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ENGINEERING AND EXPEDITIONARY WARFARE CENTER

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APPLICABILITY OF DESALINATION SYSTEMS TO DROUGHT RELIEF APPLICATIONS

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Congress tasked the Navy to write a report on "desalinization technology's application for defense and national security purposes to provide drought relief to areas impacted by sharp declines in water resources." Due to the number of variations in terminology, technology, and potential scenarios, this report will be generalized in several areas. Nevertheless, the general answer is: desalination processes have application to drought relief scenarios. Fresh water is required for nearly all human endeavors including drinking, hygiene, agriculture, and many industrial processes. As such, if a saline water source is the best available during a contingency, then desalination is fundamentally required. However, there are numerous desalination technologies, each with different characteristics and applicability to different scenarios. The appropriate water treatment system for a contingency will depend on numerous factors such as source water availability and composition, desired output quantity, desired product water quality, anticipated length of operation, urgency of need, available infrastructure, available logistics support, available personnel, local security considerations, and local regulatory considerations. The Naval Facilities Engineering Command (NAVFAC) Engineering and Expeditionary Warfare Center (EXWC) evaluated the feasibility of deploying portable desalination systems for contingency response applications at naval installations around the world, and the results are nominally extensible to civil water contingencies.

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EXECUTIVE SUMMARY

Congress tasked the Navy to write a report on "desalinization technology's application for defense and national security purposes to provide drought relief to areas impacted by sharp declines in water resources." Due to the number of variations in terminology, technology, and potential scenarios, this report will be generalized in several areas. Nevertheless, the general answer is: desalination processes have application to drought relief scenarios. Fresh water is required for nearly all human endeavors including drinking, hygiene, agriculture, and many industrial processes. As such, if a saline water source is determined to be the best available water source during a contingency, then desalination is fundamentally required. However, there are numerous desalination technologies, each with different characteristics and applicability to different scenarios. The appropriate water treatment system for a contingency will depend on numerous factors such as source water availability and composition, the desired output quantity, the desired product water quality, the anticipated length of system operation, the urgency of need, available infrastructure, available logistics support, available operating personnel, local security considerations, and local regulatory considerations. The Naval Facilities Engineering Command (NAVFAC) Engineering and Expeditionary Warfare Center (EXWC) has evaluated the feasibility of deploying portable desalination systems for contingency response applications at naval installations around the world. Though the Navy scenario is limited in scope, the results are extensible to the broader set of civil water contingencies.

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ACRONYMS AND ABBREVIATIONS

EPA	Environmental Protection Agency
EUWP	Expeditionary Unit Water Purifier
FNC	Future Naval Capability
LWP	Lightweight Water Purifier
LWPS	Lightweight Water Purification System
MF	Microfiltration
MMF	Multimedia Filter
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NSF	National Science Foundation
R&D	Research and Development
RO	Reverse Osmosis
ROWPU	Reverse Osmosis Water Purification Unit
SUWP	Small Unit Water Purifier
TWPS	Tactical Water Purification System
UF	Ultrafiltration
USA	United States Army
USN	United States Navy
USMC	United States Marine Corps

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1.0 INTRODUCTION

Congress tasked the Navy to write a report on "desalinization technology's application for defense and national security purposes to provide drought relief to areas impacted by sharp declines in water resources." Due to the number of variations in terminology, technology, and potential scenarios this report will be generalized in several areas. Nevertheless, the general answer is: desalination processes have application to drought relief scenarios. The bottom line is that fresh water is required for nearly all human endeavors including drinking, hygiene, agriculture, and many industrial processes. As such, if a saline water source is determined to be the best available water source during a contingency, then desalination is fundamentally required. However, there are numerous desalination technologies, each with different characteristics and applicability to different scenarios. The relevant question in this case is which desalination technologies and systems are appropriate for contingency drought-relief applications. Unfortunately, the answer to this question is a very complicated "it depends" based on the specific circumstances of each unique water contingency. In practice, it depends on the source water availability and composition, the desired output quantity, the desired product water quality, the anticipated length of system operation, the urgency of need, available infrastructure, available logistics support, available operating personnel, local security considerations, local regulatory considerations, and other factors.

Our public utilities system is an extremely reliable source of clean water, to the point that domestic water availability has become an afterthought for most people. It is truly extraordinary that we can turn on almost any tap in any building in the country and have a practically unlimited supply of freshwater. Clean, fresh water is among the most important commodities in the history of the world, and yet this resource is available in America for approximately $0.0015/gallon (American Water Works Association 2002). A downside of this is that we have become so accustomed to the ubiquitous availability of water that even minor disruptions can have significant negative effects.

The Navy operates and maintains several water treatment facilities at bases around the world. The Naval Facilities Engineering Command (NAVFAC) Engineering and Expeditionary Warfare Center (EXWC) has evaluated the feasibility of deploying portable desalination systems for contingency response applications at naval installations around the world. The results of the Navy analysis are nominally extensible to the broader set of civil water contingencies. In the context of civil response, one of the largest challenges to water relief operations is scale, with large communities potentially requiring hundreds of millions of gallons of water per day. This presents an extreme challenge for any water treatment system, contingency or not. The results of the EXWC analysis are included as Appendix A.

2.0 BACKGROUND

This chapter includes basic information on desalination systems as well as a brief discussion of the term "drought" to prepare the reader for the following discussion of water contingency considerations. There is a significant amount of ongoing research into desalination technologies performed by a wide range of private, academic, and government scientists; however, most prototype systems are unsuitable for contingency response due to their capacity and reliability. As such this discussion is generally focused on the characteristics of currently available systems.

2.1 Desalination

Desalination is an effect—the removal of salts from water—that is achieved by a wide variety of processes ranging from the natural hydrologic cycle to man-made industrial processes such as distillation and reverse osmosis. Each approach has pros and cons such as energy consumption, reliability, maintainability, ease of operation, etc. The most common industrial processes for desalination are distillation and reverse osmosis. Distillation is a phase-change process which entails the removal of contaminates by changing water into the vapor phase through manipulation of temperature and/or pressure, and then condensing the vapor back into clean water. Reverse osmosis is a pressure-driven process in which salt-water is pressurized to a level higher than the osmotic pressure of the solution, and water molecules are driven across a semi-permeable membrane to produce clean water. Both of these processes are employed around the world at a public utilities scale. In addition to distillation and reverse osmosis, there are a multitude of other desalination methods including forward osmosis, capacitive deionization, chemical desalination, shock electrodialysis, and more, all at various stages of technological maturity and development.

The Navy operates a variety of water purification systems with desalination capability, including deployable expeditionary systems, shipboard systems, and permanent-infrastructure water treatment facilities. Tables 1–3 show the approximate physical, operating, and performance characteristics of various currently-fielded and developmental water purification systems.

Table 1. Approximate characteristics of expeditionary water desalination systems.

Expeditionary Systems											
System	Primary Technology	Maturity	Status	Circa	Operator	Capital Cost	Output (gph)	Power (kW)	Size (cuft)	Weight (lb)	Energy (kWh/kgal)
SUWP prototype	various - RO	R&D	Testing	2015	USN, USMC	$15k	10	2	6	100	200
Army LWP	UF, RO	Available	Fielded	2005	USA	$400k	75	~10*	38	2,000	133
Navy/USMC LWPS	Media, RO	Available	Fielded	2005	USN, USMC	$250k	75	~12*	38	2,000	160
600 ROWPU	Media, Cartridge, RO	Legacy	Retired	1981	All services	$100k	480	30	380	7,300	62.5
TWPS	MF, RO	Available	Fielded	2004	USA, USN, USMC	$500k	1,500	60	590	10,000	40
3K ROWPU	Media, Cartridge, RO	Available	Fielded	1989	USA	$600k	2,000	60	1,280	15,100	30
3K TWPS prototype	Media, RO	R&D	Testing	2015	USA	$500k	2,400	60	1,280	25,000	25
EUWP Gen-1	UF, RO	R&D	Retired	2004	USA, USN	$1,500k	5,000	~80*	2,560	50,000	16

a. Systems indicated with an * asterisk include direct-drive diesel powered pumps. Power requirement is approximated.
b. Some systems include integrated power, others require external generators. Some systems are containerized, others are skid mounted. Size and weight are not a directly comparable.
c. USMC has ~220 LWPS units and ~300 TWPS units. USN has ~250 LWPS systems and ~14 TWPS

Table 2. Approximate characteristics of developmental shipboard desalination systems.

