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Blowdown Recovery System for Cooling Tower Water Treatment

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GSA's Green Proving Ground program and DOE's High Impact Technology (HIT) Catalyst program enable federal and commercial building owners and operators to make sound investment decisions in next generation building technologies based on their real-world performance.

Executive Summary

From 2014–2017, the U.S. General Services Administration's (GSA's) average nationwide water rates increased 41%. Rapidly escalating costs, mandated water-reduction targets, and the fact that an average of 28% of commercial office building water use is associated with heating and cooling led the GSA Green Proving Ground (GPG) program to select alternative water treatment (AWT) technologies for in-field validation.[1] This report summarizes the latest AWT evaluation completed in 2022.

Blowdown Recovery (BDR) System for Cooling Tower Water Treatment

This GPG program project assessed the performance of an AWT system provided by Aqualogix for treating cooling tower blowdown at the Lloyd D. George U.S. Courthouse in Las Vegas, Nevada. This AWT technology is a BDR system that optimizes tower water system performance by capturing and purifying a percentage of the blowdown. This water is returned to the condenser water system as very low conductivity, zero hardness makeup water. The BDR system incorporates side stream filtration, carbon filtration, reverse osmosis (RO) demineralization, and a control system. Unlike some other AWT systems evaluated by the GPG program to date, this AWT system does not replace the legacy water treatment system but is used in addition to chemical water treatment. An appealing aspect of this AWT technology is that the conductivity setpoint for tower blowdown remains unchanged, thus minimizing changes to established tower water system operation.

Evaluation and Summary

The main focus of this assessment was to evaluate the performance of the BDR system operating. The evaluation was designed to test the manufacturer's claim that this BDR system technology will reduce blowdown (the flushing of cooling tower water with high concentrations of minerals) by more than 45%, will reduce water consumption by more than 15%, and will deliver a payback in under 5 years. The AWT system was installed in May 2021, and the evaluation ran through October 2022.

The key takeaway from this evaluation is that this AWT system is beneficial in reducing water usage. During this project's assessment phase, the Colorado River was facing the worst drought in the river basin's recorded history, and this is where the Las Vegas Valley gets about 90% of its water.[2] Thus, the GSA Pacific Rim Region (R-9) is implementing AWT technologies that reduce cooling tower water use.

Table ES-1 presents a summary of the completed evaluation, including both quantitative and qualitative metrics. The cost of the BDR system installed for this project was $35,403 (including $688 for shipping and $1,473 for training), and the installation added another $11,422, for a total capital expenditure of $46,825.

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[1] GPG Findings 044 and report found at: https://www.gsa.gov/governmentwide-initiatives/climate-action-and-sustainability/center-for-emerging-building-technologies/published-findings/water/awt-gsa-guidance-for-cooling-towers.

[2] Las Vegas Valley Water District drought and conservation measures page at: https://www.lvvwd.com/conservation/measures/index.html.

Table ES-1: Performance Objectives

QUANTITATIVE OBJECTIVES	METRICS and DATA	SUCCESS CRITERIA	MEASUREMENT AND VERIFICATION (M&V) Results
Water/Sewer Savings	Metered water consumption. Metered blowdown. Ambient temperature and humidity.	>15% makeup water savings. >45% blowdown savings.	16% makeup water savings. 53% blowdown savings.
Maintenance Savings	Maintenance records for current cost of chemicals and labor. Maintenance records during demonstration period and estimated future for the BDR system.	No increase in legacy chemical costs excluding antiscalant. Less than 8 hours per year in maintenance costs for cleaning and maintaining the new BDR system.	Using estimate from vendor on membrane replacement, site plans to replace every 5 years.
Water Quality	Water quality testing.	No degradation in water quality (see Table 6 for listing of water quality metrics).	No substantial changes in water quality attributed to the AWT.
Cost Effectiveness[3]	Simple payback. Savings-to-investment ratio (SIR) over 15 years.	<5-year payback. >1.0 SIR.	Testbed: 4.8-year payback. 3.1 SIR. Target Load: 2.8-year payback. 5.3 SIR.
Deployment Potential	Energy and water savings across climate zones with assumed site water quality.	Payback and savings are achieved in most climate zones given the building load size and the water quality.	Deployable across all climate zones.
QUALITATIVE OBJECTIVES	**METRICS and DATA**	**SUCCESS CRITERIA**	**M&V Results**
Ease of Installation	Interview with installer. Time required to install and configure. Labor associated with installation.	<5 days to install and commission.	BDR installation went smoothly, occurred in under 5 days.
Site Safety	Chemicals.	No new safety issues as reported by facility operators.	Staff reported no safety issues or concerns with the BDR system.

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[3] BDR Testbed based on load of 1.6 million annual ton-hours, water rate of $18.97 per kGal, and electric rate of $0.10 kWh. The BDR Target Load for the AWT system deployed was 3 million annual ton-hours, GSA average water rate of $16.76 per kGal, and GSA average electric rate $0.11 kWh.

QUANTITATIVE OBJECTIVES	METRICS and DATA	SUCCESS CRITERIA	MEASUREMENT AND VERIFICATION (M&V) Results
Operability	Interview with operations and maintenance (O&M) staff. Usability opinion of facility operators.	Facility operators have few or no issues with technology.	Staff felt prototype BDR tested with some early operational issues. All issues were addressed, and staff continue to use technology.

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I. Introduction

A. WHAT WE STUDIED

Cooling Tower Background

“Many multistory commercial buildings larger than 200,000 ft^2 rely on central chilled water plants to deliver the required air conditioning to the building. A key component of water cooled by chilled water plants is a cooling tower, which cascades water across a medium (a fill) that is designed to maximize exposure of water droplets to the surrounding air, with the resulting evaporation cooling the water and allowing heat to be effectively transferred to the atmosphere. But as water is evaporated, minerals and chemicals become concentrated in the water that remains, which can lead to accelerated scale (mineral deposits) and corrosion problems. Biological growth in the cooling tower water also presents challenges and can lead to fouling, biocorrosion, and potential negative health impacts. The typical approach to controlling scale, corrosion, and biological growth is a combination of chemical treatment, careful monitoring, and blowdown—discharging water to the sanitary sewer from the bottom of the cooling tower basin, where dissolved solids are most concentrated. Makeup water is introduced to dilute the remaining solids and chemicals and to replace water lost through blowdown and evaporation.”[4]

Blowdown Recovery (BDR) System for Cooling Tower Water Treatment

This U.S. General Services Administration (GSA) Green Proving Ground (GPG) program project assessed the performance of an alternative water treatment (AWT) system for treating cooling tower blowdown. The blowdown recovery (BDR) system optimizes tower water system performance by capturing and purifying a percentage of the blowdown. This water (permeate) is returned to the condenser water system as very low conductivity, zero hardness makeup water (Figure 1). The BDR system incorporates side stream filtration, carbon filtration, reverse osmosis (RO) demineralization, and a control system. An appealing aspect of this AWT technology is that the conductivity setpoint for tower blowdown remains unchanged, thus minimizing changes to established tower water system operation.

