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Water, Waste and Climate Change: A New Decade of Challenges and Opportunities

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Title: Seawater Reverse Osmosis as part of a Practical Drought-Proofing Strategy in the Caribbean.

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Introduction

In 2009/2010 much of the Caribbean endured what many have described as a 100 year worst case drought scenario. A number of countries in the Caribbean narrowly missed reaching critical water shortages before the summer rains began in 2010 with many experiencing water shortages and instituting rationing. If the general worldwide economic situation had not put such a damper on tourism over the last few years, the water shortage issues would have in fact been worse in parts of the Caribbean.

A number of municipal entities sought rapid, short-term relief from sources as varied as barging water to temporary desalination plants, only to discover the costs, time-lines, and logistics made the quick relief sough, unattainable.

Seawater Reverse Osmosis for municipal desalination is only practical when sustainable natural resources and water reuse are no longer capable of producing the required water supply. After conservation methods and reuse have been adequately applied, seawater reverse osmosis can be applied sustainably and practically as part of a strategy to prevent water shortage over the long and the short-term basis.

There are a number of options for utilization of SWRO in a drought-proofing program including purchasing SWRO equipment, entering into a water sale agreement, and a hybrid option to hedge the bet without incurring all the capital costs or prematurely entering into a take or pay arrangement. "Hedging against a drought" by executing the long lead time items before the drought event can make utilization of quick deployment RO much more time and cost effective.

This presentation will address the practical, logistical, financial, and legal issues associated with planning for a quick deployment of reverse osmosis as well as steps that can be taken to mitigate the cost and time frame for deployment.

SWRO – A Practical Alternative?

Seawater Reverse Osmosis for municipal desalination is only practical when sustainable natural resources and water reuse are no longer capable of producing the required water supply.

- It is a fact that tourism and population growth (in much of the Caribbean) and industry (in a few island nations such as Trinidad) have exceeded the sustainable fresh water replenishment in many parts of the Caribbean.

- Increased salinity (seawater intrusion) caused from over-pumping of groundwater and contamination from human activity (nitrates from farming, wastewater contamination) continue.

- The Caribbean requires desalination for a fair amount of its water, as demand is greater than the sustainable supply in many countries (Anguilla, Antigua, Aruba, Bahamas, Barbados, Bonaire, BVI's, Cayman Inslands, Curacao, Nevis, St. Kitts, Saba, Saint Maarten, Sint Martin, Statia, TCI, Trinidad, USVI's, etc.)

- Desalination has proven to be a practical and sustainable alternative when sustainable, natural supplies of water are exhausted throughout the greater Caribbean and throughout the world (Spain, Australia, Saudi Arabia, Algeria, USA, Kuwait, Bahrain, Singapore, Egypt, Maldives, Oman, Libya, Morocco, etc.)

- The 2010 draught experienced in the Caribbean has forced some island nations that traditionally had adequate fresh water to consider emergency deal.

Planning for Drought

- It can be difficult to manage and anticipate all the dynamics between population changes, tourism levels, and the natural water supply/storage (rainfall, reservoirs, dams, aquifers).

- Due to the difficulty and costs in centralized systems and the associated collection and distribution, wastewater re-use for irrigation, farming, industry is not much utilized by Greater Caribbean municipalities.

- It can be costly and difficult to manage long-term reduction of non-revenue water

- When other practical, sustainable resources have been managed and there is a demonstrated need, desalination is a viable long-term alternative and if planned correctly can be part of a drought-proofing strategy.

Benefits of RO

Reverse Osmosis is sustainable. Seawater is abundant and energy consumption has been reduced dramatically.

