Texas Water Development Board
Report 362

Water Conservation Implementation Task Force

Water Conservation
Best Management Practices Guide

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Texas Water Development Board

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1.0 Introduction

This document is the result of the work of the Texas Water Conservation Implementation Task Force, a volunteer group of Texas citizens with experience in and commitment to using Texas water more efficiently. The Task Force was created by the 78th Texas Legislature under Senate Bill 1094. The Legislature directed the Texas Water Development Board ("TWDB") to select members of the Water Conservation Implementation Task Force from applicants representing the following entities and interest groups:

- Texas Commission on Environmental Quality
- Department of Agriculture
- Parks and Wildlife Department
- State Soil and Water Conservation Board
- Texas Water Development Board
- Regional Water Planning Groups
- Federal Agencies
- Municipalities
- Groundwater Conservation Districts
- River Authorities
- Environmental Groups
- Irrigation Districts
- Industries
- Institutional Water Users
- Professional Organizations Focused on Water Conservation
- Higher Education

The legislature charged the Task Force with reviewing, evaluating, and recommending optimum levels of water use efficiency and conservation for the state. These Best Management Practices were prepared in partial fulfillment of this charge. This document was developed by GDS Associates, Inc., Chris Brown Consulting, Axiom-Blair Engineering, Inc. and Tony Gregg, P.E. through funding from the Texas Water Development Board's Research and Planning Fund.

1.1 Background

Municipal water conservation efforts in Texas have been motivated by diverse goals such as preventing land subsidence, addressing short-term or long-term water shortages, providing environmental protection, and avoiding or postponing the high costs of new water system improvements. Through implementation of water conservation programs across the state, experience has been gained in the effective delivery of programs and lessons learned in approaches which are not as effective.

Industrial water users have also made advances in water use efficiency over the past several decades. Inspired by increasing costs of resources, such as the water itself, energy needed to pump, treat, and heat water in industrial processes, and the challenges of drought, many Texas businesses have developed or adopted techniques to lower water use. One indication of the success of industrial efforts is actual water use recorded for the manufacturing sector in the year 2000. Actual use was 70 percent of water demand projections developed in the late 1990s.

Agricultural growers using groundwater from the Ogallala Aquifer have pioneered water efficiency in agricultural irrigation in the Texas panhandle region. As early as the 1970s, low-pressure center pivot irrigation systems were reducing water use by 30 percent to 50 percent from existing irrigation methods at the time. Since then, irrigation efficiency has increased both in the sophistication of low pressure irrigation methods as well as increased efficiency in other irrigation and water management methods in agricultural production.

While there are a number of successful conservation efforts in Texas, there is an opportunity for a more comprehensive effort by all sectors of the State. The legislation that created the Water Conservation Task Force was passed in order to further conservation efforts in the State. One of the objectives of the Task Force was to gather information about the elements of successful conservation programs, good cost estimates and reliable water savings estimates for use in water resource planning. In this guide, the Task Force uses the following working definition of conservation: Those practices, techniques, programs, and technologies that will protect water resources, reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling and reuse of water so that a water supply is made available for future or alternative uses. As part of its work, the Task Force hopes to move the process of water conservation planning a significant step forward in Texas by the publication of Best Management Practice Guidelines based upon this current analysis.

1.2 Best Management Practices (BMPs)

Experience in water conservation program implementation over the decades has resulted in a body of knowledge in Texas, across the United States and around the world. Practitioners have shared these experiences and adopted the approach of the BMP. A BMP is structured for delivering a conservation measure or series of measures that is useful, proven, cost-effective, and generally accepted among conservation experts.

In Texas, conservation BMPs are designed to fit into the State's water resource planning process as one alternative to meet future water needs. As a result, each BMP should be clearly defined in its schedule of implementation, expected water savings, and costs of implementation (based on Exhibit B Guidelines for Regional Water Plan Development). Each BMP structure has several elements that describe the efficiency measures, implementation techniques, schedule of implementation, scope, water savings estimating procedures, cost effectiveness considerations, and references to assist end-users in implementation.

1.3 Development and Purpose of Best Management Practices Guide

The BMPs and the cost effectiveness tools in this Guide are offered to the state's regional water planning groups, water providers, and water users as a tool for planning and designing effective conservation programs. The Guide is organized into three sections, for municipal, industrial and agricultural water user groups ("WUG") with a total of fifty-five BMPs. At the end of each section is a chapter giving guidance on cost effectiveness evaluation for the specific BMPs in the section. Each BMP is organized to be of assistance in conservation planning, program development, implementation, and evaluation.

The BMPs can be evaluated for potential water savings and the cost effectiveness for consideration in the regional water planning process. Within each planning region, sufficient variation exists at the local water user level that more specific analysis should be done by a prospective end-user prior to adopting the BMP. Best-management practices contained in the BMP Guide are voluntary efficiency measures that save a quantifiable amount of water, either directly or indirectly, and can be implemented within a specified timeframe. The BMPs are not exclusive of other meaningful conservation techniques that an entity might use in formulating a state-required water conservation plan. At the discretion of each user, BMPs may be implemented individually, in whole or in part, or be combined with other BMPs or other water conservation techniques to form a comprehensive water conservation program. The adoption of any BMP is entirely voluntary, although it is recognized that once adopted, certain BMPs may have some regulatory aspects to them (e.g. implementation of a local city ordinance).

The Task Force unanimously agreed that the BMP Guide must be in accordance with the state's philosophy of region-based water planning. The Task Force firmly believes that applying a mandatory set of BMPs throughout Texas would **not** be appropriate. One size does not fit all in a state characterized by wide variations in climate, geography, municipal demographics, water utility and service profiles, and agricultural and industrial needs. State policies adopted to guide the implementation of water conservation in Texas must acknowledge the fundamental decision-making primacy and prerogative of regional planning groups, municipalities, industrial and agricultural water users, and water providers. Each BMP is organized into nine standardized sections (A-I), which are described in general terms below.

A. Applicability

The specific type of water user group that could potentially benefit from the BMP is described, as are the general goals for water efficiency that the BMP addresses.

B. Description

This section provides an explanation of the specifics of the conservation measure(s) included in the BMP. The best available technology that is proven and cost effective is recommended. Often a best available technology may not yet be cost effective to be implemented by all water users. Highly efficient water conservation measures that will produce cost-effective results are mentioned.

Example: The current standard for water efficient toilets is 1.6 gallon per flush ("gpf") models. Lower flush volume toilets exist such as dual flush toilets which flush 1.6 gpf for solid waste and 0.8 gpf for liquid waste, but their availability is not yet widespread in the United States. Since this technology is new and few models are available, costs are currently high but are expected to fall as additional models become available. As prices fall, this technology will become more cost effective.

C. Implementation

The basic steps to accomplish the BMP are described. If the description section includes more than one measure to complete the BMP, the implementation section will suggest necessary steps for achieving the water savings.

D. Schedule

In BMPs which have multiple implementation steps, a recommended schedule for implementation is included. In general, planning, data gathering and evaluation steps should be accomplished within 12 months of adoption of a specific BMP.

E. Scope

For simpler BMPs, the scope is complete when the steps described in the implementation section have been achieved. For more complicated BMPs, the scope indicates the level of implementation necessary to consider the BMP complete. Where different levels of implementation or constraints are present, these are described.

F. Documentation

To track the progress of a BMP, the water user should collect certain data to document progress implementing the BMP and evaluating actual water savings. This section identifies the recommended data.

G. Determination of Water Savings

This section specifies information necessary to calculate water savings from implementation of the BMP and may include statistical or mathematical formulas when appropriate.

H. Cost-Effectiveness Considerations

Basic costs of implementing the specific BMP are explained. Due to the wide variety in actual costs based upon size of program and location, ranges of costs are given where appropriate. In many cases, costs and expenses can be reduced or spread out when multiple BMPs are implemented by an entity. This section primarily serves to remind the users of costs to consider when performing a cost effectiveness analysis.

I. References for Additional Information

The BMP concludes with a listing of resources that can assist a water user in implementing the BMP.

1.4 Cost-Effectiveness Considerations

Each of the three sections of the BMP Guide, Municipal, Industrial, and Agricultural, has a dedicated chapter on cost-effectiveness analyses. Methods for determining the relationship between the value of water saved and the cost of BMP implementation are described and explained through examples. Users of the guide are encouraged to read and utilize any of the analytical tools found in these sections, if they find them to be appropriate.

1.5 Getting the Most Out of the Guide

The BMP Guide is designed for several uses and for a diverse audience of water resource planners and managers throughout the state. It has sufficient detail to be useful in the state water planning process, which is implemented at the regional level. The Regional Water Planning Groups are encouraged to review the BMPs and to consult with WUGs in their region that have an identified future need for water to determine which BMPs are appropriate and which BMPs the WUGs intend to utilize or are already using for conservation program planning and implementation. For planning purposes water conservation best management practices are not limited to those listed in this guide.

The Task Force acknowledges that the efficient use of water as a natural resource is an important planning objective and an economical means of operation and recommends that water user groups of all types evaluate the BMPs for use in their area. The first step for a municipal, agricultural or industrial water user is to review the Applicability section in a BMP to determine if the BMP is appropriate for their use. For those water users with stakeholders, a stakeholder involvement process is a valuable means of getting feedback on priority BMPs and on specific elements within a BMP which have broad support. In municipalities, stakeholders include customers and representative interest groups which have shown an interest in water issues in the community. Such groups may include representatives from neighborhood and business associations, technical groups, academics, environmentalists, and city departments. A number of the municipal BMPs recommend developing such stakeholder groups as a part of implementing the specific BMP. The Task Force also recognizes that stakeholder groups can be helpful in the initial selection of best management practices to be included in a Conservation Plan.

