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Water Resources Shaping Ohio's Future: Water Efficiency Manual for Industrial, Commercial, and Institutional Facilities (Report)

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WATER RESOURCES SHAPING OHIO'S FUTURE:

WATER EFFICIENCY MANUAL FOR INDUSTRIAL, COMMERCIAL, AND INSTITUTIONAL FACILITIES

Prepared for:
Ohio Lake Erie Commission
Ohio Department of Natural Resources (ODNR)

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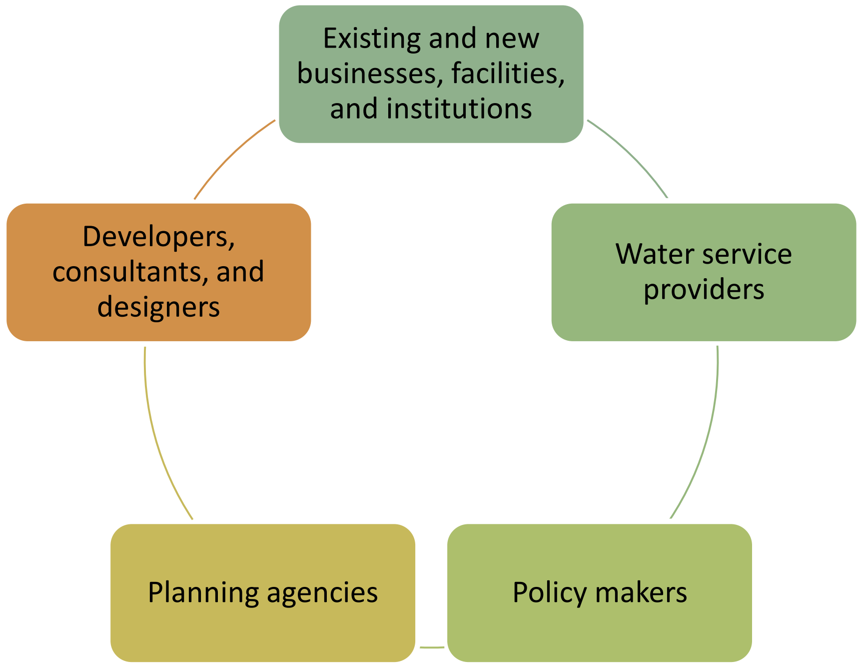

WHEN TO USE THIS GUIDE

Now	• to determine what you can do to use water efficiently, save money in your facility, and help protect Ohio's water resources.
As you apply for a water withdrawal permit	• to learn about opportunities to achieve significant energy and environmental benefits through water efficiency practices.
As you plan and budget for next year	• to identify essential programs, equipment and employee participation tools for water efficiency.
When considering to purchase	• any new cooling, heating, processing, landscaping, sanitary fixtures, facility support equipment and service contracts.
Before you seek support and engagement	• from your management, maintenance and production personnel.
Before any facility upgrade and expansions	• that can impact your water processes.
In the case of any unforeseeable water crisis	• such as drought or intensified competition for water withdrawals.

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INTRODUCTION

BACKGROUND

The state of Ohio has a wealth of renewable water resources for domestic, agricultural, and industrial uses. The state's "north coast" provides direct access to Lake Erie, one of the Laurentian Great Lakes, which together constitute over 20% of the world's fresh water. The importance of Lake Erie and its tributaries to the health and economic prosperity of northern Ohio cannot be overstated, and the State of Ohio recognizes the need for a strong stewardship role.

However, it is also true that abundance has sometimes obscured the value of Lake Erie and its water to the general public and decision makers, who assume that a vast supply implies water security. The presence of a raw water supply is a necessary but insufficient condition for satisfying the wide variety of uses and needs for water in Northern Ohio. These resources are not unlimited and are currently subject to pressures from different sources such as negative impacts of climate change, increasing water demands for hydraulic fracturing to produce oil and gas, and intensifying water scarcity issues in other regions. Meanwhile, the state's economy is heavily dependent on water resources. Several key industries in the state are water-intensive. Failing to address potential risks to these resources is likely to curtail future development or result in interregional conflicts, and/or excessive pressures on the environment. Water availability offers northeast Ohio a unique strategic advantage therefore it is critical that water use, reuse and discharge, as well as administrative and technical systems adapt over time to meet new conditions.

Moreover, water resource management in a sustainable manner is important to protect public health and natural systems, and to maintain the quality of life in the state for us and for generations to come. Ohio's water resources have always played a dominant role in supporting life and commerce in the state. Proximity to water resources has been a key factor in the development of almost every major city in the state. Agricultural and industrial developments have always been heavily dependent on water resources. While Ohio still enjoys abundant water resources—both in the form of surface water and ground water—water management is not problem free. One major water problem that the state faces is related to distribution: precipitation amounts are far from steady and predictable - resulting in floods and droughts.[1] According to Intergovernmental Panel on Climate Change (IPCC), NASA, EPA, National Research Council and others, the adverse effects of climate change are likely to intensify. In many cases, the solution to one dilemma leads to the creation of other problems with a competing need. For instance, while assuring water supplies during drought periods is critical, aquatic habitats and water-dependent recreational activities should also be considered. Whereas the quality of ground and surface water should be preserved, encouraging commercial and industrial development is also important.

Strategically managing and using water more efficiently will help Ohio meet current water needs while alleviating water challenges of the future. This means using the least quantity of water to accomplish a function, task, process or outcome. The use of improved technologies and best management practices can make delivery of equal or better service with less water possible. While water efficiency is closely linked to water conservation (and both are related to day-to-day water management), there are differences among the two. Water conservation includes any beneficial reduction in water use, loss or waste; it does not necessarily focus on completing a function using the least amount of water possible. For example, we can conserve water by avoiding activities or functions that use water. To make conservation realistic, we must also learn to use water efficiently.

[1] Governor's Blue Ribbon Task Force on Resources Planning and Development Report, 1994.

Water efficiency has several advantages and benefits: 1) Reducing water demand is faster, easier and less costly than any supply-side solution; 2) Decreasing water and wastewater treatment needs reduces costs and defers plant expansion; 3) Fewer surface and subsurface withdrawals alleviate environmental impacts; 4) Reduced groundwater contaminant intrusion and curtailing demand for new supplies of lower quality permits sustained water quality.

This research project was stimulated by Ohio's need to develop a program for water withdrawal management under the Great Lakes-St. Lawrence River Basin Water Resources Compact (hereafter referred to as "the Compact"). This is an important step in protecting the Great Lakes system from adverse impacts of withdrawal and excessive consumptive uses.

Water management (withdrawal and conservation) though state agencies existed in Ohio prior to the Great Lakes Compact as well. The facilities registration program began in 1988 to implement the Great Lake Charter.[2] Another relevant water management program, also instituted in 1988, was a withdrawal permit program requiring permits for withdrawals resulting in large new or increased consumptive uses, codified in ORC 1501.33-34, and a diversion permit program requiring permits for inter-basin transfers across the Lake Erie-Ohio River Basin boundary, codified in ORC 1501.32. The Ohio Revised Code section 1521.16 requires registration of groundwater withdrawal capacity exceeding 100,000 GPD. In areas where groundwater withdrawals exceed natural recharge, program staff can designate groundwater stress areas with special reporting requirements for all groundwater users.

The Great Lakes Compact requires each state to develop programs for water conservation measures to lower demand for water and reduce water waste, while allowing for reasonable use of water by land owners as the law allows in each of the Great Lakes states. Under the Compact, states must regulate proposals for significant increases and new water withdrawals and consumptive uses. The requirements of the Compact are most strict regarding uses that divert water out of the Lake Erie basin.

The Ohio Advisory Board made recommendations in three areas: establish a baseline for existing water withdrawals, diversions and consumption uses; develop water conservation and efficiency goals and objectives and a conservation program; and develop and implement a water withdrawal regulation management program.[3] Together these initiatives would provide the basis for Ohio's compliance with the Great Lakes-St. Lawrence River Basin Water Resources Compact.

The research team discovered four key aspects to Best Management Practices and the role of states through a literature and policy review:

1. Withdrawal registrations and permitting managed at the state level
2. State level plans for water security and adaptation
3. Local/regional water planning
4. Technical assistance provided by the state regarding adoption of BMPs across economic and use sectors

This report is organized to discuss these aspects as relevant for the following sectors of water use: public water supply, power generation, industrial processes, agriculture, mineral extraction, oil and gas production, and golf courses and amusement parks. These areas are featured because they are among the highest users of water in volume, often directly withdraw water from surface and ground water, and also are among the largest purchasers of water from public water systems. Their inclusion is based on both

[2] ODNR http://soilandwater.ohiodnr.gov/water-use-planning/water-withdrawal
[3] Ohio Great Lakes Compact Advisory Board, 2010.

data from the Ohio Department of Natural Resources and the North American Industry Classification System (NAICS).

GOAL, METHODOLOGY, AND ORGANIZATION OF THE REPORT

The goal of this project is twofold: 1) highlight the role that the state can play in the aforementioned four dimensions to help facilities and organizations employ water efficiency BMPs; and 2) provide a manual to be offered by the state officials to entities with the potential to undertake water efficiency BMPs.

The research process involved the development of a strategy for systematically reviewing existing sources of information and literature, including: 1) creating a framework and finalizing a methodology to research critical information on water conservation measures; 2) identifying databases, appropriate literature, sources and agency departments; 3) selecting titles, abstracts, and manuscripts based on explicit inclusion and exclusion criteria; 4) summarizing data in a standardized format; and 5) analyzing the data, discussing the preliminary results, and finalizing the results of the project. Our methodology is based on gathering and analyzing regulatory documentation, best management practices, and new technologies in the area of water use and conservation by sector. Three broad clusters of literature were included in our review: academic publications, sector-based studies, and best practices of state agencies.[4]

Water-intensive sectors were initially identified using the input-output model available in the IMPLAN software package. The model addresses inter-industry relationships and can illustrate what industrial sectors are buying from other industries in the state. In order to identify water-intensive industries, IMPLAN's technical input-output coefficients were used. IMPLAN is a proprietary input-output economic model that provides information on supply relationships (backward linkages) between industries. Two indicators signify water-intensive industries: 1) industry's total expenditure on water, measured in dollars, and 2) the ratio of an industry's expenditure on water to the industry's total expenditures, measured as unit expense on water. The indicator unit expenses on water reflect the share of electricity cost in 1 dollar of output of IMPLAN industry Water, sewage and other systems (IMPLAN industry code 33). Ohio's industries were ranked separately by each indicator: unit expense on water and industry's total expenditure on water bought in Ohio. As a result of this analysis we were able to identify industries that use the most water in the state of Ohio either by unit cost and/or as a total amount. The analysis of this data, however, does not reveal entities that have direct access to water and are able to withdraw water from those resources they have access to. Therefore, we used a second dataset provided by ODNR showing entities with the capacity to withdraw more than 100,000 gallons a day along with their actual annual withdrawal amounts. Combining these datasets allowed us to identify water-intensive industries. Ultimately, we aligned the growth potential of the most water-intensive industries with the priorities Ohio envisions in its State Targeted Industries and Regional Economic Competitiveness Strategy in order to identify key conservation mechanisms.[5]

The report is organized as follows: The first section provides a general toolkit for all entities with a potential to undertake water efficiency efforts including a self-assessment checklist, steps for a successful water efficiency program, technical and financial feasibility frameworks for BMPs, and water auditing tools and methodologies. The second section focuses on BMPs that apply to most commercial, industrial, and institutional facilities. The third section provides industry-specific BMPs for selected industry sectors based on data.

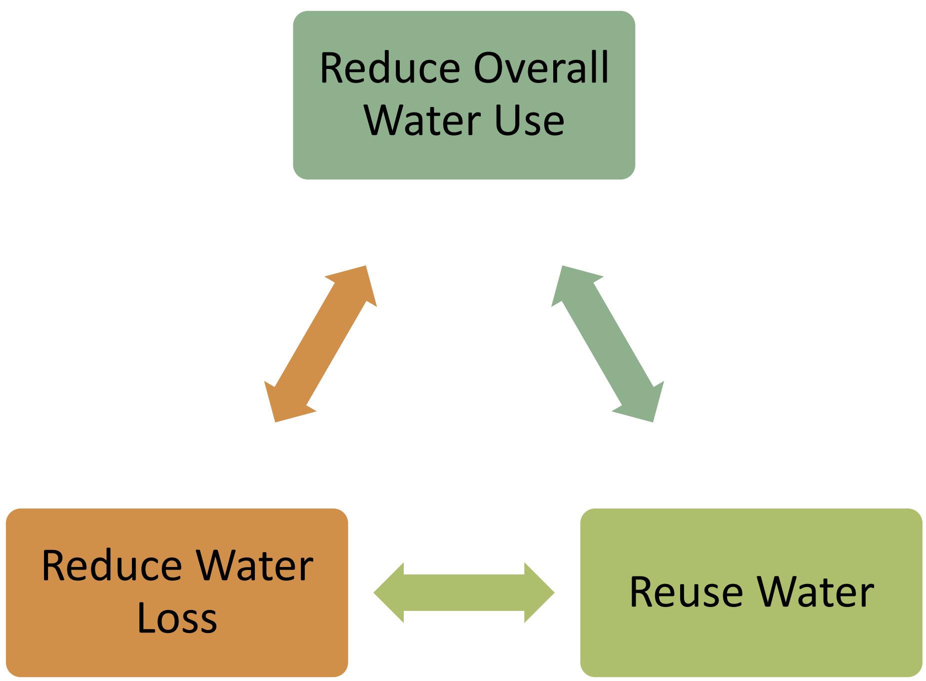
[4] The summary of relevant academic literature reviewed can be provided upon request.
[5] The results of the data analysis can be provided upon request.

GENERAL PRINCIPLES AND PRACTICES FOR SUSTAINABLE WATER MANAGEMENT

First-Mover Competitive Advantage

Start using water efficiently today and your firm will have a competitive advantage over companies that choose to wait. For a holistic approach, include water efficiency measures in your business strategic plan. Prioritize needs, set ambitious yet achievable goals, establish present performance minimums, and carefully plan for taking action.

Figure 1. **Water Efficiency Categories**



Steps for a Successful Water efficiency program

1. Set Commitment & Goals

In the initial phase, water efficiency goals can be in the form of qualitative statements and visionary commitments. Following an overall commitment, staff and resources should be allocated to measure current water use and identify opportunities and target areas for employing water efficiency measures. With this information in hand, realistic quantitative goals can be set (e.g. overall percent or number of gallons reduction in the next fiscal year). The better alternative is to use industry benchmarking information based on an operating index (e.g. gallons per pound of product manufactured).

2. Assemble Support & Resources

It is important to designate a conservation coordinator or task force leader, encourage employee participation and communicate water efficiency awareness. The task force and/or the conservation coordinator should establish a budget and funding mechanism, coordinate a water efficiency audit, oversee implementation and make periodic modifications to the program as necessary. Employee awareness and cooperation is also crucial for achieving water efficiency goals.

3. Conduct a Water Audit

A key element of any facility water efficiency program is a water audit. Prepare a water balance diagram or summary chart that shows all water use from its source through the on-site processes to evaporation and waste water discharge (total inflow equals to total outflow plus water losses). Collect necessary background site information and records, such as water and sewer bills, water meter seizes and locations. Then, conduct a walk-through survey to observe and measure water use throughout the facility using the following procedures:

- List all water-consuming equipment
- Check plumbing diagrams
- Measure water flow rates and usage
- Define water quality needs for each process
- Assess existing water-efficiency measures
- Observe shift clean-ups and process change-overs
- Identify all water losses (e.g. evaporation, leaks, etc.)
- Identify water-efficiency opportunities for each operation
- Determine the true cost of water use

4. Identify Best Water Management Practices (BMPs)

Best water management practices can be general or specific. General approaches can be applied to any type of facility, whereas specific measures are only used for certain types of facilities or industries. This manual includes detailed information about both general and specific measures. For now, we suffice to mention several general approaches to water efficiency:

- Detect unnecessary uses and fix leaks
- Consume minimum amounts of water to accomplish tasks
- Recirculate water within processes where possible
- Reuse water sequentially
- Treat and reclaim used water
- Displace potable water with non-potable where possible
- Install meters at high –flow processes and equipment
- Use pressure-reducing valves.
- Once BMPs are identified, evaluate their technical and financial feasibility to determine whether to include them in your water management plan.

5. Prepare a Plan & Implementation Schedule

Develop a water efficiency action plan that reflects a commitment of the firm and includes the following:

- The company water efficiency policy
- Measurable goals
- A summary of suggested and in-place efficiency measures
- A prioritization and evaluation framework
- A schedule for implementation and monitoring
- A list of individuals responsible for implementation
- A funding

6. Monitor Results & Publicize Success

Your successful water efficiency program deserves recognition by the community. Publicizing the success of your program helps to create good relationships with employees and the community and encourages others to get involved. Publicity options range widely from internal memos and trade publications to news releases to local media. The following tips contribute to the visibility of your water efficiency efforts:

- Encourage task force members to participate in community water conservation seminars.
- Present savings in relevant terms such as dollars, water savings per unit of product, etc.
- Exhibit and promote your program by displaying results in public reception areas, placing posters in public buildings, and developing a public relations program.
- Show how your approaches benefit the community at large

TECHNICAL AND FINANCIAL FEASIBILITY FOR BEST MANAGEMENT PRACTICES AND AUDITS

Technical and financial feasibility are among the most important criteria for making investment decisions. The BMPs proposed in this document are all technically feasible and can be cost-effective in certain situations. Whether any single BMP is suitable for each facility or organization should be assessed by the site operator or owner. This section presents a general framework for these two criteria to help managers make water efficiency decisions.
Three principles should be considered when developing or implementing BMPs:

1. **One size does not fit all:** For each sector, facility or entity, a dozen potential BMPs might exist. However, not all of them are applicable, economically or administratively feasible, or politically desirable. In some cases, employing one BMP means dismissing another—for instance, due to being applied to the same processes.
2. **Every facility is unique:** Analysis of potential benefits is unique to each facility and situation. Even for same-sector facilities - processes, equipment choices and design may vary considerably. Facilities may also be at a different stage in their water management planning. This means that one BMP that works for one facility might not apply or be desirable at another, even when in the same industrial sector.
3. **The BMPs presented here can only serve as a guide:** The goal of this report is to present a compendium of BMPs that various facilities can potentially undertake in their water management processes. This list is by no means all inclusive. Facilities should create an environment for the management team and other employees to develop innovative methods or measures for a unique water efficiency program that best fits each facility or organization.

Cost Analyses

To determine whether or not to implement BMPs some basic methodologies can be employed. Generally speaking, benefits can be compared to the short- and long-term costs of implementing a BMP. Benefits can take various forms, and can be quantitative or qualitative. The benefits that are easily and reliably quantifiable are the ones considered for cost analysis. Yet, cost analysis is only one aspect of the overall BMP evaluation for implementation. Firms may decide to undertake riskier water efficiency investments, if those investments serve other goals. Say, for instance, if proactive environmental management is likely to be influential for expanding market share, or if it is part of the organizational mission statement. These considerations are unique to each entity, and cannot be comprehensively discussed in this document. This section focuses on computational methodologies that can be employed across different sectors and entities. Examples of some quantifiable benefits include: lowering water and sewer costs, delaying development of alternative water supplies, and added productivity from a more reliable water supply. The common computation methodologies are presented below.

1. The Unit Cost of Water

When conducting a cost analysis, it is often required to compare costs based on unit costs—that is, the dollars per unit volume of water. When assessing water savings, the cost of heating water in certain processes and the cost of wastewater disposal should also be considered. This may complicate calculations because water, wastewater, and energy are measured in different units. Thus, conversion factors are a necessity.

2. Payback Period

The payback period is defined as the time it takes for an investment in efficiency to pay for itself. The simple payback in terms of years can be calculated by dividing total costs by the annual benefits. Generally, a two-year payback is deemed extremely cost-effective. Many firms may pick a three or four year payback period. Under certain conditions, firms may consider longer payback periods acceptable.

3. Return on Investment (ROI)

A metric similar to payback is return on investment (ROI): the percent of payback a BMP yields per year. ROI is 100%, in the case of a one year payback. If the payback is in 2 years, the ROI equals to 100%/2 or 50% a year.

4. Internal Rate of Return (IRR)

The internal rate of return (IRR) is often an indicator of the efficiency, profitability or desirability of an investment. The higher a BMP's internal rate of return, the more desirable it is to undertake it. As such, IRR can be used in the process of selecting or prioritizing BMPs. IRR is the effective annual interest rate at which an investment produces income. The IRR is typically compared to the interest rate on borrowed funds or the potential rate of return from other investments. The investment is generally deemed worthwhile, if its IRR is greater than the firm's cost of capital, expected rate of return, or discount rate. However, IRR is only useful to determine if a single measure is worthy of implementation; it cannot be used for evaluating mutually exclusive projects. In the case of complex series of cash flows (that are likely to change signs multiple times), there is more than one mathematical solution.

5. Net Present Value (NPV)

Net present value (NPV) is one of the most common financial metrics utilized in capital budgeting. NPV is the sum of the present values of all costs and benefits over a period of time reported at the launch of the project. Present value converts future cash transactions into equivalent values in the present taking into account the time value of money. NPV is more appropriate for long-term investments and has several advantages over payback period and ROI metrics--including the consideration of time value of money, the useful life of a new item, complex variations in annual costs and benefits over time, and residual effects at the end of the useful life. It is important to note that the financial analysis for water efficiency investment is highly reliant on how the cost saving and/or revenue generating factors are bounded and applied to the analysis. For example, an analysis bounded narrowly may only consider the cost of water supply, while more progressive approaches may also include factors such as, community good will, reduced liability, projected gains in market share, employee morale improvements/worker productivity, or reduced operating costs.

Financial and Economic Analyses

Financial and economic analyses are similar, but distinct, methods for evaluating whether a project is worthwhile. The emphasis of a financial analysis is on cash flow; the goal is to remain at least financially whole, if not better off. The focus of a financial analysis is a single entity, such as a single industrial facility. Economic analysis, on the other hand, goes beyond the perspective of a single entity and extends to the community or society as a whole. Individual entities may not be able to assess the full range of impacts their interventions can potentially have on the community. However, in certain conditions, some impacts on the community can be predictable and may be considered in evaluating BMPs.

The recommended economic screening measure for water management BMPs is a cost-effectiveness evaluation. This measure puts capital and operating programs on an equal footing. It considers ongoing operating costs or savings of some BMPs and considers the cost of tying up resources in capital improvements. Cost-effectiveness is similar to cost-benefit analysis. The difference is that cost-effectiveness accounts for the outputs produced by a project, which are not measured in monetary terms. For example, cost-effectiveness may be used in reporting the efficiency of healthcare interventions—where the intervention is typically assessed in terms of lives saved, illnesses prevented or years of life gained. In the case of water management BMPs, cost-effectiveness allows facility operators or owners to compare annual costs per gallons of water saved to a broader spectrum of benefits. This enables managers to ensure that the greatest water savings is achieved for a given expenditure.

Individual facilities may typically include capital costs of implementing the BMP, changes in operation and maintenance costs and labor costs associated with them, expectable usable life of the measure and modified risk factors. In addition to these factors, however, there are other long-term trends that are worthy of consideration in BMP evaluation. A number of these factors are easily quantifiable and thus can be directly included in the cost analysis. Others, on the other hand, are nonmonetary benefits or considerations that should be weighted along with the cost analysis. Some of the common long-term considerations are listed in Figure 2.

Figure 2. Long Term Considerations for Financial and Economic Analyses

Increased Water and Wastewater Rates

- An increased demand for water and wastewater services may require development of costly water and wastewater infrastructure--which will eventually be reflected on business costs. In the long run, water efficiency efforts may reduce business costs significantly. Water intensive industries are more likely to feel the greatest impacts of this type. While several factors influence water and wastewater rates (e.g. supply, operational and capital costs, employee salaries, etc.), rate prediction is not a reliable option. Water efficiency reduces demand and the need for costly water-and wastewater-related developments.

Increased Energy Rates

- Energy and water are interdependent. Pressures on water resources are likely to be reflected in energy prices. Energy costs are increasingly becoming an important component of business' bottom line. Water efficiency measures oftentimes can reduce energy costs in the short run. In the long run, water efficiency can reduce expected increases in energy costs.

Co-benefits of Water Efficiency

- Water management BMPs often have co-benefits beyond water savings. More water per process, output or product oftentimes means more energy, chemical, wastewater, maintenance and the like. Water savings can thus result in savings of other factors influencing business costs. For example, replacing outdated equipment for the purpose of water efficiency can actually result in energy, chemical, wastewater and even operational and maintenance costs.

Reliability of Water Supply Risks

- The long term profitability or operation of a water-dependent firm can be influenced by the local or regional water supply quantity and quality, and the risk of possible disruptions in water supply. Thus, the reliability of water supply and its impacts on business operations and profitability should be considered in the evaluation of BMPs.

Reputational Risks and Benefits

- Water efficiency is an important component of environmental stewardship. The steps an entity takes to become water-efficient reflects environmental commitment. In today's economy, many firms and organizations strive to maintain an active presence, a good reputation and strong relations with local, regional, national and even global communities. Water efficiency efforts can thus be viewed as an opportunity to maintain, reinforce or improve reputation and relationships.

SELF-ASSESSMENT CHECKLIST

Where does your firm stand on water efficiency? It is likely that your firm has already taken some water efficiency measures. The following are several questions that can help gauge your facility's current water efficiency performance.

Management Commitment and Resources

- Is water efficiency incorporated into your firm's environmental policy statement or mission statement?
- Is water management a strategic priority for your organization?
- Are water efficiency responsibilities delegated?
- Are measurable goals set and monitored?
- How is your water efficiency program communicated to employees?
- What incentives and/or feedback loops exist for employee involvement, innovative input and heightened awareness?
- Is your facility taking advantage of available help and resources from your utilities, assistance programs, vendors or consultants?
- Do you have a water management plan?
- Are employees trained on water efficiency practices?

Water Efficiency Survey

- Can you identify the actual breakdown of your water uses: cooling and heating, domestic uses, process rinsing, cleaning activities, kitchens, laundries, landscaping, water treatment regeneration, evaporation, leaks and others?
- Do you know your life cycle water costs: for example - supply water, wastewater treatment, sewer/discharge and heat and mechanical energy losses?
- Are you taking simple measures to use water efficiently such as leak inspections, eliminating unnecessary uses, using low flow devices and timers? Are these practices institutionalized?

Identifying Opportunities and Target Areas for Water Efficiency

Domestic

- Have you installed water-efficient commodes, faucet aerators and low-flow showerheads?

Heating and Cooling

- Have you eliminated once-through cooling water (used in air conditioners, air compressors, etc.) by using chillers, cooling towers or air-cooled equipment?
- Have you optimized blow-down/bleed-off control on boilers and cooling towers?
- Do you reuse condensate?

Process Rinsing and Cleaning

- Do you take advantage of improved rinsing techniques such as counter-current systems, sequential use from high quality to lower quality needs, conductivity flow controls, improved spray nozzles/pressure rinsing, fog rinsing or agitated rinsing?

- Do you turn off water when not in use by flow timers, limit switches or manually?
- Is the life of an aqueous bath being maximized through filtration and maintenance control?
- Do you use "dry clean-up" practices in lieu of hosing down and is first-pass pre-cleaning conducted with squeegees, brushes or brooms?

On-site Water Reuse

- Do you match water quality with water quantity?
- Have you considered reuse applications for process water, landscaping irrigation, ornamental ponds, flush water and cooling towers?

Landscaping

- Do you use low-flow sprinklers, trickle/drip irrigation, optimized watering schedules and water placement, preventive maintenance and xeriscaping techniques?

Kitchens

- Have you installed "electric eye" sensors for conveyer dishwashers?
- Have you considered installation of new water and energy efficient dishwashers?

Water Efficiency Action Plan

- Have you performed a cost-benefit analysis to identify water efficiency opportunities?
- Have you developed a prioritized implementation schedule?
- Are water users informed of the changes as a result of implementing the plan?
- Are there mechanisms to encourage and utilize employee feedback and input?

Monitoring and Communicating Results

- Do you post water consumption rates to your employees and management regularly?
- Are your water efficiency accomplishments being recognized through case study articles, media coverage, mentoring to other businesses, business environmental exchange programs or in award programs?

AUDITING METHODOLOGY AND TOOLS

Any water efficiency program starts with a facility water audit or survey. This section offers supplemental material and tools for the water auditors to conduct a survey. It is important to collect key information about the facility's water use before conducting a walk-through survey with the facility personnel. The Water Survey Tool at the end of this section includes background information that should be collected and recorded--ranging from location and size of the facility to inventories of water-using or-saving equipment and fixtures. During the walk-through survey -observe, measure and record:

- Hours of operation for the equipment in the facility
- Water flow and quality for each use as well as parameters such as temperature, PH, total dissolved solids and biochemical oxygen demand
- The actual amount of water being used
- Water quantity and quality specified in the equipment operating manuals

- Flow and quality of wastewater resulting from each use
- Volume of unaccounted for water (a sign of leaks)
- Internally generated fluids (e.g. water may be generated as a byproduct of certain processes).

Figure 3. Measuring In-Plant Water Usage

Submetering

Bucket & Stopwatch

Micro-weirs

Measuring In-plant Water Usage

Submetering is a very good method to precisely account for large water uses for various processing equipment. Submetering familiarizes the personnel with water use for all operations and helps them identify unnecessary water uses by equipment. Use the actual flow rather than the pipe size to obtain the proper size for a submeter. Install temporary strap-on meters to determine the approximate flow and whether it will be cost-effective to install permanent meters.

Bucket and stopwatch is another simple and accurate measurement method. To use this tool, the amount of process water for a specific time period should be collected (e.g., one quart per minute, which is equivalent to 0.25 gpm). This tool can also be used to determine leak loss.

Micro-weirs are small hand-held weirs commonly used in tight spaces to measure low flows of water (i.e. 0.5 to six gpm).

Water Survey Tool

The goal of this survey tool is to help auditors collect data. Please note that some items may not be applicable to your specific case.

Assessment Information	Company name Date of assessment
	Address
	Phone/FAX Lead assessor
	Company contact person/title
	E-mail address
	Assessment team members
	Assessment objectives Special concerns
Water Use Background Information	Average water use/bill (for previous year)
	Average water use/bill (for year before last)
	Size and location of meter(s)
	Primary water source
	Secondary water source
	Potential to reduce meter size? Savings
	Should credit be obtained for water that does not go to the sewer? (cooling towers, landscaping)
	Is an additional meter required to monitor water not being sewered?