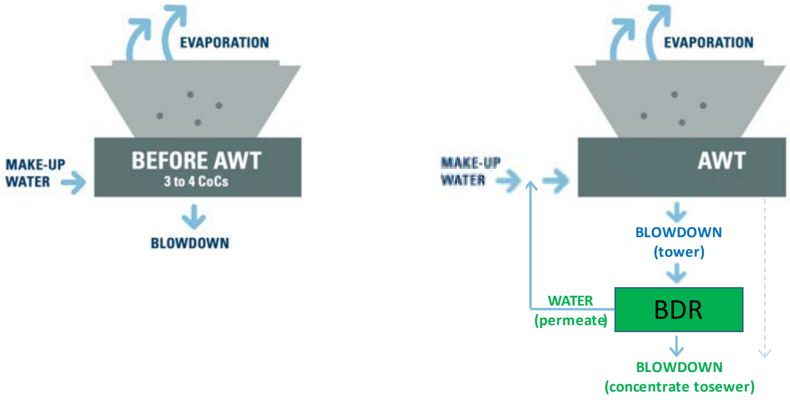

Figure 1: Simple comparison without (left) and with (right) a BDR

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[4] GPG Findings 044, from full report at: https://www.gsa.gov/governmentwide-initiatives/climate-action-and-sustainability/center-for-emerging-building-technologies/published-findings/water/awt-gsa-guidance-for-cooling-towers.

The AWT system for this project was provided by Aqualogix and was a customized retrofit of a BDR onto an existing partial water softening (PWS) system. The skid-mounted BDR system includes an RO system with associated filtration and pumps, a chemical bulk tank with pump for antiscalant, and a 250-gallon makeup reservoir. The equipment is 10 feet long and 3 feet wide, requiring a footprint of 300 ft^2. The skid weight is 920 lb dry weight (2,400 lb wet weight). Figure 2 shows two views of the BDR system.

Figure 2: BDR system installed at the Lloyd D. George U.S. Courthouse

The PWS system installed during a prior GSA GPG program project[5] conducted at this site is shown in Figure 3. The schematic in Figure 4 shows how the BDR and PWS systems were integrated together.

Figure 3: PWS system installed at the Lloyd D. George U.S. Courthouse

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[5] GPG Findings 045 and report found at: https://www.gsa.gov/governmentwide-initiatives/climate-action-and-sustainability/center-for-emerging-building-technologies/published-findings/water/awt-monitoring-partial-softening.

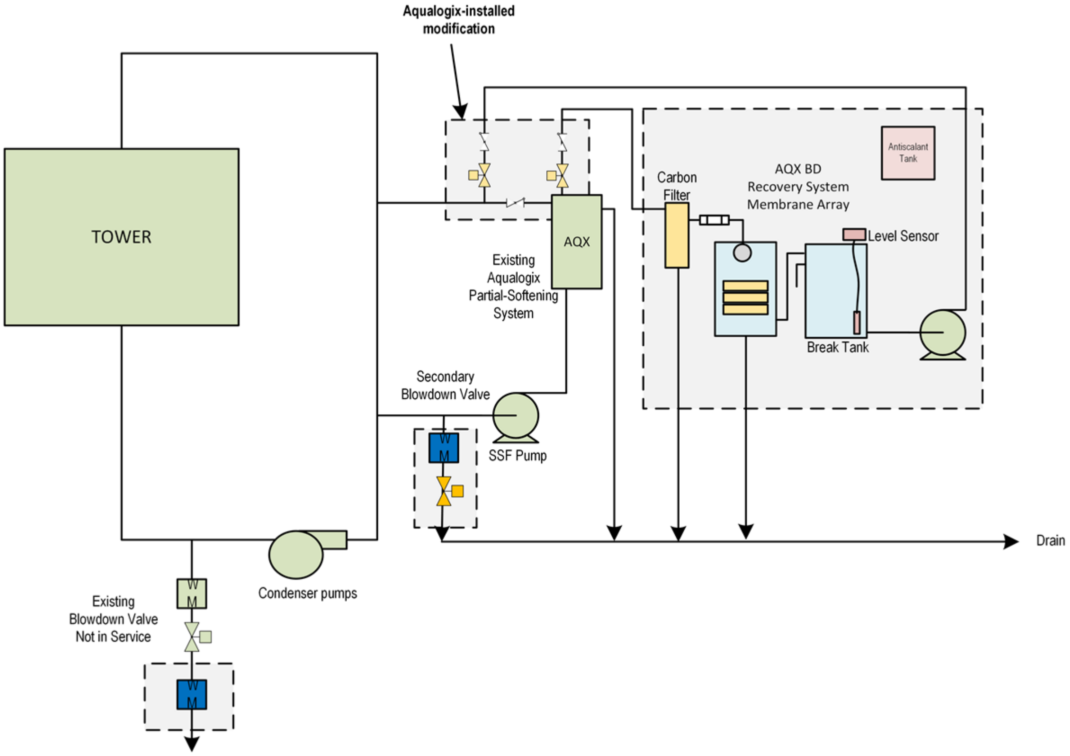

Figure 4: Schematic of BDR and PWS equipment (credit: Aqualogix)

Unlike other AWT systems evaluated by the GPG program to date, the BDR and PWS systems do not replace the legacy water treatment system but are used in addition to chemical water treatment. The focus of this assessment was to evaluate the performance of the BDR system operating independently, so the PWS system was temporarily turned off to support data collection in the 2021 evaluation. Refer to Appendix A for additional details on how BDR and PWS systems can work in tandem.

B. WHY WE STUDIED IT

Cooling tower-related water consumption is one of largest potable water loads within buildings in the United States—an average of 28% of commercial office building water use is associated with heating and cooling. From 2014–2017, GSA's average nationwide water rates increased 41%. Rapidly escalating costs and mandated water-reduction targets led the GSA GPG program to select AWT technologies for in-field validation.[6]

Cooling towers can be found in all states throughout the country, and it is assumed the BDR system technology could save water in all climate zones. Facilities with higher cooling tower utilization consequently have greater potential for cooling tower water savings, and locations with high water rates should generate the largest annual cost savings.

II. Evaluation Plan

A. EVALUATION DESIGN

The testbed was designed to evaluate the manufacturer's claim that the BDR system technology will reduce blowdown by more than 45%, will reduce water consumption by more than 15%, and will deliver payback in under 5 years. Additional evaluation criteria included ease of installation (<5 days) and the ease of use for facility operators.

GSA identified the following main objectives in the evaluation plan:

1. Verify cooling tower water savings
2. Verify cooling tower operations and maintenance (O&M) costs and plant acceptance
3. Verify cost-effectiveness.

OBJECTIVE 1: VERIFY COOLING TOWER WATER SAVINGS

The most important M&V objective was to verify the water savings. The measurements that most directly figure into the verification of water savings are:

- Cooling tower makeup water consumption
- Cooling tower blowdown water

Typical water-related costs are for the water makeup to the cooling tower which is a result of evaporation losses, drift losses, and blowdown. Secondly, there is often a cost to discharge the blowdown water. This cost is generally combined as a single fee, but it is important to measure both flow rates associated with makeup water into the system and blowdown water out of the system. Flow meters were installed on both lines to measure the amount of water in and out of the system.

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[6] GPG Findings 044 and report found at: https://www.gsa.gov/governmentwide-initiatives/climate-action-and-sustainability/center-for-emerging-building-technologies/published-findings/water/awt-gsa-guidance-for-cooling-towers.