Shipboard Systems									
System	Primary Technology	Output	Maturity	Status	Circa	Capital Cost	Output (gph)	Power (kW)	Energy (kWh/kgal)
FNC 4.6k	MMF, Cartridge, RO	Potable	R&D	Testing	2015	~$350k	190	4	20
FNC 100k	UF, RO	Potable and ultra-pure	R&D	Retired	2015	~$5M	4,166	75	18
EUWP Gen-2	UF, RO	Potable and ultra-pure	R&D	Retired	2008	$3M	12,500	200	16

Table 3. Approximate characteristics of various naval water treatment facilities.

Select Naval Locations with Water Purification Facilities							
System	Primary Technology	Water Source	Status	Circa	Capital Cost	Output (gph)	Energy (kWh/kgal)
San Nicholas Island	Media, RO	Seawater	Complete	2015	$750K	1,750	18
Guantanamo Bay	Media, Cartridge, RO	Seawater	Complete	1990-2003		52,000	9.7-16.5
Diego Garcia	Nanofiltration, RO	Seawater	Construction	2016	$27M	50,000	6.5
Camp Pendleton	Under Development	Seawater	Planning	2025??	$1.4B	2,083,000	??
Sigonella	Sand, RO	Brackish wells	Complete	2008		20,700	4.1-4.8
Bahrain	Multimedia, RO	Municipal	Complete	2010		30,500	3.7-6.1

EUWP = Expeditionary Unit Water Purifier
FNC = Future Naval Capability
LWP = Lightweight Water Purifier
LWPS = Lightweight Water Purification System
MF = Microfiltration
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UF = Ultrafiltration
USA = United States Army
USN = United States Navy
USMC = United States Marine Corps

2.2 Drought

A drought can be caused by a variety of natural or man-made causes, can emerge rapidly or slowly over time, and can be short or long duration. This presents a wide range of potential water contingency situations, and an associated range of contingency response approaches, systems, and technologies. Though the term drought is generally understood, there are a wide variety of specific definitions which can influence the nature of a response. Wilhite and Glantz (1985) reviewed more than 150 published definitions of drought to further investigate the phenomenon, and discovered that both the occurrence and severity of drought are difficult to determine based on the variety of definitions in the literature. They categorized definitions as conceptual, which are "formulated in general terms to identify the boundaries of the concept," and as operational, which "attempt to identify the onset, severity, and termination of drought episodes" (Wilhite and Glantz 1985). Conceptual definitions are generally aligned across multiple sources, that a drought is a "deficiency of precipitation that results in water shortage for some activity (e.g., plant growth) or for some group (e.g., farmer)" (Wilhite and Glantz 1985). However, there are a tremendously diverse set of criteria and opinions in the literature for when a drought starts, ends, and how severe it is. In our case, "drought relief to areas impacted by sharp declines in water resources" may be better considered as response to emergent water contingencies where locally available water resources are projected to be unable to meet local demands with currently operating treatment processes and distribution networks, for a set period of time.

3.0 SYSTEM CONSIDERATIONS

There are a variety of considerations that will impact the applicability of a water purification technology to contingency applications. Each factor is dependent on the unique characteristics of the contingency at hand. As such, it is impossible to develop a universally applicable contingency water system. The following factors must be considered when selecting a contingency response system.

3.1 Source Water Availability

One of the first considerations that will drive the choice of a contingency water purification system is the quantity, location, and composition of available water. This could be groundwater, surface water, ocean water, or reclaimed/recycled water from domestic, agricultural, or industrial processes. Most water will need to be treated, though not all water will need to be desalinated. Some water may need specific treatment processes to achieve desired product-quality levels. Source water availability is highly dependent on the specific location and conditions of a water contingency.

3.2 Water Quantity

A primary concern in a water contingency is the quantity of water required, and there is tremendous variability in this factor. Small communities needing water only for human consumption may require hundreds of gallons per day; however, large regions with human consumption, agriculture, and industrial requirements may require hundreds of millions of gallons per day. For example, Californians use around 181 gallons of fresh water per day in total for all end-use purposes (Brandt, et al. 2014) and San Diego County is home to around 3.3 million people (United States Census Bureau, 2016). This equates to a total water demand of approximately 597 million gallons per day to serve the total needs of San Diego County (including agriculture and industry). To illustrate the challenge associated with this magnitude of response, consider that the total combined Navy and Marine Corps inventory of expeditionary water purification systems that are capable of desalination includes approximately 570 Lightweight Water Purification System (LWPS) units and 314 Tactical Water Purification System (TWPS) units as shown in note c of Table 1. Running all of these units simultaneously for a 20-hour operating day would produce approximately 10 million gallons of product water—well short of the nearly 600 million gallons required by San Diego County.

It should be noted that the required product quantity will depend on whether a contingency response system is responsible for supplying all the water for the needs of the community, or whether it is part of a diversified water supply. In addition, the previous calculation discounts the potential for reduction of the water requirement due to enhanced conservation and rationing during contingency periods, as well as the fact that all product water does not need to meet the same quality restrictions. At a minimum, humans require approximately 0.8 gallons per day for survival and 4 gallons per day for cooking and hygiene purposes (Sphere 2011) ... far less than the 181 gallons per day we currently use.

3.3 Water Quality

One of the most important considerations in a water contingency response system is the required product quality. Water quality requirements will be driven by the end-use of the water. Human consumption and hygiene applications will necessitate a certain quality level. Water for agricultural use may require a lower quality level, and industrial processes (such as chemical processing or power-plant cooling) may require lower or higher quality levels depending on the specific need.

In addition to end-use, water quality levels are dependent on the anticipated duration of exposure. For example, most deployable military water purification systems are evaluated in accordance with the National Science Foundation (NSF) P248 Emergency Military Operations Microbiological Water Purifiers test protocol; however, test protocols such as these are generally tailored to cover short-term consumption of water in the field by a predominantly young and healthy military population. As such, these standards (and the associated expeditionary military water purification systems) may not be suitable to address long-term consumption by the general population, including the very young and elderly in various states of health.

Domestic drinking water regulations are established by Environmental Protection Agency (EPA) and test standards are developed by the NSF. For example, the EPA promulgates the National Primary Drinking Water Regulations, and the NSF publishes seven Point of Use / Point of Entry standards for system certification. In addition, state, regional, and local governments may also establish water quality requirements.

3.4 Anticipated Contingency Duration

The anticipated length of contingency response will inform the most appropriate type of water purification system for the application. Some systems are designed to run at the edge of the performance envelope and may necessitate more attentive system operation and more frequent maintenance. These systems are usually based on design compromises which trade filter life to minimize system size and weight for deployability purposes, and would not be appropriate for continuous operation in support of a long-term contingency. Other systems are designed with long-term use in mind, and have lower filter loading rates and other design parameters set to maximize system longevity.

3.5 Urgency of Need

Some water contingencies evolve slowly over time while others are rapid-onset events which require immediate response efforts. The urgency of need will have a significant impact on the choice of contingency response system. Do we have 24 hours to respond, or a year to plan? Rapid onset crises must be served with currently available systems; however, slowly developing contingencies may be able to employ site-specific water contingency systems matched to the local needs. In all cases, the contingency response may vary over time, and the system deployed on the first day may not be the system which remains in use for the duration of required support.

3.6 Infrastructure

The local infrastructure has a major influence on the type of system which will be suitable for a water contingency. This applies to the existing water sourcing, treatment, storage, and distribution infrastructure as well as the local transportation infrastructure and power infrastructure. A contingency water system may need to integrate with local distribution infrastructure, or the local plumbing could be a contributor to the contingency, as was the case in the 2016 Flint, Michigan water crisis. This could necessitate contingency water storage and distribution systems in addition to water purification capabilities. During the response to the 2010 Haiti earthquake, one of the key issues was how to store and distribute the clean water produced by relief systems, as early production capacity exceeded storage capacity. In addition, the local transportation infrastructure must be able to support the mobility and emplacement of a deployable water purification system to the affected region. Lastly, much has been written on the water-energy nexus. The local power infrastructure must be able to support the power requirements of the contingency water system or a contingency power system must also be deployed.

3.7 Logistics Support

Locally available logistics support will influence the type of system that is appropriate for the contingency. All water purification systems require maintenance. The availability of spare parts and consumables, and the ability to get them to the required location when needed will factor in to selecting the best system for the application.