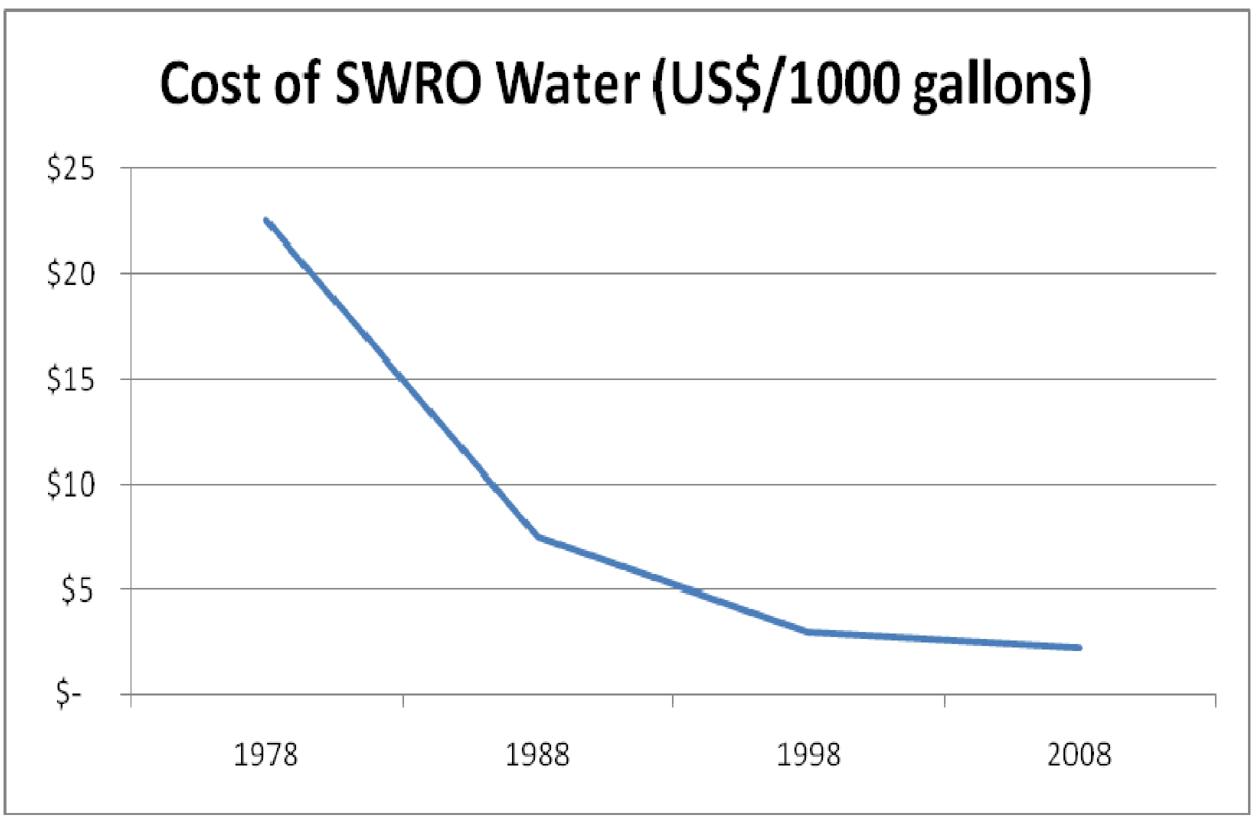
- If planned and designed properly the environmental impact negatives (brine discharge, electrical consumption) can be minimized.

- Preserving natural water sources and their associated wildlife and beauty and the ability to manage natural water supply at a sustainable level is important. Once species disappear they don't typically return. Seawater intrusion can take decades to reverse.

- Dependable, reliable, and not subject to seasonal fluctuations or drought.

