honolulu State: HI ZIP: 96813	City: State: ZIP:	System Name:
Contact: Phone:	Attention:	System Address:
Email:	Client PO #:	City: State: ZIP:
Sampler: Phone:	SGS Quote/Bottle Order #:	Contact Person:
		Tel: Email:

Turn Around Time (Business days)

- ☐ Standard 10 Business Days
- ☐ 5 Business Days RUSH
- ☐ 3 Business Days RUSH
- ☐ 2 Business Days RUSH
- ☒ 1 Business Day EMERGENCY

State Form Information

Compliance Samples Yes ☐ No ☐
Submit Results to State Portal Yes ☐ No ☐

Drinking Water Analyses (check analysis) / **Subcontracted Analysis**

Sample Location or ID	Date	Time	No. of Containers	THM 524.2	VOC 524.2	Haloacetic Acids 552.2	EDB/DBCP 504.1	Pesticides / PCBs 505	Herbicides 515.4	SOC + OP Pesticides 525.2	Carbamates 531.1	Glyphosate 547	Endothall 548.1	Diquat 549.2	Nitrate-N	Nitrite-N	Fluoride	Alkalinity	Langlier Index	TOC	DOC	UV254 / SUVA	11 Inorganic Metals *	Lead & Copper 200.8	Uranium 200.8		Dalapon 552.2		Gross-A + Total Solid	Gross- A+B	Ra 228 / Ra 226	Total Coliform (p/a)	Lab Use Only
	1/ /22																																
	1/ /22																																
	1/ /22																																
	1/ /22																																

Special Instructions:

* Inorganic Metals Include: Sb, As, Ba, Be, Cd, Cr, Hg, Ni, Se, Na, Tl

Sample Custody must be documented below each time samples change possession, including courier delivery.

Relinquished by Sampler:	Date/Time:	Received By:	Date/Time:	Relinquished By:	Date/Time:
1		1		2	
Received By:	**Date/Time:**	**Relinquished By:**	**Date/Time:**	**Received By:**	**Date/Time:**
2		3		3	

Custody Seal # Intact ☐ Not Intact ☐ Absent ☐ | Preserved where applicable: ☐ | Cooler Temp. (°C): ______ | Therm. ID: ______ | On Ice: ☐ | http://www.sgs.com/terms-and-conditions

Technical Specifications

multisensor
systems
sensing measuring protecting

Oil in Water Analyzer

MS1200

MS1200
Oil in Water Analyzer

Continuous Water Intake Protection

VOC BTEX FUEL OILS PAH

The **MS1200 Oil in Water and Pollution Analyzer** is designed to protect drinking water treatment plants from pollution events at the raw water intake. These events can result in expensive filter replacement and clean-up operations and may also affect the **quality of drinking water** produced.

In addition, the system can be used for a wide range of surface water, ground water and industrial water applications.

The MS1200 utilizes a contactless measurement technique, sensing headspace gases to provide a measurement system that is **not affected by the turbidity** of the water and has very low maintenance requirements**.**

The instrument is accurate to low ppb concentrations for a **wide range** of compounds, including fuel oils, PAH, VOCs and BTEX compounds.

Its continuous measurement mode provides immediate information on pollution levels allowing a rapid response to any event.

It is available with a **standard display or touch screen** interface.

✓ Monitors for pollution events
✓ No sensor contact with water
✓ Low maintenance, no sensor cleaning
✓ Not affected by turbidity
✓ High sensitivity, ideal for boreholes

Applications

- Monitoring of water abstraction points
- Monitoring of **drain and storm water** systems
- Detection of **fuel pollution** in surface water
- Detection of VOC breakthrough in **carbon beds**
- **Reverse Osmosis membrane** protection
- Protection of **desalination plants**

Installation

Installation is a **simple process** and consists of connecting the instrument to power and the water source to be monitored. Setup uses a user friendly app running on a laptop PC or the touchscreen interface.

case study

The Problem

In 2013 a petrochemical plant in the UK caused an oil spill into a river. The local water company extracted water from the river to supply a nearby town and had no water monitoring in place. This meant that the extraction point experienced **high levels of hydrocarbon contamination**.

The Consequences

The hydrocarbon pollution led to **significant disruption** for customers because of the halt in production. The water company also faced high costs for the clean-up. The disruption to supply led to negative PR, on a local and national level, questioning the quality of the water.

The Solution

The water company approached Multisensor Systems looking for a **reliable solution**. After some discussions, the WTP purchased an MS1200 Oil in Water Analyzer.

The MS1200 is now installed in an outbuilding at around 70 m from the extraction point. Water is analyzed for hydrocarbons and VOCS and, if there's an increased level, an **alarm is triggered and appropriate action is taken**.

Since the installation the system has protected the water plant on **several occasions** from significant pollution events.

"...without the MS1200 it is far more likely that we'll be prosecuted and make the national news."

technical specification

PARAMETER	OPERATIONAL REQUIREMENTS		NOTES
	Minimum	*Maximum*	
Supply Voltage	90 V AC	240 V AC	50 Hz or 60 Hz
Power Consumption: Standard Version Touch Screen Version		 15 W 45 W	 Typical 10 W during operation Typical 20 W during operation
Water Supply	2 l/min / 0.52 US gpm		Clear PVC tank
Water Pressure	4.0 bar / 58 psi		
Working Temp: Ambient	0°C / 32°F	40°C / 104°F	
Working Temp: Water	1°C / 34°F	40°C / 104°F	
Sampling Period	Continuous		
Detection Range	1 ppb	3000 ppb	Measured against Toluene standard. For calibration using other compounds contact Multisensor Systems
Repeatability	-2%	+2%	200 ppb sample measured using standard 1.5 l solution (Water plus Toluene dissolved in DMSO) in glass 2.5 l Winchester type bottle using magnetic stirrer at 20°C / 68°F
Accuracy	-10%	+10%	
Display Range (Default)	0 ppb	1000 ppb	Configurable on commissioning
Analog Output	4 mA	20 mA	Scalable to range required, max load 900 Ω
Analog Output Isolation	400 V DC		
Relay Voltage		50 V	3x, Alarm 1, Alarm 2 and Fault Relays with NO and NC contacts
Relay Current		5 A	
User Interface	USB-A to PC		Using Multisensor Software provided
Flow Limit Switch	Contacts closed if flow below set point		Option available on request
Instrument Case	IP65 / NEMA 4X		Coated Mild Steel
Sample Tank Material	Stainless Steel		Optional: PVC
Weight	25 kg / 55 lbs		
Dimensions	1170 x 490 x 300 mm 46 x 19.2 x 11.8 inches		Mounted on 2 separate PVC back-boards

Service and consumables

Every 6 Months: Air Filters
Every 12 Months: Air Pump

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sensing measuring protecting

www.multisensorsystems.com
e: info@multisensorsystems.com
p: +44 (0)161 491 5600

Multisensor Systems is a developer and supplier of Water and Gas Analyzers specialising in oil in water, hydrocarbon analyzers, oil in water detectors, THM Analyzers and Ammonia Analyzers based in the United Kingdom.

Multisensor Systems Ltd., Alexandra Court, Carrs Road, Cheadle, SK8 2JY, United Kingdom

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Oil in Water Analyzer

MS1700

MS1700

Oil in Water Analyzer

Monitoring oil in water in the 1 - 100 ppm range

VOC BTEX PAH

The MS1700 is a **high concentration oil in water analyzer** designed to monitor water in industrial processes and to detect fuels and other VOCs in drains and waste water networks.

The instrument works by sensing gases or volatiles to provide a non-contact measurement system with very **low maintenance** requirements.

The MS1700 is accurate in concentrations up to 100 ppm in water* and its very **wide dynamic range** allows it to be used in a variety of environments.

A **user programmable** concentration alarm threshold can be set, connecting to a relay output and an indicator on the front panel. This allows connection to other peripheral equipment such as isolation valves, pumps, samplers or audio-visual alarms.

A 4–20 mA output is provided for connection to a PLC or SCADA system.

The MS1700 can operate from 90–240 V AC or 12 V DC power supplies.

- ✓ Continuous monitoring
- ✓ Low operating and maintenance costs
- ✓ High reliability
- ✓ No reagents
- ✓ Field proven technology

*Toluene at 20 °C / 68 °F

Applications

- Monitoring of industrial **drains** and discharges
- Monitoring of process water
- Storm water measurement
- **Oil and Fuel Leak** Detection
- Detection of **VOCs in wastewater systems**
- Surface water monitoring

Installation

Installation is a **simple process** and consists of connecting the instrument to power and the water source to be monitored. Setup uses a user friendly app running on a laptop PC.

case study

Industrial Effluent: The Problem

Discharge of VOCs into wastewater is an endemic problem in engineering, chemical processing, food and beverage production and other industrial processes.

Spills can lead to **illegal discharges, pollution, fines and negative PR.**

The Consequences

Following a spill the customer was **prosecuted** by the Environment Agency resulting in financial penalties and negative publicity.

Moreover the **cost of restoration** and remediation of the environment was extremely high for which the company was liable.

The Solution

By installing the **MS1700 High Concentration Oil in Water Analyzer** at the outflow of the plant, the customer is provided data as soon as the contamination starts to increase and is able to take appropriate action, avoiding all the problems associated with an unexpected pollution event.

The MS1700 utilizes a **contactless measurement** technique that means:

✓ It does not need reagents
✓ Requires little maintenance
✓ It is robust and reliable
✓ It is cost effective

technical specification

PARAMETER		OPERATIONAL REQUIREMENTS		NOTES
		Minimum	*Maximum*	
Supply Voltage	AC Version	90 V AC	240 V AC	50 Hz or 60 Hz
	DC Version	10 V DC	15 V DC	
Power Consumption			9 W	Typical 7 W during operation
Working Temp: Ambient		0°C / 32 °F	50°C / 122 °F	Higher temperature available
Water Temperature		1 °C / 34 °F	40 °C / 104 °F	
Sampling Period		Continuous measurement		
Instrument Case		IP65 / NEMA 4X		ABS
Detection Range		1 ppm	100 ppm	Measured against Toluene standard. For calibration using other compounds contact Multisensor Systems
Accuracy		-15%	+15%	At 10 ppm at 20 °C
Analog Output		4 mA	20 mA	Scalable to range required, max load 900 Ω
Analog Output Isolation		400 V DC		
Relay Voltage			50 V	Alarm and Fault Relays with NO contacts
Relay Current			5 A	
User Interface		USB-A to PC		Using Multisensor Software provided
Data Storage		µSD Card		Instrument lifetime data stored
Instrument Weight		5 kg / 11 lbs		
Instrument Dimensions		300 x 200 x 132 mm 11.8 x 7.8 x 5.2 inches		
Sampling System Capacity		3 liters 0.8 US gal		
Sampling Sys. Dimensions		570 x 490 mm 22.4 x 19.2 inches		
Sampling Sys. Weight		12 kg / 26.4 lbs		
Sampling Chamber Material		Stainless Steel		
Water Flow Rate		2 liters per minute 0.52 US gpm		
Water Temperature		1 °C / 34 °F	40 °C / 104 °F	

Typical Target Substances

Kerosene
Diesel
Acetone
Heptane
Methanol
Ethanol
Toluene
Xylene
Benzene
Mercaptan

Consumables

Every 6 Months: Air Filters
Every 12 Months: Air Pump

MS1700 Data Sheet, 2022, 1-000119, V1.1

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www.multisensorsystems.com
e: info@multisensorsystems.com

Multisensor Systems is a developer and supplier of Water and Gas Analyzers specializing in Oil in Water, Hydrocarbon Analyzers, Oil in Water Detectors, THM Analyzers and Ammonia Analyzers based in the United Kingdom.

Multisensor Systems Ltd., Alexandra Court, Carrs Road, Cheadle, SK8 2JY, United Kingdom

Analyzers that work.

OIL / HYDROCARBONS IN WATER ANALYZER

Model 204 | **Continuous Process Analyzer for Clean/Dirty Water**

Product Features

- Proven reliability with 99% typical uptime
- No consumables required for analysis
- Completely solid state detector, no moving parts
- No field calibrations required--holds accuracy long-term
- Measures aliphatic and aromatic hydrocarbons
- Accurate and continuous analysis
- Quantitative measurement in ultra low ppb and ppm
- Fast response time
- True Liquid Validation System by Permtube
- Remote & Web based monitoring/control of analyzer
- Awarded TCEQ's "Best Available Control Technology"
- Preferred vendor by Saudi Aramco, Chevron & more

Applications

- Cooling tower / heat exchanger water • Produced water • Waste water • Storm runoff water • Boiler condensate
- Monitoring at desalination plants • Effl uent water • Bilge water discharge • Municipal water treatment plants

Product Description

The ability to analytically quantify oil/hydrocarbons in water is greatly enhanced with the Sample Transfer Stripper (exclusive ASI Membrane Technologies) and the solid state sensor offered by Analytical Systems Keco. The analyzer is simple to maintain and does not require routine calibrations in the field. It is field-proven to maintain a typical 99% up-time.

The Model 204 accurately measures total hydrocarbons including aliphatic and aromatic hydrocarbons. Alternative Oil in Water Monitors utilizing the UV Fluorescence methods do not have the ability to measure aliphatic compounds. Furthermore, the UV Fluorescence method suffers from cross-sensitivity with components in the water not intended to be measured, such as debris and contamination. This gives false high readings and false high alarms. The on-line analysis offered by the Model 204 is economically superior to inaccurate laboratory analyzers where unstable grab samples result in oil deterioration that produce analytical errors.

The liquid sample continuously flows into the analyzer and into the heated SampleTransfer Stripper unit which effectively strips the hydrocarbons from the oil in the water based in part on Henry's Law. The carrier air then sweeps the hydrocarbons to the metal-oxide sensor for quantitative analysis in ppb or ppm levels. The advanced transmitter electronics quantifies and displays the values on the back-lit LCD display, 4-20mA output loop and can communicates via RS-485 Modbus. Remote and Web based monitoring and control of the analyzer is available. The optional 'True' Liquid Validation System by PermTube is utilized to verify proper operation of the entire analyzer system–not just the sensor–with just a flip of a switch or remote activation. This onboard functional validation option introduces hydrocarbons into the analyzer flow path via Permeation Tube. A "bump" up in analyzer's reading will occur, conveniently verifying proper operation of analyzer.

ANALYTICAL SYSTEMS KECO

Phone (281) 516-3950 or (281) 664-2890
Sales@asikeco.com | service@asikeco.com

Typical Specification

DISPLAY
- Alpha Numeric LCD
- Up to four concentration display digits
- Back-lit / color display
- Non-intrusive operation (remains explosion proof)

AMBIENT TEMPERATURE RANGES
- 1°C to 55°C (operating) without ext. cooling/heating
- 0°C to 70°C (storage)
- PPB range may require temp. controlled building

ANALOG
- Isolated 4-20mA

ANALYTICAL PERFORMANCE
- Resolution: <1 to 50 ppb (app. dependent)
- Accuracy*: ±3% of full scale

*Accuracy may be improved significantly near points of interest including ppb level concentrations

- Repeatability: ±3%
- Linearity: ±1%
- Response time: Initial 60 sec. @ sensor (conc. dep.)
- Sensor life: Avg. >5-10 years

DETECTION RANGES
- 0-1 ppm by wt. (or 0-1,000 ppb by wt.)
- 0-10 ppm by wt.
- 0-50 ppm by wt.
- 0-100 ppm by wt.
- 0-500 ppm by wt.
- Customer specified (contact factory)

SAMPLING SYSTEM
- Sample Pressure Regulator (400 or 1,500 psig max)
- Sample Needle Valve
- Sample Flow Meter
- Carrier Air/Gas Flow Meter
- Secondary filter or optional AutoClean primary filter

WEIGHT
- ~250 lbs (Model 204)
- ~100 lbs (Model 204P)

DIMENSIONS
- 3 ft X 4 ft X 1 ft (Model 204)
- 2 ft X 2 ft X 1 ft (Model 204P)

UTILITIES/SETTINGS
- 110VAC or 220VAC
- 100 Watts normal, 700 Watts max
- Carrier Air/Gas: 200 ml/min (15 psig max)
- Sample flow: 60 ml/min
- Sample pressure: 30 psig (400 or 1,000 psi max)

AREA CLASSIFICATIONS OPTIONS
- Class 1 Division 1
- Class 1 Division 2
- Zone 1 or Zone 2

AVAILABLE OPTIONS
- Concentration relay alarms
- Diagnostic/fault alarms
- Low carrier, sample flow relay alarms
- RS-485 Modbus
- Remote monitoring/control with PC
- AutoClean Sample Filter
- True Liquid Validation System by Permtube

TECHNOLOGIES
- Sample Transfer Stripper™ (ASI Membrane Technology)
- 'True' Liquid Validation System by Permtube (optional)
- Other detection options available upon request

Advantages

Consumable Free There are no costly consumables needed for analysis

Dependable operation ASI Membrane Technology creates ultra-clean sample for sensor

Ultra low maintenance The analyzer is completely solid state with no moving parts

Analytical Systems Keco provides design and application engineering assistance for the User's analyzer requirements. For a quotation, please complete Analyzer Quote Request Form at **www.LiquidGasAnalyzers.com/quote**

EPA

United States
Environmental Protection
Agency

Online Water Quality Monitoring in Distribution Systems

For Water Quality Surveillance and Response Systems

Office of Water (MC 140) EPA 817-B-18-001 April 2018

Disclaimer

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Version History: This 2019 version is the second release of the document, originally published in April 2018. This release includes updated component names (Enhanced Security Monitoring was changed to Physical Security Monitoring and Consequence Management to Water Contamination Response), an updated version of Figure 1.1 that reflects the component name changes and includes the Advanced Metering Infrastructure component, updated target capabilities, an updated Glossary, and updated links to external resources.

Questions concerning this document should be addressed to WQ_SRS@epa.gov or the following contacts:

Matt Umberg
EPA Water Security Division
26 West Martin Luther King Drive
Mail Code 140
Cincinnati, OH 45268
(513) 569-7357
Umberg.Matt@epa.gov

or

Steve Allgeier
EPA Water Security Division
26 West Martin Luther King Drive
Mail Code 140
Cincinnati, OH 45268
(513) 569-7131
Allgeier.Steve@epa.gov

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- Steve Rhode, Massachusetts Water Resources Authority
- Kenneth Rotert, EPA, Standards and Risk Management Division

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Abbreviations

ADS	Anomaly Detection System
APHA	American Public Health Association
AWWA	American Water Works Association
CCT	Corrosion Control Treatment
DBP	Disinfection Byproduct
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EPA	United States Environmental Protection Agency
GIS	Geographic Information System
HOCl	Hypochlorous solution
IT	Information Technology
LIMS	Laboratory Information Management System
LSI	Langelier Saturation Index
mg/L	Milligrams per Liter
MGD	Million Gallons per Day
MVWA	Mohawk Valley Water Authority
NEMA	National Electrical Manufacturers Association
NH_3	Ammonia
NO_2	Nitrite
NO_3	Nitrate
ORP	Oxidation-Reduction Potential
OWQM	Online Water Quality Monitoring
OWQM-DS	Online Water Quality Monitoring in Distribution Systems
PWD	Philadelphia Water Department
RTCR	Revised Total Coliform Rule
S&A	Sampling and Analysis
SCADA	Supervisory Control and Data Acquisition
SRS	Water Quality Surveillance and Response System
SUVA	Specific Ultraviolet Absorbance
SWTR	Surface Water Treatment Rule
TEVA-SPOT	Threat Ensemble Vulnerability Assessment and Sensor Placement Optimization Tool
TOC	Total Organic Carbon
UV	Ultraviolet
UV-254	UV light absorbance at 254 nanometers
WCR	Water Contamination Response

Section 1: Introduction

A drinking water ***distribution system***[1] includes all infrastructure needed to convey treated, or potable, water to service connections throughout a service area. Online Water Quality Monitoring in Distribution Systems (OWQM-DS), as defined in this document, involves the use of online ***water quality instruments*** for ***real-time*** measurement of water quality at one or more locations in a distribution system. OWQM-DS enables drinking water utilities to more efficiently manage distribution system operations by detecting changes in water quality as they occur, facilitating a timely and effective response.

OWQM-DS can be implemented as a standalone monitoring program, or it can be incorporated into a ***Water Quality Surveillance and Response System*** (SRS). An SRS is a framework developed by the United States Environmental Protection Agency (EPA) to support monitoring and management of water quality from source to tap. The system consists of one or more ***components*** that provide information to guide drinking water utility operations and enhance a utility's ability to quickly detect and respond to water quality changes. The *SRS Primer* provides an overview of SRSs. The guidance provided in this document treats OWQM-DS as an implementation of the ***Online Water Quality Monitoring*** (OWQM) component within an SRS as described in the *OWQM Primer*. **Figure 1-1** illustrates the way in which OWQM can be integrated into an SRS.

The design of an SRS is flexible and can include any combination of components shown in Figure 1-1. However, it is recommended that all SRS designs include at least one surveillance component and basic capabilities for ***Sampling and Analysis*** (S&A) and ***Water Contamination Response*** (WCR). S&A is important because the surveillance components of an SRS typically provide only a general indication of a potential water quality problem; S&A establishes the capability to confirm or rule out specific contaminants or contaminant classes. WCR establishes relationships with response partners and procedures for responding to serious water quality problems such as contamination.

[1] Words in bold italic font are terms defined in the Glossary at the end of this document.

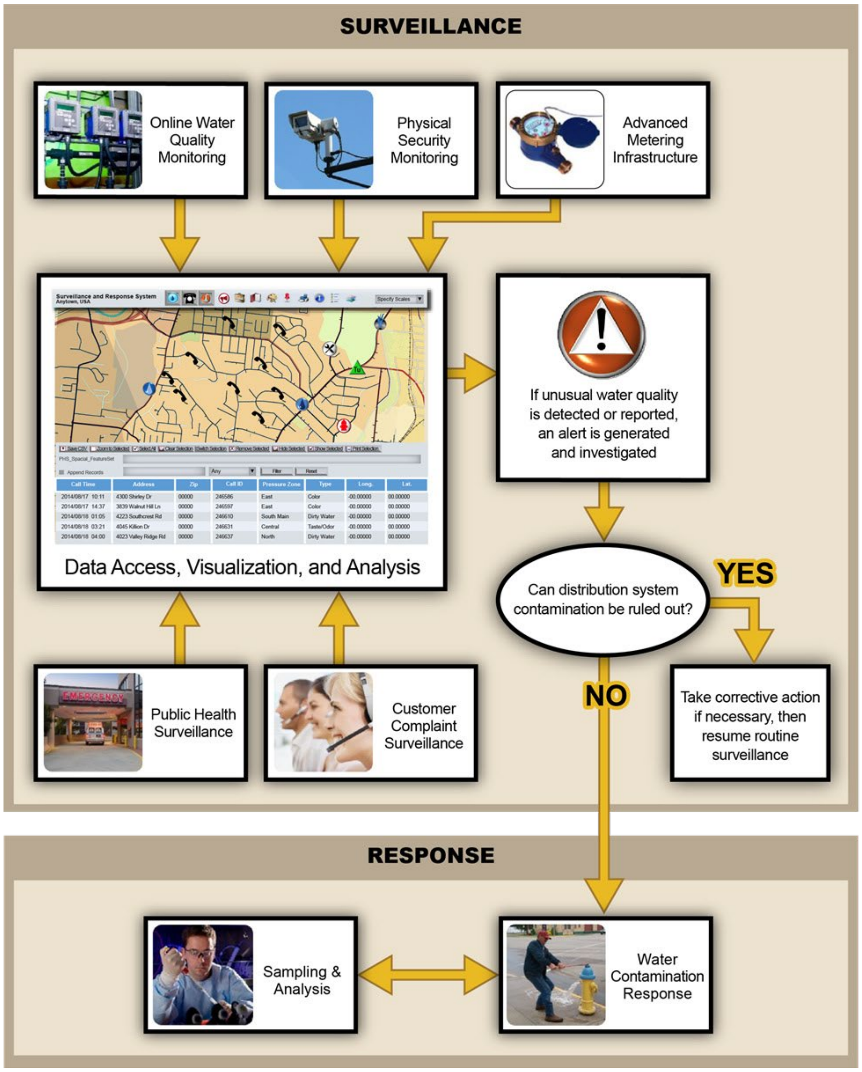


Figure 1-1. Incorporation of Online Water Quality Monitoring into a Water Quality Surveillance and Response System

1.1 Overview of Online Water Quality Monitoring in Distribution Systems

Once drinking water has left a treatment plant, the water quality changes in the distribution system due to a variety of factors:

- Changes in, and mixing of, water that is supplied to a monitoring location by multiple water sources or storage facilities at a given time
- Decay of disinfectant residual as water flows through the system
- Chemical reactions and biological processes (e.g., corrosion, nitrification, regrowth)
- Introduction of foreign substances through cross-connections, backflow, infiltration, or contamination
- Hydraulic upsets such as pressure surges or pressure transients

OWQM-DS provides information that can be used to detect these changes in water quality and determine their causes. This information can help utilities achieve the ***design goals*** described in Section 2.1.

OWQM-DS has become more prevalent in recent years due to the improved capabilities and reduced cost of required technologies, including sensors, power supplies, and communication options. The resulting data that is produced is more accurate, more timely, and more affordable.

1.2 Purpose and Overview of this Document

This document provides guidance on the design of an OWQM-DS system that is based on best practices and lessons learned from existing systems. It introduces key concepts, provides examples, and references additional resources for guidance on specific technical elements of OWQM-DS.

This document is primarily intended for use by water sector professionals involved with managing water quality and operations in drinking water distribution systems.

> **APPLICABILITY OF GUIDANCE**
>
> The methodology presented in this document can be used to design OWQM-DS systems that vary widely in complexity—from a simple system monitoring a limited number of parameters at a single location to a system that monitors multiple parameters at numerous locations.

