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Cooling Water

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INDUSTRIAL WATER TREATMENT

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COVER

Process water cooling tower at a 400-ton-per-day pulp and paper mill in the Andhra Pradesh region of India.

Photo courtesy of Edward Helmig, water consultant.

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FEATURES

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POWER

Optimizing Water Use and Minimizing Wastewater Generation within the Power Plant

The availability of a quality water supply has impacted all types of thermoelectric power generating facilities and has become a limiting factor in a number of instances related to siting and building today's new fleet of combined-cycle power projects. Global climate change has increased air temperatures and interrupted precipitation movements across the United States and around the world. Severe droughts have dramatically impacted numerous areas of the United States in recent years, forcing plants to import water from outside sources, curtail generation, and/or shut down operations all together.

In addition to water supply limitations, other elements such as price of natural gas and the increase of renewable energy sources on the grid has caused many plants to shift their operational scenarios. Power plants that were once designed to operate as baseloaded facilities are now being called upon to operate on an intermediate, or sometimes cyclic basis because of dispatch and other restrictions. Older plants that were originally designed for baseload operation run most efficiently at that baseload point, including efficiencies related to water usage and wastewater production.

Changes in air, water, and wastewater regulations are also having an impact on many plants' water and wastewater picture. Because of changes in air quality regulations, plants have been required to incorporate additional air quality control systems; this equipment likely has also had an impact on the water and wastewater systems within the plant. This new equipment often requires additional water makeup or increases wastewater discharge, changing the landscape of the water box for the plant.

A new water supply regulation was recently finalized and wastewater related regulations are also on the horizon for existing power generating facilities in the not so distant future. The Environmental Protection Agency's (EPA's) final 316(b) Cooling Water Rule under the Clean Water Act was finalized and released by May 19, 2014 (1), and is estimated to impact the water supply side of at least 544 existing power plants across the United States.

On the wastewater side, an update to the EPA's Effluent Limitation Guidelines (ELGs) for the steam electric power generating point source category is currently anticipated for final issue no later than September 30, 2015. These ELGs are technology-based limits and the amendment is expected to impact primarily coal-fired facilities. However, more and more facilities are also noting additional water quality based effluent limits (WQBEL) such as total maximum daily load (TMDL) limits becoming part of their National Pollutant Discharge Elimination System (NPDES) permits as regulators work to protect and improve impaired receiving water bodies. These are generally water body specific limits that depend on what contaminants the water body is considered impaired by. For instance, plants that discharge into the Chesapeake Bay watershed may experience tight NPDES limits on nitrogen and phosphorus compounds because of eutrophication in the Bay.

Given the number of water-related pressures that today's power plant fleet is dealing with, having a clear understanding of how the plant manages its water and wastewater internally is increasing in importance. Proactive management of how water is used in a power plant can do more than reduce water consumption and wastewater generation. It can also lower operational costs and help a plant plan for the future. One of the best ways that a plant can manage its water resources more effectively is to develop a plant-wide water management plan— a comprehensive site-wide strategy for maximizing water use efficiency, minimizing wastewater discharge, and encouraging a policy of sustainability and reuse/recycle to the maximum extent practical to control a plant's water footprint.

Getting Started

The first step in developing a water management plan is to define the plant's existing conditions. A plant water balance was likely created during the initial plant design; however, over the course of time equipment is added, streams are rerouted, or equipment is removed from service to adapt to changing plant needs. Unfortunately, in most cases, the plant water balance doesn't always get a corresponding update. After a few (or many) years of operation, a plant may believe that they know where all the water is going, but that may not be the case in reality. Therefore, drawing and detailing the plant water balance should be the first step in your plan. The water balance should identify all water consumers and wastewater producers throughout the facility and indicate all the flow routes and distribution pathways. Figure 1 shows a typical water balance diagram for a coal-fired power plant.

Analyzing the existing plant water picture. Development of a plant water balance should begin by walking down the plant water and wastewater systems and mapping out all water users, wastewater generators, sumps, ponds, and other containments in the form of

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a block diagram. The block diagram should include any and all potential water and wastewater flow pathways whether they are constant or only intermittent flows. Each flow should then be characterized in terms of major water quality constituents.