Industrial WUGs should consider employees from all affected departments, customers, suppliers, and regulators and impacted water users, including agricultural or municipal interests, as potential stakeholders. Depending upon the size of the business and the proposed BMPs, the process can be either formal or informal. The industrial WUG can also use the guidance included in the Employee Programs BMP as part of the process of selecting the appropriate BMPs. For those industrial WUGs that are already implementing an Environmental Management System the stakeholder process may be defined and can be used to help pick the appropriate BMPs. In the industrial setting, executive management support is essential for success and should be sought early in the planning process.

Agricultural WUGs at the farm level may include employees, suppliers and regulators among potential stakeholders. A valid input process may be an informal survey of individuals to solicit input for choosing the best BMPs. For political subdivisions of the State of Texas that deliver irrigation water to agricultural users, the stakeholder group may include representatives from agricultural and water conservation organizations, municipal, and rural water supply entities, and local, state, or federal governmental agencies.

In writing a Conservation Plan it is important for the WUG to follow state, local and, in some cases, federal guidelines which may include requirements for certain plan elements such as a utility profile and seasonal demand. Such requirements are often specific to the WUG, the type of water demand, and the political boundaries in which a WUG operates. Texas has numerous groundwater districts, river authorities, and irrigation districts all of which have specific authority and the potential for unique requirements within their area or operation. The BMPs are designed to be used as a resource in developing that part of a water conservation plan where specific measures, the schedule and scope of implementation, and the anticipated savings and costs are addressed.

Each BMP was prepared through research of literature and with the insight and experience of Task Force members, Board staff, and technical consultants to provide information based upon real world results of conservation program implementation. Because of the information accumulated in the development of the Guide, each BMP can serve as a program guide as well as a planning tool. Conservation program managers wishing to use the BMPs in program delivery should pay close attention to the Implementation, Schedule, Scope, and Documentation sections. Each of these sections contains information which can assist existing conservation programs as well as new conservation efforts to increase their effectiveness. Each BMP also includes a reference section with additional resources to assist conservation practitioners in delivering high quality programs with real water savings.

The BMP also has information that can assist managers, auditors and policy makers in evaluating the impact of conservation programs. The Documentation, Determination of Water Savings, and Cost Effectiveness Considerations sections are provided to assist in program evaluation. Each section of BMPs, municipal, industrial and agricultural, has a Cost-Effectiveness Chapter, which provides tools for doing cost-benefit analysis by each of the major types of WUGs.

The Task Force presents this Guide as a tool for advancing the practice and effectiveness of water conservation in Texas. The insights distilled in the enclosed BMPs come from years of conservation practice by the Task Force members. That same experience leads the Task Force to view this as a living document, with the recognition that further implementation of conservation practices will bring new insight, more study will provide new information, and new technology will improve savings. The Task Force members encourage conservation managers, planners, practitioners and policy makers to give feedback to the Texas Water Development Board about the BMP Guide in the hopes that it will be updated regularly over the years ahead.

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2.0 BMPs for Municipal Water Users

Water consumption by water utilities serving municipal water customers is driven by a wide variety of domestic, commercial, industrial and institutional needs. BMPs have been developed for utilities to both improve water use efficiency of their own operations and for programs to improve the efficiency of their customers.

It is important that water utilities focus on the efficiency of their supply operations while promoting water efficiency to their customers. A utility can reduce water loss through careful and regular monitoring of its water delivery systems through the System Water Audit and Water Loss BMP. In addition, the Water Conservation Pricing BMP can provide an effective method of encouraging water efficiency by the customer through feedback from the cost of the water to the user. The Prohibition on Water Wasting BMP can help send a message to users about the value of water as well as educate the general populace about simple steps to save water.

Despite the variety of water uses and numbers of water users, many patterns of water use, especially in domestic water use are common. As a result a number of conservation measures have been developed in municipal settings over the past several decades to reduce the total gallons consumed for daily activities without reducing the benefit of the water used. The Showerheads, Faucet Aerators and Toilet Flapper Retrofit BMP and the Residential Toilet Replacement Programs BMP focus on indoor water use. The Residential Clothes Washer Incentive Program BMP encourages the installation of water efficient clothes washers.

The School Education BMP affects water consumption through changes in behavior as students learn about water resources and the wise use of water. The Water Survey for Single-Family and Multi-Family Customers BMP educates customers about specific water saving opportunities as well as water wasting practices which may be present in their home or business.

Outdoor water uses driven by climatic differences, and water needs of different plants, and used for diverse purposes result in BMPs which are focused on good landscape management principles. The Landscape Irrigation Conservation and Incentives BMP focuses on water savings that can be obtained through efficient operation of automatic irrigation systems, while the Water Wise Landscape Design and Conversion Programs BMP focuses on landscape materials.

A utility can reduce water loss through careful and regular metering of water delivered to billed as well as unbilled water uses and through proper maintenance of meters as through the Metering of All New Connections and Retrofit of Existing Connections BMP. For agencies or utilities offering water to wholesale customers who in turn serve retail customers, the Wholesale Agency Assistance Programs BMP offers methods for promoting water conservation among the retail water utilities. In addition, the Conservation Coordinator BMP can provide an effective method of ensuring that the utility's conservation programs are well administered and effective. The Reuse BMP outlines how utilities can make more efficient reuse of their existing supplies.

The Public Information BMP can affect water consumption through changes in behavior as customers learn about water resources, the wise use of water and the utility's conservation program. The Rainwater Harvesting/Condensate Reuse BMP focuses on water savings that can be obtained through capturing rainwater or the condensate from large cooling systems while the New Construction Graywater BMP focuses on reuse of water which has been used in washing clothes.

Commercial water uses also have a variety of practices and equipment that can benefit from efficiency measures. The Municipal BMPs also include those focused on good water use practices for Park Conservation and for Conservation Programs for Industrial, Commercial, and Institutional Accounts.

Best-management practices contained in the BMP Guide are voluntary efficiency measures that save a quantifiable amount of water, either directly or indirectly, and can be implemented within a specified timeframe. The BMPs are not exclusive of other meaningful conservation techniques that an entity might use in formulating a state-required water conservation plan. At the discretion of each user, BMPs may be implemented individually, in whole or in part, or be combined with other BMPs or other water conservation techniques to form a comprehensive water conservation program. The adoption of any BMP is entirely voluntary, although it is recognized that once adopted, certain BMPs may have some regulatory aspects to them (e.g. implementation of a local city ordinance).

2.1 System Water Audit and Water Loss

A. Applicability

This BMP is intended for all Municipal Water User Groups ("utility"). This BMP should be considered by a utility that:

1) would like to analyze the benefits of reducing its unaccounted for water,
2) has not conducted a periodic water audit,
3) wants to determine if under-registering meters is impacting its revenues, or
4) has not implemented a leak reduction program.

To maximize the benefits of this BMP, the utility uses the information from the water audit to revise meter testing and repair practices, reduce unauthorized water use, improve accounting for authorized but unbilled water and implement effective water loss management strategies. HB 3338 only requires a water utility to conduct a water audit every five years. By adopting this BMP, a utility will be implementing a more frequent implementation of water auditing and loss reduction techniques than required by HB 3338. Small utilities may want to use parts of this BMP, without following every step.

B. Description

System water audits and water loss programs are effective methods of accounting for all water usage by a utility within its service area. Performing a reliable water audit is the foundation of proper water resource management and loss control in public drinking water systems. There has been much recent interest in revising and developing water audit procedures to move away from simply considering "unaccounted for water" to a systematic methodology of accounting for all water uses. The structured approach of a water audit allows a utility to reliably track water uses and provide the information to address unnecessary water and revenue losses. The resulting information from a water audit will be valuable in setting performance indicators and in setting goals and priorities for cost-effectively reducing water losses.

Compiling a water audit is a two-step approach, a top-down audit followed by a bottom-up audit. The first step, the top-down audit, is a desktop audit using existing records and some estimation to provide an overall picture of water losses. For those utilities that gather the information necessary to fill in the Texas Commission on Environmental Quality's Utility Profile, (http://www.tnrcc.state.tx.us/permitting/forms/10218.pdf) that information is the first step of a top-down audit. If a utility has been conducting a water audit using the American Water Works Association ("AWWA") M36 Manual, the utility will already have the data needed to complete the first step of this audit. The records that will be needed include quantity of water entering the system, customer billing summaries, leak repair summaries, average pressures, meter accuracy test, meter change-out summary, permitted fire hydrant use, and other records that may be kept on water theft and unmetered uses such as street cleaning. AWWA is currently revising the M36 Manual, which will provide additional guidance on implementing this BMP. TWDB will also be publishing a report on HB 3338, which will have information that will assist in implementing this BMP.

The second step of the audit, the bottom-up approach, involves a detailed investigation into actual policies and practices of the utility. This part of the audit is phased in over several years. There are several areas to be addressed including development of better estimates of water use by the fire department, water used in line flushing and street cleaning, and metering of all authorized uses. The procedures of the detailed water audit also include using night flow and zonal analysis to better estimate leakage; analysis of leakage repair records for length of time from reporting to repair of the leak; and analyzing pressure throughout the system.

Several indicators from the analyses in a water audit should be considered by utilities in order to improve water loss control procedures. These include:

1) Real Losses
Losses due to leakage and excess system pressure. Real losses can be reduced by more efficient leakage management, improved response time to repair leaks, improved pressure management and level control, and improved system maintenance, replacement, and rehabilitation. The cost of real losses is estimated using the marginal production costs, such as energy and chemicals needed to treat and deliver the water.

2) Apparent Losses
Losses due to meter accuracy error, data transfer errors between meter and archives, data analysis errors between archived data and data used for billing/water balance, and unauthorized consumption including theft. The cost of apparent losses is estimated using the retail commodity rates.

