NAVFAC EXWC Successfully Demonstrates Real-time Water Quality Monitoring System

NESDI-Sponsored Effort Designed to Prevent Interruptions from Natural Disasters & Intentionally Destructive Actions

PERSONNEL FROM THE Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC), formerly the Naval Facilities Engineering Service Center, have successfully demonstrated the feasibility of On-line Water Quality Monitoring (OWQM), a real-time drinking water quality monitoring system at Naval Base Ventura County (NBVC) to assure Safe Drinking Water Act (SDWA) compliance and sound water quality surveillance.

Drinking water systems are vulnerable to interruption from natural disasters (including earthquakes and floods), deterioration of infrastructure, and intentionally destructive actions. Significant water quality problems are associated with the loss of chlorine residual in the water distribution system and the promotion of biological growth. The SDWA requires that detectable chlorine residual be maintained in the water distribution system to ensure proper safeguards against biological-related illnesses. These water quality problems have a direct impact on consistently achieving regulatory compliance.

The Navy must be able to provide safe drinking water in sufficient quantity to its installations to accomplish its primary mission of national defense. For the first time, the Navy has validated through a pilot-scale demonstration an effective and timely method to monitor drinking water quality. The standard practice for water quality compliance is to manually collect grab samples for laboratory analysis on a weekly or quarterly basis. This procedure does not allow water system staff adequate time to respond to changes in water quality and therefore, increases the chance of poor water quality events occurring outside "normal" sampling events. Often times, this practice also does not provide adequate information to enable the assessment and mitigation of water quality issues.

Navy water infrastructure managers need cost-effective real-time water quality monitoring technologies for improving compliance and water system operations, as well as ensuring the health and safety of base personnel. OWQM coupled with automated notification and mitigation procedures could address this deficiency. Benefits of implementing OWQM systems include:

- Contaminant warning
- Regulatory compliance (e.g., prevention of nitrification)
- Operational support (e.g., reduction of water age)

Navy water utilities have not implemented an OWQM strategy to date due to the limited availability of proven cost effective technologies. Emerging water quality monitoring technologies need to be evaluated periodically and the information passed along to installations so sound investments in OWQM systems may be possible.

With funding provided by the Navy Environmental Sustainability Development to Integration (NESDI) program, NAVFAC EXWC personnel have demonstrated several of the latest OWQM technologies at NBVC in Port Hueneme, California. While the field installation of OWQM systems was first reported in the fall 2009 issue of *Currents*, in this article the findings and lessons learned from the pilot demonstration of OWQM system are presented.

Contaminant Warning

Three major contaminant areas for consideration for OWQM include:

- Chemical (including biotoxins)
- Biological (pathogens)
- Radioactive material

Since thousands of potential contaminants could poison a water system, either intentionally or unintentionally, it would not be realistic to attempt to monitor for individual contaminants. Instead, surrogate parameters (measurable properties of water that are affected to some degree by most known contaminants) that react to the various contaminant classes are measured. Prior identification of the potential contaminants that may be introduced into a water distribution system helps in the selection of the right instruments to be used in a monitoring station. A list of potential contaminants also provides water utility managers with insight into the potential threats to their systems and provides public health officials a sense of the medical emergencies that might occur. The U.S. Environmental Protection Agency (EPA) developed a list of twelve contaminant classes (shown in the following table) and, through extensive testing, determined a detection level for each.

Changes in surrogate parameters can alert water system operators to the presence of some contaminants. Surrogate parameters can be measured by commercially available and relatively affordable instruments. However, the effectiveness of these instruments varies and their sensitivity may not be sufficient to detect minor (but real) impacts due to other impurities in the water. Furthermore, changes in water quality and surrogate parameters also occur due to the dynamic nature of distribution systems (e.g., operational changes or source water blending). EPA recommends the use of Total Organic Carbon (TOC), conductivity, and chlorine residual as the primary surrogate parameters based on the relationship of changes in these parameters with the twelve classes of contaminants shown in the figure below.