The flows are measured with meters, and the tons of heat rejected are calculated as:

Evaporated Water (gallons) x 8.345 (lb/gallon) x heat of vaporization (Btu/lb)/12,000 (Btu/ton)

and:

Evaporated Gallons = Makeup (gallons) – blowdown (gallons) – leakage (gallons)

This allowed all water consumption to be normalized by expressing water consumption per heat rejected by the cooling tower as gallons per MMBtu. In doing so, we were able to offer an effective comparison between the baseline and demonstration periods.

Additionally, a factor was applied to account for water losses in the system due to drift and minor leakages. During the baseline data period, cycles of concentration (CoC) were measured using both water balance and conductivity methods that are defined as:

$$CoC\ (Water\ Balance) = \frac{Makeup}{Blowdown + losses}$$

$$CoC\ (Conductivity) = \frac{Blowdown\ Conductivity}{Makeup\ Conductivity}$$

System losses are not directly measured but can be estimated using these two CoC equations. The makeup and blowdown flows are measured utilizing flow meters. The system losses are estimated by inputting a value in the denominator of the first equation that yields a CoC identical to the one calculated in the second equation. For various data points at different loads, this value will be different. During a prior PWS evaluation, it was found that the losses are closely estimated at various loads using the following equation:

% losses = 0.0014 x evaporation rate (lpm) + 0.0118

Appendix A explores the subtle details of evaluating CoC based on the water balance (volume) method for a BDR system. The manufacturer has found it helpful to define Operating CoC vs Effective CoC. Within the main body of this report, when BDR is operational, the CoC (Water Balance) is calculated utilizing Blowdown (concentrate to sewer) in the formula--refer to label in Figure 1.

Monthly water reports included conductivity, pH, alkalinity, hardness, and CoC.

OBJECTIVE 2: VERIFY COOLING TOWER O&M COSTS AND PLANT ACCEPTANCE

To verify the O&M costs, the following data was collected:

- Estimated cost for cleaning the existing baseline system
- Cost of O&M labor and chemicals for the existing baseline system
- Estimated O&M labor and materials cost for maintaining the BDR system.

The operation of the water treatment system was monitored over the demonstration period to ensure that the operation of the units would not cause any unforeseen issues. O&M staff were interviewed to understand any issues related to the system. The maintenance requirements in terms of personnel labor were documented for both the baseline and demonstration periods. Prior maintenance logs and costs were reviewed.

OBJECTIVE 3: VERIFY COST-EFFECTIVENESS

The cost-effectiveness was evaluated at the selected facility based on the water and sewer savings, equipment and installation costs, and O&M costs versus the incumbent water treatment methodology. The measured performance for these metrics was compared to the manufacturer's claims for the system being evaluated as a part of this demonstration.

The quantitative and qualitative performance objectives for the project are provided in Table 3 and Table 8, respectively.

B. TESTBED SITE

Candidates for this technology are buildings or other installations that have a cooling tower used for evaporative cooling on-site. The testbed site selected for this evaluation project was the Lloyd D. George U.S. Courthouse located at 333 Las Vegas Boulevard South in Las Vegas, Nevada, as shown on the map in Figure 5 and pictured in Figure 6.

Figure 5: Location of the Lloyd D. George U.S. Courthouse (credit: MapQuest)

Figure 6: Picture of the Lloyd D. George U.S. Courthouse (credit: Gregg Tomberlin, NREL)

The building is approximately 450,000 square feet and has a relatively long cooling season. The building currently uses three chillers. Two chillers are rated at 350 tons and one at 450 tons. The condensers for the chillers use water from three cooling tower cells located on the roof of the building. The cooling system prior to installation of the partial water softening system typically ran at 2.8 CoC. After installation of the PWS system, the cooling system typically ran at about 4.2 CoC. GSA O&M procedures require that cooling towers have a CoC of 2 or greater (met throughout). A higher CoC correlates with less blowdown and reduced makeup water consumption for the cooling tower.

The Colorado River is facing the worst drought in the river basin's recorded history, and this is where the Las Vegas Valley gets about 90% of its water.[7] So the GSA Pacific Rim Region (R-9) is implementing AWT technologies that reduce cooling tower water use.

The annual daily range of high and low temperatures for Las Vegas, Nevada, is shown in Figure 7.

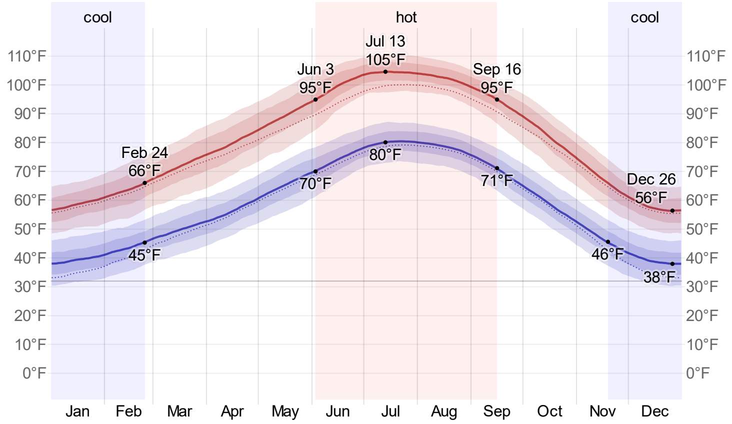

Figure 7: Average daily temperature range for Las Vegas, NV (credit: Weather Spark)

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[7] Las Vegas Valley Water District drought and conservation measures page at: https://www.lvvwd.com/conservation/measures/index.html.

C. METHODOLOGY

Quantitative Study Design

Two key measurements to assess water usage of a cooling tower are the blowdown water flow and the makeup water flow. New meters to measure both flow rates were installed at the beginning of this project. To determine the metrics described previously, the data points listed in Table 1 were collected using the indicated instruments. Data was logged every minute during the testing periods.

Table 1: Monitoring Points and Instrumentation

Monitoring Point	Sensor/Monitor	Notes
Blowdown water meter.	New totalizing flow meter in addition to the existing FTB4100 series totalizing flow meter from PWS project.	Data from new 4-20 mA output card.
Blowdown conductivity.	Existing site meter.	Data from new 4-20 mA output card.
Blowdown PH.	Existing site meter.	Data from new 4-20 mA output card.
Blowdown ORP.	Existing site meter.	Data from new 4-20 mA output card.
Makeup water meter.	New totalizing flow meter in addition to the existing FTB4100 series totalizing flow meter from PWS project.	Data from new 4-20 mA output card.
Ambient dry bulb temperature.	Monitor located outside.	
Ambient relative humidity.	Monitor located outside.	
Cooling tower basin corrosivity.	AWT internal corrosion monitoring device checked with new PH and conductivity meters.	Located on AWT skid. Data to be downloaded and transferred to NREL.
Cooling tower overflow.	Level switches that will sense an overflow of the cooling tower basin and alert staff.	
AWT blowdown and regen flow rate.	Totalizing flow meter at the AWT skid discharge.	
Water input to AWT skid.	Totalizing flow meter at the AWT skid discharge.	
AWT skid energy usage.	Meter at AWT skid.	
Data logging equipment.	Two Campbell Scientific CR1000 data loggers with cell phone modem, required peripheries, and other supplies.	

Data was collected remotely at NREL's office in Golden, Colorado. Information was sent via a modem connection from a data logger. Installation of instrumentation took place prior to baseline testing and was noninvasive. Commissioning took place immediately after installation, and data was collected until the end of the 2022 AWT evaluation period.