The most difficult challenge in developing the water balance is usually obtaining a suitable amount of water quality information for each stream present in the plant. Most plants have a relatively clear picture of what is going into and out of the facility, but generally collect little information regarding internal plant streams. Sources of data may include: operator/chemistry technician logs and rounds, distributed control system (DCS) data on flows, pump run times, sump/pond levels, and on-line water quality analyzers, among other things. This water balance should include average daily usage rates as well as peak and minimum flows to create an accurate picture of the plant's water footprint. Reduced load operations (if they are relevant for a unit), partial plant operations (for instance, single-unit operation in a two-unit plant), as well as other off-design operating scenarios should be included, as appropriate, as they can greatly affect water consumption rates and wastewater production.

Depending on the raw water source, operating cycle, weather, and various other drivers, the characterization of each water stream may vary over time. By including minimum, average and peak flows for each water stream, in addition to a range of water quality information, the plant personnel can understand where any water issues may lie or opportunities for optimization may exist.

Numerous data points collected during different times of year and at different operating loads provide a much more accurate picture of the water quality, whereas a single point or small number of data points provides only a snapshot in time. A simple method for tracking all of this information is simply to use an Excel spreadsheet (see Table A for an example template). However, a number of engineering and consulting firms have developed specialized tools to aid in this process. The more information collected, the more accurate the picture of the plant's current water situation will be. Correlating the data with plant operation (load the plant was at when the data was collected) is very important in developing an accurate picture.

Filling in any gaps. It is quite likely that the plant will discover during the initial collection process and analysis of that data that there are a number of data gaps where flows are not routinely monitored or water quality of streams