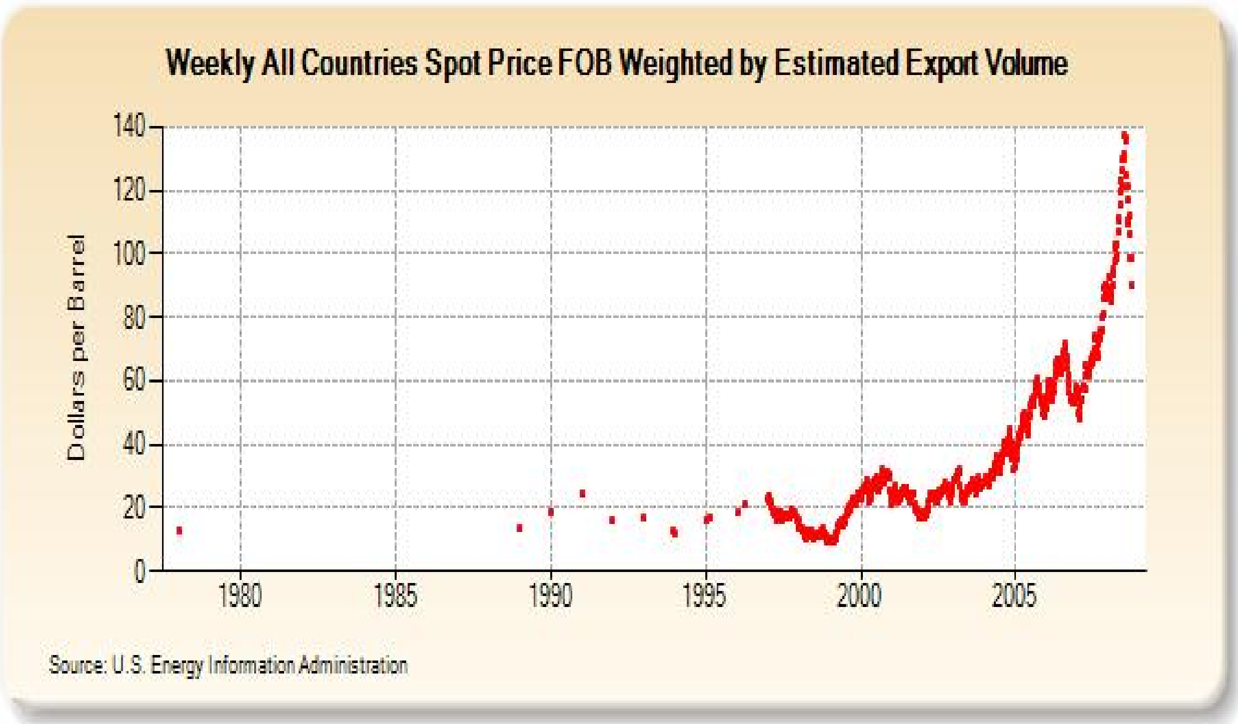
- While still more expensive than natural water supplies, has become cost comparative to treatment and transport of natural supplies in some areas (California).

The chart below demonstrates the average cost of water produced by SWRO from 1980-2008 in plants 5,000 CMD (1,320,000 Gallons per day) and larger.



The reductions in the cost of SWRO are attributable to a number of factors including great improvements in energy recovery device efficiency (with the widespread use of isobaric energy recovery devices), improvements in membrane performance, and economy of scale improvements using larger single train designs. This reduction in cost per delivered unit of desalted water is even more remarkable considering the rise in fuel prices over the same period. Please see the oil price chart below.

World Crude Oil Spot Prices (Dollars/Barrel)



Comparative Municipal Water Prices (to Customer)

A random sampling of water prices (to consumers) confirms what would be expected that users of natural water sources (St. Lucia / New York City) have are considerably less expensive than communities that are dependent on desalination although there are a whole host of other issues that create wide differences in the water pricing (distribution losses, subsidies, local labor and energy costs, comparative environment, etc.) Desalination is more expensive than ground sources but it's only too expensive until there is no sustainable alternative.

Naturally, desalination is more expensive than natural water sources. However there are a number of factors that influence the cost of desalted water.

- The scale of economics is a major factor in the water price in a water sale/lease agreement (The price per gallon (cubic meter) is much cheaper on a 10,000,000 gallon per day (GPD) plant than a 100,000 GPD plant.