Qualitative Study Design

To assess whether the technology was well received by the system operators and maintenance staff, key staff members were interviewed as to their satisfaction with the operation of the new system. Operator logs were reviewed during both the baseline and testing periods. Any maintenance records or costs were considered as to their relevance to the technology implementation.

Data Analysis

The effectiveness of the technology was demonstrated by comparison between the measured metrics with and without the AWT technology installed. The initial testing period—the baseline test period—was conducted before the AWT technology was installed.

After all instrumentation was installed and tested, the baseline test period data collection began. The demonstration test period with the AWT technology installed and operational began after adequate baseline data had been collected. Due to various issues in 2021 that are discussed later, the testing period was extended into 2022. The final testing schedule is shown in Table 2, along with the historical weather data highlighted in Figure 8 for the 2022 evaluation period, which spanned August 1 through October 14 (as highlighted by green box).

Table 2: Final Testing Schedule

	Baseline	2021 Evaluation	2022 Evaluation	Units
Testing Period	30	15	57	days

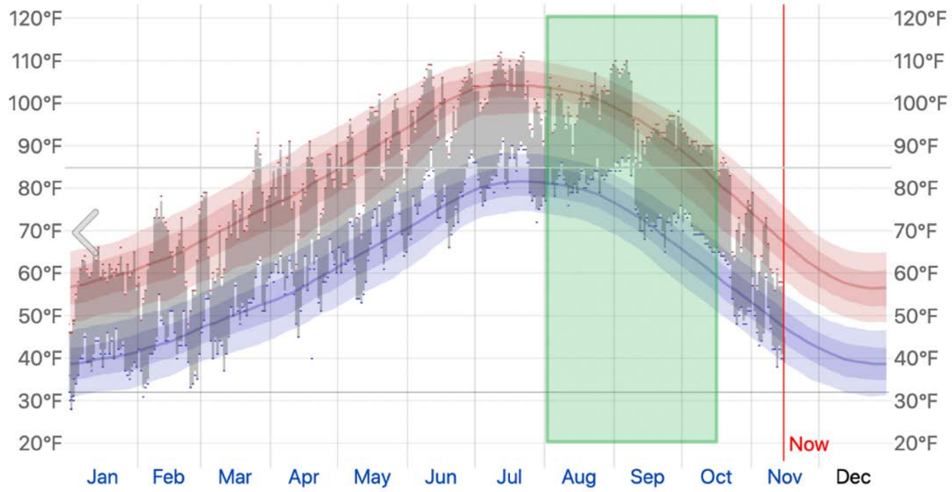

Figure 8: Evaluation daily temperature range in 2022 for Las Vegas, NV (credit: Weather Spark)

III. Demonstration Results

A. QUANTITATIVE RESULTS

Quantitative results are discussed below relative to the objectives set out at the start of the evaluation and are summarized in Table 3.

Table 3: Quantitative Objectives and Results

QUANTITATIVE OBJECTIVES	METRICS and DATA	SUCCESS CRITERIA	M&V Results
Water/Sewer Savings	Metered water consumption. Metered blowdown. Ambient temperature and humidity.	>15% makeup water savings. >45% blowdown savings.	16% makeup water savings. 53% blowdown savings.
Maintenance Savings	Maintenance records for current cost of chemicals and labor. Maintenance records during demonstration period and estimated future for the BDR system.	No increase in legacy chemical costs excluding antiscalant. Less than 8 hours per year in maintenance costs for cleaning and maintaining the new BDR system.	Using estimate from vendor on membrane replacement, site plans to replace every 5 years.
Water Quality	Water quality testing.	No degradation in water quality, including pH, hardness, alkalinity, silica high range, chloride anions, salt anions, sulfate anions, phosphate, copper, iron, and biological growth.	No substantial changes in water quality attributed to the AWT.
Cost Effectiveness[8]	Simple payback. SIR over 15 years.	<5-year payback. >1.0 SIR.	Testbed: 4.8-year payback. 3.1 SIR. Target Load: 2.8-year payback. 5.3 SIR.
Deployment Potential	Energy and water savings across climate zones with assumed site water quality.	Payback and savings are achieved in most climate zones given the building load size and the water quality.	Deployable across all climate zones.

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[8] BDR Testbed based on load of 1.6 million annual ton-hours, water rate of $18.97 per kGal, and electric rate of $0.10 kWh. The BDR Target Load for the AWT system deployed was 3 million annual ton-hours, GSA average water rate of $16.76 per kGal, and GSA average electric rate $0.11 kWh.

WATER SAVINGS

Makeup water and blowdown were metered prior to the installation of the AWT system to develop a baseline, and these were measured throughout the 2021 and 2022 evaluations. The PWS system was turned off to support data collection in the 2021 evaluation. Based on 2021 data analysis, both the BDR and PWS systems were in operation during the 2022 evaluation as BDR system performance could be analyzed. The evaporation, evaporation heat, and normalized water consumption per heat rejected by the cooling tower are shown in Table 4, along with CoC based on the water balance (volume) method:

$$CoC\ (Water\ Balance) = \frac{Makeup}{Blowdown + losses}$$

GSA O&M procedures require that cooling towers have a CoC of 2 or greater (met throughout). A higher CoC correlates with less blowdown and reduced makeup water consumption for the cooling tower. The success criteria by evaluation phase are shown in Table 5.

Table 4: Water Savings

	Baseline	2021 Evaluation	2022 Evaluation	Units
Testing Period	30	15	57	days
Blowdown	128,114	43,081	112,194	gallons
Makeup	394,456	239,086	706,695	gallons
Drift Losses	12,030	11,926	31,855	gallons
Evaporation	254,312	184,079	562,646	gallons
Evaporative Heat	2,217	1,604	4,904	MMBtu
Water Consumption per Heat Rejected	177.9	149.0	144.1	gallons per MMBtu
CoC Water Balance (volume method)	2.8	4.34	4.91	

Table 5: Water/Sewer Savings: Success Criteria by Evaluation Phase

Success Criteria	2021 BDR Evaluation	2022 BDR Evaluation
Water Consumption Reduced Percentage	**16.2%**	**16%**
Blowdown Reduced Percentage	**53.5%**	**53%**

Useful metrics from the 2021 evaluation, which spanned June 1 through August 28, for BDR system performance analysis was shortened to a single consecutive 15-day stretch due to these two events:

1. The water treatment company for the Lloyd D. George U.S. Courthouse did not properly maintain chemicals in the cooling tower loop for most of the 2021 evaluation. The facility chemical tank with chlorine/bromine was found empty in the July timeframe. While this was unrelated to the BDR system, it did negatively impact the metrics, as the BDR system was designed to work in tandem with proper chemical water treatment. The BDR system required more frequent RO membrane cleanings during the 2021 evaluation, as the system was compensating for improper facility chemical treatment. The Aqualogix team helped identify these water treatment issues.
2. A site power outage event on August 28 led to a water overflow event at the BDR reservoir tank when systems powered back on. Post-event analysis determined this event was caused by how the drain was metered specifically to support this evaluation. The BDR system was turned off until the metered drain could be repiped to prevent a similar event from occurring. More details are provided in the Operability section.

The BDR system showed encouraging performance during the 2021 evaluation, so the team decided to extend testing into 2022. A new water treatment company was brought on board and officially took over responsibility on July 1, 2022. The chemical water treatment issues were addressed, and the 2022 evaluation spanned August 1 through October 14. There were two short pauses during the 2022 evaluation window, although useful metrics were collected for a combined 57-day analysis.