3) Unavoidable Annual Real Losses ("UARL")
This represents the theoretically low level of annual real losses in millions of gallons daily ("MGD") that could exist in a system if the current best management practices for leak management are successfully implemented. It is based on data obtained from systems where effective leakage management was implemented. The calculation of the UARL is based on number of miles of water mains, number of service connections, average water pressure, and length of service connections. The UARL is allocated to service lines and water mains. The revised AWWA M36 Manual will provide details on how to calculate unavoidable annual real losses.

4) Infrastructure Leakage Index ("ILI")
Ratio of annual real losses divided by UARL. The ILI provides a ratio of current leakage relative to the best level obtainable with current best management practices for leakage. A ratio of 1.0 would indicate that the utility has reduced losses to the theoretically lowest level possible.

5) Economic Level of Leakage ("ELL")
This is a calculation based on the cost of reducing leakage. It is the theoretical level at which the cost of leakage reduction meets the cost of the water saved through leakage reduction. These costs include not only the cost of producing water but also the avoided cost of replacing the water.

In order to reduce water losses due to leakage, a utility should maintain a proactive water loss program. A structured approach to leakage management has proven to be successful in limiting losses. Potential elements of an active water loss program include:

1) Conducting regular inspections and soundings of all water main fittings and connections;
2) Using a water loss modeling program. A model can range from the AWWA M36 Manual Water Audit Spreadsheet to a commercially available statistical model;
3) Metering individual pressure zones;
4) Establishing district metering areas ("DMA") and measuring daily, weekly or monthly flows with portable or permanently installed metering equipment;
5) Continuous or intermittent night-flow measurement;
6) Installing temporary or permanent leak noise detectors and loggers;
7) Reducing repair time on leaks since long-running small to medium size leaks can be the greatest volume of annual leakage;
8) Controlling pressure just above the utility's standard-of-service level taking into account fire requirements, outdoor seasonal demand and requisite tank filling;
9) Operating pressure zones based on topography;
10) Limiting surges in pressure; and
11) Reducing pressure seasonally and/or where feasible to reduce losses from background leaks.

If a utility has not had regular leak surveys performed it will probably need at least three leak surveys performed in consecutive years or every other year for these reasons:

1) The first survey will uncover leaks that have been running for a long time;
2) The second survey will uncover additional long-running leaks whose sounds were masked by larger nearby leaks; and
3) By the third survey, the level of new leaks should start to approximate the level of new reported leaks.

The utility should make every effort to inform customers when leaks exist on the customer side of the meter. If customer service line leaks are significant, a utility might consider the option of making the repairs itself.

The utility should reduce apparent losses since reducing these losses will increase utility revenue. Some of the areas that should be examined are:

1) Customer meter inaccuracy due to meter wear, malfunction or inappropriate size or type of meter;
2) Data transfer error when transferring customer metered consumption data into the billing system;
3) Data analysis errors including poor estimates of unmetered or unread accounts;
4) Inaccurate accounting resulting in some accounts not being billed for water use;
5) All forms of unauthorized consumption including meter or meter reading tampering, fire hydrant theft by contractors, unauthorized taps, and unauthorized restoration of water service cutoffs; and
6) Unmetered municipal connections (every effort should be made to meter municipal connections in order to better account for water use).

C. Implementation

To successfully implement this BMP, the utility should start by forming a working group from the following work areas: management, distribution, operations, production, customer service, finance, and conservation. Each of these work areas has an essential role to play in implementing this BMP. Smaller utilities may have the same person doing several of these functions and therefore the working group may just be one or two individuals. The utility should also consider a public involvement process to solicit outside input as well as to enhance public relations.

Initially the working group should focus on gathering relevant data and identifying current practices listed above in Section B that form the basis for the top-down audit. Some of the questions that should be addressed during the top-down audit are:

1) How often do we test production meters? Commercial meters over 1 inch? Over 2 inches?
2) How often do we replace or repair ⅝ and ¾-inch meters?
3) How inaccurate are the ⅝ and ¾ inch meters on average when they are replaced?
4) Do we estimate total leakage from each leak based on the leakage flow rate and length of leakage from time reported when we fix leaks?
5) How long does it take to repair leaks, itemized by size of leak?
6) Are customers encouraged to report leaks?
7) Do we have a system for tracking location of leaks and a method to calculate when it is cost-effective to replace mains and service lines?
8) Are meter readers trained to look for and report leaks?
9) Do we adjust consumption records when billing records are adjusted?
10) Is backwash and other in-plant water use optimized?
11) How effective is our theft reduction program?

Based on the data collected and information from the questions above, the utility should have enough information to complete a top-down audit.

An ILI of 3 should be used as an example of an achievable target. If the ILI is 3 or below, then further implementation of the BMP is not required until the following year. This would indicate that the utility already has an effective water audit and water loss program. If the ILI is above 3, then the utility should implement a more effective water audit and water loss program. The utility then proceeds to conduct a bottom-up audit.

In conducting the bottom-up audit, the utility addresses the relevant issues identified during the top-down audit and further investigates those issues discussed in Section B. The utility uses the results of the audit to focus on the best approaches to reduce both real and apparent losses. Depending on whether the ILI is relatively high or low determines the number of years it may take to reduce the ILI to 3.

Each subsequent year, the utility completes another top-down audit. Over time the utility should be able to gradually reduce its ILI to 3. If the utility finds the ILI is increasing, then it should perform a bottom up audit.

D. Schedule

To accomplish this BMP, the utility should:

1) Gather the necessary information for conducting the top-down audit, develop the procedures and complete the audit within the first twelve (12) months of implementing this BMP.
2) The bottom-up refinements should start to be implemented in the twelve (12) months immediately following the completion of the top-down audit if the ILI exceeds 3.
3) Based on the goal of achieving an ILI target of 3, the utility continues to implement bottom-up refinements to reduce real and apparent losses each subsequent year until the utility achieves an ILI of 3.
4) The utility's ILI should be calculated each year.

E. Scope

To accomplish this BMP, the utility should:

1) Conduct a periodic system audit following the methodology contained in the revised AWWA M36 Manual and the report that TWDB is preparing as part of implementing HB 3338.
2) Develop and perform a proactive distribution system water loss program and repair identified leaks.
3) If the utility's ILI is greater than 3:
    a. Implement a pressure reduction strategy if warranted;
    b. Implement a program to reduce real losses, including a leak detection and repair program;
    c. Implement a program to reduce apparent losses; and
    d. Advise customers when it appears that leaks exist on the customer's side of the meter and evaluate a program to repair leaks on the customer's service line.

F. Documentation

To track the progress of this BMP, the utility should gather and have available the following documentation:

1) A copy of each annual system audit, the ILI for each year, and a list of actions taken in response to audit recommendations.
2) Annual leak detection and repair survey, including number and sizes of leaks repaired.
3) Number of customer service line leaks identified and actions taken to repair these leaks.
4) Pressure reduction actions taken, if any; and
5) Annual revenue increased through reducing apparent losses.

G. Determination of Water Savings

Potential water savings are an integral part of the system water audit process and should be contained in the audit report. Based on the results of the audit, the utility should set goals for reducing its losses.

H. Cost-Effectiveness Considerations

Direct costs that should be considered in implementing this BMP include the initial and ongoing costs for performing and updating the water audits and capital costs for items such as leak detection equipment and billing software upgrades. Utilities may wish to do the work in house with technical staff or by using outside consultants and contractors.

A recommended method to make cost effectiveness decisions is based on the economic value of real losses and apparent losses. (*See* Section I. References for Additional Information, 4.) Real losses are losses due to leaks and are valued at actual costs to produce and deliver the water. Apparent losses, sometimes called paper losses, are those attributable to meter and billing inaccuracies and are valued at the retail rates charged by the utility. The amount of lost revenue due to real losses, based on the utility's marginal production cost, and apparent losses, valued at the retail rate charged to customers, can be compared to the costs of reducing the sources of loss.

I. References

1) *Water Loss Control Manual,* Julian Thornton, McGraw-Hill 2002.
2) *M36 Manual,* AWWA, 1999.
3) *Applying Worldwide BMPs in Water Loss Control,* AWWA Water Loss Control Committee, Journal AWWA, August 2003.
4) *Survey of State Agency Water Loss Reporting Practices: Final Report to the AWWA Technical and Education Council,* Beecher Policy Research, 2002.
5) *Benefit Cost Analyses of Leak Reduction Program: A Note for the Canadian Water and Wastewater Association*, Alan Lambert, 2002.

2.2 Water Conservation Pricing

A. Applicability

This BMP is intended for all Municipal Water User Groups ("utility") wishing to send price signals to customers to encourage water conservation. A utility may have already accomplished this BMP if it currently has a conservation price structure.

B. Description

Water Conservation Pricing is the use of rate structures that discourage the inefficient use or waste of water. Conservation pricing structures include increasing unit prices with increased consumption such as inverted block rates, base rates and excess use rates such as water budget rates, and seasonal rates. Seasonal rate structures may include additional charges for upper block (outdoor) usage or excess-use surcharges for commercial customers to reduce demand during summer months. The goal of conservation pricing is to develop long run consumption patterns consistent with cost. Under this BMP, utilities should consider establishing rates based upon long-run marginal costs, or the cost of adding the next unit of capacity to the system. An established cost of service methodology should be followed whenever rates are developed or proposed for change.

This BMP addresses conservation pricing structures for retail customers. For utilities supplying both water and sewer service, this BMP applies to pricing of both water and sewer service. Utilities that supply water but not sewer service should make good faith efforts to work with sewer agencies so that those sewer agencies do not provide sewer services for a declining block rate.