- The length of the water sale agreement/lease greatly effected the water sale price. Depreciating non-recoverable "sunk" costs over 20 years is significantly more affordable than over 6 months.

Random Sampling of Water Rates in the Caribbean and the US

Location	Anguilla	Antigua	Bahamas	Barbados	Cayman	New York	St. Kitts	St Lucia
Water Price $/1000 gal	26.83	9.39	12.10	14.75	74.97	9.03	32.3	3.28
Water Source	SWRO desal, ground	SWRO desal, ground	SWRO desal, ground	Ground water, BWRO desal	SWRO desal	Surface	Surface, ground	Surface, ground

Typical SWRO Plant - What's it all about?

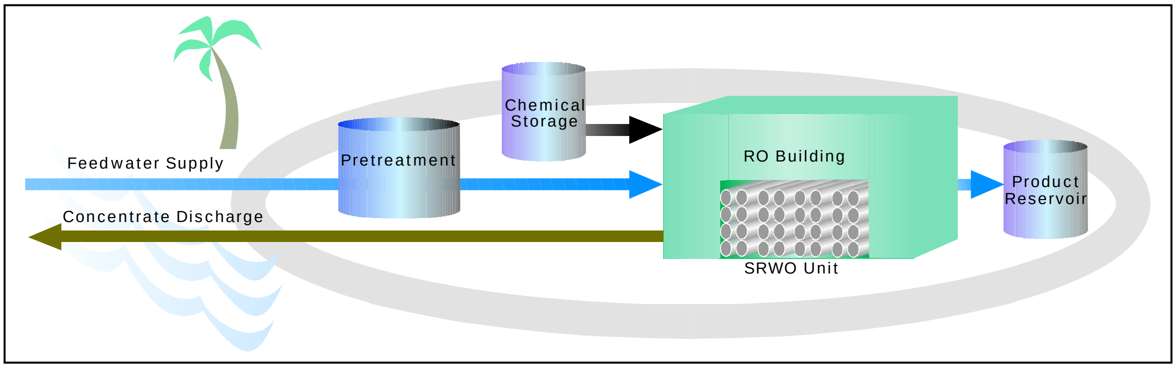


Figure 2: Typical SWRO Plant

Site and Building

The site as a whole generally includes:

- The plant building
- Outdoors chemical storage area.
- Production reservoir.
- Wastewater collection and discharge system.

Feed Water Supply

Feed water to the desalination system is collected from a seawater intake or beach wells located as near the plant site as is possible. From the intake, a feed pump will convey feed water to the pretreatment system.

Pretreatment

The seawater must be treated before it reaches the RO unit to remove suspended solids. Typically, multimedia filters are used to effectively remove solids. The filters are designed to operate at a loading rate consistent with the overall plant design.

Recently, there has been much increased use in the application of back-washable, hollow fiber ultrafiltration systems as pretreatment for SWRO systems. Filtered water flows to the reverse osmosis unit.

Sea Water Reverse Osmosis Unit

The core desalination operation is reverse osmosis. The process elements of a typical desalination unit are cartridge filters, an RO feed pump, an energy recovery device, an

RO membrane unit, and auxiliary systems for cleaning and chemical addition. Figure 3 shows a photograph of a 250,000 GPD containerized SWRO plant.