MAINTENANCE SAVINGS

To verify the O&M costs or savings, the following data was collected:

- Estimated changes in labor costs for cleaning cooling towers and condenser tubes
- Cost of O&M labor and chemicals for the existing baseline system
- Estimated O&M labor and materials cost for maintaining the AWT system, as provided by the vendor.

The operation of the water treatment system was monitored over the demonstration period to ensure that the operation of the unit did not cause any problematic issues. O&M staff were interviewed to understand any issues related to the system.

O&M for the unit consists primarily of semi-annual system checks and annual instrument calibration. No increase in legacy chemical costs was necessary, excluding antiscalant for the BDR system. These items can be contracted through the vendor, with the majority of the costs being travel to the site. The AWT supplier will provide training to do this work for a one-time fee of $1,473 (including materials and special tools) that was included in the capital cost. An increase in annual maintenance was included at $475 per year to cover the labor for the system checks and annual calibration and replacing membranes every 5 years (that averages out to $125 per year). An estimate was provided by the vendor on membrane replacement and site plans to replace it every 5 years.

The BDR system was retrofitted between the 2021 and 2022 evaluations to add a self-cleaning functionality for the RO membranes. This added feature keeps the amount of O&M labor to a minimum.

WATER QUALITY

On a monthly basis, cooling towers are tested for effectiveness of water treatment—including alkalinity, pH, conductivity, scale, and corrosion inhibitors. Chemicals and biological treatment dosage and water blowdown rates are adjusted, as required. GSA has developed water chemistry standards, shown in Table 6, as a guideline to determine the acceptability of cooling tower basin water quality for a given water treatment technology. It should be noted that adherence to these ranges is not the only indicator of a technology's success. The operation of a water treatment technology is unique, and the function of the materials used in the design may result in water quality that falls outside the ranges defined in the project specifications.

There were no negative changes to water quality attributed to the BDR system in 2021. Under the direction of the new water treatment company that took over in 2022, water quality met all the criteria.

Table 6: Water Quality Criteria (as defined by GSA)

Test	Acceptable Ranges
Total Alkalinity (ppm)	100–1,000
pH	7.3–9.0
Chloride (ppm)	10–500
Cycles of Concentration (CoC)	>2
Total Hardness (ppm)	500–1,500
Conductivity (mmHOS)	<2,400
Bacteria Count (cfu)	<80,000
Iron (ppm)	<4
Calcium Hardness (ppm)	<500
Magnesium Hardness (ppm)	<100
Chlorides (ppm)	<250
Salt (ppm)	<410
Sulfates (ppm)	<250
Silica (ppm)	<150
ORP (mV)	>300
90-Day Copper Coupon (mpy)	<0.2

COST-EFFECTIVENESS

The primary savings on the project were due to water savings. No reduction in cleaning labor costs were identified during the testing. The cooling towers were neither more difficult to clean nor required more frequent cleaning, but there were no reductions in either metric.

The cost of the BDR system installed for this project was $35,403 (including $688 for shipping and $1,473 for training), and the installation added another $11,422, for a total capital expenditure of $46,825. Cost savings are realized from water savings.

The measured 1.6-million-ton hour annual load at the testbed site was lower than the expected target load of 3 million-ton hours. So Table 7 also shows a column assuming the target load and 2017 GSA average water costs of $16.76 per kGal (the 2017 rate was used to be consistent with other GPG AWT evaluations).

Table 7: Economic Assessment Worksheet

Description	Testbed	Target Load and GSA Utility Rates	Notes
Equipment cost ($)	$35,403	$35,403	Includes startup. Assumes $688 shipping and $1,473 for training.
Installation cost ($)	$11,422	$11,422	Assumes 120-V config for BDR, and no tie-in with Building Automation System.
Annual maintenance increase ($)	$475	$475	Includes $350 annual support, membranes replaced every 5 years ($125 per membrane).
Annual water savings (gal)	554,880	1,040,400	Testbed had 1.6 million annual ton-hours (or 187-ton avg load); Target Load was 3 million annual ton-hours.
Annual water cost savings ($)	$10,526	$17,437	Testbed water cost $18.97 kGal; GSA avg. water rate $16.76 kGal.
Annual technology electricity use (kWh)	3,541	3,541	8,760 hours at 0.404 kW for BDR.
Annual increase in electricity ($)	354	390	Testbed electric rate $0.10 kWh; GSA avg. electric rate $0.11 kWh.
Total annual savings ($)	$9,697	$16,573	
Payback (years)	4.8	2.8	
SIR (15 years)	3.1	5.3	

B. QUALITATIVE RESULTS

To assess whether the technology was well received by the system operators and maintenance staff, key staff members (property and building managers, O&M staff, and new water treatment company) were interviewed as to their satisfaction with the operation of the new system.

Qualitative results are discussed below relative to the objectives set out at the start of the evaluation and are summarized in Table 8.

Table 8: Qualitative Objectives and Results

QUALITATIVE OBJECTIVES	METRICS and DATA	SUCCESS CRITERIA	M&V Results
Ease of Installation	Interview with installer. Time required to install and configure. Labor associated with installation.	<5 days to install and commission.	BDR installation went smoothly, occurred in under 5 days.
Site Safety	Chemicals.	No new safety issues as reported by facility operators.	Staff reported no safety issues or concerns with the BDR system.
Operability	Interview with O&M staff. Usability opinion of facility operators.	Facility operators have few or no issues with technology.	Staff felt prototype BDR tested with some early operational issues. All issues were addressed, and staff continue to use technology.

EASE OF INSTALLATION

The AWT system was shipped in a crate (Figure 9) that fit through a 3-ft wide door. Setting the skid, wiring, and plumbing was straightforward. The installation is separate from the main cooling system, only treating a portion of the flow. If the skid can be located close to the cooling water supply and return piping, the side stream piping runs are short. The ties into the cooling water systems do not take much time or expense. For the Lloyd D. George U.S. Courthouse, the skid footprint was 300 ft^2. The skid weight is 920 lb dry weight (2,400 lb wet weight). Most buildings are capable of handling equipment of this size without issue. The target goal was to complete the installation in less than 5 days, which was met. After the decision was made on 120/240/480 V for the BDR pump, then the electrical run was straightforward. The implementation of the technology, including installation and commissioning, was satisfactory.

From a logistical standpoint, this system is easily deployed, installed, and operated. The technology fits onto a small footprint skid that can be set in place, installed, and commissioned in a short period of time. Piping to and from the skid is the hardest cost to predict, although the skid blowdown just needs a nearby drain location for discharge. Makeup water to the skid from city water will depend upon the location of the skid relative to a local tie-in point.

Figure 9: BDR system in shipping crate

SITE SAFETY

Site safety concerns are minimal with this AWT system. Staff reported no safety issues or concerns. The electrical system has disconnects on the skid, so staff felt comfortable with the setup. And there were no concerns with selection of the antiscalant selected for use in the BDR chemical bulk tank.

OPERABILITY

The key staff member from the new water treatment company mentioned the BDR conceptually makes sense, although this was a new scenario working around demonstration hardware and additional training was requested. Because the company joined the project later (July 2022), it wanted to see BDR in operation for a full year before making a final decision on effectiveness. The company felt more comfortable with the PWS system, as it is more common in the industry.