*Table 1.*Water Balance and Costs

Source of water use	Gallons per year (est.)	Percent of total	Water cost ($/yr)	Sewer cost ($/yr)	Energy/other costs (4/yr)
Domestic					
Heating/cooling					
Rinsing/cleaning					
Landscaping					
….					
….					
….					
….					
….					
Unaccounted for					
Total					

Firm Background Data		
	Number of employees	
	Shifts per day	Operating days/week
	Size of and type of plant (sq. ft.)	
	Year built/renovated	
	Business type (manufacturing, college, office, etc.)	
	If manufacturing, list products and annual production rate	
	If service or institutional sector, list clients, occupancy rates, meals served per year, etc.	
	Other pertinent facility data	
	Current and past water efficiency program measures (policies, training, awareness and goals)	

System Parameters	Number, types and sizes of buildings at complex
	Grounds (approximate size in acres) Garages/motor pool/support buildings (approx. sq. ft.)
	On-site water treatment description, rate and costs
	Wastewater treatment description, rates and operating costs
	Notes
Manufacturing Processes Water Use	Volume used directly in product, per year
	Description of water used in processing
	Volume used in production
	Notes

Washing, Rinsing and Sanitation	Volume used in cleaning, rinsing and sanitation
	Description of washing and sanitation processes
	Number of mop sinks, etc.
	Have improved rinsing techniques (such as counter-current systems, conductivity flow controls, improved spray nozzle/pressure rinsing, etc.) been considered?
	Are "dry clean-up" practices used instead of hosing down and first-pass pre-cleaning conducted with squeegees, brushes or brooms?
	Is water cut off when not in use by flow timers, limit switches or manually?
	Notes
Heating and Cooling	Description of cooling tower evaporative coolers (rated tonnage, types and uses)
	Water rate used in cooling towers and equipment
	Is condensate being reused?
	Description of once-through cooling requirements
	Volume used in once-through cooling (air conditioners, air compressors, vacuum pumps, rectifiers, hydraulic equipment, degreasers, etc.)
	Or has once-through cooling water for these uses been eliminated through use of chillers, cooling towers or air-cooled equipment?
	Has blow-down bleed-off control on boilers and cooling towers been optimized?
	Notes

Domestic Water Uses	Toilets (number, type and tank volume)
	Urinals (number and volume)
	Lavatory sinks (number and estimated flow)
	Showers (number and estimated flow)
	Are water-efficient commodes (1.6 gpf), faucet aerators (0.5-1.0 gpm) and low-flow showerheads (2.5 gpm) in use?
	Notes
Landscaping and Outdoor Water Use	Landscape irrigation (estimated gallons per unit of time)
	Acreage/square footage landscaped and description
	Watering/irrigation system techniques and schedule
	Are low-flow sprinklers, trickle-drip irrigation, optimized watering schedules and water placement, preventive maintenance and xeriscaping techniques in place?
	Notes

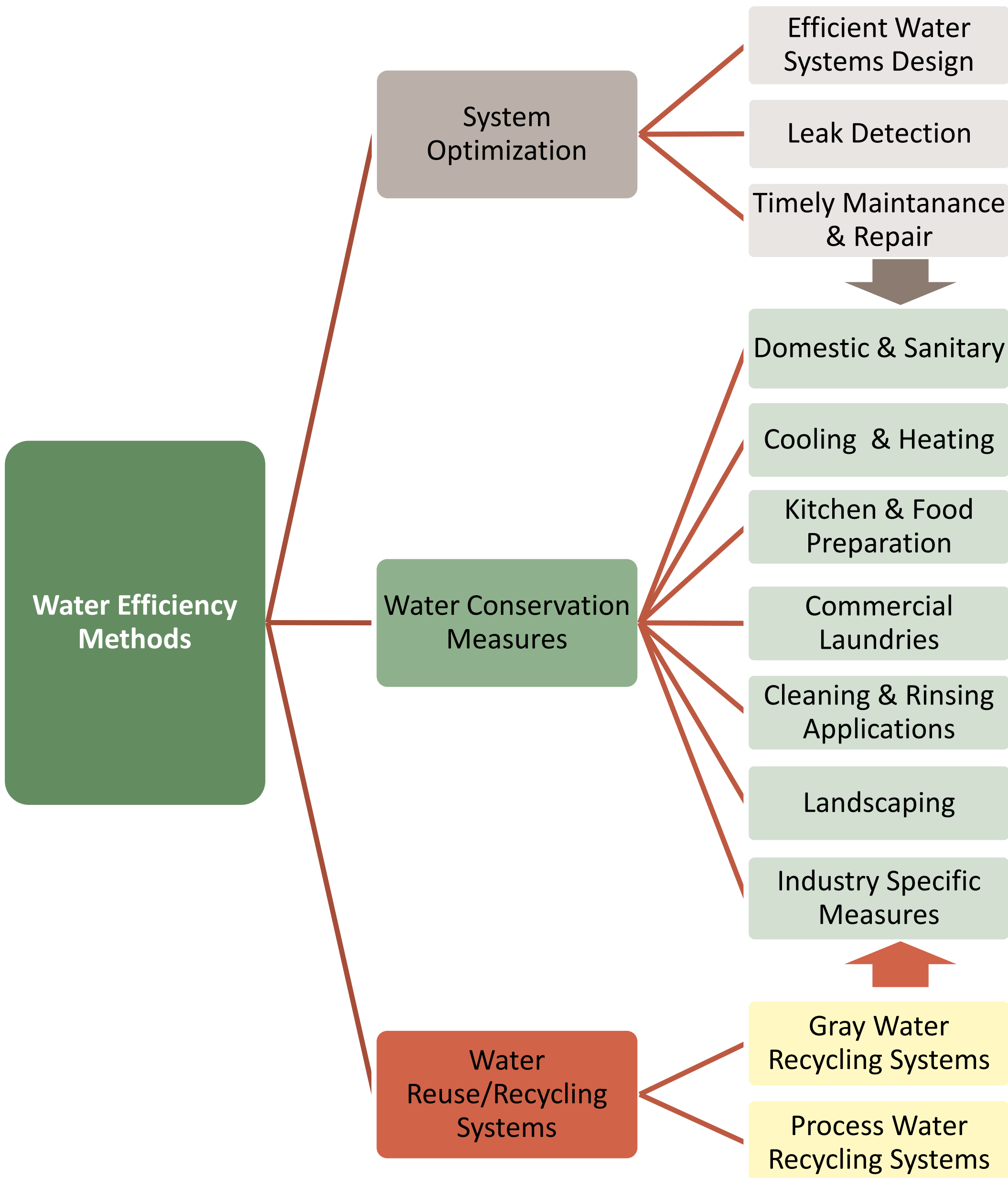
Kitchen and Canteen	Dishwasher(s) description, use and volume
	Kitchen faucet/pre-rinse sprayers [number and flow rate (gpm)]
	Icemakers, air-or water-cooled and water usage
	Garbage disposals in use
	Are "electric eye" sensors for conveyor dishwashers installed?
	Have new and water- and energy-efficient dishwashers been considered for future purchse?
	Notes
Other Water Uses and Losses	List any quantifiable leaks and estimated rates)
	Any other miscellaneous uses of water (car washes, wet scrubbers, ornamental ponds, dust control, etc.)
	Notes

Additional Needs	Factors that could affect, increase or decrease water use
	Any other major opportunities and assessment opportunities revealed, including Energy efficiency Lighting Heat recovery Solid waste reduction Pollution prevention

WATER USE BEST MANAGEMENT PRACTICES FOR COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL FACILITIES

There are multiple strategies to use water more efficiently in commercial, industrial and institutional facilities. Some strategies are specific to certain facilities or processes, while others are more general and can be employed across different types of facilities. Generally speaking, there are three major types of methods to use water efficiently and by extension eliminate the need to withdraw more water. These methods and their categories are illustrated in Figure 4.

Figure 4. **Water Efficiency Methods for Commercial, Industrial, and Institutional Facilities**



SANITARY/DOMESTIC USES

It might seem that water use and cost savings achievable through efficiency measures are negligible in commercial and industrial facilities. While sanitary and domestic uses are not typically among the highest use operations in these facilities, water efficiency measures can be taken easily and cost-effectively for sanitary and domestic uses.

***Figure 5.* Sanitary and Domestic Uses**

	Toilets	Urinals	Faucets & Showerheads
Basics	Two basics types of toilets on the market: 1) Tank-style; 2) Flush-valve, also known as flushometer.	Two types of urinals in the market: 1) flush valve urinals; 2) non-water-using urinals with a cartridge on the bottom.	Can be equipped with a flow-restriction device that controls the amount of water delivered through the fixture. There are two main types of flow restrictors: 1) aerator flow restrictors and; 2) laminar flow restrictors.
Regulatory Performance Reauirements	The Energy Policy Act of 1992 requirement: Tank-type toilets manufactured and sold after 1994 should use no more than 1.6 gallons per flush, or gpf. Likewise, flushometer valve-type toilets must use no more than 1.6 gpf.	The EPAct of 1992 requirement: Urinals manufactured after 1997 must use no more than 1.0 gallon per flush.	Requirements set in EPAct of 1992: Public lavatory faucet (e.g. office buildings) must use no more than 0.5 gpm (at 60 psi), and public lavatory faucet metered 0.25 gallon per circle. Showerheads must use no more than 2.5 gpm (at 80 psi).
Efficiency Options	Good operations and maintenance practices; retrofit; replacement with High Efiiciency Toilets (HETs)	Good operations and maintenance practices; retrofit; replacement with High Efficiency Urinals (HEUs)	Good operations and maintenance practices; retrofit; replacement with flow rates lower than maximums listed above.

Table 2. Water Efficiency Upgrade Summary for Domestic Applications

Water Efficiency Upgrade Summary: Domestic Applications				
Fixtures	**Styles/Flow Rates**	**Ages**	**Water Efficiency BMPs/Water Saving Estimates**	**Notes**
Toilets Flushometer Type	Flushometer 1.6 gpf	Post 1994	Install dual flush valve. Saves 20% (0.3 gpf average savings)	User education suggested. Consider HET for new applications.
	Flushometer 3.5 gpf	1977 to early 1990s	Install new HET or 1.6 gpf ULF models. Saves 1.9-2.2 gpf. Consider valve inserts. Save 0.5 gpf.	Must change both bowl and valve.
	Flushometer 4.5 gpf	Pre-1980s	Install 3.5 gpf valve retrofit with no charge to china bowl. Saves 1.0 gpf. Examine dual flush valves.	Flushometer valves used in commercial high use areas. Not recommended by OEM.
Toilets Tanks Type	Tanks-type Gravity-1.6 gpf	Post 1994	Consider HET for replacements or new applications.	Look for EPA WaterSense labeled HETs.
	Tanks-type Gravity-3.5 gpf	1977 to mid-1990s	Install HET or 1.6 gpf gravity/pressurized flush models. Saves 1.9-2.2 gpf. Consider early closing flapper. Saves 0.5-1.0 gpf.	Displacements devices/dams not typically recommended for 3.5 gpf units. Adjustable for quality performance.
	Tanks-type Gravity-5.7 gpf	Pre-1980	Install HET or 1.6 gpf gravity flush or pressurized flush models. Consider dams, displacement devices or early closure flapper. Saves 0.75-2 gpf.	Consider pressurized tank systems for high use areas. Do not use bricks. Loose granules inhibit flapper performance.
Urinals	Flushometer 1.0 gpf	Post 1994	Consider HEU at time of replacement. Saves 0.5 gpf	Urinals available as low as 0.125 gpf.
	Flushometer 1.6 gpf		Install repair valves to 1.0 or 0.5 gpf for non-pooling styles. Saves 0.6-1.1 gpf.	For non-pooling styles
	Flushometer 3.0 gpf		Replace urinal fixture and retrofit valves to 1.0 gpf or HEU. Saves 2.0 gpf.	
Showerheads	2.5 gpm	Post mid-1990s	Replace with lower flow showerheads available down to 1.5 gpm. Saves 1.0 gpm.	Energy savings can be two times water savings.
	3-5 gpm	Post 1980	Install 2.5 gpm or lower showerheads.	
	5-8 gpm	Pre-1980	Install 2.5 gpm showerheads.	
Kitchen Faucets	2.2 gpm	Post 1994	Install aerators to reduce flow to 2.5 gpm.	No less than 2.5 gpm for kitchen applications. Yields energy savings.
	3-7 gpm	Pre-1980		
Lavatory Faucets	2.2 gpm	Post 1994	Install 0.5 faucet aerators for public restroom applications.	Yields energy savings. Consider sensor-controlled or metered 0.5 gpm aerators are industry standards for public restrooms.
	3-7 gpm	Pre-1980	Install aerators to reduce flow to 1.0 gpm or as little as 0.5 gpm.	

COOLING AND HEATING

Some of the largest water use in industrial and commercial facilities can be attributed to cooling towers. For example, air conditioning systems and a wide range of industrial activities generate excess heat that is absorbed and transferred by cooling towers. Often times, cooling towers operate at once through open systems. Despite the fact that water cycles through a closed loop cooling tower, approximately 20 to 30 percent and sometimes even more of the total facilities' water is consumed in cooling towers. Therefore, best management practices applied to cooling towers can result in significant water savings. Figure 6 below shows a description of water consumption and water balance in cooling towers.

***Figure 6.* Cooling Tower Water Balance**

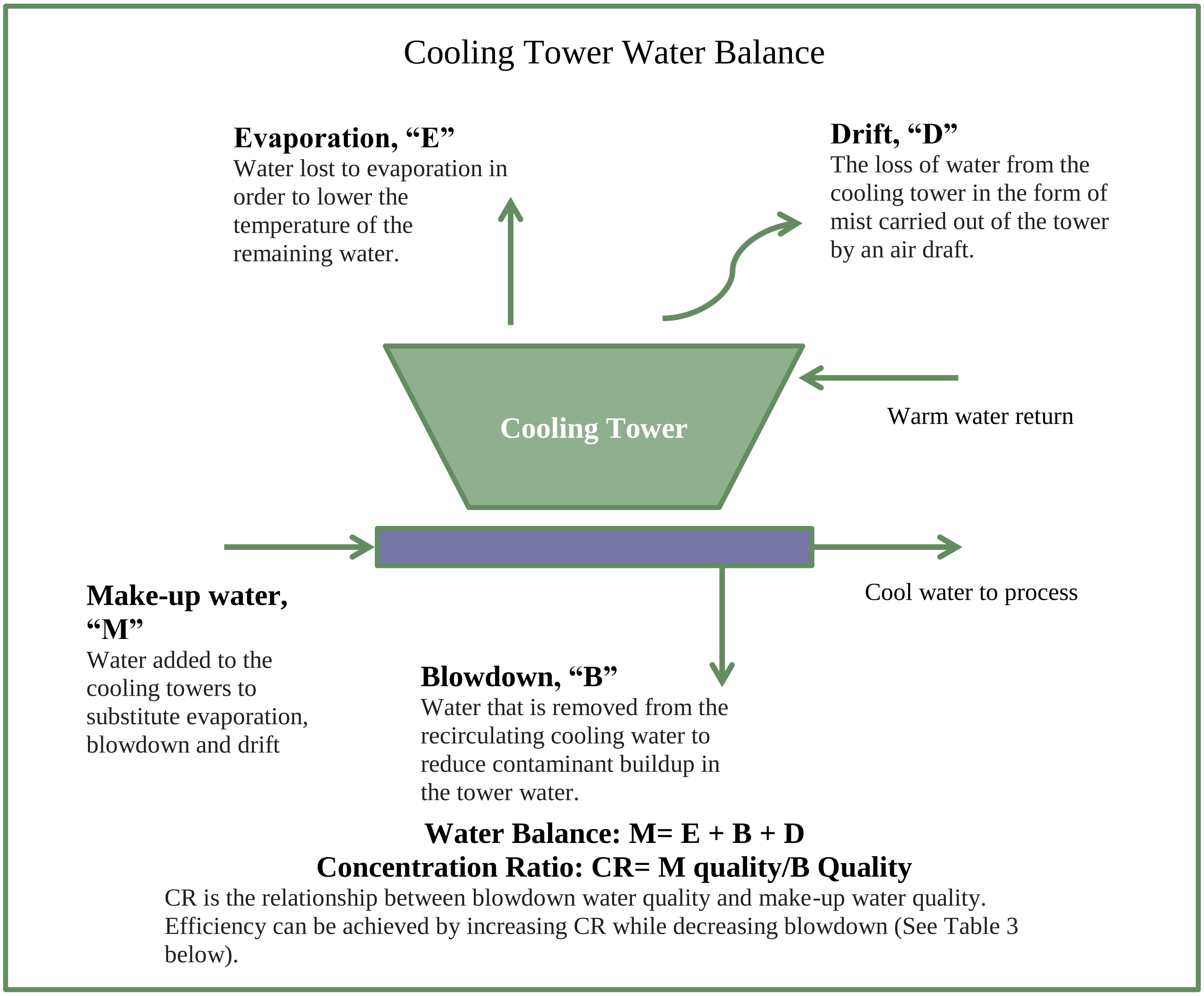


Table 3. **Percent of Make-up Water Saved**

Initial Concentration Ratio*	New Concentration Ratio										
		2	2.5	3	3.5	4	5	6	7	8	9	10
	1.5	33%	44%	50%	53%	56%	58%	60%	61%	62%	63%	64%
	2	--	17%	25%	30%	33%	38%	40%	42%	43%	44%	45%
	2.5	--	--	10%	16%	20%	25%	28%	30%	31%	33%	34%
	3	--	--	--	7%	11%	17%	20%	22%	24%	25%	26%
	3.5	--	--	--	--	5%	11%	14%	17%	18%	20%	21%
	4	--	--	--	--	--	6%	10%	13%	14%	16%	17%
	5	--	--	--	--	--	--	4%	7%	9%	10%	11%
	6	--	--	--	--	--	--	--	3%	5%	6%	7%

*Concentration ratio is the relationship between blowdown water quality and makeup water quality. This ratio can be calculated through dividing total dissolved solid of blowdown by total dissolved solid of make-up water.

Table 4. **Water Efficiency and Treatment Options Summary for Cooling Towers**

Water Efficiency and Treatment Options Summary: Cooling Towers

Option	Advantages	Disadvantages
Operation improvements to control blowdown and chemical additions	Low capital costs Low operating costs Low maintenance requirements	None
Sulfuric acid treatment	Low capital costs Low operating costs Increased concentration ratio, when alkalinity limited	Potential safety hazard Potential for corrosion damage if overused
Side stream filtration	Low possibility of fouling Improve operation efficiency	Moderately high capital cost Not effective on dissolved solids Additional maintenance
Ozonation	Reduced chance for organic fouling Reduced liquid chemical requirements	High capital investment Complex system Possible health issue
Magnet System	Reduce or eliminate chemical usage	Cutting-edge technology Controversial performance claims
Reuse of water within the facility	Reduces overall facility water consumption	Potential for increased fouling, scale or corrosion Possible need for additional water treatment

Boilers

Table 5. **Maximum Recommended Concentration Limits**

Maximum Recommended Concentration Limits			
Boiler Operating Pressure (psig)	**Total Dissolved Solids (ppm)**	**Total Alkalinity (ppm)**	**Total Suspended Solids (ppm)**
0-50	2,500	500	--
50-300	3,500	700	15
300-450	3,000	600	10

Table 6. **Best Management Practices for Boiler Blowdown Optimization**

Best Management Practices for Boiler Blowdown Optimization
Monitor blowdown rates, feedwater quality and blowdown water quality.
Consult with experienced vendors and boiler service providers to determine best water treatment program to complement water efficiency goals.
Establish maximum boiler water contaminant levels.
Estimate cost and operation savings in water use, heat loss and chemical loss that can be accomplished by modifying concentration ratios.
Evaluate implementing systems to continuously monitor and blowdown boiler water.

KITCHEN AND FOOD PREPARATION

Table 7. **Commercial Kitchen/Cafeteria Operations**

Commercial Kitchen/Cafeteria Operations						
Equipment	**Type**	**Water Use**			**Savings Potential**	**Notes**
		Traditional	Existing Standards	High Efficiency		
Commercial Dishwashers	Undercounter	1-1.8 gal/rack	No standard	1 gal/rack	Up to 0.8 gal/rack	Machines with an overall height of less than 36"; rack of dishes remains stationary within machine during sequential wash and rinse sprays. High temp machines are most water efficient.
	Stationary Single tank Door	1.1-2.2 gal/rack	No standard	0.95 gal/rack	Up to 1.2 gal/rack	Includes machines commonly referred to as pot, pan and utensil washer. Also applies to machines in which the rack revolves on an axis during the wash and rinse cycles. High temp machines are the most water efficient.
	Single Tank Conveyor	0.7-1.4 gal/rack	No standard	0.7 gal/rack	Up to.7 gal/rack	A single tank conveyor machine has a tank for wash water followed by a final sanitizing rinse and does not have a pumped rinse tank.
	Multi-tank Conveyor	0.54-1.2 gal/rack	No standard	0.54 gal/rack	Up to 0.58 gal/rack	Machines with one or more tanks for wash water and one or more tanks for pumped rinse water. Followed by a final sanitizing rinse.
Pre-rinse Spray Valves	Handheld hose-mounted dish sprayers	2-5 gpm	1.6 gpm at 60 psi		0.4-3.4 gpm	
Commercial Steam Cookers	Compartment Steamers	25-35 gal/hr	No standard	Energy Star cookers average 2 gal/hr	Up to 33 gal/hr	

Table 8. **Best Management Practices for Dishwasher Water Efficiency**

Best Management Practices for Dishwasher Water Efficiency
Behavioral Changes
Educate staff about the benefits of water efficiency and the importance of hand scraping before loading a dishwasher.
Instruct staff to quickly report leaks and troubleshoot.
Run rack machines only if they are full.
Try to fill each rack to maximum capacity.
Mechanical Changes
Reuse rinse water to pre-rinse or wash dishes.
Install advanced rinse nozzles.
Install "electric eye sensors" to allow water flow only when dishes are present.
Install door switches for convenient on/off access.
Check voltage of booster heater to make sure it fits the machine.
Use "steam doors" to prevent loss of water due to evaporation.
Check volumes of service and estimate facility needs. A better option may be a larger machine that has a lower water flow per rack rate

Table 9. **Best Management Practices for Kitchen Faucets, Pre-rinse Sprayers, Ice Machines, & Garbage Disposals**

Best Management Practices for Kitchen Faucets, Pre-rinse Sprayers, Ice Machines, & Garbage Disposals
Adjust flow valve to reduce water flow.
Check for leaks and worn gaskets.
Install a flow restrictor to limit maximum flow rate to 2.5 gpm or less.
Install a 2.5 gpm faucet aerator, maximizing flow efficiency by increasing airflow to the stream.
Consider infrared or ultrasonic sensors that activate water flow only in the presence of hands or some other object.
Install pedal operated faucet controllers to ensure valves are closed when not in use.
Educate staff to look for leaks and broken faucets in their area.
Do not leave faucets on to thaw vegetables and other frozen foods.
Install high-efficiency pre-rinse sprayers that use 1.6 to 2.65 gallons of water per minute and have an automatic shut-off valve at the hose head to supply water as needed.
Install air-cooled ice machines that use ten times less water than water-cooled machines.
Balance ice quality, machine cleaning and water efficiency for optimum operation of ice machines.
Minimize or eliminate garbage disposals use from kitchen operations. Employ one of the two options: 1) Use strainers or traps that have a mesh screen to collect food waste for proper waste treatment; 2) Install strainers in sinks, leaving the food matter in the sink for disposal in trash receptacles or composing units.
Post water conservation tips and reminders to staff around work areas.

Cleaning and Rinsing Applications

Table 10. **Best Management Practices for Cleaning and Rinsing Applications**

Best Management Practices for Cleaning and Rinsing Applications
Dry Clean-up
Sweep floors instead of hosing them with water.
Vacuum or sweep dry material spills such as salt or dyes and particulate emissions (dust) instead of using water.
Use squeegees and scrapers first to remove residuals from machines, such as ink sludge from machine troughs between color change-overs.
Use rubber squeegees to collect food processing residuals from the floor before hosing with water.
Use "pigs" to purge residuals from pipes before flushing with water.
Eliminate/Reduce Floor Washing by: • Finding and eliminating the source of spills and leaks that create a need for washing. • Spot mopping when necessary. • Using floor mats, "clean-zones" and other means to reduce the tracking of waste and dirt residuals in the facility.
Efficient Spray Washing/Rinse
Avoid using a hose as a broom; it is a waste of valuable labor, water and energy.
Use efficient spray nozzles with automatic shutoffs on the end of hoses.
Consider high-pressure washers to clean more quickly and efficiently.
Consider pressurized air-assisted spray nozzles to provide more cleaning force with less water.
Use low-flow "fogging" nozzles to rinse parts efficiently.
Put flow restrictors in water lines that supply hoses and pressure washers.
Use timers to shut off process water rinses when process is shut down.
Turn off running water when not in use.
Ensure stationary spray nozzles are aimed properly.
Review nozzle spray patterns for optimum application. Fan, cone, hollow cone, air atomizing, fine spray and fogging are a few examples of nozzle spray patterns.
Replace worn spray nozzle heads. They can result in poor spray patterns and excessive water consumption.
Use countercurrent washing techniques.
Use conductivity controllers to regulate rinse water flow rates.
Use spray washing/rinsing techniques for tank cleaning vs. refilling/dropping tank wash-water.
Other Improvements to Cleaning Process
Use Teflon surface coated tanks, vats, pipeline and other equipment for easier cleaning during process line changeovers and clean-up.
Take advantage of changes in the type, temperature and concentration of cleaning solutions to save water.

Figure 7. **Benefits of Dry Cleaning**

Did You Know that by Dry Cleaning You Can Save Water while…

LANDSCAPING

Figure 8. **Best Management Practices for a New or Revised Landscape Project**

A) Planning & Design

- Place plants in groups according to their respective water needs (hydrozoning), and design an irrigation system that properly matches the needs of the plants, soils and weather conditions.
- Incorporate high water demanding plants at the bottom of slopes.
- Minimize the use of impervious surfaces to reduce runoff and subsequent stormwater pollution.
- Consider using porous materials such as porous concrete or permeable paving methods.
- Consider grading and directing surface run-off and rainfall gutters to landscaped areas as opposed to drainageways that exit the property.

B) Soil Analysis & Improvement

- Organic matter such as compost, mulch or manure increases the water holding capacity of soil and can help improve water distribution.
- When improving the soil of a given area, it is important to treat a large area around the planting to allow ample space for root systems.
- Do not allow heavy construction equipment to compact soil around existing trees or other sensitive natural areas.

C) Proper Plant Selection

- Plant native species to reduce maintenance costs and benefit from their ability to develop symbiotic relationships with other native plants.
- Pay attention to the water demand, pest tolerance, soil nutrient, and drainage requirements of plants when selecting them.
- Choose plants based on soil testing that helps determine soil quality, nutrients present and absorptive capacity.

D) Proper Turf Areas

- Remember turf grass has the highest water consumption of any plant type. Plant grass only when it will provide optimal functional and aesthetic benefits.
- Avoid very small turf areas (under 10 feet wide).
- For optimum water use turf grass should be cut to the maximum recommended height of its type.
- When possible, plant alternative groundcovers that require less maintenance and water.
- In the summer, water turf less frequently but deeply (instead of frequent light watering) to promote deep root development.

E) Efficient Irrigation

- Install automatic controllers to save labor and deliver water when needed. Adjust controllers regularly for weather changes and plant growth.
- Use drip irrigation and microsprays that spread water at the base of the plant to minimize evaporation and save water by not wetting the entire ground surface.
- Ensure the uniformity of the water being applied by the irrigation system.
- Use automatic systems with rain shut-off devices.
- Be cautious of overspraying that covers concrete or other impervious areas.
- Do not overwater landscape.

F) Proper Maintenance

- Mow grass at a proper height. Do not remove more than one-third of the leaf blade during mowing.
- Regular aeration of clay soils will improve water holding capabilities and prevent runoff.
- Monitor irrigation schedules to replace evapotranspiration (i.e. the sum of evaporation and transpiration).
- Analyze the soil several times during the season to be sure nutrient levels are maintained.
- Inspect, adjust and replace sprinkers, filters, valves and emission devices for proper operation once a month.

Figure 9. **Best Management Practices for Existing Landscapes**

A) How to Water

- Water in the early morning or late evening in order to maximize absorption and minimize evaporation.
- Water only when wind is less than 10 miles an hour.
- Be sure irrigation system is balanced, especially in turf areas. A balanced or matched system provides the same precipitation rate whether using a quarter inch circle pop-up spray head or a full circle rotor type sprinkler.
- Maintain a record of the amount of rainfall at various locations throughout the facility and adjust the operating time of the irrigation system to replace the evapotranspiration minus the weekly rainfall.
- Ensure the sprinklers are not over-spraying buildings, sidewalks or pavement.

B) Amount of Water Plants Require

- Assess the characteristics of a site through a water audit. Audits evaluate the specific water needs and conditions of an existing site.
- Consider that every square foot of watershed hardscape can shed more than 25 gallons of irrigation water every year.
- Use evapotranspiration data to help determine a plant's water needs.
- Water deeply once or twice a week instead of lightly every day.
- To prevent runoff or deep percolation below the roots, never apply water faster than the soil can take it in or more than the soil can hold.

Maximum Sprinkler Run Time (Minutes Per Application)

Soil Type	Sprinkler type	
	Spray	Rotor
Sand	15-20	45-60
Loam	10-15	30-45
Clay	7-10	20-30

C) System Maintenance Considerations

- Use the same size nozzle and same brand of sprinklers when replacement is needed.
- Ensure spray heads are aligned with grade and do not operate on the same valve with rotors.
- Regulate pressure properly for system demands.
- Many times a rotor or spray head will be mounted incorrectly in an attempt to cover a greater area. Replace with proper unit for the job.
- Check for leaking valves.
- Inspect low-volume emitters for any stoppage.
- Inspect sprinklers for clogged nozzles distorting the spray pattern.

D) Irrigation System Operations

- Consider adding a rain shutoff device to your automatic irrigation control system.
- Consider alternative sources for irrigation water, including the use of wells as opposed to city water, water reuse options from air conditioning condensate, storm water retention ponds, cisterns or non-contact cooling water.
- Incorporate separate irrigation zones for all irrigated plant hydrozones, and use separate irrigation zones for turf areas.
- Use dedicated water meters for landscaping water use.
- Use drip or other low volume irrigation wherever possible.

E) Water Efficient Technologies

Automatic Irrigation Timer: An automatic irrigation timer can be installed on an existing manual irrigation system to operate the sprinklers on the proper days of the week with appropriate run time. More elaborate controllers offer extra flexibility to manage larger sites with many different hydrozones and site conditions.
"Smart" Controllers: Unlike traditional controllers, which are really just timers, "smart" controllers work by monitoring and using information about site conditions (such as soil moisture, rain, wind, slope, soil, plant type and more), and applying the right amount of water based on those factors.
Centralized Irrigation Controllers: Often used to manage many irrigation controllers spread out among many sites, a typical central irrigation control system utilizes a computer to create, adjust and save irrigation schedules for multiple controllers at various locations.
Computer Software: Software programs have been developed to assist the designer and water manager in the analysis of the efficiency of an existing or newly-designed irrigation system (e.g. *Hyper-SPACE*TM*; SPACE Irrigation Survey*TM.)
Flow Control Nozzles: Each sprinkler nozzle is equipped with a flow-control device that compensates for flow changes and maintains a uniform pressure.
Sensors: Several types of sensors are available that take the human factor out of irrigation system operation (i.e. Rain shut-offs; Freeze sensors; Wind sensors; Flow sensors; Soil moisture measurement; and Weather stations)

INDUSTRY SPECIFIC BEST MANAGEMENT PRACTICES

Use for Public Water Supply

In 2012, public water supply withdrawals by 610 facilities constituted 16.6% of total registered withdrawals in the state, at some 1, 370 million gallons per day (MGD). Surface water withdrawals constituted 905 MGD at 126 facilities; groundwater withdrawals constituted 464 MGD from 509 facilities.[6]

Ohio's Current Management Framework for Public Sector Water Withdrawals and Use

The Ohio Environmental Protection Agency, Division of Drinking and Ground Waters (OEPA-DDGW) regulates the construction and operation of public water supply, treatment and distribution systems. ODNR Division of Soil and Water Resources provides water supply planning assistance to purveyors, described in the document "Community Water Supply Planning in Ohio," available on the ODNR website. Regional water plans were completed in the 1970s for the entire state. Plans for the Northeast and Northwest districts were updated in the 1980s. The emphasis of the plans is on water supply development, not conservation.

Review of Public Water Supply Best Management Practices

The best management practices included in this section would apply to water treatment plants, waste water plants and other public facilities.