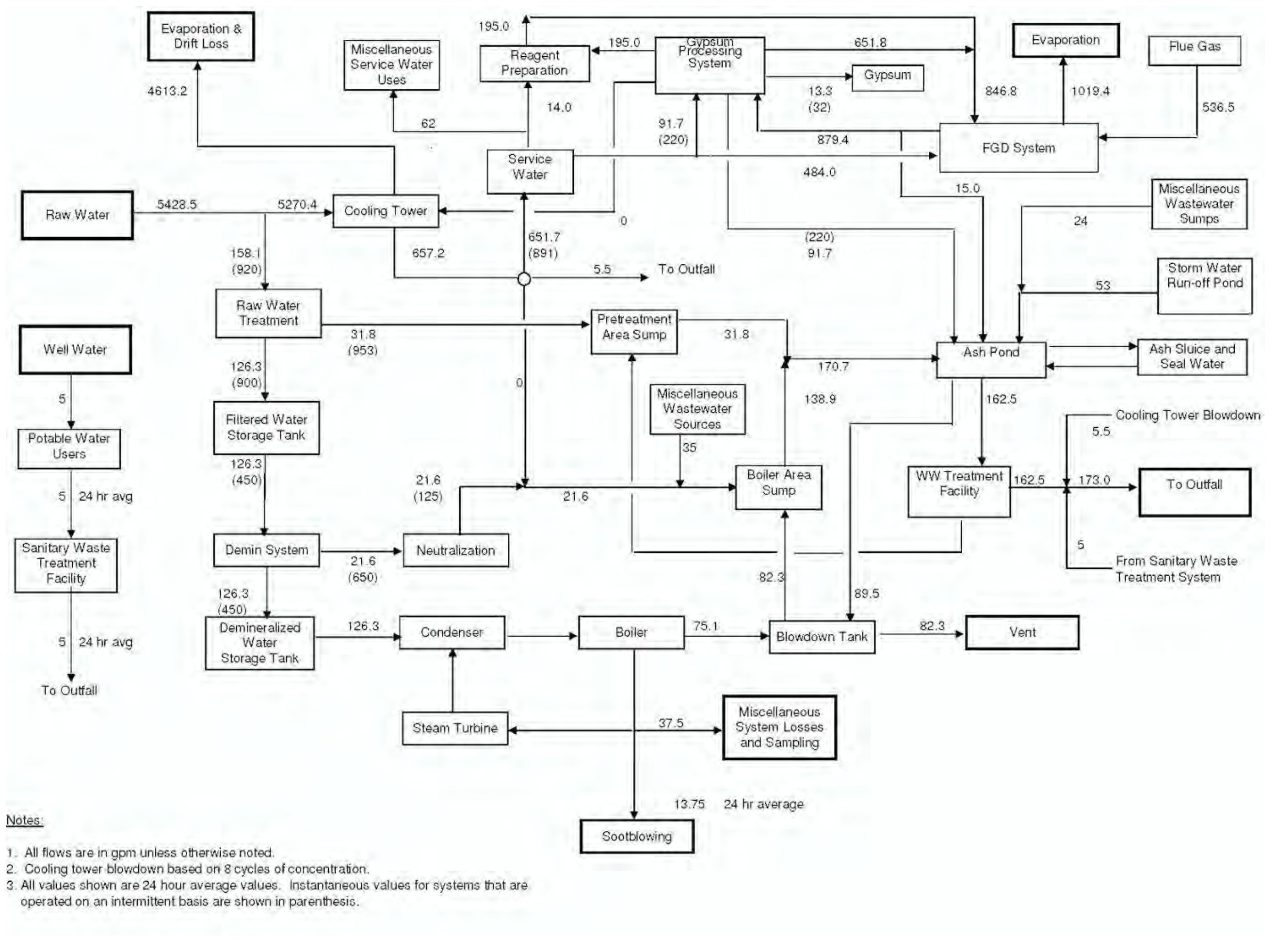

Figure 1. Typical water mass balance for a coal-fired power station.

TABLE A
Typical Water Quality Tracking Spreadsheet

Description		*Raw Water Supply*	*Raw Water Supply to Power Plant Users*	*Plant Water Influent*	*Sanitary Waste to Blowdown Sump*	*Supply to Demin Treatment/*
Stream #		1	2	3	5	6
Normal flowrate (gpm)		936	448	35	48	413
Symbol	*Constituent*	mg/L	mg/L	mg/L	mg/L	mg/L
Al	Aluminum	0.03	0.03	0.03	0.03	0.03
Hg	Mercury	0.00005	0.00005	0.00005	0.00005	0.00005
Ca	Calcium	75	75	75	75	75
Mg	Magnesium	16	16	16	16	16
Fe	Iron	1.3	1.3	1.3	1.3	1.3
Na	Sodium	116	116	116	116	116
HCO_3-	Bicarbonate	320	320	320	320	320
Cl^-	Chloride	440	440	440	440	440
SO_4	Sulfate	47	47	47	47	47
NO_3	Nitrate	51	51	51	51	51
HPO_4^{3-}	Phosphate	2.4	2.4	2.4	2.4	2.4
SiO_2	Silica	5	5	5	5	5
F^-	Fluoride	0.5	0.5	0.5	0.5	0.5
Ba	Barium	0.01	0.01	0.01	0.01	0.01
CN	Cyanide as CN	0.027	0.027	0.027	0.027	0.027
Cr	Chromium	0.01	0.01	0.01	0.01	0.01
Co	Cobalt	0.01	0.01	0.01	0.01	0.01
Cu	Copper	0.01	0.01	0.01	0.01	0.01
Pb	Lead	0.01	0.01	0.01	0.01	0.01
Mn	Manganese	0.06	0.06	0.06	0.06	0.06
Ni	Nickel	0.008	0.008	0.008	0.008	0.008
K	Potassium	18	18	18	18	18

are not analyzed. Once these data gaps are identified, a sampling plan should be developed to determine the water quality and flowrate data that is missing. In preparing a sampling plan, first define what water quality characteristics the plant needs to test for, where the best location is to collect a sample to obtain that information, and what sampling and testing methods are appropriate to obtain the desired level of data accuracy.

Much of the data may need to be obtained through field testing— setting up portable flow monitors and collecting samples for laboratory analysis. However, some of those data gaps may be able to be filled in by doing a little math and using additive processes. If the line is a common header that combines various streams, a simple mass balance of each stream is sufficient for determining the resulting water quality in the common header. Save money and time wherever possible by looking for these types of opportunities.

Different sampling techniques and different sample preparations are required for different types of analyses and different types of locations (sumps or impoundments versus closed conduit versus tank versus open channel). It is imperative to sample where quality changes because of the process or chemicals are added to the system. Obtaining expert advice to aid in developing the plan is often prudent if the plant is not familiar with sampling techniques and sample preparations (particularly for low-level metals testing) in order to ensure accurate collection of data.

In order to determine water flowrates in locations where permanent plant monitors are not installed, portable flow monitors may be used. There are various kinds of flowmeters, but the two types that are most appropriate for this application are ultrasonic flowmeters and magnetic insertable flowmeters. Ultrasonic flowmeters work well on clean pipes, but will not work well for pipes with internal build up or where the pipe configuration does not provide sufficient straight pipe lengths for their proper installation.