3.8 Available Operating Personnel

Nearly all water purification systems require trained personnel to set up, and most require full-time system operators. Some systems can be operated remotely; however, they require trained personnel onsite to perform maintenance when necessary. The availability of trained personnel will factor into the type of system which is suitable for any given water contingency.

3.9 Local Security

Because it is such a critical commodity, water contingencies can result in significant local instability. Depending on the nature of the contingency, there may be a high level of civil unrest. In this type of scenario, relief systems and workers may be targeted by hostile groups seeking to advance a political or other agenda. In addition, components of a water purification system may be pilfered by vandals in an attempt to capitalize on the valuable hardware and materials.

3.10 Local Regulations

Local regulations may influence everything from water quality to environmental impact constraints. This could affect aspects of system employment including system siting, water source availability, and discharge quality, quantity, and rate. Some localities may place significant restrictions on the handling of purification byproducts (such as brine discharge) and what sources of water can be recycled (such as grey-water), which can significantly limit the water available for purification. Local regulations and permits are cited as one of the major considerations and schedule drivers to the implementation of local desalination plants in California (Mulligan 2016).

3.11 Overall Water Cycle

Desalination or other treatment of water is only one phase of a significantly broader water cycle. When selecting a system for contingency response, the whole water cycle must be taken into consideration. This includes: water source identification and quality analysis; raw water collection, transport, and storage; water treatment; water treatment byproduct handling; product water quality analysis; product water storage and quality maintenance; product water transport and distribution; water use/consumption; and water waste management (possibly to include collection and recycling).

4.0 CONCLUSIONS

Water contingencies can result from a variety of natural and man-made causes and the production of fresh water will be required in nearly all response activities. As such, desalination is a very relevant process to water contingency scenarios. Desalination is achievable by a variety of processes at various levels of technical maturity and scales of production. Desalination systems range from individual-scale systems for survival kits to multi-million gallons per day water treatment plants for public utilities applications. The most common industrial desalination processes are distillation and reverse osmosis. Every water contingency is unique, and as such, contingency water response will be site-specific and application-specific, and not all applications will require desalination.

Major challenges for civil-scale water contingency response include the required volume of clean water (and the associated energy required to support water production), the availability of source water, the required product water quality, integration with existing infrastructure, the ability to store and handle clean product water, and the potential duration of contingency response efforts.

Contingency response efforts for any given scenario will evolve over time and the system employed on day one may not be the one used throughout the contingency. Lastly, conservation efforts can drastically reduce the required water volume in contingency scenarios and should be practiced as a matter of course to preserve water as a natural resource.

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APPENDIX A

NAVFAC TECHNICAL REPORT - TR-EXWC-EX-1901 FEASIBILITY STUDY OF PORTABLE WATER DESALINATION SYSTEMS FOR WATER CONTINGENCIES AT REMOTE NAVAL INSTALLATIONS

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TECHNICAL REPORT
TR-NAVFAC-EXWC-EX-1901
DECEMBER 2018

FEASIBILITY STUDY OF PORTABLE WATER DESALINATION SYSTEMS FOR WATER CONTINGENCIES AT REMOTE NAVY INSTALLATIONS

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14. ABSTRACT The Navy operates several water treatment facilities at remote installations around the world. Water contingencies at these locations can result in significant risk to personnel, loss of mission capability, and cost to recover. This study considers the feasibility of employing mobile desalination systems to support water contingencies at remote Navy installations. Most Navy installations that currently produce their own potable water do not have simple, reliable backup systems to sustain production if a water plant becomes inoperable. This study considers the viability of developing, strategically pre-positioning, and maintaining such assets, making them available to provide potable water from various water sources including ocean desalination and brackish water in support of global water contingencies. This study will analyze the total costs, benefits, and risks associated with maintaining three types of water system contingency response capabilities. Analysis includes consideration for whether the required equipment is located centrally or on-site, and whether it is owned by the Navy or leased during contingencies.				
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EXECUTIVE SUMMARY

Naval Facilities Engineering Command (NAVFAC) sponsored the NAVFAC Engineering and Expeditionary Warfare Center (EXWC) to study the feasibility of using Low Energy Contingency Desalination (LECD) systems as a potential solution to provide potable water to remote U.S. Navy installations during water contingencies.

The supply of potable water as a resource in and around U.S. Navy installations worldwide is vital to the survival of Department of Defense (DoD) personnel and continued mission effectiveness of the Navy. Water supply infrastructure depends on numerous personnel and conditions. The unpredictable nature of these dependencies can result in reduced water processing capability at any time. Equipment breakdown, operator error, or natural disasters can compromise a water supply system. In the last 20 years, water supply system failures occurred in multiple remote Navy installations. NAVFAC provided subject matter expert (SME) support during many of these contingencies, and documented lessons learned from each.

In addition to ensuring the continuous supply of potable water to DoD personnel, operations often require the delivery of potable water to communities needing Humanitarian Assistance and Disaster Relief (HA/DR) support. As an organization, NAVFAC is committed to maintaining a dependable supply of water even during crisis events. However, it is difficult to predict when and where failures may occur in the current water supply system. As a result, the U.S. Navy is susceptible to incurring high costs associated with contingency response and recovery.

The cost comparisons in this report do not include a value for loss of mission capability as a result of a water contingency. Therefore, the enclosed cost estimates must be considered minimum values. This report also implies the value of fully resourcing and conducting preventative maintenance activities. Ongoing preventative maintenance allows for the acquisition and application of parts, labor, and engineering support to minimize the potential for water contingencies. In addition, ongoing preventative maintenance and inspections can inform repairs, maintenance, and future system designs.

EXWC is a recognized Navy SME for water treatment, storage, and distribution systems, including expeditionary-, shipboard-, and facilities-scale water systems. EXWC's Seawater Desalination Test Facility (SDTF), located on Naval Base Ventura County in Port Hueneme, CA, provides expertise on desalination for all branches of service and Navy installations around the world.

NAVFAC, as the supporting agency for base utilities operations, has the opportunity to provide a holistic approach to ensure the uninterrupted supply of potable water to Navy installations worldwide. To meet this need in a time of fluctuating budgets, aging infrastructure, and recurring natural disasters, EXWC SDTF recommends a two-pronged approach: (1) aggressive preventative maintenance of existing water systems and (2) a tailored contingency response capability for each installation based on mission criticality.

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1.0 INTRODUCTION AND BACKGROUND

The Department of the Navy (DON) has major installations located around the world. Twenty-two main installations operate outside the continental United States (OCONUS) and rely on on-base water processing facilities. These facilities serve a total population of 71,000 military and civilian personnel, and the water plants have a total production capacity of 15.7 million gallons per day (Fortenberry and Condit 2018).

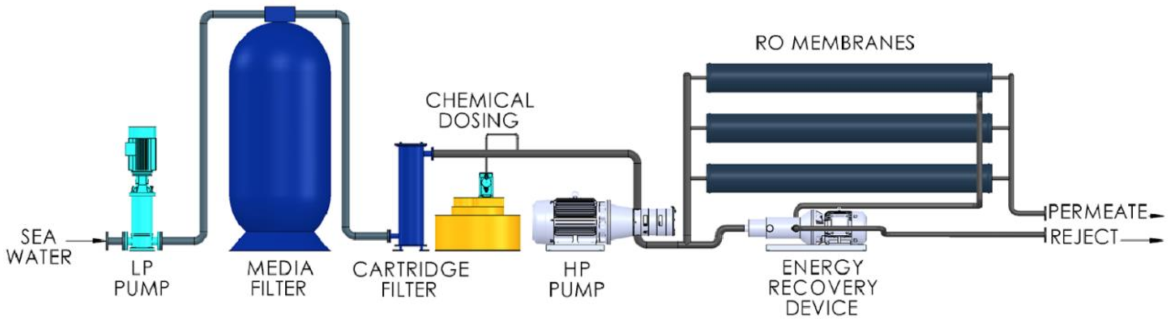

Figure 1-1. Typical Reverse Osmosis System Layout

A significant majority of these locations use a Reverse Osmosis (RO) system for water purification, depicted in Figure 1-1. At many of these installations, the RO systems provide the only reliable potable water source for personnel. Providing potable water is a critical and core mission of the Naval Facilities Engineering Command (NAVFAC).