The remaining sections of this document cover the following topics:

- **Section 2** describes a framework for designing an OWQM-DS system and introduces high-level design goals for these systems.
- **Section 3** provides guidance on selecting monitoring locations for OWQM-DS.
- **Section 4** provides guidance on selecting water quality parameters for OWQM-DS.
- **Section 5** provides guidance on the design of monitoring stations for OWQM-DS.
- **Section 6** provides guidance on the development of an information management system and analysis techniques to support OWQM-DS.
- **Section 7** provides guidance on developing an alert investigation procedure to support OWQM-DS.
- **Section 8** describes a process for developing a preliminary design for an OWQM-DS system.
- **Section 9** presents example OWQM-DS applications, including a summary and explanation of relevant monitoring locations and water quality parameters.
- **Section 10** provides case studies from utilities that have implemented OWQM-DS.
- **Section 11** presents lessons learned from utilities that have implemented OWQM-DS.
- **Resources** presents a comprehensive list of documents, tools, and other sources cited in this document that are useful for implementing activities described in this document.
- **References** presents a complete list of supporting documents and sources cited in this document.
- **Glossary** provides definitions of terms used in this document, which are indicated by bold, italic font at their first use in the body of this document.

Section 2: Framework for Designing Online Monitoring Systems

The OWQM-DS design process follows the principles of project management and master planning that are described in Sections 2 and 3 of *Guidance for Developing Integrated Water Quality Surveillance and Response Systems*. This section presents a framework for designing an OWQM-DS system, as shown in **Figure 2-1**. While depicted as a linear process, in practice it is iterative. Decisions or findings in downstream steps may require that earlier steps be revisited.

Figure 2-1. Online Monitoring System Implementation Framework

2.1 Establish Design Goals

A utility planning to implement OWQM-DS should first establish the overall purpose of such a system and the decisions the data it produces is intended to support. The purpose and intent will inform the development of high-level design goals, and more specific ***applications***, to guide OWQM-DS implementation. Design goals are the benefits a utility expects to achieve by implementing OWQM-DS. The establishment of design goals is critical to ensuring that an OWQM-DS system will provide information that is useful to a utility.

Examples of common, high-level design goals that cover most OWQM-DS applications are to (1) monitor for ***contamination incidents*** and (2) optimize distribution system water quality.

2.1.1 Monitor for Contamination Incidents

The presence of a contaminant in a drinking water distribution system has the potential to cause harm to the community and utility infrastructure. Contamination incidents may be unintentional (e.g., treatment process failure and contaminant pass through, backflow incidents) or intentional (e.g., purposeful contamination of a storage ***tank***). OWQM-DS information can be used to detect contamination incidents, enabling a utility to isolate affected areas of its system and implement corrective actions, as needed.

Due to the uncertainty regarding the occurrence and nature of contamination incidents, design of an OWQM-DS system to achieve this design goal faces the following challenges:

- It is very unlikely that the contaminant involved in a specific contamination incident can be predicted with certainty. Thus, for an OWQM-DS system to be effective, it must be capable of detecting a wide range of contaminants. For this reason, water quality parameters that are responsive to a variety of contaminants are most often used to achieve this design goal.
- A contamination incident could occur anywhere in a distribution system; therefore, an OWQM-DS system should cover as much of a system as feasible.
- Contamination incidents are typically transient and occur over a short time-period; thus, rapid detection is important.
- Contamination incidents of high consequences are rare, but their impact could be significant (i.e., low probability of occurrence, but high impact); thus, alerts must be reliable.

2.1.2 Optimize Distribution System Water Quality

Optimization of distribution system water quality involves operating a treatment plant and distribution system in a manner that meets selected water quality objectives. To achieve this design goal, a utility must:

- Understand how treatment plant and distribution system operations impact water quality throughout a distribution system.
- Use OWQM-DS information to inform treatment and system operations to:
  - Support water quality goals such as chlorine residual management and corrosion control.
  - Prevent water quality problems such as nitrification, regrowth, and disinfection byproduct (DBP) formation.

2.2 Establish Performance Objectives

Performance objectives and their associated metrics are measurable indicators of how well an OWQM-DS system is operating. Throughout design, implementation, and operation of a system, a utility can use performance objectives to determine whether the system is operating within acceptable tolerances. While specific performance objectives should be developed by each utility in the context of its unique design goals, common performance objectives include operational reliability, information reliability, and sustainability.

Operational Reliability

Operational reliability is the degree to which an OWQM-DS system is performing at a level capable of achieving selected design goals. It depends on proper maintenance of equipment and information management systems necessary to operate a system. Considerations that can impact operational reliability include accessibility of monitoring stations for maintenance, suitability of ***water quality sensors*** to the chemistry and quality of distribution system water (e.g., impact of pH or dissolved iron on instrument performance), environmental impact on monitoring stations (e.g., humidity, ambient temperatures), and availability of suitable training for personnel responsible for maintaining OWQM-DS equipment. Example metrics used to monitor operational reliability include:

- Percentage of time that an OWQM-DS system is fully operational
- Average response time to correct equipment problems

Information Reliability

Information reliability is the degree to which information produced by an OWQM-DS system is of sufficient quality to support decision-making. Specifically, utility personnel must be able to interpret the difference between typical water quality variability and changes indicative of a water quality issue requiring a ***response action***. Considerations for information reliability include the representativeness of the water monitored at each monitoring location, compatibility of sensors with water chemistry (e.g., water matrix effects that interfere with instrument measurements), sensor capabilities (e.g., detection limits), maintenance of sensors, operation of sensors within their defined capabilities, and ***data analysis*** methods.

> **IDENTIFICATION OF FALSE NEGATIVES**
>
> False negatives represent a change in water quality that is not identified as such. This could be tested by using alternative sources of data that identify changes in water quality, such as customer complaints, and comparing the results of their investigations with OWQM-DS data collected during the same period.

Information reliability can be characterized through ***data quality objectives***, which are metrics or criteria that establish the quality and quantity of data needed to support decisions. Examples of data quality objectives that might be considered for OWQM-DS include:

- Data ***accuracy***
- Data ***completeness***
- Number of false alerts per month
- False negatives

Data quality objectives are important to build confidence in data collected for any environmental monitoring program.

Sustainability

Sustainability is the degree to which benefits derived from an OWQM-DS system justify the cost and level of effort required for its continued operation. Benefits are largely determined by the design goals that OWQM-DS information supports. For example, an annual reduction in chemical usage (e.g., chlorine) can be achieved due to more efficient chemical dosing or improved water turnover in a storage tank, which can be guided by OWQM-DS data. Other benefits may be difficult to quantify, such as increased confidence of utility managers and operators in their ability to detect water quality problems; however, these benefits should still be captured and described, as they are important to gauging the sustainability of an OWQM-DS system. Costs include the capital and ongoing expenditures required to operate OWQM-DS equipment, as well as the effort required to analyze OWQM-DS data and investigate ***alerts***. Example metrics for sustainability include:

- ***Consequences*** avoided through early detection of, and response to, contamination incidents
- Value of non-monetary benefits gained from the operation of an OWQM-DS system, including a reduction in customer complaints
- Cost to maintain an OWQM-DS system

2.3 Review Distribution System Resources

Prior to designing an OWQM-DS system, it can be helpful to compile and assess distribution system information resources to support the design process. Reviewing these resources prior to and during design can help to ensure that the resulting system addresses selected design goals. Examples of utility resources that can be reviewed during an assessment are described below.

Distribution System Hydraulic Resources

- **Hydraulic and water quality models.** A hydraulic model is a mathematical representation of hydraulic conditions present in a distribution system under a certain set of conditions. Likewise, water quality models are mathematical representations of the water quality present in a distribution system under a certain set of conditions. Models can be used to understand flow paths and ***hydraulic connectivity*** throughout a distribution system and determine the impact of operations on flow paths and connectivity. If a model includes water quality modeling capabilities, such as chlorine residual decay models, it can also be used to estimate the impact of distribution system operations on water quality as water travels through a system. Models can also be used to identify areas with low flow and high water age that may be subject to regrowth and nitrification.
- **Distribution system maps and storage facility specifications.** Distribution system maps and ***storage facility*** specifications provide details that can be used in the absence of, or to supplement, hydraulic models to show connectivity and storage capacity.
- **Existing flow and pressure meter records.** Existing flow and pressure meters in a distribution system may have been installed to monitor discrete areas, wholesale customers, or high-demand customers. Records of flow and pressure can be used to validate portions of a hydraulic model.
- **Tracer study results.** Tracer studies monitor the ***concentration*** profile of known chemicals as they pass through a distribution system. Study results provide measured details of hydraulic connectivity that can be used to validate or calibrate hydraulic models. In the absence of a hydraulic model, these results can be used to understand flow paths and hydraulic connectivity throughout the area evaluated during a study.

Distribution System Water Quality Resources

- **Records of previous water quality problems.** Records of water quality problems (e.g., regrowth, nitrification, total coliform hits, DBP occurrences) that have occurred include details of the nature and location of the problem, impact on water quality, date of occurrence, other conditions at the time (e.g., temperature, pH, total organic carbon), and known or potential causes of the problem.
- **Customer complaint records.** Records of customer complaints contain details of specific water quality problems (e.g., red water, dirty water, taste and odor) that have previously occurred in a distribution system.
- **Regulatory compliance data.** Records of compliance data related to federal regulations (e.g., Surface Water Treatment Rule [SWTR]) and state regulations (e.g., monitoring disinfectant residuals for ground water) can provide details of problem areas of a distribution system.
- **Initial Distribution System Evaluation Results for Stage 2 Disinfectant and Disinfection Byproducts.** Results from this one-time requirement identify areas of a distribution system with the potential for high DBP concentrations. These results can be used to learn about distribution system hydraulics and areas in a system with low flow and high water age.
- **Methodology for identifying Revised Total Coliform Rule (RTCR) sample siting plans.** RTCR sample siting plans specify where in a distribution system RTCR compliance samples are collected. The intent of the plan is to select sample sites that are representative of water quality in the system.
- **Surveys or special studies.** Results from surveys or special studies, such as sanitary surveys, chlorine residual surveys, iron occurrence surveys, corrosion control surveys, and condition assessments, contain details of analyses focused on particular aspects of a distribution system. These results may provide insight into the location and frequency of water quality problems in a system.

- **Cross-connection control program.** Information from a cross-connection control program provides details of known sites within a distribution system where backflow is a concern.
- **American Water Works Association (AWWA) Partnership for Safe Water Assessment Results.** The Distribution System Optimization Program, as described on the AWWA Partnership for Safe Water Website, has identified three system integrity performance indicators: water quality preservation (chlorine residual), hydraulic reliability (pressure), and physical security (main break frequency). These indicators form the basis for a self-assessment to help utilities identify performance-limiting factors and develop improvement plans.

2.4 Design the Online Monitoring System

The major design elements associated with OWQM-DS are summarized in **Figure 2-2** and briefly described in this section. Detailed guidance on each design element is presented in Sections 3 through 7. Once the design elements have been developed, project details should be captured in a design document as discussed in Section 8.

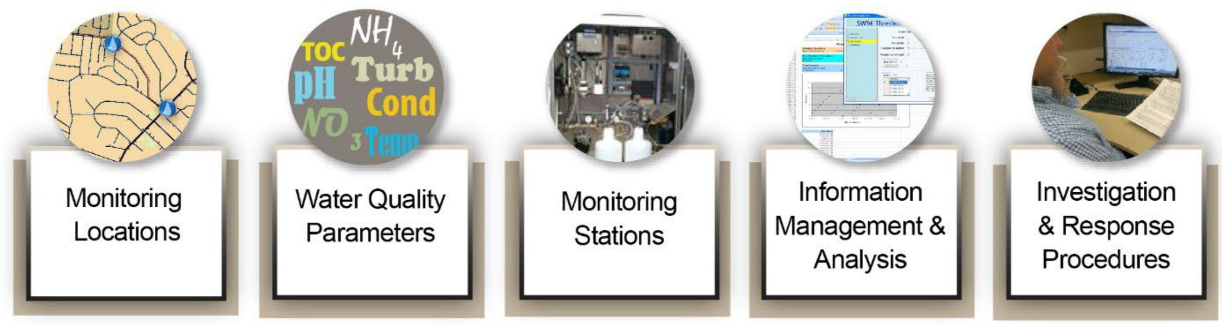


Figure 2-2. Online Monitoring System Design Elements

Select Monitoring Locations

Monitoring locations should be selected based on design goals selected for OWQM-DS as well as information collected during a distribution system assessment. The final selection of locations is often a compromise between ideal locations determined to achieve a particular design goal, the potential for locations to support multiple design goals, and installation considerations such as accessibility, security, and environmental conditions. Guidance on the selection of monitoring locations is discussed in detail in Section 3.

Select Water Quality Parameters

The selection of water quality parameters is based on design goals selected for OWQM-DS as well as information collected during a distribution system assessment. Specific design goals can only be achieved if parameters relevant to those goals are monitored. Guidance on the selection of water quality parameters is discussed in detail in Section 4.

Design Monitoring Stations

The design of monitoring stations is based on the monitoring locations and water quality parameters selected for OWQM-DS. It includes selection of water quality instruments and ancillary equipment necessary to bring sensors into contact with a water sample and transmit data. The station design can dramatically impact capital and operating costs for an OWQM-DS system, as well as data accuracy and completeness. Guidance on the design of monitoring stations is discussed in detail in Section 5.

Develop an Information Management and Analysis System

Information management systems receive, process, analyze, store, and present data generated by monitoring stations. An information management system may also be capable of generating alerts and sending notifications to designated personnel when water quality ***anomalies*** are detected. Information management and analysis are discussed in detail in Section 6.

Develop an Alert Investigation Procedure

Once a water quality anomaly has been detected, an investigation should be undertaken to determine the cause of the anomaly. The process of developing an ***alert investigation*** procedure is described in Section 7.

Section 3: Monitoring Locations

A monitoring location is the site in a distribution system where water is sampled to measure water quality in real time. Selection of these locations should be guided by chosen design goals and information from a distribution system assessment.

TARGET CAPABILITY
OWQM-DS locations are sufficient to fully achieve selected monitoring goals.

This section is divided into subsections that cover the following topics:

- Common monitoring locations
- Tools to support selection of monitoring locations
- Installation sites

3.1 Common Monitoring Locations

It would be ideal for an OWQM-DS system to produce data that is representative of an entire distribution system, but budgetary constraints often limit the number of monitoring stations that can be installed. Therefore, monitoring locations should be strategically selected to maximize the extent to which design goals are realized. Common monitoring locations are explained in the following subsections.

Distribution System Entry Points

Distribution system entry points include the locations where water from treatment plants, wholesale interconnects (where treated water enters a system), or the output of one or more wells directly feeds into a system. As such, entry points are vital locations that should be monitored for all OWQM-DS systems.

Monitoring at entry points is an important aspect of the design goals mentioned in Section 2.1. OWQM-DS data at the entry points provides a useful benchmark for optimization of distribution system water quality. It also provides a ***baseline*** that can be used to help confirm or rule out a ***possible*** contamination incident detected at a downstream monitoring location in a distribution system. This data can also be used in water quality models (e.g., chlorine residual decay, DBP formation) to predict distribution system water quality. It can also guide treatment plant maintenance planning (e.g., replacement of adsorptive media based on data rather than on time in service).

Operational Control Points

Operational control points include storage facilities, chlorine residual booster stations, and pump stations. Monitoring at, or downstream of, operational control points provides an operator with information that can be used to adjust operations that impact distribution system water quality. OWQM-DS data from locations downstream of a control point may provide the most useful information to guide system operations, as water quality at a downstream location can show the impact of an operational change at a control point. However, it is often easier and less expensive to install monitoring stations at utility facilities associated with operational control points because these facilities frequently satisfy many of the installation requirements identified in Section 5.

Prioritization of operational control points for monitoring should be informed by a distribution system assessment, discussed in Section 2.3, and may include the following:

- **The population downstream of a control point.** Average flow rate exiting the control point can be used as a surrogate for the population downstream of the point and can be obtained from ***Supervisory Control and Data Acquisition*** (SCADA) system records, hydraulic models, existing flow meters, or tracer study results.
- **Hydraulic travel time from a treatment plant or upstream operational control point and hydraulic connectivity to other stations.** This information can often be obtained from distribution system ***asset*** design drawings and specifications, hydraulic models, distribution system maps, or operator knowledge.
- **History of water quality or compliance issues at, or downstream of, an operational control point.** This information may be available from federal or state regulatory sampling results, customer complaints, water quality problems, other water quality data, and an Initial Distribution System Evaluation.

WATER VARIABILITY

Prior to confirming a monitoring location, one or more extensive sampling events should be conducted at the location to determine whether the water quality is sufficiently stable to allow for detection of changes that support selected design goals.

Additional Monitoring Locations

Additional monitoring locations beyond entry points and operational control points can provide information to better meet design goals. Examples of these locations include the following:

- **Critical customers.** Stations can be installed upstream of critical customers or areas (e.g., hospitals, stadiums, universities, entertainment districts, manufacturers that use large volumes of water) to protect large and/or vulnerable populations in the event of a contamination incident. Stations should be located a sufficient distance upstream of an asset to allow time to detect and respond to an incident. Critical customers can be identified using details from distribution system maps, hydraulic models, and ***geographic information system*** (GIS) resources.
- **Interconnects.** Interconnects with downstream customers can be monitored to determine the quality of water transferred between systems. Interconnects can be identified using distribution system maps.
- **Areas of concern.** Areas that have a history of water quality problems (e.g., nitrification incidents, undetectable chlorine residual levels, lead pipes) areas that experience low flow and pressure, and far reaches of the distribution system can be monitored to identify the onset of future problems. Areas of concern can be identified through a review of federal or state regulatory sampling results, customer complaint records, records of water quality problems, special studies, and Initial Distribution System Evaluation results.
- **Mixing zones.** For distribution systems supplied by multiple sources with different water quality (e.g., surface water, ground water), areas where water from different sources meet and mix can be monitored to characterize the frequency and duration of mixing, and possibly the boundaries of the mixing zones. Mixing zones can be identified using utility personnel knowledge of a distribution system or hydraulic models.

3.2 Tools to Support Selection of Monitoring Locations

A number of tools can be used to provide information to support the selection of monitoring locations. Three general classes of such tools are described in the following subsections:

- Hydraulic models
- Water quality models
- Sensor placement optimization tools

Methodologies that use these tools for single objective and multi-objective placement of monitoring stations are discussed in *Water Science & Technology: Water Supply* (Rathi, et al., 2015).

Hydraulic Models

Hydraulic models are mathematical representations of distribution system hydraulics under various conditions. EPANET is a common, open-source hydraulic modeling platform that is frequently used in the industry. Hydraulic models can be used to:

- Understand hydraulic connectivity between potential monitoring locations and other distribution system elements, such as operational control points.
- Determine travel time between locations in a distribution system.

Water Quality Models

Water quality modules can be incorporated into most distribution system hydraulic modeling software to estimate water quality as water travels through a system (e.g., EPANET). Water quality modeling can provide additional information to:

- Understand how water quality parameters change as water travels through a system.
- Predict water quality parameter values downstream of operational control points.

Station Placement Optimization Tools

Station placement optimization software, such as the Threat Ensemble Vulnerability Assessment and Sensor Placement Optimization Tool (TEVA-SPOT), uses complex algorithms to identify and prioritize monitoring locations for a specific objective, such as minimizing the time to detect an incident or minimizing consequences over a large ensemble of possible contamination scenarios. Examples of how TEVA-SPOT has been used to locate monitoring stations are provided in guidance developed by the Philadelphia Water Department and CH2M (PWD, 2013), a summary of SRS pilot projects that employed TEVA-SPOT (EPA, 2015), and a presentation on sensor network design and performance (Janke, et al., 2009).

Use of optimization software may be constrained by “fixing” one or more monitoring locations that are priorities for monitoring. For example, utilities may want to fix locations at distribution system entry points, operational control points, and critical facilities at which the consequences of water contamination could be severe (e.g., hospitals, universities, government buildings, entertainment venues). The optimization software can then be used to identify additional locations while considering the detection capabilities provided by the fixed locations.

Other station placement optimization tools are available, and not all require a ***distribution system model***. One such method identifies a monitoring location intended to minimize the time to detect a contamination incident (Schal, et al., 2014). This is a simplified method that may be appropriate for relatively small and simple distribution systems, if the above approaches are not feasible.

3.3 Installation Sites

Checklist for Assessing Potential Monitoring Locations (Microsoft Word)

*Note that the document that is currently open may need to be downloaded and opened offline to access this checklist.

The physical installation of a monitoring station should be as close as feasible to the monitoring location (e.g., water main, tank) to minimize the time between sample collection and analysis. Selection of a monitoring station installation site is often influenced by a variety of site-specific considerations such as those identified in the OWQM site evaluation checklist that can be accessed by clicking on the box to the right. If a suitable installation site near the monitoring location cannot be found, alternate locations will need to be considered. Completed checklists should be incorporated with the preliminary OWQM-DS system design template found in Section 8.

Section 4: Water Quality Parameters

This section describes water quality parameters that may be useful for OWQM-DS. Information about the online instruments used to measure these parameters is available in *List of Available OWQM Instruments*. The scope of this document is focused on water quality parameters; therefore, operational parameters (e.g., pressure, flow) are not covered in this section.

TARGET CAPABILITY
The OWQM-DS parameters monitored are sufficient to fully achieve selected monitoring goals.

Within the context of OWQM-DS, there is a wide range of water quality parameters that can be monitored to contribute to selected design goals. These parameters can be grouped into core parameters that should be monitored as part of every OWQM-DS system and additional parameters that can be monitored to achieve utility-specific design goals.

Core Water Quality Parameters

Table 4-1 provides an overview of a core group of water quality parameters as defined in this document. These parameters are fundamental to understanding water chemistry and are useful in identifying a broad spectrum of water quality changes in a distribution system. Furthermore, the interdependencies among these core parameters make them useful during the investigation of a water quality change. For example, the rate of chlorine residual decay typically increases as temperature increases. A situation in which chlorine residual decay is greater than anticipated at a given temperature would warrant further investigation.

Table 4-1. Overview of Core Water Quality Parameters

Parameter	Parameter Description
Chlorine residual	• Defined as the concentration of either free chlorine, total chlorine (free chlorine plus chloramines), or monochloramine. • Concentration must be maintained within lower and upper bounds, as required by federal or state regulations. • Decreases in chlorine residual can signal the potential for regrowth of biological organisms and biological processes in a distribution system, including those that cause nitrification. • Many chemical contaminants that could enter a system will react with chlorine residual, causing a decrease in residual concentration.
pH	• Defined as the negative logarithm of the concentration of hydrogen ions in an aqueous solution. • Is necessary to understand water chemistry (e.g., chemical speciation, reaction rates). • Can be used along with other parameters to determine the corrosion potential of water in a distribution system. • Chemical contaminants with acidic or basic functional groups that could enter a system can change the pH of water; however, the magnitude of a change in pH will be inversely related to the buffering capacity of the water.

Parameter	Parameter Description
Specific conductance	• Defined as the measure of the ionic strength of a solution. • Commonly used as a surrogate for total dissolved solids. • Can be used to track different water supplies (e.g., ground water, surface water) feeding into a distribution system (assuming those supplies have measurably different values for specific conductance), thus providing a better understanding of system hydraulics. • Some chemical contaminants that could enter a system have charged functional groups that can dissociate and form ionic species when dissolved in water, thus increasing the specific conductance of the water; however, a high contaminant concentration may be necessary to produce a measurable change in specific conductance.
Temperature	• Defined as the measure of the thermal energy in water. • Influences chemical equilibrium and kinetics, which may impact water quality in a distribution system and, thus, is an important parameter to monitor at any monitoring location. • Integrated into water quality sensors that measure temperature-dependent parameters (e.g., pH, specific conductance) to enable temperature compensation to those parameter measurements. • Can be used to track different water supplies (e.g., ground water, surface water) feeding into a distribution system (assuming those supplies have measurably different values for temperature), thus providing a better understanding of system hydraulics. • A rapid change in temperature can indicate a large inflow of a foreign fluid (e.g., plumbing high-flow cross-connection) into a system.

Additional Water Quality Parameters

Table 4-2 provides an overview of additional water quality parameters that may be useful for an OWQM-DS system to meet utility-specific, and in some cases site-specific, design goals. The parameters listed below are supplementary to the core parameters and can identify specific types of water quality changes in a distribution system.

Table 4-2. Overview of Additional Water Quality Parameters

Parameter	Parameter Description
Alkalinity	• Defined as the measure of a water's buffering capacity (i.e., its ability to resist a change in pH when an acid or base is added), typically measured in carbonate equivalents. • Influences the stability of distribution system water pH and, thus, impacts corrosion control. • Can be used to calculate the likelihood of calcium carbonate pipe scale formation due to calcium carbonate saturation in water.
Ammonia, free (NH_3)	• Defined as the concentration of dissolved ammonia (NH_3) in solution. • Can be added during treatment to form chloramines. • Can exert a chlorine demand. • As monochloramine decays it releases ammonia. Nitrifying bacteria (i.e., nitrification) consumes ammonia and converts it to nitrite and nitrate. High levels of ammonia should be avoided to prevent the likelihood of nitrification.
Apparent color	• Defined as the color of an unfiltered water sample due to both dissolved and suspended material. • An increase in apparent color can signal a potential hydraulic upset that could impact water quality (e.g., iron release).