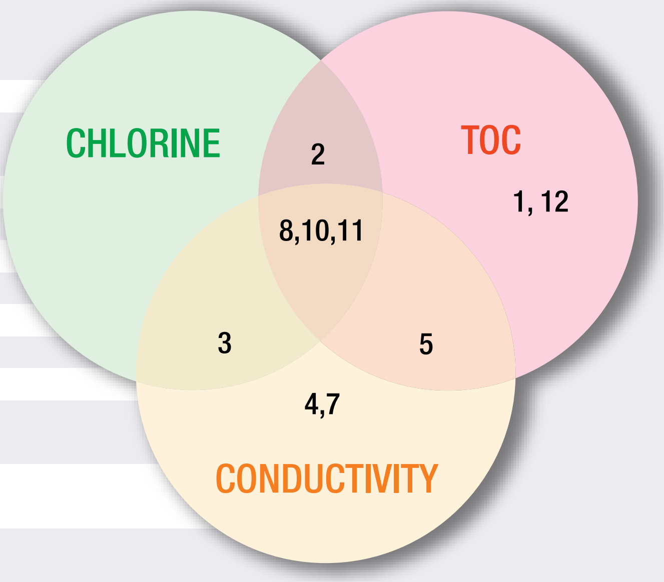
Selection of On-line Monitoring Technologies

Real-time drinking water quality monitoring technologies demonstrated at NBVC consisted of two OWQM stations equipped with the best competing technologies available

Contaminant Categories and Detection Potential Using On-line Monitoring and Laboratory Analysis

Class	Description	On-line Monitoring	Laboratory Analysis
1	Petroleum products	M	H
2	Pesticides (with odor or taste, chlorine reactivity)	H	H
3	Inorganic compounds	H	H
4	Metals	M	H
5	Pesticides (odorless, chlorine resistant)	H	M
6	Chemical warfare agents	L	M
7	Radionuclides	M	H
8	Bacterial toxins	H	M
9	Plant toxins	M	M
10	Pathogens causing diseases with unique symptoms	H	M
11	Pathogens causing diseases with common symptoms	H	M
12	Persistent chlorinated organic compounds	M	H

Note: The letters represent detection potential: H=high, M=medium, L=low.



Three surrogate parameters detect 12 classes of contaminants.

at that time. Surrogate parameter selection was based on analysis conducted by the EPA and its subsequent recommendations for contaminant monitoring and consideration of the particular conditions of the Port Hueneme water system for regulatory compliance and operational support. The following sensor technologies were selected for the demonstration system:

- Hach Water Panel (total chlorine, pH, conductivity, turbidity, temperature)
- ATI Water Panel (total chlorine, free chlorine, pH, conductivity, oxidation reduction potential (ORP), turbidity)
- s::can ammo::lyser (ammonia, pH, temperature, potassium)
- s::can Ultraviolet-Visible (UV-Vis) spectro::lyser (TOC, dissolved organic carbon (DOC), nitrate, turbidity, UV fingerprint—200–400 nanometers)

In addition, the following non-water quality monitoring technologies were demonstrated:

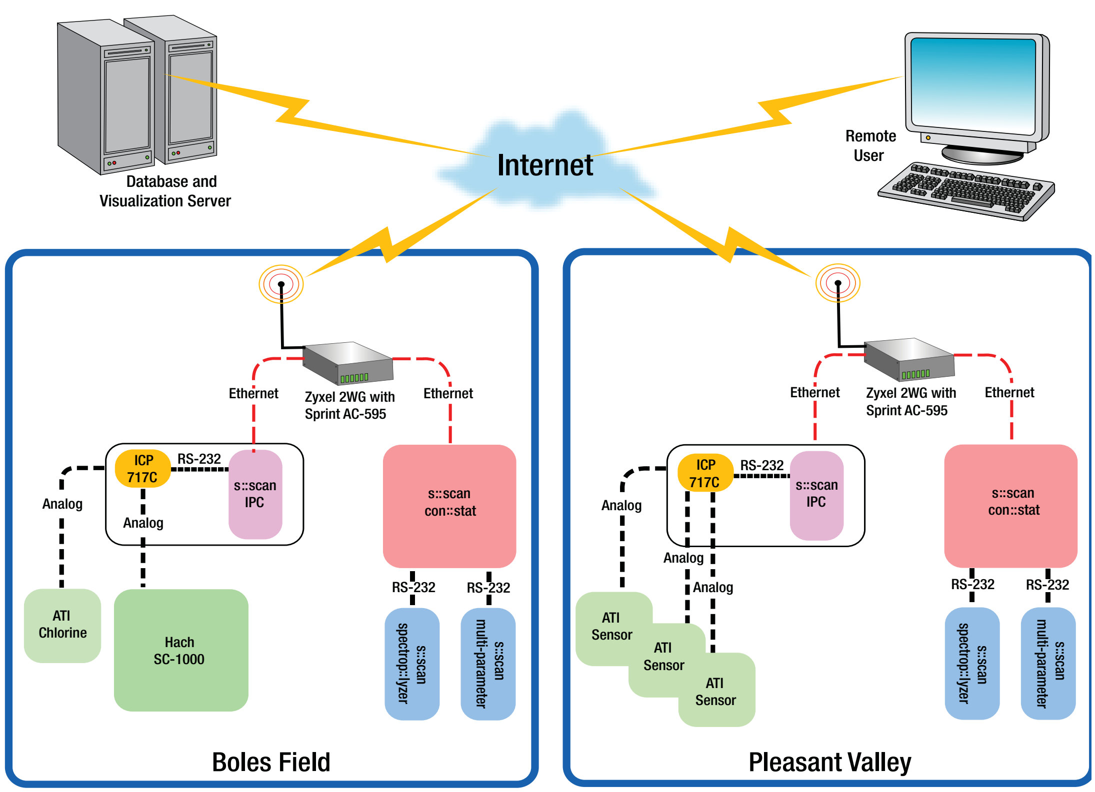
- s::can Event Detection System (EDS) software
- CH2M Hill Postgres Central Database
- CH2M Hill spatial OWQM dashboard