Federal, State and Local Administrative Framework & Programs

The USEPA has several programs related to water conservation, efficiency and overall stewardship of surface and ground water. The agency is also responsible for protecting drinking water through regulations and administrative programs through the Safe Drinking Water Act of 1974. The agency currently funds research on sustainable water infrastructure that includes new predictive modeling tools, decision support tools, innovative techniques to increase water efficiency, and improvement of green infrastructure. [7]

Best practices regarding water infrastructure are characterized as Climate Ready Water Utilities program, which provides technical assistance to water systems and agencies at the state and regional level regarding the likely impacts of climate change on water resources, and tools and techniques to respond.[8]

The USEPA is also adopting an overall sustainability framework for future program design and administration. This framework was presented in 2013 in a publication by the National Academies of Sciences entitled *Sustainability for the Nation: Resources Connection and Governance Linkages*.[9] The

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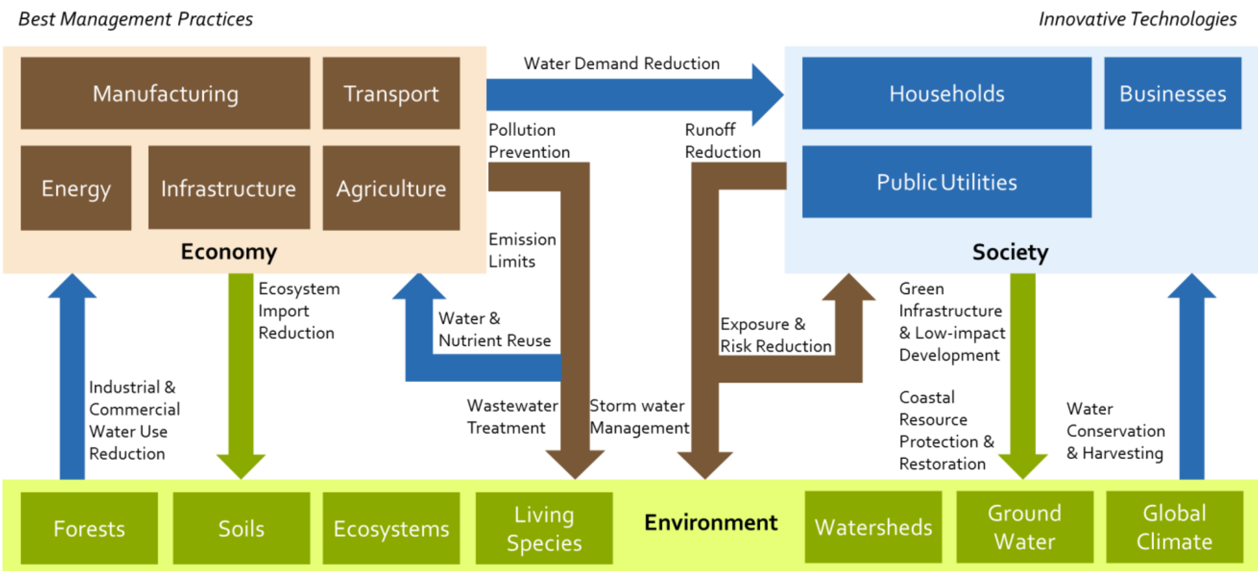
[6] ODNR Division of Soil and Water Resources 2012 Water Withdrawal Summary Report. Available at URL: http://soilandwater.ohiodnr.gov/portals/soilwater/pdf/water_withdrawal/2012WWFRAnnualRpt.pdf
[7] USEPA Sustainable Water Infrastructure Research. Available at URL: http://www2.epa.gov/water-research/sustainable-water-infrastructure-research
[8] USEPA Climate Ready Water Utilities. Nd. Available at URL http://water.epa.gov/infrastructure/watersecurity/climate/index.cfm
[9] Available for free download at National Academies Press, URL: http://www.nap.edu/search/?term=sustainability

book outlines an alternative regulatory and decision making process for USEPA that uses a systems approach to incorporate sustainability and problem solving into the agencies activities. Building on this approach, a triple value model for water resources management has been developed at the Ohio State University Center for Resilience. Figure 10, (based on Fiksel, et al 2013) presents this model.

Figure 10. **Triple Value Framework and Water Resources**



Source: Based on Fiksel et al. 2013, Figure 4.

Urban Public Water Systems Sustainability

With nearly 75% of people on Earth living in metropolitan areas, consideration of urban water usage is a critical component to effective water management. The current best practices approach is to consider the long-term sustainability of urban water systems. Several different frameworks have been proposed, although all share some characteristics. Known as sustainable urban water management (SUWM), integrated urban water management (IUWM), or water sensitive cities (WSC), these frameworks shift water management from a focus on supply sources and increasing access to water to a more integrated approach to include the source of the water and access for adequate supply, but also to recycling wastewater (including stormwater), reducing overall demand for cleaned water, and ensuring water systems are resilient (adaptable to future conditions).[10] In part this shift is a product of a recognition that even in parts of the world that are more water "rich," such as the Great Lakes basin, maintaining the

[10] *See* 1) van der Steen, P. 2007. Report providing an inventory of conventional and of innovative approaches for urban water management. UNESCO-IHE Institute for Water Education. Part of the SWITCH (Sustainable Water Management Improves Tomorrow's Cities' Health) program. Deliverable D1.1.1, In Sustainable Water Management in the City of the Future; 2) Blackmore, J. & R. Plant. 2008. Risk and Resilience to Enhance Sustainability with Application to Urban Water Systems. Journal of Water Resources Planning and Management. 134, 3: 224-233; 3) Rijke, J., M Farrelly, R. Brown & c. Zevenbergen. 2013. Configuring transformative governance to enhance resilient urban water systems. *Environmental Science and Policy* 25: 62-72; 4) Wong, T. & R. Brown. 2009. The water sensitive city: principles for practice. Water Science & Technology 60, 3: 673-682.

current set of practices will become cost prohibitive and exacerbate pollution and degenerate ecosystem services. The approaches also build on recognition of the mutually reinforcing benefits to ecology, society and the economy that might be gained through a more integrated approach.

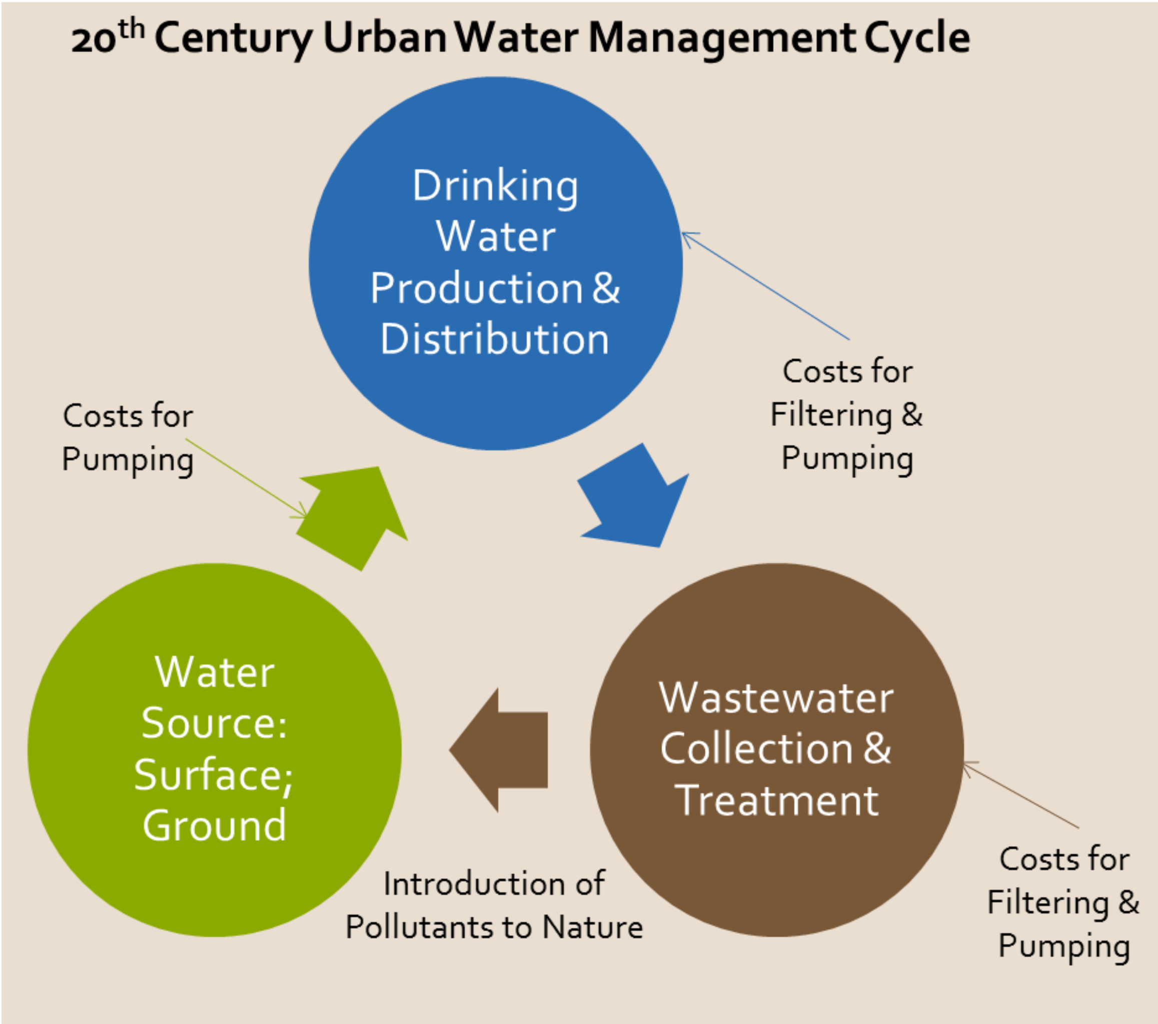
These frameworks have been derived in part on the basis of global initiatives on sustainability, including Agenda 21, the Dublin Statement, the Millennium Development Goals, the World Bank Water Resources Sector Strategy, and the European Community's Urban Wastewater Treatment Directive.[11] Changes to urban water management practices have also begun in the United States in arid regions of the country.

Integrated urban water management embodies a shift at the conceptual level from risk minimization to system resilience in which the system is considered holistically, uncertainty is accepted, and adaptive capacity is the focus of system design and operation rather than economic efficiency alone.[12]

The traditional urban water management cycle in the United States (see Figure 11 below) entails the following: fresh water is withdrawn from a source (either surface water or groundwater) and is treated to potable drinking water standards and distributed to households, industry and other facilities. Potable water is used for drinking, cooking, washing food, food processing, and otherwise for human consumption. It is also used for washing non-food items, in cooling systems, for landscaping irrigation, and for conveyance of human sewage waste to sewage treatment plants. Some of the supply of potable water enters the stormwater systems from runoff over urban lawns and streets. The energy cost to move and treat water to achieve consumption standards is significant, as are the energy and chemical costs to treat sewage. Once treated, wastewater is discharged back into surface water, which, if the source for human use, must be treated again prior to consumption.

[11] van der Steen, P. 2007. Report providing an inventory of conventional and of innovative approaches for urban water management. UNESCO-IHE Institute for Water Education. Part of the SWITCH (Sustainable Water Management Improves Tomorrow's Cities' Health) program. Deliverable D1.1.1, In Sustainable Water Management in the City of the Future.
[12] Blackmore, J. & R. Plant. 2008. Risk and Resilience to Enhance Sustainability with Application to Urban Water Systems. Journal of Water Resources Planning and Management. 134, 3: 224-233.

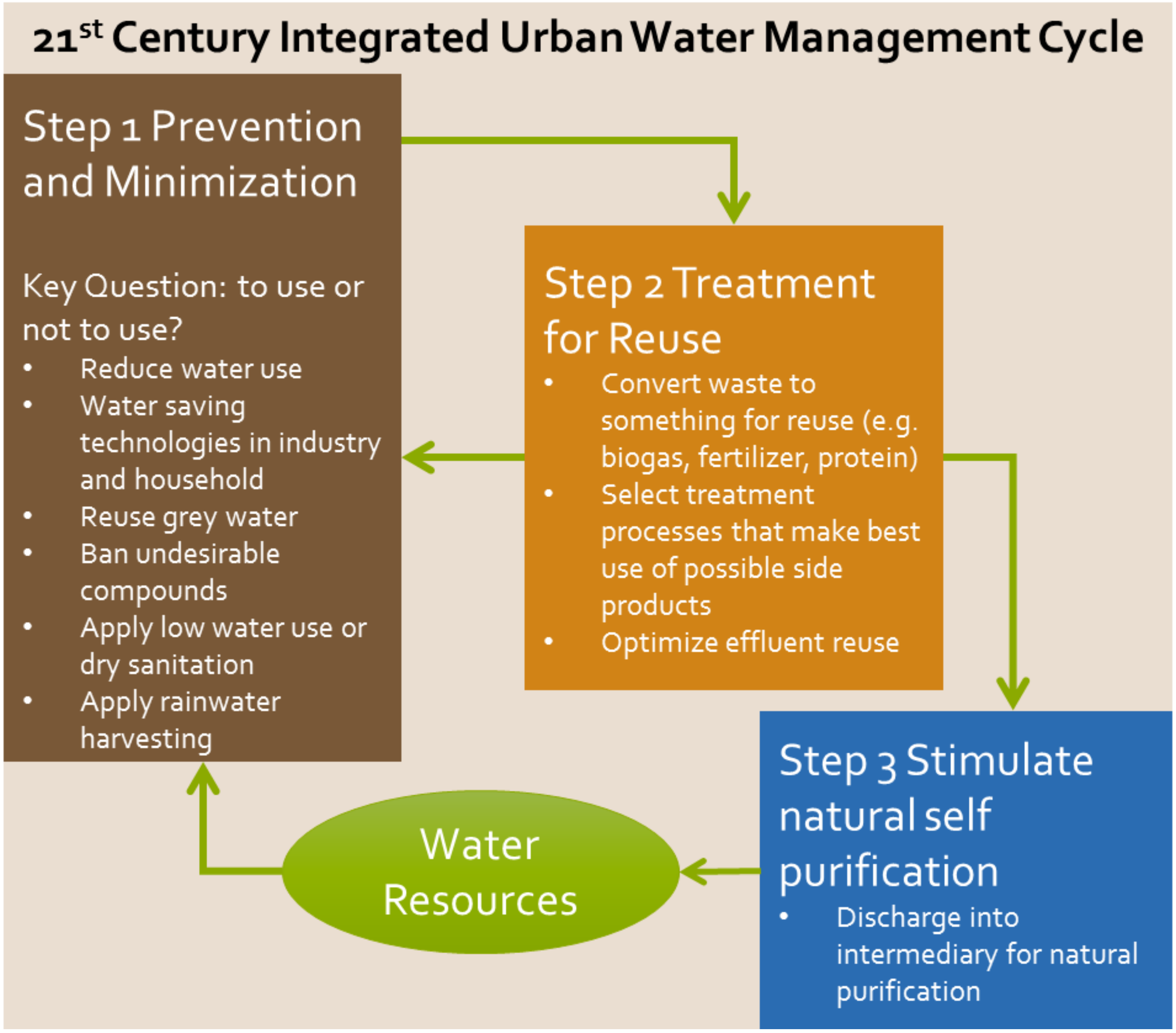
Figure 11. **20th Century Urban Water Management Cycle**



Source: Based on Nhapi and Gijzen 2005 in van der Steen 2008

Figure 12 presents an alternative water management framework. The shift to more integrated or sustainable urban water management approaches introduces several new practices: adoption of a watershed approach to strategic planning; overall demand reduction through conservation practices and technologies; separation of waste streams to minimize treatment needs (grey water vs. black water); reuse of waste water for non-consumptive uses such as the use of grey water for irrigation or in toilets; harvesting of rain water and use of storm water as a water resource; and harvesting of materials from waste water for energy production or fertilizer. These practices seek to minimize the withdrawal of water from the source, use water in the most efficient way possible, and convert waste in the cycle to energy and other products.

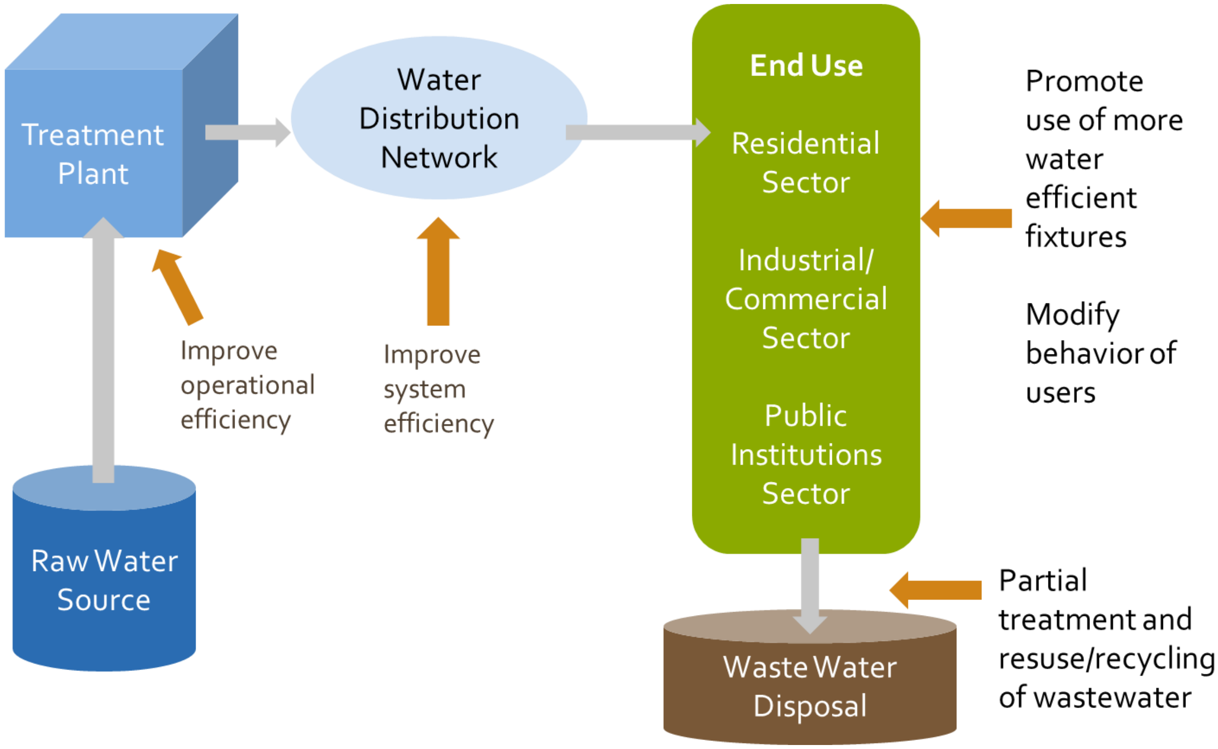
Figure 12. 21st Century Integrated Urban Water Management Cycle



Source: Based on Nhapi and Gijzen 2005 in van der Steen 2008

One of the central components of an integrated approach is to incorporate water demand management for public water supply (PWS). Figure 13 presents a schematic diagram of the key areas for water demand management in water supply systems. Public water suppliers, wastewater treatment providers, industry and business, and households can adopt these practices.

Figure 13. **Water Demand Management Intervention Points**



Source: after Kayaga and Smout, 2011

Adoption of a more integrated water cycle in urban areas would require a shift or transformation in the governance of water systems at the regional level. At minimum it would require a heightened collaboration between municipal drinking water agencies and city or regional sewer agencies to coordinate demand management, harvesting of storm water as a resources, and other alterations to practices.

Technology, Management and Monitoring Practices

A shift to demand management and integrated water resources management in urban areas by public water providers and sewer districts would also require, in many cases, retrofits to existing urban water infrastructure and processes. It implies adoption of more flexible infrastructure systems (green infrastructure for storm water, for example), possible separation of waste water systems for recycling/reuse of water, and harvesting of nutrients for other uses prior to discharge of wastewater into water bodies.

Separation of waste water systems allows for reduced treatment costs, as water is reclaimed from the waste stream for non-potable purposes, such as landscaping, industrial processes, cooling towers, toilet flushing and other processes. Such systems can be cost-effective in retrofit situations.[13] In the Ohio Lake Erie basin, separated or dual systems may not at this time make sense for public systems; however, increases in energy costs for treatment or changing drought conditions might warrant consideration of water reclamation for non-potable uses. For Ohio communities outside the Lake Erie basin, particularly in times of drought, reclamation of wastewater for non-potable uses could provide water supply to industry and for irrigation with reduced costs when compared to the costs to supply potable water. These collaborative practices exist among some industries, but the state could encourage consideration through its regulatory and management programs.

Demand management consists of five components: 1) reducing the quantity of water required to accomplish a specific task; 2) adjusting the nature of the task so it can be accomplished with less water or lower quality water; 3) reducing losses in movement from source through use to disposal; 4) shifting time of use to off-peak periods; and 5) increasing the ability of the system to operate during droughts.[14]

Several key intervention points for water demand management (or conservation) exist in urban water systems. These include improving the efficiency of water treatment processes, reduction in system losses in the water distribution network, and promotion of more efficient water devices and appliances among customers.[15] Reduction of water use can result in lower volumes of wastewater thereby reducing treatment needs. A second source of inflow to waste water treatment plants is groundwater infiltration; inspection of pipes to inhibit this infiltration can also reduce treatment costs.

Improving operational efficiency at treatment plants includes attention to energy use. Water and wastewater systems are significant energy consumers, with an estimated 3-4% of total U.S. electricity

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[13] Okun, D. 2000. Water Reclamation And Unrestricted Nonpotable Reuse: A New Tool In Urban Water Management. *Annu. Rev. Public Health*.21:223–4.
[14] Brooks, DB. 2006. An operational definition of water demand management. *Int J Water Resour Dev* 22:521-528; cited in Mohapatra, S & A. Mitchell. 2009. Groundwater Demand Management in the Great Lakes Basin---Directions for New Policies. *Water Resour Manage* 23:457-475 DOI 10.1007/s11269-008-9283-3.
[15] Kayaga, S. 2011. Ch. 2 Introduction to Water Demand Management. In Water Demand Management in the City of the Future, S. Kayaga and I. Smout, eds. Water, Engineering and Development Center. Leicestershire: United Kingdom. Available at http://www.lboro.ac.uk/wedc/

consumption used for the movement and treatment of water and wastewater.[16] If the amount of energy required to heat water for various uses is included, the figure rises to 13% of electricity consumption.[17] In California, 19% of the state's energy consumption is for pumping, treating, collecting and discharging water and wastewater. Operations can be audited for energy consumption, but one significant source of energy savings can be a measured by the reduction in the input to a treatment plant brought about by demand-reduction strategies.

Much of the cost for treatment of raw water and of wastewater is from energy consumption. Table 11 arrays the intervention points for energy savings at municipal WWTPs.

Table 11. **Energy Efficiency Strategies for Municipal WWTPs**

Focus Efforts for Energy Savings	
✓ Process Energy	Focus on biggest energy consumers at WWTP
✓ Operational Controls	Tailor operations to meet seasonal and diurnal changes
✓ Quality vs. Energy	Balance water quality goals with energy needs
✓ Repair and Replacement	Consider equipment life and energy usage to guide repair and replacement
✓ Biosolids	Consider tradeoffs between treatment energy and improved biosolids quality
✓ Infiltration/Inflow	Address I&I to reduce treatment energy
✓ Leaks and Breaks	Address leaks and breaks to reduce pumping energy
✓ On-Site Renewable Energy	Consider opportunities for on-site generation to reduce energy purchases
✓ Conservation	Educate the community: Less water reduces WWTP loads and energy needs

Source: Daw et al, 2012, Table 3.

A significant best practice entails the availability of decision support tools for public water system providers to use to complete integrated urban water management plans, water supply plans and other plans and strategies required by law or economic efficiencies. Figure 14 demonstrates case studies of integrated/sustainable urban water management.

[16] J. Daw, K. Hallett, J. DeWolfe and I. Venner. 2012. *Energy Efficiency Strategies for Municipal Wastewater Treatment Facilities*. Technical Report # NREL/TP-7A30-53341. *National Renewable Energy Laboratory*, U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. Available at URL: http://www.nrel.gov/docs/fy12osti/53341.pdf. Accessed May 2, 2014.
[17] Smedley, T. 2013. Available at URL; http://www.theguardian.com/sustainable-business/energy-water-greater-impact-nexus. Accessed May 2014.

Figure 14. **Case Studies of Integrated/Sustainable Urban Water Management**

International

The World Bank
Integrated Urban Water Management
http://water.worldbank.org/iuwm
UNESCO Urban Water management Program
Urban Water Series http://unesdoc.unesco.org/images/0019/001910/191066E.pdf
Asian Development Bank
Good Practices in Urban Water Management: Decoding Good Practices for a Successful Future
http://www.adb.org/sites/default/files/pub/2012/good-practices-urban-water-management.pdf
Features 8 cities
SWITCH (http://www.switchurbanwater.eu)
Sustainable Water Management in the City of the Future
http://www.switchurbanwater.eu/outputs/pdfs/SWITCH_-_Final_Report.pdf

The United States

American Water Resources Association
Case Studies in Integrated Water Resources Management
http://www.awra.org/committees/AWRA-Case-Studies-IWRM.pdf

States

California
Bay Point, CA Golden State Water Company
http://www.gswater.com/bay-point/files/2012/12/BayPoint_2010UWMP_000.pdf
Claremont, CA Golden State Water Company
http://www.gswater.com/claremont/files/2012/12/ClaremontCDfinal_000.pdf
San Diego Urban Water Management Plan
http://www.sdcwa.org/uwmp
San Diego Integrated Regional Water Management Plan
http://www.sdirwmp.org/2013-irwm-plan-update - codeword
Pennsylvania
Philadelphia Green City, Clean Waters
http://phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan
http://www.phillywatersheds.org/watershed_issues/infrastructure_management
Louisiana
Greater New Orleans Urban Water Plan http://livingwithwater.com/reports/
Ohio
Cincinnati Stormwater Management Strategic Plan
https://msdgc.org/about_msd/strategic_plan/index.html
Legal & Regulatory Practices

POWER PLANTS

Use of Water in Power Plants

Power plants are the largest use sector and contribute to water supply stress across the country. According to a 2011 report by The Union of Concerned Scientists, water-cooled thermoelectric power plants in the United States in average withdrew 60 billion to 170 billion gallons (180,000 to 530,000 acre-feet) of freshwater from rivers, lakes, streams, and aquifers, and consumed 2.8 billion to 5.9 billion gallons (8,600 to 18,100 acre-feet) of that water on a daily basis. 67 percent of those withdrawals, and 65 percent of that consumption was attributed by the report to large coal fleet. The report also found that the source of water and its intensity varies regionally. Power plants in areas where water is scarce rely more on groundwater, whereas power plants in east of the Mississippi river relied heavily on surface water. In terms of water intensity (i.e. the amount of water used per unit of electricity generated), power plants in the West were found to be more water-efficient. The greater amount of water used for each unit of electricity produced in the East was attributed to not being fitted for recirculating, dry cooling, or hybrid cooling technologies.[18]

Generally speaking, water used at power plants can be one of two types: cooling water and process water. Process water makes up less than 15% of the water consumed for power generation and is used to make steam and meet other needs at the plant such as scrubbing, ash handling, dust suppression, and plant service water. Cooling water constitutes a significantly larger share of water withdrawal amounts in power plants and is used to condense steam. Cooling water is typically used in two different categories of power plant technologies:

- Open-loop or once-through power plants withdraw water from a water source that flows through heat exchangers to condense the steam in a single pass. Almost all of the water withdrawn is returned back to the source. Consumption is merely 1% of the total water withdrawn and is due to evaporation.
- Closed-loop or wet cooling tower power plants generally withdraw smaller amounts of water from a water source. Water passes through the heat exchangers and is then recycled in a cooling tower. In the cooling towers, heat is dissipated through evaporation of the cooling water and the cooled water is recycled back through the condenser.

[18] Averyt, K., J. Fisher, A. Huber-Lee, A. Lewis, J. Macknick, N. Madden, J. Rogers, and S. Tellinghuisen. 2011. *Freshwater use by U.S. power plants: Electricity's thirst for a precious resource.* A report of the Energy and Water in a Warming World initiative. Cambridge, MA: Union of Concerned Scientists. Retrieved from: http://www.ucsusa.org/assets/documents/clean_energy/ew3/ew3-freshwater-use-by-us-power-plants.pdf

Table 12. Best Management Practices for Power Plants

	Best Management Practices for Power Plants
1	Return once-through water to reservoir for reuse in order to minimize the actual amount of water consumed in the system.
2	Maximize the use of wastewater from one process as source water for another process that requires lower quality water.
3	Repair and maintain all equipment routinely to minimize water loss.
4	Collect and utilize storm water run-off where feasible.
5	Arrange a task force team to monitor and optimize water usage at all times.
6	Boost awareness of best management practices by participating in water conservation technical organizations.
7	Assess water-efficient processes when considering capital investments.
8	Evaluate standard operating procedures to ensure water usage optimization, and regularly incorporate best practices and lessons learned.
9	Minimize cooling water consumption by using computer controlled systems to adjust for certain climatic conditions.
10	Employ dust suppression chemistry where appropriate to minimize water usage.
11	Engage employees in water conservation and drought mitigation efforts.

Table 13. Suggestions for Prolonging Life of Existing Power Plant Cooling Reservoirs

	Suggestions for Prolonging Life of Existing Power Plant Cooling Reservoirs
1	Evaluate the use of alternative water sources and examine the option of using a different source or quality of water for some processes.
2	Assess current pump configurations in terms of placement, arrangement and size to ensure maximum reservoir capacity.
3	Construct or improve water transportation infrastructure to access remote water sources and minimize transport losses.
4	Obtain additional water supply where possible.
5	Add pumping capability and/or adjust pumping schedule where suitable to entirely utilize make-up water sources with variable availability.
6	Evaluate the use of municipal sewage effluent in lieu of fresh water as primary or secondary source of water where appropriate and feasible.
7	Employ advanced water treatment systems to facilitate use of poorer quality water.
8	Upgrade power plant processes and/or equipment to minimize consumption of water to the extent possible.
9	Collected storm runoff can either be treated or used directly in some plant processes, displacing other sources.
10	Coordinate water withdrawal with surrounding water-users to ensure adequate supply.
11	Actively participate and support the development of additional water reservoirs.

MANUFACTURING (GENERAL)

Introduction

According to the U.S. Geological Survey's (USGS) Water Science School, large industrial consumers of water produce commodities as varied as food, paper, chemicals, refined petroleum, and primary metals. Every manufactured product uses water during some part of the production process. Industrial water use includes purposes such as fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product; or for sanitation needs within the manufacturing facility. In 2005, 88 percent of all industrial water was self-supplied;[19] the balance was delivered from a public supplier.[20]

In 2005, industrial water withdrawals were an estimated 18,200 million gallons per day (Mgal/d).[21] Industrial withdrawals were about 4 percent of the nation's total withdrawals and about 9 percent of total withdrawals for all categories excluding thermoelectric power. Surface water was the source for 83 percent (15,000 Mgal/d) of total industrial withdrawals, whereas groundwater accounted for about 17 percent of withdrawals (3,110 Mgal/d). Nearly all (92 percent) of the surface-water withdrawals and (99 percent) of the groundwater withdrawals for industrial use were freshwater. For 2005, total industrial withdrawals were 8 percent less than during 2000.

Ohio withdrew 703 Mgal/d of fresh water in 2005, including 554 Mgal/d of surface water and 149 Mgal/d of groundwater; no saline water was withdrawn in Ohio. Ohio's share of water withdrawal among states was 4%, while the top states in water withdrawal, Louisiana (17%), Indiana (12%), and Texas (11%) accounted for 38% of total withdrawals. The largest fresh groundwater withdrawals were in Georgia, Louisiana, and Texas, which together accounted for 23 percent of the total fresh groundwater withdrawals. Texas accounted for 71 percent of the saline surface-water withdrawals for industry.

In Ohio, four counties were responsible for 60% of all self-supplied fresh ground water withdrawals for industrial uses: Hamilton (35.39 Mgal/d or 23.8%), Ross (23.98 Mgal/d or 16.1), Butler (18.61 Mgal/d or 12.5%), and Montgomery (11.11 Mgal/d or 7.5%). Three counties were responsible for 65% of the total fresh surface water withdrawals for industrial uses in 2005: Jefferson (144.14 Mgal/d or 26.0%), Cuyahoga (114.72 Mgal/d or 20.7%), and Lorain (100.95 Mgal/d or 18.2%).