For conservation pricing structures to be effective, customers should be educated on the type of rate structure that the utility uses and be provided monthly feedback through the water bill on their monthly water use. Most customers do not track water use during the month because of the difficulty and inconvenience of reading the meter. When customers read their bill, they most often just look at the total amount billed. Conservation pricing has the advantage of providing stronger feedback to the customers who will see a larger percent increase in their water bill than the increase in water use. Utilities should move toward adopting billing software that allows customers to compare water use on their bill with average water use for their customer class as well as their individual water use for the last 12 months. The rate structure should be clearly indicated on the water bill.

It is not recommended that a minimum monthly water allotment be included in the minimum bill. The AWWA notes that minimum charges are often considered to work counter to conservation goals and are unfair to those who use less than the monthly minimum. A customer who does not use the entire amount included in the minimum during the billing period will be charged for the water allotment regardless, and thus may feel he should find a way to use the additional water. A customer in a house with all efficient fixtures and appliances can use 1000 gallons or less per month and may be inclined to increase their water use if a minimum bill includes more than 1000 gallons[1]. In the Residential End Use Study[2], approximately 6 percent of homes had a per capita use of less than 1000 gallons per month.

C. Implementation

Successful adoption of a new rate structure may necessitate developing and implementing a public involvement process in order to educate the community about the new rate structure. The new rate structure should adhere to all applicable regulatory procedures and constraints. If the conservation pricing structure to be implemented is substantially different from current practices, then a phase-in approach may be appropriate.

Public involvement in the development and implementation of conservation rates can help assure that the goals of the conservation pricing initiatives will be met and accepted by local constituents. Public meetings, advisory groups, and public announcements are among ways to generate public involvement.

Development of conservation-based rate structures is more than just selection of arbitrary usage breaks. The process requires consideration of the effect on water demand and water utility finances.

1) Basic rate structure considerations should include rates designed to recover the cost of providing service and billing for water and sewer service based on actual metered water use. Conservation pricing should provide incentives to customers to reduce average or peak use, or both. The conservation rate structure can be designed to bring in the same amount of revenue, often termed revenue neutral, as the previous rate structure.
2) Only one type of conservation pricing is required for this BMP. Conservation pricing is characterized by one or more of the following components:
   a. Seasonal rates to reduce peak demands during summer months. There are a variety of approaches including having increasing block rates only during the summer months or having a year round block rate structure with higher block rates during the summer months.
   b. Rates in which the unit rate increases as the quantity used increases (increasing block rates). For block rate structures, the rate blocks should be set so that they impact discretionary use. A utility should analyze historical records for consumption patterns of its customers. The first block should typically cover the amount of water for normal household health and sanitary needs. To increase the effectiveness of this rate structure type, the additional revenue from the higher blocks should be associated with discretionary and seasonal outdoor water use.
      - Rates for single family residential and other customer classes may be set differently to reflect the different demand patterns of the classes.
      - The price difference between blocks is very important in influencing the customer's usage behavior. Price increases between blocks should be no less than 25 percent of the previous block. For

maximum effectiveness, the price difference going from one block to the next highest block is recommended to be at least 50 percent of the lower block. For example if the third block of a four-block rate structure is $4.00 per 1000 gallons, the fourth and final block should have a rate of at least $6.00 (50 percent higher) per 1000 gallons. Any surcharge based on water usage should be included when calculating these percentages.

c. Rates based on individual customer water budgets in which the unit cost increases above the water budget. Water budget rate structures are based on the philosophy that a certain amount of water is adequate for all normal necessary uses, and uses above that amount are considered excessive and charged as excessive. For example, Irvine Ranch Water District in California[3] sets the excess use charges at 200 percent of the base rate. Typically there should be an indoor and an outdoor component to a water budget.
   - For residential rates, the indoor component should be based upon estimates of average family use. The outdoor component is based upon landscape area. For business customers, water budgets will often be based upon historical average for indoor water use, and outdoor component based upon landscape area.
   - To qualify as a conservation rate, utilities that implement water budget based rate structures typically begin excess rate charges for landscaped areas at no more than 80 percent of average annual reference evapotranspiration replacement rates.

d. Rates based upon the long-run marginal cost or the cost of adding the next unit of capacity to the system.

3) Conservation pricing should use a consumption charge based upon actual gallons metered. The minimum bill for service should be based on fixed costs of providing that service which generally includes service and meter charges. Including an allotment for water consumption in the minimum bill does not promote conservation and it is recommended that if a minimum is included, it not exceed 2000 gallons per month. Utilities including a water allotment in the minimum bill should consider eliminating that allotment within five years of implementing this BMP.

4) Adoption of lifeline rates neither qualifies nor disqualifies a rate structure as meeting the requirements of this BMP except that the minimum bill guidelines should be followed. Lifeline rates are intended to make a minimum level of water service affordable to all customers.

5) The utility should educate customers about the rate structure and use billing software that allows the customer to compare water use on their bill with average water use for their customer class as well as their individual water use for the last 12 months. The rate structure should be clearly indicated on the water bill. The utility may want to consider implementing the Public Information BMP in conjunction with this BMP in order to provide customers information on how to reduce their water bill under a conservation rate structure.

6) In order to be able to set up an effective irrigation rate, the utility should consider adopting rules or ordinances requiring new commercial and industrial customers to install separate irrigation meters and consider retrofitting current commercial and industrial customers with irrigation meters. It is important for commercial and industrial customers to have a separate irrigation meter so they can better understand how much water they are using for irrigation. This provision is optional for this BMP.

D. Schedule

Utilities pursuing this BMP should begin implementing this BMP according to the following schedule:

1) The utility should follow applicable regulatory procedures and adopt a conservation oriented rate structure within the first twelve months. The conservation rate structure should be designed to promote the efficient use of water by customer classes as outlined in this BMP.
2) At least annually, a utility should review the consumption patterns (including seasonal use) and its income and expense levels to determine if the conservation rates are effective and make appropriate, regular rate structure adjustments as needed.
3) At least annually, the utility should provide information to each customer on the conservation rate structure.
4) If not already in place, within five years or when the utility changes billing software, whichever is sooner, the utility bill should provide customers with their historical water use for the last 12 months and a comparison of water use with the other customers in their customer class. The rate structure should be clearly indicated on the water bill.
5) While not required to be implemented as part of this BMP, within one year the utility should consider adopting service rules or an ordinance requiring all new commercial and industrial customers to install separate irrigation meters and the feasibility of retrofitting commercial and industrial current customers with irrigation meters.

E. Scope

To accomplish this BMP, the utility should implement a conservation-oriented rate structure and maintain its rate structure consistently with this BMPs definition of conservation pricing and implement the other items listed in D above.

F. Documentation

To track this BMP, the utility should maintain the following documentation:

1) A copy of its legally adopted rate ordinance or rate tariff that follows the guidelines of this BMP;

2) Billing and customer records which include annual revenues by customer class and revenue derived from commodity charges by customer class for the reporting period;
3) Customer numbers and water consumption by customer class at the beginning and end of the reporting period;
4) If a water allotment is included in the minimum bill, a cumulative bill usage analysis similar to Figure C-3 in the AWWA M1 Manual;
5) A copy of the education materials on the conservation rate sent to customers for each calendar year this BMP is in effect;
6) A utility bill meeting the parameters and schedule in Section D;
7) Optional provisions:
    a. A copy of the rule or ordinance requiring all new commercial and industrial customers to install separate irrigation meters; and
    b. Implementation and schedule for an irrigation meter retrofit program for current commercial and industrial customers or a feasibility analysis of an irrigation meter retrofit program for current commercial and industrial customers.

G. Determination of Water Savings

The effect of conservation pricing implementation is very specific to each utility. Elasticity studies have shown an average reduction in water use of 1 to 3 percent for every 10 percent increase in the average monthly water bill.[1] When implementing a conservation pricing structure, consideration should be given to the factors that influence whether the new structure results in a reduction in water use. The *Water Price Elasticities for Single-Family Homes in Texas* (*See* Section I. References for Additional Information, 1) study included several significant findings that water savings can be expected:

1) Average price is better than marginal price in explaining the quantity of water demanded by customers.
2) Customers have a general lack of awareness of their block rates.
3) The water savings that accompanies a switch to a block rate may be lost in subsequent years if water rates do not keep up with inflation.
4) Customers do not understand the link between water use and sewer billing and therefore do not tend to factor sewer prices into their water use decisions.
5) The study did find price elasticities of approximately -0.20, which translates into a reduction of 2 percent in water use for a 10 percent increase in price.

The utility should focus on a rate design that sends the appropriate price signal to customers to reduce discretionary water use. To remain effective, the rates need to be adjusted periodically to take into account inflation as well as other factors.

H. Cost Effectiveness Considerations

A cost effectiveness analysis can be done by comparing the cost of implementing this BMP to the anticipated water savings from adopting the conservation rate structure. The costs for implementing a rate structure change are associated with managing a stakeholder involvement process and costs for consultant services, if needed, and there may be one time only costs associated with developing and adopting ordinances and enforcement procedures. There may be significant costs associated with reprogramming the billing system if this step isnecessary.

I. References for Additional Information

1) *Principles of Water Rates, Fees, and Charges (M1 Manual)*, AWWA, 2000.
2) *Residential End Uses of Water,* AWWA Research Foundation, 1999
3) *Irvine Ranch Excess Use Residential Water Rate*
4) http://www.irwd.com/FinancialInfo/ResRates.html
5) *Water Price Elasticities for Single-Family Homes in Texas*, Texas Water Development Board, August 1999.
6) *Designing, Evaluating, and Implementing Conservation Rate Structures*, California Urban Water Conservation Council, July 1997.
7) *Effectiveness of Residential Water Price and Nonprice Programs*, AWWARF, 1998.
8) *San Antonio Sample Water Bill* http://www.saws.org/service/ebill/saws%20ebill%20sample.htm
9) *Example Rate Structures*
   - *City of Austin Water Rates* http://www.ci.austin.tx.us/water/rateswr03.htm
   - *Dallas Water Utilities* http://www.dallascityhall.com/dallas/eng/pdf/dwu/conservation_rate_100101.pdf

2.3 Prohibition on Wasting Water

A. Applicability

This BMP is intended for all Municipal Water User Groups ("utility"). This BMP should be considered by utilities that have customers who continue to waste water despite the efforts of the utility to educate customers to reduce waste of water. Many customers who are cooperating with conservation efforts may lose their inclination to conserve water if other water customers are ignoring efficient water management practices and continuing to irrigate the streets and parking lots or allow outside leaks to run visibly for long periods. In these circumstances, the utility's efforts in limiting water waste should find acceptance by the general public. The specific measures listed as part of this BMP can be implemented individually or as a group. Upon review, a utility may find that it is already implementing one or more these elements and it may want to adopt additional elements outlined below.

Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

Water waste prohibition measures are enforceable actions and measures that prohibit specific wasteful activities. Under this BMP, the utility enacts and enforces ordinances to prohibit wasteful activities including: water waste during irrigation, failure to fix outside faucet leaks, service line leaks (on the customer side of the meter), sprinkler system leaks; once-through use of water in commercial equipment, non-recirculation systems in all new conveyer and in-bay automatic car washes and commercial laundry systems; non-recycling decorative water fountains; and installation of water softeners that do not meet certain regeneration efficiency and waste discharge standards.

Water waste during irrigation includes: water running along the curb of the street, irrigation heads or sprinklers spraying directly on paved surfaces such as driveways, parking lots and sidewalks in public right of ways; operation of automatic irrigation systems without a functioning rain shut off device or soil moisture sensor; a wind sensor and/or freeze sensors in some areas of the State; operation of an irrigation system with misting heads caused by water pressure higher than recommended design pressure for the heads, or broken heads; and spray irrigation during summer months between the hours of 10 a.m. and 6 p.m. Summer months are generally considered June 1 through September 30, but utilities may select a longer or shorter timeframe. Utilities may want to consider not allowing spray irrigation until as late as 8 pm in summer months. An exemption for these watering hours should be included for newly installed landscapes for a limited period of time.

C. Implementation

The utility should consider stakeholder group information meetings, especially for those affected by the landscape component of this BMP. Working with stakeholder groups is important to achieving "buy in" from the landscape industry and water customers.

Utilities with ordinance making powers may want to consider amending landscaping or irrigation ordinances that may have provisions that could be changed to increase water efficiency. For example, Corpus Christi has irrigation system regulations[1] requiring drip irrigation in landscaped areas between the sidewalk and the street. Plan customer follow-up compliance and education after ordinance passage. Implement ordinance and tracking plan for violations, compliance notifications, and enforcement.

Utilities that lack ordinance making powers may want to develop a plan for educating customers, especially those directly affected, about the requirements of a water waste prohibition program; plan a program including stakeholder meetings as needed; plan a follow-up compliance and education program; and implement a water waste program and tracking plan for violations and compliance notifications.

D. Schedule

Utilities pursuing this BMP should begin implementing this BMP according to one of the following approaches:

1) <u>For utilities with ordinance making powers</u>
   a. In the first twelve (12) months: Plan, develop, and pass an ordinance, including stakeholder meetings as needed. Develop a plan for educating customers, especially those directly affected by the requirements that are enforced as a result of the ordinance.
   b. After Ordinance Passage (In the 2nd year and on): Continue implementation and an outreach program for customers. Continue compliance education and initiate enforcement programs. Enforcement can include citations with fines and service interruption for repeat offenders. Or,

2) <u>For tilities that lack ordinance-making powers</u>
   In the first twelve (12) months: Plan a program including stakeholder meetings as needed. Implement a water waste program and tracking plan for violations and compliance notifications.

E. Scope

To accomplish this BMP, the utility should adopt water waste prohibitions policies, programs or ordinances consistent with the provisions for this BMP specified in Section C.

F. Documentation

To track the progress of this BMP, the utility should gather and have available the following documentation:

1) Copy of water waste prohibition ordinances enacted in the service area;
2) Copy of compliance or enforcement procedures implemented by utility; and
3) Records of enforcement actions including public complaints of violations and utility responses.

G. Determination of Water Savings

Total water savings for this BMP can be estimated from each water wasting measure eliminated through the actions taken under this BMP. For the replacement of inefficient equipment, the water savings are the difference in use between the new or upgraded equipment and inefficient equipment (*See* Industrial Cooling Processes BMP for additional information). For landscape water waste, the savings can be calculated based on estimated savings from each water waste warning or enforcement. There will be additional savings from the education of customers who may change some of their inefficient water use practices. These savings could be determined by surveys.

H. Cost Effectiveness Considerations

The primary costs associated with implementing this BMP will be ongoing administrative and staff costs. There may some one time only costs associated with developing and adopting ordinances and enforcement structures. If a utility chooses to implement fines as part of its program, the revenues from those can be included in the cost effectiveness analysis.

I. References for Additional Information

1) *Corpus Christi Irrigation System Regulations* http://www.cctexas.com/
2) *A Water Conservation Guide for Public Utilities*, New Mexico Office of the State Engineer, March 2001.
3) *City of Wichita Falls Drought Emergency Ordinance,* http://www.cwftx.net/drought/ordinance.PDF
4) *El Paso Water Conservation Ordinance,* http://www.epwu.org/ordinance.html
5) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.

2.4 Showerhead, Aerator, and Toilet Flapper Retrofit

A. Applicability

This BMP is intended for a Municipal Water User Group ("utility") that has at least 20 percent of the homes and apartment units it serves constructed prior to 1995 and for which there has not been an active retrofit program for efficient showerheads and faucet aerators. This BMP is often implemented in conjunction with Residential ULFT Replacement BMP and/or the Water Survey for Single-Family and Multi-Family Customers BMP. Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

Plumbing retrofits have usually included showerheads and kitchen and bathroom faucet aerators. Recent studies have shown that replacing toilet flappers[1] is also an effective method of conserving water in the residential sector. Four types of high quality, low flow plumbing devices are to be installed under this program: showerheads rated at 2.0 gallons per minute ("gpm") or less; kitchen faucet aerators of 2.2 gpm or less, bathroom faucet aerators of 1.5 gpm or less, and toilet flappers that flush the toilet at the design flush volume for that toilet model.

Studies have shown that many 1.6 gallons per flush ("gpf") toilets that have been installed are flushing at more than 1.6 gpf. If 1.6 gpf toilets are installed, the flush volume should be checked and, if needed, the water level in the tank should be adjusted to restore the flush volume to 1.6 gpf. If after the water level in the tank is adjusted, the flush volume is still well above 1.6 gpf, it is likely that the toilet originally had an early closure flapper. Using the model number, usually located on the inside of the tank and the research on compatibility of flappers[2] the flapper required to restore the flush volume to 1.6 gpf can often be determined. If the flapper is one of several early models of closure flappers, the flapper could be replaced during the survey and/or the information on the correct replacement flapper should be provided to the customer.

The utility may meet the requirements of this BMP through enforceable ordinances and inspection programs requiring replacement of inefficient plumbing when ownership of the property transfers or by date certain no later than five years.

C. Implementation

Under this BMP, the utility should:

1) Identify single-family ("SF") and multi-family ("MF") residences constructed prior to 1995. The utility may have data showing the number of SF homes existing at the end of 1994 or census data can be used. The 2000 Census data can be used to determine the total number of housing units constructed prior to 1995. The only drawback is that the construction data cannot be separated into SF and MF units. Another approach would be to use the Census data from 1990 and 2000, which includes the number of housing units by type for 1990 and 2000.

This data can be used to estimate SF Units (detached units in the Census data) at the end of 1994. A linear growth assumption yields the following approach. Take the difference (2000 detached units-1990 detached units) and multiply by 40 percent (4 years) and add this to the 1990 detached units. This produces an estimate of SF units at the end of 1994. A similar calculation can be done for MF units.

2) Develop a plan to directly install plumbing devices in single-family homes and multi-family residential facilities or, alternatively, provide kits for installation with follow up inspections; and

3) If feasible, include a program to restore the flush volume of 1.6 gpf toilets to the design flush volume.

After determining the potential number of participants, select at least one of these approaches:

1) Direct Install and Kit Distribution Program
2) Ordinance Approach: Upon Change of Ownership of Property
3) Ordinance Approach: By Date Certain

D. Schedule

Based on the approach(es) selected, the following schedule should be followed:

1) <u>Direct Install and Kit Distribution Approach</u>
In the first twelve (12) months: Plan a program including stakeholder meetings as needed. Locate plumbing contractors or retrofit companies who may be interested in bidding on this program. Determine plan for educating homeowners, apartment owners and managers, plumbers, and realtors about this program. Solicit bids and initiate the program. Include inspections by utility personnel or third party to verify plumbing device installation. Each year 10 percent of eligible single-family homes and 10 percent of eligible multi-family units should be retrofitted to maintain program development. Continue program until 50 percent of eligible single-family houses and multi-family units are retrofitted.

2) <u>Ordinance Approach: Upon Change of Ownership of Property</u>
In the first twelve (12) months: Plan a program including stakeholder meetings as needed. Consider offering rebates for all or a portion of the time this program will be in place. For example, offer rebates for five years and publicize this so customers can take advantage of rebates and retrofit in the early stages of the program. Develop a plan for educating realtors and title companies about this requirement. Determine how change of ownership can be obtained from County Appraisal Districts. Plan follow up inspection program or buyer/seller certification program to assure compliance. Develop and pass ordinance. Implement ordinance and tracking plan for number of units retrofitted. In the second year of the program, continue implementation and outreach program for realtors and title companies. As long as the program is in place, continue compliance program.