Magnetic insertable flowmeters are a better option in these situations; however, these devices require a hot tap for installation. In locations where open channel flow measurement is necessary, a temporary Parshall flume is generally recommended. Although sometimes challenging to install correctly, these devices are usually the best option in this situation where other methods of flow measurement are impractical. For smaller water lines, additional devices may not be required if dealing with minimal flows. In these situations, water flow can be captured in a bucket and timed with a stop watch to estimate the flowrate. Simply calculate the flowrate by dividing the volume of water obtained per the time spent filling the bucket.

Portable composite sample collection devices are recommended for collecting water samples for laboratory water quality analysis. However in some situations, particularly where flows and water quality are generally known to be very consistent over the course of the day, grab sampling techniques may be appropriate for sample gathering. The plant must evaluate the use of composite samplers versus grab sampling for each sampling location. Use of composite samplers generally provides more accurate data than grab sampling, but it is a more costly method. In most situations, a combination of both sample methods across the plant site at different locations is the ideal solution.

Determining speciation of some water quality constituents (especially metals) can be important for treatment purposes and/or the impact to aquatic species. It is important to work with a team that includes consultants, the water treatment chemical supplier(s), and plant personnel. Enduser staff will understand the power plant processes as well as water treatment and chemistry needs to ensure good data is collected via appropriate sampling protocols and the right laboratory testing methods in order create an accurate picture. The data will provide the required intelligence for selecting an appropriate water or wastewater treatment technology (if necessary), sizing determination, defining operating and maintenance costs, and understanding resulting water qualities, among other factors.

Developing the Plan

Once the plant water balance is developed and the mass balance of contaminants is tracked throughout the plant, staff can use this tool to assess how operational changes, or stream re-direction might allow the plant to reuse some internal wastewater streams and reduce its water footprint, or reduce the level of contaminants that are discharged or that need to be removed.

To use this tool effectively, the plant must first determine what goals it desires to achieve in implementing a water management plan for the facility. Is the plant experiencing pressure to conserve on the water supply end? Is the goal the minimization of wastewater discharge or elimination of certain wastewater streams? Do certain wastewater constituents need to be addressed because of an NPDES permit renewal or addition of new plant systems? Are there other issues of concern? Defining the plant's desired goals prior to making changes within the plant is crucial to optimize the water management plan and make effective use of resources.

Assess the situation. If near-term plant plans include the addition of new plant equipment, such as new air pollution control equipment, start by overlaying the impact that the new system or equipment will have on the existing picture. What will this new system necessitate— does it require water, does it produce wastewater? If yes, what are the required or predicted qualities and quantities? Can an existing plant wastewater stream be recycled to provide a source of water to this new system? How will the introduction of the new system impact other wastewater streams? First evaluate any proposed plant upgrades or equipment changes so you have an accurate picture of the plant water needs moving forward.

Next, evaluate any expected impacts from upcoming NPDES permit renewals or water supply permit renewals. How will these renewals impact processes and operations within the plant boundaries and the plant water balance? Redefine the plant's water management goals based on this information for the upcoming future, if needed.

Finally, evaluate reuse opportunities within the plant. Once data has been collected and the streams have been characterized, an evaluation of the resulting water balance is necessary. There may be flows that can be re-routed to other parts of the plant for reuse, such as sending reverse osmosis (RO) reject to a cooling tower. This simple change will reduce the makeup water supply required for the tower, which is typically the largest user of water in a power plant.

Another wastewater stream that may be suitable for reuse is heat recovery steam generator (HRSG)/boiler blowdown. This stream is typically condensate quality during normal operation and therefore could be re-introduced into the service water system or at the inlet of the demineralized water treatment system. Many other streams, including water treatment backwash waste, cooling tower blowdown, sample panel waste, and even storm water, provide potential reuse opportunities, depending on their flowrate and quality and the corresponding needs of other water users within the plant.

Coal-fired power plants tend to provide the greatest opportunities for recycle or reuse of wastewater streams given their substantial need for water (even degraded quality wastewater) for services such as ash conditioning or coal pile dust control. For combined-cycle plants, however, opportunities are much more limited and require more creativity. Each plant situation is unique and each reuse opportunity must be evaluated and impact fully assessed prior to implementation. Any recycle/reuse evaluation should include the following assessments at a minimum:

- Water quality pros and cons analysis that detail the impact on the individual plant system as well as on the overall plant water and wastewater flow and quality picture.