Managers and O&M staff felt the installed BDR system was at a prototype stage versus well-tested. There were some leak events during the 2021 and 2022 evaluations that influenced their perspective, but those issues were resolved. A water overflow event occurred at the BDR reservoir tank after a site power failure in 2021. Post-event analysis determined this event was caused by piping unique to this testbed, as shown in Figure 10, with a check-valve on the metered drain line not functioning when both the PWS and BDR systems returned to operation. With the final discharge to drain being restricted by the meter placement, the BDR tank filled to overflow at the top. The tank overflow line was repiped to match a normal installation, so it is now open to the drain to prevent a similar event from occurring.

There were two other smaller leaks in 2022 after the BDR system was retrofitted to add a self-cleaning functionality for the RO membranes. Some short straight sections of pipe near the membranes, as shown in Figure 11, and the pump had to be replaced with machined stock pipe. Aqualogix was quick to implement these fixes, and the system has been in operation without any additional incidents as of publication of this report.

Figure 10: Piping unique to this testbed: metered drain (left), overflow repiped (right)

Figure 11: Retrofit to original BDR test unit to add self-cleaning functionality

IV. Summary Findings and Conclusions

A. OVERALL TECHNOLOGY ASSESSMENT AT DEMONSTRATION FACILITY

The key takeaways from this evaluation that started in May 2021 and ran through October 2022 are:

- Water savings from the BDR system exceeded the success criteria, reaching 16% makeup water savings and 53% blowdown savings while meeting GSA water standards and payback targets.
- Another takeaway from the evaluation of the BDR system is that the conductivity setpoint for blowdown remains unchanged.

B. LESSONS LEARNED AND BEST PRACTICES

The team recognized contributing factors played a role in the 2021 events, from having to replace the water treatment company to the customized retrofit of a BDR onto an existing PWS system with unique metering to support this evaluation. Based on the 2022 evaluation, GSA R-9 regional staff view this AWT system as beneficial in reducing water usage and are continuing to use this technology. Lessons learned:

- Importance of a water treatment company properly maintaining cooling tower systems, as that impacts performance of both the AWT and chemical water treatment systems.
- Variation in payback is influenced by water rates and whether the AWT is operating near target load.
- BDR with self-cleaning functionality reduced the amount of O&M labor.
- Minimize the number of fittings as best practice. The manufacturer now offers a modular BDRS design with simplified piping when BDR and PWS systems are combined, as shown in Figure 12.

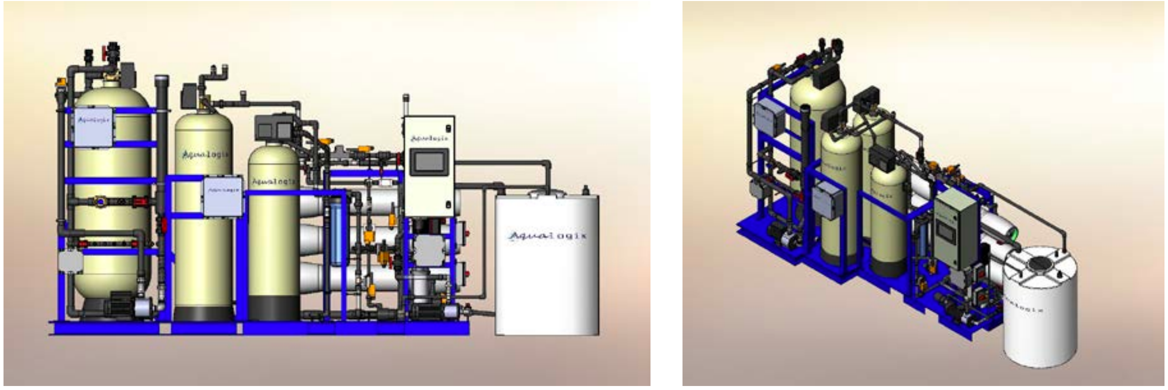


Figure 12: BDRS production unit (credit: Aqualogix)

C. DEPLOYMENT RECOMMENDATIONS

The BDR is deployable across all climate zones and the system can be scaled to meet various cooling loads. From a logistical standpoint, this system is easily deployed, installed, operated, and maintained.

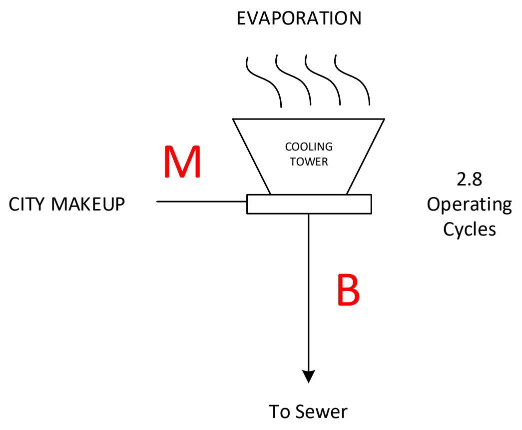
V. Appendices

A. OPERATING CYCLES VS EFFECTIVE CYCLES (CREDIT: AQUALOGIX)

Water savings measures using blowdown recovery (BDR) and/or partial water softening (PWS) systems reduce sewer discharge and lower city water makeup demand. A commonly used performance metric is cycles of concentration. However, where BDR is employed, a distinction must be made between the cycles of concentration at which the cooling system is operating, and the effective cycles yielded from the secondary processing of the blowdown.

The following examples are intended to illustrate this difference.

Baseline (before any AWT)



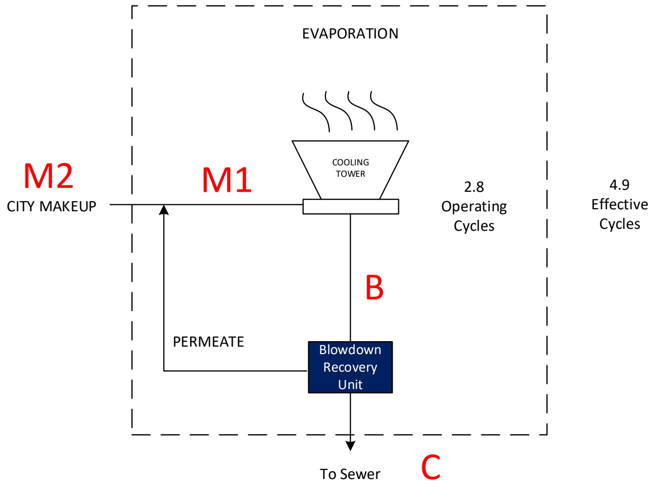
In the original baseline condition, the cooling system is operating at the limits set by the water treatment provider (e.g., hardness, conductivity, silica).

The operating cycles are calculated by dividing the makeup by the blowdown volume:

$$\text{Operating Cycles} = M / B$$

Note that drift (a small loss of water droplets at the cooling tower) has been ignored for simplicity in these examples.

BDR System



With BDR, the cooling system is operated at the same operational limits set by the water treatment provider, as in the baseline operation above.