Parameter	Parameter Description
Dissolved oxygen (DO)	• Defined as the concentration of dissolved oxygen in solution. • Is an oxidant that can affect metal solubility and release.
Dissolved organic carbon (DOC) Total organic carbon (TOC)	• Defined as the concentration of organic carbon (compounds that contain carbon and hydrogen) in solution. • TOC includes suspended and dissolved organic carbon. • DOC is the fraction of organic carbon that passes through a filter with a 0.45 micrometer pore size. • Presence of DOC/TOC during chlorination can result in DBP formation. • Assimilable organic carbon portion of DOC can support biological regrowth in distribution systems. • An increase in DOC and TOC can indicate the presence of an organic chemical (e.g., pesticides, biotoxins, petroleum products) in a system. • An increase in DOC and TOC can exert a chlorine demand, reduce the chlorine residual concentration, and create an opportunity for chlorine-sensitive pathogens (e.g., *Vibrio cholerae*) and biotoxins (e.g., botulinum toxin) to survive.
Disinfection byproducts*	• Defined as the concentration of total trihalomethanes or 5 haloacetic acids • Concentration must be maintained below maximum contaminant levels specified by the Disinfectants and Disinfection Byproducts Rules.
Hydrocarbons	• Defined as the concentration of long-chain, organic compounds that include hydrogen and carbon in solution (online instrumentation commonly measures unsaturated organic compounds). • Can enter a system during intentional or unintentional backflow incidents and low-pressure incidents in pipes buried in contaminated soil. • Can impart an objectionable odor to water, and can be difficult to remove from distribution systems and household plumbing materials.
Nitrite and nitrate	• Defined as the concentration of nitrite (NO_2) and nitrate (NO_3) in solution. • Are regulated contaminants. • Measurable concentration of nitrite, or increases in nitrate from baseline levels, can signal the onset of nitrification in chloraminated distribution systems.
Ortho-phosphates	• Defined as the concentration of inorganic compounds, consisting of phosphorus and oxygen in solution. • Can be used to monitor the efficacy of corrosion control treatment if a phosphate-based inhibitor is used during treatment.
Oxidation-reduction potential (ORP)	• Defined as the measure of the potential flow of electrons between reducers and oxidizers, which characterizes the oxidizing or reducing potential of a solution; positive values indicate an oxidizing environment and negative values indicate a reducing environment. • Can be used for understanding corrosion control and metal solubility. • Closely related to chlorine residual and typically responds linearly to chlorine residual changes. • A decrease in ORP can indicate the presence of chemical contaminants that exert an oxidant demand.

Parameter	Parameter Description
Spectral absorbance	• Defined as the measure of wavelength absorption across the ultraviolet (UV)/visible spectrum. • Can provide derived measurements for other water quality parameters (e.g., DOC/TOC, nitrite, nitrate). • The DOC/TOC ratio can be used to indicate a change in the organic composition of water, potentially indicating the presence of an organic contaminant. • Spectral absorption profiles of distribution system water can provide a baseline spectral fingerprint; deviations from this baseline can be used to detect anomalous water quality and may indicate the presence of a contaminant. • Some inorganic and most organic chemicals absorb in the UV/visible spectrum; as such, a change in spectral absorption may indicate the presence of a chemical contaminant introduced into a distribution system. • Differential spectral analysis is a rapid method to compare the significance of a change between a baseline water quality and a potential anomaly.
Turbidity	• Defined as the measure of the cloudiness of water due to dissolved or suspended particles. • An increase in turbidity can indicate hydraulic upsets or intrusions in a distribution system.
UV-254	• Defined as the light absorption at the ultraviolet 254nm wavelength. • Can provide a surrogate measure of DOC/TOC. • UV-254 and DOC measurements can be used to calculate Specific Ultraviolet Absorbance (SUVA). • A change in SUVA can indicate a change in the organic composition of water, potentially indicating the presence of an organic contaminant.

*Note that DBPs are measured using online Gas Chromatographs

The water quality parameters selected from Tables 4-1 and 4-2 should be those that are most useful for achieving selected design goals. When selecting parameters, consider that some provide innate benefits, while others may complement different monitored parameters and provide more useful information when measured together. For example, nitrification and regrowth is often exacerbated when high temperatures accelerate chloramine decay and the growth rate of nitrifying bacteria, producing free ammonia; thus, monitoring chlorine residual, free ammonia, and temperature together can provide a more reliable indication of nitrification. Additional examples of parameter combinations that can be selected for a number of OWQM-DS applications are presented in Section 9.

CONTAMINATION DETECTION

The ability to detect distribution system contamination by continuous monitoring of water quality parameters is a novel design goal of OWQM-DS. The parameters most valuable for monitoring for contamination incidents (chlorine residual, ORP, pH, specific conductance, temperature, DOC/TOC, and spectral absorbance) are identified in Tables 4-1 and 4-2. A more detailed discussion of this design goal and other OWQM-DS applications can be found in Section 9.

Online instruments that measure additional parameters of interest, such as radionuclides (e.g., alpha, beta, gamma levels), toxicity, and refractive index, have not yet been used in OWQM-DS systems on a wide scale. Instruments that measure radionuclides typically have a minimum detection limit that is higher than the maximum contaminant levels established by EPA. Instruments that measure toxicity and refractive index effectively are commercially available, but have not been used widely in OWQM-DS systems. *List of Available OWQM Instruments* provides more information on these technologies.

Section 5: Monitoring Stations

Once monitoring locations and parameters have been selected, monitoring stations can be designed. Each station should consist of the water quality instruments and other equipment necessary to measure and process a sample, and then collect and transmit data to a utility's ***control center***. The design of a station will depend on:

- The monitoring location
- Water quality parameters to be monitored at the location
- Practical considerations for installation and maintenance of the station

TARGET CAPABILITY

OWQM-DS stations are designed to fully achieve selected monitoring goals.

A basic functional block diagram of a ***monitoring station*** is shown in **Figure 5-1**, which delineates the station functions as follows:

- **Instrumentation.** Provides the means to measure selected water quality parameters.
- **Computing element.** Facilitates the transfer of OWQM-DS data and other datastreams to the communications function, enables remote control of monitoring stations, and provides processing capabilities at stations.
- **Communications.** Provide a means to transfer data collected by a monitoring station to a control center and instructions from a control center to a station.
- **Power supply and distribution.** Supplies sufficient power to energize equipment in a monitoring station.
- **Accessories.** Perform other functions not defined above.
- **Station structure.** Provides a means to mount and protect instrumentation and ancillary equipment both from the environment and potential tampering.

The following sections describe each of the functions identified in Figure 5-1.

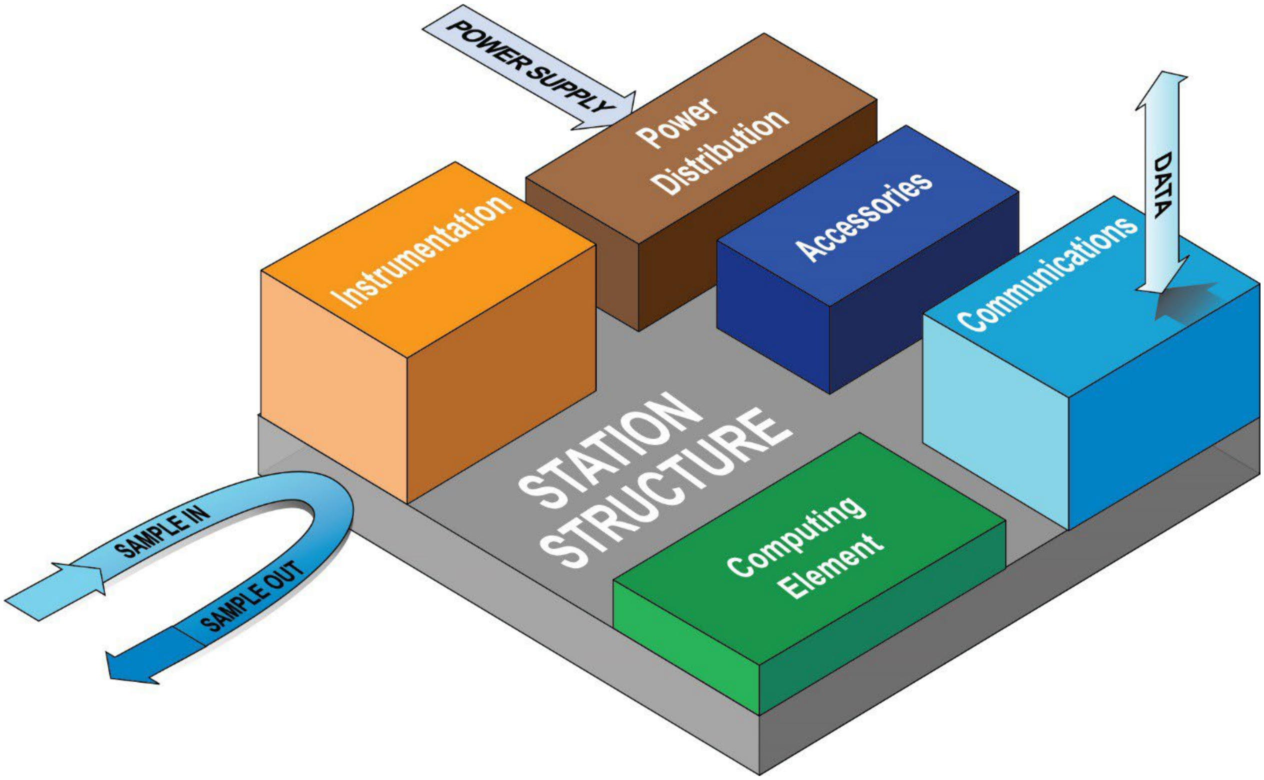


Figure 5-1. Functional Block Diagram of a Monitoring Station

5.1 Instrumentation

In many cases, multiple sensor technologies are available to measure a given water quality parameter, and specific instruments will need to be selected for a monitoring station. Several factors warrant consideration when selecting an instrument, including instrument performance, sampling approach, sampling and analysis interval, environment at an installation site, ***lifecycle cost***, and vendor support *List of Available OWQM Instruments* provides an overview of water quality parameters and related sensor technologies, as well as factors that should be considered during the selection process.

> **TIERED STATIONS**
>
> Because some instrumentation can be expensive, installing different tiers of monitoring stations can be a cost-effective option. For example, a limited number of monitoring stations that monitor both core and additional water quality parameters could be installed at critical monitoring locations, while additional stations monitor only core parameters. This approach can help to minimize the cost of an OWQM-DS system while also providing robust monitoring at critical locations.

The most common sampling approach for OWQM-DS involves connecting a sample side stream from a distribution main or tank to sensors inserted into a flow-cell contained inside a monitoring station. This method requires installation of piping or tubing to move the sample to the flow-cell. Some instruments designed for use in a flow-cell are equipped with wipers, brushes, or compressed air to control sensor fouling.

If a monitoring station uses a flow-cell, it will produce a waste stream that requires disposal. If a station houses a water quality instrument that adds reagents to sample water, additional requirements may dictate the method of waste stream disposal. The most convenient method of waste disposal is to direct waste streams into a sanitary sewer, if available and permissible. At installations where a sewer is not available, a dry pit is typically used, which may require additional approvals (note that dry pits must be designed to accommodate the flow of the waste stream).

5.2 Computing Element

Each monitoring station should include a local computing element that is typically a proprietary instrument controller (e.g., Hach SC1000, s::can con::cube, YSI IQ SensorNet). Alternatively, an industrial computer can be used to provide more complex and flexible processing capabilities.

A local computing element provides functions that may include the following:

- Controlling instrumentation (e.g., setting of timing intervals between measurements)
- Monitoring instrumentation and transferring analysis results to the communications function
- Monitoring instrumentation and communications for failures or error flags
- Managing and monitoring accessory functions (e.g., detection sensors, cameras)
- Controlling local functions (e.g., enabling the collection of a grab sample based on local or remote triggers)
- Providing more complex software algorithms for data validation and anomaly detection

5.3 Communications

The selection of a communications solution to transmit data from a monitoring station to a control center is often influenced by a station's location and proximity to existing communications solutions available to a utility (e.g., city or county network). Communications solutions can include wired and wireless technologies. *Guidance for Designing Communications Systems for Water Quality Surveillance and Response Systems* provides further details for common communications options as well as a set of evaluation criteria to support the selection process.

5.4 Power Supply and Distribution

The choice of power supply for a monitoring station is often limited by the location where the station is installed and power requirements for station equipment. Where readily available, grid power is often the simplest and least expensive power supply. However, if grid power is not available nearby, extending it to a station may be equally or more expensive than using an alternative supply (e.g., solar supported by batteries). When using grid power, it is suggested that stations have a dedicated circuit on the main breaker panel or a line conditioner to avoid erratic voltage or circuit breaker trips. To ensure continued operation of a station during minor power outages, an uninterruptible power supply should also be installed. *Guidance for Building Online Water Quality Monitoring Stations* provides additional guidance on power distribution.

5.5 Accessories

Additional features and functions may be provided as part of a monitoring station, such as:

- Autosamplers, consisting of bottles and valving, that facilitate the automatic collection of water samples at a station immediately after a water quality anomaly is detected
- Lighting and other accessories to assist with maintenance activities
- Sensors to detect leakage from plumbing or flooding by other means
- Cameras and door switches for security
- Additional communications equipment (e.g., Ethernet switches)
- Operator interface terminal to interact with a local computing element to support calibration and troubleshooting

Guidance for Building Online Water Quality Monitoring Stations provides further details related to accessories and how they can be incorporated into a monitoring station.

5.6 Station Structure

The station structure for a monitoring station includes the materials and devices used to mount or house OWQM-DS equipment. Where a flow-cell is used, the flow-cell is part of a station. In-pipe sensors typically require a connection to a separate controller and communications equipment installed outside of a pipe. To achieve selected design goals and performance objectives, stations may need to be installed inside existing buildings, near other equipment, or inside a structure built specifically for the station. The nature of a specific installation site will influence the station structure. Stations are typically constructed using one of four primary design types:

- **Wall-mounted racks.** Assembled by securing instruments and related equipment to a mounting panel that is attached to a wall.
- **Free-standing racks.** Constructed by securing instruments and related equipment to a mounting panel that is attached to an open, structural frame that provides access to both sides of the panel.
- **Enclosed stations.** Designed to house instruments and related equipment inside a custom, prefabricated, or National Electrical Manufacturers Association (NEMA) rated enclosure.
- **Compact stations.** Smaller versions of enclosed stations that can be designed around one or two reagent-based instruments or a flow-cell with multiple reagentless instruments to measure multiple parameters.

INSERTION SENSORS

At the time of document publication, flow and pressure sensors are the most common types of sensors that can be inserted directly into a pipe. Temperature, chlorine residual, and spectral absorbance insertion sensors are also available, but they are not as commonly used.

Guidance for Building Online Water Quality Monitoring Stations provides details for each of these monitoring station designs.

Section 6: Information Management and Analysis

The data generated by monitoring stations must be converted into actionable information to achieve selected design goals and provide a utility with the maximum value for its investment. Actionable information is produced by analyzing OWQM-DS data, along with supporting information, and presenting relevant results to an end user in a manner that is easy to understand. To achieve these objectives, an OWQM-DS information management system must be a combination of ***hardware***, software, tools, and processes to collectively support an SRS and provide users with information needed to monitor real-time system conditions.

TARGET CAPABILITY

An information management system is used to provide data storage, access, analysis, notification, and visualization capabilities.

The development process discussed in this section is consistent with the general principles of information management system design presented in Section 4 of the *Guidance for Developing Integrated Water Quality Surveillance and Response Systems*, with additional considerations that are specific to an OWQM-DS information management system. This section is divided into subsections that cover the following topics:

- Data validation
- Anomaly detection
- Information management system architecture
- Information management system requirements

6.1 Data Validation

Accurate data is needed to achieve OWQM-DS design goals, maximize the benefit and sustainability of an OWQM-DS system, and build confidence in information generated by the system. However, even when effective data quality objectives have been established and are being achieved overall, invalid data values are inevitable due to issues such as instrument malfunction, flow or pressure irregularities, and improper maintenance.

INFORMATION UTILIZATION

During a forum with chief information officers (CIOs) from 50 major utilities across the United States, the CIOs estimated that only 10 to 15 percent of the information gathered by their organizations is properly evaluated. Automated analysis and effective visualization of data can help to address this underutilization of collected data.

Data validation involves the identification of data that is inaccurate so that it can be handled in a manner that does not negatively impact the intended use and further analysis of the data. The most straightforward method for identifying invalid data is to consider the data values themselves. For example, values that are outside of an instrument's measurement range, as well as null data (missing or zero) or non-numeric values (e.g., "N/A"), are considered invalid. Data validation can also utilize patterns in data values. Data is typically invalid during data "flatlines," in which data values remain constant for an extended period, and during periods of extreme variability, in which the frequency and magnitude of changes in data values are physically improbable.

Common methods of managing invalid data include flagging or removing invalid values. Some data validation technologies contain logic for "cleaning" the data, in which invalid data values are replaced with values deemed more likely to better represent true water quality. This practice provides a complete dataset for analysis, but there cannot be complete confidence that the replacement values are accurate.

Regardless of the approach used for OWQM-DS data validation, it is best practice to retain the original data values to maintain data integrity. For data to be used in an OWQM-DS system, data validation must be automated and occur before anomaly detection takes place.

Supplemental information can also be used for data validation. **Table 6-1** lists information types that can indicate when data being produced by a water quality instrument is likely inaccurate.

Table 6-1. Supplemental Datastreams that can be Used to Validate Data

Information Type	Information Source	Relevance
Water quality instrument fault indicator	Station water quality instruments	Signals that an instrument is functioning in a manner that could produce inaccurate data
Communications system status indicator	Information management system	Signals a station communications system malfunction, which can cause flatlined or null data
Station flow and pressure data	Station flow meters or pressure sensors	Can be reviewed to determine whether values are outside of water quality instrument manufacturer specifications, which can cause a malfunction or produce inaccurate data
Maintenance mode indicator	Switch located at a station (e.g., manual switch, door interlock)	Signals that utility personnel are working on the station (e.g., calibrating a water quality instrument, replacing a sensor), which can produce inaccurate or null data
Station environment information (e.g., temperature and humidity data, surveillance video)	Station accessories (e.g., sensors, cameras)	Can be reviewed to determine if conditions at a station could have caused instruments to malfunction

In addition to the automated data validation methods above, an information management system can be designed to allow utility personnel to manually flag data as inaccurate during data review or alert investigations. Staff can identify invalid data that is not detectable by automated techniques using both their knowledge of typical water quality at monitoring locations and additional resources (e.g., system operations information, equipment maintenance records, grab sample results).

FAULT CODES

Some complex instruments may provide "fault codes" that not only indicate that a fault has occurred, but also include details of the fault. Understanding the meaning of these fault codes is necessary to understand the implication of the code with respect to data quality.

In some cases, it may be unnecessary to implement a separate data validation method because the capability to manage invalid data is built into the information management system. For example, a sophisticated ***data analysis tool*** may have processes that ignore data flagged by water quality instruments. However, if data validation is not incorporated into an information management system, there may be ways to implement data validation algorithms at certain points in the system (e.g., by a monitoring station local computing element).

6.2 Anomaly Detection

Unlike data validation, in which inaccurate values are identified, this section describes techniques for analyzing data to identify anomalies. Anomalies are changes in OWQM-DS data values that require attention from utility personnel and may prompt response actions.

While operators can visually review data daily, automated analysis techniques are also available. An ***Anomaly Detection System*** (ADS) is a data analysis tool designed to detect anomalies or deviations from an established baseline. The complexity of ADSs can vary widely, as well as the time and technical expertise required to implement them. Three categories of automated analysis techniques are described below.

Threshold Analysis

Threshold analysis is a process in which an alert is automatically generated when a parameter's value surpasses a pre-defined threshold. Threshold values should be based on the normal range of values for a given parameter at a given monitoring location so that threshold exceedances are indicative of a water quality anomaly, as shown in **Figure 6-1**. A comparison of basic threshold analysis to more sophisticated techniques for anomaly detection was presented in *Journal AWWA* (Umberg and Allgeier, 2016).

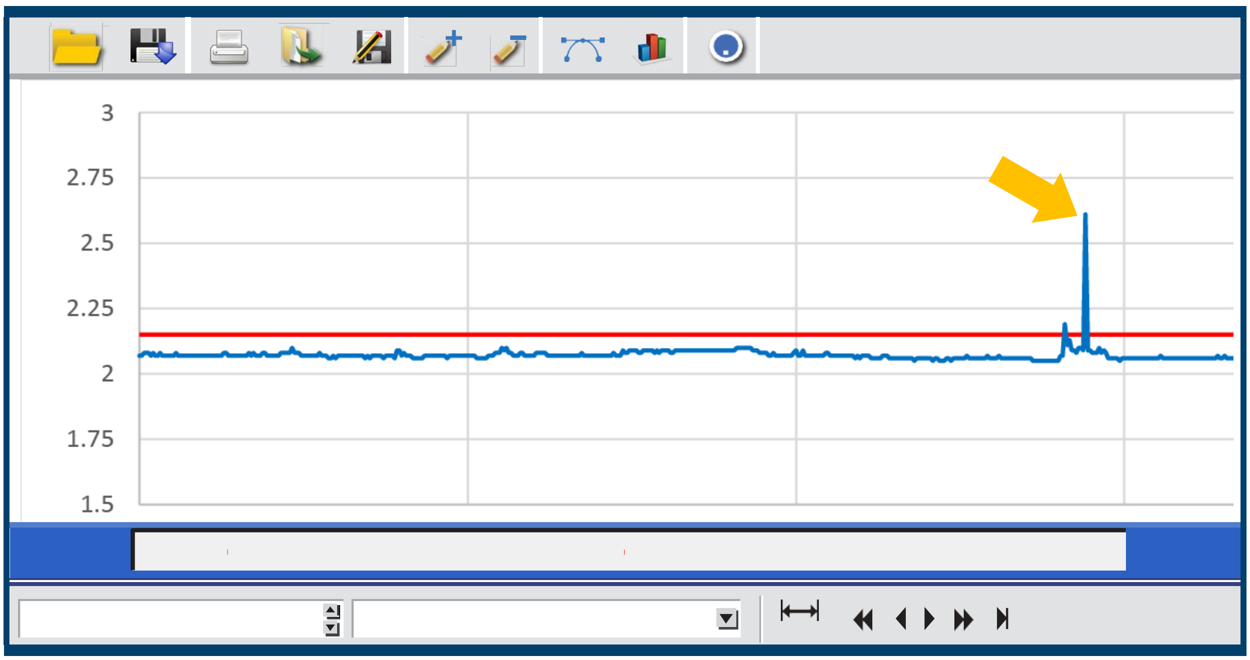


Figure 6-1. Example of Threshold Analysis

In general, threshold analysis is easy to implement and is a standard feature in most information management systems (including SCADA systems). Many utilities already use thresholds for treatment plant process control; similar types of thresholds can be used to guide distribution system operations. For example, thresholds can be established at monitoring locations and used to adjust booster chlorination doses or monitor the efficacy of flushing activities. Therefore, utilities may already have a process that can be used to establish thresholds for anomaly detection.

Complex Analysis

While thresholds can be useful for anomaly detection, in some cases, multiple parameters could be within established threshold limits, but the relationship between them may indicate an anomaly. These types of water quality anomalies cannot be detected by thresholds, but may be detected using statistical techniques that can simultaneously analyze multiple parameter values at a given monitoring location.

Common techniques consider the rate of change in a single parameter at a single monitoring location or the relationship between values for a given parameter across multiple locations. For example, one location's chlorine values could be compared to the range of values seen at upstream locations, including the distribution system entry point supplying the location, during a time-period consistent with the hydraulic travel time between the locations. It would be expected that the downstream chlorine values would be similar to, or lower than, the upstream values by some predictable amount. If this is not the case, an alert could be automatically generated to indicate an anomaly.

Complex analysis can also combine water quality data with operational information. For example, different threshold values for chorine residual could be used to generate an alert based on whether a storage facility located near a given monitoring station is in fill or drain mode.

ADS Software

Anomaly detection can also be performed using software developed specifically for analysis of time-series data. These products use a variety of statistical and computer science techniques to analyze data. The ADS software available at the time of writing generally fall into two categories:

- **ADS software integrated into station hardware.** Some instrument vendors offer ADS software integrated with their hardware (and, thus, the software is installed at each monitoring station). Examples include Hach's Event Monitor and s::can's ana::tool.
- **ADS software that is independent of sensor vendor.** This software is often installed at a central location and operates independently of any station hardware or information management system. This ADS software may be proprietary (examples include OptiWater's OptiEDS and s::can's ana::tool) or open source (such as CANARY, developed by EPA and Sandia National Laboratories).

> **ADS CONFIGURATION**
>
> Proper ADS configuration is necessary to reliably detect water quality anomalies without excessive invalid alerts. Note that some complex ADSs may require significant time and/or effort for configuration.

Further details about ADS software can be found in the report for the *Water Quality Event Detection System Challenge: Methodology and Findings* (EPA, 2013) undertaken as part of the EPA's SRS program.

Most information management systems include standard statistical analysis functions that can be implemented to perform simple real-time analysis and basic anomaly detection. The values that trigger an alert for these analyses can be determined by calculating typical values in representative historic data. *Exploratory Analysis of Time-series Data to Prepare for Real-time Online Water Quality Monitoring* provides additional guidance on techniques for establishing a baseline using representative ***historical data***.

Prior to selecting an ADS, multiple options should be evaluated using representative historical data to determine which option can most reliably differentiate between true water quality anomalies and typical water quality variability at each monitoring location.

6.3 Information Management System Architecture

The design of an information management system should be captured in a system ***architecture***, which is the set of hardware, software, processes, and services associated with the system. Information management functions can be supported by a variety of system architectures, but they will most likely be centralized (e.g., in a server at a utility's operations center). In this case, data is transmitted from monitoring locations to this centralized system.

The architecture of an information management system may involve interaction with multiple source systems. For example, supplemental data may be stored in separate systems, or external software may be used for data analysis. In some cases, these systems can be integrated, though significant effort may be needed to interface with legacy systems.