Many industrial processes use a significant amount of water. For example, it takes about 270 gallons of water to produce $1 worth of sugar; 200 gallons of water to make $1 worth of pet food; and 140 gallons of water to make $1 worth of milk.[22]

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[19] Procured from a source other than a public supplier
[20] The latest data available from USGS. The data on 2010 USGS will be released in late 2014, according to the USGS's website. Source: http://water.usgs.gov/edu/wuin.html
[21] According to USGS, the data only reflects self-supplied water. For more information, see Estimated Use of Water in the United States in 2005 report at http://pubs.er.usgs.gov/publication/cir1344

[22] Tracey Schelmetic. "Down the Drain: Industry Water Use." Industry Market Trends, April 10, 2012. http://news.thomasnet.com/IMT/2012/04/10/down-the-drain-industry-water-use/

A 2010 report titled *Direct and Indirect Water Withdrawals for U.S. Industrial Sectors*,[23] conducted by civil engineers at Carnegie Mellon University, broke down water usage by industry sector, taking into consideration both direct water usage — which means bringing water into a manufacturing facility for your industrial process — and indirect water usage — when a manufacturing facility is buying items from the supply chain that were manufactured by someone else using water, then incorporating those materials into the finished product. Besides agriculture and power-generation industries, the most water-intensive industries are textile and garments, meat production, beverage industry and automotive manufacturing.

According to the Alliance for Water Efficiency (AWE),[24] the most common uses for water in manufacturing are cooling, process uses, cleaning, employee sanitation, and steam generation. There are great water conservation and increased efficiency potential present in all five of these uses.

Cooling Water

Every manufacturing process involves the use of energy. There are four ways to handle this "waste heat." By far, the two best ways are (1) to modify existing processes so that energy is conserved and less waste heat is generated and (2) to find ways to capture the "waste heat" for uses in the manufacturing processes. An example of this is co-generation. Even with the best energy efficiency practices, cooling may still be needed. This cooling can be performed either with air or with water. Air cooling has been used for centuries, but it has its economic limits. Where water must be used, there are three ways to dissipate the waste heat: single-pass cooling, a recirculating cooling pond, or a cooling tower.

Water is often the most acceptable medium to transfer heat away from the machinery. It was once common to use single-pass cooling water, and simply dispose of the hot water into the sewer after a single pass through the machinery or equipment. This method is rarely used today because of water costs, regulations prohibiting single-pass cooling, and other options available for the reuse of cooling water. The other two methods are the use of a recirculating cooling pond or cooling tower. In these two cases, cooling water is pumped to a cooling pond or tower where evaporative techniques are employed to rid the waste heat and cool the water. The cooled water is then reused in the equipment cooling system or for some other beneficial use in the building or project. This is not to say there is no water loss and water waste because of this process; in fact, most cooling towers are notoriously inefficient in the use of water as was described in the section above on power generation.

Process Water

There are many uses of water within any manufacturing process. Each process is different, but many diverse manufacturing operations use water for:

[23] Blackhurst, Michael, Chris Hendrickson and Jordi Sels i Vidal (2010). Direct and Indirect Water Withdrawals for U.S. Industrial Sectors. *Environ. Sci. Technol.*, 2010, 44 (6), pp 2126–2130. http://pubs.acs.org/doi/pdfplus/10.1021/es903147k

[24] The Alliance for Water Efficiency is a stakeholder-based 501(c)(3) non-profit organization dedicated to the efficient and sustainable use of water. Headquartered in Chicago, the Alliance serves as a North American advocate for water efficient products and programs, and provides information and assistance on water conservation efforts. http://www.allianceforwaterefficiency.org/about/default.aspx

1. Cleaning and rinsing products, parts and vessels;
2. Transporting parts or ingredients;
3. As a lubricant;
4. As a solvent or reactant in a chemical reaction;
5. Forming a water seal to block out contact with air;
6. Pollution control; or
7. Inclusion in the product, such as in beverage manufacturing.

When examining a manufacturing operation, it is important to take all water saving opportunities into consideration, including the use of water-efficient equipment as well as the use of water conserving practices.

AWE ranks five water saving possibilities to look at in any manufacturing operation. This order starts at the simplest and proceeds towards those that requiring larger changes. These include:

1. Adjusting the flow of water;
2. Modifying the equipment or installing water saving devices;
3. Replacing existing equipment with more water-efficient equipment;
4. Water treatment, recycling, and reuse and
5. Changing to a waterless process.

Reuse and recycling of water produced within the facility is a promising option. The quantity and quality of discharge from each operation can be examined to assess a possibility to reuse water in another process with or without additional treatment.

Steam Generation and Boilers

Some manufacturing processes use water to generate steam needed for their operation. Steam boilers lose water as the steam escapes the system. This water loss can be minimized with heat exchangers to collect the condensate and return it to the boiler.

Boilers suffer the same water quality problems as cooling towers. As the water vapor (steam) escapes the system, the minerals in the water are left behind. These minerals are referred to as Total Dissolved Solids (TDS). If the TDS is not removed from the boiler water, a build-up of the minerals will collect on the inside of the boiler and pipes. This build-up is called "scale". The accumulation of scale can greatly hamper the efficiency of the system and eventually cause catastrophic failure. To prevent scale, some of the boiler water must be periodically removed and replaced with fresh water; referred to as "blow-down".

Blow-down water losses can be reduced by similar means as those used in the efficient operation of cooling towers: acidification of the water, side-stream filtration, magnetic pulse technology, and scale inhibitors.

Sanitation, Irrigation, Food Service and Housekeeping

All manufacturing facilities have restrooms, general areas that must be cleaned, landscaping that requires watering, and in many cases, food services. In some cases on-site laundry facilities are required for uniforms and special clothing. Water efficiency in these areas is also important (See Water Use Best Management Practices for Commercial, Industrial and Institutional Facilities in this report).

Water Audits

A thorough audit of water use is usually needed to assess where the water is used, the water quality needs of each end use, and where savings opportunities exist. Industrial processes are often complicated and sensitive to water quality. The facility engineers and management must be intimately familiar with and involved in the audit process to achieve a satisfactory plan for water use reduction.

The strategies of reduce, reuse, and recycle should be applied to all water uses in a manufacturing facility. Oftentimes relatively simple water use reductions can be accomplished by reusing the water several times before discharging it into the sewer system. For example, many manufacturing facilities are surrounded with irrigated landscape; much of the water used in manufacturing is suitable for irrigating the landscape, sometimes requiring only minimal treatment. Caution should be used if the water collects solvents or toxic chemicals during the manufacturing process as these pollutants can percolate into the groundwater when applied as part of irrigation water.

Water utilities have discovered the best water-related actions for the manufacturing sector are working with the facility managers and engineers to provide a comprehensive survey of water use and water efficiency strategies. Water audits are scalable and dependent upon the complexity of the system and technology for which the audit is being performed. A comprehensive, whole system audit, can be time consuming and may require someone familiar with manufacturing processes and techniques of engineering analysis. Comprehensive audits within process industries require highly skilled, technically experienced individuals (preferably engineers) to perform the required water balance calculations, technical analyses of processes, and development of cost-effective strategies and plans for reducing water consumption. Furthermore, the utility must be dedicated to ongoing improvements which may require repeated site visits and meetings with engineers and management to prepare and implement a suitable water efficiency action plan.

For more details, review the Alliance's Water Conservation Program Operation and Management AWWA G480-13.[25]

General Electric has also developed a guide to water efficiency entitled Solutions for Sustainable Water Savings[26] that features four major steps for the water efficiency process:

1. Baseline Water Footprint
2. Identify Efficiency Opportunities

[25] http://www.awwa.org/store/productdetail.aspx?productid=36141161
[26] http://infohouse.p2ric.org/ref/50/49016.pdf

3. Prepare an optimization Plan
4. Execute and Measure

The guide features solutions for reducing a water footprint and provides case studies of companies across different industries, including:

- Canbra Foods
- Cinergy
- CMS Electric Company
- Ford
- Dupont
- The Earth Rangers Center
- Repsol YPF
- Unilever

The American Society of Mechanical Engineers (ASME) developed an inventory of some new technologies and best management practices that are relevant across of many process industries. [27]These water efficiency technologies include:

- Measurement, monitoring and controls systems (e.g., more precise control and distribution of water in spray systems)
- Linking process control with mechanical considerations associated with membranes
- Flue gas moisture capture
- Dry and near-dry machining to minimize water use
- SCADA advances
- Alternative cleaning technologies to reduce or eliminate the need for water
- Better water disinfection technologies to make wash processes more efficient (e.g., ozone, UV)
- Advanced cooling technologies (e.g., air-cooled condensers, hybrid wet-dry systems)

Water treatment and reuse technologies identified by ASME include:

- Membrane technologies (in order of decreasing porosity)
  - Microfiltration (MF)
  - Ultrafiltration (UF)
  - Nanofiltration (NF)
  - Reverse osmosis (RO)
- Biological treatment
  - Aerobic
  - Anaerobic
- Upflow Anaerobic Sludge Blanket (UASB) Reactor

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[27] ASME Water Management Technology Best Management Practices and Innovations for the Process Industries. Final Report. (2010, June). https://community.asme.org/center_for_research_and_technology_development/m/mediagallery2/2856/download.aspx

- Specific example of modular technology
- For treatment of organic wastewater treatment
- Ideal for industries such as food processing and pulp & paper
- Activated Sludge Process (ASP) followed by membrane bioreactors (MBRs)
  - Specific example of a newer combination of technologies
- Gravity separation
- Advanced oxidation processes
  - Photocatalysis
  - Supercritical water oxidation
  - Electron beam irradiation
- Filtration
  - Including advanced tertiary filtration (e.g., electrofiltration)
- Microbial fuel cells for wastewater treatment
  - Waste to energy process
- Resins
- Advanced adsorption
- Disinfection
  - Ultraviolet (UV) disinfection
  - Ozonation

The following section will look at the best practices for the following manufacturing industries:

- Steel and Iron Manufacturing
- Chemical Industry
- Petrochemical Industry
- Food Processing

IRON AND STEEL

Introduction

The Steel Industry is essential to the quality of life of American people and to the vitality of many industries that use steel as a backbone of their processes, products and infrastructure. To produce steel, manufacturing facilities use one of two processes: the basic oxygen furnace (BOF) or the electric arc furnace (EAF). The BOF process uses 25-35 percent old steel (scrap) to make new steel. BOFs make up approximately 40 percent of today's steelmaking in the U.S. The EAF process uses virtually 100 percent old steel to make new steel. EAFs make up about 60 percent of today's steelmaking in the U.S.[28] The American Iron and Steel Institute notes that, next to iron and energy, water is the industry's most important commodity.

[28] According to the American Iron and Steel Institute (AISI), http://www.steel.org/en/About%20AISI.aspx

The American steel sector has been recognized as having the steepest decline of total air emissions among nine manufacturing sectors studied in the EPA 2008 Sector Performance Report.[29] A helpful tool that the industry is using as part of this process is the Life Cycle Assessment (LCA) approach, which is helpful for measuring a more comprehensive environmental impact for a manufactured material. Among other things, LCA considers the total environmental impacts generated by the production, as well as use and end-of-life (recycling or disposal) phases of a product. Steel has life cycle advantages over competing materials because of its relatively low energy use, high recyclability, the conservation of natural resources, such as water, and the extensive re-use of by-products.

While steelmakers require approximately 75,000 gallons of water to produce one ton of steel,[30] that number includes water that has been recycled, and process and cooling water that has been reused. Typically, more than 95% of the water used in steelmaking is recycled. Due mainly to evaporation losses, steelmakers require 13,000–23,000 gallons of additional water per ton of product through all stages of production.[31]

Iron and Steel, like other industries, falls under the general regulations on water withdrawals with some specific regulations developed for industrial wastewater.[32] In 1995, The U.S. EPA Office of Compliance created "Profile of the Iron and Steel Industry."[33] This very detailed document describes main processes in the Iron and Steel Industry and explains how water is used for steelmaking in terms of inputs and outputs. In terms of the water withdrawals for the industry, the document mentioned some European practices in water recycling and substitution technologies; however, it primarily focuses on water discharge and air pollution.

Steelmakers use water for various processes and purposes, for example, as a coolant for equipment, furnaces, and intermediate steel shapes; a cleansing agent to remove scale from steel products; a source of steam; a medium for lubricating oils and cleaning solutions; and a wet scrubber fluid for air pollution control.[34] Presence of various steel industry operations depends on a type of facility; whether it is integrated mills, minimills, or finishing mills.

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[29] 2008 Sector Performance report. United States Environmental Protection Agency, September 2008. http://www.portcompliance.org/pdfs/2008-sector-report-508-full.pdf

[30] AISI, Public Policy Statements – 1999-2000, 106th Congress, p.21. In 2008 Sector Performance Report.

[31] DOE. (2003, July). Industrial Technologies Program, Steel Industry of the Future Report on Water Use in the Industries of the Future: Steel Industry (citing: Wakelin, David H. ed. 1999. The Making, Shaping and Treating of Steel: Ironmaking Volume, 11th ed. Pittsburgh, PA, p. 386-93; and Yamada, L. 1998. Market Magic: Riding the Greatest Bull Market of the Century. New York: John Wiley & Sons, Inc., at 160; AISI, communication with Tom Tyler, EPA, February 4, 2008.)

[32] See water resources regulations and standards on the Energy and Environmental Affairs page of the Mass.gov website: http://www.mass.gov/eea/agencies/massdep/water/regulations/regulations-and-standards.html#2 (http://www.mass.gov)

[33] Sector Notebook Project. Document EPA/310-R-945-005 http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/iron-stl.pdf

[34] DOE, Industrial Water Use and Its Energy Implications, http://www1.eere.energy.gov/industry/steel/printable_versions/news_detail.html?news_id=7885, citing AISI, Public Policy Statements—1999-2000, 106th Congress, Washington, DC: AISI, 1999, p. 21.

The processes can be grouped into three purposes:[35]

1. Material conditioning
2. Air pollution control
3. Heat transfer

The largest water use is to transfer heat (approximately 75% of all water used in steel production). Primary iron and steelmaking processes require heating the raw materials beyond the melting point of iron, in the range of 2,600–3,000 degrees Fahrenheit (°F), while hot-rolling operations require heating the materials to 2,100-2,300 °F. The equipment used for processing is protected by a combination of refractory linings and water-cooling of the refractory and shell of the equipment. Coke oven gas, blast furnace gas, and the off gas from basic oxygen furnaces and electric arc furnaces must be treated to remove air pollutants. In the case of coke oven gas and blast furnace gas, this is generally accomplished by using the gases as process fuels as alternatives to fossil fuels in boilers for cogeneration of steam and electricity. [36]

Cooling coke after it has been carbonized in coke ovens takes approximately 8,000–8,500 gallons of water per ton of coke; in boilers for converting coke oven gas, tars, and light oils it takes 40,000–120,000 gallons per ton of coke; and in boilers for converting blast furnace gas. An average company uses about 20,000–60,000 gallons of water per ton of iron. In production and finishing processes, hot strip mills, which compress reheated steel slabs into hot-rolled sheets and coils through a series of rollers, use the most water (1,000–2,000 gallons per ton of hot rolled strip).[37]

The second-highest usage of water is marked for air pollution control (13%). Primary operations use water in wet scrubbers for air pollution abatement. Water is also used for acid control in pickling operations and for wet scrubbers in coating operations that have caustic washing operations.

Finally, approximately 12% of water is used for material conditioning. Water is used for dust control in sinter feeds, slurrying or quenching dust and slag in blast furnaces, mill scale removal in hot- rolling operations, as a solvent for acid in pickling operations, or rinsing in other rolling operations.[38]

Similarly to many types of manufacturing processes, there are consumptive and non-consumptive uses of water in steel production. Since water is not a part of a final steel product, only evaporative losses count toward consumptive use. Evaporation is accounted in operations including slag quenching at blast furnaces and basic oxygen furnaces, coke quenching in coke ovens, spray chamber cooling at casters, and evaporation in cooling towers.

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[35] According to Rick Johnson, contributing to Industrial Water Management, A System Approach. Center for Waste Water Reduction Technologies, American Institute of Chemical Engineers, New York. P.5-62.

[36] Industrial Water Management, A System Approach. Center for Waste Water Reduction Technologies, American Institute of Chemical Engineers, New York. P.5-63.

[37] DOE, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program, Water Use in Industries of the Future, 2003, http://www.ana.gov.br/Destaque/d179-docs/PublicacoesEspecificas/Metalurgia/Steel_water_use.pdf

[38] For detailed description of water use for various operations in the steel industry see Table 5-17 in Industrial Water Management, A System Approach. Center for Waste Water Reduction Technologies, American Institute of Chemical Engineers, New York. P.5-63.

Return-flow uses are associated with operations where water is supplied to the unit and recycled or treated and discharged. Water supply may come from surface water sources, groundwater sources, and as treated water from a municipal sewage treatment plant. Water is also used for heat transfer from the processes, for treating and washing product, and as a solvent for electrolytic plating operations. Return-flow water is used in contact and noncontact operations. Contact operations, for example, include contact cooling (quenching) in coke oven gas treatment, slag handling in basic oxygen furnaces, electric arc furnaces, continuous casters, scale breaking in hotrolling operations, acid pickling, etc. Noncontact water is used in a series of heat exchangers in coke oven gas treatment, blast furnaces, basic oxygen furnaces, electric arc furnaces, hotrolling operations, cold-rolling operations, boilers, annealing furnaces, and coating lines.

The techniques, equipment, technologies and their efficiency, and the incoming water quality are the key factors affecting water demand and water conservation potential in iron and steel production. [39] The highest consideration should be given to the iron and steel integrated plants with a production capacity of about 2.5 million tons of liquid iron.[40]

Ohio is a steel-producing state and for a long time it has remained among the top three steel-producing states in the nation. The steel industry sits at the base of a number of supply chains that are critical sources of income and work opportunities for the state's residents − from autos and aircraft parts to energy production and appliances. Today Ohio's steel industry directly employs more than 22,000 Ohio residents and generates more than 100,000 jobs in supply and steel consumption industries.[41] This industry is one of the core economic base industries in Ohio, and it is important to secure resources for the successful development of this industry. At the same time, the industry should continue to develop new technologies and follow best management practices to ensure conserving water and reducing the impact of water consumption on the local ecosystem, agriculture and drinking water supply.

Best Management Practices for Water Conservation and Recycling in the Iron and Steel Industry

The best management practices for the iron and steel industry usually target energy saving and reducing air pollution. Sometimes water consumption is discussed as an energy nexus with heavy emphases on waste water treatment and recycling. Multiple industrial associations and projects offer databases of industrial efficiency case studies and technology advancements that are exemplified further in this section of the report.

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[39] Lens, P., Hulshoff Pol, L., Wilderer, P., and Asano, T. (2002). Water Recycling and Resource Recovery in Industry: Analysis, Technologies and Implementation (Integrated Environmental Technology). IWA, London.
[40] See more information on water uses at specific plants in Cagin, V. and Yetis, U. (2011). Water Reuse Strategies: Iron and Steel Industry Case Study. Chapter 10 in *Security of Industrial Water Supply and Management*, NATO Science for Peace and Security Series C: Environmental Security. Edited by Atimtay, A.T., Sikdar, S.K. http://link.springer.com/book/10.1007%2F978-94-007-1805-0
[41] According to the Ohio Steel Council: http://www.ohiosteel.org/economic-impact/facts-and-figures/employment/

The Institute for Industrial Productivity's project offers an industrial efficiency technology database that emphasizes energy management systems.[42] It features three programs under the U.S. Iron and Steel Chapter, namely:[43]

Better Plants Program

The Better Plants Program is a voluntary initiative in which industrial plants can participate by registering to voluntarily commit to reduce energy intensity by 25% over ten years. Participating companies gain recognition and technical support from the U.S. Department of Energy (DOE). The program builds on the success of the former Save Energy Now LEADER program, which was launched in 2009 to contribute to the goal of achieving a 25% reduction in industrial energy intensity by 2017.

Superior Energy Performance

Superior Energy Performance is a certification program in the US that provides industrial facilities with a roadmap for achieving continual improvements in energy efficiency while maintaining competitiveness. The program provides a transparent, globally accepted, system for verifying energy performance improvements and management practices. It is anticipated that Superior Energy Performance will launch nationally in 2012.

Industrial Technologies Program (ITP)

The Advanced Manufacturing Office (AMO) is the lead US government program working to develop and deploy new, energy-efficient technologies for manufacturing. (AMO was formerly known as the Industrial Technologies Program.)

According to the JRC (needs spelled out) Reference Report of Best Available Techniques Reference Document for Iron and Steel Production,[44] water and waste water management practices in this industry should consider various water systems in operation: completely closed, semi-closed or open circuits. There are only a few completely closed looped systems. Closed circuits can be used, for example: for cooling circuits operated with demineralized or softened water at specific installations; for continuous casting molds, or at boilers in power plants, which are generally cooled through an exchanger water/water. Here the second circuit of water is used as a semi-closed circuit with a cooling tower.

Below are three examples where semi-closed systems are used:

- in cooling towers for decreasing the water temperature. There is a need to bleed off a small discharge flow to limit the salt concentration in the water preventing the deposition of these salts and consequently corrosion and further possible leakages
- for the recycling of waste water after treatment for further uses not requiring such high quality water as for the first use. Since some undesirable substances can build up, a small amount of

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[42] This database aims to help decision makers identify technologies and measures that improve productivity and profits while reducing energy consumption and CO_2 emissions in industry, and assist companies in assessing the cost-effectiveness of energy efficiency investment options. http://ietd.iipnetwork.org/category/enms

[43] Same, http://ietd.iipnetwork.org/content/iron-and-steel#programs

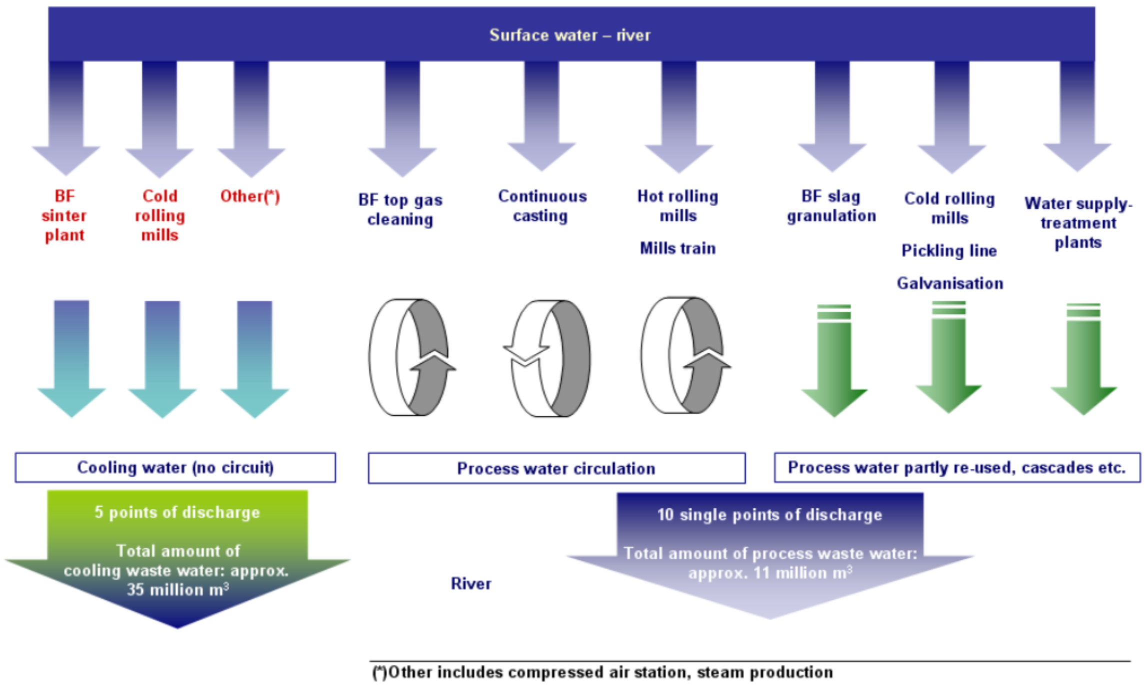
[44] Remus, R., Aguado-Monsonet, M.A., Roudier, S., & Sancho, L.D. (2013). Best Available Techniques (BAT) Reference Document for Iron and Steel Production. JRC Reference Report. European Commission. http://eippcb.jrc.ec.europa.eu/reference/BREF/IS_Adopted_03_2012.pdf

water has to be bleed off and lead to a waste water treatment plant before final discharge. This amount needs to be replenished with fresh water

- for process water which can be led into a close cycle. Since some undesirable substances can build up, a small amount of water is led to a waste water treatment plant before discharging. This amount needs to be replenished with fresh water.

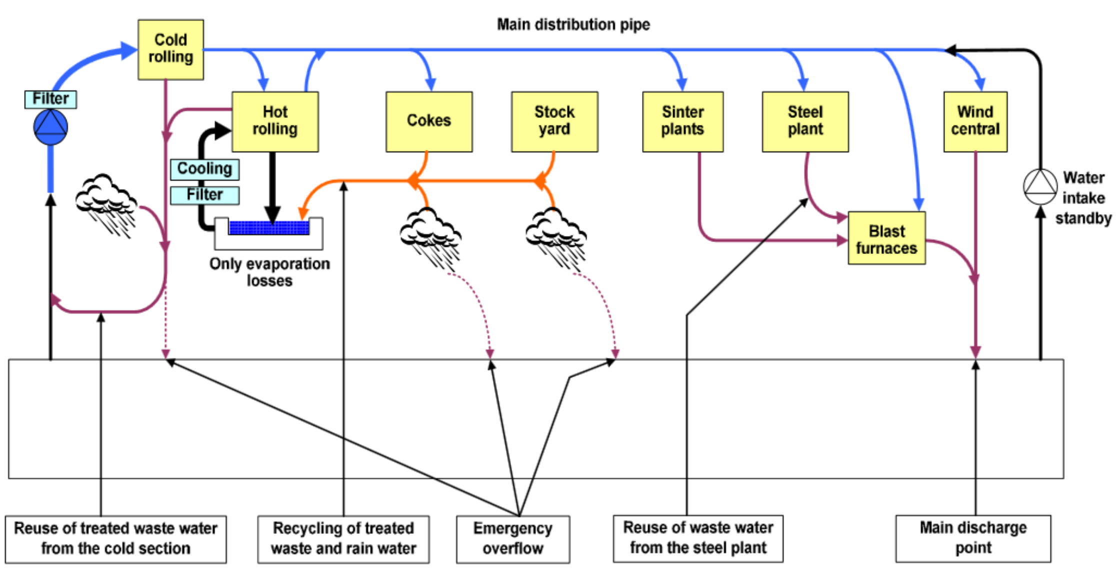
Water management in an integrated steelworks operation primarily depends on local conditions, but above all depends on the availability and quality of fresh water and legal requirements. The following two figures present additional examples of two different global systems from two integrated steelworks with separate circuits due to the local design of the plant (see Figure 15) and with a counter flow cascade system with steel production steps (from a cold rolling mill to the blast furnace) (See Figure 16).

Figure 15. **Example for the Water Management of an Integrated Steelworks with Separate Circuits**



Source: [316, Eurofer 2009]

Figure 16. **Example for the Water Management of an Integrated Steelworks Using a Cascade System**



Source: [316, Eurofer 2009]

Techniques which lead to reduced water intake and minimizing the amount of discharge waste water in the aforementioned examples include:

- avoiding the use of potable water for production lines
- increasing the number and/or capacity of water circulating systems when building new
- plants or modernizing/revamping existing plants
- centralizing the distribution of incoming fresh water
- using the water in cascades until single parameters reach their legal or technical limits
- using the water in other plants if only single parameters of the water are affected and further usage is possible
- keeping treated and untreated wastewater separated - making it possible to dispose of waste water in different ways at a reasonable cost
- using rainwater whenever possible.

Additional examples of reducing water consumption for the iron and steel industry has been offered by Cagin and Yeits (2011) and include:[45]

- Rehabilitation of existing make-up water pre-treatment systems and performing pretreatment where applicable (to increase quality of incoming water via decreasing the salt contents) which will increase recovery rate and decrease amount of make-up water.

- Diversion from the utilization of certain water types (i.e. diverting from mixed water use to a surface water supply in sensitive processes such as new technology blast furnaces).

- Reuse of blow down water from flow through cooling systems as make-up water for semi-closed and closed circuits.

- Chemical substitution or redesigning of the parameters in chemical dosing operations for water conditioning and modernization of water supply equipment and systems, i.e. addition of formaldehyde during blow downs when cyanide treatment arises to be necessary.

- Recovery of blow-down waters prior to discharge using membrane systems.

- Review of design parameters of chemical dosing operations and physical treatment units in which cooling waters are directly in contact with process gases, scale and slag for better separation of phases, i.e. application of hydrocyclonage to separate the sludge flow from wet scrubbing of BF Gas into two flows; one with a low zinc content, which can be recycled to the sinter plant, and a second with a high zinc content, which can be stored or disposed.

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[45] Cagin, V. and Yetis, U. (2011). Water Reuse Strategies: Iron and Steel Industry Case Study. Chapter 10 in Security of Industrial Water Supply and Management, NATO Science for Peace and Security Series C: Environmental Security. Edited by Atimtay, A.T., Sikdar, S.K. http://link.springer.com/book/10.1007%2F978-94-007-1805-0

- Implementation of advanced treatment for wastewater, which is rich in phenol and ammonium, originating from by-product management operations of coke oven processes, in order to prevent the receiving environment from excess eutrophication phenomena and even to reuse the water within the facility.

- Monitoring the make-up water consumptions via online systems.

- Prevention of hydrocarbon contamination in hot rolling operations. Reduction of oil and lubricant losses is a preventive measure against the contamination of process waters and the included scale. The use of modern design bearings and bearing seals for work-up and back-up rolls and the installation of leakage indicators in the lubricant lines (pressure monitoring equipment e.g. at hydrostatic bearings) can reduce the hydrocarbon content (oil) of scale and waste water and reduces the oil consumption by 50–70%.

- Pretreatment of fine scale sludge in order to enable the fine scale sludge to be recycled to the sinter process. Treatment of scale sludge from laminar flow horizontal sedimentation tanks in radial sedimentation units results in a fine scale sludge consisting mainly of very small scale particles which absorb oil to a very high degree. This hampers the recycle of fine scale sludge to the sinter process due the potential risk of increased emissions of VOC and potentially dioxins and problems in waste gas purification systems.

- Use of blow down waters that do not contact directly with gases and materials in coke wet quenching process.

Finally, ***Save Water PA,*** a statewide, nonprofit organization that represents a new effort on behalf of a broad partnership of public, private, and nonprofit organizations to promote voluntary water conservation and provide technical assistance on water use issues offers suggestions on practices that can help manufacturing save water:[46]

General Manufacturing

- Install water-efficient plumbing fixtures with auto-sensors in employee bathrooms.
- Monitor water meters during work stoppages to identify leaks.
- Minimize blowdown in cooling towers.
- Reuse process water or harvest rainwater for use in cooling tower make-up water.
- Eliminate use of "once-through" cooling.
- Replace water-cooled equipment with air-cooled models.
- Maximize condensate return in boiler units.
- Reduce water temperature to minimize evaporative loss where possible.
- Install water-efficient kitchen equipment in cafeterias.
- Eliminate or minimize use of water for shop floor and equipment cleanup.
- Reuse and recycle process water to maximize its effectiveness.

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[46] For more information and additional resources on water conservation go to http://www.savewaterpa.org/audience/businesses/manufacturing/

- Minimize need for landscape irrigation outside offices and facilities.

Fabricated Metal Part Manufacturing

- Reduce or eliminate water used in machining. Dry machining, for example, eliminates the use of water and wastewater treatment. Use of water jet type machining is highly water intensive.
- Install flow restrictors to prevent water in supply pipes from exceeding a predetermined flow rate. A flow restrictor provides a constant water flow and is therefore best suited for rinsing processes.
- Install conductivity controllers, which measure the total dissolved solids in rinse water, to regulate the flow of fresh rinse water into the system.
- Install rinse timers, which are generally preferred for intermittent rinses because they eliminate operator error. Rinse timers installed in conjunction with flow restrictors can provide precise control when the incoming water pressure may rise and fall.
- Use counter-current cascade rinsing to reuse water from one rinsing operation in another, less critical rinsing operation before being discharged to the sewer.
- Employ spray rinsing, which uses considerably less water than immersion rinsing.
- Spray rinse parts over catch tanks allow for water recycling or reuse.
- Use high-pressure, low-volume spray or fog nozzles, which use much less water than conventional spray systems.
- Use air blowers to remove dust or rags to wipe down parts. This can reduce the frequency of refreshing washing baths.