Figure 3: Photograph of Seven Seas Water SWRO 250,000 GPD Containerized Unit

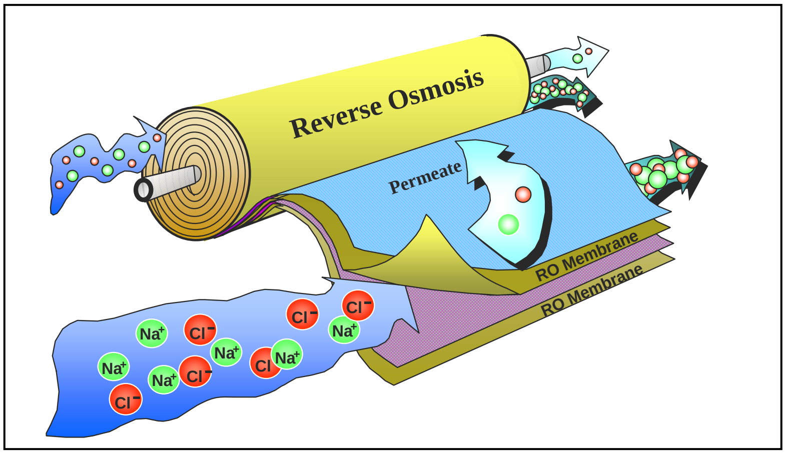
Cartridge Filtration

Water is conveyed to the cartridge filters from the media filters. The cartridge filter system is used to remove fine suspended matter from water, typically down to 5 microns in size. A cartridge filter consists of a filter housing and filter elements mounted to tube supports.

Reverse Osmosis

In reverse osmosis, water under pressure is forced across a membrane element with a portion of the feed permeating the membrane and the balance of the feed water sweeping along the membrane surface and exiting without passing through the membrane. In the case of seawater, the membrane will freely pass water but will reject most of the dissolved minerals as well as any small particles. An illustration of an RO membrane element is shown in Figure 4.

Figure 4: RO Membrane Element



SWRO plants typically employ spiral wound, thin film composite polyamide membrane elements to separate dissolved salts from the seawater. The process can convert, or "recover" approximately forty (40) percent of the incoming seawater as desalted product in a single stage system. The remaining approximately sixty (60) percent of the incoming water is concentrated by the salts rejected from the product and is returned to the sea. Two stage SWRO units recover approximately sixty (60) percent of the incoming seawater as product.

The high pressure required for RO treatment is provided by a high-pressure pump.

High Pressure Pump

Energy Recovery Device

Permeate from the RO system flows to the post-treatment system. Concentrate (reject) from the RO systems flows through the energy recovery device and is then discharged back to the sea.

Energy Recovery

The pressure required for RO treatment is provided by a high-pressure pump. Because of the relatively high energy requirements, most SWRO systems are equipped with an energy recovery device that recovers energy from the pressurized RO concentrate leaving the system. The energy recovery system typically recaptures anywhere from 20 - 50 % of the initial pumping energy.

Concentrate Discharge

Concentrate from the RO system is discharged back to the sea through a reject pipeline or through a deep well.

Clean-In-Place System

A membrane cleaning system is normally provided to clean RO membrane elements if suspended solids or precipitates foul them. Cleaning procedures are undertaken when operating pressures or RO permeate production falls outside normal operating limits. The system used to effect this cleaning, referred to as the Clean-In-Place (CIP) procedure, consists of: a chemical tank; a pump to re-circulate the cleaning chemicals through the RO membranes; a cartridge filter to remove any solid contaminants or scale.

Post Treatment

Post-treatment of the RO permeate is needed to create a potable water that is properly adjusted for storage and distribution. A calcium carbonate filter and a sodium hypochlorite addition system are typically provided for pH adjustment, re-mineralization, and disinfection of the final product. After post-treatment, the product water is delivered to a production reservoir.

Instrumentation

Instrumentation typically includes: pressure gauges, pressure switches, conductivity indicators and transmitters, temperature indicators and transmitters, level indicators and switches, and flow indicators and transmitters. The system is normally equipped with sample ports so that water samples may be collected at various locations in the process.

Electrical and Control System

The power and control system typically includes power distribution components, control panels, instrument panels, and programmable control devices. The control system typically provides for complete automatic operation of the desalination system. A central control system will control, monitor performance, and record operating data for all aspects of the desalting plant. It will provide plant operating status, alarm messages, data collection, protective shutdowns, and automatic regulation of the plant equipment.