This section includes three examples of information management system architectures that can be used for OWQM-DS:

- Existing control system
- Dedicated information management system
- Hosted solutions (including cloud-based services)

These examples are intended to illustrate system architecture approaches that may be taken depending on a utility's existing ***Information Technology*** (IT) infrastructure and system requirements. All examples assume that each monitoring location has a communication device that transmits data to a central location.

Existing Control System

In some cases, information management requirements for OWQM-DS can be met entirely through an existing control system. For example, data generated by monitoring stations can be added to an existing SCADA system used for process monitoring and control. This arrangement would likely use existing SCADA elements, such as a historian for data storage and a human-machine interface for visualization of OWQM-DS data. **Figure 6-2** shows an example of this type of architecture.

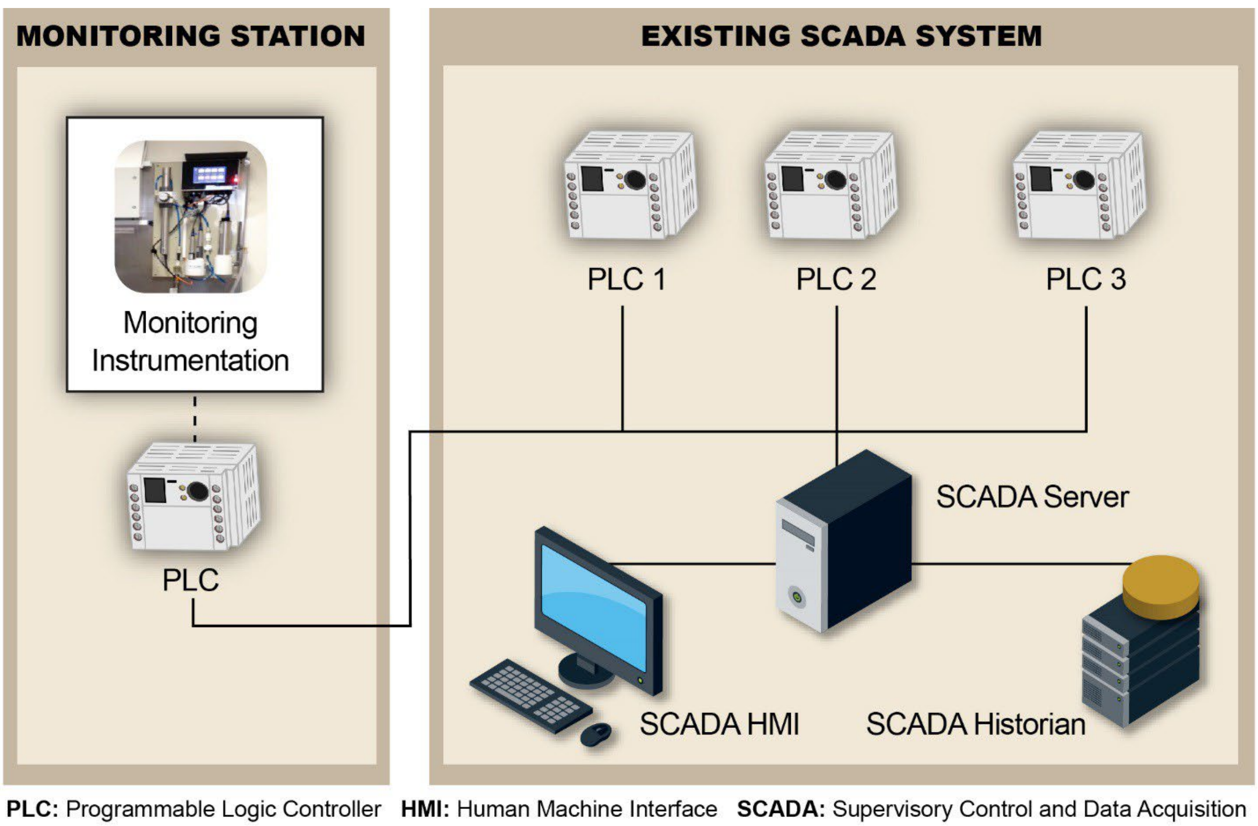


Figure 6-2. Example of Information Management as an Extension to an Existing SCADA System Architecture

Dedicated Information Management System

In cases where an existing control system does not satisfy information management requirements for OWQM-DS, a dedicated information management system may be appropriate. The following are examples of when this may occur:

- An OWQM-DS system produces data that is difficult to store in a SCADA historian. For example, instruments that measure spectral absorbance over multiple wavelengths can generate a spectral profile as an array of 256 data points for each sample. The design of some SCADA historians is not optimal for storing such arrays, but alternate database structures are available to store these complex ***datastreams*** more efficiently.
- An OWQM-DS system requires access to data on networks (e.g., a utility's business network) that cannot be accessed by a SCADA system due to security policies.
- Remote access to OWQM-DS data is required, and security policies preclude remote access to the SCADA system.

The use of a dedicated information management system for OWQM-DS provides greater flexibility for achieving the required functionality. It also allows for connection with other utility information management systems, such as a laboratory information management system (LIMS), that contain analytical results from grab samples collected from a distribution system. **Figure 6-3** illustrates a conceptual architecture of a dedicated information management system with connections to a customer information system, LIMS, and work order system. SCADA data could also be utilized with such an architecture if implemented in a manner that complies with utility information security policies.

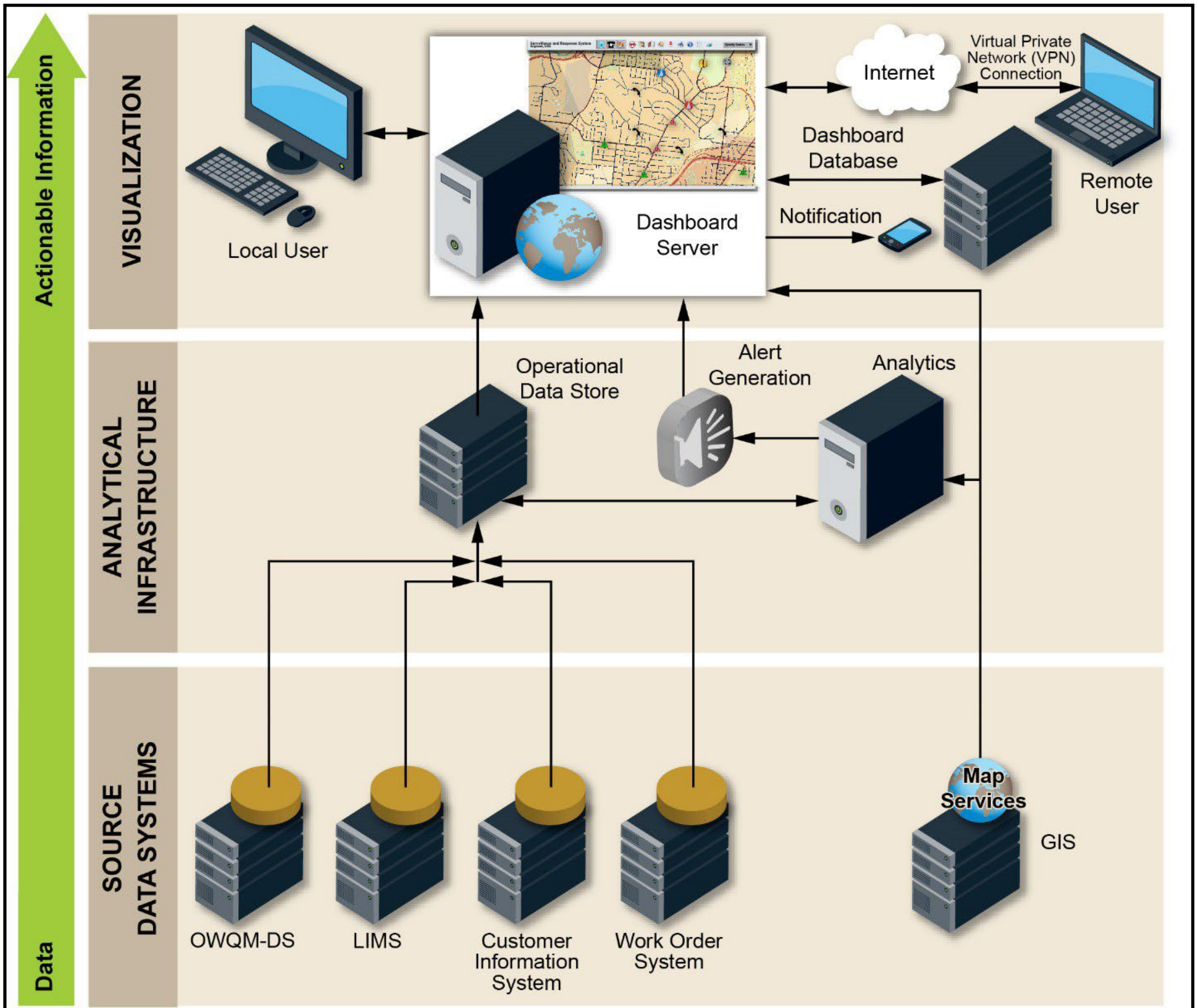


Figure 6-3. Example of a Dedicated Information Management System

This type of architecture can also incorporate more powerful analytics and visualization approaches, such as a ***dashboard***, which is a visually oriented ***user interface*** that integrates and displays data from multiple sources spatially and graphically. An example of a GIS-based dashboard designed to display data from monitoring stations is shown in **Figure 6-4**. Additional information resources that can support the interpretation of OWQM-DS data, such as LIMS and customer complaint information, can be incorporated into a dashboard design. Presenting information from a variety of resources in a spatial context can be valuable during the investigation of a water quality anomaly, as discussed in Section 7. *Dashboard Design Guidance for Water Quality Surveillance and Response Systems* provides additional information about the features and design of dashboards.

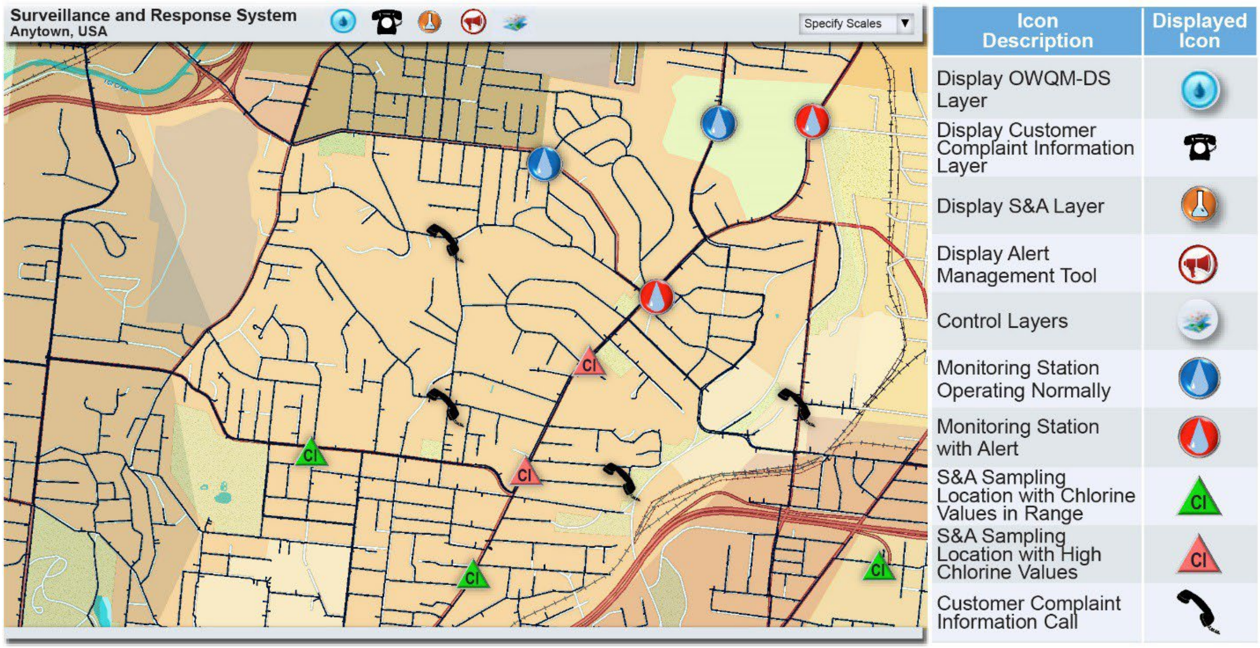


Figure 6-4. Example of a Dashboard Display

Hosted Solutions

Hosted solutions can also be used for information management systems. The decision to use a hosted solution should be based on whether there is a preference to procure and manage an information system within a utility or contract information management capabilities as a third-party service. A hosted solution generally has low capital costs and does not require the time and technical expertise necessary to implement and maintain a new system. A hosted solution may also be used temporarily if responsibilities for managing the information management system will change. Under this scenario, a hosted solution may be used initially to reduce capital costs and internal staffing requirements. Once a utility is ready to take over responsibility for the system, it can be migrated to an internally managed system.

A hosted solution can vary in complexity (e.g., if supplemental data is integrated) and can be used to meet all or some requirements of an information management system. Potential functions of a hosted solution can include data storage, data analysis, and ***data access***. If a hosted solution is used for data storage, OWQM-DS data (as well as relevant supplemental data, if desired) is transferred directly from each station's local computing element to the external system, often via the internet. For external data analysis, relevant data is transmitted to an external system, and the output is returned to the utility and displayed through visualization tools. Hosted solutions generally contain a user interface for data access and analysis, as well as alert notification and tracking. Users can often access the password-protected system from any device connected to the internet, including work or home computers and mobile devices. Some challenges with this approach can include security concerns during data transmission or storage, potential difficulty using the information stored in the hosted system outside of its provided functions, and loss of ownership of the data. However, data security concerns are currently being addressed by technology providers that are developing large data portals for smart city programs (e.g., Microsoft Trusted Data Platform, Amazon Web Services, Cisco CDP, Mtuity Atlantis).

Many vendors now collect, store, and process data and provide a user interface to the data using a proprietary cloud. However, this approach can present a potential issue or concern when data in the proprietary cloud requires integration with other data that resides within other utility information management systems. Where a vendor offers data in a proprietary cloud, there should be an option to automatically pass this data to a utility's information management system for further processing and storage. This strategy allows for data from all sources to be stored in a normalized database for processing and the information generated to be utilized by a dashboard.

A hosted solution can be used for a SCADA system architecture or a dedicated information management system architecture. In both cases, the analytics and data storage can be provided by ***cloud services***. For a SCADA-hosted architecture, the functions provided by the SCADA server and SCADA historian shown in Figure 6-2 would be in the cloud. For a dedicated information management system, the hosted architecture would provide the functions shown in the analytical infrastructure layer in Figure 6-3.

6.4 Information Management System Requirements

An effective information management system provides users with the information they need when they need it and in a usable, easily consumable format. Information management systems for OWQM-DS are unique for every utility due in part to differences in existing systems and capabilities, expertise of utility personnel responsible for developing and using the systems, expected uses of the system, and resources available to develop the system.

Section 4 of the *Guidance for Developing Integrated Water Quality Surveillance and Response Systems* describes a methodical process for selecting and implementing an information management system. An important first step in this process is developing requirements for a system in the following two categories.

- ***Functional requirements*** define key features and attributes of a system that are visible to end users. Examples of functional requirements include the way data can be accessed, the types of tables and plots that can be produced through a user interface, the means by which alerts are transmitted to utility personnel, and the ability to generate custom reports. Functional requirements are generally defined by end users.
- ***Technical requirements*** are system attributes and design features that are often not readily apparent to end users but are essential to meeting functional requirements and other design constraints. Examples of technical requirements include system availability, information security and privacy, backup and recovery, data storage needs, and integration requirements. Technical requirements are generally developed by IT personnel or derived from IT standards.

HELPFUL HINT

Throughout the selection and implementation process, information technology (IT) personnel and staff responsible for OWQM-DS implementation should compile requirements across users and prioritize them in light of design goals, performance objectives, and available resources. Coordination between the design team and end users is needed to precisely describe and refine necessary functionality.

The *Information Management Requirements Development Tool* is a software tool designed to help users define, prioritize, and document requirements for an information management system. This tool is populated with functional and technical requirements commonly used to support OWQM-DS operations. It also allows users to generate a consolidated list of functional and technical requirements that can be used to develop design and/or bid documents.

Functional Requirements

Before developing functional requirements, expected uses of an information management system for OWQM-DS should be defined. Expected uses are simply the ways users expect to interact with a system. For example, users may want to review recent distribution system water quality data to guide system operations, be notified of anomalous water quality conditions, or access a variety of information resources to investigate the cause of a water quality anomaly. Section 4.2 of *Guidance for Developing Integrated*

Water Quality Surveillance and Response Systems provides guidance on identifying expected uses of a system, as well as their relationships to functional requirements.

The expected uses of an information management system should guide the development of detailed functional requirements. **Table 6-2** provides examples of functional requirements.

Table 6-2. Examples of Information Management System Functional Requirements

Requirements	Description
Robust time-series plotting	The system should allow users to create time-series plots that display multiple parameters on the same plot. Users should be able to customize the plots, including specifying the time-period and parameters to display.
Threshold analysis and alerting	The system should be able to produce automated alerts if data values fall outside of pre-defined thresholds. These thresholds should be configurable and specific to each parameter.
Automated report generation	The system should provide automated reports that can be customized by individual users. These reports should provide analysis output, time-series plots, statistical summaries of validated data, and a summary of flagged data.
Data export	Users should be able to export data from the system in a format that can be imported into analytical software, such as a spreadsheet program.
Incident reporting	Users should be able to obtain a list of water quality incidents based on user-defined filter criteria such as type of incident, date range, or cause of incident.
Automatic data validation	The system should perform real-time data validation and flag data points using system and/or user-defined logic.
Alert notifications	The system should contain flexible and robust alert transmission options. These can include: • The ability to receive and view alert details on mobile devices, including smartphones • The ability to identify the staff member who should receive alert notifications based on the time of day and day of the week • The ability to resend notifications if acknowledgement is not received in a pre-defined time-period; the notification can be re-sent to either the intended receiver or sent to someone else
Investigation tracking	The system should allow users to enter and view real-time alert investigation details through the user interface. The system should require alerts to be acknowledged and then to be closed out within a defined time-period.
Other data sources	The information management system should provide access to the latest information from the following resources: • Customer complaints database • Work order system • LIMS
Remote access	Users should be able to access the system remotely (i.e., outside of the utility's computer network) over a secure connection.
GIS-based presentation of monitoring station operating status	Colored icons should be used to identify the current operating status of each monitoring station on the GIS display using the following attributes: • Blue – Normal operation, all systems operating • Yellow – Some subsystems (e.g., sensors) not functioning to specification • Red – Station producing an ADS alert • Gray – Station not communicating and assumed to be offline
Mouse over and drill down capability	When users hover over an icon on the map, a pop-up box should appear that displays high-level information associated with the icon (e.g., hovering over a monitoring location should display data values, instrument status, a list of hydraulically connected locations, and its physical location).

Requirements	Description
	These pop-up boxes should contain hyperlinks that take the user to detailed information, such as time-series plots of OWQM-DS data or guides for investigating water quality at a location.
Display of overlays	Multiple overlays can be displayed at the same time. Overlays that may be displayed concurrently include: • Distribution system model showing mains, pressure zones, and utility facilities • Map view showing major highways and community facilities • Monitoring station location and status • Latest work order locations
Hydraulic modeling and forecasting	The system should be able to trace a water quality incident from a specified location in the distribution system and predict arrival times at all downstream monitoring locations.

Technical Requirements

Technical requirements are often dependent on functional requirements and should be developed after the functional requirements have been defined. Generally, development of technical requirements is the responsibility of IT personnel who consider the technical aspects of the information management system design that are necessary to meet functional requirements. Technical requirements will also be informed by IT policies such as security protocols and the need to adapt the system over time to incorporate new functions, datastreams, and features. **Table 6-3** provides examples of technical requirements.

Table 6-3. Examples of Information Management System Technical Requirements

Requirements	Description
Design flexibility and ability to accommodate changing requirements	The system should have the flexibility to change key parameters and display features without modifying the underlying code. These changes include updates to the user interface as well as adding, removing, or changing datastreams, monitoring locations, and external data sources.
Encryption	All interactions with the information management system should be encrypted via Secure Socket Layer.
Individual login accounts	Users should have individual login accounts, and administrators should be able to track system use for individual users. Tracking may include the times a user is logged on and actions taken.
Map service utilization	The information management system should be able to read and display map services provided by the utility's GIS using a configurable list of map services.
Operational data store size	The operational data store should provide ready access to the last 90 days of data for all source data systems used in the information management system.
Parameter data storage	The information management system should provide storage of datastreams for spectral profiles (256 datapoints per sample).
Vendor-neutral platform or open architecture	The system must be able to interface with any vendor's technology.
Minimal programming expertise required	The system should be able to be installed and configured by staff with intermediate skills and experience designing or implementing IT systems. Installation can require some integration and design work, but should not require extensive coding or engineering.

Section 7: Alert Investigation Procedure

An alert investigation procedure for OWQM-DS formalizes and standardizes the investigation of distribution system water quality anomalies. Such a procedure is triggered by notification of an alert and continues until (1) an explanation for the alert is identified, or (2) all activities are completed and water contamination cannot be ruled out.

TARGET CAPABILITY

A procedure that facilitates timely and efficient investigation of OWQM-DS alerts has been developed, documented, and put into practice.

This section describes considerations for development of an alert investigation procedure for OWQM-DS and covers the following topics:

- Developing an effective alert investigation procedure
- Developing tools to support investigations
- Preparing for real-time alert investigations

7.1 Developing an Effective Alert Investigation Procedure

This section describes an approach for developing an alert investigation procedure, which consists of the following three activities:

- Define potential alert causes
- Establish an ***alert investigation process***
- Assign roles and responsibilities

Define Potential Alert Causes

Consideration of potential alert causes provides a useful starting point when developing an alert investigation procedure as they help define types of information to consider during the investigation. **Table 7-1** lists and describes the most common causes of both ***invalid alerts*** (not due to anomalous water quality conditions) and ***valid alerts*** (triggered by anomalous water quality conditions) based on experience from utilities that have implemented OWQM-DS systems (EPA, 2014).

Table 7-1. Common High-level Causes of Alerts

Alert Cause		Description
Invalid Alerts	OWQM-DS equipment issue	An alert triggered by inaccurate data values due to a malfunction or failure of station hardware, data transmission, or data handling
	Data analysis issue	An alert caused by an artifact of an ADS (i.e., an alert is produced even though data is within the normal range of values and variability)
Valid Alerts	Treatment or distribution system equipment malfunction	An alert due to a water quality change caused by a malfunction or failure of treatment equipment (e.g., chlorine feed system) or distribution system equipment (e.g., pump)
	Change in distribution system operations	An alert due to a water quality change caused by unusual distribution system operations, such as a change in pumping, valving, or treatment processes
	Distribution system issue	An alert due to a water quality change caused by distribution work or a distribution system upset, such as a main break or pressure surge
	Water contamination	An alert triggered by accidental or intentional introduction of a foreign substance into a distribution system, which may or may not be harmful

Establish an Alert Investigation Process

The core of an effective alert investigation procedure is a detailed, step-by-step alert investigation process for identifying the cause of an alert. The alert investigation process is generally structured to consider the most likely causes first, allowing contamination to be quickly ruled out for the majority of alerts. If no cause can be identified by the end of the process, water contamination is considered possible and designated personnel are notified.

Each step of an alert investigation process should be documented and include the following information:

- Detailed instructions for completing the step
- Roles and names of specific individual(s) responsible for completing the step
- Information resources that should be consulted during the step
- Actions that should be taken, including personnel to be notified, upon completion of the step

The *Alert Investigation Procedure Template* provides a framework for documenting an alert investigation process clearly and completely. The template, which includes a checklist, can be opened by clicking on the box to the right.

Alert Investigation Procedure Template (Microsoft Word)

*Note that the document that is currently open may need to be downloaded and opened offline to access this template.

An alert investigation process can be visually depicted in a diagram that shows the progression of steps through the entire process. This simplified representation of the process allows individuals with responsibilities for discrete steps to see how their activities support an overall investigation.

Figure 7-1 provides an example of an alert investigation process diagram. The major steps and decision points are shown in the flow chart on the left side of the figure. Additional detail on the actions implemented are shown to the right in the figure.

A range of estimated times for properly trained personnel to complete steps in the investigation is shown on the left edge of Figure 7-1. Totaling the length of time required for each step yields the time required for a full investigation. The shortest investigations are those in which an alert cause is identified in an early step (e.g., if the data is found to be inaccurate and only the first step of the investigation process must be completed).