The NAVFAC Engineering and Expeditionary Warfare Center (EXWC) traditionally provides technical support when U.S. Navy installations face obstacles in supplying potable water. In a majority of historical cases, depleted water supply issues are caused by component failures. These failures are often exacerbated by a lack of preventative maintenance and a shortage of backup components.

In the event of a system failure, contingency solutions typically cause the disruption of work, loss of mission capability, risk to personnel, and expensive emergency support and capability recovery. Additionally, when system losses have occurred at Navy installation water plants with no available contingency solutions, personnel have performed ad-hoc interim emergency repairs which may cause insufficient water production and high system risk.

The ability to deliver clean, healthy, potable water to DoD operational forces is critical to the effectiveness of U.S. military forces. A slight reduction in the intake of water can leave personnel incapacitated and ineffective.

Figure 1-2 provides an excerpt from a U.S. Army TARDEC report (Balling 2009) that details the amount of water one soldier needs. This data further instills the importance of ensuring systems are maintained and effectively provide clean, potable water to DoD forces at remote installations.

- **Water weighs ~8.3 pounds per gallon.**
- **3-4% water deficit (2-3 quarts) significantly reduces performance (up to 48%)**
- **6-8% water deficit (4-6 quarts) renders a soldier completely ineffective**
- **Minimum water consumption is 1-3 gallons/soldier/day**
- **Universal unit level average is 6.6 gallons/soldier/day (53 pounds)**
- **Fully developed theater requires 15.6 gallons/soldier/day or 129.5 pounds**

Figure 1-2. Individual Water Requirements

1.1 Project Approach

NAVFAC Headquarters sponsored EXWC to evaluate the use of Low Energy Contingency Desalination (LECD) units to support Navy installations during system failures and water shortages. This report focuses on the feasibility of deploying desalination systems to remote Navy installations in the event of a water contingency. EXWC personnel concentrated on the following areas of interest:

1. Determine the viability of developing portable desalination water assets for remote Navy installations. These assets would be capable of providing potable water from various water sources, including ocean and brackish water resources.
2. Identify the risks associated with multiple contingency-response courses of action. The team conducted two analyses to determine the projected costs, benefits, and risks associated with (1) continuing the current reactive contingency response process and (2) having an LECD unit pre-deployed to support emergent contingencies. The team then compared the costs and benefits between the two approaches.

1.2 Seawater Desalination Test Facility Capabilities

The EXWC Seawater Desalination Test Facility (SDTF), located on Naval Base Ventura County (NBVC) in Port Hueneme, CA, has been operating continuously since its establishment in 1985. Presently, U.S. Army and Navy civilian personnel operate the SDTF and have over 110 years of combined technical experience in water treatment system design and operation.

EXWC operates the SDTF in partnership with the U.S. Army Tank Automotive Research Development and Engineering Center (TARDEC). This collaboration enables government personnel to develop lifecycle engineering and logistics knowledge, gain practical experience in both laboratory and field settings, and conduct training in support of Department of Defense (DoD) water treatment facilities.

The SDTF performs assessment, design, testing, and fabrication of water purification, packaging, and distribution systems for expeditionary, shipboard, and facility applications. SDTF personnel support the full lifecycle of water purification systems, from research and development through preliminary system design, testing, final design, production, and operational support. This support covers the development and testing of individual components all the way through fully developed turn-key water purification plants. The SDTF's strong working relationships with DoD customers, water industry and academic researchers, and water industry system suppliers enable personnel to develop high-performance, reliable, and cost-effective water treatment system solutions for many applications.

1.2.1 SDTF Response to Water Contingency Events

SDTF personnel have responded to multiple Navy water contingencies from 1990 to 2016, which are listed in Table A-1 and Table A-2 in APPENDIX A. In a recent example, when Hurricane Irma struck the lower East Coast in late summer of 2017, the dangerous hurricane necessitated the evacuation of 3,500 civilian and military personnel from Naval Air Station Key West. During and after the storm, the base was without power, potable water, and waste-water treatment. While EXWC promptly responded with SME support, the response was limited by a lack of available contingency water purification systems.

In addition to the Irma response, EXWC also provided Humanitarian Assistance and Disaster Relief (HA/DR) support for Hurricane Katrina recovery efforts in 2005 and Operation Unified Response in Haiti in 2010. The Haiti response, in particular, demonstrated the capability of Navy assets to support HA/DR efforts; the RO system aboard the aircraft carrier USS Carl Vinson (CVN-70) delivered 147,591 gallons of fresh water. Photos from this operation are included as Figure 1-3 and Figure 1-4.

Figure 1-3. USS Carl Vinson Sailors Fill Water Containers at Port Au Prince, Haiti 2010

Figure 1-4. Sailors Aboard USS Carl Vinson Sailors Load Water for Delivery

2.0 PROBLEM DEFINITION

EXWC's first action was to analyze the problems experienced in providing potable water to Navy installations. The organization took a systems engineering approach to address these issues.

2.1 Current Situation

Not all Navy Installations have a reliable potable water backup system. As a result, if a water plant becomes inoperable due to lack of maintenance, breakdown, disaster, or terrorist activity, significant system downtime could occur, leading the installation to reduce or eliminate critical services provided to DoD forces. An investigation into the current water supply revealed four potential root causes which could lead to installation issues:

1. Potable water plant remoteness: The remoteness of some installations, compared to CONUS sites, leads to higher service costs and impairs the ability of SMEs to service the water supply systems effectively.
2. Compartmentalization and decentralization: NAVFAC currently allows for regional and local management and maintenance of the water systems, resulting in a compartmentalized and decentralized approach. This prevents NAVFAC from standardizing water systems and thus increases training, maintenance, and supply costs.
3. Costs to operate and maintain existing infrastructure: The maintenance and operating costs of potable water systems continue to increase. In a fiscally-constrained environment, budgetary pressures can lead remote installations to defer routine and critical infrastructure maintenance.
4. Plant operator quality in remote locations: Recruiting highly qualified plant operators, compensating them appropriately, and enticing them to stay at a remote location is challenging.

Any combination of these root causes at a remote installation can lead to an aging potable water system in a state of disrepair and vulnerable to significant downtime.

3.0 ANALYSIS

This section estimates the costs of contingency water response activities. For the purposes of this analysis, we compared three different water contingency response courses of action (COA) including 1) reactive contingency response with commercial water purification systems leased for a specific period, 2) reactive contingency response with Navy-owned assets, and 3) proactive pre-positioning of contingency response assets at each remote installation.

3.1 Possible Contingency Sites

The Navy has approximately twenty-two OCONUS installations which operate an on-site water treatment facility. The water requirement at these installations ranges from 5,000–160,000 gallons per day (GPD) with one site requiring 750,000 GPD.

3.2 Contingency Water System Assumptions

The following assumptions were established to underpin this analysis:

1. Contingency water purification equipment will be used up to 90 days, including critical spares and consumables.
2. Water contingencies necessitating support are on overseas U.S. Navy bases only.
3. NAVFAC Public Works (PW) or other local personnel would determine the placement and infrastructure needs to interface with contingency water purification equipment.
4. Contingency water demand will be 50% of a 50 gallon per person per day baseline requirement: for essential use only.
5. Contingency water systems will be able to treat fresh, brackish, and seawater sources.
6. Local operators can be trained to operate contingency response systems.
7. Water systems will be containerized to facilitate transportation.
8. Material handling equipment will be available at base locations to offload and position equipment.

3.3 Baseline Costs for Reactive Contingency Response COAs

Table 3-1 depicts the estimated labor hours and costs for a reactive response COA. A labor rate of $125 per hour is assumed for the purposes of this calculation.