Programmable Logic Computer (PLC) display screen

SWRO Plant: Major Long Lead Items:

While there exist containerized SWRO plants that are pretested, ready to go, and can ship out in a matter of days there are other aspects of installing the plant (civil works, legal, administrative) that can cause significant delays with the actual start-up. Some of the major items that can cause delays are:

Civil Works

- Seawater Intake or Beach Wells - Feed water is collected from an Open Seawater Intake or Beach Wells.
- Brine Outfall – The concentrated seawater (typically 50-60% of the feed water) is discharged back to the ocean or into a deep injection well at 30-40% greater salinity.
- Land Preparation – A suitable site has to be obtained, cleared, leveled, and occasionally remediated (compaction, pilings, etc.) as needed to have a suitable site .
- Building – Most short-term solutions do not require a building to house a containerized plant but shelter and facilities for storage, maintenance, work, employee services must be considered.

Contractual and Legal

- Land needs to be acquired through lease or allocation by the government and/or water authority.
- Environmental Impact Analysis, Permits for seawater extraction, brine disposal can be required.
- Suitable electrical supply, and a rate structure needs to be established for the plant use.
- A workable water sale agreement (WSA) or lease should be vetted to ensure there are no undue delays caused by prolonged negotiations.

Challenges for RO Use in Drought Planning

Of course it is not typically practical or viable to have a desal system on standby if not in regular use. This is due to a number of reasons, not least of which is that a turnkey equipment purchase of a SWRO plant can be expensive and if the system is not regularly used the upkeep and maintenance require specialized skills

Procuring an emergency supply poses a whole new sets of challenges in meeting immediate drought relief including:

- Timing can be longer than hoped for.
- Costs for a short term supply under a lease and/or build-own-operate (BOO) arrangement can be expensive
- If no set-aside budget for emergencies, can be difficult to pay for on a turn-key or monthly basis with costs higher than budgeted.

Solutions – Small RO Plant Supply (up to 250,000 GPD)

- Can use containerized quick-deployment units
- Possible to utilize existing permeate storage
- Possible to utilize temporary low cost method for intake /outfall
- Possible to utilize existing electrical supply to power units
- Can typically allocate land for plant on a short term basis
- On temporary/emergency basis environmental permits might be waived.
- If partial supplement of total water supply cost increment might be manageable

Solutions – Medium RO Plant Supply (1,000,000 to 6,000,000 GPD)

- Can use containerized quick-deployment units
- Can require additional permeate storage which is expensive and has long lead times.
- Typically require new feed water supply (intake or wells) and brine disposal (open ocean outfall or brine injection wells) which are expensive and have long lead times.
- Typically require dedicated high voltage line (460-480 V, transformers, etc. to power units which might require negotiations with power company.
- Typically require land acquisition or lease
- Typically require environmental study and permits for feed water withdrawal and disposal.
- If significant supplement of total water supply cost increment probably not manageable within existing rate structure

Solutions - Hedging against drought with RO

- Hedging the bet" (allocating for the long lead time "items")
- Long lead time "items" are also typically expensive ,sunk costs. If managed in a pre-emptive manner it could make an emergency water supply more affordable and much faster to delivery.
  - Ensure that there is adequate permeate storage, piped into the desalination site.
  - Allocate and set-aside land for desalination plant use.
  - Conduct environmental study and acquire permits.
  - Commission adequate feed water supply and brine disposal.
  - Ensure there is an available high voltage supply available to the site with an agreed upon rate from the power company.
  - Ensure there is a mechanism in-place to handle higher rates during a drought (drought relief surcharge, allocation set-aside, emergency fund, etc.)
  - Hedging the bet" (allocating for the long lead time "items")
  - With long lead time "items" properly managed, time to delivery of potable water from seawater can be reduced from 3-12 months to 4-9 weeks
  - With long lead time items capitalized the water sale agreement water price can be reduced from greatly depending on size of the plant, length of agreement and other factors.
  - A number of desalination companies maintain ready-to-deploy desalination containers that can be shipped to the site and producing water quickly and comparatively inexpensively.
  - With long lead time items properly completed a lot of water supply contractor risk is mitigated, further aiding speed and costs reduction.