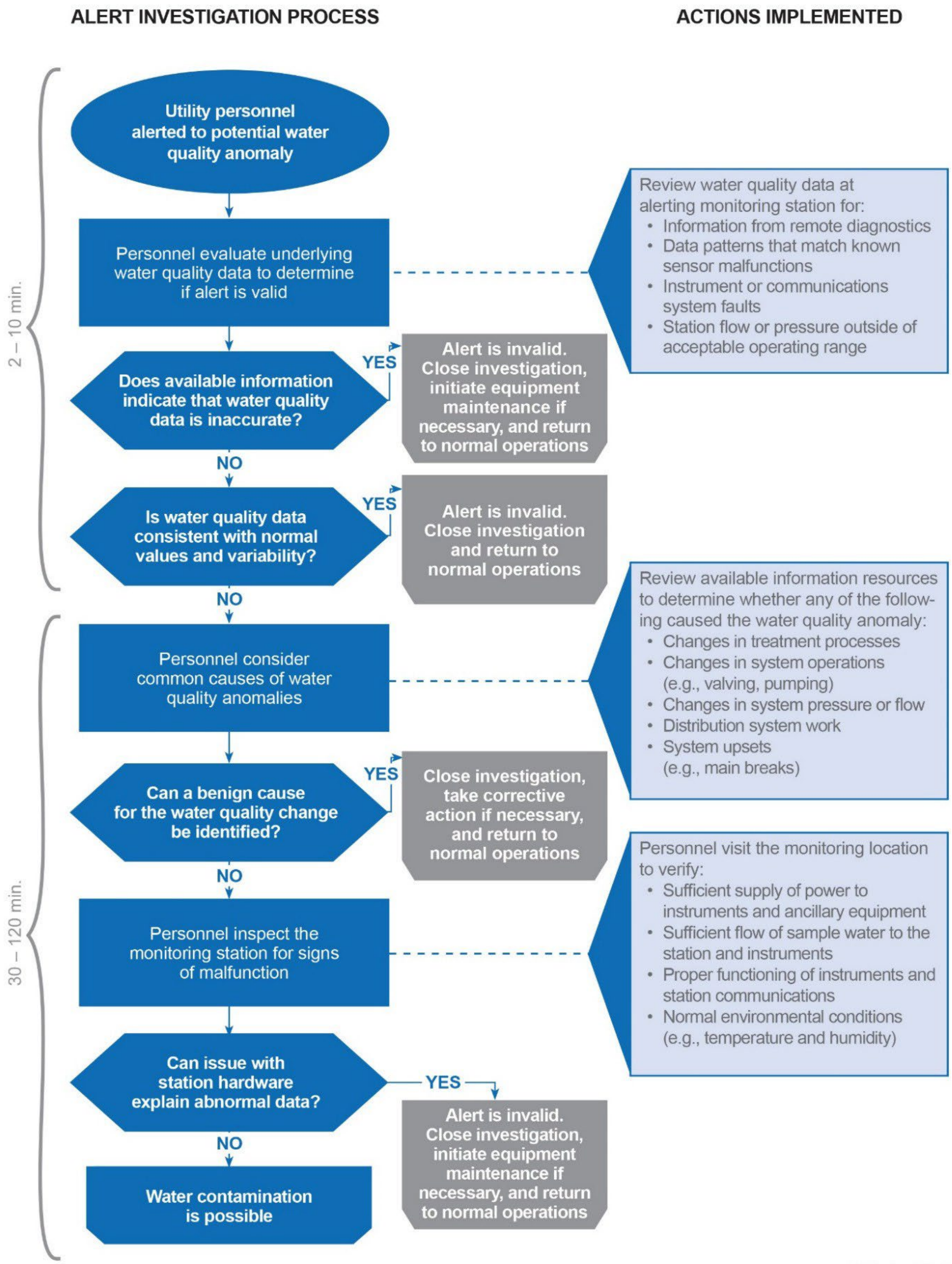


Figure 7-1. Example Alert Investigation Process Diagram

The specific actions included in an alert investigation process depend largely on the availability of relevant information and how it can be accessed (e.g., through an information management system or by calling various utility departments). It is important to identify these information resources as an alert investigation process is being developed. **Table 7-2** provides examples of supplementary information that may be useful during an investigation. Data available through existing information management systems may impact the activities included in an alert investigation process and, conversely, the information needed to support investigations may inform information management system requirements (see Section 6.4).

Table 7-2. Additional Information Sources for Use in an Investigation

Information Type	Example Information	Value to Alert Investigation
Instrument performance indicators	Instrument error codes, remote diagnostics indicators, and data quality indicators	Assist in determining whether data is valid; malfunctioning instruments may generate error codes useful for assessing data quality
Communications system status indicators	System error codes, communications status between the monitoring station and the central location	Assist in determining whether data is valid; malfunctioning communications may result in missing or incorrect data
Instrument maintenance records	Maintenance records and instrument logs	Assist in determining whether data is valid; instrument maintenance activities and ongoing instrument performance issues may result in missing or inaccurate data points
Distribution system operations information	Tank levels, pump status, valve status, system flow, and pressure data	Support investigation of the cause of water quality changes and the impact of operations on water flow paths; changes in operations often cause changes in system flow paths and corresponding changes in the water quality measured at a monitoring location
Treatment process information	Treatment process settings, chemical doses, and treatment process monitoring data	Support investigation of the cause of water quality changes and identification of water source(s) supplying each monitoring location; treatment process settings often affect distribution system water quality
Distribution system work records	System maintenance records and work orders	Support investigation of the cause of water quality changes; system work or upsets can impact system flow paths and water quality
Customer complaint records	Customer complaint entries	Support investigation of the cause of water quality changes; some water quality changes impact water aesthetics, which customers can detect and report
Modeling results	System flow rate and flow path	Support investigation of the cause of water quality changes; modeling results can provide insight into flow paths between monitoring locations
Sampling results	Results from analysis of grab samples, including those collected during inspection of the alerting monitoring station	Assist in determining whether data is accurate, and provide water quality data from additional monitoring locations to support investigation of the cause of water quality changes
Calendar of regional events	Date and time of large community events	Support investigation of the cause of water quality changes; large events that significantly alter water demand in a specific area can impact system flow paths and water quality

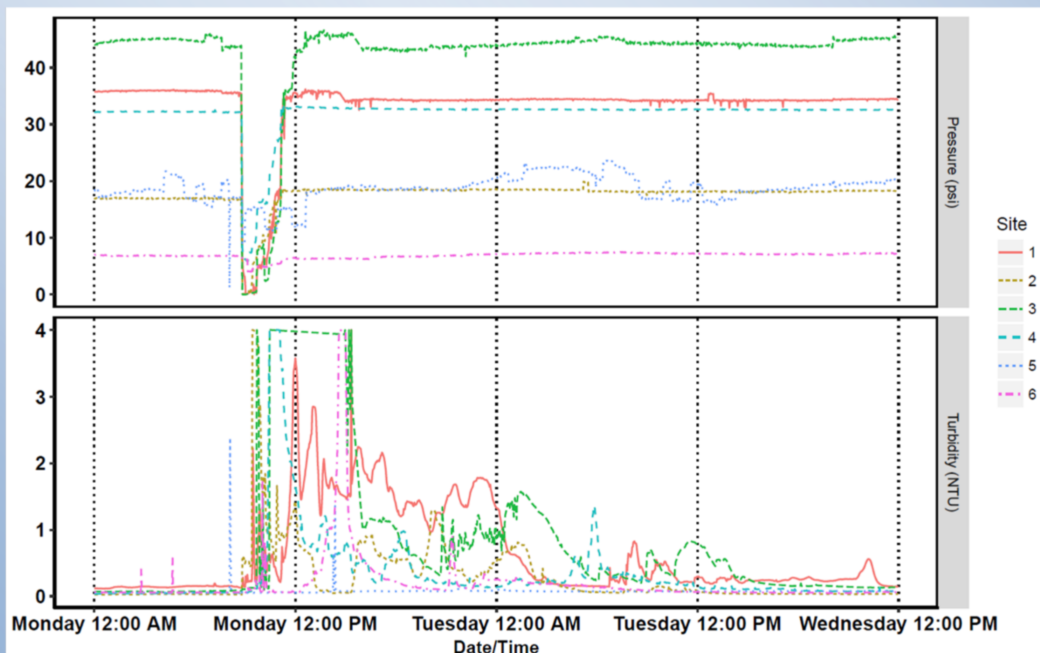
An alert investigation process may point to the need to make additional datastreams available to investigators or improve access to existing datastreams. Desired updates to information management systems should be noted during development of the alert investigation procedure. This information is particularly useful for developing requirements if a new information management system will be implemented or if existing systems will be updated.

Using Data from Hydraulically Connected Monitoring Stations

Data from hydraulically connected monitoring locations upstream and downstream of a location where an alert is generated can provide the following insight during an investigation:

- The presence of a similar water quality change at more than one location can increase confidence that a water quality change is real.
- If a water quality change can be seen at an upstream location, that information can be used to identify potential sources of a change. Conversely, if a change was not present upstream, it can be concluded that the cause of a water quality anomaly occurred between the locations or that the alert is due to a station-specific issue.
- Water quality at downstream locations can be reviewed to see whether the anomalous water quality arrives there in a time-period consistent with the hydraulic travel time between locations.

An example of how OWQM-DS data has been used to support investigations is displayed in the graph below. This graph shows how online turbidity data generated at hydraulically-connected monitoring stations can be used to detect and track the impact of a transmission main break in an upstream area of the system.



Assign Roles and Responsibilities

Once an alert investigation process is defined, responsibility for every activity must be assigned to one or more individuals. Roles for alert investigations should align with existing job functions. Leveraging existing expertise in this manner can reduce the amount of new training required and can result in increased acceptance of new responsibilities for investigating alerts.

Arrangements should be made for providing constant coverage of alert investigation responsibilities. Approaches to ensuring around-the-clock coverage include:

- Training personnel from all shifts on the alert investigation procedure
- Assigning backup personnel for each activity for cases when the primary investigator is unavailable
- Cross-training investigators on multiple roles
- Assigning personnel to be on-call for critical investigative functions, particularly those requiring a decision about the validity of an alert

Table 7-3 provides example of generic roles and responsibilities for investigating an alert.

Table 7-3. Example of Generic Roles and Responsibilities for Alert Investigations

Role	Alert Investigation Responsibilities
Water quality manager	• Receives alerts • Manages investigation of alerts • Facilitates communication among investigators • Decides whether an alert is valid and indicative of possible contamination
Water quality specialist	• Leads or assists with the investigation of alerts using knowledge of the distribution system and historical water quality
System operator	• Provides information on plant or system operations as needed • Collaborates with alert investigators about potential causes for changes in water quality
Distribution system maintenance staff	• Provides information about current distribution system operations and maintenance activities, as well as any system upsets
Sensor technician	• Provides information about recent sensor issues and equipment maintenance • Assists in the investigation of alerts by inspecting OWQM-DS equipment to determine whether it is operating properly

7.2 Developing Investigation Tools

This section describes tools that can be developed from this documentation to assist investigators in efficiently carrying out their responsibilities. The investigation tools that will be discussed in this section include:

- Checklists
- Records of previous alert investigations
- Quick reference guides
- Other information sources

Checklists

Alert investigation checklists guide personnel through their investigative responsibilities and allow them to document activities and findings. The checklists can ensure consistency among investigators, verify that all activities are completed, and reduce the time required to conduct alert investigations. Checklists generally list the activities assigned to a specific individual, and thus multiple checklists may be developed to support an alert investigation procedure.

A checklist should be streamlined, concise, and intuitive for personnel trained on the corresponding procedure. It should guide personnel through the steps of an investigation and provide space for them to record important information (e.g., an explanation of the cause of the alert, the explicit data used) for each activity completed. In some cases, it may be sufficient to simply check a box indicating completion of an activity. In others, an investigator may need to record a time or provide more details on activities or conclusions.

Record of Alert Investigations

It is important to formally document each alert investigation, including the steps implemented, information used, and the likely cause of an alert. In addition, it can be valuable to retain resources used during an investigation, such as screen shots of the water quality changes that triggered an alert. These records can be used to monitor the frequency of alerts by cause categories and can serve as a resource during investigation of future alerts. For example, if an investigator cannot readily identify the cause of a water quality change, the records can be filtered by location or parameter impacted to see whether a similar change triggered an alert in the past and, if so, whether a cause was identified.

Table 7-4 provides examples of alert categories that can be used to populate a record of alert investigations. While these examples require users to select a main category and a subcategory, they could be adapted to use only one level of classification.

Table 7-4. Example of Alert Categories

Main Category	Subcategory
Invalid Alert	Inaccurate data: sensor issue
	Station power or flow loss
	Data collection failure
	No significant deviation from normal water quality
	Other
Valid Alert, Cause Identified	Verified non-standard system operation
	Treatment plant change or upset
	Distribution system work
	Main break
	System pressure or flow anomaly
	Other
Valid Alert, Cause Not Identified	Possible contamination

There are a variety of ways to document alert investigations. Simple solutions include keeping a spreadsheet on a shared drive or a paper record in a central location. **Figure 7-2** provides an example of a spreadsheet record in which investigators can select from the pre-defined alert categories shown in Table 7-4. This example shows key fields that are recommended for inclusion in a record of alert investigations. A record could be expanded to list the water quality parameters that triggered an alert, personnel who supported the main investigator, and any other information deemed useful to the record.

	A	B	C	D	E	F	G
1	**Alert Date/Time**	**Alert Location**	**Investigator**	**Investigation Start Date/Time**	**Investigation End Date/Time**	**Alert Cause Category**	**Notes**
2	5/4/2017 2:15	Park St Storage Tank	John Webber	5/4/2017 2:20	5/4/2017 3:15	Invalid alert: Inaccurate data: sensor issue	Chlorine sensor obviously malfunctioning
3	5/14/2017 13:22	South Pump Station	John Webber	5/14/2017 13:35	5/14/2017 14:00	Valid alert: cause identified: Verified non-standard system operation	The unusual change in water quality can be attributed to opening of Valve 28a
4	6/1/2017 14:58	University Hospital	Andre Brown	6/1/2017 15:10	6/1/2017 15:30	Invalid alert: No significant deviation from normal water quality	The water quality change is consistent with what is seen when Tank A begins aining
						Invalid alert: Inaccurate data: sensor Invalid alert: No significant deviatio Invalid alert: Data collection failure	

Figure 7-2. Example Spreadsheet for Documenting Alert Investigations

If a dashboard will be used to support an SRS, electronic alert investigation tracking may be incorporated into its design. For example, electronic checklists can be developed that automatically enter investigation records into a data management system, facilitating further analysis and use of the records. See *Dashboard Design Guidance for a Water Quality Surveillance and Response System* for more information.

Quick Reference Guides

While many alert investigation activities become second nature to investigators, additional tools may be useful for guiding investigators through complex or less frequently implemented tasks. Development of quick reference guides, in which key information is concisely summarized in an easily accessible form, ensures investigators can quickly and easily get the information they need.

Examples of quick reference guides that can be useful for OWQM-DS include:

- A list of contact information for all individuals who investigators may need to contact during alert investigations
- Monitoring location-specific guidelines for investigating water quality anomalies that include details such as a summary of system facilities that can impact the location's water quality
- A summary of OWQM-DS equipment in use, including instrument faults produced and common issues encountered
- A distribution system map or a summary of the connectivity between monitoring locations
- A list of water quality changes that occur under different conditions (e.g., nitrification, pressure transients, chemical contamination, biological contamination).

7.3 Preparing for Real-time Alert Investigations

This section describes a suggested process for putting an alert investigation procedure into practice. Effective implementation is crucial, as the benefits of OWQM-DS can be fully realized only if alerts are investigated and responded to appropriately. The following topics are covered in this section:

- Training
- Preliminary operation
- Real-time operation

Training

Proper training ensures that all utility personnel with a role in the investigation of an alert are aware of their responsibilities and have the knowledge and expertise needed to execute those responsibilities. It is suggested that training on an alert investigation procedure include the following:

- An overview of the purpose and design of OWQM-DS
- A detailed description of an alert investigation procedure and the role of each participant
- A review of checklists, quick reference guides, user interfaces, and other tools available to support alert investigations
- Instructions for both entering new records of alert investigations and retrieving previous records to support new alert investigations

Section 6 of *Guidance for Developing Integrated Water Quality Surveillance and Response Systems* provides general guidance on implementing a training and exercise program. In general, classroom training is used first to orient personnel to a procedure and their responsibilities during alert investigations. Once personnel are comfortable with a procedure, drills and exercises give them the opportunity to practice performing their responsibilities in a controlled environment. The *SRS Exercise Development Toolbox* is an interactive software program designed to assist utilities in the design and execution of exercises.

Preliminary Operation

Following initial training, a period of ***preliminary operation*** allows personnel to practice their responsibilities in test mode before transitioning to real-time operation. For example, staff can be asked to investigate alerts (either all alerts or a subset) in batches as they have time—not necessarily as alerts are generated. At this stage, investigators may or may not receive alert notifications such as emails or text messages.

During preliminary operation, it may be useful to hold regular meetings with all investigators to discuss recent data and alerts. It is generally most effective if participants are asked to perform specific analyses or alert investigations before each meeting, and then discuss conclusions, observations, insights, and challenges as a group. These meetings can be held frequently initially, but become less frequent as proficiency increases and issues are resolved. Meeting once or twice per month during the period of preliminary operation would be appropriate and sufficient for most OWQM-DS design goals.

Preliminary operation provides excellent opportunities to refine an alert investigation procedure and investigation tools. Based on feedback from investigators, responsibilities can be clarified, unnecessary steps can be eliminated, existing tools can be refined, new tools can be developed if needs are identified, and roles can be better integrated into existing job functions.

> **VALUE OF PRELIMINARY OPERATION**
>
> Do not rush preliminary operation. It provides an opportunity for personnel to practice their responsibilities and learn the data used during investigations, thus improving the efficiency of alert investigations.

Real-time Operation

During real-time operation, alerts are investigated as they are generated, and WCR is activated if a contamination incident is considered possible. The transition from preliminary operation to real-time operation should be clearly communicated to all utility personnel with a role in alert investigations. This includes establishing a date for the transition to real-time operation and providing expectations for how alert investigations will be performed and documented.

After transitioning to real-time operation, it is important to continue to oversee and support investigators. Documentation of alert investigations should be regularly reviewed to ensure that all personnel are accurately and thoroughly carrying out their responsibilities, and individual instruction should be provided to individuals who are not doing so. Ongoing drills, exercises, and training are important to ensure that staff remain familiar with their responsibilities and to address any changes such as updates to a procedure or investigation tools. Finally, it is important to thoroughly train new staff on their responsibilities and the analysis of OWQM-DS data.

REGULARLY REVIEW AND UPDATE THE ALERT INVESTIGATION PROCEDURE

Routine updates to the alert investigation procedure and investigation tools are necessary to maintain their usefulness. Recommendations for procedure maintenance include these:

- Designate one or more individuals with responsibility for maintaining alert investigation materials.
- Establish a review schedule (annual reviews should suffice in most cases).
- Review the record of alert investigations, conduct tabletop exercises, and solicit feedback from investigators to identify necessary updates.
- Establish a protocol for submitting and tracking change requests.

Section 8: Preliminary Design

The information presented in the previous sections of this document can guide development of a preliminary design of an OWQM-DS system that supports a utility's design goals and performance objectives. If OWQM-DS will be a component of a multi-component SRS, the design of the integrated system will likely be guided by a project management team. In this case, guidelines for design of the individual components should be provided to the personnel implementing the components and should include the following:

- Overarching design goals and performance objectives for the SRS
- Existing resources that could be leveraged to implement the SRS components, including personnel, procedures, equipment, and information management systems
- Project constraints, such as budget ceilings, schedule milestones, and policy restrictions
- Instructions or specific guidelines for the development of preliminary component designs

If an OWQM-DS system will be part of a larger SRS, it should be incorporated into a master plan, as described in Section 3 of *Guidance for Developing an Integrated Water Quality Surveillance and Response System*. Master planning for an SRS involves the development of a complete SRS design, which can be implemented in phases based on available resources.

Regardless of whether OWQM-DS will be developed as a stand-alone component or as part of a multi-component SRS, the preliminary design should be documented in sufficient detail to assess whether it can achieve the selected design goals within project constraints. The *Preliminary Design Template* can be opened and edited by clicking on the box to the right. Utilities can update and expand on this template throughout the design process until the final design is completed. A complete design for an OWQM-DS system may be captured in a number of technical documents and specifications that support the overarching design document.

Preliminary Design Template (Microsoft Word)
*Note that the document that is currently open may need to be downloaded and opened offline to access this template.

This template covers the following aspects of the design of an OWQM-DS system:

- **Component implementation team.** Identify personnel from the various departments of a utility who will have a role in the design, implementation, operation, and maintenance of an OWQM-DS system. Document the role, responsibilities, and estimated time commitment of each team member.
- **Design goals and performance objectives.** Use the overarching SRS design goals and performance objectives to develop design goals and performance objectives that will guide the design of an OWQM-DS system.
- **Monitoring locations.** Identify preliminary monitoring locations and briefly describe the rationale for location selection. If necessary, prioritize the locations and include potential backup locations should a preferred location prove infeasible.
- **Water quality parameter selection.** List the parameters to be monitored and briefly describe the rationale for parameter selection.
- **Monitoring station design.** Summarize the key attributes of the design of the monitoring station that will be installed at each monitoring location.

- **Information management requirements.** Summarize the preliminary functional and technical requirements for an information management system designed to support operation of a utility's OWQM-DS system.
- **Training Plan.** Describe the training that will be provided to utility personnel to support OWQM-DS system operations.
- **Budget.** Provide an order-of-magnitude budget for OWQM-DS system implementation.
- **Schedule.** Provide a preliminary schedule for implementation of an OWQM-DS system.

An OWQM-DS system can be implemented in phases, which can allow a utility to incorporate lessons learned from early phases into the final system, accommodate budgetary constraints, provide adequate time for training, and allow personnel to gradually acclimate to the new system.

HELPFUL HINT

It can be useful to develop a preliminary alert investigation procedure in parallel with developing a preliminary design of an OWQM-DS system. Information in this procedure can inform various aspects of the design, such as information management requirements.

If multiple designs emerge during the design process, an evaluation of alternatives should be conducted to consider the cost and benefits associated with each. For example, some alternatives may offer tradeoffs between the number of parameters monitored and the number of monitoring locations. Each of these alternatives will likely have different capabilities and a different cost for procurement, operation, and maintenance throughout the life of the system. *Framework for Comparing Alternative Water Quality Surveillance and Response Systems* provides a systematic process for comparing alternative designs that considers both the capabilities and cost of each design.

FUNDING OPPORTUNITIES

Both financial and personnel resources are required to implement an OWQM-DS system. There are a variety of methods to fund such a project. For information on current federal, state, local, private, and other sources of funding that your utility may be able to use to implement a system, visit EPA's *Water Finance Clearinghouse*.

Section 9: Example Applications

This section provides examples of OWQM-DS applications that align with the design goals discussed in Section 2.1. Each example includes a summary of a given application and describes types of monitoring locations and water quality parameters that can facilitate that application.

9.1 Monitoring for Contamination Incidents

Contamination incidents in distribution systems can include both intentional incidents (e.g., malicious insertion of contaminants into a system) and unintentional incidents (e.g., cross-connections). Research has shown that the most useful water quality parameters for detecting contamination are chlorine residual, pH, specific conductance, temperature, DOC/TOC (or a surrogate), ORP, and spectral absorbance (EPA, 2005a; EPA, 2005b; EPA, 2005c; EPA, 2009; and Allgeier, et al., 2010).

Although contamination incidents are rare, the consequences can be extreme. OWQM-DS data can be used to detect contamination incidents in sufficient time to implement response actions that limit the spread of a contaminant in a distribution system and protect public health (i.e., limit fatalities and illnesses).

Monitoring Locations

The uncertainty of the location and extent of a potential contamination incident can make it a challenge to identify effective monitoring locations. The approach commonly used for such a problem is to optimize locations for a specific objective, such as minimizing the time to detection. The objective most often used in reported studies and system designs is to optimize locations to reduce overall consequences from a large ensemble of simulated contamination incidents. In other words, locations are selected to provide rapid detection of simulated contamination incidents that produce the most severe consequences.

Monitoring at the following types of monitoring locations can provide information that can be used to detect contamination incidents:

- **Entry points to distribution system.** Provide a baseline for distribution system water quality.
- **Locations identified using station placement optimization tools.** Maximize the effectiveness of an OWQM-DS system to detect contamination with respect to a specific objective, such as minimizing the time to detection or minimizing consequences from a large ensemble of simulated contamination incidents.
- **Locations identified by distribution system models or operator experience.** Can be used to detect contamination incidents that have the potential to impact a large population (e.g., incidents at, or directly downstream of, large storage ***reservoirs*** or pump stations).

Water Quality Parameters

Table 9-1 presents the water quality parameters that can be monitored to detect contamination incidents.

Table 9-1. Water Quality Parameters for Broad-Spectrum Monitoring for Contamination

Role in Application	Parameter	Purpose of Monitoring Parameter
Sufficient for detecting a wide range of contaminants	Chlorine residual†	• Many chemical and microbial contaminants will react with chlorine residual, thus decreasing the residual concentration.
	pH†	• Chemical contaminants with acidic or basic functional groups can change the pH; however, the magnitude of a change in pH will be inversely related to the buffering capacity of the water.
	Specific conductance†	• Some chemical contaminants have charged functional groups that can dissociate and form ionic species when dissolved in water, thus increasing the specific conductance of the water. • A measurable change in specific conductance may only occur when contaminant concentrations are relatively high.
	Temperature†	• A rapid change in temperature can indicate a large inflow of a foreign fluid (e.g., cross-connection and backflow from an industrial customer).
	Spectral absorbance	• Some inorganic and most organic chemicals absorb in the UV-visible spectrum. As such, a change in spectral absorption may indicate the presence of a chemical contaminant. • Some spectral instruments provide a spectral fingerprint. A change in the spectral fingerprint from an established baseline can indicate the presence of a contaminant.
Increase the number of contaminants that can be detected and the degree of confidence in contaminant detection	DOC/TOC	• Many contaminants of concern are organic chemicals, and the presence of these contaminants can increase DOC/TOC concentrations. • An increase in DOC/TOC can exert a chlorine demand, reduce the chlorine residual concentration, and create an opportunity for the survival of chlorine-sensitive pathogens (e.g., *E. coli*) and biotoxins (e.g., microcystins).
	ORP	• A change in ORP can indicate the presence of a contaminant with oxidizing or reducing potential. • Can be used to confirm changes in chlorine residual concentrations.
	UV-254	• UV-254 and DOC measurements can be used to calculate SUVA (specific ultraviolet absorbance). • A change in SUVA can indicate a change in the organic composition of the water, potentially indicating the presence of an organic contaminant.