CHEMICAL INDUSTRY

Introduction

Chemicals are used to make almost every product in the US and worldwide. Over the years, the chemical industry made good progress to reduce its environmental footprint. However, some negative effects are well-known and documented. As one of the most heavily regulated industries, chemical manufacturing is subjected to a number of requirements aimed at minimizing releases of chemical substances throughout the manufacturing process.

Chemical Manufacturing is also an energy-intensive sector. While most of public attention in the US is given to energy conservation and reducing emission of air pollutants from the industry, the comprehensive data on water use are relatively unknown, especially with regard to water withdrawal.[47] According to the latest environmental statistics, the chemical manufacturing industry in the United States discharges about 42.7 million pounds of water annually.[48]

[47] Industrial Water Management, A System Approach. Center for Waste Water Reduction Technologies, American Institute of Chemical Engineers, New York. Chapter 5, P.5-26.
[48] 2008 Sector Performance report. Chemical Manufacturing. United States Environmental Protection Agency, September 2008. P.27.http://www.portcompliance.org/pdfs/2008-sector-report-508-full.pdf

The chemicals industry is very diverse, comprising:

- basic or commodity chemicals
- specialty chemicals derived from basic chemicals (adhesives and sealants, catalysts, coatings, electronic chemicals, plastic additives, *etc.*)
- products derived from life sciences (pharmaceuticals, pesticides and products of modern biotechnology)
- consumer care products (soap, detergents, bleaches, hair and skin care products, fragrances, *etc.*).[49]

Most of the output from chemical companies is used by other chemical companies or other industries (e.g. metal, glass, electronics), and chemicals produced by the industry are present in countless consumer products (e.g. automobiles, toys, paper, clothing). The sector is often categorized into "commodity" and "specialty-batch" production, where commodity manufacturers create products in large quantities under continuous processing conditions while specialty-batch manufacturers develop products for specific "niche" markets, making complex products in small quantities and changing their process lines several times a year.[50]

Most of the water used by the chemical industry is for return-flow applications. There is consumptive use associated with non-contact cooling water. Discharged water is warmer than when it was withdrawn, creating increased evaporation rates--even though the increased evaporation occurs after discharge, it is still water lost to the Basin, and counted by ODNR as consumptive use. ODNR estimates once-through cooling methods to consume 1% of water withdrawn.

Water in chemical production plants is used for heating or cooling products and equipment, for vacuum creation, steam production, preparation of solvents and reaction media, extractive or absorptive reagents, product rinsing and distillation. Most of the technological processes take place at high temperatures and pressure. For such technologies demineralized high-purity water is required. Water consumption is determined by production capacity, the type of production and technology. In addition, water consumption depends on the qualification of servicing personnel, type of water resources at the enterprise, and the level of requirements or compliance policies for factories to use zero wastewater discharge technologies.[51]

The largest use of water in the chemical industry is for cooling, with steam (heating and autoclaving) and process water (for mixing, dilution, reactants, wash or rinse water). Water reuse, especially closed-loop cooling with cooling towers, is usually not accounted for in the estimate of the total water used by the industry. Where open-cycle cooling with cooling towers is used, it can represent up to 90-95% reduction in freshwater withdrawn for cooling purposes. For closed cycle cooling processes, ODNR estimates consumptive use to be 10-15% of water withdrawn.

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[49] OEDC Environmental outlook for the Chemical Industry. OEDC. 2001. http://www.oecd.org/env/ehs/2375538.pdf
[50] According to 2008 Sector Performance report, this sector is defined as NAICS 325 (SIC 28). Chemical Manufacturing. United States Environmental Protection Agency, September 2008. P.27.http://www.portcompliance.org/pdfs/2008-sector-report-508-full.pdf
[51] Chemical Industry. Jurby. http://www.jurby.com/en/industries-we-serve/chemical-industry-/

Ten processes account for over 95% of the water use in the chemical industry; including six methods for producing Synthesis Gas (Syngas) (87%) and production of hydrogen (7%). The production of various chemicals requires different amounts of water. For example, producing silicon-based chemicals requires large quantities of water, yet the top manufactured chemicals by volume (including nitrogen, ethylene, ammonia, phosphoric acid, propylene, and polyethylene) require far less water during production.[52]

According to the Ohio Chemistry Technology Council, chemistry companies in Ohio directly employ about 46,000 people, and indirectly contribute 156,000 jobs to the economy. Every year, Ohio's chemistry companies produce high-technology products that generate more than $20 billion in sales.[53] With the prospects of Marcellus and Utica shale development significant growth is expected in this sector over the next 5-10 years, especially in petrochemical and polymer industries. The reduced price of natural gas, which is abundant in shale, translates into lower cost ethane, which is used to make ethylene, a key ingredient in manufactured goods.[54]

Most of the challenges of water reuse and conservation in the chemical industry reside in the domain of modified general practices of water use by manufacturing facilities, such as improvement of water use management system, educating employees on the importance of water conservation, and continuing research and development effort focused on new technologies employing low water and energy usage. Some specific practices in chemical enterprises should be focused on reducing water losses and water reuse in cooling processes.

The following discussion sets forth best management practices that have been identified in the United States and Europe and already adopted by some prominent chemical manufacturers featured in case studies (i.e. BASF, DOW).[55]

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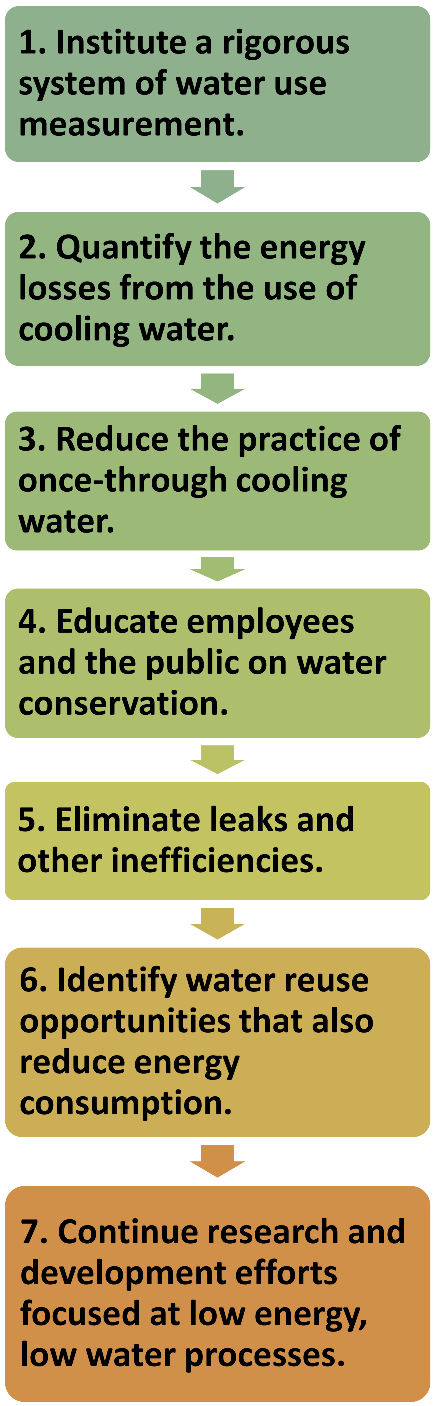
[52] Byers, W., CG. Lingren, C. Noling, D. Peters. Industrial Water Management: A System Approach. CH2M Hill, Inc. New York, 2003.
[53] Ohio Chemistry Technology Council, http://www.ohiochemistry.org/aws/OCTC/pt/sp/industry
[54] See more at: http://blog.americanchemistry.com/2013/04/when-it-comes-to-chemical-manufacturing-jobs-ohio-is-having-seconds/#sthash.h7XTt09n.dpuf
[55] 2008 Sector Performance report, this sector is defined as NAICS 325 (SIC 28). Chemical Manufacturing. United States Environmental Protection Agency, September 2008. P.32-35. http://www.portcompliance.org/pdfs/2008-sector-report-508-full.pdf
Jensen, C. Water Solutions and Strategies in the Chemical Industry. Chapter 10 in Water and Sustainable development: Opportunities for the Chemical Sciences: A Workshop Report to the Chemical Science Roundtable. National Academic Press. 2004. http://www.ncbi.nlm.nih.gov/books/NBK83738/
Gunderson, J. Water Treatment: Chemical and Pharmaceutical Industries. Industrial WaterWorld. Retrieved May 15, 2014. http://www.waterworld.com/articles/iww/print/volume-12/issue-05/feature-editorial/water-treatment-chemical-and-pharmaceutical-industries.html



General Best Management Practices for Water Reuse and Conservation – Chemical Industry

1) **Institute a rigorous system of water use measurement**. Although the instrumentation need not be sophisticated, it should be reliable and all significant water uses should be measured and recorded.

2) **Quantify the energy losses from the use of cooling water.** Given the increasingly short supply of water, it could be that for some processes cooling is no longer best accomplished using water. A comprehensive evaluation of energy usage should be performed.

3) **Reduce the practice of once-through cooling water.** Cooling towers should be utilized wherever possible to decrease energy consumption and reuse as much cooling water as possible.

4) **Educate employees and the public on the importance of water conservation.** Employees generally respond to issues on which they're well informed and on which management attention is focused, as indicated by training and other emphases.

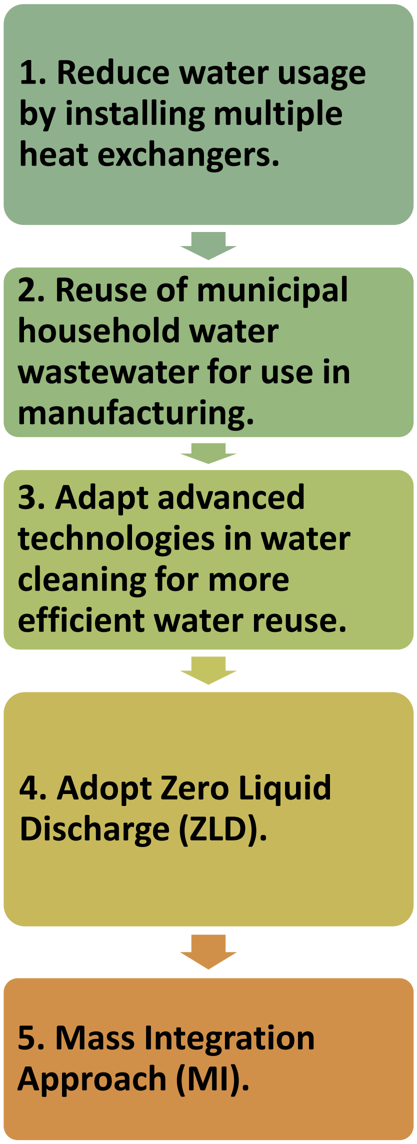
5) **Eliminate leaks and other inefficiencies.** Although a number of facilities have implemented housekeeping and/or water conservation programs, leaks in sewer systems and other piping continue to waste water.

6) **Identify water reuse opportunities that also reduce energy consumption.** The chemical industry has often failed to explore water reuse because of its extensive infrastructure investments. As water and energy costs escalate, the drivers for water reuse increase, and the opportunities for associated energy reductions are numerous.

7) **Continue research and development efforts focused at low energy, low water processes.** Several chemical companies report impressive advances in processes that were previously thought impractical. Technology is likely to be integral in realizing even greater gains in the challenge of water and energy minimization.[56]

[56] Water use in industries of the future. Chemical Industry. Industrial Water Management, A System Approach. Center for Waste Water Reduction Technologies, American Institute of Chemical Engineers, New York. Chapter 5, P.5-33.

Specific Best Management Practices for Water Reuse and Conservation – Chemical Industry



1) **Reduce water usage by installing multiple heat exchangers.** Installation of multiple heat exchangers allows for the reduction of cooling water usage. This can be done in conjunction with improving cooling towers, upgrading and cleaning equipment to improve heat transfer, repairing and upgrading steam traps, repairing stream leaks and changing operating procedures to minimize water usage.[57]

2) **Reuse of municipal household water wastewater for use in manufacturing.** In some cases it is feasible to treat and subsequently reuse municipal household water wastewater for use in manufacturing processes and then in cooling towers.[58]

3) **Adapt advanced technologies in water cleaning for more efficient water reuse.** Separation membranes are a class of technologies with diverse and rapidly growing users. Adoption of reverse osmosis and nanofiltration can significantly increase water reuse at chemical industry facilities.[59]

4) **Adopt Zero Liquid Discharge (ZLD).** There is a growing trend in the chemical industry to adopt ZLD, a practice where not a drop of water is allowed to leave a chemical plant. Innovative technologies such as membrane filtration and thermal evaporation/crystallization are used to treat, recycle, and reuse wastewater. ZLD had been successfully incorporated in California, Arizona, and Nevada.[60]

5) **Mass Integration Approach (MI)**. This new approach addresses the global flow of mass within the processes in order to optimize the allocation, separation, generation and routing of streams and species, including water and contaminants. For a set of water-using units, it is desired to determine a network of interconnections of water streams

[57] 2008 Sector Performance report, this sector is defined as NAICS 325 (SIC 28). Chemical Manufacturing. United States Environmental Protection Agency, September 2008. P.32-35. http://www.portcompliance.org/pdfs/2008-sector-report-508-full.pdf

[58] Gunderson, J. Water Treatment: Chemical and Pharmaceutical Industries. Industrial Water World. Retrieved May 15, 2014. http://www.waterworld.com/articles/iww/print/volume-12/issue-05/feature-editorial/water-treatment-chemical-and-pharmaceutical-industries.html

[59] Jensen, C. Water Solutions and Strategies in the Chemical Industry. Chapter 10 in Water and Sustainable development: Opportunities for the Chemical Sciences: A Workshop Report to the Chemical Science Roundtable. National Academic Press. 2004. http://www.ncbi.nlm.nih.gov/books/NBK83738/

[60] Gunderson, J. Water Treatment: Chemical and Pharmaceutical Industries. Industrial WaterWorld. Retrieved May 15, 2014. http://www.waterworld.com/articles/iww/print/volume-12/issue-05/feature-editorial/water-treatment-chemical-and-pharmaceutical-industries.html

among the units so that the overall fresh water consumption is minimized while the processes receive water of adequate quality.[61]

Future Approaches

The Organization for Economic Co-operation and Development (OECD), an intergovernmental entity that represent 30 industrialized countries in North America, Europe and the Pacific, as well as the European Commission, looked at the future approaches to environmental outlook for the chemical industry and outlined them within three major sections:

- creating a holistic approach to chemical safety that not only addresses the risks to man and the environment resulting from the production of individual substances, but also the risks posed by products made from these substances and by the use of natural resources and energy to create these substances and products:
    - improving the knowledge base for the design of safe chemicals
    - finding ways to better evaluate and manage the risks resulting from the release of chemicals from products
    - finding the right means to balance the efficacy of products with their overall "environmental and health performance" which will require an Integrated Product Policy
    - effective implementation of an Extended Producer Responsibility regime to ensure that industry takes the Responsible Care concept a step further; this would also mean that large multinational companies which apply Responsible Care will make efforts to assist small- and medium sized enterprises in implementing more comprehensive pollution prevention, resource efficiency and safety policies
    - further developing and extending the concept of the chemicals industry as a "service industry"; as these chemical "service" companies focus on providing a function for their customers rather than a product, they have more opportunities to reduce risks at the production, use and waste disposal stage; chemicals users and governments could work together to develop, apply and propagate this concept

- examining and responding to the possible negative impacts on chemical safety resulting from the increasing globalization of the chemicals industry:
    - supporting the development of the chemical safety regimes in non-OECD countries. One way of doing this would be to involve them more closely in OECD work; and
    - finding ways to respond to potential negative impacts on the environment due to the fast pace of restructuring and reorganization in multinational enterprises. If national structures cannot adequately deal with this, closer international co-operation might be needed to develop efficient and fast international information exchange and control systems

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[61] Raskovic, P. Water Conservation in the Chemical Process Industry – Mass Integration Approach. Chapter 3. *Security of Industrial Water Supply and Management*, NATO Science for Peace and Security Series C: Environmental Security. Edited by Atimtay, A.T., Sikdar, S.K. http://link.springer.com/book/10.1007%2F978-94-007-1805-0

- facilitating and promoting environmental democracy in relation to chemical safety, so that all stakeholders will be better informed and on an equal footing when discussing relevant environmental issues:
    - information on releases and the safety of chemicals needs to be made widely available; public right-to-know should be strengthened as much as possible and yet be compatible with justified business interests;
    - information should be made available in a way that will make it possible for public interest groups and the public to understand the implications of the information in terms of risks to human health and the environment; and
    - efforts should be made to educate the public about chemical safety and, where necessary, to provide public interest groups with resources so that they can play an equitable role in policy discussions related to chemical safety.[62]

PETROLEUM REFINING INDUSTRY

Introduction

The processing of refining crude oil into petroleum requires the withdrawal and consumption of large amount of water in the US. Water is primarily used in the production of steam and for cooling, with some water also used to remove inorganic compounds during processing. This water use is in addition to and separate from the water necessary to extract crude oil from the earth and the "produced" water withdrawn as a by-product of extractive operations. The amount of water withdrawn and consumed is directly related to the volume of petroleum production. Estimates from the US Energy Information Administration (EIA) put the refining capacity of the US as of February 2014 at nearly 18 million barrels per day (approximately 750 million gallons per day)[63].

Peter Gleick produced the most frequently used estimate for water withdrawal by refineries, pegging it at 12.5 gallons of water for every gallon of crude refined[64]. By this standard, US refineries in 2014 withdraw on average 9.4 billion gallons of water each day in order to refine 17.9 million barrels of crude per day. As a benchmark, a typical refinery, according to the Department of Energy, withdraws water at a rate of 3-4 million gallons per day[65].

Though certainly large withdrawers of water, consumed water amounts to only a fraction of that which is necessary for petroleum refining operations. The water consumed is almost entirely due to use as an on-site

[62] OEDC Environmental outlook for the Chemical Industry. OEDC. 2001. http://www.oecd.org/env/ehs/2375538.pdf
[63] U.S. Energy Information Administration. (2014, February). U.S Operable Crude Oil Distillation Capacity. http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mocleus2&f=m
[64] King, C. W., & Webber, M. E. (2008). The water intensity of the plugged-in automotive economy. Environmental Science & Technology, 42(12), 4305-4311. http://www.researchgate.net/publication/23495753_Water_intensity_of_transportation/file/9fcfd5140a4f462c2f.pdf
[65] DoE, U. S. (2006). Energy demands on water resources: Report to Congress on the interdependency of energy and water. Washington, DC: US Department of Energy. http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf

coolant, which is lost through evaporation.[66] Estimates vary, but every gallon of final refined product typically consumes 1-2.5 gallons of water, with more precise estimates placing the value at 1.5 gallons of water[67,68]. Based on this and national refining capacity, it can be estimated that refineries in the US consume approximately 1.1 billion gallons of water per day.

The petroleum refining industry has been active in with water efficiency, most notably they have experienced more than a 95% decrease in water consumption since 1975 - when the industry was averaging slightly more than 45 gallons of water consumed per gallon of refined product[69]. Refineries are noted as having the highest water-recycling rate of any major industry - a given quantity of raw water is typically reused nearly 8 times before being discharged[70].

Due to costs of implementing water reuse and recycling programs, progressive efforts are primarily practiced in water stressed locations or where sources of freshwater are expensive. Ohio, though typically viewed as water secure due to its relative abundance of precipitation, groundwater, and surface water, is not immune from the issues associated with water stressed locations. As a "medium to high stress" state, largely due to a higher than average population density, Ohio should pursue policies that promote efficiencies within petroleum refineries in order to reduce overall withdrawals and limit consumption.

Much of the literature with regard to best practices relates to the use of alternative sources of water such as municipal treated wastewater, on-site water capture, and process water reuse. Additionally, refineries in water-stressed areas have begun to use brackish or saline water sources from nearby bays and aquifers as sources in order to reduce freshwater withdrawals. Efficiency gains are also sought from the processing itself, with engineers looking to use so-called "pinch" analyses to determine the best ways to use, direct, capture, and redirect process water in order to reduce overall water needs[71,72]. The largest consumptive losses, in terms of energy and water, stem from evaporation and represent a potential source of efficiency gains in both respects. Furthermore, cogeneration of power on site is also a potential source of water and

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[66] Worrell, E. & Galitsky, C. (2005, February). Energy Efficiency Improvement and Cost Saving Opportunities for petroleum Refineries. An Energy Star Guide for Energy and Plant Managers. Ernst Orlando Lawrence Berkley National Laboratory. LBNL-56183. http://www.energystar.gov/ia/business/industry/ES_Petroleum_Energy_Guide.pdf

[67] Wu, M., Mintz, M., Wang, M., & Arora, S. (2009). Water consumption in the production of ethanol and petroleum gasoline. *Environmental Management*, *44*(5), 981-997. http://link.springer.com/article/10.1007/s00267-009-9370-0/fulltext.html

[68] Ellis, M., Dillich, S., & Margolis, N. (2001). Industrial water use and its energy implications. Washington, DC: US Dept of Energy, Office of Energy Efficiency and Renewable Energy. http://aceee.org/files/proceedings/2001/data/papers/SS01_Panel1_Paper03.pdf

[69] Ellis, M., Dillich, S., & Margolis, N. (2001). Industrial water use and its energy implications. Washington, DC: US Dept of Energy, Office of Energy Efficiency and Renewable Energy. http://aceee.org/files/proceedings/2001/data/papers/SS01_Panel1_Paper03.pdf

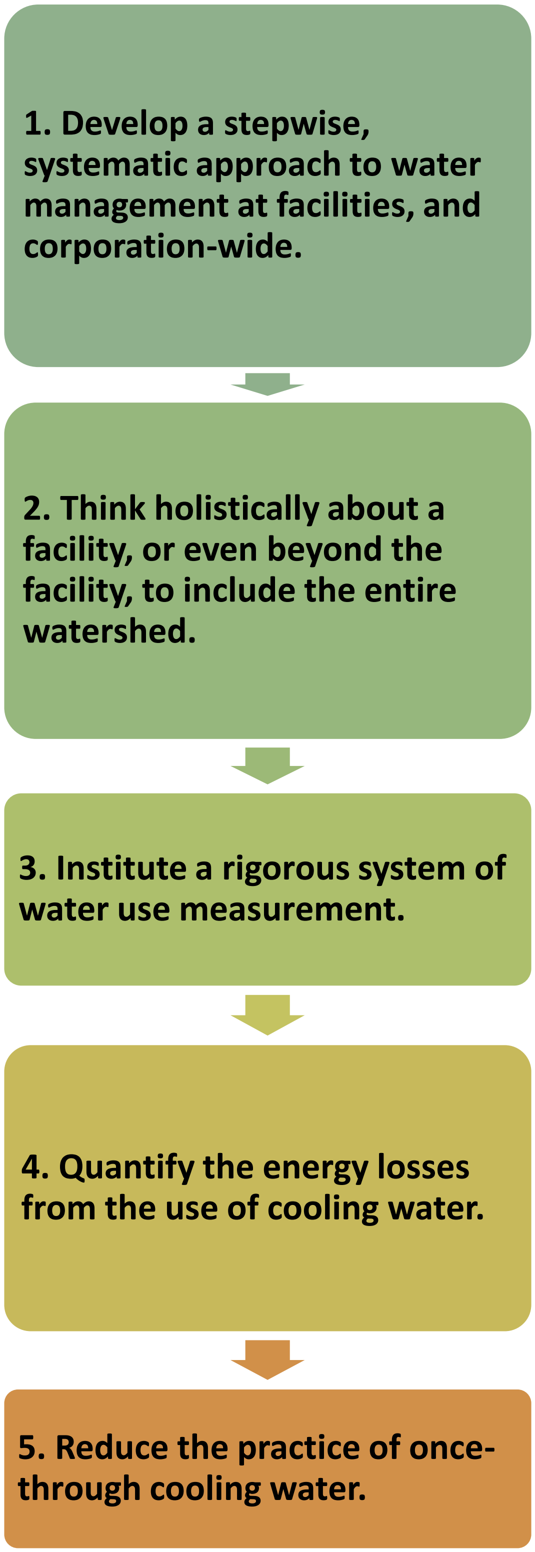
[70] Ellis, M., Dillich, S., & Margolis, N. (2001). Industrial water use and its energy implications. Washington, DC: US Dept of Energy, Office of Energy Efficiency and Renewable Energy. http://aceee.org/files/proceedings/2001/data/papers/SS01_Panel1_Paper03.pdf

[71] Hwang, S., & Moore, I. (2011). Water network synthesis in refinery. Korean Journal of Chemical Engineering, 28(10), 1975-1985. http://download.springer.com/static/pdf/28/art%253A10.1007%252Fs11814-011-0087-4.pdf?auth66=1401554605_f68cfa8985e0fc248dd10173c2541813&ext=.pdf

[72] Pombo, F. R., Magrini, A., & Szklo, A. (2013). An analysis of water management in Brazilian petroleum refineries using rationalization techniques. Resources, Conservation and Recycling, 73, 172-179. http://www.sciencedirect.com/science/article/pii/S0921344913000335

energy savings, with heated water from on-site energy thermoelectric turbines being reused elsewhere in the refinery, and vice versa.

The following discussion sets forth best management practices that have been identified in regions around the country and world for conserving water and reducing the impact of water consumption from the production of petroleum on the local ecosystem, agriculture, and drinking water supply.



Best Management Practices for Water Conservation -- General Practices for Companies Engaged in Petroleum Refining

1) Develop a stepwise, systematic approach to water management at facilities, and corporation-wide.

o Water use reduction and management has often been done on a piecemeal basis within individual departments. Results have often been less than satisfactory, or programs have not been carried through or measured. Water management must be viewed as an *ongoing* management process.

2) Think holistically about a facility, or even beyond the facility, to include the entire watershed.

o As mentioned previously, each industry and facility can have a mass balance drawn around it; when this is done, it can be seen that changes in one part of the system affect the entire system. When this is understood, changes that detrimentally affect the system can be avoided, and changes that increase efficiency in all parts of the system can be planned.

3) Institute a rigorous system of water use measurement.

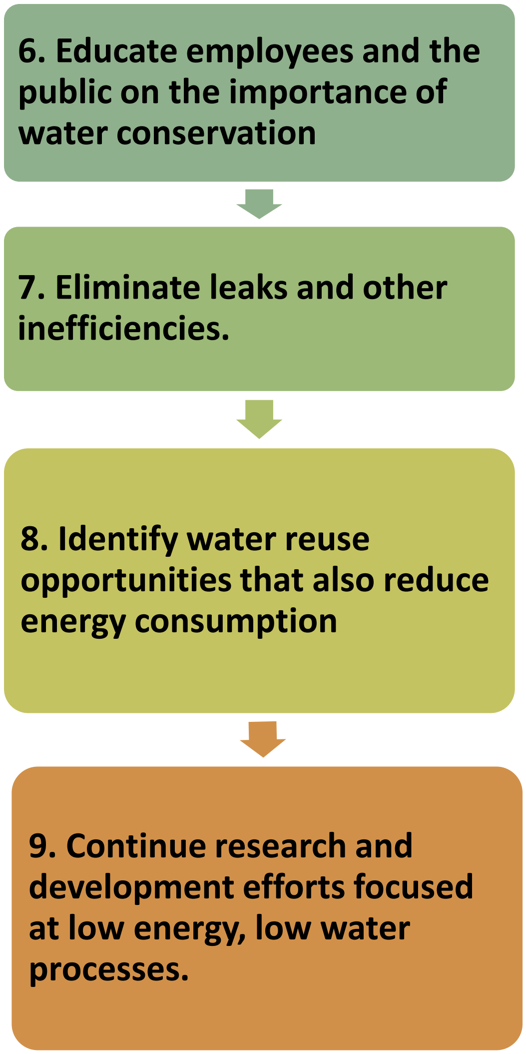
o Although the instrumentation need not be sophisticated, it should be reliable and all significant water uses should be measured and recorded.

4) Quantify the energy losses from the use of cooling water.

o Given the increasingly short supply of water, it could be that for some processes, cooling is no longer best accomplished with water. A comprehensive evaluation of energy usage should be performed.

5) Reduce the practice of once-through cooling water.

Cooling towers should be utilized wherever possible to decrease energy consumption and reuse as much cooling water as possible.



6) Educate employees and the public on the importance of water conservation.

- Employees generally respond to issues on which they're well informed and on which management attention is focused, as indicated by training and other emphases.

7) Eliminate leaks and other inefficiencies.

- Although a number of facilities have implemented housekeeping and/or water conservation programs, leaks in sewer systems and other piping continue to waste water.

8) Identify water reuse opportunities that also reduce energy consumption.

- Industry has often failed to explore water reuse because of its extensive infrastructure investments. As water and energy costs escalate, the drivers for water reuse increase, and the opportunities for associated energy reductions are numerous.

9) Continue research and development efforts focused at low energy, low water processes.

- Several companies report impressive advances in processes that were previously thought impractical. Technology is likely to be integral in realizing even greater gains in the challenge of water and energy minimization.[73]

[73] Byers, W., Lindgren, G., Noling, C., & Peters, D. (2003). Industrial Water Management: A Systems Approach, Second Edition.
http://www.wiley.com/WileyCDA/WileyTitle/productCd-0816908753.html (Download CD Files)

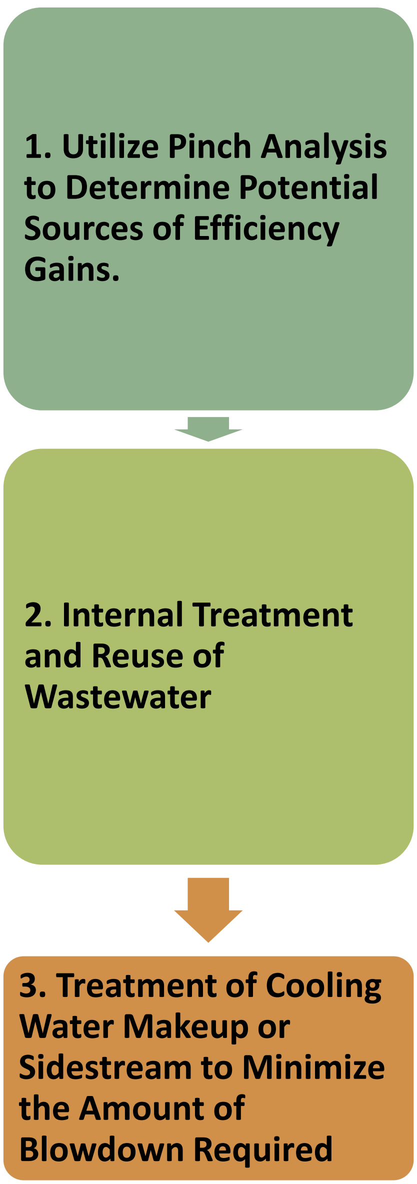
Best Management Practices for Water Conservation during Petroleum Refining

Reuse and recycling of water within refinery operations fall into three primary categories. The potential for reuse within the facility is determined by the initial use of the water due to changes in water chemistry and/or contamination.

Steam Systems - Systems that utilize steam for heat transfer and direct contact applications.

Cooling Systems - Those systems utilized to dissipate and transfer heat, typically with excess energy released into the environment.

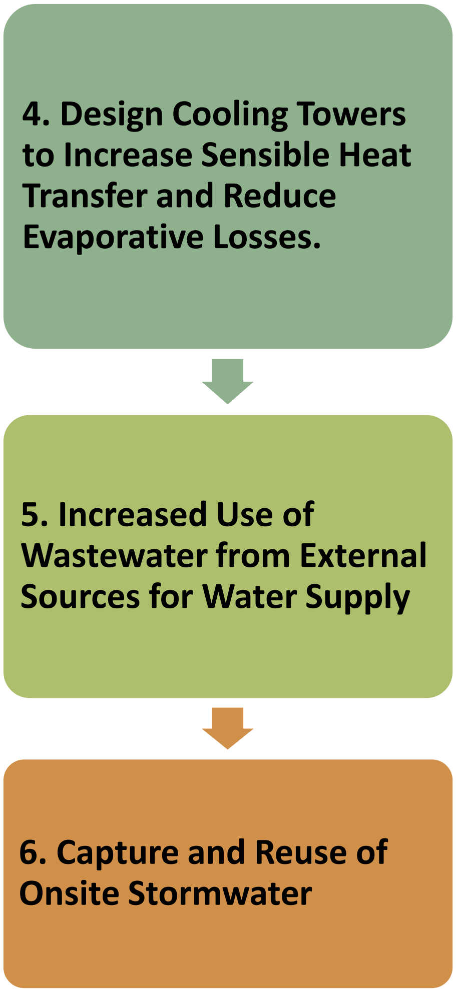
Process Operations - The recycling of sour water and other process by-products for other refinery processes, depending on water chemistry requirements.