3) Ordinance Approach By Date Certain
In the first twelve (12) months: Plan a program including stakeholder meetings as needed. Consider offering rebates for all or a portion of the time this program will be in place. For example, offer rebates up to Year 4 and publicize this so customers can take advantage of rebates and reduce the enforcement required in Year 5. Determine plan for educating homeowners, apartment owners and managers, plumbers, and realtors about this requirement. Plan follow up inspection program or buyer/seller certification program to assure compliance. Develop and pass ordinance. Implement ordinance and tracking plan for number of units retrofitted.

Years 2, 3, and 4: Continue implementation. Continue educating homeowners, apartment owners and managers, plumbers, and realtors about this ordinance.

Year 5: If 50 percent of eligible households have not been retrofitted, prepare education campaign about upcoming deadline and fines that may occur if retrofit does not take place by said deadline. Prepare compliance program. After deadline, issue citations for those not complying.

E. Scope

To accomplish this BMP, the utility should do the following:

1) Develop and implement a plan to distribute or directly install high quality, efficient plumbing devices to single-family and multi-family units constructed prior to 1995.
2) Implement the distribution or installation programs to achieve retrofits on at least 10 percent of eligible single-family units and 10 percent of eligible multi-family units each year. Utilities with more than 200,000 connections should retrofit at least 20,000 eligible homes and units each year.
3) Within five years of implementing this program, retrofit at least 50 percent of eligible single-family houses and multi-family units with the specified devices. For utilities with more than 200,000 connections, at least 100,000 eligible homes and units should be retrofitted within five years. Or,

   Adopt an enforceable ordinance or rules requiring replacement of inefficient plumbing fixtures, including toilets greater than 1.6 gallons per flush, when ownership of the property transfers or by date certain no later than five years from adoption of the BMP, and implement the ordinance or rules including a compliance program.

F. Documentation

To track the progress of this BMP, the utility should gather and have available the following documentation:

1) An inventory of the number of single-family and multi-family buildings completed prior to 1995, which are targeted by this BMP;
2) If applicable, certified copies of adopted ordinances and rules requiring retrofit of plumbing fixtures upon transfer of property ownership or by date certain for each utility that has selected this program option;
3) For each year of implementation, maintain records of the number of showerheads, bathroom faucet aerators, kitchen faucet aerators and toilet flappers (by category) installed in single-family and multi-family units.

G. *Determination of Water Savings*

Calculate water savings as follows:

Water Savings = *Number of Devices Retrofitted* x *Device Savings*
Where Device Savings may be found in the Retrofit Device Savings Table, and
Number of Devices Retrofitted = *1.0* x *Number Devices installed* (when using Ordinance Approach or Direct Installation Approach), or
Number of Devices Retrofitted = *0.3* x *Number Devices installed* (when using Kit Distribution Approach)

Retrofit Device Savings Table

Device	Initial Savings (gpd per device)	Device Life Span (Savings)
Showerheads and Faucet Aerators	5.5 gpd	Permanent*
Toilet Flapper	Up to 12.8 gpd **	5 years

Notes: (*) The actual device life span is 5 to 15 years; the savings are permanent because inefficient equipment can no longer be purchased. The Texas Performance Standards for Plumbing Fixtures[3] forbids importation or sale of inefficient fixtures into Texas. Plumbing standard provisions of the Energy Policy Act took effect in 1994 thereby ensuring that inefficient fixtures would not be manufactured in neighboring states[4].

(**) Residential End Use Study[5] average for toilet leakage was 9.5 gpcd, which can be translated to gpd per toilet by multiplying by average household size (2.7) and dividing by average number of bathrooms (2) per single-family house. The utility should try to estimate actual savings based on measured leakage rate. (9.5gpcd x 2.7) / 2=12.8 gpd per toilet

H. *Cost-Effectiveness Considerations*

The significant expenses associated with this BMP will be the costs of purchasing the devices, the distribution costs, and administrative costs. Usually contractors have been hired to conduct kit installation and door-to-door distribution programs. Labor costs are usually bid based on a unit cost per showerhead, aerator or flapper installed or per kit delivered. There will be labor costs for utility staff to bid the project, oversee the contractor and conduct spot inspections of the contractor's work. Utility staff often run programs where customers pick up kits. Labor costs range from $10 to $30 per SF customer for showerhead and aerator installation and an additional $5 to $20 per toilet for replacement. MF customers will usually use their own staff for installation.

High quality showerheads purchased in bulk are available starting at less than $2 each with aerators costing less than $1 each. Flappers range in cost from $3 to $10. When choosing between models of equipment that have varying degrees of water efficiency, only the incremental cost of the more water efficient equipment should be compared with the benefits to the utility in order that the maximum water efficiency benefit can be developed.

Administration of the program can be conducted by utility staff or contracted out. If a utility chooses to implement the ordinance approach there may be costs for inspections in order to verify installation and discourage fraud. Marketing and outreach costs may range from $5 to $10 per SF customer. Administrative and overhead costs range from 10 to 20 percent of labor costs. If this program is combined with the Residential ULFT Replacement BMP, there should be efficiencies in these costs.

To calculate the total cost per unit, total all costs and divide by the number of units being retrofitted.

I. *References for Additional Information*

1) Department of Energy 1998 Plumbing Product Rules
http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/plmrul.pdf

2) *Maximum Performance Testing of Popular Toilet Models,* William Gauley and John Koeller, May 2004.
http://www.cuwcc.org/Uploads/product/Map_Update_No_1_June_2004.pdf

3) *BMP Cost Savings and Guide,* California Urban Water Conservation Council, July 2000.

4) Texas Performance Standards for Plumbing Fixtures
http://www.capitol.state.tx.us/statutes/docs/HS/content/word/hs.005.00.000372.00.doc

5) *Residential End Uses of Water*, AWWA Research Foundation, 1999.

6) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.

7) *Impacts of Demand Reduction on Water Utilities,* AWWA Research Foundation, 1996.

8) *Residential End Uses of Water,* AWWA Research Foundation, 1999.

9) *Quantifying the Effectiveness of Various Water Conservation Techniques in Texas,* Texas Water Development Board, May 2002.

10) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
11) *Lower Colorado River Authority Frequently Asked Questions about its On-Sewage Rules* http://www.lcra.org/water/faq_septic.html
12) *Marin Municipal Water District Plumbing Fixture Certificate* http://www.marinwater.org/TOSforms.pdf
13) *Summary of Residential End Use Study* http://www.aquacraft.com/Publications/resident.htm
14) *Toilet Flappers: A Weak Link in Conservation,* John Koeller, P.E. , CUWCC, March 2002. http://www.cuwcc.com/Uploads/product/Flappers_Weak_Link.pdf

2.5 Residential Toilet Replacement Programs

A. Applicability

This BMP is intended for a Municipal Water User Group ("utility") that has at least 20 percent of its homes and apartment units in its service area constructed prior to 1995 and for which there has not been an active retrofit program to replace high flush volume toilets with 1.6 gallons per flush toilets ("ULFT"). A utility that has initiated some of the program elements listed below prior to adopting the BMP can provide documentation of a previous retrofit program or voluntary retrofits by customers as described in Section E. This BMP is often implemented in conjunction with the Showerhead, Aerator, and Toilet Flapper Retrofit and/or the Water Survey for Single-Family and Multi-Family Customers BMPs. Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

ULFT replacement programs are an effective method of achieving water efficiency in the residential sector[1,2,3]. ULFTs are toilets that use 1.6 gpf or less including dual flush toilets that can flush at either 1.6 gpf or 0.8 to 1.0 gpf. State and federal requirements prohibit installation of new toilets using more than 1.6 gpf. Under this BMP, the utility would develop and implement a program to replace existing toilets using 3.5 gpf or more in single-family and multi-family residences. To accomplish this BMP, the utility first identifies single-family and multi-family residences constructed during or prior to 1995.

C. Implementation

Implementation should consist of at least one of the following:

1) A program for replacing existing pre-1995 high water-use toilets with efficient (1.6 gpf or less) toilets in single-family and multi-family residences. The Showerhead, Aerator, and Toilet Flapper Retrofit BMP outlines a method for determining the number of homes and apartments constructed before 1995.
    a. ULFT models that are used in retrofit programs should maintain 2.0 gpf or less regardless of what replacement flapper is used[11]
    b. ULFT replacement programs should offer free toilets or rebates for toilet replacement. Incentives and promotion of the program should be sufficient to retrofit at least 5 percent of eligible homes each year.
2) A retrofit ordinance triggered when ownership of the property changes. The ordinance would require all plumbing fixtures in the house or multi-family unit to meet current plumbing standards when the ownership of the property changes. For example, the Lower Colorado River Authority ("LCRA") requires homes that are being enlarged to be retrofitted with 1.6 gallon per flush toilets as part of its septic regulations[4]. The LCRA requires verification inspections. Several cities in California have implemented ordinances requiring retrofit upon change in

ownership. The buyer and seller certify that the plumbing fixtures meet the efficiency standards[5]. In these cities, no inspection is required.

3) A retrofit ordinance by date certain no later than five years after adoption of the BMP. The ordinance would require all plumbing fixtures in the house or multi-family unit to meet current plumbing standards by a specific date.

D. Schedule

Based on the program(s) selected, use the appropriate schedule**:**

1) Toilet Retrofit Program
In the first twelve (12) months: Plan a program including stakeholder meetings as needed. Locate plumbing contractors or retrofit companies who may be interested in bidding on this program. Develop a plan for educating homeowners, apartment owners and managers, plumbers, and realtors about this program. Solicit bids and initiate the program. Include inspections by utility personnel or third party to verify installation. In order to effectively implement this program, each year 5 percent of eligible single-family homes and 5 percent of eligible multi-family units should be retrofitted.