† Core parameters

Figure 9-1 shows time-series plots of OWQM-DS data following the addition of aldicarb, glyphosate, secondary wastewater effluent, and microbial growth media (e.g., terrific broth) into drinking water. It is important to note these examples are for illustrative purposes and summarize the best available data to represent contamination incidents in a distribution system:

- Aldicarb was selected to represent the carbamate class of pesticides, while glyphosate was selected to represent organophosphorus herbicides and insecticides. Following the addition of both aldicarb (top left) and glyphosate (top right), free chlorine and ORP levels decreased and TOC increased.
- Secondary wastewater effluent was selected to represent contamination of drinking water with untreated wastewater (health and safety concerns precluded the use of raw wastewater in the study). Following the addition of secondary wastewater effluent (bottom left), free chlorine decreased while TOC and specific conductance increased.
- Terrific broth was selected to represent contamination of drinking water with bacteria in growth media. Because most bacteria exist as vegetative cells that are highly susceptible to inactivation by chlorine, addition of a co-contaminant, such as terrific broth, is necessary to quench the chlorine residual and maintain viability of the bacteria. Following the addition of terrific broth (bottom right), free chlorine decreased and TOC concentration increased.

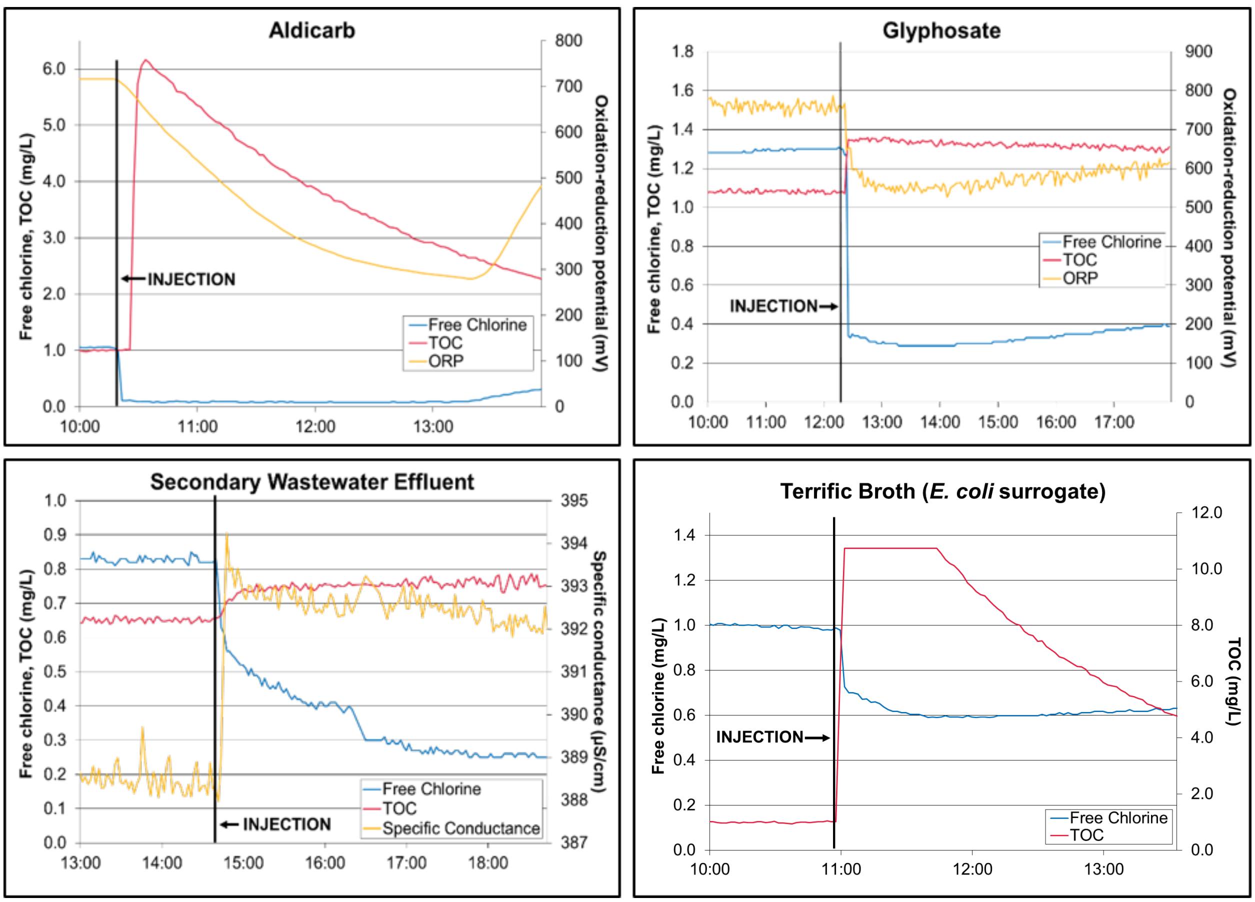


Figure 9-1. Data Following Addition of Contaminants into Drinking Water

Monitoring stations designed for comprehensive monitoring for contamination incidents can be expensive due to the addition of water quality parameters such as spectral absorbance or DOC/TOC. By selecting locations that can be used to collect data for other applications, the overall benefit to a utility can be maximized.

9.2 Monitoring for Red Water and Particulate Matter Incidents

Red water incidents are typically associated with elevated levels of iron release and often caused by water chemistry changes or hydraulic scouring of iron pipe walls. In some cases, red water can also be caused by a failure of treatment plants to adequately remove dissolved or particulate iron from source or process water. Particulate matter incidents are typically associated with turbid or cloudy water and can be caused by hydraulic upsets due to distribution system flushing, main breaks, and pressure surges. For more information on red water and particulate matter incidents, see the AWWA manual M58 *Internal Corrosion Control in Water Distribution Systems* (Hill and Cantor, 2011).

Red water and particulate matter incidents can cause problems, such as discoloration of porcelain plumbing fixtures in homes, stained clothing, unpleasant odors, and the release of contaminants accumulated in pipe scales (e.g., lead, arsenic). Customers can experience these problems for days after a large main break, both in areas where an upset occurs and in more distant areas of a system. OWQM-DS data can be used to provide timely detection of red water and particulate matter incidents, which can enable utilities to take corrective actions to contain and flush affected areas.

Monitoring Locations

Monitoring at the following types of monitoring locations can provide information that can be used to detect red water and particulate matter incidents:

- **Entry points to a distribution system.** Provide a baseline for distribution system water quality.
- **Areas where older, unlined iron pipes are in use.** Indicate areas in the system that may be susceptible to these types of incidents.
- **Areas with historically high volumes of customer complaints.** Indicate areas in the system that have experienced similar types of incidents in the past that have not been addressed.

Water Quality Parameters

Table 9-2 presents water quality parameters that can be monitored to detect red water and particulate matter incidents.

Table 9-2. Water Quality Parameters for Red Water and Particulate Matter Incident Monitoring

Role in Application	Parameters	Purpose of Monitoring Parameter
Necessary and sufficient to monitor for red water and particulate matter incidents	Chlorine residual†	• A reduction in chlorine residual is expected during red water/particulate matter incidents as chlorine can react with dissolved metal species or suspended particles.
	pH†	• A reduction in pH can indicate suitable conditions for red water/particulate matter incidents.
	Specific conductance†	• If a distribution system is supplied by multiple sources, a change in specific conductance might indicate a change in source water that can disrupt pipe scales, causing iron and particulate release from pipe walls.
	Temperature†	• An increase in temperature can increase metal solubility, increasing the potential for red water incidents from iron release.
	Turbidity	• An increase in turbidity can indicate that a red water/ particulate matter incident is occurring.
Achieve more reliable and specific detection of red water and particulate matter events	Apparent color	• Cloudiness or colored water (red to reddish-brown, yellow, or black) can indicate that an incident is occurring.
	DOC/TOC	• An increase in TOC with relatively stable DOC concentrations can indicate the release of organic particulate matter from biofilms.

† Core parameters

Figure 9-2 shows a time-series plot of monochloramine, turbidity, DOC, and TOC data during a particulate matter incident at a utility facility. At the onset of the incident, the monochloramine concentration decreased, turbidity and TOC levels increased, and the DOC concentration remained stable. These changes were consistent with the expected parameter responses identified in Table 9-2. Following an investigation of the water quality changes, it was determined that a particulate matter incident occurred because of a major pipeline operation that caused a flow reversal, stirring up sediment and biofilm in the pipeline. Utility personnel implemented response actions, and the OWQM-DS data began to return to normal operating ranges.

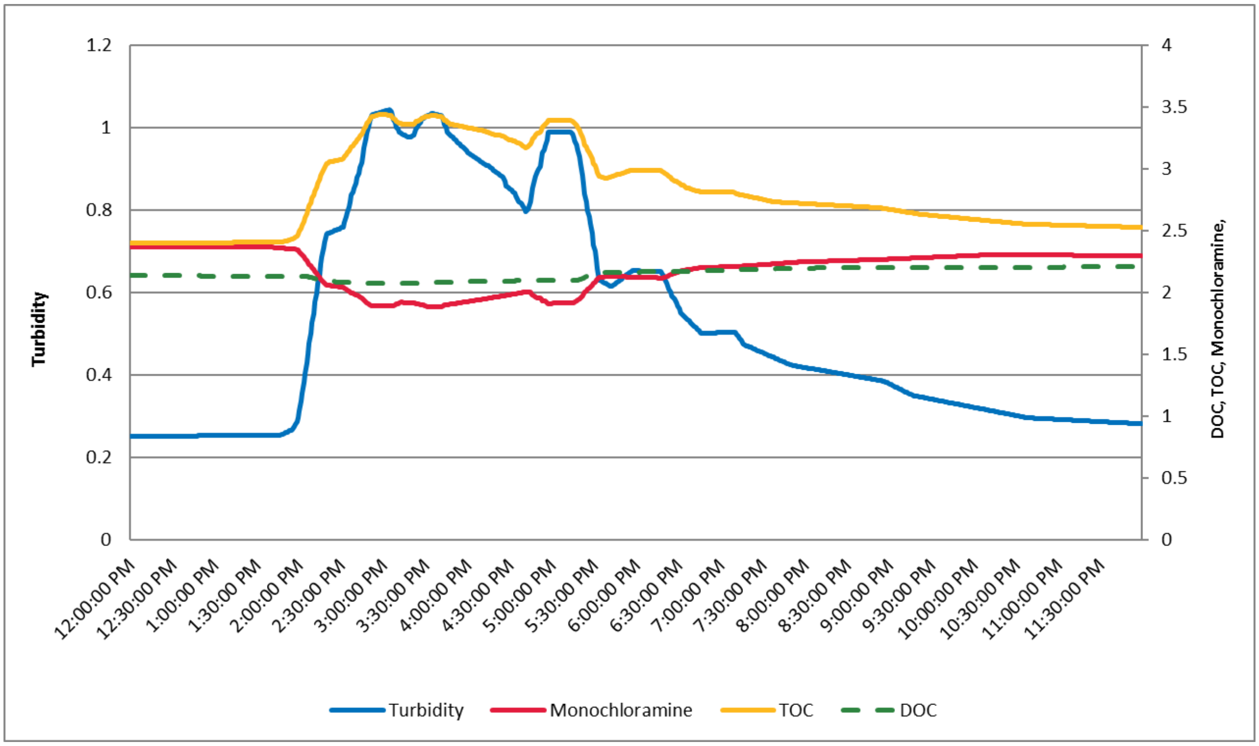


Figure 9-2. Data During a Particulate Matter Incident

Figure 9-3 shows ***spectral fingerprints*** generated before and during the particulate matter incident. The data collected during the incident, when compared to data collected before the incident, showed an increase in spectral absorption. The "delta fingerprint" datastream indicated the difference in absorbance between the two datasets across the UV-visible spectrum. This data was used to support the investigation of the particulate matter incident described above.

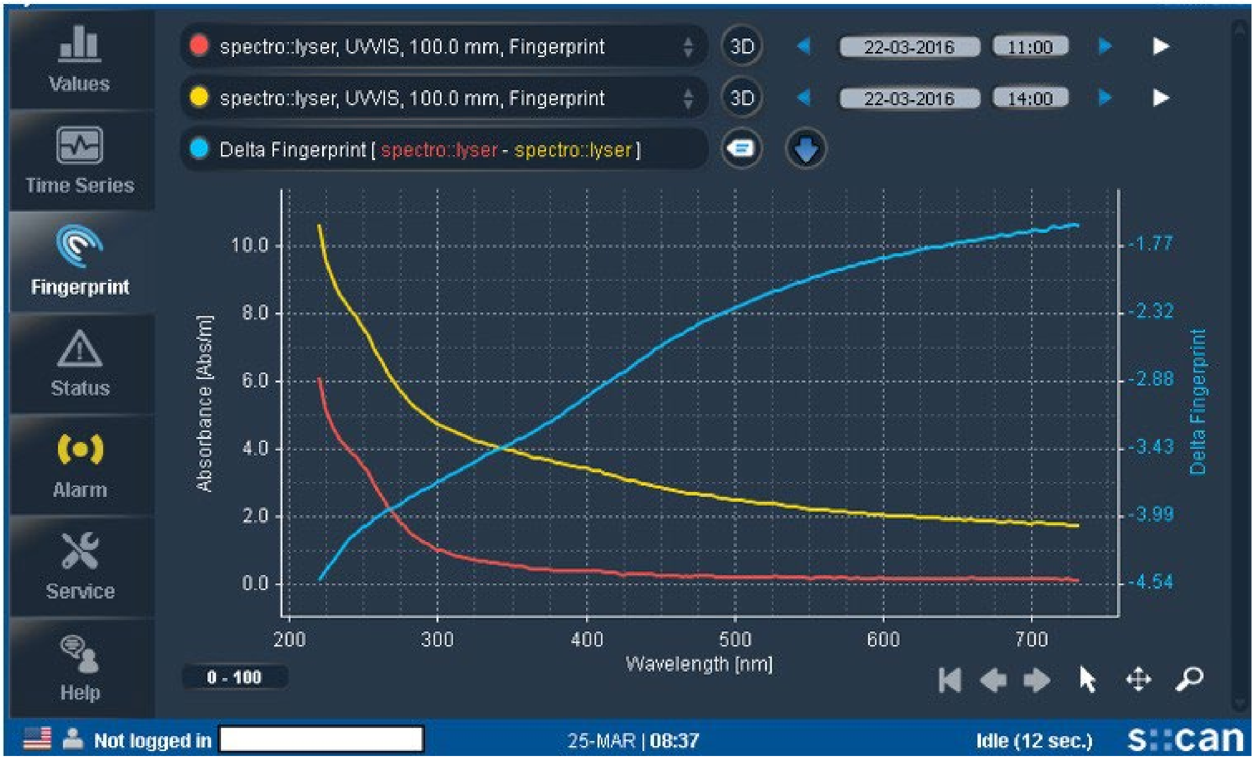


Figure 9-3. Spectral Fingerprints Before and During a Particulate Matter Incident

9.3 Chlorine Residual Management

Free chlorine and chloramines are residual disinfectants that are commonly used to provide continuous control of microbial regrowth in drinking water distribution systems. However, the chlorine residual decreases as water ages in a system. As such, the SWTR specifies that grab samples collected at a system's entry points cannot have a chlorine residual of less than 0.2 mg/L for more than four hours and no more than 5% of samples collected from within a system can have an undetectable concentration for any two consecutive months. The AWWA Partnership for Safe Water's Distribution System Optimization Program has set residual goals for free chlorine (0.2 – 4.0 mg/L) and chloramines (0.5 – 4.0 mg/L), for 95% of monthly routine grab samples collected in a system (Lauer, 2010).

Utilities strive to ensure that water with a chlorine residual within desired operating limits is delivered to all customers. Lower limits can be established based on the federal or state regulations (e.g., SWTR) and AWWA goals mentioned above. Upper limits can be based on customer acceptance and must be below the maximum disinfectant residual level of 4.0 mg/L established by the Stage 1 Disinfectants and Disinfection Byproducts Rule. OWQM-DS data can be used to guide residual disinfectant dosing at treatment plants and booster stations. It can also guide the operation of storage facilities to better manage water age and be used to evaluate the effectiveness of flushing programs for maintaining chlorine residuals within a target range. For more information on chlorine residual management, refer to AWWA manual *M20 Water Chlorination/Chloramination Practices and Principles* (AWWA, 2006) and the Water Research Foundation *Impact of Distribution System Water Quality on Disinfection Efficacy* (Baribeau, et.al, 2005).

Monitoring Locations

Monitoring at the following types of monitoring locations can provide information that can be used to manage chlorine residual concentrations:

- **Entry points to a distribution system.** Provide a baseline for the chlorine residual in water entering the system.
- **Storage tanks and reservoirs.** Provide information that can be used to adjust the operation of tanks and reservoirs (e.g., cycling water more frequently to reduce residence times, boosting chlorine levels) to maintain acceptable chlorine residual concentrations. If it is not feasible to monitor water quality on an outflow line or if it is desirable to place a station in an alternate location to achieve multiple design goals, a station can be located in an area of the distribution system that receives water from the storage facility.
- **Outflow from disinfectant booster stations.** Informs the dosing of chlorine added to water, which can be adjusted by an operator or automated process to maintain a sufficient residual in areas of a system that experience chronically low residual levels.
- **Point of entry to critical customer facilities.** Indicates whether water of an acceptable quality is delivered to critical facilities, such as hospitals, that may have requirements for residual levels for prevention of regrowth of bacteria or specific pathogens.
- **Areas with historically low residual.** Provide information that can be used to determine the efficacy of actions taken to maintain chlorine residual concentration within a target range in these areas.

Water Quality Parameters

Table 9-3 presents water quality parameters that can be monitored to manage chlorine residual concentrations. (Note: the purpose of a given monitoring parameter is dependent on whether free chlorine or chloramines are used within a system, as shown in the table).

Table 9-3. Water Quality Parameters for Disinfectant Residual Management

Role in Application	Parameters	Purpose of Monitoring Parameter
Necessary and sufficient for managing chlorine residual in all distribution systems	Chlorine residual†	• Provides a direct measure of the chlorine residual. • For chlorinated systems, free chlorine should be monitored • For chloraminated systems, total chlorine or monochloramine should be monitored
	pH†	• Can affect chlorine speciation (HOCl is the stronger disinfectant and is the dominant chlorine species below pH 7.5). • Can affect the rate of chloramine formation due to changes in reaction rates (lower pH increases the concentration of HOCl and decreases the concentration of NH_3 ; likewise, higher pH decreases the concentration of HOCl and increases the concentration of NH_3).
	Specific conductance†	• If a distribution system is supplied by multiple sources, a change in specific conductance can help to identify a source change as the cause of an abrupt change in chlorine residual concentration.
	Temperature†	• An increase in temperature can create conditions suitable for chlorine residual decay and microbial regrowth.

Role in Application	Parameters	Purpose of Monitoring Parameter
Necessary for managing chlorine residual in chloraminated systems	Ammonia, free	• Specific chlorine to ammonia ratios are required for optimal monochloramine formation. • Measuring free ammonia can provide information on monochloramine formation and available ammonia for downstream chlorine residual boosting. • In a distribution system, excessive free ammonia can indicate the start of chloramine degradation.
Can be used to verify changes in chlorine residual levels	ORP	• Responds linearly to changes in chlorine residual concentrations. • Can be important when switching from free chlorine to chloramine, as ORP values are higher for free chlorine; therefore, a decrease in ORP is expected when switching from free chlorine to chloramine and an increase is expected when switching from chloramine to free chlorine.

† Core parameters

Figure 9-4 shows a time-series plot of chlorine residual, specific conductance, and temperature in a reservoir experiencing chlorine residual decay. Note that the monitoring station at this reservoir is equipped with two chlorine residual instruments that produce primary and secondary chlorine residual data (shown as "Redundant Chlorine Residual" in the figure). At the onset of this incident, chlorine residual concentrations from both instruments decreased. However, specific conductance levels remained relatively constant over this time, which led investigators to rule out the possibility that a change in the source supplying water to this monitoring location caused the chlorine decay. Further investigation of this incident determined that the decrease in chlorine residual was due to an increase in temperature and high water age in the reservoir.

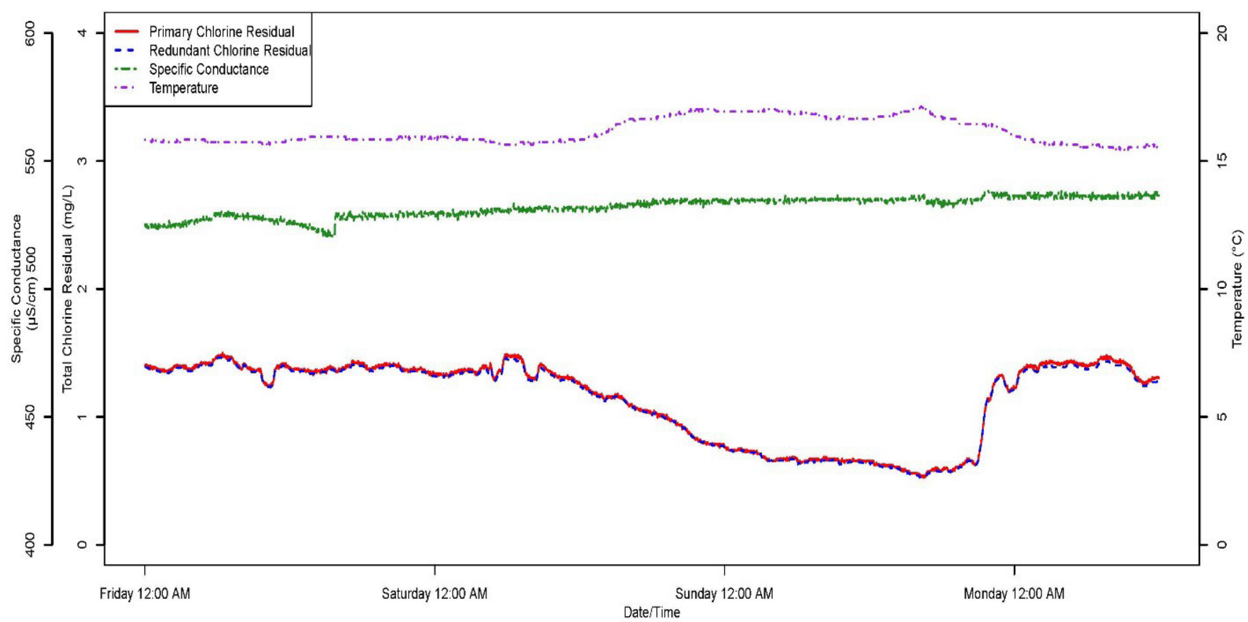


Figure 9-4. Data During an Occurrence of Chlorine Residual Decay in a Reservoir

9.4 Verify Effectiveness of Nitrification Control

Nitrification is a microbial process that is caused by the presence of free ammonia and ammonia-oxidizing bacteria that require ammonia for energy. During this process, ammonia is sequentially oxidized to nitrite and then nitrate through biological and chemical processes. Nitrification in a drinking water distribution system creates water quality problems such as increased nitrite and nitrate levels; reduced alkalinity, pH, dissolved oxygen, and chloramine residual levels; and increased potential for bacterial growth. Storage tanks and reservoirs can be especially prone to nitrification due to the potential for long residence times and high temperatures, both of which exacerbate chloramine decay. For more information on nitrification, refer to the EPA distribution system issue paper "*Nitrification*" (EPA, 2002)" and the AWWA manual *M56 Fundamentals and Control of Nitrification in Chloraminated Drinking Water Distribution Systems* (AWWA, 2013).

Nitrification can occur even in the most carefully operated and maintained systems. OWQM-DS data can be used to detect conditions that indicate the onset of nitrification (enabling utilities to take response actions to prevent or limit nitrite and nitrate formation), reduce the cost of mitigation (e.g., the cost of draining and cleaning a storage facility), and maintain regulatory compliance.

Monitoring Locations

Monitoring at the following types of monitoring locations can provide information that can be used to guide nitrification control:

- **Entry points to a distribution system**: Provide a baseline for the Cl_2:NH_3-N ratio as well as the chloramine and free ammonia concentrations in water entering the system.
- **Storage tanks and reservoirs**: Provide information that can be used to detect and manage nitrification. If it is not feasible to monitor an outflow line or if it is desirable to place a station in an alternate location to achieve multiple design goals, a station can be located in a downstream area of the distribution system that receives water from the storage facility.

Water Quality Parameters

Table 9-4 presents water quality parameters that can be monitored to inform actions to control nitrification. This table is based on recommendations given in the AWWA manual *M56 Nitrification Prevention and Control in Drinking Water* (AWWA, 2013); however, some recommendations have been modified to apply to online water quality monitoring.

Table 9-4. Water Quality Parameters for Verifying the Effectiveness of Nitrification Control

Role in Application	Parameters	Purpose of Monitoring Parameter
Necessary and sufficient for detecting nitrification incidents	Chlorine residual†	• Total chlorine or monochloramine should be monitored. • A reduction in chlorine residual is expected during nitrification due to the degradation of chloramines. • Low chlorine residual concentrations can increase the potential for bacterial growth, including nitrifying bacteria that can exacerbate nitrification.
	pH†	• A reduction in pH can indicate suitable conditions for nitrification.
	Specific conductance†	• If a distribution system is supplied by multiple sources, specific conductance can be used to determine whether a monitoring location is receiving water from a source that is more likely to promote nitrification.
	Temperature†	• An increase in temperature can create suitable conditions for bacterial growth and nitrification.

Role in Application	Parameters	Purpose of Monitoring Parameter
	Ammonia, free	• An initial increase followed by a decrease in free ammonia can signal the initial onset of nitrification. As chloramines decay ammonia is released, nitrifying bacteria will oxidize excess ammonia to nitrite and then nitrate.
Achieve more timely confirmation of nitrification incidents	Nitrate	• An increase in nitrate concentration indicates a nitrification incident.
	Nitrite	• A measurable concentration of nitrite that coincides with an increase in nitrate and a decrease in ammonia can signal the oxidation of ammonia to form nitrite and nitrate.