One station utilizes both a Hach monitoring panel and an ATI chlorine analyzer; the other station includes a full suite of ATI analyzers. The monitoring station with the Hach panel includes the standard CL-17 analyzer for measurement of total chlorine and an ATI Q45H analyzer for measurement of free chlorine. The other station includes two ATI Q45H analyzers—one configured for combined chlorine measurement and one for free chlorine. Because the Hach panel CL-17 chlorine analyzer requires the use of reagents (N, N-diethyl-p-phenylenediamine sulfate (DPD) and buffer solution) that cannot be discharged to the ground water, this system has been installed where a sanitary drain is available. Both stations used the s::can UV-VIS spectro::lyzer and ammo::lyser.

Selection of Data Handling & Transfer

The two monitoring stations were configured for data collection and transfer only (no automated sample collection, direct operator interaction, or centralized supervisory control and data acquisition data archiving was used).

The data are transferred to a central server by cellular data communication using Carrier Detect Multiple Access for further analysis and visualization. The data are then loaded into a data warehouse where they can be used by a web server process for presentation and visualization to the end users. Data handling and transfer is illustrated in the following figure.

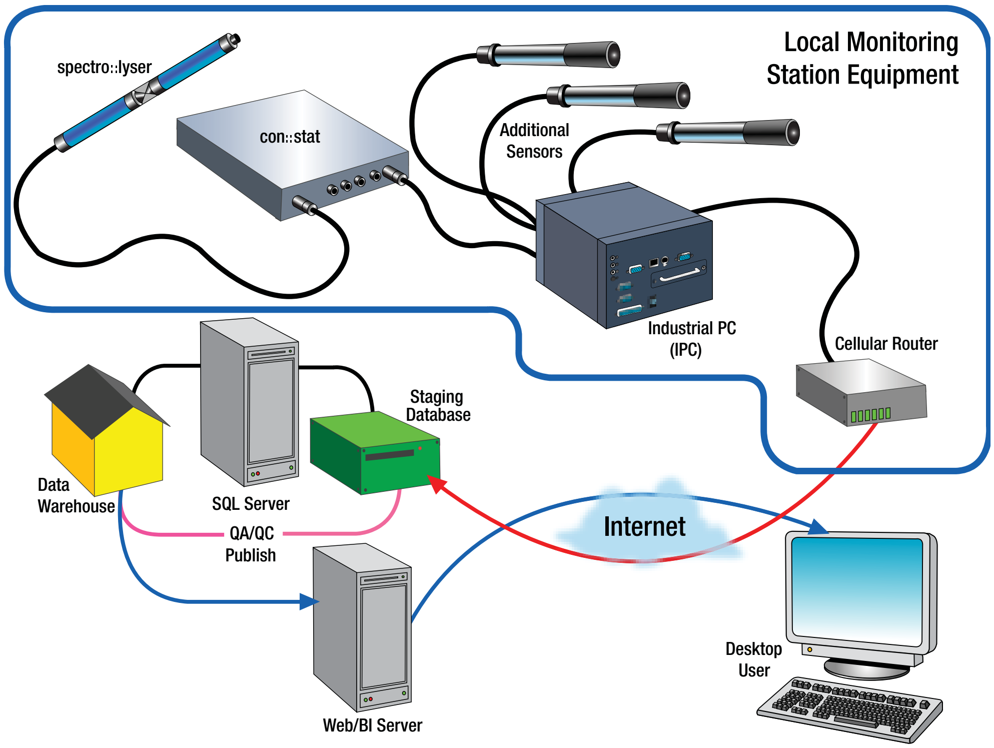


Data handling system block diagram.