Table 3-1. Baseline Costs for a Reactive Response COA

Fully burdened labor rate estimate = $125/hr

ACTIVITY	Estimated Hours	Cost
Phase 1- REACTION TO EVENT		
Identify contingency event problem variables (WHAT, WHERE, WHY, WHEN)	10	$ 1,250
Identify and communicate with local points of contact (WHO)	20	$ 2,500
Analyze site conditions: type of water available, condition of infrastructure, local personnel	20	$ 2,500
Determine installation water quantity and quality needs	10	$ 1,250
Identify possible water treatment solutions and select to appropriate systems (HOW)	40	$ 5,000
Determine method of acquiring contingency equipment and initiate acquisition	40	$ 5,000
Identify and arrange for funding to support contingency response	40	$ 5,000
Prepare and ship water contingency equipment to location via air, ground, or sea	40	$ 5,000
Identify and mobilize a response team	40	$ 5,000
Phase 2- DURING EVENT (90-day contingency)		
Coordinate with local PW on siting and system configuration to interface with existing infrastructure	40	$ 5,000
Assess local water sources and determine how to get water to contingency equipment	40	$ 5,000
Conduct inspection and inventory of equipment	20	$ 2,500
Conduct initial maintenance on equipment	20	$ 2,500
Set up and commission equipment	20	$ 2,500
Conduct training for local support staff	40	$ 5,000
Conduct periodic water quality verification[1]	30	$ 3,750
Assist local personnel with operation and maintenance of water purification equipment[1]	720	$ 90,000
Phase 3- AFTER EVENT		
Decommission equipment	40	$ 5,000
Flush and drain equipment, and preserve membranes	20	$ 2,500
Refurbish, repair, and resupply system	80	$ 10,000
Pack up equipment and ship back to source	60	$ 7,500
Total estimated labor for reactive response	1390	$ 173,750
Spares and consumables		$ 30,000
Travel costs, assume 6 week trip x 2 people, OCONUS		$ 30,000
Shipping costs for purification systems (expedited air-freight of ISO container type units overseas)		$ 50,000
REACTIVE COSTS FOR A 90 DAY CONTINGENCY, LESS COST OF PURIFICATION SYSTEM		**$ 283,750**

[1] Ongoing continuous activity during a contingency response operation at an approximate cost of $1,041 per day.

3.4 Contingency Water Purification System Characteristics

Table 3-2 provides details and cost estimates for three different types of government-owned water purification systems, including the legacy 600 gallons per hour (GPH) Reverse Osmosis Water Production Unit (ROWPU), notional 600 GPH ROWPU-Enhanced (notional system with estimated capabilities), and demonstrated prototype 3K GPH Tactical Water Purification System (TWPS).

Table 3-2. Navy Expeditionary Water Purification System Characteristics

System	600 GPH ROWPU	600 GPH ROWPU ENHANCED	3K TWPS
Rated System output, Seawater source, gallons per day (GPD)	12,000	16,000	48,000
Rated System output, Seawater source, gallons per hour (GPH)	600	800	2,400
Rated System output, Seawater source, gallons per min (GPM)	10	13	40
Rated system output, Fresh/brackish source (GPD)	19,200	25,000	60,000
Rated system output, Fresh/brackish source (GPH)	960	1,250	3,000
Rated system output, Fresh/brackish source (GPM)	16	21	50
Raw feedwater flowrate, (GPM)	33	33	90
Recovery, Seawater source	30%	40%	44%
Recovery, Fresh/brackish source	48%	63%	56%
Power source, generator , Kw	30	30	60
Packaging	skid or trailer mounted	skid or trailer mounted	20 ft container
RO Vessels	5	TBD	5
RO membranes per vessel	2	TBD	5
Total number of RO membranes	10	TBD	25
RO membrane size	6 in x 40	8 in x 40	8 in x 40
Total RO membrane area, ft2	3,000	TBD	10,000
Cost per unit	$ 75,000	$ 150,000	$ 600,000

3.5 Reactive Contingency Response COAs

Here we consider two reactive contingency response scenarios. In COA-1, government personnel respond to a contingency with leased commercial water purification systems. A variety of containerized/deployable water purification systems are available from commercial suppliers, in a range of capacities and costs. This COA is lease-based and requires no capital investment in purification systems or ongoing maintenance to ensure system availability; however, response time may be impacted as this COA will require the execution of a contract or lease agreement and time by the supplier to prepare the unit for mobilization. Commercially available water purification systems range in capacity from 2,000–288,000 GPD at associated lease costs of approximately $2,500–$30,000 per month.

In COA-2, government personnel respond to a contingency with Navy-owned and maintained contingency water purification systems. This COA incurs a capital investment cost and ongoing maintenance costs to ensure system readiness; however, this COA has the benefit of immediately available systems for response activities. For the purposes of COA-2 we consider a contingency response kit consisting two 3K-TWPS units and four 600 ROWPU-Enhanced units at a total approximate cost of $1.8M. This set of systems allows for scaled contingency response ranging from 16,000–160,000 GPD of production capability from worst-case raw seawater sources

(25,000–220,000 GPD from freshwater), and is capable of supporting contingencies at all remote installations apart from the location requiring 750,000 GPD.

Table 3-3 shows a cost comparison of the reactive response COAs using leased commercial systems and Navy-owned contingency response assets. The scenarios were based on randomly selected installations at contingency rates of one-to-five occurrences in a ten-year period. Commercial systems were selected to match the demand at the randomly selected installations for each contingency. Costs are considered on a net-present-value basis assuming 3% inflation. Both COAs incur the $283,750 baseline cost articulated in Table 3-1. COA-1 (commercial) costs are based on manufacturer-provided lease rates for systems identified to support contingency requirements the randomly selected installations. COA-2 (Navy) costs include initial capital costs of $1.8M for the contingency response systems as well as a $90,000 per year annual maintenance cost (equating to 5% of the system value).

The comparative analysis reveals that COA-2, the Navy-owned response capability, costs anywhere from $1.85M to $2.4M more than the equivalent commercial response. This is due to the initial capital cost of the systems as well as the recurring maintenance costs over the ten-year period.

Table 3-3. Relative Costs of Reactive Response with Commercial vs. Navy-owned Systems.

Random Location 1	Random Location 2	Random Location 3	Random Location 4	Random Location 5	Random year (of occurance)				
Site 10					5				
Site 3	Site 5				2	5			
Site 8	Site 1	Site 20			4	3	5		
Site 21	Site 12	Site 1	Site 13		4	4	1	3	
Site 6	Site 9	Site 8	Site 2	Site 7	2	1	2	2	3

Scenario 1 (1 event in 10 years)		
Year	COA 1: Commercial Lease Cost ($)	COA 2: Navy Owned Cost ($)
1	$ -	$ 1,800,000.00
2	$ -	$ 90,000.00
3	$ -	$ 90,000.00
4	$ -	$ 90,000.00
5	$ 302,750.00	$ 373,750.00
6	$ -	$ 90,000.00
7	$ -	$ 90,000.00
8	$ -	$ 90,000.00
9	$ -	$ 90,000.00
10	$ -	$ 90,000.00
NPV (3% inf)	$261,154.81	$2,672,677.67
	Cost delta	$2,411,522.86

Scenario 2 (2 events in 10 years)		
Year	COA 1: Commercial Lease Cost ($)	COA 2: Navy Owned Cost ($)
1	$ -	$ 1,800,000.00
2	$ 369,250.00	$ 373,750.00
3	$ -	$ 90,000.00
4	$ -	$ 90,000.00
5	$ 396,800.00	$ 373,750.00
6	$ -	$ 90,000.00
7	$ -	$ 90,000.00
8	$ -	$ 90,000.00
9	$ -	$ 90,000.00
10	$ -	$ 90,000.00
NPV (3% inf)	$690,336.71	$2,940,139.26
	Cost delta	$2,249,802.56

Scenario 3 (3 events in 10 years)		
Year	COA 1: Commercial Lease Cost ($)	COA 2: Navy Owned Cost ($)
1	$ -	$ 1,800,000.00
2	$ -	$ 90,000.00
3	$ 396,800.00	$ 373,750.00
4	$ 302,750.00	$ 373,750.00
5	$ 302,750.00	$ 373,750.00
6	$ -	$ 90,000.00
7	$ -	$ 90,000.00
8	$ -	$ 90,000.00
9	$ -	$ 90,000.00
10	$ -	$ 90,000.00
NPV (3% inf)	$893,272.47	$3,184,457.32
	Cost delta	$2,291,184.84

Scenario 4 (4 events in 10 years)		
Year	COA 1: Commercial Lease Cost ($)	COA 2: Navy Owned Cost ($)
1	$ 302,750.00	$ 1,800,000.00
2	$ -	$ 90,000.00
3	$ 302,750.00	$ 373,750.00
*4	$ 699,550.00	$ 657,500.00
5	$ -	$ 90,000.00
6	$ -	$ 90,000.00
7	$ -	$ 90,000.00
8	$ -	$ 90,000.00
9	$ -	$ 90,000.00
10	$ -	$ 90,000.00
NPV (3% inf)	$1,192,532.29	$3,191,800.28
	Cost delta	$1,999,267.99