Public / Private Partnership

The Public Private Partnership (PPP) can bring to bear the best of both the Water Authority and the water service provider to deliver the lowest cost water solution in the fastest period of time. The Water Authority would execute the concrete steps needed to ensure that if required, drought relief from desalination could be activated quickly and at a cost that can be managed through mechanisms already in place. The water service provider would guarantees delivery time, quality and quantity of potable water production, deliver a ready-to-deploy system, as well as being responsible for all costs to design, build, operate and maintain the plant.

Case Study – Dellis Cay TCI, 50,000 GPD

(installed, commissioned and producing water in four (4) weeks

A large development was planned for a small island that is part of the Turks and Caicos Islands, known as Dellis Cay. The developers believed that there were adequate water resources but quickly discovered that the resources did not exist and had a man-amp of over 250 people and a project start date and no water. In order to proceed with the project they required a desalination unit as soon as possible. While this case is more closely related to planning than drought the requirements were the same, an urgent need for water where none existed.

The long lead time items that can cause delays were addressed as follows:

- The Client allocated appropriate land.
- The Client executed appropriate permits
- SSW specified and managed the drilling of two wells, one for feed; one for brine discharge.
- SSW secured an appropriate potable water storage facility
- SSW oversaw the construction of the appropriate supporting foundation for the production equipment.
- SSW worked with the local electric utility to ensure an adequate power source and transformer were provided in time to support start-up.

From the date of contract signing, the groundwork was complete and a containerized SWRO plant capable of producing 50,000 gpd was shipped to the site, installed and commissioned in just under four (4) weeks.
Plant produced water of less then 230 ppm TDS from a feed water salinity of 33,100 ppm with a power consumption is minimized at 11.5kW/1000 US gallons (3.08kW/m^3)

Case Study – WAPA USVI 1.5 MGD SWRO

(Completed and producing water in 87 days)

The Power and Water Authority for the US Virgin Islands (WAPA) was experiencing unscheduled water shortages at their Richmond St. Croix facility due to breakdowns in the aged fleet of thermal desalination units. While this again was not caused by drought it none-the less created water shortages that could only effectively and speedily be addressed by employing desalination.

Long lead-time items addressed

- Existing intake / outfall could be utilized
- Suitable power supply was near-by
- Suitable Potable water storage was connected to site
- WAPA owned the site which was available, approved for use and permitted.

However , connection from the existing intake and significant site preparation (compaction, trenching, pipe runs, electrical termination to site, transformers, etc.) was required. Photos and a list of the major site works are listed in the following pages.

Site Prior to Work

Excavation of the SWRO pipe trench
Required for piping to bring feed water to the SWRO units and bring away brine discharge and product water.

SWRO Site Back Fill and Compaction
To provide a level, stable surface for heavy equipment.

SWRO Plant Trench Construction

Multi Media Filter Pad Preparation

Formation of the MMF Pad


Covering the Electrical Underground Cables


Final Grading of the SWRO Pad


Pouring of the SWRO Equipment Pad


2.5 MVA Transformer and MDP Install


Mechanical, MMF Installation


Mechanical – Media Loading for the Multimedia filters, 133 tons in 24 hours

Mechanical – Feed Pump Area (feeds raw seawater to the MMF)
- 4 Intake Pumps are piped in parallel with 1 being an installed standby