† Core parameters

Figure 9-5 shows a time-series plot of monochloramine, nitrate (NO_3-N), and tank level data during a nitrification incident in a storage tank. Nitrification had already been occurring in the tank prior to the time-period shown in the plot, but it had not been detected due to stratification in the tank. However, when the tank level began to decrease due to emergency water use for firefighting, a decrease in monochloramine and an increase in nitrate were detected soon after, indicating that nitrification was occurring. When fresh water began to refill the tank, the water quality returned to normal levels.

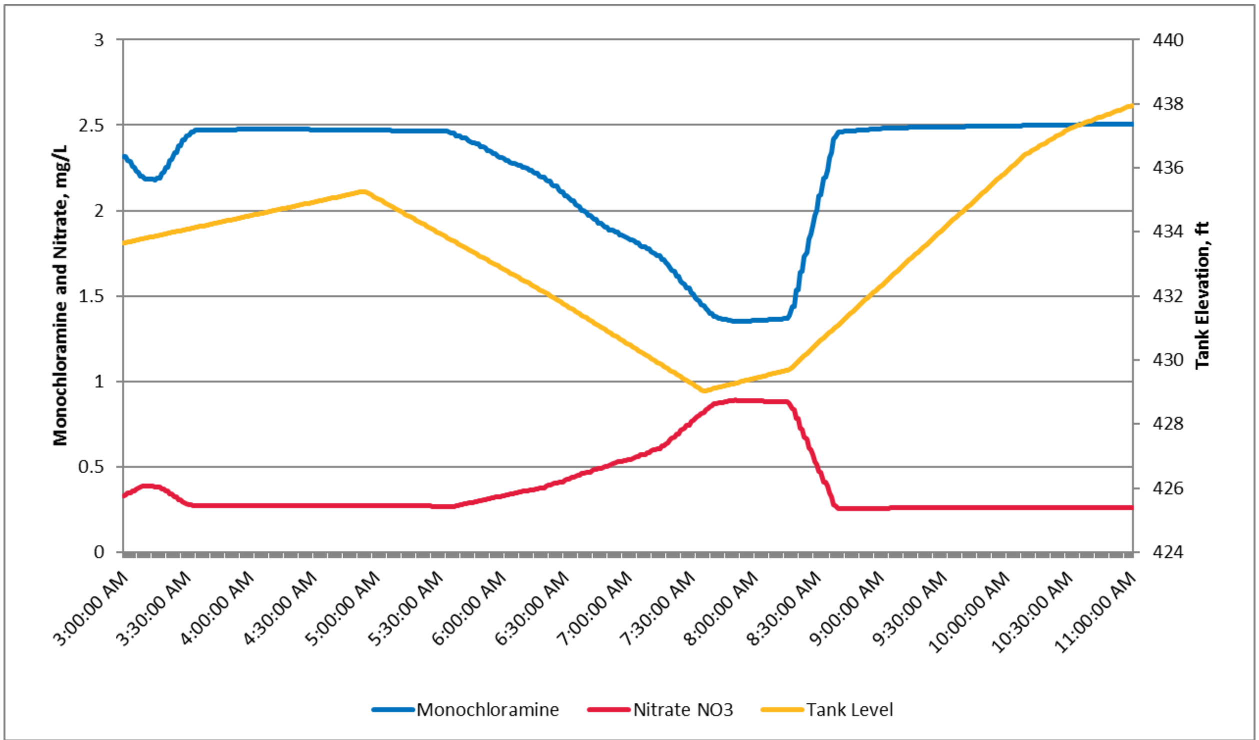


Figure 9-5. Data During a Nitrification Incident

9.5 Verify Effectiveness of Corrosion Control

Corrosion in drinking water distribution systems can occur through an electrochemical process between metal surfaces (e.g., pipes, fittings, faucets, valves) and water. Metals can be released from these surfaces into drinking water if a protective barrier along the surfaces has not been established or if particulate metals have been released, as was discussed in Section 9.2. Additionally, metals can be released when changes to water chemistry occur, which can destabilize the protective barrier and corrosion by-products. Once the protective barrier has been compromised, the exposed metal can be corroded and a new protective barrier must be established for corrosion control.

Adjustment of parameters such as pH and alkalinity, as well as addition of ortho-phosphate, has been widely used in successful Corrosion Control Treatment (CCT) programs; monitoring these parameters can provide insight into the efficacy of CCT. Chemical saturation indices, such as the Langelier Saturation Index (LSI), can be calculated based on pH, alkalinity, conductivity, and temperature values to provide an indication of the calcium saturation and potential for calcium carbonate pipe scale formation. The LSI can be calculated using **Equation 9-1**, which was derived from *Standard Methods for the Examination of Water and Wastewater* (APHA, et al., 2012) and *Chemical Equilibria in Water Treatment* (Langelier, 1946). Additional tools, such as Pourbaix diagrams, can be used with OWQM-DS data to determine changes to mineral stability that can lead to metal release. For more information on corrosion control, see AWWA manual *M58 Internal Corrosion Control in Water Distribution Systems* (Hill and Cantor, 2011).

$$LSI = pH_a - pH_s$$

Where:

pH_a = the actual pH of water

$pH_s = pK_2 - pK_s + p[Ca^{2+}] + p[HCO_3^-] + 5pf_m$

Where:

p preceding a variable designates $-\log_{10}$ of that variable
K_2 = second dissociation constant for carbonic acid, at the water temperature
K_s = solubility product constant for $CaCO_3$ at the water temperature
$[Ca^{2+}]$ = calcium ion concentration, g-moles/L
$[HCO_3^-]$ = bicarbonate ion concentration, g-moles/L
f_m = activity coefficient for monovalent species at the specified temperature

Equation 9-1. Langelier Saturation Index

Understanding the potential for corrosion within a distribution system and the efficacy of protective pipe scale formation can support a utility's ability to optimize CCT and prevent the release of lead and copper into a system. In addition to maintaining compliance with the Lead and Copper Rule, this can prevent an erosion of customer confidence and reduce the cost of replacing premise plumbing.

Monitoring Locations

Monitoring at the following types of monitoring locations can provide information that can be used to verify the effectiveness of corrosion control:

- **Entry points to a distribution system.** Provide a baseline for distribution system water quality.
- **Areas that exhibit variable water quality parameter values.** Provide information from areas that may be susceptible to corrosion. These areas may exist in mixing zones (for systems that are supplied by multiple sources) and areas with high water age.

Water Quality Parameters

OWQM-DS systems can include water quality parameters known to promote corrosion, inhibit corrosion, and indicate optimal CCT within a distribution system. **Table 9-5** presents parameters that can be monitored to verify the efficacy of corrosion control treatment. This table is based on recommendations given in the AWWA manual *M58 Internal Corrosion Control in Water Distribution Systems* (AWWA, 2013); however, some recommendations have been modified to apply to OWQM-DS.

Table 9-5. Water Quality Parameters for Verifying Effectiveness of Corrosion Control

Role in Application	Parameters	Purpose of Monitoring Parameter
Necessary and sufficient to verify effectiveness of CCT	Chlorine residual†	• Corrosion can release particulate and dissolved metal species that can react with and consume chlorine residual.
	pH†	• A significant change can indicate suitable conditions for corrosion and metal release.
	Specific conductance†	• Specific conductance can be converted to an approximate concentration of total dissolved solids and used in Equation 1. • If a distribution system is supplied by multiple sources, specific conductance data can be used to determine whether a monitoring location is in a mixing zone and thus subject to significant shifts in water quality that could promote corrosion.
	Temperature†	• An increase in temperature can increase metal solubility and release.
	Alkalinity	• Directly impacts the stability of distribution system water pH. • Can be used to calculate the LSI. • Can be used with pH adjustments for corrosion control.
Necessary if a phosphate-based inhibitor is used for CCT	Ortho-phosphate	• Decrease in ortho-phosphate can indicate a reduction in the efficacy of CCT.
Achieve more timely and reliable detection of problems with CCT	Apparent color	• Red water due to ferric iron release and yellow or black due to ferrous iron release.
	DO	• Is an electron acceptor at the cathodic side of an electro-chemical interaction between the pipe wall and the water. • Is an oxidant that can affect metal solubility and release.
	ORP	• Can be used to analyze metal solubility and the potential for release. • Is particularly important for utilities switching from free chlorine to chloramines for disinfection, as use of chloramines results in lower ORP values compared to free chlorine, which can cause a change in metal speciation.
	Spectral absorbance	• Can be used to monitor iron oxide concentrations by measuring the primary spectral absorbance wavelength.
	Turbidity	• Cloudiness or colored water (red to reddish-brown, yellow, or black) can indicate that distribution system corrosion is occurring.

† Core parameters

Figure 9-6 shows a theoretical example of a time-series plot of pH, alkalinity, and chlorine at a ground water and surface water mixing zone. A treatment process error allowed the ground water to enter the distribution system unchlorinated and unbuffered. This error caused the pH to decrease and the chlorine residual to drop. The decrease in chlorine residual also decreased the ORP, thereby causing destabilization of pipe scales and metal release. pH and alkalinity adjustments were made to correct this error and return the water quality to normal levels.

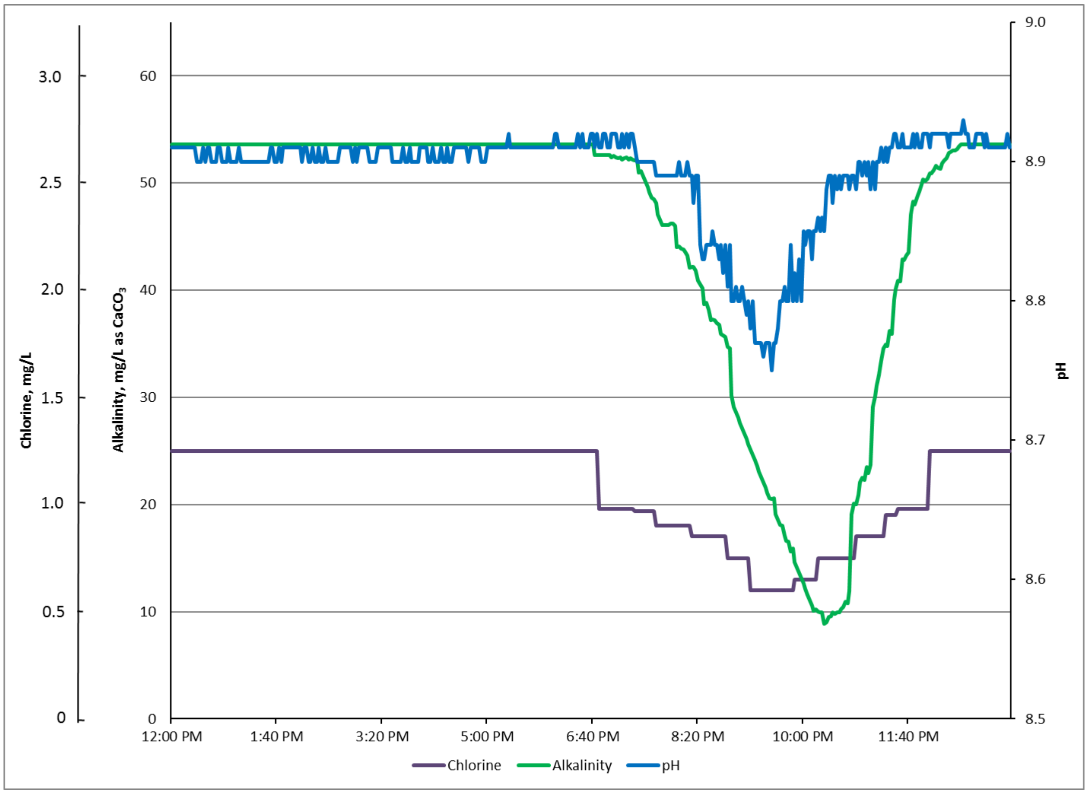


Figure 9-6. Data Affecting Corrosion Control Treatment

While OWQM-DS systems can provide useful information about the effectiveness of corrosion control, there are limitations to this application. First, water samples are taken from the bulk water in a main rather than at the water-pipe interface where corrosion occurs. Water quality at this interface can be significantly different from water quality in bulk solution. Furthermore, water quality can change as it travels through and resides in a premise plumbing system. Even with these limitations, online monitoring of bulk water quality in a distribution main can provide useful information about the stability of water quality parameters that are important for corrosion control. To augment this application of OWQM-DS, grab samples for other parameters, such as aluminum and sulfate, can be collected at the tap.

9.6 Source Tracking

Many utilities use multiple source waters to meet water demands in their distribution systems. Throughout a given day, water from different sources can serve the same area of a system. If these sources have water qualities that are significantly different from each other, source changes can significantly and abruptly change distribution system water quality in that area.

Significant changes in water quality that is delivered to a given area can potentially impact the aesthetics of water (e.g., taste and odor) and compliance with federal or state regulations. OWQM-DS data can be used to identify the water source that is supplying an area at a given time, which can guide system operations to manage mixing and enable utilities to meet water quality requirements, respond to customer complaints, and inform key industrial customers of water quality changes that could impact internal processes.

Monitoring Locations

Monitoring at the following types of monitoring locations can provide information that can be used to track sources:

- **Entry points to a distribution system.** Provide a baseline for water quality in the distribution system.
- **Mixing zones.** Provide information on frequency and duration of mixing.

Water Quality Parameters

Table 9-6 presents water quality parameters that can be monitored to track water sources that are feeding a given area**.** (Note: this table assumes the sources providing water to a distribution system have consistently different values for the parameters listed.)

Table 9-6. Water Quality Parameters for Source Tracking

Role in Application	Parameters	Purpose of Monitoring Parameter
Necessary and sufficient for source tracking	Chlorine residual†	• Monitor the impact of source mixing on maintenance of chlorine residual.
	pH†	• A change can be a direct indicator of a source change.
	Specific conductance†	• A change can be a direct indicator of a source change.
	Temperature†	• A change can be a direct indicator of a source change.
Achieve more reliable source tracking	DOC/TOC	• A change can be a direct indicator of a source change.
	Spectral absorbance	• A change in the delta can be a direct indicator of a source change.

† Core parameters

Figure 9-7 shows a time-series plot of conductivity data during a daily source water change. Specific conductance decreased during the source water change and then remained stable until the next cycling.

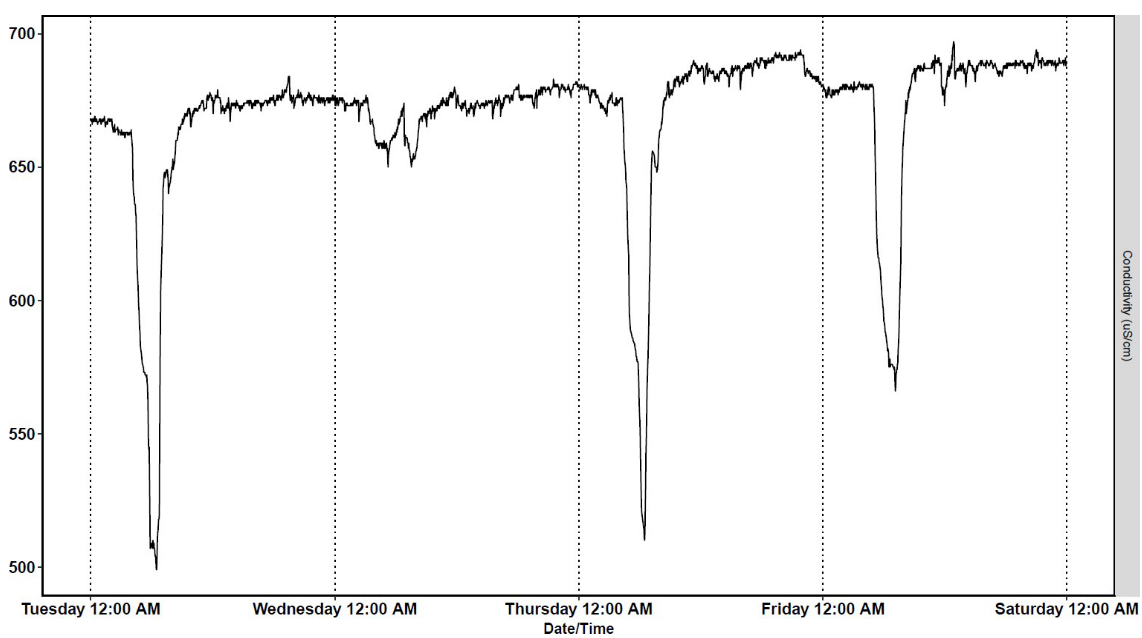


Figure 9-7. Data During Source Water Changes

9.7 Summary of Online Monitoring System Applications

A summary of the suggested monitoring locations and water quality parameters that can facilitate the examples of OWQM-DS applications is provided in **Table 9-7.**

Table 9-7. Summary of Monitoring Locations and Water Quality Parameters to Support Example Applications

Applications	Locations	Parameters
Monitoring for contamination incidents	• Distribution system entry points • Locations identified using optimization tools • Locations identified by distribution system models or operator experience	• Chlorine residual* • pH* • Specific conductance* • Spectral absorbance* • Temperature* • DOC/TOC • ORP • UV-254
Monitoring for red water/ particulate matter incidents	• Distribution system entry points • Areas where older, unlined iron pipes are in use • Areas with historically high volumes of customer complaints	• Chlorine residual* • pH* • Specific conductance* • Temperature* • Turbidity* • Apparent color • DOC/TOC
Chlorine residual management	• Distribution system entry points • Storage tanks and reservoirs • Booster station outflow • Entry of critical facilities • Areas with historically low residual	• Chlorine residual* • pH* • Specific conductance* • Temperature* • Ammonia, free* • ORP
Verify effectiveness of nitrification control	• Distribution system entry points • Storage tanks and reservoirs	• Ammonia, free* • Chlorine residual, total* • pH* • Specific conductance* • Temperature* • Nitrate • Nitrite
Verify effectiveness of corrosion control	• Distribution system entry points • Areas that exhibit variable water quality parameter values	• Alkalinity* • Chlorine residual* • pH* • Specific conductance* • Temperature* • Ortho-phosphate* • Apparent color • DO • ORP • Spectral absorbance • Turbidity

Applications	Locations	Parameters
Source Tracking	• Distribution system entry points • Mixing zones	• Chlorine residual* • pH* • Specific conductance* • Temperature* • DOC/TOC • Spectral absorbance

* Parameters are necessary and sufficient for achieving the design example. (Note: free ammonia and ortho-phosphate are only necessary and sufficient for chloraminated systems and systems using a phosphate-based inhibitor for CCT, respectively.)

Table 9-7 summarizes locations and parameters for specific applications and shows that the incremental addition of one or more monitoring locations or parameters can result in a system that achieves multiple design goals. For example, if monitoring stations were initially installed for disinfection residual management, the addition of locations identified through optimization software and addition of spectral absorbance instruments at strategically selected locations could provide capabilities to monitor for contamination incidents. Likewise, chlorinated systems considering switching to chloramination could add free ammonia instruments to select locations to achieve both disinfection residual management and verification of nitrification control.

Section 10: Case Studies

This section provides case studies of utilities that have implemented OWQM-DS systems. Each case study provides high-level utility information, describes how OWQM-DS data is used, and provides details on the OWQM-DS system design (e.g., monitoring locations, water quality parameters, monitoring station structure, information management and analysis approach, alert investigation procedure).

10.1 Philadelphia Water Department

Philadelphia Water Department (PWD) is a combined urban utility that serves treated drinking water to 1.6 million customers in Philadelphia, Pennsylvania. Raw water is pumped from the Delaware and Schuylkill Rivers and treated at three water treatment plants that produce an average of 250 MGD of water. Chloramines are used as a secondary disinfectant in the water.

PWD has used OWQM-DS data to:

- **Monitor for contamination incidents.** The primary concerns are intentional contamination of the distribution system and detection of water quality changes that occur during operational events.
- **Optimize distribution system water quality.** Data helps to establish baseline water quality conditions to ensure that water quality parameters are in acceptable ranges and inform distribution system operations.

Monitoring Locations

The OWQM-DS system consists of 38 fixed stations that are located at distribution system entry points, storage tanks, reservoirs, fire stations, a hotel, a hospital, and inside an enclosure within a public right-of-way. Some of these locations were selected based on results from sensor placement optimization software analyses, while others were determined based on their ability to impact system operations. PWD also has eight mobile stations, or "rapid deployment stations," that facilitate timely installations to achieve short-term monitoring goals at a wide range of potential locations.

Water Quality Parameters

The monitoring stations monitor a range of water quality parameters that includes total chlorine, pH, specific conductance, temperature, ORP, turbidity, and UV-254. (Note: PWD also monitors fluoride in real time.)

Monitoring Station Structure

Every fixed monitoring station has redundant total chlorine instruments to enable the comparison of data that is generated by identical instruments. Most stations use a cellular network to transmit OWQM-DS data from the stations to a central location for analysis. However, some stations at PWD facilities use Ethernet cable to transmit data. Additionally, autosamplers are incorporated with some stations to facilitate the automatic collection of water samples. PWD deployed stations in the form of wall-mounted racks, enclosed stations, and compact stations. **Figure 10-1** shows one of the compact stations (i.e., rapid deployment stations).

Figure 10-1. Philadelphia Water Department Rapid Deployment Station

Information Management and Analysis

PWD incorporates OWQM-DS data into its SCADA system. The data is also directed to a centralized ADS that automatically generates alerts based on changes in data for individual parameters and relationships between multiple parameters. OWQM-DS data, alert information, and information related to other SRS components is integrated into a dashboard. **Figure 10-2** shows a screenshot of the dashboard. Personnel can also use supplementary information management software to review historical data.

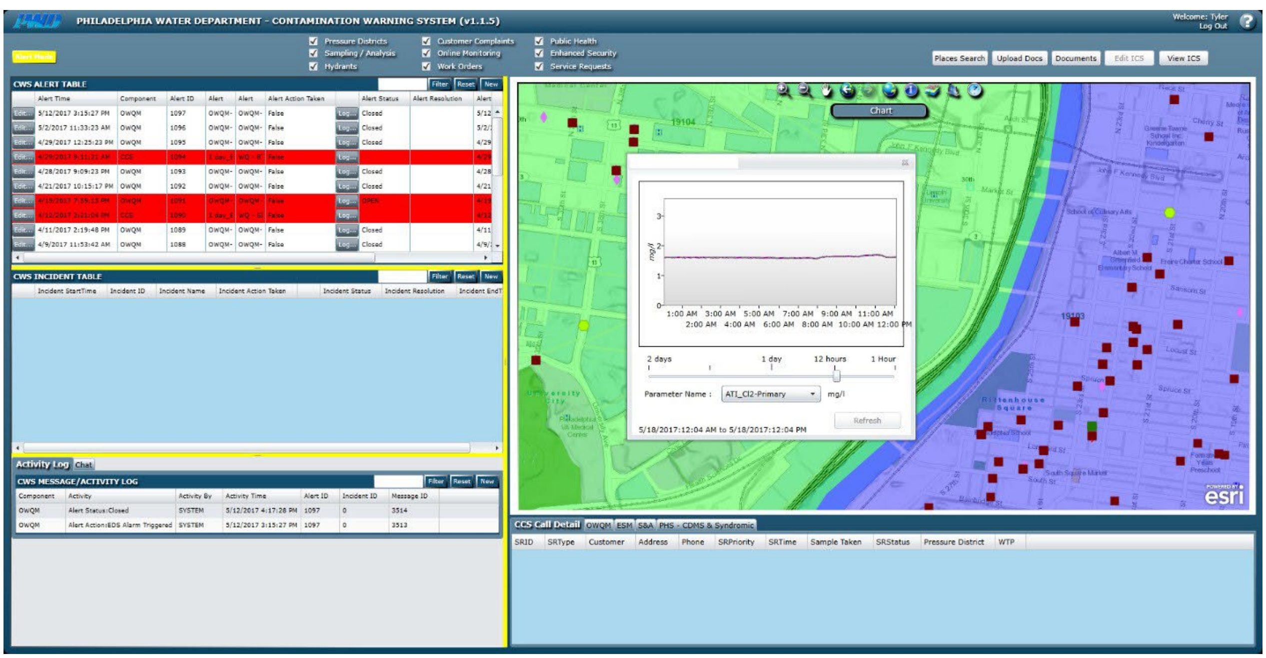


Figure 10-2. Philadelphia Water Department SRS Dashboard

Alert Investigation Procedure

PWD has a Consequence Management Plan that guides the investigation of, and response to, a possible ***water quality incident***. Personnel are available at all times to investigate alerts. Personnel have found that using OWQM-DS data along with customer complaint information can be very effective for timely detection and response to water quality incidents in the distribution system.

10.2 City of Dayton Water Department

The City of Dayton Water Department serves treated drinking water to over 400,000 customers in and around Dayton, Ohio. Dayton collects water from approximately 110 production wells in the Miami and Mad River Well Fields. Raw water is pumped from the Great Miami River Buried Valley Aquifer to two water treatment plants that produce an average of 65 MGD of water. Free chlorine is used as a secondary disinfectant in the water.

Dayton has used OWQM-DS data to:

- **Monitor for contamination incidents**. The primary concern is intentional contamination of the distribution system.
- **Optimize distribution system water quality**. Data helps to ensure that monitored parameter values remain within normal operating ranges, inform reservoir operation, and identify unexpected system conditions (e.g., a valve being closed when it was thought to be open).

Monitoring Locations

The OWQM-DS system consists of 12 monitoring stations located at distribution system entry points, storage tanks, booster stations, and pump stations. Dayton selected monitoring locations to monitor as much of the distribution system as feasible, including major storage systems, pump stations, and the furthest reaches of the distribution system.