Scenario 5 (5 events in 10 years)		
Year	COA 1: Commercial Lease Cost ($)	COA 2: Navy Owned Cost ($)
1	$ 369,250.00	$ 1,800,000.00
*2	$ 974,750.00	$ 941,250.00
3	$ 396,800.00	$ 373,750.00
4	$ -	$ 90,000.00
5	$ -	$ 90,000.00
6	$ -	$ 90,000.00
7	$ -	$ 90,000.00
8	$ -	$ 90,000.00
9	$ -	$ 90,000.00
10	$ -	$ 90,000.00
NPV (3% inf)	$1,640,418.72	$3,489,968.64
	Cost delta	$1,849,549.93

*Multiple contingency responses in this year

3.6 Pre-positioned Water Purification Systems

COA-3 involves pre-positioned contingency purification systems that are integrated with the existing infrastructure and which can be employed immediately by local plant operators. While this provides immediate response capability, the cost to realize this COA is extremely expensive. Based on the water demand at each of the twenty-two installations, outfitting them with appropriate contingency systems would require the procurement of fifty-two 3K-TWPS and forty-three 600 ROWPU-E units at an initial capital cost of $37.5M. This COA would also incur a $1.875M/yr expense assuming a 5% cost for ongoing maintenance.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are based on the previous comparative analysis as well as SDTF personnel experience from supporting multiple contingency response operations.

4.1 Facility Contingency Risk Analysis

This analysis considered only the direct costs of contingency response and did not consider the value of the loss of mission capability incurred by a water contingency. Pre-positioning water contingency response equipment is extremely expensive; however, it provides immediate and comprehensive contingency response capability. At some installations, capability loss due to a water contingency may be unacceptable and worth the cost of installing and maintaining a dedicated contingency response system. For these installations, we recommend simple and robust systems based on the design principles employed in the 3K-TWPS prototype system and the reverse osmosis seawater desalination system developed for Naval Base Ventura County, San Nicolas Island.

To minimize mission risk to the Navy, we recommend a risk assessment of the installations considered in this analysis to determine which locations merit on-site contingency response capability.

4.2 Configuration Management

Each individual water plant at an OCONUS Navy installation is a site-specific design, with little-to-no consistency around the world. As such, it is very challenging to obtain comprehensive plant configuration management information to inform contingency response operations and recommended inventory levels for critical spare parts.

To help maximize plant readiness and minimize the risk of water contingencies, we recommend a configuration audit of remote Navy water purification infrastructure and the establishment of a centralized configuration management database for this critical infrastructure. This will aid in the identification of critical spare parts and significantly streamline contingency response activities.

4.3 Operator Training and Preventative Maintenance

We should maximize readiness and minimize preventable contingencies by conducting preventative maintenance and modernization of the existing water purification infrastructure. To this end, we must ensure that all plant operators have the necessary training and qualifications to safely and effectively operate and maintain the water treatment facilities. In addition, we recommend the establishment of a globally available water system reach-back capability and help-desk for remote plant operators. Establishing this relationship and support mechanism would enhance plant operators' ability to operate and maintain their systems, and would streamline support activities in the event of a contingency. To quantify the benefits of enhanced maintenance, we recommend a follow-on analysis of increased system maintenance levels and their projected effect on system reliability and contingency response requirements.

4.4 Further Evaluation of Commercial vs. Navy-owned Contingency Response Systems

Lastly, we recommend a continuation of this analysis to further explore the differences between COA-1 and COA-2—commercial system response versus Navy-owned system response. There are additional variables to explore such as the relative difference in response time, incidental availability of commercial systems, ability to establish contracts and lease agreements, and second-order benefits of Navy-owned capability.

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GLOSSARY

DoD	Department of Defense
ESC	Engineering Service Center
EUWP	Expeditionary Unit Water Purifier
EXWC	Engineering and Expeditionary Warfare Center
FOB	Forward Operating Base
GTMO	Guantanamo Bay
GPD	Gallons per Day
GPH	Gallons per Hour
GPM	Gallons per Minute
HA/DR	Humanitarian Assistance and Disaster Relief
kWh/kgal	Kilowatt Hours per Kilo Gallons
LECD	Low Energy Contingency Desalination
MGD	Millions of Gallons per Day
MUSE	Mobile Utilities and Support Equipment
NALF	Naval Auxiliary Landing Field
NAS	Naval Air Station
NAVFAC	Naval Facilities Engineering Command
NBVC	Naval Base Ventura County
NCEL	Naval Civil Engineering Lab
NFESC	Naval Facilities Engineering Service Center
ONR	Office of Naval Research
PLC	Programmable Logic Controller
RO	Reverse Osmosis
ROWPU	Reverse Osmosis Water Production Unit
SDTF	Seawater Desalination Test Facility
SME	Subject Matter Expert
SOP	Standard Operating Procedure
SOW	Statement of Work
TARDEC	Tank Automotive Research Development and Engineering Center
TWPS	Tactical Water Purification System
USN	United States Navy

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APPENDIX A
EXWC HISTORICAL INVOLVEMENT IN NAVFAC CONTINGENCY WATER OPERATIONS

A.1 Overview

This appendix contains information on EXWC's involvement in supporting water plant systems for NAVFAC. Table A-1 contains information for multiple locations. Table A-2 focuses on a major effort to rebuild the Reverse Osmosis plant at the San Nicolas Island Outlying Landing Field.

Table A-1. EXWC Support to Other Shore Water Treatment Facilities

EXWC Project Support (Year)	Location	EXWC Support Cost	Original Client Request (CNO, OPS, FAC, PW)	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2016	Flint, Michigan	$2,000	CNO	Lead contamination in potable water system due to leaching in water lines. Raw water supply was corrosive because it was untreated. The acidic water leached the lead out of the water distribution piping system.	Provided technical consulting over E-mail with several options. Technical input with alternatives using RO technology.	Bill Varnava, Micah Ing
2015	GTMO	$13,500	NAVFAC SE	High pressure pump failed, resulting in a deficiency of 100,000 gallons per day of potable water supply. GTMO requested technical support for the RO operators.	EXWC staff set up and operated 3K GPH ROWPU units. EXWC provided technical support regarding the training of U.S. Army units to GTMO staff and a site survey of the RO Plant. In addition, technical input and options for execution were provided during the decision making process.	Bill Varnava, Micah Ing
2015	Camp Lemonier, Djibouti, Africa	$2,000	OPS	RO Plant system failure to PLC controller. Requested technical assistance getting it back on-line.	Provided technical consulting over phone.	Bill Varnava, Micah Ing

Table A-1. EXWC Support to Other Shore Water Treatment Facilities

EXWC Project Support (Year)	Location	EXWC Support Cost	Original Client Request (CNO, OPS, FAC, PW)	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2014	NAS Sigonella	$5,000	CNO, NAVFAC LANT	The Operator in Charge of NAS I and NAS II Water Plants needed operational support.	EXWC assessed an inquiry for literature review of two water plants. EXWC reviewed the Public Works Department's SOP's for both NAS I and NAS II Water Plants. EXWC assessment was needed to tighten up existing documents and complete the administrative portion of the SOPs. Efforts also included a review of drinking water deficiencies and other recommendations to the Situation Reports and Fitness Reports, as needed.	Bill Varnava, Micah Ing

Table A-1. EXWC Support to Other Shore Water Treatment Facilities

EXWC Project Support (Year)	Location	EXWC Support Cost	Original Client Request (CNO, OPS, FAC, PW)	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2013	GTMO	$5,000	NAVFAC SE	System failure on the high pressure pump on RO train and well failure. Needed recommendations on alternatives for a replacement water resource.	EXWC provided an analysis of technical alternatives to high pressure pump and well system failure. EXWC provided a course of action with options for NAVFAC leadership to consider. A technical summary of the alternatives analysis was provided and included short-term and long-term options.	Bill Varnava, Joseph M Saenz (Manny)
2012	NAS Sigonella	$17,000	NAVFAC LANT	Numerous failed water resource infrastructure components (2 RO Plants, 3 water treatment plants, and wells), lack of documentation, and poor maintenance, which lead to system failure.	Performed well site inspections; reviewed and updated SOPs; reviewed system operating data and performance; performed plan inspections; and repaired plant and facility infrastructure. Performed trouble shooting and repairs and conducted training. Reviewed corrosion control design and operational plan.	Bill Varnava, Micah Ing, Mark Silbernagel,