The operating cycles remain the same:

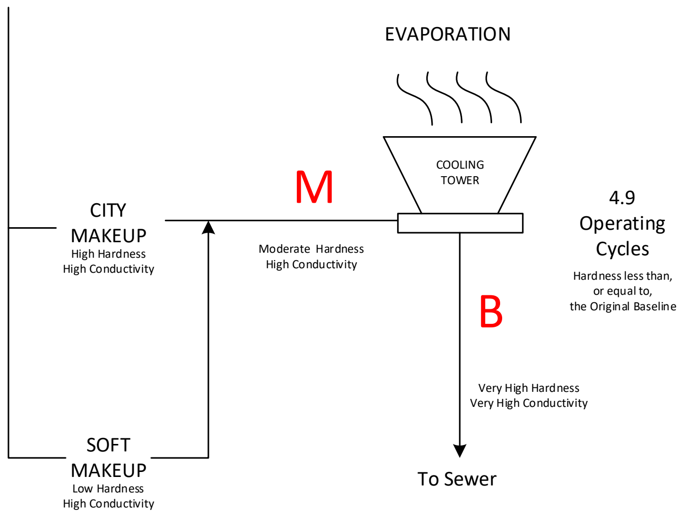
$$\text{Operating Cycles} = M1 / B$$

Using a BDR, the blowdown no longer goes to the sewer. Rather, the BDR unit returns a percentage of the received blowdown back to the cooling system as purified makeup ("permeate"). Only the concentrate from the BDR goes to the sewer.

The concentrate can be viewed as the new blowdown, allowing an “Effective Cycles” to be calculated:

Effective Cycles = M2 / C

PWS System



Partial softening is used to allow higher operating cycles in the cooling system, without exceeding the hardness limit specified by the water treatment provider for the original baseline operation.

This is accomplished by blending softened water with the city makeup to reduce the overall makeup hardness (allowing higher cycles at the same hardness limit).

The operating cycles are calculated by dividing the makeup by the blowdown volume:

Operating Cycles = M / B

Table A-1 illustrates how partial softening allows an increase from 4 to 8 cycles while maintaining 400 ppm hardness in the cooling water:

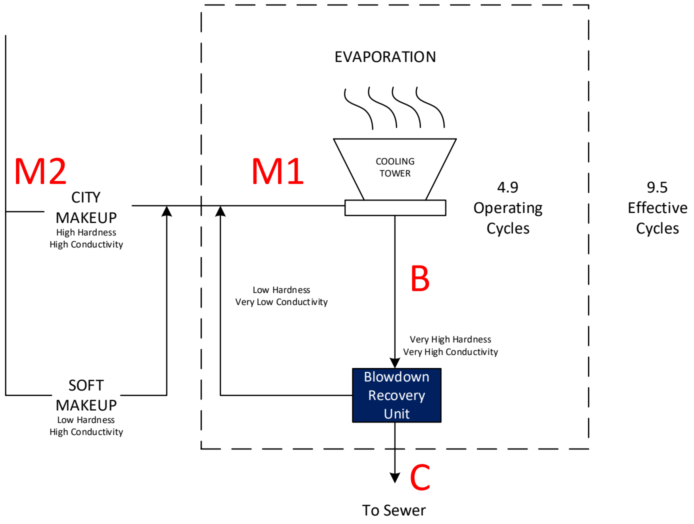
Table A-1: Partial Softening: Increase CoC While Maintaining Hardness of 400 ppm

City Water Total Hardness	Percent Softened	Makeup Total Hardness	Total Hardness Limit (ppm)	CoC Operating
100	0	100	400	4.0
100	10	90	400	4.4
100	20	80	400	5.0
100	30	70	400	5.7
100	40	60	400	6.7
100	50	50	400	8.0

For a complete discussion of partial-softening, refer to NREL/TP-7A40-76756,

Continuous Monitoring and Partial Water Softening for Cooling Tower Water Treatment.

BDR and PWS systems combined



Partial softening is used to allow higher operating cycles in the cooling system, without exceeding the hardness limit specified by the water treatment provider for the original baseline operation.

The operating cycles are calculated by dividing the makeup by the blowdown volume:

Operating Cycles = M1 / B

When combining partial softening with BDR, the blowdown no longer goes to the sewer. Rather, the BDR unit returns a percentage of the received blowdown back to the cooling system as purified makeup (“permeate”). Only the concentrate from the BDR goes to the sewer.

The concentrate can be viewed as the new blowdown, allowing an “Effective Cycles” to be calculated:

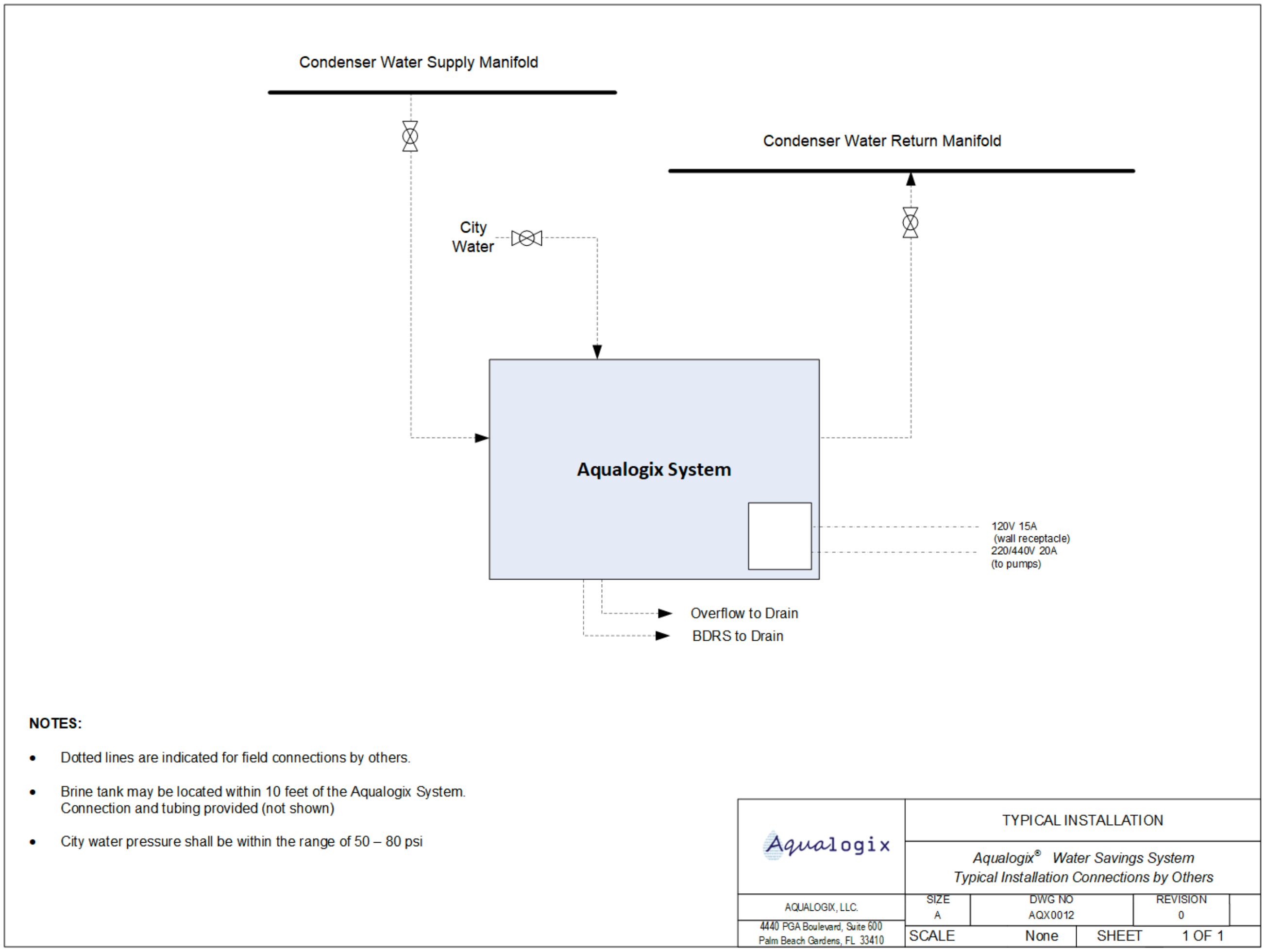
Effective Cycles = M2 / C

Table A-2 shows how BDR can be combined with partial softening to achieve higher effective cycles of concentration and overall sewer reduction. These calculations are based on average evaporative load of 400 tons, baseline operating CoC of 2.8, and average BDR recovery rate of 53% (based on Table 5).