1) **Utilize Pinch Analysis to Determine Potential Sources of Efficiency Gains -** Pinch analysis was developed to improve efficiency in terms of energy. In the case of refineries, the majority of water consumption also occurs during a high energy loss process that requires evaporative cooling. Pinch analysis looks at the minimum consumption of freshwater necessary for each operation, designs distribution mechanisms to ensure adequate flow rates, and makes modifications to the existing structure of water and wastewater distribution in order to maximize reuse and minimize the generation of wastewater and evaporative consumption.

2) **Internal Treatment and Reuse of Wastewater -** Due to regulations, many refineries already engage in the treatment of wastewater, though some still send wastewater streams to municipal or third party treatment faculties. By housing treatment facilities on site the opportunities for reuse improve, and the total freshwater withdrawals are reduced. Reuse non-contact (uncontaminated) condensate within refinery steam systems whenever possible. Contaminated or potentially contaminated condensates may be a good choice for reuse in crude desalting due to low levels of total dissolved solids. Boiler blowdown water may also be a good source for reuse in other applications in which moderate levels of total dissolved solids are acceptable.

3) **Treatment of Cooling Water Makeup or Sidestream to Minimize the Amount of Blowdown Required -** Blowdown is typically required in order to maintain water chemistry standards necessary for safe and efficient boiler operations. By pretreating the boiler water, blowdown, and hence wastewater, can be reduced.



4) Design Cooling Towers to Increase Sensible Heat Transfer and Reduce Evaporative Losses - Evaporative losses are the largest consumptive use of water in a refinery and therefore water consumption can be greatly reduced by cutting evaporative cooling. This is done through a shift towards latent (non-evaporative) heat transfer methods. Since cooling water is generally flexible in terms of its quality specifications, it is a prime candidate for reusing water from other sources, such as boiler blowdown, and treated wastewater (either municipal or on-site).

5) Increased Use of Wastewater from External Sources for Water Supply - On-site treatment and reuse of wastewater streams is desirable in its own right, but the use of treated municipal wastewater streams also presents a potential source to reduce overall freshwater withdrawals. Distance and cost may make this difficult so colocation of municipal wastewater treatment facilities near refineries can make this more feasible[74].

6) Capture and Reuse of Onsite Stormwater - Depending on the size of the facility, and the amount of annual rainfall, captured stormwater has the potential to be used in the refining process, whether it be for safety (fire systems) or for use in the cooling or boiler water systems. The amount of pre-treatment will depend on the end use[75].

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[74] Byers, W., Lindgren, G., Noling, C., & Peters, D. (2003). Industrial Water Management: A Systems Approach, Second Edition.
http://www.wiley.com/WileyCDA/WileyTitle/productCd-0816908753.html (Download CD Files)

[75] IPIECA. (2010). Petroleum refining water / wastewater use and management. IPIECA Refinery Water Management Task Force.
http://www.ipieca.org/publication/petroleum-refining-water-wastewater-use-and-management

FOOD PROCESSING

Introduction

The production of food in a manufacturing setting often requires large quantities of fresh water for the transporting, cleaning, processing, and formulating of products. Oftentimes water is explicitly used to meet federal sanitary requirements, limiting the prospects for process reuse and the recycling of municipal wastewater. Due to the diversity of food products and the production processes necessary, quantities of water used can vary dramatically among products. It is estimated that industry-wide, the average water use is approximately 8.6 gallons of water per unit of output.[76]

Water conservation and reuse within the industry has arisen as an important topic in part due to regulations of effluent and the costs associated with this. Reduction in total effluent discharged, can lower costs significantly. Cost savings from water use reduction of 15-30% can be achieved, with attractive returns on investment. Since profit margins are low in food processing, improved efficiency in water use can improve net profit margins[77].

As mentioned previously, fresh water is used in a wide range of applications for food processing including as a raw material, separating agent, washing medium, delivery medium, and heat transfer medium. Decreasing water consumption in individual processes is certainly helpful, but a more comprehensive integrated approach to facility design has proven itself very effective. Reductions in use, must be balanced against fear of foodborne illnesses and other contaminations, making reduction and reuse efforts in the industry slower to take hold than in other less sensitive industries[78]. This contributes to the fact that the food processing industry recycling rate has remained nearly constant over several decades even as other industries saw their recycling rates double. In 1990, the recycling rate for the industry remained at 2:1, meaning that a given amount of water is typically used twice within the facility before being discharged[79].

The key idea for the minimization of water is through reusing water from one operation to another in which the water quality is appropriate. Food processing, somewhat unique among manufacturing industries, relies heavily on batch and semi-continuous processes, making the prospects for the minimization of water more complex, but not impossible. Whereas continuous processes need only consider flow rates and concentration limits, batch processes must also take into account the dimensions of time and varying resource demands over time. Reusing effluent in a batch process context, when appropriate, typically requires larger storage capacity than would otherwise be necessary in a continuous production process, increasing up front capital costs. The low profit margins and low recycling rate,

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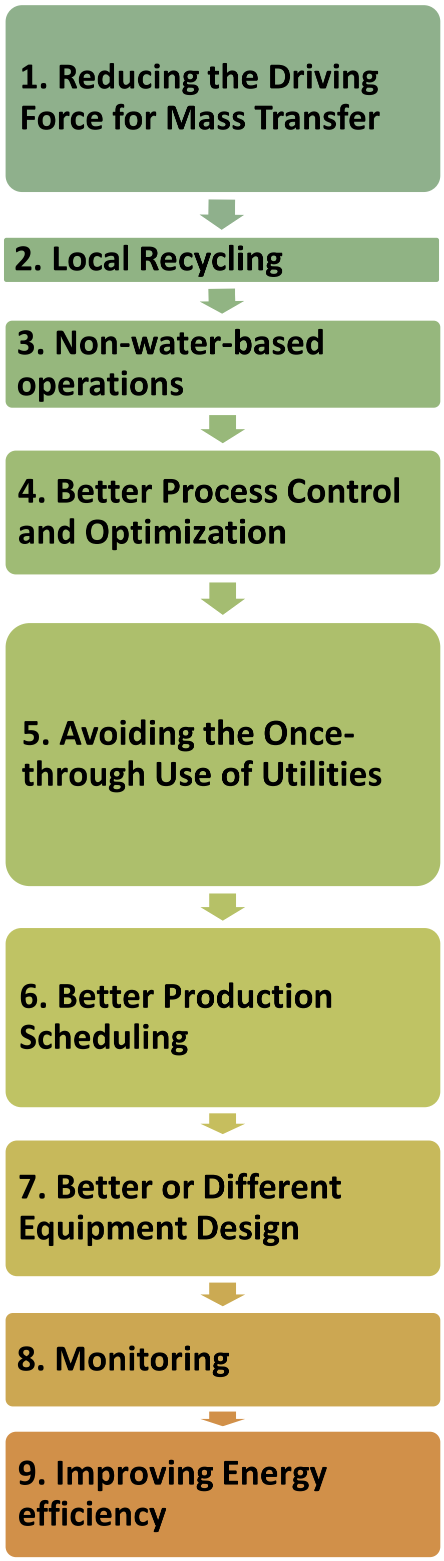
[76] Ellis, M., Dillich, S., & Margolis, N. (2001). Industrial water use and its energy implications. Washington, DC: US Dept of Energy, Office of Energy Efficiency and Renewable Energy. http://aceee.org/files/proceedings/2001/data/papers/SS01_Panel1_Paper03.pdf
[77] Klemes, J., Smith, R., & Kim, J. K. (Eds.). (2008). Handbook of water and energy management in food processing. Elsevier. Availability online is limited.
[78] Klemes, J., Smith, R., & Kim, J. K. (Eds.). (2008). Handbook of water and energy management in food processing. Elsevier. Availability online is limited.
[79] Ellis, M., Dillich, S., & Margolis, N. (2001). Industrial water use and its energy implications. Washington, DC: US Dept of Energy, Office of Energy Efficiency and Renewable Energy. http://aceee.org/files/proceedings/2001/data/papers/SS01_Panel1_Paper03.pdf

however, often mean that there are low-hanging fruit for water reduction that can be addressed and that have low payback times.

As with many industries, water and energy management are often linked during the processing of food due to the use of cold and hot water (often as steam) for varying processes as well as for quality control. For this reason, engineers often seek efficiencies that create both water and energy minimization. The most frequently cited method is to use water heated or cooled during a previous batch, process, or step to pre-heat or pre-cool water for future batches, processes, or steps. If water quality can be maintained, direct mixing provides the highest benefits in reduced energy and water use. When this is not possible, a heat exchanger can be used prior to effluent treatment.

Table 14. **Specific Best Management Practices for the Food Industry**

Where feasible, re-chlorinate and recycle transport water.
For product transport use conveyor belts. Preferably, use "rabbit-ear" or V-shaped roller supports that are easier to clean.
Where feasible, use pneumatic conveying systems.
Instead of flat bottom troughs, use flumes with parabolic cross-sections.
Investigate the use of these alternatives in water-intensive units: 1) rubber-disc scrubbing units instead of raw product cleaning and peeling; 2) steam vs. water blanchers, or 3) evaporative coolers instead of water-cooled systems.
Optimize depth of product on conveyors for maximizing wash water efficiency.
Establish optimal nozzle size and pressure.
Replace eroded and non-functional nozzles.
Split spray wash units into two or more sections, and establish a counter-flow reuse system.
Control belt sprays with a timer to allow for intermittent application of chlorinated water.
Consider installation of soaking units where indicated.



Best Management Practices for Water Conservation during Food Processing

1) **Reducing the Driving Force for Mass Transfer** – when water is used as a mass transfer agent in, for example, extraction, absorption or stripping operations, the water flow rate can be reduced by reducing the driving force. However, it should be noted that a small driving force often results in a large capital investment for equipment and may, for example, increase the number of stages in the extraction operation.
2) **Local Recycling** – water can be (partly or totally) recycled locally for the operation.
3) **Non-water-based operations** – Water using operations can be replaced by non-water using processes, for example, using crystallization for the separation task, rather than extraction using water.
4) **Better Process Control and Optimization** – process controls can be put in place to avoid excessive or unnecessary use of water in the operation. Process optimization can be useful to identify any existing spare capacity in the water using operation, leading to savings in water usage.
5) **Avoiding the Once-through Use of Utilities** – steam, hot water and cooling water are widely used in the food industry to supply hot or cold energy. If the usage of these utilities is based on once-through systems, a large amount of water is required. In order to save water consumption, it is common industrial practice to use recirculating systems in which the energy contained in the water (or steam) is delivered to the process indirectly, for example, through a heat exchanger, and the water is collected or returned for reuse or recycling.
6) **Better Production Scheduling** – production scheduling can be organized to minimize water requirements for the whole manufacturing process. For example, product changeover between different products in multiproduct batch processing can be minimized to reduce water requirements for washing.
7) **Better or Different Equipment Design** – the equipment can be designed inherently to use a smaller amount of water. For example, water can be saved by introducing a drift eliminator in the cooling tower, which reduces the loss of water caused by drift. For the use of water in internal vessel cleaning, distribution of water with spray-balls is effective.
8) **Monitoring** – water leakage can be prevented or minimized by close monitoring of the flow rate, pressure or concentrations of process streams or water streams.
9) **Improving Energy Efficiency** – water is widely used as an energy carrier in the process industries. Improving energy efficiency or reducing energy demand for a site provides water savings. Pinch technology or heat integration

techniques are widely employed to minimize energy consumption and improve energy efficiency[80].

Table 15. **Best Management Practices for the Beverage Industry**

Set pumped cooling and flushing water to the minimum requirement.
Discharges from tank cleaning, keg washes and fermenters, bottle and can soak and rinse water, cooler water and flush-water, filter backwash, and pasteurizer and sterilizer water are potentially reusable. Measure and monitor these uses for reusing purposes.
Investigate areas for reuse including first rinses in wash cycles, can shredder, bottle crusher, filter back-flush; caustic dilution, boiler make-up, refrigeration equipment defrost, and floor and gutter wash. If retreated, cooler water can be reused in many instances.

MINING

Introduction

Ohio has a number of mining industries, many of which use significant amounts of water. Among the mining industries the use varying amounts of water:

- Limestone and dolomite
- Sand and gravel
- Sandstone and conglomerate
- Clay and shale
- Peat
- Coal
- Gypsum
- Salt

Oil and Gas is another active mining business in Ohio but because so many new water facility registrations are coming from that industry, best management practices for water conservation therein are considered separately. However, many of the principles for water conservation are the same for all mining industries. Accordingly, the discussion below will include reference to some oil and gas practices that also apply to mining in general, and accordingly may be repetitive with those management practices identified in the hydraulic fracturing discussion.

Water intake for all mining must be monitored for (1) restrictive or altered water flow, (2) impact on ecology and aquatic habitats, especially for fish, and (3) impact on groundwater supplies. Because of the potential for mine related wastewater to be contaminated with sedimentation, pollution or nutrients, mining companies must comply with regulations that ensure that such water does not adversely affect

[80] Klemes, J., Smith, R., & Kim, J. K. (Eds.). (2008). Handbook of water and energy management in food processing. Elsevier. Availability online is limited.

waters downstream if released. As a result, mining companies have developed wastewater treatment strategies to minimize the release of polluted water into the environment.[81]

Such wastewater treatment is only relevant to this analysis insofar as the water may be a source of reuse, and therefore capable of reducing the overall volume of water that otherwise might be required for mining operations. Accordingly, a cursory discussion of best management practices in the recycling of wastewater is included herewith.

Water has a number of uses in the mining industry. One common use of water, especially for open pit mining, is for wetting roads in order to reduce suspended dust. Another significant use for water can be found in coal mining, where acidic material must remain saturated and out of contact with the atmosphere, and the best way to accomplish this may be through infiltrating large amounts of surface water into the spoil.[82] Other common uses for water include: transportation of ore and waste, separation of materials through physical and chemical processes, cooling of power generation systems, and washing equipment.[83]

Best Management Practices for Companies in the Mining Industries

1) **Embed Water Conservation Strategies into the Company Culture at All Levels.** Analysis of water conservation should be part of the company culture, and should have executive level oversight. Leading practices include tying executive compensation to performance on water management goals, and regular board level briefings on performance on water management goals.[84] Mine operators should insist that contractors and subcontractors also embed good water stewardship strategies into their company culture.[85]

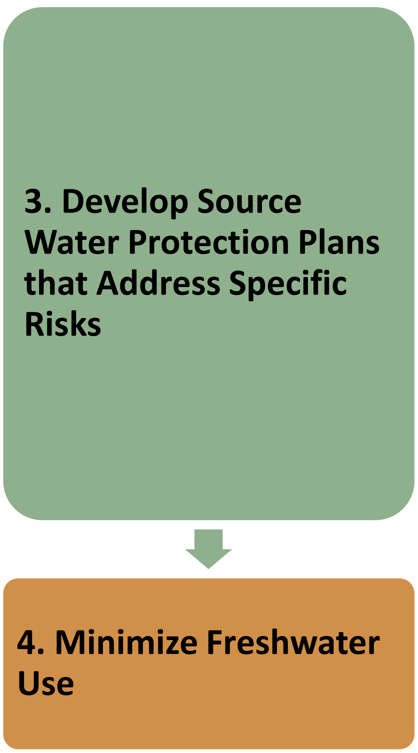
2) **Limit Withdrawals to Maintain Minimum Flow Rates for Rivers and Streams**. Operators can voluntarily limit withdrawal from areas with low flow rates. One way to do this is to base their withdrawal limits on a percentage of daily flow to maintain minimum daily flow rates. This addresses two concerns: ensuring adequate downstream flow for human uses and

[81] *See e.g*. "How Is Water Managed and Treated in Mining," found at: http://www.miningfacts.org/Environment/How-is-water-managed-and-treated-in-mining/
[82] Office of Water, Engineering and Analysis Division, U.S. Environmental Protection Agency (2000). Coal ReMining Best Management Practices Guidance Manual. Section 5, pp. 8-9,, found at: http://water.epa.gov/scitech/wastetech/guide/coal/upload/2009_03_26_guide_coal_manual_bmpmanual1.pdf
[83] Prosser, I., Wold, L. and Littleboy, A. 2011. Water in Mining and Industry. CSIRO, at 137. Found at: http://www.publish.csiro.au/?act=view_file&file_id=9780643103283_Chapter_10.pdf
[84] Freyman, M. 2014 February. Hydraulic Fracturing & Water Stress: Water Demand by the Numbers. Ceres Report at 38. Found at: https://www.ceres.org/resources/reports/hydraulic-fracturing-water-stress-water-demand-by-the-numbers.
[85] *Id*., at 43.

ensuring adequate water for ecological maintenance.[86] It also helps prevent increased concentration of nutrients and pollutions dangerous to humans and wildlife.

a. **Examine Historical Natural Flow Regime Data to Determine Minimum Pass-by Flow Rates.** Withdrawals should be within acceptable environmental limits. What those limits are will depend upon the circumstances, but for Pennsylvania and New York, some experts have recommended that flow rates should be maintained at a minimum of 30% of the average daily flow rate, or 30% of the average monthly flow rate, whichever is greater.[87] If flow rates are below these numbers, other sources of water should be found. This includes those occasions where the flow rate is low due to prior withdrawals that same day.

b. **Compare Withdrawal to the Lowest Average Flow Rates.** Withdrawals that are below 10% of the lowest average, consecutive 7-day flow that would occur in a ten-year period are considered small relative to the flow of the stream.[88] Larger withdrawals, however, should trigger higher scrutiny, and pass-by flow tests.



3) **Develop Source Water Protection Plans that Address Specific Risks**. Be prepared to protect fish stock. During key spawning times, for instance, there may be no solution other than cessation of withdrawals.

a. **Avoid withdrawing from cold-water habitats and high quality streams**. Such streams may be the only nearby water source at a well pad, but they should nonetheless be sources of last resort. Operators should develop withdrawal strategies that protect loss of walleye and steelhead spawning areas.

b. **Withdraw And Store Water When Flow Rates Are High.** Summertime is when flow rates tend to be lowest. Operators should consider withdrawal and storage when flows are high, and reduce withdrawal when rates are low, such as in late summer.

4) **Minimize Freshwater Use**. Operational strategies for conserving freshwater include:

a. **Recycle When Possible.** Many companies are adopting a "no discharge of wastewater" policy, meaning 100% reuse

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[86] Rahm, B. and Riha, S. 2012. Toward Strategic Management of Shale Gas Development: Regional, Collective Impacts on Water Resources. *Environmental Science and Policy, 17,* 12, 16 (citing a New York State Department of Environmental Conservation proposal).

[87] *Id*. The authors did not endorse any specific strategy. *Id.,* at 21. However they did raise concerns about withdrawal water from small streams under any circumstances. *Id*., at 17. For a general analysis of stream gaging strategies, data assessment and flow rate goals, *see* "National Streamflow Information Program," United States Geological Survey, found at: http://water.usgs.gov/nsip/goals9.html. Of course, the vast majority of surface water used in hydraulic fracturing in Ohio will come from ponds or storage facilities, and not directly from streams.

[88] *Id*. *See also* Mitchell, A., Small, M., and Casman, E. 2013. Surface Water Withdrawals for Marcellus Shale Gas Development: Performance of Alternative Regulatory Approaches in the Upper Ohio River Basin. *Environ. Sci. Technol, 47,* 12669, 12673, for a discussion about how using short-term records to determine 7-day lowest average rate can be misleading.

or recycling. This can be done through treatment facilities or through reverse osmosis processes.[89] In the meantime, recycling technologies are rapidly improving. Operators should continually assess the status of new technologies for improvements in cost and recovery of clean water, especially those that relate to membranes.[90] Further, thermal processing can be combined with membrane processing to enhance total clean water recovery and significantly improve brine water reduction economics.[91] Among the available technologies for recycling water:

i. **Passive treatment methods.** Passive treatment methods are those that take advantage of naturally occurring chemical and biological processes to cleanse contaminated mine waters.[92] They tend to take more time and space than active remediation, and have less certain results. However they are also generally much less expensive than active remediation.[93] They include limestone drains, alkalinity producing systems, constructed wetlands, biochemical reactors, phytotechnologies and permeable reactive barriers.[94]

ii. **Active treatment methods.** Active treatment technologies require the input of energy and chemicals. They are more reliable and act more quickly, and as a result are more commonly used in active mines.[95] They include, among others, fluidized bed reactors, reverse osmosis, zero valent iron, rotating cylinder treatment systems, ferrihydrate adsorption, electrocoagulation, ion exchange, biological reduction and ceramic microfiltration.[96]

b. **Identify Alternative Sources of Water that Do Not Compete with Community Water Supplies:** Mining operations may not require potable water. The Operator should begin with a preference for lower quality water. Underground freshwater aquifers should be considered as the source of "last resort."

i. **Dewatering of Mines.** Mines that go beneath the water table usually need to be pumped, which draws down the water table in the surrounding strata. Water

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[89] A Catalogue of Good Practices in Water Use Efficiency. 2012 January. *Water Resources Group 2030*, World Economic Forum Annual Meeting, at 30. Found at: http://www.2030wrg.org/wp-content/uploads/2012/06/3.-Good-Practices-Catalogue_final_low-res.pdf.

[90] Among the relevant technologies that are rapidly advancing: mechanical vapor recompression, electrodialysis (for produced water), and advanced membrane coatings (to improve membrane life; produced brine contains high concentrations of organic particulates that can foul the membrane). Hayes, T., at xiv-xv (tasks 7-10).

[91] Hayes, T. at xi.

[92] Skousen, J. 1998. Overview of Passive Systems for Treating Acid Mine Drainage. West Virginia Extension Service. Found at: http://www.wvu.edu/~agexten/landrec/passtrt/passtrt.htm.

[93] *Id.*, at 1.

[94] U.S. Environmental Protection Agency. 2014 March. Reference Guide to Treatment Technologies for Mining-Influenced Water. EPA Report No. 542-R-14001, at pp. 11-37. Found at: http://nepis.epa.gov/Exe/ZyNET.exe/P100I4PB.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2011+Thru+2015&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A\zyfiles\Index%20Data\11thru15\Txt\00000009\P100I4PB.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h|-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p|f&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

[95] *See* MiningFacts.org, *supra*, note 1.

[96] *Id*., at 38-72.

extracted as a byproduct of the mining operations can be reused, thereby reducing the amount of freshwater needed in other operations elsewhere. Often this water is acidic and contains toxic metals or other pollutants, and this water may need to be treated before it can be used.[97]

ii. **Use of Brackish Water.** Some separation processes are more effective using saline water than fresh water.[98] Brackish water can be taken from the water table without impacting the freshwater table, if the aquifers are not interconnected.

c. **Use Third Party Wastewater When Possible.** Operator can acquire third party waste water, most commonly from municipal wastewater treatment plants or industries, such as "effluent" water – water that has been used and treated but would otherwise flow downstream and out of the state.[99]

5. Water Conservation

5) Water Conservation

a. **Use the Best Available Technology.** Leaks should be minimized with better pipes and pumps. When feasible, pipes should be above ground, making it easier to detect leaks. Evaporation control covers should be used for freshwater storage facilities when feasible. Water efficiency measures should be deployed at all stages of the drilling, completing and producing of wells. For instance, in Texas Anadarko uses limestone to build roads to reduce the amount of water required to suppress dust.[100]

b. **Imbedding "shadow prices."** Operators can include externalities in determining the cost of water. By incorporating the true cost of water, more water conservation measures may be economically justified.[101]

c. **Capture drainage water.** Precipitation at the mine site can be captured using liners and pipes and directing the water to storage facilities. Tailings dams can be used to ensure freshwater does not come into contact with contaminated water.[102]

d. **Develop dry processing strategies.** Dry processing has been successfully deployed with gypsum, phosphate and other minerals. However they may introduce new challenges, such as dust generation.[103]

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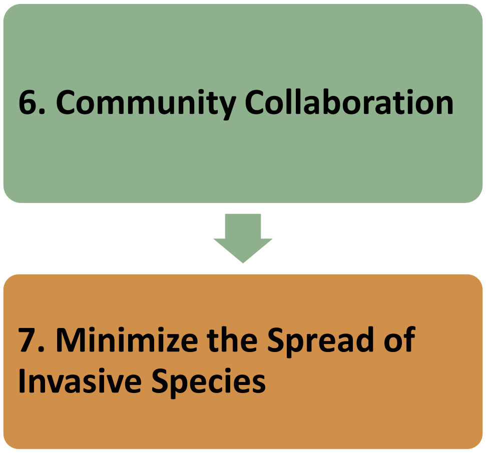
[97] Prosser, at 137.
[98] *Id*., at 139.
[99] Shell and Anadarko, for example, purchase effluent water from local municipalities to use in its hydraulic fracturing process. Freyman, *supra*, at 12. *See also* Hayes, T. at xiii (task 6: alternative water sources available in the Barnett region).
[100] Freyman, M. at 40.
[101] *See id*. (citing the Nestle food and beverage company for pioneering this practice).
[102] *See e.g*. Miningfacts.org, *supra*, note 1.
[103] Prosser, at 139.



6) Community Collaboration

e. **Agriculture and Industry**. Work cooperatively with agriculture and other industries to minimize stream impacts and ensure sufficient water for irrigation.

f. **Community Groups and Government Agencies**. Communicate with local communities to identify important uses and critical value of local water sources. This includes engaging the community before operations, and continuing thereafter.[104]

7) Minimize the Spread of Invasive Species. Disinfect water suction hoses when water withdrawal occurs**.**

HYDRAULIC FRACTURING

Introduction

The hydraulic fracturing of rock in order to increase formation permeability, especially when used in conjunction with horizontal drilling, requires significant amounts of water. Each year thousands of new wells are completed in the United States using this technique to increase oil and gas production. In many states, shale development is highly reliant upon surface or groundwater resources in areas where water resources are under stress due to drought conditions. The most problematic areas exist in the American west, such as with the Eagle Ford Shale formation in Texas, which shale development experts call "ground zero" for water sourcing risks, due to high population density, intense shale development and ongoing drought conditions.[105]

Indeed much of Ohio is considered not immune to stressed water environments, notwithstanding a relative abundance of precipitation, groundwater and surface water. Indeed, Ohio is considered to be a "medium to high stress" state, meaning that 20-40% of the available water supply is being used.[106]

This contrasts to other regions, especially in the American West, where hydraulic fracturing is occurring in areas of draught.[107] In California and Colorado, for instance, over 95% of hydraulically fractured

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[104] *Id*., at 44 (citing complaints from the communities about a lack of preparation for the rapid pace of development).
[105] Freyman, M. (2014, February) Hydraulic Fracturing & Water Stress: Water Demand by the Numbers. *Ceres Report*. Page 8? Retrieved from https://www.ceres.org/resources/reports/hydraulic-fracturing-water-stress-water-demand-by-the-numbers. While the water demand numbers for hydraulic fracturing have gotten a great deal of media coverage, net water use from hydraulic fracturing is only a fraction of that used for the mining industry in general. In Texas, for instance, where the shale industry is mature, shale gas uses less than 1% of the water overall, while net water use for aggregate and lignite mining comprises 2/3 of the total water used in the mining industry. *See* Nicot, J. & Scanlon, B. (2012). Water Use for Shale Gas Production in Texas. *Environmental Science & Technology*, *46*, 3583-84.
[106] Freyman, at 6. Ohio's population density contributes to its water stress.
[107] Since 2011, over half of hydraulic fracturing has occurred in areas listed as suffering draught conditions. Freyman, at 6.

completions were in areas of either high or extremely high stress (extremely high stress means over 80% of available water in use).[108]

Ohio, on the other hand, has a climate more comparable to Pennsylvania, where water is relatively abundant. Very few wells drilled in the Marcellus have been located in high water stress regions.[109] Yet Marcellus Shale water consumption has received considerable scrutiny, and has engendered water use studies in conjunction with some of the shale formations found in high water stress regions.[110] Reasons for this include the fact that the Marcellus is the second highest overall water use shale, next to the Eagle Ford in Texas, together with the fact that the Marcellus uses a relatively high volume of water per horizontal well – averaging between 4.4 to 5.3 mm gallons per well.[111] But the most compelling reason why water use has been heavily scrutinized for the Marcellus is because there are no saltwater disposal wells in Pennsylvania, so wastewater has to be trucked out of state– an expensive operation unless it is recycled. Accordingly, in the Marcellus, reducing wastewater has become as much an economic as an environmental concern.

Hydraulic fracturing in horizontal wells currently requires volumes of freshwater that typically range from between 1-7 mm gallons per well, depending primarily upon the length of the completion zone and the geology of the rock formation. Gas wells tend to use more water than oil wells (4.8 mm gallons vs. 3.2 mm gallons average for horizontal wells).[112] Typically water is either trucked or piped to the drilling location. However truck and pipeline flow rates are usually insufficient to match the necessary injection rates, so water is generally stored on site in a tank battery or in an impoundment.[113]

In Ohio, completion of horizontal wells using hydraulic fracturing techniques is on the rise. In 2011, only 33 such wells had been completed. By the spring of 2014, over 800 horizontal wells had been completed in the Utica Shale. Industry analysts anticipate horizontal well completions could approach 1000 wells per year in the Utica,[114] and the Ohio Department of Natural Resources has projected that as many as 19,000 total horizontal wells could be drilled in the Utica.[115] Moreover, the Utica is only one formation that

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[108] *Id*.
[109] Almost no wells drilled in the Marcellus between January 2011 and May 2013 were in high or extremely high water stress regions. *Id*. at 23 (Figure 8).
[110] *See e.g*. Hayes, T. & Severin, B. (2012). Barnett and Appalachian Shale Water Management and Reuse Technologies. *RPSEA Report, No. 08122-05*. Retrieved from http://www.netl.doe.gov/file%20library/research/oil-gas/Natural%20Gas/shale%20gas/08122-05-final-report.pdf.
[111] Freyman, at 22 and 35. The different numbers depend upon whether you count the life cycle water use, which is higher. Another recent report indicated that the range is between 1-5 mm gallons for the Barnett and Appalachian shale provinces. *See* Hayes, T. & Severin, B. (2012, March 30). Barnett and Appalachian Shale Water Management and Reuse Technologies. *Research Partnership for Secure Energy for America (RPSEA), Report No. 08122-05,* xii. Increasingly long zones for completion may account for the more recent projections of up to 7 mm gallons.
[112] Freyman, at 20.
[113] Nicott, J. & Hayes, T. (2011) Feasibility of Using Alternative Water Sources for Shale Gas Well Completions, *RPSEA, Report No. 08122-05,* 6
[114] *See e.g*. Thomas, A. et al (2012) "An Analysis of the Economic Potential for Shale in Ohio," *Urban Publications*, Cleveland State University. Retrieved from http://engagedscholarship.csuohio.edu/urban_facpub/453/
[115] Downing, B. (2014, March 17). Ohio Could Add 19,000 Utica Wells in Next 19 Years. *Akron Beacon Journal*. Retrieved from http://www.ohio.com/news/ohio-could-add-19-000-utica-wells-in-next-19-years-new-state-report-says-1.474119 (citing new report from Ohio Department of Development).

might be susceptible to increased production through hydraulic fracturing. Ohio has other low permeability formations that may be rich in organic material.[116]

Accordingly, operating companies have sought access to sources of large volumes of inexpensive water to conduct operations. The cheapest water for operators to access is surface water – especially that surface water that can be found near the wellhead -- which water can be recovered easily with a pump and piped or trucked to the drilling location. Since drinking water quality is not required for hydraulic fracturing operations, surface water provides the vast majority of the industry supply.[117] Although surface and groundwater are linked, since precipitation ultimately replenishes ground water supplies, generally it is preferable to use surface water. Overuse of groundwater not only reduces drinking water supply, it also can lead to land subsidence, reduction in surface water flow, and ultimately to unsustainable water supplies.[118]

Surface water withdrawal during times of drought carries the most environmental risk, insofar as it may reduce stream flow rates in riparian and floodplain habitats. However the State also has an interest in maintaining natural seasonal variability in surface water conditions, which is also important to healthy aquatic ecosystems.[119]

Much of the literature with regard to best practices relates to strategies for recycling of drilling wastewater and produced water from the well. New technologies are being developed, both for pressure driven (reverse osmosis) and for electrically driven (electro dialysis) filtration, which promise improved economics for recycling.[120] However recycling is only one important consideration to best management practices for water use in completing a well using hydraulic fracturing.