Table A-1. EXWC Support to Other Shore Water Treatment Facilities

EXWC Project Support (Year)	Location	EXWC Support Cost	Original Client Request (CNO, OPS, FAC, PW)	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2010	Haiti	$100,000	CNO	Provide potable water to earthquake survivors.	The NAVFAC Engineering Service Center (ESC), now EXWC, and TARDEC were tasked with refurbishing, repairing, and replenishing the Expeditionary Unit Water Purifiers (EUWPs), and prepare for deployment. The EUWPs were not sent to Haiti due to a change in mission status.	Bill Varnava, Mark Miller, Micah Ing, Joseph M Saenz (Manny)
2009	NALF San Clemente Island	$18,500	NAVFAC SW OPS	NAVFAC Southwest (SW) requested an evaluation to install water resource infrastructure for RO, intake, and wells. The purpose of this water resource exploration effort was to identify and site potential proven water resource technologies.	NAVFAC ESC provided guidance on proven water resource technologies related to the use of an RO potable water unit. Findings were based on the evaluation of technical literature, geologic maps, topographical maps, aerial photographs, and satellite images, including a field effort. A planning report was produced.	Joseph M Saenz (Manny), Kimo Zaiger, Bill Varnava, Bryan Long

Table A-1. EXWC Support to Other Shore Water Treatment Facilities

EXWC Project Support (Year)	Location	EXWC Support Cost	Original Client Request (CNO, OPS, FAC, PW)	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2008	Navy Base Diego Garcia	$5,000	NAVFAC PAC	Groundwater was contaminated with Trihalomethanes (THMs) and other disinfection by-products. Groundwater needed to be treated.	NAVFAC ESC provided a technical review of the situation and presented alternative solutions. ESC reviewed MILCON design for proposed membrane treatment plant.	Bill Varnava
2008	U.S. Army - IRAQ Camp Anaconda, FOB Delta Al Kut	$150,000	CENTCOM U.S. ARMY	U.S. Army needed technical assistance in commission and operation of water packaging plants.	EXWC provided field support to the water packaging systems. Systems set-up, maintenance, and system operations were performed by ESC onsite.	Bill Varnava, Micah Ing
2006	Camp Lemonier, Djibouti, Africa	$285,000	CENTCOM, U.S. MARINE CORPS	Experienced impact of drought. Twelve deep dry holes (+800 feet below ground surface) drilled in the area. RO Plant was producing non-potable water. Required well siting and RO Plant inspection of well field. Leaking RO plant and well water resource infrastructure.	Over several field efforts, the RO facility and associated well field were assessed. The brine water outfall was also evaluated and described as a trench offsite. Wells supporting the RO facility were assessed and found to be leaking and contained high saline water concentrations. A report was completed.	Joseph M Saenz (Manny) and Ennie Lory

Table A-1. EXWC Support to Other Shore Water Treatment Facilities

EXWC Project Support (Year)	Location	EXWC Support Cost	Original Client Request (CNO, OPS, FAC, PW)	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2006	NEA Bay Indian Reserva-tion, Washing-ton, United States	$25,000	U.S. Office of Public Health	Emergency response to replenish water supply at NEA Bay Indian Reservation. The reservation was under drought conditions and needed a way to replenish storage tanks.	NAVFAC ESC provided input and spares for unit deployment. TARDEC set up and deployed one 100,000 GPD EUWP developed by the Office of Naval Research (ONR). The EUWP was shipped from Port Hueneme, CA to the NEA Bay Indian Reservation.	Bill Varnava, Mark Miller
2005	Hurricane Katrina Response	$100,000	CNO, FEMA	Emergency response to Hurricane Katrina that disrupted the potable water supply to southern and southeastern, United States.	NAVFAC ESC set up and deployed two 100,000 GPD EUWP, developed by ONR. The EUWP was sent to Pascagoula, Mississippi and New Orleans, Louisiana.	Ted Kueper, Bill Varnava, Micah Ing, Mark Silbernagel, Mark Miller

Table A-1. EXWC Support to Other Shore Water Treatment Facilities

EXWC Project Support (Year)	Location	EXWC Support Cost	Original Client Request (CNO, OPS, FAC, PW)	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2004	U.S. Coast Guard, Port Clarence, Alaska	$50,000	ONR	Emergency response to replenish water supply. The storm conditions fouled the water supply and melt ponds were contaminated. The facility needed a way to replenish storage tanks.	NAVFAC ESC and TARDEC provided input and provided spares for unit deployment. TARDEC set up and deployed one 100,000 GPD EUWP developed by ONR.	Mark Miller, Mark Silbernagel
TOTAL ESTIMATED COST		**$778,000**				

Note: Table Revised 3-19-2018.

Table A-2. EXWC Support to San Nicolas Island Water Treatment Facility

EXWC / ESC Project Support (Year)	Overall Estimated Total Cost to Build or Repair	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2012 - 2015	$830,000	Customer needed to increase water production, improve efficiency, and reduce maintenance. Customer was constrained with the existing electrical infrastructure and brine water discharge amount. The old plant was plagued with multiple maintenance and operational issues. The plant was aging and described corrosive leaking. As a result, the customer asked EXWC SDTF personnel to provide new options. The best option selected was to upgrade the old infrastructure with a new RO Plant.	EXWC SDTF staff designed, built, and installed a new RO Plant with two trains and a multimedia cartridge filter. Each train can produce 21,000 gallons of potable water per day. The new plant operated with a higher system recovery of 42%, which reduces the brine discharge by 50%.	Bill Varnava, Micah Ing, Mark Silbernagel, Mark Miller
2007-2009	$1,200,000	Customer requested the phase two for the installation of a seawater intake well field. Customer needed to increase raw water production and install new water distribution lines between the well field and RO Plant.	NAVFAC ESC assisted NAVFAC SW PW and NBVC in writing a detailed Independent Government Estimate, Scope of Work, Statement of Work. ESC participated in negotiations for selecting the Prime Contractor. Seven new saltwater intake wells were designed, sited, and installed at Coast Guard Beach. NAVFAC ESC provided project oversight. Combined, old and new wells totaled to 15 seawater intake wells.	Joseph M Saenz (Manny)

Table A-2. EXWC Support to San Nicolas Island Water Treatment Facility

EXWC / ESC Project Support (Year)	Overall Estimated Total Cost to Build or Repair	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2007-2009	-	Seawater wells were fouling due to iron-forming bacteria growing within the seawater intake well field, on ground submersible pumps, water distribution lines, and transmission lines, thus causing the RO filters to clog. An iron forming bacteria assessment report was completed.	NAVFAC ESC provided technical field support for developing and re-developing the existing wells that were providing a raw water resource to the RO Plant. Specific well development protocols were updated for these field efforts.	Joseph M Saenz (Manny)

Table A-2. EXWC Support to San Nicolas Island Water Treatment Facility

EXWC / ESC Project Support (Year)	Overall Estimated Total Cost to Build or Repair	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2006-2007	-	USN was informed that the existing brine water line south of a rock structure could no long be used by the County of Ventura and U.S. Navy Environmental Department. The existing leach field was not working properly due to a decrease in sediment percolation rates, causing brine water to pond up and form a lake. Staff built a new 400-foot perforated leach that was installed subsurface on the north side of the jetty by SNI personnel, without engineering support. The NBVC Public Works Department requested support for brine discharge line modeling efforts along north side of rock wall at Coast Guard Beach.	NAVFAC ESC compiled and synthesized historical data and conducted a field survey, followed by cross-section development on north side of rock structure. Selected discharge rates and concentrations for modeling efforts showing existing brine water discharge line goals could not be met. New cross sections were developed for the South Side. Detailed geologic cross sections were constructed at Coast Guard Beach. North beach flow iterations were completed and models suggested the location of brine water discharge technology couldn't meet goals. ESC submitted five technical reports to Public Works. ESC provided support for well development efforts. Specific well development tools were created for these field efforts.	Joseph M Saenz (Manny)