Table A-2: BDR and PWS Systems Combined: Higher Effective CoC and Sewer Reduction

Operating Cycles	Evaporation (gallons/year)	Blowdown (gallons/year)	Concentration (gallons/year)	Effective CoC	Sewer Reduction
3.3	6,307,200	2,742,261	1,261,440	6.0	64%
3.8	6,307,200	2,252,261	1,036,183	7.1	70%
4.3	6,307,200	1,911,273	879,185	8.2	75%
4.8	6,307,200	1,659,789	763,503	9.3	78%
5.3	6,307,200	1,466,791	674,724	10.3	81%
5.8	6,307,200	1,314,000	604,440	11.4	83%
6.3	6,307,200	1,190,038	547,417	12.5	84%
6.8	6,307,200	1,087,448	500,226	13.6	86%
7.3	6,307,200	1,001,143	460,526	14.7	87%
7.8	6,307,200	927,529	426,526	15.8	88%
8.3	6,307,200	864,000	397,440	16.9	89%
8.8	6,307,200	808,615	371,963	18.0	89%
9.3	6,307,200	759,904	349,556	19.0	90%
9.8	6,307,200	716,727	329,695	20.1	91%
10.3	6,307,200	678,194	311,969	21.2	91%
10.8	6,307,200	643,592	296,052	22.3	92%
11.3	6,307,200	612,350	281,681	23.4	92%
11.8	6,307,200	584,000	268,640	24.5	92%
12.3	6,307,200	558,159	256,753	25.6	93%

B. MANUFACTURER CUT SHEET



NOTES:

- Dotted lines are indicated for field connections by others.
- Brine tank may be located within 10 feet of the Aqualogix System. Connection and tubing provided (not shown)
- City water pressure shall be within the range of 50 – 80 psi

TYPICAL INSTALLATION

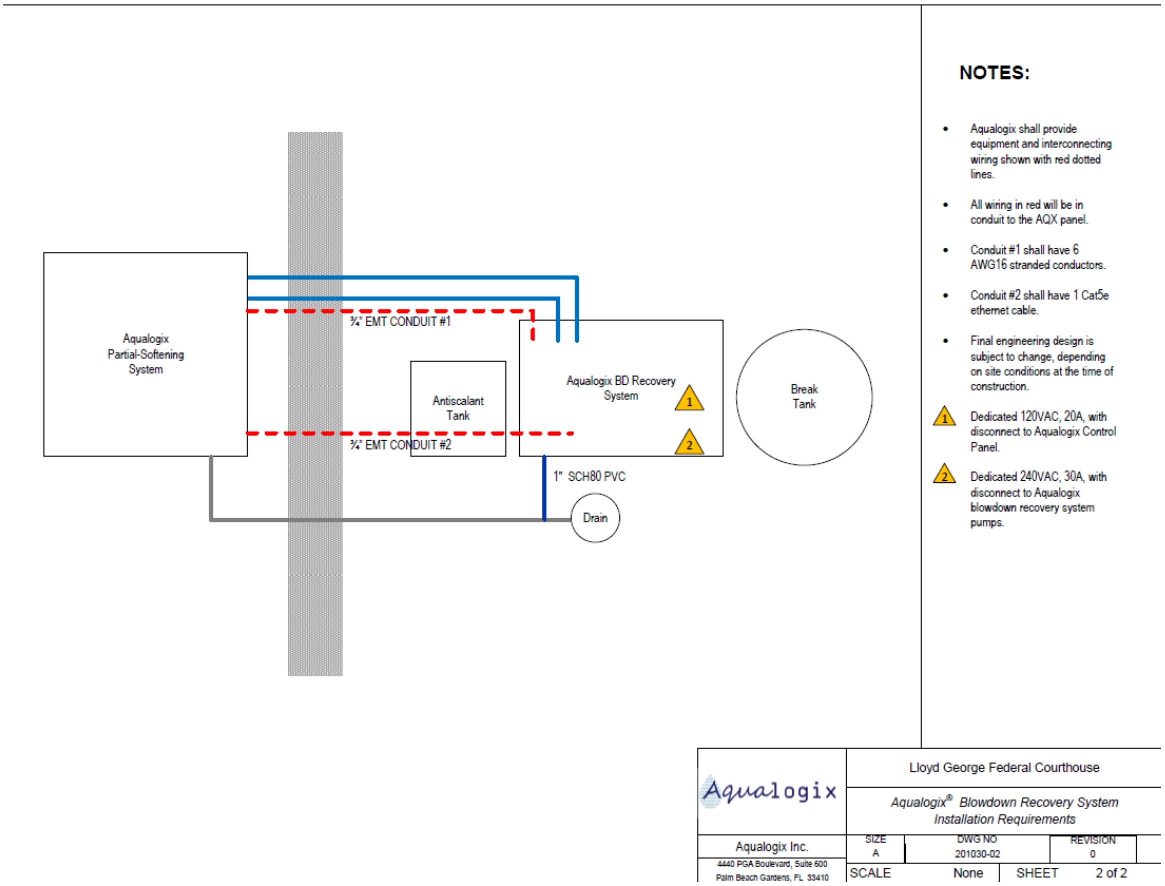
Aqualogix® Water Savings System
Typical Installation Connections by Others

AQUALOGIX, LLC.
4440 PGA Boulevard, Suite 600
Palm Beach Gardens, FL 33410

SIZE	DWG NO	REVISION
A	AQX0012	0

SCALE None SHEET 1 OF 1

Figure B-1: Aqualogix typical installation drawing (credit: Aqualogix)



NOTES:

- Aqualogix shall provide equipment and interconnecting wiring shown with red dotted lines.
- All wiring in red will be in conduit to the AQX panel.
- Conduit #1 shall have 6 AWG16 stranded conductors.
- Conduit #2 shall have 1 Cat5e ethernet cable.
- Final engineering design is subject to change, depending on site conditions at the time of construction.

⚠1 Dedicated 120VAC, 20A, with disconnect to Aqualogix Control Panel.

⚠2 Dedicated 240VAC, 30A, with disconnect to Aqualogix blowdown recovery system pumps.

Lloyd George Federal Courthouse

Aqualogix® Blowdown Recovery System
Installation Requirements

Aqualogix Inc.
4440 PGA Boulevard, Suite 600
Palm Beach Gardens, FL 33410

SIZE A
DWG NO 201030-02
REVISION 0
SCALE None
SHEET 2 of 2

Figure B-2: Aqualogix customized BDR retrofit onto existing PWS for site (credit: Aqualogix)