Data Management System Design

The OWQM data flows from an Industrial Personal Computer (IPC) in the monitoring station to the central database utilizing a web service application (shown in the following figure). Once the data are received by the central server, they are processed and stored in the central database.

The central database runs a polling process every two minutes. This process queries the database to determine the most recent data timestamp to ensure that all collected data are transferred even in the event of a transaction or communication failure in the previous polling cycle.



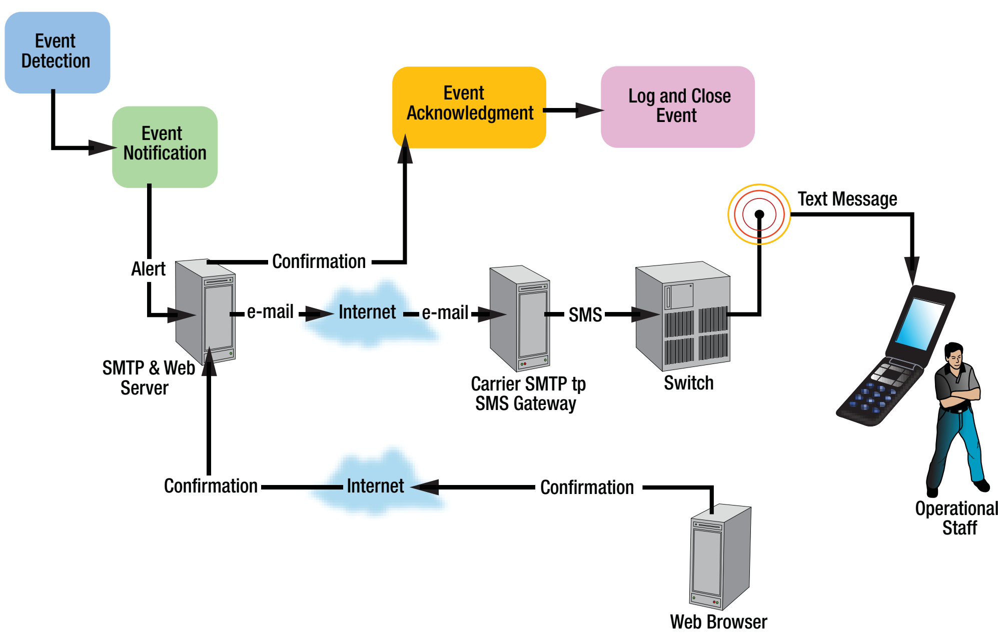
OWQM information flow diagram.

Water Quality Event Notification & Confirmation

Event notification is the final step of the event detection process. Anomalous behavior must be communicated to pertinent operations staff after the previous steps of data collection, verification, processing, and analysis against the methods defined above have been completed.

The data flow depicted in the following figure portrays this process flow with both the local processing of data at each monitoring location and also centralized processing of multiple sites. The aggregated data at the centralized server are analyzed in further detail via spectral fingerprint matching and differential data analysis.

Once an event is verified, operations staff is notified. While notification can happen in a number of ways, the operations staff has elected to get text messages via their existing cellular phones. Operations staff may then further investigate the event by navigating to the OWQM web site to view the data in more detail.



Event notification and confirmation data flow.

The OWMQ station at the Pleasant Valley Gate—where the water main enters NBVC.

The OWMQ station at Bolles Field aboard NBVC.

System Evaluation

Two sites (shown in the above images) were selected to investigate the benefits of OWQM technologies:

- Pleasant Valley Gate—where the water main enters the Base. This station monitors the source water and assists with management of the system as needed due to source water changes.
- Bolles Field—a remote loop in the distribution system where the issues of low chlorine residual and nitrification tend to occur.

Both OWMQ stations experienced some initial equipment problems due to anomalous water quality in the distribution system. However, using the techniques listed below, these problems were mitigated or eliminated:

- Iron oxide fouling—mitigated with the addition of an autobrush and stainless steel housing for the spectro::lyser.
- Air in distribution system—mitigated with the addition of the degasser for the ammonia analyzer and will be a standard recommendation.
- Calcium carbonate corrosion—eliminated by replacing the spectro::lyser aluminum body with a stainless steel body.