   In the 2nd year and after: Each year 5 percent of identified eligible single-family homes and multi-family units are to be retrofitted. The program should be continued until 50 percent of eligible single-family homes and multi-family units are retrofitted in order to achieve a reasonable water efficiency benefit. Or,

2) Ordinance Approach: Upon Change of Ownership of Property
Consider offering rebates for all or a portion of the time this program will be in place. For example, offer rebates for five years and publicize this so customers can take advantage of rebates and retrofit early in the program.

   In the first twelve (12) months: Plan a program including stakeholder meetings as needed. Develop a plan for educating realtors and title companies about this requirement. Determine how change of ownership can be obtained from County Appraisal Districts. Plan follow up inspection program or buyer/seller certification program to assure compliance[5] after retrofit. Develop and pass ordinance. Implement ordinance and tracking plan for number of units retrofitted.

   In the 2nd year and after: Continue implementation and outreach program for realtors and title companies. Continue verification inspections or buyer/seller certification program to assure compliance as needed. Or,

3) Ordinance Approach: By Date Certain
Consider offering rebates for all or a portion of the time this program will be in place. For example, offer rebates up to Year 4 and publicize this so customers can take advantage of rebates and reduce the enforcement required in Year 5.

In the first twelve (12) months: Plan a program including stakeholder meetings as needed. Determine a plan for educating homeowners, multi-unit owners and managers, plumbers, and realtors about this requirement. Plan follow-up inspections or buyer/seller certification program to assure compliance after retrofits are completed. Develop and pass ordinance. Implement ordinance and tracking plan for number of units retrofitted.

Years 2, 3, and 4: Continue implementation. Continue educating homeowners, multi-unit owners and managers, plumbers, and realtors about this ordinance.

Year 5: If 50 percent of eligible homes and units have not been retrofitted, prepare education campaign about upcoming deadline and fines that may occur if retrofit does not take place by deadline. Prepare compliance program. After deadline, issue penalties for those not complying.

E. Scope

Annually, the ULFT replacement program should replace at least 5 percent of the estimated number of eligible toilets within the service area.

In order to accomplish this BMP, the utility should perform the following:

1) Develop and implement a plan to distribute or directly install high quality ULFTs to eligible single-family and multi-family units;
2) Implement the distribution or installation programs so as to achieve ULFT retrofits on at least 5 percent of eligible single-family units and 5 percent of eligible multi-family units each year. Utilities with more than 200,000 eligible connections should retrofit at least 20,000 eligible homes and units each year.
3) Within ten years of implementing this program, retrofit at least 50 percent of eligible single-family homes and multi-family units with ULFTs. For utilities with more than 200,000 eligible connections, at least 100,000 eligible homes and units should be retrofitted within ten years. Or,
4) Adopt an enforceable ordinance or rules requiring replacement of ULFTs greater than 1.6 gallons per flush, when ownership of the property transfers or by date certain no later than five years from adoption of the BMP, and implement the ordinance or rules with a verifiable inspection program for each property.

F. Documentation

To track this BMP, the utility should gather the following documentation:

1) The eligible number of single-family residences and multi-family units in the service area;
2) The average number of toilets per single-family residence; the average number of toilets per multi-family unit;

3) The average persons per household for single-family residences; the average persons per household for multi-family units;
4) The housing resale rate for single-family residences in service area; the housing resale rate for multi-family units in service area;
5) The number of ULFT installations credited to the program participant's replacement program, by year, including brand and model of toilets installed;
6) Description of ULFT replacement program, if applicable;
7) Estimated cost per ULFT replacement, if applicable;
8) Estimated water savings per ULFT replacement; and
9) Description of retrofit upon resale inspection and enforcement program, if applicable.

G. Determination of Water Savings

(*See,* Section I. References for Additional Information, 2 and 9)

Average Daily Savings = SF x (10.5 x Hs) / Ts + MF x (10.5 x Hm) / Tm

Where SF = Number of SF Toilets Retrofitted
MF = Number of MF Toilets Retrofitted
Hs = Number of people in average single family household
Hm = Number of people in average multi-family household
Ts = Average number of toilets per SF house
Tm = Average number of toilet per MF unit

For **Single Family Homes:**
10.5 = gallons saved per capita per day if all toilets replaced in each household[5]
Dual Flush ULFTs increase savings by 25 percent.

For **Multi-Family Units:**
10.5 = gallons saved per capita per day if all toilets replaced in each unit[8]
Dual flush ULFTs increase savings by 25 percent

H. Cost-effectiveness Considerations

The rebates to the customers for installation of ULFT toilets are the most significant costs of this program. If the rebate cost for the toilet is set too low, only those customers planning to retrofit will do so. If the rebate is set too high, the utility will be overpaying for customers to retrofit. Most utilities have found a rebate to work effectively if set between $70 and $100 per toilet.

Some utilities find it is more cost effective to provide toilets free of charge to their customers. Toilets can be purchased from wholesalers by the truckload for $50 to $70. There may be additional costs for storage and distribution of the toilets.

Administration of the program can be conducted by utility staff or contracted out. There will be labor costs for application processing and inspections to verify installation, determine if the water level in the tank is properly set, and discourage fraud. Inspection costs will be lower per toilet for multi-family retrofits due to the higher volume of toilets per application, but generally, labor costs range from $10 to $40 per toilet. Marketing and outreach costs range from $5 to $20 per toilet. Administrative and overhead costs range from 10 to 20 percent of labor costs. If this program is combined with the Showerhead, Aerator, and Flapper Retrofit BMP, there will be efficiencies in these costs.

To calculate the total cost per unit, total all costs and divide by the number of units being retrofitted.

I. References for Additional Information

1) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
2) *Residential End Uses of Water,* AWWA Research Foundation, 1999.
3) *Jordan Valley (Utah) Study of ULF Toilet Fixture,* Paula Mohadjer. http://www.cuwcc.org/Uploads/product/Jordan_Valley_ULFT_study.pdf
4) *Lower Colorado River Authority Frequently Asked Questions about its On-Sewage Rules.* http://www.lcra.org/water/faq_septic.html
5) *Summary of Residential End Use Study.* http://www.aquacraft.com/Publications/resident.htm
6) *Impacts of Demand Reduction on Water Utilities,* AWWA Research Foundation, 1996.
7) *BMP Cost Savings and Guide,* California Urban Water Conservation Council, July 2000.
8) *Quantifying the Effectiveness of Various Water Conservation Techniques in Texas,* Texas Water Development Board, May 2002.
9) *Dual-flush Toilet Project,* Canada Mortgage and Housing Corporation, September 2002. http://www.cmhc.ca/publications/en/rh-pr/tech/02-124-e.pdf
10) *Dual Flush Toilet Fixtures,* John Koeller and Company, December 2003. http://www.cuwcc.org/Uploads/product/Dual_Flush_Fixture_Studies.pdf
11) *Water Closet Performance Testing,* National Association of Home Builders, September 2002. http://www.cuwcc.org/Uploads/product/NAHB_ToiletReport.pdf
12) *Maximum Performance Testing of Popular Toilet Models,* William Gauley and John Koeller, December 2003. http://www.cuwcc.org/Uploads/product/MaP_Final_Report.pdf
13) *Performance Testing of Wall Mount Siphon Jet Toilets at the University of Washington,* Roger van Gelder, June 2003. http://www.cuwcc.org/Uploads/product/MaP_Final_Report.pdf
14) *Marin Municipal Water District Plumbing Fixture Certificate.* http://www.marinwater.org/TOSforms.pdf
15) *Waste Not, Want Not: The Potential for Urban Water Conservation in Calofornia*, Pacific Institute, November 2003.

2.6 Residential Clothes Washer Incentive Program

A. Applicability

This BMP can be implemented by any Municipal Water User Group ("utility") that has residential customers. A utility that has initiated some of the program elements listed below prior to adopting the BMP can provide documentation of a previous clothes washer incentive program as described in Section F. Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

Under this BMP, the utility would develop and implement an incentive program to encourage customers to purchase efficient clothes washers. Water efficiency for clothes washers is best described by using water factor ("WF") terminology. WF is calculated by dividing the gallons of water used to wash a full load of clothes by the capacity of the washer tub in cubic feet. An efficient washer using 27 gallons for a full load of clothes and a 3 cubic foot tub would have a WF of 9. According to the tiers recommended by the Consortium for Energy Efficiency ("CEE") in 2004, a clothes washer would need to have a WF equal to or less than 9.5 to be considered an efficient washing machine.[1]

In 2001, Texas passed legislation requiring washing machine manufacturers to report on the efficiency of clothes washers sold in Texas. The report for 2002 showed that only 4.4 percent of washers sold in Texas had a WF equal to or less than 9.5. The report[2] for 2003 showed that 9.4 percent of washers imported into Texas had a WF equal to or less than 9.5. While the trend in Texas is positive, the market share is well below the reported 30 percent market share in Washington State and 50 percent market share in the Seattle area where a regional incentive and marketing program for efficient washers has been in place for several years.[3]

Conventional top-loading clothes washers use 41 gallons per load on average while efficient clothes washers use 11 to 25 gallons per load. The typical household washes an average of just more than one load per day.[4,5] Manufacturers started producing efficient clothes washer models in the late 1990s in anticipation of rules being adopted by the Department of Energy ("DOE") setting higher efficiency standards. The DOE did adopt rules in 2001 with a two-step phase-in of higher efficiency standards. Clothes washers manufactured after 2004 will be required to meet a modified energy factor ("MEF") of 1.04 (20 percent more efficient than the current standard). This level will remain in effect until 2007, at which time an MEF of 1.26 (35 percent higher than the current standard) will be required.

If manufacturers continue with current trends in design of efficient clothes washers, the 2007 standard should result in significant water savings. However, some manufacturers may design washers with a normal cold-water wash and rinse cycle to be used with specially formulated soaps that could meet the 2007 standard without any increase in water efficiency.