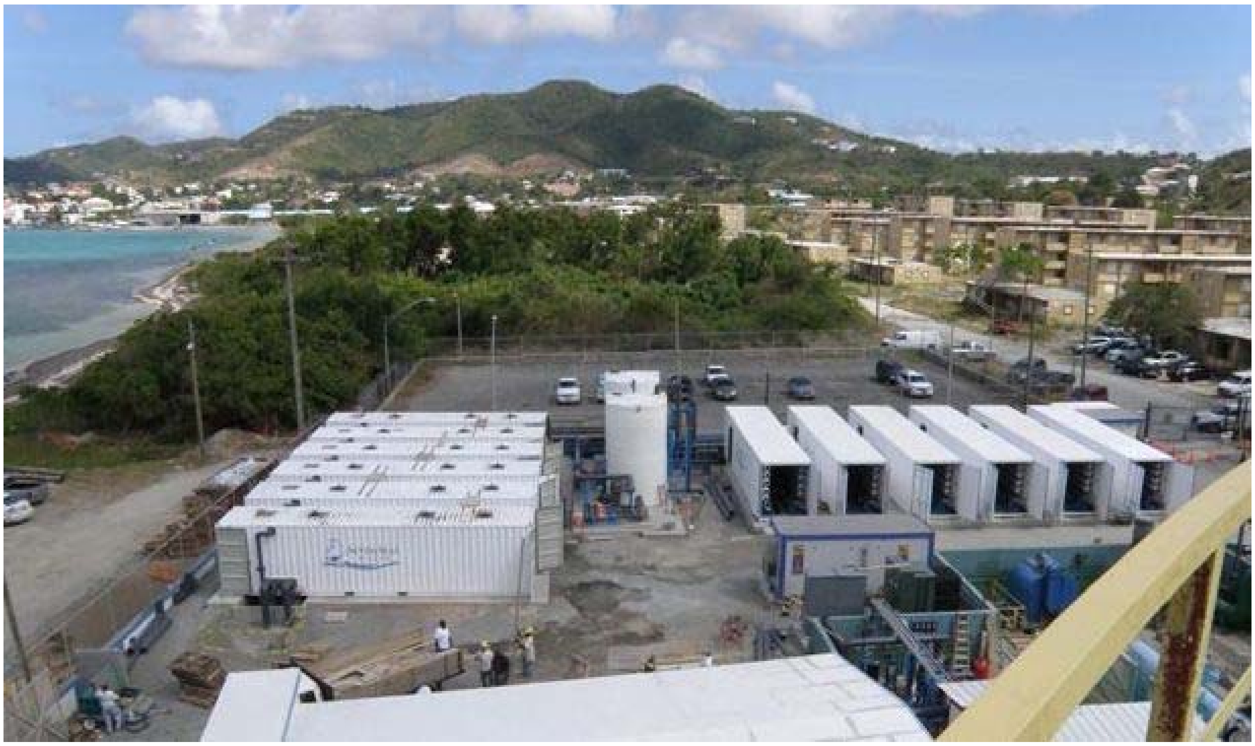
Mechanical – SWRO Plant Placement
- 1.5 MGD of SWRO containers were placed in 1 day.

Mechanical – Membrane Loading

Mechanical – MMF Feed Piping (connecting from feed pumps, to MMF racks, to RO Plants)

Project Commenced on February 2, 2009

The Full 1.5 MGD Plant was completed in 87 days on April 29,2009
Capacity Test was completed on April 30,2009 and Plant produced 1.52 MGD
Since Startup the plant has averaged 1.43 MGD with an Average Conductivity of 480 uS/cm. The Electrical Consumption of the Plant is 10.57 kWhr/kgal.



Conclusions

- When natural potable water and wastewater treatment for re-use have been maximized, SWRO is a viable alternative for a sustainable water supply and can be part of a drought proof strategy.

- There are a number of options for utilization of SWRO in a drought-proofing program including purchasing SWRO equipment, entering into a water sale agreement, and a hybrid option to hedge the bet without incurring all the capital costs or prematurely entering into a take or pay arrangement.

- "Hedging against a drought" by executing the long lead time items before the drought event can make utilization of quick deployment RO much more time and cost effective.

- Planning needs to include legal, logistical, and mechanisms to handle costs to implement.