The following discussion sets forth best management practices that have been identified in regions around the country for conserving water and reducing the impact of water consumption from hydraulic fracturing on the local ecosystem, agriculture and drinking water supply.

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[116] The Marcellus Shale has also been drilled in Ohio using horizontal drilling technology, and other formations, such as the Clinton Sandstone and the Huron Shale, might eventually receive such treatment. *See e.g.* http://gomarcellusshale.com/group/tuscarawascountyohio/forum/topics/horizontal-clinton-well-by-enervest

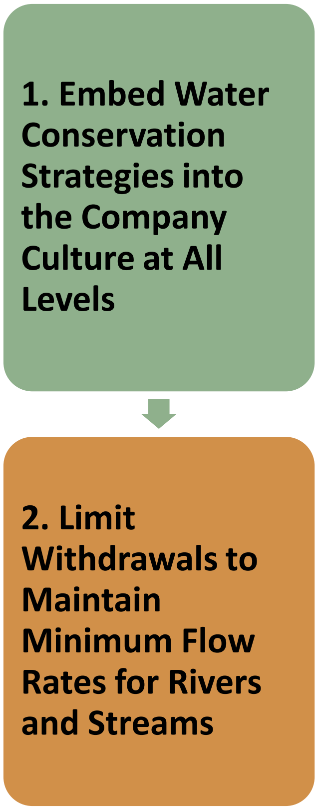
[117] Mitchell, A., Small, M., & Casman, E. (2013). Surface Water Withdrawals for Marcellus Shale Gas Development: Performance of Alternative Regulatory Approaches in the Upper Ohio River Basin. *Environ. Sci. Techno, 47,* 12670. (noting that more than 85% of the Marcellus Shale industry's water comes from surface waters).

[118] Winter, T., et al. (1989). Ground Water and Surface Water: A Single Resource. *U.S. Geological Survey Circula*, 1139.

[119] Mitchell, A., et al, at 12669.

[120] Hayes, T. at xi.

Best Management Practices for Water Conservation in Oil and Gas Industry



1) Embed Water Conservation Strategies into the Company Culture at All Levels. Analysis of water conservation should be part of the company culture, and should have executive level oversight. Leading practices include tying executive compensation to performance on water management goals, and regular board level briefings on performance on water management goals.[121] Further, hydraulic fracturing is just one aspect of water use in the oil and gas industry. Operators use water for other operations, as do contractors and subcontractors. Operators should insist that contractors and subcontractors also embed good water stewardship strategies into their company culture.[122]

2) Limit Withdrawals to Maintain Minimum Flow Rates for Rivers and Streams. Operators can voluntarily limit withdrawal from areas with low flow rates. One way to do this is to base their withdrawal limits on a percentage of daily flow to maintain minimum daily flow rates. This addresses two concerns: ensuring adequate downstream flow for human uses and ensuring adequate water for ecological maintenance.[123] It also helps prevent increased concentration of nutrients and pollutions dangerous to humans and wildlife.

a. Examine Historical Natural Flow Regime Data to Determine Minimum Pass-by Flow Rates. Withdrawals should be within acceptable environmental limits. What those limits are will depend upon the circumstances, but for the Marcellus, some experts have recommended that flow rates should be maintained at a minimum of 30% of the average daily flow rate, or 30% of the average monthly flow rate, whichever is greater.[124] If flow rates are below these numbers, other sources of water should be found. This includes those occasions where the flow rate is low due to prior withdrawals that same day.

b. Compare Withdrawal to the Lowest Average Flow Rates. Withdrawals that are below 10% of the lowest average, consecutive 7-day flow that would occur in a ten-year period are considered small relative to the flow of the stream.[125] Larger withdrawals, however, should trigger higher scrutiny, and pass-by flow tests.

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[121] Freyman, at 38.
[122] *Id*., at 43.
[123] Rahm, B. & Riha, S. (2012). Toward Strategic Management of Shale Gas Development: Regional, Collective Impacts on Water Resources. *Environmental Science and Policy*, *17*, 16 (citing a New York State Department of Environmental Conservation proposal).
[124] *Id*. The authors did not endorse any specific strategy. *Id.,* at 21. However they did raise concerns about withdrawal water from small streams under any circumstances. *Id*., at 17. For a general analysis of stream gaging strategies, data assessment and flow rate goals, *see* "National Streamflow Information Program," United States Geological Survey, found at: http://water.usgs.gov/nsip/goals9.html.
[125] *Id*. *See also* Mitchell, A., et al, 12673, for a discussion about how using short-term records to determine 7-day lowest average rate can be misleading.

3. Develop Source Water Protection Plans that Address Specific Risks

3) Develop Source Water Protection Plans that Address Specific Risks. Be prepared to protect fish stock. During key spawning times, for instance, there may be no solution other than cessation of withdrawals.

a. Avoid withdrawing from cold-water habitats and high quality streams. Such streams may be the only nearby water source at a well pad, but they should nonetheless be sources of last resort. Operators should develop withdrawal strategies that protect loss of walleye and steelhead spawning areas.

b. Withdraw And Store Water When Flow Rates Are High. Summertime is when flow rates tend to be lowest. Operators should consider withdrawal and storage when flows are high, and reduce withdrawal when rates are low, such as in late summer.

Best Management Practices for Water Conservation during Well Completion Operations Using Hydraulic Fracturing

1. Minimize Freshwater Use

1) Minimize Freshwater Use. Operational strategies for conserving freshwater include:

a. Recycle. Treat and reuse both flow-back and produced waters. This strategy not only reduces the stress on water resources, it also saves on water, trucking and saltwater disposal well costs. Recycling technologies are rapidly improving.[126] In some cases, it may not make sense, such as when the volume returned is too small or too contaminated with salt, heavy metals or naturally occurring radioactive materials. However the goal should be to recycle 100% of returned or produced water from the well bore.[127] Some strategies include:

i. **Determine feasibility of capture and assess content of flow-back water.** Before flow-back or produced water can be recycled, it first must be captured and tested. Typically about one third of the water used in hydraulic fracturing returns to the surface before production begins. It must be determined if these volumes are sufficient for recycling, and if the total dissolved solid concentration contained therein is appropriate for diluting for reuse, or if it should be sent submitted for processing.[128]

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[126] A number of oil and gas service companies have developed recycling technologies, including service industry giants like Schlumberger, Halliburton and Baker Hughes. *See e.g.* Sider, A. (2012, November 12). Drillers Begin Using Frack Water. *The Wall Street Journal*. Retrieved from http://online.wsj.com/news/articles/SB10001424052970203937004578077183112409260
The leader in Ohio for this service is currently Baker Hughes, which works with Chesapeake to recycle produced and drilling wastewater. Chesapeake has drilled the majority of horizontal wells in Ohio.

[127] 100% recycling is apparently achievable both technically and economically. Apache is recycling 100% of its produced water in the Permian Basin, and Chesapeake is recycling nearly 100% of its produced water and drilling wastewater in the Marcellus. Freyman, M. at 10.

[128] Hayes, T. at xiii (tasks 4 and 5).

ii. **Combine thermal processing with membrane processing.** Using both processes together can enhance total clean water recovery and significantly improve brine water reduction economics.[129]

iii. **Assess new membrane technology.** New technologies, or existing technologies adapted to use in shale development, are being developed. Operators should continually assess the status of new technologies for improvements in cost and recovery of clean water, especially those that relate to membranes.[130]

iv. **Conduct a lifecycle water analysis.** Water volume and makeup produced during different stages of the life of the well are likely to vary, depending upon the conditions. Generally, the magnitude of water and salt generation is very high in early stages of shale development, compared to later stages[131] (unlike for conventional oil and gas production). Each stage will require different strategies for recycling, suggesting the need for life cycle planning for each period throughout the lifetime of the well, the pad, and the field, depending upon how production is mixed.[132]

b. **Identify Alternative Sources of Water that Do Not Compete with Community Water Supplies:** Hydraulic fracturing normally does not require potable water. The Operator should begin with a preference for lower quality water.[133] Underground freshwater aquifers should be considered as the source of "last resort."

v. **Wastewater.** Operator can acquire third party waste water, most commonly from municipal wastewater treatment plants or industries, such as "effluent" water – water that has been used and treated but would otherwise flow downstream and out of the state.[134] Another source might be acid mine drainage.[135]

vi. **Brackish Water**. Brackish water is defined as water that is not fresh, yet not as salty as seawater. Brackish groundwater is found beneath the freshwater table, but can be produced in much the same manner that fresh groundwater is produced. But it is important to establish that the brackish water aquifer is not interconnected with the freshwater reservoir, or it may impact the freshwater aquifer.

c. **Water Conservation-**

vii. **Use the Best Available Technology.** Leaks should be minimized with better pipes and pumps. Evaporation control covers should be used for storage facilities when feasible. Water efficiency measures should be deployed at all stages of the drilling,

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[129] Hayes, T. at xi.

[130] Among the relevant technologies that are rapidly advancing: mechanical vapor recompression, electrodialysis (for produced water), and advanced membrane coatings (to improve membrane life; produced brine contains high concentrations of organic particulates that can foul the membrane). *Id.*, at xiv-xv (tasks 7-10).

[131] Hayes, T. at xvi.

[132] *Id*. Data is not yet available from the Utica well production to assess the nature and the life cycle of water production, but produced water from the Marcellus has been analyzed, and found to be produced in relatively low volumes over the life of the well compared to conventional oil and gas wells and for other shale. However the water tends to be higher in salinity, heavy metals and naturally occurring radioactive materials. Jaing, M., Hendrickson, C., & VanBriesen, J. (2014). Life Cycle Water Consumption and Wastewater Generation Impacts of a Marcellus Shale Gas Well. *Environ. Sci. Technol, 48*. 1912.

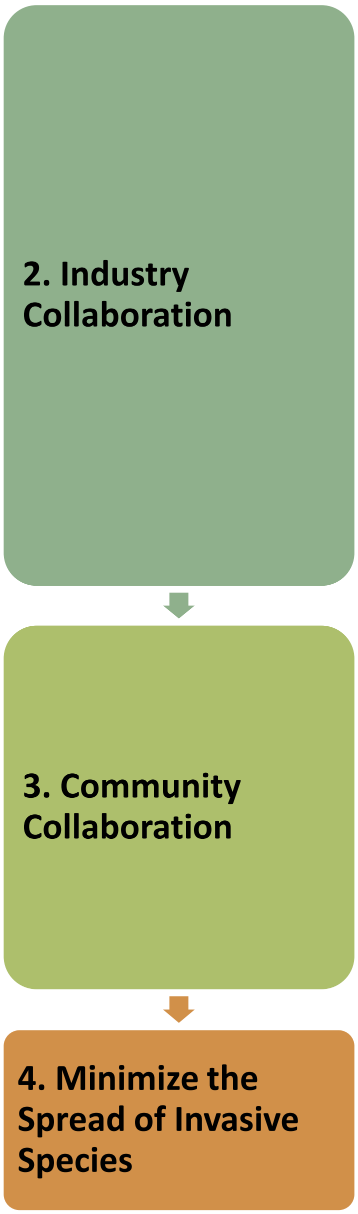
[133] The hydraulic fracturing technology deployed will control the level of tolerance for water quality. For instance gel-based technologies tends to require higher quality water than does slickwater-based hydraulic fracturing.

[134] Shell and Anadarko, for example, purchase effluent water from local municipalities to use in its hydraulic fracturing process. Freyman, *supra*, at 12. *See also* Hayes, T. at xiii (task 6: alternative water sources available in the Barnett region).

[135] Nicot at 6.

completing and producing of wells. For instance, in Texas Anadarko uses limestone to build roads to reduce the amount of water required to suppress dust.[136]

viii. **Imbedding "shadow prices."** Operators can include externalities in determining the cost of water. By incorporating the true cost of water, more water conservation measures may be economically justified.[137]



2) Industry Collaboration

a. Private Investment into Water Infrastructure. Operators should look for opportunities to make private investment into water storage and recycling infrastructure, with large companies taking the lead. Joint investment into the infrastructure enables parties to risk longer term cost recovery.

b. Centralize pipeline networks and storage facilities. Shared infrastructure and centralized storage may be critical to the cost effectiveness of recycling. Large operators should take the lead here as well. Networks can be set up whereby smaller producers can deliver water into or take water out of the system. If no large operator exists, then smaller companies can develop a cooperative.[138]

c. Create database for pipeline locations. Making this database available to oil and gas industry and other industries can help solve sourcing challenges and developing local water sourcing and recycling infrastructure.

3) Community Collaboration.

a. Agriculture and Industry. Work cooperatively with agriculture and other industries to minimize stream impacts and ensure sufficient water for irrigation.

b. Community Groups and Government Agencies. Communicate with local communities to identify important uses and critical value of local water sources. This includes engaging the community before operations, and continuing thereafter.[139] The Louisiana Department of Conservation, for example, collaborated with the oil and gas industry to identify management strategies that ensured that freshwater aquifers were not threatened by exploitation of the Haynesville Shale.[140]

4) Minimize the Spread of Invasive Species. Disinfect water suction hoses when water withdrawal occurs**.**

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[136] Freyman, M. at 40.

[137] *See id*., at 40 (citing the Nestle food and beverage company for pioneering this practice).

[138] *Id*. Freyman argues that with water hauling costs reaching as much as half the development costs in some areas, shared pipelines and storage facilities should be cost effective.

[139] *Id*. at 44 (citing complaints from the communities about a lack of preparation for the rapid pace of development).

[140] *See* Statement of James H. Welsh, Louisiana Commissioner of Conservation, "Proceedings of the Technical Workshops on Hydraulic Fracturing Study: Water Resources Management," Environmental Protection Agency 600/R-11/048 (May 2011) at 34, found at: http://www2.epa.gov/sites/production/files/documents/HF_Workshop_4_Proceedings_FINAL_508.pdf

AGRICULTURE

Introduction: Water Productivity (Crop per Drop)

Water productivity (WP) for agricultural operations equates to the net return of food for a unit of water used. There exists a wide scope of applications for improving water productivity and practices ranging from improvements in water harvesting to irrigation and interactive water management systems. Furthermore, there are aspects that are not directly related to water conservation approaches but have a significant impact on water use. These indirect water productivity impacts include soil fertility, pest and disease control, crop selection and/or access to better markets.[141] Lastly, water productivity is influenced by regulatory requirements that in some drought ridden states have established water usage limits while other states have opted for volunteer approaches to include best management practices and suggested technologies.

The Food and Agriculture Organization of the United Nations describes water productivity "to denote the amount or value of product over volume or value of water depleted or diverted. The value of the product might be expressed in different terms (biomass, grain, money) - crop per drop' approach".[142] The crop per drop concept has been primarily applied to the amount of production per unit of water; however, it has recently been expanded to consider other social benefits including nutritional value of crop (nutrient per drop), food security (sustainable livelihood per drop), jobs (jobs per drop), and feeding capacity (capita per drop). The conceptual expansion of water productivity to include multiple measures and dimensions can be beneficial, in that is provides for richer discourse on the meaning of water for food production, as well as detrimental, with multiple definitions of productivity the value might be dependent on the intent of the analysis and readily available data. Nonetheless, water productivity continues to be instrumental to well managed agricultural operations.

A large amount of information is available on agricultural water harvesting (withdrawal) and use. Therefore, the following is organized by two subsections: (1) Regulatory Guidance and (2) Best Management Tools and Technologies and Approaches for Ohio and states similar to Ohio. Each subsection provides a brief summary and web links to prominent Federal, State, and Non-governmental water management programs.

Regulatory Programs - Federal

The National Resource Conservation Service (NRCS), a department within the United States Department of Agriculture, is considered by many as the leading Federal agency for assisting in restoring watershed health on private land. The agency provides technical and financial assistance to producers who implement conservation practices and management strategies, including the restoration and protection of wetlands, which benefit water quality and improve water management.[143] The science behind the implementation of these conservation practices and management strategies is developed and supported by the NRCS Science and Technology Divisions, National Technical Support Centers, the Water and Climate Center, and the Wetlands Team, who are continually developing new tools to, among other things, improve snowmelt prediction capabilities, improve current conservation practice technology, improve models to track nutrients, and improve irrigation efficiency so that agricultural producers can

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[141] Molden, David; Murray-Rust, Hammond; Sakthivadivel, R; Makin, Ian (2003) A Water-productivity Framework for Understanding and Action. Found in *Water Productivity in Agriculture: Limits and Opportunities for Improvement – CAB International. Retrieved May 2014, from* http://publications.iwmi.org/pdf/H032632.pdf
[142] *See* http://www.fao.org/docrep/006/y4525e/y4525e06.htm
[143] *See* http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/

more efficiently use water, increase water storage, and protect water quality by minimizing the potential loss of sediment and nutrients from their operations by applying science based conservation practices.

While the USDA tends toward conservation of water resources, the USEPA is mostly concerned with protecting water resources from contamination and discharge. The EPA: Clean Water Act was created for purposes of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources, providing assistance to publicly owned treatment works for the improvement of wastewater treatment, and maintaining the integrity of wetlands. The agricultural subsection of the Act primary focuses on discharge and related impacts to rivers and streams from agricultural operations. A brief review of recent enforcement cases suggests that a large part of agricultural concern comes from illegal discharges from animal feeding lots, destruction of wetlands, overuse of chemicals and pesticides, and solids and bio-solids loading from improper tilling and drainage. Some agricultural regulations under the act include:

- Animal Feeding Operations
- Aquaculture Projects
- Concentrated Aquatic Animal Production Facilities
- Biosolids and Agriculture
- Nonpoint Source Pollution and Agriculture
- Estuaries and Agriculture
- National Coastal Water Program and Agriculture
- Oil Spill Prevention, Control and Countermeasures (SPCC) Plan and Agriculture
- TMDLs and Agriculture
- Wetlands and Agriculture

The Food and Drug Administration is primarily concerned with water within the area of food safety and hygiene. The FDA Agricultural Water Fact Sheet[144] describes basic requirement for all agricultural water. Agricultural water within the FDA is defined as water used in activities where it is intended to, or is likely to, contact either the produce itself or surfaces that come into contact with the produce (food-contact surfaces), including water used in: growing, including - irrigation water directly applied, preparing crop sprays, and growing sprouts, harvesting, packing, and holding, including: washing or cooling produce, and preventing dehydration The definition of agricultural water does not include indirect water application methods utilized during growing activities (i.e., water that is not intended to, or is not likely to, contact produce that is covered by the rule or food-contact surfaces), such as furrow irrigation of fruit-bearing trees.

There is currently a proposed FDA rule that identifies routes of microbial contamination of produce and sets requirements to prevent or reduce the introduction of pathogens. Agricultural water is one identified route of contamination; water can be a carrier of many different microorganisms of public health concern and water used for produce production presents different microbial quality demands depending on its use. The proposed rule defines agricultural water as water used in covered activities on covered produce where it is intended to, or is likely to, contact covered produce or food-contact surfaces, including: water used in growing (including irrigation water directly applied, water used for preparing crop sprays, and water used for growing sprouts) and in harvesting, packing, and holding (including water used for washing or cooling harvested produce and water used to prevent dehydration) (proposed § 112.3(c)). Agricultural water has

[144] http://www.fda.gov/downloads/Food/GuidanceRegulation/FSMA/UCM360242.pdf

been identified as one probable route of produce contamination with pathogens that can cause human illness. How and when water is applied on the farm is dependent on the type of produce being grown. Several requirements under this program are substantial and are expected to influence water withdrawal and use approaches:

- Require that all agricultural water must be of safe and sanitary quality for its intended use (proposed § 112.41).
- Require inspection, maintenance, monitoring, and follow-up actions related to the agricultural water sources and water distribution systems under your control and water used for growing, harvesting, packing, and holding of covered produce; including requiring inspection of the entire agricultural water system under your control at the beginning of each growing season and maintenance of the system to prevent it from becoming a source of contamination to covered produce (proposed §§ 112.42 and 112.46);
- Require treatment of agricultural water that you use if you know or have reason to believe that the water is not safe and of adequate sanitary quality for its intended use, including requirements for treatment methods, treating such water, and monitoring its treatment (proposed § 112.43);
- Establish specific requirements for the quality of agricultural water that is used for certain specified purposes, including provisions requiring periodic analytical testing of such water (with exemptions provided for use of public water supplies under certain specified conditions or treated water), and requiring certain actions to be taken when such water does not meet the quality standards (proposed §§ 112.44 and 112.45);
- When agricultural water is used for sprout irrigation water, applied in a manner that directly contacts covered produce during or after harvest (including as ice), used to make a treated agricultural tea, used to contact food-contact surfaces (including as ice), or used for hand washing during or after harvest, you must test the water using an appropriate analytical method. If you find that there is any detectable generic E. coli in 100 ml of water, you must immediately discontinue use of that source of water and/or its distribution system for these uses and take specified follow-up actions. Follow-up actions include making changes to the system and re-testing, or treating the water.
- When agricultural water is used during growing activities for covered produce (other than sprouts) using a direct water application method you must test the quality of water using an appropriate analytical method. If you find that there is more than 235 colony forming units (CFU) (or most probable number (MPN), as appropriate) generic E. coli per 100 ml for any single sample or a rolling geometric mean (n=5) of more than 126 CFU (or MPN, as appropriate) per 100 ml of water, you must immediately discontinue use of that source of agricultural water and/or its distribution system for these uses and take specified follow-up actions. Follow-up actions include making changes to the system and re-testing, or treating the water.

Regulatory Programs – Ohio

The Ohio Department of Natural Resources is the lead state agency regarding water withdrawal notifications for agricultural operations.[145] According to the Ohio Revised code any owner of a facility, or combination of facilities, with the capacity to withdraw water at a quantity greater than 100,000 gallons per day (GPD) is required to register such facilities with the Ohio Department of Natural Resources

145 http://www.agri.ohio.gov/topnews/waterquality/

(ODNR), Division of Water. Ohio has a number of programs designed to assist agricultural operators in water conservation program development for example the Agricultural Pollution Abatement Rules that established Ohio's Agricultural Pollution Abatement Program (APAP) may provide farmers with cost share assistance to develop and implement best management practices (BMP) to protect Ohio's streams, creeks, and rivers. This program has been successful in helping to alleviate concerns associated with agricultural production and silvicultural[146] operations which can create soil erosion and manure runoff.

Like the Federal EPA the Ohio EPA is also active with water management approaches for agricultural operations.[147] Under the Clean Water Act, every state must adopt water quality standards to protect, maintain and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the goal of "swimmable/fishable" waters. Water quality standards are ambient standards as opposed to discharge-type standards. These ambient standards, through a process of back calculation procedures known as total maximum daily loads or waste-load allocations form the basis of water quality based permit limitations that regulate the discharge of pollutants into surface waters under the National Pollutant Discharge Elimination System (NPDES) permit program. Although the Ohio EPA is primarily concerned with discharge limitations and contamination of water ways, the program has a direct impact to water system management particularly associated with runoff, dilution, and downstream water withdrawal quality attainment.

Designed to help protect the Great Lakes, the Great Lakes Compact consists between eight states: Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin.[148] It is important to note that the Ohio Farm Bureau members supported the Great Lakes Water Management legislation that recently passed under the Kasich Administration which outlines state regulations on water withdrawals.[149] The passage of the legislation allows for water management programs closer to the source of use and prompted The Farm Bureau members to adopt the following policy at the most recent annual meeting:

"The Great Lakes are one of America's most important natural public treasures. Together, the Great Lakes account for 90 percent of the United States' surface fresh water resources. The Great Lakes states and Canadian provinces serve as stewards of this resource and have a shared duty to protect, conserve and manage these renewable but finite waters. As a result we believe: The authority to control, protect, and conserve the Great Lakes from diversion lies with the Great Lakes states and Canadian provinces; Water resources should be regulated at the state level, not the federal level, reducing the chance that water resources could be exploited by other states; and we should continue to monitor and actively participate in the implementation of the Great Lakes Compact to ensure that agricultural interests are represented and concerns addressed."

Conservation Programs (Outside of Ohio)

A number of states outside of Ohio are active in agricultural water management practices and have issued reports describing regulatory requirements and best management practices. The following selection of

[146] Silviculture refers to the establishment and management of trees for wood production.
[147] *See* OEPA: Water Quality Standards Program
[148] http://www.cglg.org/projects/water/index.asp)
[149] http://ofbf.org/)

programs and links are provided of available reports:

The Minnesota Agricultural Water Quality Certification Program is a voluntary program designed to accelerate adoption of on-farm conservation practices that protect Minnesota's lakes and rivers. Producers who implement and maintain approved farm management practices will be certified and in turn assured that their operation meets the state's water quality goals and standards for a period of 10 years. This program dovetails into several connected management frameworks including the Minnesota Water Sustainability Framework (2011) and the Minnesota Water Sustainability Framework: Agricultural Water Use: Technical Team Report.

Among other areas of water management, Michigan has created Generally Accepted Agricultural and Management Practices for Irrigation Water Use.[150] This document provides a comprehensive approach for irrigation water use and planning. Likewise Pennsylvania's Water Management Plan[151] along with Indiana's Water Drainage Management Report[152] and the Indiana Dept. of Natural Resources: Report on Indiana Water Use Efficiency and Conservation provide a considerable amount of information pertaining to water storage, irrigation and drainage system planning to mitigate water loss and improve water retention and re-use.

A number of non-governmental organizations are also active in influencing the agriculture water policy-making process and in such case are too numerous to list. However, a brief review of the most active associations is provided.

The *Ohio Farm Bureau Federation* is a member of the American Farm Bureau Federation, a national organization of farmers and ranchers.[153] The purpose of the bureau is to advocate in the best interests of the farmers. These often include issues regarding water management and conservation. Most recently, the Farm Bureau has been active in influencing the drainage ditch policy making process in Ohio. *The Irrigation Association* focuses on water management companies and professionals in agriculture, landscape and golf.[154]

While the Farm Bureau Federation tends to attract agricultural operators concerned with legislation that may have a perceived economical detriment to their business, the *Ecological Farming Association's Water Stewardship Project* provides education and outreach materials about implementing on-farm water conservation measures. The project is funded in part by a grant from the California Department of Food and Agriculture and is designed to encourage voluntary action.[155]

Best Management Plans: Approaches, Tools & Technology

According to a recent study published by the USDA, "Irrigated agriculture, which accounts for 80-90 percent of consumptive water use in the United States, represents a significant share of the value of U.S.

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150 *See* http://www.michigan.gov/documents/mdard/2014_IRRIGATION_WATER_USE_GAAMPs_452845_7.pdf?20140514105835.
151 *See* http://www.elibrary.dep.state.pa.us/dsweb/View/Collection-10554
152 *See* http://www.indianacca.org/abstract_papers/papers/abstract_54.pdf
153 *See* http://ofbf.org/
154 *See* http://www.irrigation.org/About/Members.aspx.
155 *See* http://www.eco-farm.org/programs/cawsi/

agricultural production".[156] A large amount of irrigated water for agricultural operations is procured from surface and groundwater. Better management of water designed to improve water productivity will reduce the consumption and harvesting. For example the Kings River Conservation District [157] stresses the use of:

Laser Leveling

- Many growers are leveling their fields to improve irrigation efficiency and reduce soil erosion by controlling the velocity of the irrigation water they apply. By making the field uniform in slope, the grower will know when to cut off irrigation water and have no tail water exit the field.

Tail Water Returns

- Some growers with large integrated operations collect their tail water for reuse on the next field in line. All the water is eventually recirculated, and they enjoy very high irrigation efficiency.

Conversion to High Efficiency Systems

- Many growers have or are in the process of converting to drip or micro sprayer irrigation systems, which run according to the crop cover usage. These systems deliver water directly to each plant and have minimal risk of runoff issues.

Irrigation Scheduling

- With water being a major cost to growers, the application of water exactly when the crop needs it and in the amount needed is becoming more important. In addition, water stress is a great management tool for certain crops to spur plant growth in certain directions (more reproductive growth, less vegetative). Many growers take advantage of irrigation practice review services that give irrigation uniformity evaluations and tips for better management.

Best management approaches for agricultural water use tend to fall into two broad categories: General BMPs and Site Specific BMPs. The links and resources that follow provide information on these programs, tools and techniques for increasing water productivity in agriculture operations.

General BMPs

Best management water withdrawal and use practices for agricultural operations are wide-ranging and difficult to bound. Nonetheless they tend to focus on water use related to on-farm and water district delivery systems (withdrawal and staging), cropping practices, animal feeding operations, and land management. Several organizations have developed fairly comprehensive BMPs for Agricultural operations; however, the Texas program is probably the most developed.

Texas provides one of the more comprehensive BMPs for agricultural operations and includes sections on agricultural procurement, water use, educational materials, cropping practices, land management, on-farm and water district delivery systems.[158] According to the Texas BMPs agricultural water approaches consist of a combination of site-specific management, educational, and physical practices. Water Use Management BMPs may include irrigation scheduling to determine when to irrigate crops, volumetric

[156] Schaible, Glenn and Aillery, Marcel (2012). Water Conservation in Irrigated Agriculture: Trends and Challenges in the Face of Emerging Demands. Economic Information Bulletin No. (EIB-99). Retrieved May 2014, from http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib99.aspx#.U3O0evlSaHy
[157] Kings River Conservation District. Agricultural Management Practices. Retrieved May 2014, from http://www.krcd.org/water/water_quality/ag_mgt_practices.html
[158] *See* https://www.twdb.texas.gov/conservation/BMPs/Ag/index.asp

measurement of irrigation water use to provide information regarding the performance of irrigation systems, crop residue management and conservation tillage to preserve soil moisture and on-farm irrigation audits to increase water efficiency in irrigation.

Land management systems BMPs can include furrow dikes to reduce water runoff from agricultural row crops, land leveling to increase the uniformity with which water is applied to an irrigated field, conversion of supplemental irrigated farmland to dry-land farmland which uses rainfall to irrigate agricultural lands, and/or brush control/management to reduce evapotranspiration in order to improve water quality and water yield.

On-farm water delivery systems BMPs include lining of on-farm irrigation ditches and replacement of on-farm irrigation ditches with pipeline, low pressure center pivot sprinkler irrigation systems for irrigation of land with flat to modest slopes, drip-micro irrigation systems for more efficient irrigation, use of gated and flexible pipe for field water distribution, surge flow irrigation to apply irrigation water to furrows to aid in reduction of deep percolation, and the use of linear move sprinkler systems for more efficient irrigation of certain shaped field and/or fields with elevation changes.

In water district delivery systems, lining or replacement of the irrigation canals with pipeline improves efficiency and reduces or eliminates seepage, facilitating conveyance of water to a group of users. Finally, other systems that aid in efficient use of water include tailwater recovery and reuse systems, which make use of the irrigation water that runs off the end of an irrigated field" (Texas BMP).

While there is much to be learned from water strained states (e.g. Texas), states closer to Ohio have been active in development BMPs. Pennsylvania State Extension[159] as well as Indiana[160] have created Best Management Practices for agriculture water use. In the case of Pennsylvania, BMPs range from the core conservation practices (no-till, buffers, cover crops and nutrient management plans) to more sophisticated versions of these four coupled with multiple technologies. For example bundling systems like is the case with some of the regional treatment systems that bundle digesters with energy production and even wastewater treatment.

Indiana BMPs for agriculture include a Drainage Handbook.[161]The Handbook: (1) explains and clarifies federal, state, and local laws and regulations affecting drainage improvement activities within the State of Indiana; (2) provides descriptions of specific "Best Management Practices", which define how work should be performed with a minimum of adverse environmental impact; and (3) explains procedures for timely access to agencies' drainage-related personnel. In addition, the Indiana Irrigators have created a variety checklists and assessment materials to guide BMP development.