As a result of experience with various manufacturers' sensors, the Hach water panel will be replaced with a smaller, multi-parameter probe for conductivity, chlorine residual, and turbidity. This decision is based on the fact that the Hach CL-17 Chlorine Analyzer requires the use of reagents in the field and has relatively high maintenance requirements. In addition, the Hach Panel has reached its useful life and should be replaced with a more robust and sustainable technology.

The Data Communication and Management systems performed extremely well and can be easily applied at different locations. The web site was accessed by the end users and provided real-time data about the distribution system. For this project, the data were collected and processed independently of a Defense network, and accessed through a secure web-site managed by the contractor (CH2M Hill). For the data to be collected, processed and managed on a Defense network there will be additional requirements to assure the security of the information.

Real-time monitoring of water quality parameters can assist in regulatory compliance, especially where there are known issues. The distribution system at NBVC continues to have nitrification problems as the water supply uses chloramines. Issues, such as this, can be monitored and addressed more quickly and effectively with real-time monitoring in place. Problems such as water aging and changes to the source water can be identified by monitoring water quality parameters. OWQM systems enabled these impacts to be mitigated. Due to lower demands on the water distribution system during non-fire flow events, the NBVC water system also suffers from water aging and associated low-chlorine residual. OWQM systems assisted with control of this issue as well.

Conclusions

Qualitative and quantitative results for accuracy, maintenance, and usability were compiled into recommendations for implementation at other new site installations. Recommendations from the project's successful outcomes as they relate to the use of the technology by the Navy are:

- The use of OWQM systems should be considered for all installations that are required to meet the SDWA's regulatory compliance requirements.

- The use of OWQM systems should be considered for all installations for which their Vulnerability Assessments have indicated a security risk associated with potential contamination of the water supply.
- Periodic maintenance and use of consumables and moving components in sensors adds a level of complexity and cost (in dollars and manpower) that must be minimized for a practical system.
- Selection of instruments for accuracy, reliability, usability and overall cost is important.
- The system must be locally managed and integrated into the day-to-day management and monitoring of the water system to provide the greatest value.

OWQM system costs are based on the particular installation and the size and layout of the water distribution system. For the NBVC demonstration, two monitoring stations were adequate, however other installations may require more monitoring stations. The cost of implementing monitoring stations will be dependent on their location and availability of the services required at that site. Overall, the costs based on the demonstration system are approximately:

- $147,000: capital cost per installation
- $116,500 to $141,500: capital cost per monitoring station (dependent on site improvements required)
- $8,100: annual operation and maintenance cost per site

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Technical Memorandum (TM-NAVFAC ESC-EV-1201), Demonstration of Real-Time Drinking Water Quality Monitoring Technologies, documents the findings in greater detail and provides information that may assist activities determine if OWQM stations would be beneficial for their facilities. (To download a copy of this report, log into the NESDI web site at www.nesdi.navy.mil with your username and password. Once on the web site, select "Projects and Proposals" then "Manage Any Project" then "356" in the "Text Search" field. Once you have found project 356, select "Edit" then "Files/Photos" then "Upload Reports and Files" where you will find a pdf version of the report. Alternatively, you can contact Steve Fann for a copy of the report.) ⚓

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The Basics About the NESDI Program

THE NESDI PROGRAM seeks to provide solutions by demonstrating, validating and integrating innovative technologies, processes, materials, and filling knowledge gaps to minimize operational environmental risks, constraints and costs while ensuring Fleet readiness. The program accomplishes this mission through the evaluation of cost-effective technologies, processes, materials and knowledge that enhance environmental readiness of naval shore activities and ensure they can be integrated into weapons system acquisition programs.

The NESDI program is the Navy's environmental shoreside 6.4 Research, Development, Test and Evaluation program. The NESDI technology demonstration and validation program is sponsored by the Chief of Naval Operations Energy and Environmental Readiness Division and managed by the Naval Facilities Engineering Command. The program is the Navy's complement to the Department of Defense's Environmental Security Technology Certification Program which conducts demonstration and validation of technologies important to the tri-Services, U.S. Environmental Protection Agency and Department of Energy.

For more information, visit the NESDI program web site at www.nesdi.navy.mil or contact Leslie Karr, the NESDI Program Manager at 805-982-1618, DSN: 551-1618 or leslie.karr@navy.mil.