- New equipment or devices required to enable reuse. Often additional piping and valves may be only necessary equipment required to enable water reuse.

- Additional treatment required to enable reuse. Certain streams may be suitable for reuse only after additional treatment is performed to remove certain contaminants.

- A capital and operational cost analysis (cost-benefit analysis) for each reuse opportunity.

Evaluation of operational changes. The operating profile of the power plant tends to impact water and wastewater flowrates and water qualities throughout the facility, sometimes in ways that might not be expected. This may require that the team evaluate various plant operating scenarios of interest in developing and implementing a water management plan. Off-design operating conditions, especially at multi-unit sites with integrated water and wastewater systems, often can produce the most challenging water operating scenarios and can drive decisions related to equipment sizing. If the plant has the ability to be baseloaded, intermediately dispatched and even variable operation, then the treatment system operations will be dramatically impacted. This can lead to a wide range of influent and effluent flows from each of the systems.

Overall plant operating scenarios are generally not under the staff's control. However, operation of different plant systems individually or in concert with one another are normally under the realm of plant control, and making small changes in this area can produce significant results when it comes to improving the plant water picture. The plant cooling tower, if a wet cooling system is used, is generally the best place to start since it is generally the largest user of water and often the largest producer of wastewater in many power plants.

It may be worthwhile to investigate the implementation of upgrades to a water supply treatment system, changes in cooling tower water chemical treatment programs, or the addition of a cooling tower side-stream treatment system to improve cycles of concentration, decrease supply water requirements, and minimize wastewater (blowdown) generation. Just keep in mind that increasing cycles of concentration impacts (usually negatively) the quality of cooling tower blowdown water and cooling tower drift so be sure that those impacts are evaluated in the overall cost-benefit analysis of any such decision making process.

There are a host of other operational changes that can have a positive impact on the overall plant water picture. In many instances, troubleshooting and correcting situations where equipment is not operating per design can lead to significant improvements in the plant water balance. Some areas to evaluate operations include:

- Minimization of and/or collection and reuse of flush waters for slurry lines, gypsum systems, and clarifier sludge systems.

- Ion-exchange systems that require frequent regeneration. One option worth evaluating is off-site regeneration of this equipment.

- Filters that require frequent backwashes.

- Membrane systems requiring frequent cleaning.

- Trenches and sumps that require additional water supply (usually supplied via hose) to keep them flowing. This is symptomatic of a bigger problem in the system as no sump is designed that way.

- Smooth out water treatment system operations that may have become erratic because of cycling plant operations. This may require the installation of additional equipment such as recirculation lines for clarifiers to maintain flow and water quality or tanks to provide buffer storage capacity.

Depending on plant overall water picture and level of concern related to water and wastewater, there are other higher level operational changes that may be worth considering during the evaluation process. Operational changes such as landfilling gypsum instead of washing it to permit resale, or changing fuel supplies to lower chloride containing coals can significantly reduce wastewater volumes. Landfilling gypsum eliminates a large volume wastewater stream creating by washing operations. Changing to a lower chloride coal source, or upgrading the fuel gas desulfurization (FGD) scrubber materials of construction could make sense financially if the changes can reduce or eliminate concerns with treatment and disposal of purged wastewater. Changes of this magnitude may not be on the table today, but should be potentially long-term considerations if the plant is facing serious water related challenges in the future.

Evaluate Plant Water Streams

If a plant's storm water system can be easily divertible, then reusing storm water within the plant may make sense if the water quality is adequate, if the need for additional water supply exists, or if regulations requiring the segregation and separate treatment of contact and non-contact are enacted. For plants located in relative wet regions, capturing, storing, and re-introducing storm water as "service" water may help alleviate the challenges related to insufficient incoming volume from the water source.

Non-contact storm water is classified as precipitation that does not come in contact with process and chemical equipment. Types of non-contact storm waters include building downspouts, roadway runoff, and areas external to berms/containments, among others. Minimal treatment may be required to treat non-contact storm water, depending on the re-use opportunity. Contact wastewaters come in contact with process equipment and chemical containment areas. They are sometimes required to be segregated as part of plant discharge permits. These streams also may have opportunities for reuse within the power plant, but may require higher levels of treatment prior to reuse, depending on their quality. However, they should be characterized and accounted for and the evaluation of their potential should be included as part of the plant water management plan. Treatment and reuse may be more cost effective than treatment for discharge in the overall analysis, depending on the plant's overall wastewater restrictions.