- Indiana Irrigators: Voluntary Conservation and Efficiency Efforts – Suggested BMP Checklist
- Purdue Extension Water Quality Program: Field Assessment & On-Farm Soil Monitoring for Water Resource Protection
- Clean Water Act Section 319 (H) Agricultural Guidance for Indiana

Comprehensive farm management has a direct influence on water withdraw and use. Therefore, The Minnesota Department of Agriculture (MDA) created The Agricultural BMP Handbook for Minnesota that includes a literature review of empirical research on the effectiveness of 30 agricultural conservation

[159] *See* http://extension.psu.edu/aec/best-management-practices
[160] *See* http://www.in.gov/idem/nps/3470.htm
[161] *See* http://www.in.gov/dnr/water/4892.htm.

practices that address current Minnesota water quality concerns. The inventory includes information on conservation practices, a summary of existing scientific literature and cost and economic considerations for each practice. Likewise the Georgia Soil & Water Conservation Commission established "Best Management Practices for Georgia Agriculture: Conservation Practices to Protect Surface Water Quality".[162]

The Ohio State University Extension has also addressed Agricultural Best Management Practices. However, they are careful to state that before choosing one or several BMPs to implement, producers should consider a balance between two factors: 1) Can the BMP achieve the water quality goal? and 2) Is the BMP economically feasible? The OSU extension acknowledges that BMPs can consist of many possible approaches and that after reviews possible alternatives, "the producer must make a decision about which BMP or combination of BMPs to implement. The BMP should be designed to meet realistic production goals, and tailored to the specific location".[163]

Due to the vast array of information available on BMPs, the OSU extension recommends that specific geographic areas and farming operators contact an OSU Extension, SCS and SWCD. Two publications, Best Management Practices for Preventing Contamination of *Ohio's Ground and Surface Waters* (Bulletin 818), and *Crop Production Alternatives* (Bulletin 812), are available through the local Extension office.

Location Specific Approaches

Because management practices are often location specific, the USDA – National Resource Conservation Service delivers conservation technical assistance through its voluntary Conservation Technical Assistance Program (CTA). CTA is available to any group or individual interested in conserving natural resources and sustaining agricultural production in this country. The CTA program functions through a national network of locally-based, professional conservationists located in nearly every county of the United States. The CTA Program provides land users with proven conservation technology and the delivery system needed to achieve the benefits of a healthy and productive landscape. The primary purposes of the CTA Program are to:

- Reduce soil loss from erosion
- Solve soil, water quality, water conservation, air quality, and agricultural waste management problems
- Reduce potential damage caused by excess water and sedimentation or drought
- Enhance the quality of fish and wildlife habitat
- Improve the long term sustainability of all lands, including cropland, forestland, grazing lands, coastal lands, and developed and/or developing lands
- Assist others in facilitating changes in land use as needed for natural resource protection and sustainability

Similar to the CTA, the New York City Watershed Region: Watershed Agricultural Council consists of locations specific approaches, but with a focus on a whole farm plan. This consists of a holistic approach to farm management designed to identify and prioritize environmental issues without compromising the farm business. This Whole Farm Plan is a voluntary program in which a farmer signs an agreement to

[162] Georgia Soil and Water Conservation Commission. Best Management Practices for Georgia Agriculture Conservation Practices to Protect Surface Water Quality. Retrieved May 2014, from http://gaswcc.georgia.gov/sites/gaswcc.georgia.gov/files/2013AgManualINTERACTIVE2%20%281%29.pdf

[163] Ohio State University Extension. Agricultural Best Management Practices. Retrieved May 2014, from http://ohioline.osu.edu/aex-fact/0464.html

work with a multidisciplinary planning and implementation team in which best management practices are selected and implemented.

GOLF COURSES, AMUSEMENT PARKS AND OTHER RECREATION FACILITIES

The primary water usage in golf courses and other recreational facilities such as amusements parks is for irrigation of turf and landscaping and any water features such as slides or pools. An overview on water usage and best management practices are presented for golf courses (many of which apply to general landscaping practices) and then other kinds of recreation & amusement parks.

Water Use by Golf Courses

According to a study conducted by the United States Golf Association (USGA) in 2012, the average 18-hole golf course in the United States consists of 100 acres. More than 1.5 million acres of maintained turf grass (greens, tees, fairways, rough) exist on golf facilities in the U.S. More than 1.1 million acres, or 80 percent of maintained turfgrass, are irrigated.[164] This translates to over 2 billion gallons of water per day for golf course irrigation. Audubon International estimates that the average American course uses 312,000 gallons per day. In arid regions such as in a place like Palm Springs, each course may use up to a million gallons per day. That is, each course each day in Palm Springs consumes as much water as an American family of four uses in four years.[165]

The volume of water used by golf courses from surface water and ground water is significant enough to be tracked by the state of Ohio. According to the Ohio DNR's water withdrawal maps from 2005, golf courses in the counties in the Great Lakes basin withdrew surface and ground water which comprised anywhere from .1% to 15.9% of all water withdrawals in these counties. The total water withdrawals in 2005 by golf courses were 9.08 million gallons per day.[166] Ohio's golf courses vary in their needs for irrigation systems, but in the North Central part of the country, including Ohio, courses on average irrigate 66 acres of turf grass, applying 13.9 inches of water overall to the course per season.

Water Use by Recreation Theme Parks, Amusement Parks, Water Parks, and Zoos

Theme parks of various kinds constitute a multi-billion dollar segment of the tourism industry. According to the Institute for Theme Park Studies in Florida, estimating the number of theme parks (including amusement and water parks) in the United States is challenging given the wide variety of types and features included in various tourist-oriented parks. Estimates range from 290 by O'Brien's *The Amusement Park Guide*, to 450 by the International Association of Amusement Parks and Attractions, to

[164] USGA. 2012. Golf's Use of Water: Solutions for a More Sustainable Game. Available at URL: http://www.usga.org/uploadedFiles/USGAHome/Course_Care/Golf_and_the_Environment/Water/214418 Lyman, Greg - How Much Water Does Golf Use.pdf. Accessed May 2014

[165] Deford, F. / NPR 2008. Water-Thirsty Golf Courses Need to Go Green. National Public Radio Program Transcript.

[166] Authors calculation based on ODNR/DSWR Water Withdrawal Atlas. 2005. Available at URL: http://soilandwater.ohiodnr.gov/maps/water-withdrawal-atlas. Accessed May 2014

more than 1000 waterparks in North America (including municipally owned waterparks and indoor/resort style facilities.[167]

Common water use at theme parks includes landscaping and turf, and in that regard the best management practices would be similar to golf courses. However, water use at water parks, or for water rides, implies significantly greater water use, and is discussed below after the section on golf courses.

Golf Course Best Management Practices

Administrative Framework & Programs

Best practices today on golf courses the world over take an integrated approach that includes initial landscape design and management, choice of vegetative materials, water demand reduction, water reuse, and reduction in the use of chemicals such as pesticides, herbicides and fertilizers.

Integrated golf course management includes a range of best management practices, but the overall shift in design and management of golf courses has been "from working *against* to working *with* biological systems, creating courses that, to great extent, are ecologically functional and healthy open spaces". This approach to golf course design and management requires a high level of planning for the course, including mapping the different water resources on the site, and regular monitoring of the outcomes of various BMP adoption to ensure water conservation is achieved and water quality is protected.[168]

The United States Golf Association (USGA) adopted environmental principles for golf course design and operations which include many aspects related to water conservation, protection of water quality, and reduction of disturbance to natural water areas. [169]

Legal & Regulatory Practices

Golf courses are subject to water quality regulations and storm water management requirements promulgated by state agencies and local jurisdictions under the Clean Water Act. Some states have additional requirements for golf courses, particularly those states in arid climates (such as the US southwest and west) or that have experienced repeated drought (such as the US southeast). Many states have published guides for best management practices, often working with universities in the state.

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[167] Institute for Theme Park Studies, nd. Frequently Asked Questions. Available at URL: http://www.themeparkcity.com/itps/index.htm. Accessed May 2014.

[168] LandStudies & Pennsylvania Environmental Council. 2009. The Golf Course Water Resources Handbook of Best Management Practices. Available at URL: http://www.pecpa.org/sites/pecpa.org/files/downloads/Golf_BMP_Handbook_3.pdf

[169] USGA (United States Golf Association). 2014. Environmental Principles for Golf Courses in the United States. Available at URL: https://www.usga.org/course_care/articles/environment/general/Environmental-Principles-for-Golf-Courses-in-the-United-States/. Accessed May 2014.

Regulations for use of recycled/effluent water are comparable for those for other crops. In some states, use of recycled water is mandatory for approval of new golf courses. Other states require use of the lowest quality water that is available for irrigation purposes.[170]

Colorado

Regulations affecting golf courses include those in four major categories: solid and hazardous waste, pesticides, water bodies and endangered species. These regulations are promulgated and implemented by the state's department of health, department of agriculture and department of environmental protection.[171]

New Jersey

New Jersey requires permits for golf course water withdrawal. The Permit application requires identification of water conservation measures, analysis of water use, and provisions for worker education about conservation that the course has put in place.[172]

Tennessee

The state of Tennessee offers a handbook for golf course environmental management development by several of the state's agencies, the Tennessee Valley Authority, the USEPA and the University of Tennessee.[173]

Technology, Management and Monitoring Practices

Water Conservation best practices on golf courses are constituted by five types of strategies: design courses to save water by reducing turf and directing natural flow of water from rainfall to plants and water storage areas; change vegetation types and maintenance to require less water for irrigation; use new irrigation system technologies; find alternative water sources, including recycled water; and educate course managers and operations personnel to conserve water. These strategies are discussed below.

Course and Landscape Design

Golf course architects, primarily trained as landscape architects, can adopt design elements that reduce the need for irrigation systems and their use. These include shaping the earth to collect rainwater runoff and sub-surface drainage in on-site storage lakes or areas needing heavier watering. Location of ponds should

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170 Thomas, R. 2011. Gray is the New Green. *Golf Course Industry Magazine.* Available at URL: http://www.golfcourseindustry.com/gie-71111-gray-is-the-new-green.aspx. Accessed May 2014.

171 Colorado DPH&E (Department of Public Health & Environment). 2002. Greening Your Gold Course: A Pollution Prevention Guide for Colorado Golf Courses. Available at URL: http://www.gcsaa.org/uploadedfiles/Environment/Get-Started/BMPs/A-Pollution-Prevention-Guide-for-Colorado-Golf-Courses.pdf. Accessed May 2014.

172 (New Jersey DEP nd).Water Conservation And Drought Emergency Management Plan Report For Golf Courses/Irrigation. Available at URL: http://www.nj.gov/dep/watersupply/pdf/Cv.Wcp-golf.pdf. Accessed May 2014.

173 Broder, M. & Samples, T., editors. nd. Tennessee Handbook for Golf Course Environmental Management. Available at URL http://tennesseeturf.utk.edu/pdffiles/golfcourseenvironmgmt.pdf. Accessed May 2014.

be away from natural wetland areas on courses, and should be identified to enhance recharge if ground water constitutes the majority of water in the pond.[174]

A second water conservation strategy is to reduce the overall presence of turf grass on the course. Many courses today have reduced overall turf areas resulting in water savings of 50% or more. Golf course sites with poor or inconsistent soils are capped with a layer of sand to allow water infiltration from rain and irrigation.[175]

Golf course design best practices include avoidance and minimization of environmental impacts, storm water management through draining and devises, development of a comprehensive master plan for the course, and detailed construction documents to ensure the course is built as designed.[176]

Vegetation Selection and Care

Research at several universities has led to development of new grasses for turf that require less water (U. of Nebraska, Penn State U., Texas A & M, U. of Minnesota), are more tolerant to cold (Oklahoma State U.), are more tolerant to salt, allowing for irrigation with brackish water in coastal areas (U. of Georgia), and require less pesticide use (Rutgers). These varieties have been tested and resulted in water savings of 30% to 50% depending on site and weather conditions.

Selection of plants native to the region can reduce the need for irrigation because they are adapted to the climatic and competitive conditions of their indigenous area. The Audubon Society recommends that 80% of landscaped areas in golf courses can be native plants. Other benefits from native plants beyond reduced irrigation include less maintenance overall, habitat for wildlife, increased biodiversity, reduced need for chemicals on the course, and opportunities to educate golfers on ecological conditions.[177]

Use of pesticide, herbicide and fertilizers directly impacts the amount of water used on a golf course and the generation of polluted water. Worldwide, pesticide use per acre, per year, on golf courses averages 18 pounds, while use of these types of chemicals per acre, per year, in agriculture is only 2.7 pounds.[178]

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[174] Connecticut DEP (Department of Environmental Protection). 2006. Best Management Practices for Golf Course Water Use. Available at URL: http://www.ct.gov/deep/lib/deep/water_inland/diversions/golfcoursewaterusebmp.pdf. Accessed May 2014.

[175] Snow, J. 2001. Water Conservation on Golf Courses. Reprint from International Turf Producers Foundation. Available at USGA URL: http://www.usga.org/Content.aspx?id=25918. Accessed May 2014.

[176] Virginia Golf Course Superintendents Association. 2012. Environmental Best Management Practices for Virginia's Golf Courses. Available at URL: http://pubs.ext.vt.edu/ANR/ANR-48/ANR-48_pdf.pdf. Accessed May 2014.

[177] LandStudies & Pennsylvania Environmental Council. 2009. The Golf Course Water Resources Handbook of Best Management Practices. Available at URL: http://www.pecpa.org/sites/pecpa.org/files/downloads/Golf_BMP_Handbook_3.pdf

[178] World Watch Institute. 2013. Matters of Scale—Planet Golf. World Watch Magazine, March/April 2004, 12 (2). Available at URL http://www.worldwatch.org/node/797. Accessed May 2014.

Excessive use of nitrogen requires increased watering, so experts advise balancing the use of potassium and nitrogen carefully.[179]

Although the length of turf grass on golf courses has limits (to avoid compromising the playing area), adjusting mowing heights to longer lengths can reduce the need for watering, as more water is trapped in the grass itself, and root systems for longer grass tend to extend deeper into soils, thereby allowing for increased uptake of moisture from soils [180]

In addition, soil cultivation techniques on the course such as spiking, slicing and aeration can improve water infiltration and minimize runoff from irrigation or rainfall events, reducing overall consumption of water.

Irrigation Technologies and Management

Irrigation technology improvements include better sprinkler head design, head spacing, and pressure selection. State of the art computerized control systems, responding to on-site weather stations, weather reporting services and soil sensors, reduce over-irrigation. [181] Using these technologies, courses have reduced water use by 35% or more, and saved energy costs by 50% by scheduling irrigation during nighttime hours.[182]

In a study conducted by the Environmental Institute for Golf in 2005, more than 2500 golf course superintendents from the nation's nearly 17,000 golf courses reported using irrigation scheduling techniques that can reduce overwatering: turf observations (97%); soil moisture observations or sensors (85%); short term weather forecasts (49%); ET from a weather service (18%); ET from on-site weather station (17%); other techniques (12%); none (1%).[183]

All water used to irrigate turf grass should be buffered from entering surface water on the course by vegetation designed to slow down and filter the water prior to entering the surface water. Mowing should be kept back away from this riparian area to ensure this filtering effect. Re-establishment of natural

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[179] Snow, J. 2001. Water Conservation on Golf Courses. Reprint from International Turf Producers Foundation. Available at USGA URL: http://www.usga.org/Content.aspx?id=25918. Accessed May 2014. University of Georgia Cooperative Extension. Best Management Practices for Landscape Water Conservation. Available at URL: http://www.commodities.caes.uga.edu/turfgrass/georgiaturf/Water/Articles/B1329.pdf. Accessed May 2014.

[180] University of Georgia Cooperative Extension. Best Management Practices for Landscape Water Conservation. Available at URL: http://www.commodities.caes.uga.edu/turfgrass/georgiaturf/Water/Articles/B1329.pdf. Accessed May 2014.

[181] University of Georgia Cooperative Extension. Best Management Practices for Landscape Water Conservation. Available at URL: http://www.commodities.caes.uga.edu/turfgrass/georgiaturf/Water/Articles/B1329.pdf. Accessed May 2014.

[182] Snow, J. 2001. Water Conservation on Golf Courses. Reprint from International Turf Producers Foundation. Available at USGA URL: http://www.usga.org/Content.aspx?id=25918. Accessed May 2014.

[183] Environmental Institute for Golf. 2005. Golf Course Environmental Profile. Summary of Volume II Water Use and Conservation Practices on US Golf Courses. Available at URL http://www.eifg.org/wp-content/uploads/2012/07/golf-course-environmental-profile-water-use-summary.pdf. Accessed May 2014.

floodplains on courses can act as this buffer area as well.[184] The required width and location of buffer areas can be identified by a registered landscape architect or by staff from the county soil and water conservation district.

Recycled Water and Alternative Water Sources

Golf course equipment needs to be washed to remove grass clippings and soil. If not properly controlled, these areas can cause water pollution from contaminants of grass, soils, soap, oil residue, fertilizer and pesticide residues. Best practices are to establish a washing station that collects and filters water. The best system is one that is a closed loop system where water is filtered and treated and use again. Washing water should not be discharged to surface water directly or indirectly through ditches and storm drains.

In the same USGA study, superintendents described the sources of irrigation water for US golf courses (multiple uses possible). Fifty two percent of the golf courses use water from lakes and ponds for irrigation, with 46% using on-site wells. Only seventeen percent withdrew water from rivers, streams and creeks, and 14% of the courses used drinking water from municipal water systems. Only 12% of the courses use reclaimed/effluent/recycled water. In the American southwest 37% of courses use reclaimed/effluent/recycled water, but nationally 66% of superintendent respondents said they would use effluent water but there was not a source available or infrastructure to deliver it from providers.

Collection and storage of stormwater from impervious surfaces surrounding the club house and parking lots can provide an alternative source of irrigation water, as well as removing pollutants and slowing water velocities, which can cause damage to course water features. Rainwater can be encouraged to infiltrate through course design, or can be impounded for use in irrigation systems. Stormwater storage areas can be incorporated as water features on the course, and can be designed to provide value for wildlife habitat as well.

Reuse of gray water (water from showers, washing machines, air conditioners) for irrigation reduces the need for fertilization, increases ground water recharge and reduces fresh water use.

Use of treated effluent from municipal sewage treatment facilities has become more common on golf courses. The water may be treated to a second or tertiary level, the same level required prior to discharge into surface water. In some communities in the southwest, use of recycled water on golf courses is mandatory. More than 1000 courses in the US use this source of water as of 2011. The turf grass on golf courses filters the effluent as it infiltrates into soils and ground water, avoiding nutrient contamination. This management approach has been integrated successfully at golf courses that are combined with homes and townhomes. The sewage treatment plant required for the resort's homes can supply effluent that is then used for turf grass irrigation.[185]

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[184] LandStudies & Pennsylvania Environmental Council. 2009. The Golf Course Water Resources Handbook of Best Management Practices. Available at URL: http://www.pecpa.org/sites/pecpa.org/files/downloads/Golf_BMP_Handbook_3.pdf

[185] LandStudies & Pennsylvania Environmental Council. 2009. The Golf Course Water Resources Handbook of Best Management Practices. Available at URL: http://www.pecpa.org/sites/pecpa.org/files/downloads/Golf_BMP_Handbook_3.pdf

WATER PARKS AND THEME PARKS WITH WATER RIDE FACILITIES

According to Eric Hansen for Hotel and Leisure Advisors, standard practices at waterparks and water theme parks is to conserve or reuse most water that is initially put into the water features at the park. Water that is consumed (used and discharged into the sanitary system, evaporated, lost due to splash out, and lost due to cleaning constitutes only 2% or 3% of water in the entire system on a daily basis. The more water a waterpark conserves (i.e. does not discharge to the sanitary sewer system) the greater return on investment. Thus, water parks and water features are designed to re-filter and reuse all but a small percentage of the millions of gallons that may be used. As the H & LA organization suggests, a water theme park is operated like a giant swimming pool. Once water is put into the "pool", most water is retained and is treated to be safe for human contact.

Ohio's more than 150 theme parks, waterparks and facilities in the amusement and recreation industry withdrew more than 62 million gallons of water in 2012 from surface (50 million) and ground water (12 million).

Current best practices in water parks include reduction in use of water for landscaping (as described above). However, some newly designed water parks are focusing on more sustainable practices for cleaning water to avoid the use of chlorine and other harsh chemicals. In East Huzhou City in China, the park uses a micron filtration system, oozing and carbon technologies, avoiding the need for chlorine. A park in Eau Claire, Wisconsin is using sphagnum moss to clean water, reducing the use of pool chemicals by 90%. Flushing the park previously required 1.5 million gallons of water throughout the year, but now only requires 150,000 gallons. Instead of discharging wastewater from splash back and washing to the city system, the park cleans the water with moss filtration devices and recycles it back to the park, saving an additional 375,000 gallons per month (Courtland/Environmental Leader, 2011).[186]

[186] Courtland, P. 2011. First Steps for Sustainable Waterparks. *Environmental Leader: Environment and Energy Management News.* Available at URL: http://www.environmentalleader.com/2011/08/23/first-steps-for-sustainable-waterparks/. Accessed May 2014.

APPENDIX

Practices in States Regarding Aspects of Integrated Water Management and Water Planning

Many states across the US engage in state-level water planning and management. The approach has been adopted in states with water supply challenges, but because the practices adopted are focused on reducing demand for water usage, these frameworks are relevant for reducing water withdrawals in the Great Lakes system as well.

In Georgia, state law requires that appropriate state agencies develop policies, management practices and guidance for regional water planning. The comprehensive approach includes water resource assessments (which identify levels of consumption to prevent negative ecological impacts), regional forecasts of water supply, and regional water development and conservation plans. Water demand management practices apply to municipal water withdrawal permit holders, which are required to submit conservation plans for the Public Water System (PWS) that they manage. Public and private water suppliers much conduct regular water system audits, implement a conservation-oriented rate structure and adopt water billing that reflects consumer usage, adopt a water loss control program, meter all water uses, collect information on water use by the largest water users/customers, meter water reuse, consider the use of greywater where appropriate as a substitute for higher quality water, and develop programs to replace or retrofit inefficient plumbing fixtures.[187]

The State of New Jersey's Division of Water Supply and Geoscience administers the permit systems for PWS agencies. Permits for PWS agencies require adoption of a Water Conservation and Drought or Water Supply Emergency Management Report. Information required as part of this report includes system capacity, analysis of water use on a per capita basis, the measure adopted for leak detection and repair, long range plans to reduce unaccounted-for water, efforts to educate the public on water conservation, and measures to plan for drought conditions and water supply.[188]

The State of California requires each urban water supplier providing over 3,000 acre-feet of water annually or serving more than 3,000 connections to develop an urban water management plan. These plans use a 20-year horizon, updated every five years. The Department of Water Resources (DWR) reviews these plans to ensure requirements in the Urban Water Management Planning Act have been met. The Act requires identification of sources of water, anticipated ground water pumping and a description of each water demand management program the supplier has in place to reduce per capita consumption of water.[189] A guidebook is provided by the State to assist water suppliers in completing the UWMP.[190] California provides technical assistance to water suppliers through the state's research and analysis unit.

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[187] Georgia Water Council. 2008. Georgia Comprehensive State-wide Water Management Plan.
[188] New Jersey, Division of Water Supply and Geoscience, n.d. Water Conservation And Drought Or Water Supply Emergency Management Plan Report For Public Water Supply Systems. Available at URL: http://www.nj.gov/dep/watersupply/pdf/Cv.Wcp-ws.pdf. Accessed May 2014.
[189] State of California, California Water Code Division 6, Sec. 10630-1034
[190] California Department of Water Resources. 2010. Guidebook to Assist Urban Water Supplier to Prepare a 2010 Urban Water Management Plan. Available at URL http://www.water.ca.gov/urbanwatermanagement/docs/2010FinalUWMPGuidebook_linked.pdf

The DWR also coordinates the program for Integrated Regional Water Management (IRWM), a collaborative effort to manage all aspects of water resources in one of the state's four designated water regions, and is currently developing a strategic plan for IRWM.[191]

The State of Maryland's Department of the Environment developed a guideline document for water conservation plans for the state's public water systems that includes best management practices. The Maryland Water Conservation Act, passed in 2002, requires certain public water systems to submit information about their water conservation best management practices when applying for new or renewed water appropriation permits. These plans are required for water systems that serve a population of greater than 10,000 and produce more than 100 gallons of water per capita per day and for systems that are awarded financial assistance from the State for infrastructure improvements. Under the Act, Maryland's Department of the Environment issues guidance for public water systems on best management practices for improving water conservation and efficiency in water use, treatment, storage, and transmission. The plan developed by a PWS evaluates current and projected water use, assesses infrastructure, operations, and management practices, and describes actions to be taken to reduce water losses, waste, or consumption and increase the efficiency with which water is used, treated, stored, and transmitted. Maryland's guidelines are based on the USEPA Water Conservation Plan guidelines, available at: http://www.epa.gov/WaterSense/pubs/guide.html. The state's water conservation plan content includes identification of water conservation measures, including metering, water accounting and loss control, pricing, customer-oriented information and educations programs. The state's guidelines also recommend a set of strategies for water conservation: water use audits, rebates and incentives, water reuse and recycling, and landscape efficiency.[192]

Great Lakes States

In the states subject to the Great Lakes Compact, support for adoption of integrated water management in larger cities and metropolitan regions could reduce withdrawal of water by public systems as conservation practices are adopted and water is used more efficiently, including through recycling and reuse.

For example, in Minnesota, public water suppliers serving more than 1,000 people and required to incorporate demand reduction measures into the water supply plan. Cities in the Twin Cities Metropolitan Areas are required to develop water supply plans as part of their local comprehensive plans. The state provides a downloadable template to assist in local water supply planning.[193]

In Pennsylvania, the commonwealth's water plan was revised in 2009 and includes specific requirements for each of the state's water planning regions, including the Great Lakes. The Plan adopts Integrated Water Resources Management as a framework as a recommendation to link the state's natural water resources plan with agency programs for sewage facilities, stormwater management, water supply, flood

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[191] http://www.water.ca.gov/irwm/stratplan/
[192] Maryland, Department of the Environment. nd. Guidance For Developing & Implementing A Water Conservation Plan: Best Management Practices For Water Conservation & Water Use Efficiency For Maryland Public Water Systems. Available at URL: http://www.mde.state.md.us/programs/Water/WaterConservation/WaterAuditing/Documents/Water%20Conservation%20Plan%20Guidance-2013may.pdf. Accessed May 2014.
[193] http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/eandc_plan.html

control and watershed protection. This approach should then be adopted by municipal and county PWS entities. In addition, Pennsylvania's governor, through executive order, created the Sustainable Water Infrastructure Taskforce in 2008, which required the "Pennsylvania Infrastructure Investment Authority, the Department of Environmental Protection, and the Department of Community and Economic Development to review all existing policies, procedures, rules, regulations and program guidance governing the planning, permitting, operation and maintenance as well as provide any financial and compliance assistance related to Pennsylvania's water infrastructure".[194]

In Michigan, the state's Department of Environmental Quality (DEQ) and the Community Water Supply Program oversee community public water supply regulations. Community public water supply entities (Type 1 category) provide year round service to not less than 25 residents or 15 living units, and include municipalities (as well as apartments, nursing homes and mobile parks with access and treatment of water). The agency's Water Use Program focuses on withdrawal and water conservation strategies.[195] The state's Water Conservation and Efficiency Program Review, developed in 2013 as part of its implementation of the Great Lakes Compact, specifies water conservation and efficiency goals across the state, and for entities withdrawing large quantities of water, including public water systems. Any proposed withdrawals requiring a permit are reviewed according to this criterion:

> Michigan's water withdrawal assessment process requires that all LQWs be measured against a pre-defined ecologically-based withdrawal limit for the water source in question. The assessment process uses a series of statutory gradations of projected impact to the resource from Zone A (least impact) to Zone D (an ARI, which is prohibited) as the basis for determining whether a withdrawal is authorized and, if so, under what conditions.[196]

In New York state, the Department of Environmental Conservation regulates water withdrawals by industrial, commercial and municipal entities. Any system with the capability to withdraw 100,000 GPD or more must be granted a permit from the state. The permit application requires identification of water sources, a map of water withdrawal sites and whether any inter-basin diversions occur. All applications for water withdrawal permits require a water conservation program that demonstrates water conservation and efficiency measures the applicant has in place. Public water supply applications include evidence from the PWS annual water supply audit.[197]The state offers a Water Conservation Manual for use by PWS entities as a guideline for development of a water conservation plan.[198]

The Wisconsin Department of Natural Resources regulates surface water, groundwater and drinking water systems. The agency regulates municipal water systems (community water system owned by a county, city, village, town, town sanitary district, utility district, or public institution as defined in s. 49.10 (12) (f)

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[194] Pennsylvania Department of Environmental Protection. 2009. State Water Planning Principles: Executive Summary. Available at http://www.pawaterplan.dep.state.pa.us/docs/Publications/3010-BK-DEP4227.pdf. Accessed May 2014.

[195] http://www.michigan.gov/deq/0,4561,7-135-3313_3684_45331---,00.html

[196] Michigan Water Conservation and Efficiency Program Review 2013; http://www.michigan.gov/deq/0,4561,7-135-3313_3684_45331-266261--,00.html

[197] NYS Department of Environmental Conservation. 2014. Water Conservation Requirements. Available at URL: http://www.dec.ny.gov/lands/86945.html

[198] NYS Department of Environmental Conservation. 1989. Water Conservation Manual. Available at URL: http://www.dec.ny.gov/docs/water_pdf/waterconsman.pdf

1., Stats., or a privately owned water utility serving any of the above) and public water system (a system providing piped water to the public for human consumption, if the system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year). Any improvements to existing systems or development of new systems must obtain a permit from Wisconsin DNR based on submission of a water system plan.

Wisconsin law (S. 281.348, Wis. Stats.) requires that all water utilities that serve a population of 10,000 or more people will be required to develop a water supply service area plan by 2026. Water supply service area plans are required currently for communities in the Great Lakes basin that plan to start a new withdrawal or increase an existing withdrawal over an established baseline. Communities located outside of the Great Lakes basin that apply for a new or increased diversion of Great Lakes water also need to submit a water supply service area plan. The water supply service area plan must include information about current sources of water, future demand and population projections; supply options to meet future needs including a cost-effectiveness analysis of different options with consideration for a regional or individual water system, water conservation alternatives; and an assessment of environmental and economic impacts of different supply options. The plan covers water supply for up to 20 years.[199]

State Technical Assistance

Many states provide significant guidance, technical assistance and regulation regarding municipal (urban) water management practices. In the Great Lakes basin, Michigan and Minnesota have online resources to assist public water supply entities with integrated water resources planning, including conservation techniques. Figure 17 shows some examples of state level online resources for water management.

[199] Wisconsin Department of Natural Resources. Nd. Water Topics. Available at URL: http://dnr.wi.gov/topic/WaterUse/serviceAreaPlan.html. Accessed May 2014.

Figure 17. **Examples of State Level Online Resources for Water Management**

Minnesota DNR Demand Reduction Measures for Public Water Suppliers
http://files.dnr.state.mn.us/waters/watermgmt_section/appropriations/demand_reduction_measures_introduction.pdf

Minneapolis-St. Paul Metropolitan Council Water Supply Planning Guidance and Tools
http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning/Guidance-and-Planning-Tools.aspx

Water Conservation Toolbox for Water Providers
http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning/Water-Conservation-Toolbox-Suppliers.aspx

Michigan Water Withdrawal Assessment Tool
http://www.miwwat.org

The SWITCH Program (Sustainable Water Management Improves Tomorrow's Cities' Health) focused on adoption of new management strategies and infrastructure in 8 cities worldwide. Part of the program developed an on-line decision support tool for water managers called City Water.
Decision Support Tools Training Module
http://www.switchtraining.eu/fileadmin/template/projects/switch_training/files/Modules/Module_reduced_size/Switch_Training_Kit_Module_6.pdf

City Water Tool Description
http://www.switchurbanwater.eu/outputs/pdfs/WP1-2_GEN_PBN_Decision_support_tools_for_integrated_urban_water_management_systems.pdf