Table A-2. EXWC Support to San Nicolas Island Water Treatment Facility

EXWC / ESC Project Support (Year)	Overall Estimated Total Cost to Build or Repair	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
2003	$86,000	In June 2003 a water shortage at San Nicolas Island resulted in the high potential for shutting down island operations. Raw water production was isolated to one well. Critical personnel were instructed to remain on the island and non-essential personnel were sent to mainland. In September 2003, NAVAIR (Joel Tules) issued an Urgency Justification to move forward with the installation of new water resource infrastructure on San Nicolas Island.	NAVFAC ESC designed, sited, and selected well drilling and development technologies, including construction materials for the installation of 8 Saltwater Intake Wells. ESC selected drilling methods and well construction materials during the construction phase of the project. ESC developed an SOW and Independent Government Estimate in order to select a drilling contractor.	Joseph M Saenz (Manny),Tim McEntee
1994	$250,000	Customer needed a treatment plant for surface water at SNI. ESC designed and installed the plant to meet the surface water treatment rules in accordance with federal, state, and local regulations and guidelines.	The Naval Facilities Engineering Service Center (NFESC) designed, built and installed a surface water treatment plant to meet the surface water treatment rule.	Ted Kueper, Mark Silbernagel, Bill Varnava

Table A-2. EXWC Support to San Nicolas Island Water Treatment Facility

EXWC / ESC Project Support (Year)	Overall Estimated Total Cost to Build or Repair	Customer Challenges	EXWC Project Description	DoD Technical Staff Providing Support
1990	$150,000	Under drought conditions, barging water was the most reliable means of providing a potable water supply to USN staff. Personnel wanted a more reliable source of potable water. The Naval Civil Engineering Lab (NCEL) provided technical and design support to install a new RO Plant.	NCEL modified, installed, and commissioned two 600 GPH ROWPUs to provide potable water. Each ROWPU was capable of producing 10 GPM of potable water and used media cartridge filter pretreatment. The ROWPUs eliminated the need to barge potable water and were in operation from 1990 to 2001 at which time they were replaced with 2 commercial RO systems built by Parker Village Marine, formerly Village Marine Tec. NCEL and NFESC provided technical support to SNI and Public Works on the RO plant from 1990 to 2001.	Ted Kueper, Mark Silbernagel,
TOTAL ESTIMATED COST		**$2,666,000**		

Note: Table Revised 3-19-2018.

APPENDIX B
EXISTING DOD AND COMMERCIAL CONTINGENCY WATER TREATMENT SYSTEMS

B.1 United States Army and Navy 3K TWPS

The United States Army Tank and Automotive Research, Development, and Engineering Center (TARDEC) tasked EXWC with developing a new prototype design for a 3,000 gallons per hour (3K) Tactical Water Purification System. The EXWC Seawater Desalination Test Facility (SDTF) utilized its expertise in the desalination field to complete an in-house design. The SDTF conducted component tests on media and cartridge filter configurations, designed and built breadboard prototype units, and incorporated its best practices from lessons learned from fielded expeditionary units. The successful design included:

- Media Filter Housing (custom design)
- Cartridge Filter Housing (custom design)
- Enhanced Energy Recovery System
- Compact layout inside a 20-foot International Standards Organization (ISO) Container

The design process included multiple tests on the media and cartridge filters and an endurance test on the breadboard design that lasted over 2,000 hours. The unit is capable of producing 72,000 GPD from a fresh water source and 50,000 GPD from a sea water source.

The research and development on the 3K-TWPS is exemplary of the work that the SDTF performs on a continuous basis. The overall unit size, construction, and throughput is ideal for what is needed for water support contingency effort.

B.2 Commercially Available Contingency Response Systems

There are a few private companies, such as GE ZENON and Seven Seas Water, which will lease containerized RO plants with capacities up to 288,000 gallons per day. To-date, private industry has indicated that these RO products require a minimum of a 2-year lease period or demand the government buy the water produced for a specific rate. This specific rate is estimated to be $6 million for a 2-year period.

Alternatively, NAVFAC could purchase and preposition RO plants capable of producing 50,000 to 200,000 gallons of potable water per day at various locations. These units could be stored with the Mobile Utilities and Support Equipment (MUSE) generators and teams could be trained to operate and maintain the units. The teams would link the water and power units to provide a rapid response capability. The use of MUSE generators is a long-term solution that would enable proactive responses to system failures or other instances. Efficient planning and coordination in advance would result in positive results in the event of a crisis.

APPENDIX C
CASE STUDIES

C.1 Camp Lemonnier, Djibouti

The single water facility at Camp Lemonnier in Djibouti supplies approximately 400,000 gallons of potable water per day. The installation uses the produced water for drinking, sanitary flushing, galley operations, and firefighting. The operation of the facility relies on an automated control system centralized through a Programmable Logic Controller (PLC). In November 2015, the water facility was powered down to prevent damage during a routine change in the power supply configuration for the base. When the water facility was re-energized, normal operations could not be restored. It was determined that the analog control board portion of the PLC had short-circuited and this resulted in a loss of the programmable logic program.

The technical after action report noted the following issues:

1. The need for a comprehensive assessment and inventory of high-risk components.
2. The location and currency of spare parts.
3. A lack of identifiable subject matter experts.

In response, the technical after action report recommended the following actions:

1. Implement an inventory database with a preventative maintenance schedule.
2. Itemize and procure critical spare parts.
3. Provide a source on standby technical assistance/support for critical utilities.

The after action report and subsequent recommendations are indicative of typical and frequent emergency water system outages.

C.2 Guantanamo Bay, Cuba

In April 2013, the water processing facility at Guantanamo Bay (GTMO) had a reduction in process capability. Two of the six RO water processing trains went offline and the water facility was unable to meet the water supply demand. Mechanical issues impacting five of the large water plant intake pumps (880 GPM each) caused the diminished capability.

The water demand for GTMO is approximately 1.05 million gallons per day (MGD), which supports the base population of about 5,000 personnel. The remaining operational RO systems were only able to produce 800,000 GPD, leaving a deficit of about 200,000 gallons per day. The total potable water storage capacity at GTMO is around 11 million gallons, but, due to the issues with the RO system, the total stored water was reduced to approximately 6.5 million gallons.

The drop in reserve storage capacity occurred over a 30-day period that resulted in a critical water issue the following month. To meet the demand and replenish the water storage, GTMO would have needed an additional 200,000 GPD of potable water production.

To replenish the water storage capacity at GTMO (11 million gallons), approximately 4.5 million gallons of fresh water needed to be produced.

To meet this demand, the Tactical Water Purification Systems (TWPS) and appropriate military units were needed to support. The TWPS is the primary water system used by the military and it can produce approximately 1,200 GPH from sea water sources. Assuming a daily mission run time of 20 hours per day times 1,200 GPH results in a daily production of 24,000 GPD.

Table C-1 provides the estimated time to replenish 4.5 million gallons of water.

Table C-1. Estimated Daily Production and Time to Replenish Water

Number of TWPS	Daily Production (GPD)	Time to Replenish Supply (Days)
6	144,000	30
8	192,000	24
10	240,000	19
12	288,000	15

C.3 Reconditioning, Refurbishing, and Deploying the EUWP GEN I

The Expeditionary Unit Water Purifier (EUWP) GEN I was a prototype technology demonstrator built by the Office of Naval Research (ONR) in 2005. It consists of an ultrafiltration and reverse osmosis skid capable of producing 100,000 GPD of fresh water from a seawater source. The Bureau of Reclamation currently owns the 2 remaining EUWP GEN I units. One was previously located at the Seawater Desalination Test Facility at EXWC in Port Hueneme, CA and the other unit was in Alamogordo, NM with the Bureau of Reclamation’s brackish ground national desalination research facility (BGNDRF) facility.

The EXWC unit was reconditioned and set up for deployment in January 2010 to support the Haiti Earthquake relief, however it was not deployed in theater due to its large logistics footprint, specialized training required, and ability to handle and store a sufficient water supply. Since this event, the unit has not been operated or maintained. The EUWP GEN I unit stored in Alamogordo has suffered several years of wear and tear, and its current condition is unknown.

Reconditioning, repairing, and resupplying the EUWP GEN I to support a mission would take significant effort and time, costing approximately $250K to $300K to refurbish, repair, resupply, and deploy a civilian team in theater for 30 days. Additionally, as the EUWP GEN I were originally prototypes, the spare parts and logistics chain needed to support unit does not exist. There are also only a handful of government representatives from the Bureau of Reclamation, U.S. Navy and U.S. Army that know how to operate EUWP GEN I. Personnel from Parker Village Marine, formerly Village Marine Tec, who built and designed the EUWP units in 2003, are no longer with the company.

The high cost of repair and deployment, the lack of spare parts, and the diminished number of knowledgeable operators make the EUWP GEN I not viable for use in a mission.

Figure C-1. EUWP GEN I