Identify Stakeholders and Obtain Support

Within any power plant, there are a wide variety of stakeholders who may have a vested interest in development and implementation of a plant-wide water management plan. These include plant operators, engineers, environmental staff, plant manager, maintenance staff, and many others who may be impacted by water-related issues and proposed changes. Gaining support and buy-in from all stakeholders is crucial to the success of any project. The goals should be developed in concert with all stakeholders and any resulting changes to plant operations or processes should be agreed upon and evaluated from all relevant perspectives.

Even after operational changes are implemented and/or new systems installed, the process is still not finished. Once these changes are begun, operators must be trained to understand and operate the plant in a new fashion. New maintenance programs or schedules may be needed. Methods of monitoring and analysis must also be established to ensure that the plan is adhered to and the plant staff does not fall back into old habits. The plan must have management buy in and support to ensure that it will be maintained. The success of the plan should also be continually verified and adjustments made as necessary through the use of routine inspections, monitoring and testing, and program audits.

Project Considerations

Sustainability or water conservation practices are becoming more and more important within power plants as both supply and discharge waters are receiving attention from a regulations standpoint. With this heightened scrutiny, implementing sustainable practices within the plant is a must if water use optimization and/or discharge minimization are plant goals. When selecting major equipment for a new power plant project, low water consumer equipment should be considered at the onset to minimize the plant's water footprint. If such considerations cannot be performed, design teams should look for ways to optimize the major equipment that could minimize supply needs and wastewater generation.

Once equipment is selected, a water management plan for all project phases should be developed, including construction and commissioning/startup phases. Chemical cleaning, flushing, hydro-testing, and other plant commissioning activities require a significant amount of water and produce significant wastewater streams. Plans for use minimization and recycle/reuse, where practical, should be included in the project water management plan that is developed during the design phase of the project. Rental treatment equipment such as mobile demineralizers, RO systems, and filtration systems may be employed to clean up and treat flush and hydro waters for reuse. The use of project sustainability metrics, which analyze a project in terms of its vulnerability to and resilience against water-related changes such as future water supply availability, quality or cost, help with planning for the life of the plant and not just the current state.

Be Prepared

Looking forward, water-related challenges are likely to continue to grow in importance for the electric power industry over the next decade and beyond. Siting of new plants is already constrained by access to water supply, especially quality freshwater sources. Electric power is frequently assigned the lowest priority for water allocation after residential, commercial, industrial, and agricultural uses. With limited freshwater supplies and increasing demands, it is critical to examine options for reducing anticipated demand within the electric sector given its critical role in powering the U.S. economy.

Changing environmental regulations are causing wastewater-related challenges that the industry must also contend with, further squeezing the operational water "box" that a plant can operate within. To address these growing concerns, power generating stations are forced to reexamine their plant's water footprint and assess how they can best use their resources while balancing the requirements of multiple new environmental regulations with economic and operational priorities.

Proper planning will equal future success. As new and/or updated water regulations and power market challenges come down the pipeline, plants that are prepared to tackle these challenges head-on will come out ahead in the long run. Evaluating the current plant water and wastewater conditions, conducting sampling and flow measurement programs, and assessing current wastewater treatment systems are key to development of a baseline and plan of attack for dealing with potential changes. Knowing exactly where your plant's starting point is and developing a solid data history is crucial to determining what you may need to do to meet future sustainability or regulatory challenges.

References

1. U.S. EPA. "EPA Finalizes Standards to Protect Fish, Aquatic Life from Cooling Water Intakes", http://yosemite.epa.gov/opa/admpress.nsf/596e17d7cac720848525781f0043629e/f14b3341fbd63e8085257cdd006fb489!OpenDocument (accessed May 19, 2014).
2. Layman, C. "Why Your Power Plant Needs a Water Management Plan", *Power*, http://www.powermag.com/why-your-power-plant-needs-a-water-management-plan/, accessed May 16, 2014 (published Nov. 1, 2013).
3. U.S. Geological Survey. *The World's Water*. http://water.usgs.gov/edu/earthwherewater.html (accessed May 16, 2014).

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