Water Quality Parameters

The monitoring stations monitor a range of water quality parameters that includes free chlorine, pH, specific conductance, temperature, and turbidity. Some stations monitor all of these parameters, while other stations monitor free chlorine only.

Monitoring Station Structure

A mix of radio and fiber optic cable is used to transmit OWQM-DS data from monitoring stations to a central location for analysis. Dayton deployed stations in the form of wall-mounted racks. **Figure 10-3** shows a typical installation.

Figure 10-3. City of Dayton Water Department Monitoring Station Installation

Information Management and Analysis

Dayton incorporates OWQM-DS data into its SCADA system. Threshold values have been configured in the SCADA system to automatically generate alerts based on changes in data for individual parameters. Operators can access SCADA screens to view current parameter values and time-series plots of data from the past year. Other utility personnel can view this data in read-only mode via the utility's Intranet site. Microsoft Excel files that contain water quality reports are provided to personnel daily.

Alert Investigation Procedure

If a water quality anomaly is detected, personnel review data from the alerting station(s) and other stations to determine whether an on-site investigation and water quality testing are required. Response actions are implemented following an on-site investigation, as needed.

10.3 Mohawk Valley Water Authority

The Mohawk Valley Water Authority (MVWA) serves treated drinking water to approximately 126,000 customers in and around Utica, New York. MVWA delivers raw water from the Hinckley Reservoir and provides treatment at a single water treatment plant that produces an average of 19 MGD of water. Free chlorine is used as a secondary disinfectant in the water.

MVWA has used OWQM-DS data to:

- **Monitor for contamination incidents.** The primary concerns are intentional and unintentional contamination of the distribution system.
- **Optimize distribution system water quality.** Data is monitored to evaluate the effectiveness of treatment (including CCT), inform the dosing of chlorine at booster stations, and ensure that all measured values remain within normal operating ranges.

Monitoring Locations

The OWQM-DS system consists of 15 stations that are located at the distribution system entry point, storage tanks, and booster stations. Locations were selected based on a ranking of critical facilities, availability of historical water quality data collected from a location, whether a location typically experiences high water age, and the extent to which a location satisfied station installation requirements (e.g., sufficient space, accessibility, available communication solution).

Water Quality Parameters

The monitoring stations monitor a range of water quality parameters that includes free chlorine, pH, specific conductance, temperature, turbidity, and UV-254. Some stations monitor all of these parameters, while others monitor free chlorine only.

Monitoring Station Structure

All monitoring stations use a fixed radio network to transmit OWQM-DS data from the stations to a central location for analysis. Autosamplers are incorporated with some stations to facilitate the automatic collection of water samples. MVWA deployed stations in the form of wall-mounted racks.

Information Management and Analysis

MVWA incorporates OWQM-DS data into its SCADA system. **Figure 10-4** shows a screenshot of one of the utility's SCADA system screens. Threshold values have been configured in the SCADA system to automatically generate alerts based on changes in data for individual parameters. Operators can access SCADA system screens to view current parameter values and time-series plots of data. Other personnel with appropriate clearances can also access this data via the internet on a password-protected website.

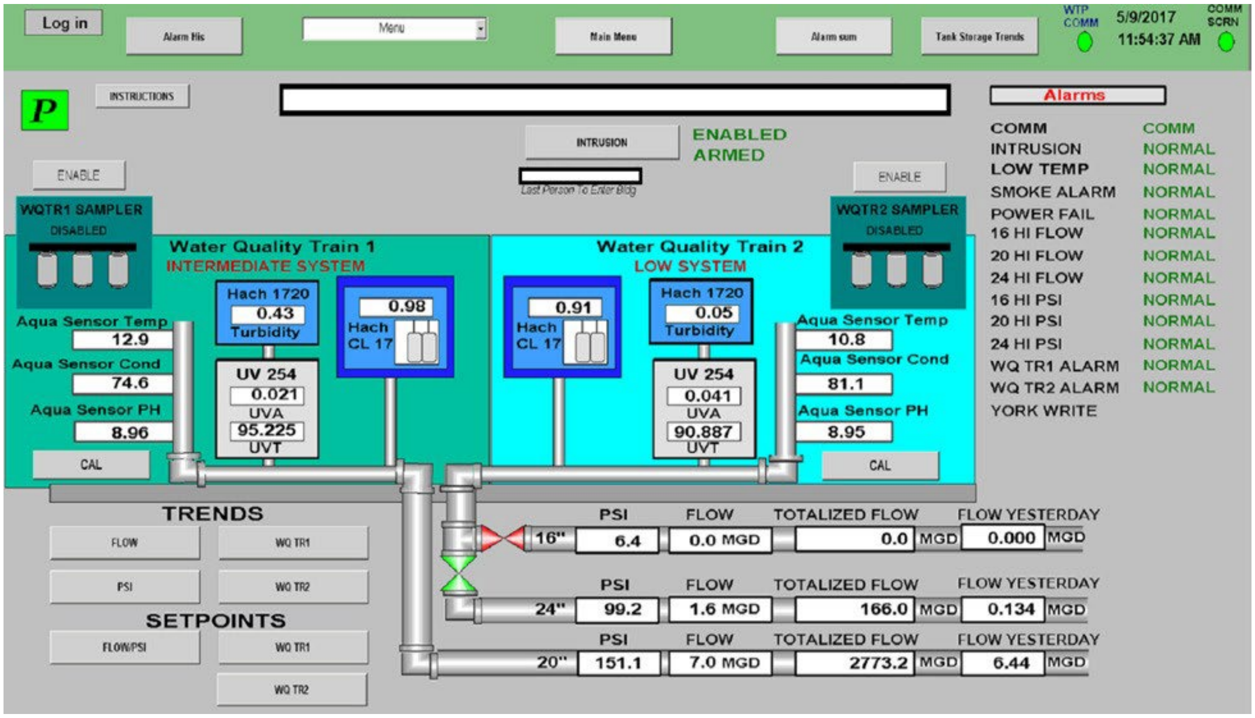


Figure 10-4. Data on a Mohawk Valley Water Authority SCADA Screen

Alert Investigation Procedure

If a water quality anomaly is detected, personnel review data from the alerting station(s) and other stations to determine whether an on-site investigation is required. Response actions are implemented as needed following an on-site investigation.

Section 11: Lessons Learned

An overview of lessons learned, as shown below, can be critical to designing, implementing, and maintaining a successful OWQM-DS system. *Summary of Implementation Approaches and Lessons Learned from the Water Security Initiative Contamination Warning System Pilots* (EPA, 2015) covers additional lessons learned that can help utilities implement a more efficient, cost-effective system.

- **Establish a strong business case and staffing plan with sustainability in mind.** It is important to develop both a strong business case for how OWQM-DS data will be used to support day-to-day operations and utility goals, as well as a staffing plan that specifies how operation and maintenance activities will be incorporated into existing or projected personnel job functions. These materials can help build support for an OWQM-DS system among senior management and users at all levels, which is critical to ensure that the system will be used and maintained effectively.
- **Engage all stakeholders from the beginning of OWQM-DS system design.** It is important to engage all personnel responsible for design, implementation, and maintenance of an OWQM-DS system. Each of these stakeholders can provide a unique perspective on how a system should be designed with respect to their area of expertise.
- **Use a phased approach for OWQM-DS system implementation.** It can be effective to initially install a limited number of monitoring stations, possibly with a variety of viable technologies, to gain practical experience and generate real-world, OWQM-DS data before final selection of instrumentation for an entire OWQM-DS system. This approach allows utilities to assess water quality instruments against performance objectives (e.g., data quality), determine whether the data collected can be used to achieve selected design goals, understand requirements for information management and analysis software, and determine how data will be managed and used. If a selected instrument is new to a utility, this approach can also provide insight to the training, level of effort, and funding required to operate and maintain the system. Experience and information gained during such a demonstration period can then be used to inform future phases of implementation.
- **Consider specialized capabilities required of personnel.** A review of existing staff, roles, and responsibilities may present a need for additional training or hiring of new staff. Specific capabilities that may be required for successful operation and maintenance of an OWQM-DS system include these:
    - Developing protocols (e.g., standard operating procedures, quality assurance project plans) to use OWQM-DS data to inform treatment and distribution system operations
    - Calibrating, maintaining, troubleshooting, and repairing instrumentation as well as analog and digital electronic equipment
    - Maintaining highly integrated systems related to water quality instrumentation, communications, and data acquisition
    - Interpreting OWQM-DS data and data analysis results, which may require an understanding of mathematical and statistical techniques used by ADS software, to inform treatment and distribution system operations
    - Performing complex chemical analyses (e.g., of volatile and semi-volatile organics) and using quality assurance techniques (e.g., automated drift correction) to enable the use of sophisticated instrumentation and sampling equipment

- **Discuss OWQM-DS system design with utilities that have implemented systems of their own.** Utilities that have implemented OWQM-DS systems can provide valuable feedback on the performance of water quality instruments and information management and analysis software, as well as how to incorporate OWQM-DS-related activities into day-to-day operations at a utility.

ADDITIONAL INFORMATION

For information on utility experience with OWQM-DS instruments and information management and analysis software, and/or to be put into contact with utilities that have implemented OWQM-DS systems, contact WQ_SRS@epa.gov.

Resources

Introduction

Water Quality Surveillance and Response System Primer

This document provides an overview of SRSs, and serves as a foundation for the use of technical guidance and products used to implement an SRS. EPA 817-B-15-002, May 2015.
https://www.epa.gov/sites/production/files/2015-06/documents/water_quality_sureveillance_and_response_system_primer.pdf

Online Water Quality Monitoring Primer for Water Quality Surveillance and Response Systems

This document provides an overview of OWQM, a component of an SRS. It also presents basic information on the goals and objectives of OWQM within the context of an SRS. EPA 817-B-15-002A, May 2015.
https://www.epa.gov/sites/production/files/2015-06/documents/online_water_quality_monitoring_primer.pdf

Framework for Designing Online Monitoring Systems

Guidance for Developing Integrated Water Quality Surveillance and Response Systems

This document provides guidance for applying system engineering principles to the design and implementation of an SRS to ensure that the system functions as an integrated whole and is designed to effectively perform its intended function. Section 2 provides guidance on establishing a project team and coordinating SRS implementation activities. Section 3 provides guidance on developing a master plan for an SRS. EPA 817-B-15-006, October 2015.
https://www.epa.gov/sites/production/files/2015-12/documents/guidance_for_developing_integrated_wq_srss_110415.pdf

American Water Works Association Partnership for Safe Water

A four-phase distribution system optimization program for drinking water distribution systems that add a residual disinfectant and are interested improving performance.

Monitoring Locations

EPANET

Software that models the hydraulic and water quality behavior of water distribution piping systems.
https://www.epa.gov/water-research/epanet

Threat Ensemble Vulnerability Assessment and Sensor Placement Optimization Tool (TEVA-SPOT)

Software that provides command-line interfaces to computational tools that compute impacts for contamination incidents and optimizes monitoring locations in a water distribution system.
https://software.sandia.gov/trac/spot/

Checklist for Assessing Potential Monitoring Locations

A checklist that can be used to assess potential monitoring locations with respect to monitoring station installation requirements.
Click this link to open the template.

Monitoring Parameters

List of Available OWQM Instruments

This spreadsheet provides an overview of available online water quality monitoring instruments that have been used for source water and distribution system monitoring. The instrument list can be filtered and sorted according to the criteria specified in the column headings.
https://www.epa.gov/waterqualitysurveillance/online-water-quality-monitoring-resources

Monitoring Stations

Guidance for Designing Communications Systems for Water Quality Surveillance and Response Systems

This document provides guidance and information to help utilities select an appropriate communications system to support operation of an SRS. It provides rigorous criteria for evaluation communications system options, evaluates common technologies with respect to these criteria, describes the process for establishing requirements for a communications system, and provides guidance on selecting and implementing a system. EPA 817-B-16-002, July 2016.
https://www.epa.gov/sites/production/files/2017-04/documents/srs_communications_guidance_081016.pdf

Guidance for Building Online Water Quality Monitoring Stations

This document provides guidance for designing OWQM stations for both source water monitoring and OWQM-DS. It describes different station designs and provides detailed design schematics, describes basic station equipment and station accessories, and provides considerations for fabricating and installing OWQM stations. EPA 817-B-18-002, May 2018.
https://www.epa.gov/sites/production/files/2018-05/documents/guidance_for_building_owqm_stations_05092018_0.pdf

Information Management and Analysis

Guidance for Developing Integrated Water Quality Surveillance and Response Systems

This document provides guidance for applying system engineering principles to the design and implementation of an SRS to ensure that the system functions as an integrated whole and is designed to effectively perform its intended function. Section 4 provides guidance on developing information management system requirements, selecting an information management system, and IT master planning. Appendix B provides an example outline for an IT operations and maintenance plan. EPA 817-B-15-006, October 2015.
https://www.epa.gov/sites/production/files/2015-12/documents/guidance_for_developing_integrated_wq_srss_110415.pdf

Exploratory Analysis of Time-series Data to Prepare for Real-time Online Water Quality Monitoring

This document describes methods for analyzing time-series water quality data to establish normal variability for water quality at unique monitoring locations. It also describes how the results of this exploratory analysis can be used to develop tools and training to prepare utility personnel for real-time analysis of OWQM-DS data. EPA 817-B-16-004, November 2016.
https://www.epa.gov/sites/production/files/2016-11/documents/exploratory_analysis_of_time-series_data_for_owqm.pdf

Dashboard Design Guidance for Water Quality Surveillance and Response Systems

This document provides information about useful features and functions that can be incorporated into an SRS dashboard. It also provides guidance on a systematic approach that can be used by utility managers and IT personnel to define requirements for a dashboard. EPA 817-B-15-007, November 2015.
https://www.epa.gov/sites/production/files/2015-12/documents/srs_dashboard_guidance_112015.pdf

Information Management Requirements Development Tool

This tool is intended to help users develop requirements for an SRS information management system, thereby preparing them to select and implement an information management solution. Specifically, this tool (1) assists SRS component teams with development of component functional requirements, (2) assists IT personnel with development of technical requirements, and (3) allows the IT design team to efficiently consolidate and review all requirements. EPA 817-B-15-004, October 2015.

https://www.epa.gov/waterqualitysurveillance/information-management-requirements-development-tool

Alert Investigation Procedure

OWQM Alert Investigation Procedure Template (Word File)

The alert investigation procedure template includes an editable flow diagram, table, and checklists that can be used to document the utility's role in an OWQM alert investigation process. April 2018.
Click this link to open the template

Guidance for Developing Integrated Water Quality Surveillance and Response Systems

This document provides guidance for applying system engineering principles to the design and implementation of an SRS to ensure that the system functions as an integrated whole and is designed to effectively perform its intended function. Section 6 provides guidance on developing a training and exercise program to support SRS operations. EPA 817-B-15-006, October 2015.
https://www.epa.gov/sites/production/files/2015-12/documents/guidance_for_developing_integrated_wq_srss_110415.pdf

SRS Exercise Development Toolbox

Software that helps utilities and response partner agencies to design, conduct, and evaluate exercises around contamination scenarios. These exercises can be used to develop and refine investigation and response procedures, and train personnel in the proper implementation of those procedures. The toolbox guides users through the process of developing realistic scenarios, designing discussion-based and operations-based exercises, and creating exercise documents. March 2016.
https://www.epa.gov/waterqualitysurveillance/water-quality-surveillance-and-response-system-exercise-development-toolbox

Preliminary Design

Preliminary OWQM Design Template (Word File)

This Word template can be used to document aspects of OWQM component design such as the component implementation team, design goals and performance objectives, preliminary monitoring locations, preliminary water quality parameters, preliminary monitoring station design, preliminary information management requirements, initial training requirements, budget, and schedule. April 2018.
Click this link to open the template

Framework for Comparing Alternatives for Water Quality Surveillance and Response Systems

This document provides guidance for selecting the most appropriate SRS design for a utility from a set of viable alternatives. It guides the user through an objective, stepwise analysis for ranking multiple alternatives and describes, in general terms, the types of information necessary to compare the alternatives. EPA 817-B-15-003, June 2015.
https://www.epa.gov/sites/production/files/2015-07/documents/framework_for_comparing_alternatives_for_water_quality_surveillance_and_response_systems.pdf

Water Finance Clearinghouse

This website provides information on current federal, state, local, private, and other sources of funding for water related projects.
https://ofmpub.epa.gov/apex/wfc/f?p=165:6:9900315311146::NO:6::

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Glossary

accuracy. The degree to which a measured value represents the true value.

alert. An indication from an SRS surveillance component that an anomaly has been detected in a datastream monitored by that component. Alerts may be visual or audible, and may initiate automatic notifications such as pager, text, or email messages.

alert investigation. The process of investigating the validity and potential causes of an alert generated by an SRS surveillance component.

alert investigation checklist. . A form that lists a sequence of steps to follow when investigating an SRS alert. This form ensures consistency with an alert investigation procedure and provides documentation of the investigation of each alert.

alert investigation process. A documented process that guides the investigation of an SRS alert. A typical procedure defines roles and responsibilities for alert investigations, includes an investigation process diagram, and provides one or more checklists to guide investigators through their role in the process.

anomaly. A deviation from an established baseline in a monitored datastream. Detection of an anomaly by an SRS surveillance component generates an alert.

anomaly detection system (ADS). A data analysis tool designed to detect deviations from an established baseline. An ADS may take a variety of forms, ranging from complex computer algorithms to thresholds.

application. A specific use of OWQM-DS to meet a design goal. An example would be monitoring of chlorine residual to optimize distribution system water quality.

architecture. The fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution. The architecture of an information management system is conceptualized as three tiers: source data systems, analytical infrastructure, and presentation.

asset. A piece of equipment, IT system, instrument, or other physical resource used in the implementation of an SRS component or system.

baseline. Values for a datastream that include the variability observed during typical system conditions.

cloud service. A third-party provider of data storage or a computer application that uses the Internet as a means of transmitting data to a client.

completeness. The percentage of data that is of sufficient quality to support its intended use.

component. One of the primary functional areas of an SRS. There are five surveillance components: Online Water Quality Monitoring, Physical Security Monitoring, Advanced Metering Infrastructure, Customer Complaint Surveillance, and Public Health Surveillance. There are two response components: Water Contamination Response and Sampling and Analysis.

concentration. In solutions, the mass, volume, or number of moles of solute present in proportion to the amount of solvent or total solution. Common measures are molarity, normality, percent and by specific gravity scales.

consequence. An adverse public health or economic impact resulting from a contamination incident.

contamination incident. The presence of a contaminant (microorganism, chemical, waste, or sewage) in a drinking water distribution system that has the potential to cause harm to a utility or the community served by the utility. Contamination incidents may have natural (e.g., sloughing of pathogens from accumulated biofilm), accidental (e.g., chemicals introduced through accidental cross-connection), or intentional (e.g., purposeful addition of a contaminant at a fire hydrant) causes.

control center. A utility facility that houses operators who monitor and control treatment and distribution system operation, as well as other personnel with monitoring or control responsibilities. Control centers often receive system alerts related to operations, water quality, security, and some of the SRS surveillance components.

dashboard. A visually oriented user interface that integrates data from multiple SRS components to provide a holistic view of distribution system water quality. The integrated display of information in a dashboard allows for more efficient and effective management of water quality and the timely investigation of water quality anomalies.

data access. The process of retrieving data from an information management system for review and analysis.

data analysis. The process of analyzing data to support routine system operation, rapid identification of water quality anomalies, and generation of alert notifications.

data analysis tool. Any tool used to analyze data for the purpose of generating useful information.

data quality objectives. Qualitative and quantitative statements that clarify study objectives, define the appropriate types of data, and specify the tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.

datastream. A time series of values for a unique parameter or set of parameters. Examples of SRS datastreams include, chlorine residual values, water quality complaint counts, and number of emergency department cases.

design goal. The specific benefits to be realized through deployment of an SRS and each of its components. A fundamental design goal of an SRS is detecting and responding to drinking water contamination incidents. Additional design goals for an SRS are established by a utility and often include benefits to routine utility operations.

distribution system. The infrastructure needed to convey water from a treatment plant, well, interconnection, or other entry point to service connections throughout a city, town, or county.

distribution system model. A mathematical representation of a drinking water distribution system, including pipes, junctions, valves, pumps, tanks, reservoirs, and other appurtenances. These models predict flow and pressure of water through the system, and, in some cases, water quality.

functional requirement. A type of information management requirement that defines key features and attributes of an information management system that are visible to the end user. Examples of functional requirements include the manner in which data is accessed, types of tables and plots that can be produced through the user interface, the manner in which component alerts are transmitted to investigators, and the ability to generate custom reports.

geographic information system (GIS). Hardware and software used to store, manage, and display geographically referenced information. Typical information layers used by water utilities include utility infrastructure, hydrants, service lines, streets, and hydraulic zones. GIS can also be used to display information generated by an SRS.

hardware. Physical IT assets such as servers or user workstations.

historical data. Data that has been generated and stored, including recent data that is readily available in an information management system as well as older data that has been stored or archived in a historian.

hydraulic connectivity. The hydraulic relationship between locations in a distribution system. Two locations are hydraulically connected if water flows from one to the other.

information management system. The combination of hardware, software, tools, and processes that collectively support an SRS and provide users with information needed to monitor real-time system conditions. The system allows users to efficiently identify, investigate, and respond to water quality incidents.

information technology (IT). Hardware, software, and data networks that store, manage, and process information.

interconnects. Interconnects are connections between different systems. They could be to wholesale customers, from wholesale suppliers, or from neighboring systems

invalid alert. An alert from an OWQM-DS system that is not due to a true water quality anomaly or a contamination incident.

lifecycle cost. The total cost of a system, component, or asset over its useful life. Lifecycle cost includes the cost of implementation, operation and maintenance, and renewal.

monitoring station. A configuration of one or more water quality sensors and associated support systems, such as plumbing, electric, and communications that is deployed to monitor water quality in real time at a specific location in a drinking water distribution system.

Online Water Quality Monitoring (OWQM). One of the surveillance components of an SRS. OWQM utilizes data collected from monitoring stations that are installed at strategic locations in a utility's source waters and/or distribution system. Data from the monitoring stations is transferred to a central location and analyzed for water quality anomalies.

operational control point. A location within a distribution system, such as a water storage facility, booster station, or pump station, where operational adjustments are made to achieve design goals.

performance objectives. Measurable indicators of how well an SRS or its components meet selected design goals.

possible. In the context of the threat level determination process, water contamination is considered possible if the cause of an alert from one of the surveillance components cannot be identified or determined to be benign.

preliminary operation. A period of SRS component operation during which all equipment and IT systems are operational, but data analysis and investigations are not performed in real time. The purpose of preliminary operations is to evaluate the performance of the SRS component, address problems, and allow personnel to become familiar with SRS component procedures.

Physical Security Monitoring (PSM). One of the surveillance components of an SRS. PSM includes the equipment and procedures used to detect and respond to security breaches at distribution system facilities that are vulnerable to contamination.

real-time. A mode of operation in which data describing the current state of a system is available in sufficient time for analysis and subsequent use to support assessment, control, and decision functions related to the monitored system.

reservoir. A structure designed to store very large volumes of finished water, which may be located underground, in-ground, or at grade.

response activity. An action taken by a utility, public health agency or another response partner to minimize the consequences of an undesirable water quality incident. Response actions may include issuing a public notification, changing system operations, flushing the system, or others.

Sampling and Analysis (S&A). One of the response components of an SRS. S&A is activated during Water Contamination Response to help confirm or rule out possible water contamination through field and laboratory analyses of water samples. In addition to laboratory analyses, S&A includes all the activities associated with site characterization. S&A continues to be active throughout remediation and recovery if contamination is confirmed.

spectral fingerprint. The spectral absorbance of a sample over a range of wavelengths (typically in the visible and ultraviolet spectrum). Spectral fingerprints can be measured for specific compounds or complex mixtures, and can be a means of identifying the presence of a specific compound or a change in the characteristics of a complex mixture.

storage facility. A structure in a distribution system where water is temporarily held, such as a tank or reservoir.

Supervisory Control and Data Acquisition (SCADA). A system that collects data from various sensors at a drinking water treatment plant and locations in a distribution system, and sends this data to a central information management system.

tank. A structure designed to store large volumes of finished water, which may be at grade or elevated.

technical requirement. A type of information management requirement that defines system attributes and design features that are often not readily apparent to the end user, but are essential to meeting functional requirements or other design constraints. Examples include attributes such as system availability, information security and privacy, backup and recovery, data storage needs, and inter-system integration requirements.

threshold. Minimum and/or maximum acceptable values for individual datastreams that are compared against current or recent data to determine whether conditions are anomalous or atypical of normal operations.

user interface. A visually oriented interface that allows a user to interact with an information management system. A user interface typically facilitates data access and analysis.

valid alert. Alerts due to water contamination, verified water quality incidents, intrusions at utility facilities, or public health incidents.

Water Contamination Response (WCR). One of the response components of an SRS. This component encompasses actions taken to plan for and respond to possible drinking water contamination incidents to minimize the response and recovery timeframe, and ultimately minimize consequences to a utility and the public.

water quality incident. An incident that results in an undesirable change in water quality (e.g., low residual disinfectant, rusty water, taste & odor, etc.). Contamination incidents are a subset of water quality incidents.

water quality instrument. A unit that includes one or more sensors, electronics, internal plumbing, displays, and software that is necessary to take a water quality measurement and generate data in a format that can be communicated, stored, and displayed. Some instruments also include diagnostic tools.

water quality sensor. The part of a water quality instrument that performs the physical measurement of a water quality parameter in a sample.

Water Quality Surveillance and Response System (SRS). A system that employs one or more surveillance components to monitor and manage source water and distribution system water quality in real time. An SRS utilizes a variety of data analysis techniques to detect water quality anomalies and generate alerts. Procedures guide the investigation of alerts and the response to validated water quality incidents that might impact operations, public health, or utility infrastructure.