It is possible for states to adopt more stringent standards than will result from the DOE rulemaking. For example, the California Energy Commission ("CEC") has adopted rules requiring that residential clothes washers not exceed a WF of 8.5 by 2007, decreasing to a WF of 6.0 in 2010.

To be effective, the incentive offered should bridge at least one-half of the gap in the price difference between the efficient machines and conventional ones. As with any incentive program, the amount of the incentive will impact the participation in the program. Fully featured inefficient machines cost approximately $400 while the least expensive efficient machines cost from $600 to more than $1000. So for the least expensive machines, the price difference is $200. The price difference is the most important part of the buying decision for low-income customers. In addition, low and moderate income customers would be more likely to purchase the efficient washer if they got the incentive in the form of a discount at the time of purchase rather than waiting four to six weeks for a rebate.

A clothes washer incentive program is most effective when offered in conjunction with local gas and/or electric utilities since the incentive can be increased and the marketing reach should expand. The energy savings are a result of more efficient motors, less energy required for heating hot water as less hot water is used, and shorter drying time because the spin cycle on efficient washers is much faster. Many water utilities in Texas and in other parts of the country have already successfully partnered with a local energy company.

Incentives should only be given to those customers who install washers that qualify as water efficient. A list of efficient washers is maintained and regularly updated by the Consortium for Energy Efficiency ("CEE"). CEE, a nonprofit public benefits corporation, develops national initiatives to promote the manufacture and purchase of energy-efficient products and services. The U.S. Department of Energy and Environmental Protection Agency both support CEE through active participation as well as funding. The CEE Residential Clothes Washer Program has tiers for both water and energy efficiency. The CEE list has been used by many utilities as the source of qualifying washers to receive an incentive.

C. Implementation

Develop and implement a clothes washer incentive program designed to increase the market share of efficient clothes washers to at least 20 percent by the second year of implementation. The program should be offered to customers in single-family homes (including duplexes and triplexes) and in multi-family units that have in-unit washer connections. Approach the local gas and/or electric utility to join in a partnership to implement the program. Organize stakeholder meetings. Develop a marketing plan for educating customers, appliance stores, and realtors about this program. Initiate the program.

D. Schedule

The following schedule should be considered:

1) Plan, implement and market an efficient clothes washer incentive program within six (6) months of adopting this BMP.
2) Continue marketing efforts to achieve at least 20 percent market penetration for efficient washers by the end of the second year after implementing this BMP.

E. Scope

In order to accomplish this BMP, the utility should perform the following:

1) Develop and implement a plan to offer incentives for the purchase of efficient clothes washers.
2) Within two years of implementing this program, increase the market share of efficient clothes washers to at least 20 percent of local clothes washer sales.

F. Documentation

To track this BMP, the utility should gather the following documentation:

1) The number of single-family homes and multi-family units with in-unit washer connections;
2) The average number of persons per household for single-family homes and for multi-family residences;
3) The number of efficient clothes washer incentives issued each year, by year, including brand, model, and water factor of each efficient washer;
4) Estimated water savings per efficient washer; and
5) Average total washer sales per year in the service area.

G. Determination of Water Savings

Savings = EWS x 5.6 x Hs + EWM x 5.6 x Hm

Where EWS = Number of single family efficient washer incentives
EWM = Number of in-unit multi-family washer incentives
Hs = Number of people in average single family household
Hm = Number of people in average multi-family household

Single Family:
5.6 = gallons saved per capita per day
Multi-Family In-Unit:
5.6 = gallons saved per capita per day

H. Cost Effectiveness Considerations

The rebates to the customers for installation of water efficient clothes washers are the most significant costs of this program. If the rebate cost for the clothes washer is set too low, only those customers already planning to buy an efficient washer will do so. If the rebate is set too high, the utility will be overpaying for customers to retrofit. Most utilities that implement this

BMP have found a rebate to work effectively if set between $50 and $100 per efficient clothes washer. If partnering with an energy utility, the gas or electric utility rebate will add an additional $50 to $100. Some utilities have started offering tiered rebates based on the efficiency of the washer; the higher rebates are offered for washers in the lowest water factor tier.

Administration of the program can be conducted by utility staff or contracted out. Washer inspections are sometimes performed in order to verify installation and discourage fraud. Labor costs range from $15 to $35 per clothes washer. Marketing and outreach costs range from $5 to $15 per clothes washer. Administrative and overhead costs range from 10 to 20 percent of labor costs.

To calculate the total cost per unit, total all costs and divide by the number of units being retrofitted.

I. *References for Additional Information*

1) Consortium for Energy Efficiency Clothes Washer Page http://www.cee1.org/resid/seha/rwsh/rwsh-main.php3
2) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
3) Energy Star Clothes Washer Sales Data for Seattle and Washington State, Al Dietemann, Seattle Public Utilities, July 2004.
4) *Residential End Uses of Water,* AWWA Research Foundation, 1999.
5) *US DOE Volume Purchase Program,* Sandi Edgemon, Pacific NW National Laboratory, 1997.
6) *Impacts of Demand Reduction on Water Utilities,* AWWA Research Foundation, 1996.
7) *BMP Cost Savings and Guide,* California Urban Water Conservation Council, July 2000.
8) *Seattle Home Water Conservation Survey*, Aquacraft, Inc., 2001 http://www.aquacraft.com/
9) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
10) California Energy Commission http://www.energy.ca.gov/appliances/clothes_washers/notices/2003-09-17_Washer_Final.PDF
11) Energy Star http://www.energystar.gov/index.cfm?c=clotheswash.pr_clothes_washers Austin WashWise Program http://www.ci.austin.tx.us/watercon/sfwasher.htm
12) *Seattle Home Water Conservation Study*, Aquacraft Inc., 1999 http://www.aquacraft.com

2.7 School Education

A. Applicability

This BMP is intended for a Municipal Water User Group ("utility") that serves schools as a part of its customer base. Lessons learned by students about good water use habits are often shared with the whole family. A utility may have already accomplished this BMP if it has a current school education program that meets the criteria of this BMP. Before deciding whether this BMP is necessary, review existing curriculum to see if the local school district is already offering a water conservation related curriculum.

Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

School education programs, while not directly related to an equipment change, may result in both short and long-term water savings. Behavioral changes by the students based upon greater knowledge are often shared with parents and implemented at home. To be effective, a school education program should provide curriculum material appropriate to the grade level of the student, increasing in complexity from elementary school through high school. If such a curriculum does not already exist, local curriculum experts may be willing to help develop the desired materials.

A complementary aspect can be to include a water audit unit as part of the curriculum where the students take flow measurements of showerheads and faucet aerators at their homes. If the showerheads and faucet aerators are higher than the current standard, the students would receive efficient showerheads and faucet aerators to install with the assistance of their parents. This unit can be successfully implemented in grade 5 or higher and can meet the requirements of this BMP without additional curriculum development.

The circumstances and challenges of the local water resources should be considered in choosing or developing a conservation curriculum. Grade level appropriate material is important in ensuring that the students understand the information. When possible, curriculum material used in the classroom should address the Texas Essential Knowledge and Skills[6] ("TEKS") for the grade level and subject area. Texas state education guidelines for testing of skills are an important consideration as well. A quality water conservation program for schools provides teachers with materials that contribute to learning mathematics, science, social studies and history while educating the students about water conservation and local water resources. Already developed curriculum is available from the Texas Water Development Board, EPA, other public agencies, nonprofit organizations and private companies.

Another option beyond offering a supplemental curriculum is to offer an education entertainment show for grades 1 to 4. These shows can be very popular with teachers and often do not have the same requirement for the material to meet TEKS. In addition, the percentage of students that can be reached is often higher than for adoption of a curriculum.

To evaluate the effectiveness of the education materials, presentation or show, the utility should use an evaluation tool such as a pre- and posttest or survey.

C. Implementation

Implementation should consist of at least the following actions:

1) Evaluate local, regional, state or national resources available to determine applicability to the utility's local water conditions. Consider creating an advisory committee of local educators to assist in choosing or creating the curriculum;
2) Implement a school education program to promote water conservation and water conservation related benefits.

   Programs include working with school districts and private schools in the water suppliers' service area to provide instructional assistance, educational materials, and classroom presentations that identify urban, agricultural, and environmental issues and conditions in the local watershed and water service area. When possible, educational materials should meet the TEKS guidelines.

   A water oriented curriculum that is focused on conservation and resource issues should be made available for all grades.

   a. Grade appropriate programs and/or materials should be implemented for grade levels 1 to 6 initially. Alternatively, a presentation or educational show can be offered for some or all of these grade levels.
   b. For grades 7 to 8 and for high school students, the utility should do one of the following: distribute grade appropriate materials for high school science, political science, or other appropriate classes; present assembly type programs to high schools; sponsor science fairs with emphasis on conservation; or implement education programs with community groups like Scouts, 4-H clubs, etc.

The utility can elect to meet this BMP by focusing only on grades 1 to 6 or 7 to 12 and achieving higher participation rates.

In conjunction with the Showerhead and Aerator BMP, consider providing a water audit unit as part of the curriculum where the students take flow measurements of showerheads and faucet aerators at their homes. If the showerheads and faucet aerators are higher than the current standard, the students would receive efficient showerheads and faucet aerators to install with the assistance of their parents. This unit can be successfully implemented in grade 5.

D. Schedule

Depending on the program option(s) selected, the following schedule should be followed:

1) Utility should adopt or develop the program in the first year and start implementation in the second year for grades 1 to 4.
2) Utility should adopt or develop the program in the second year and start implementation in the third year for grades 5 to 6.
3) Utility should adopt or develop the program in the third year and start implementation in the fourth year for grades 7 to 8.
4) Utility should adopt or develop the program in the fourth year and start implementation in the fifth year for grades 9 to 12.

E. Scope

Select items 1 and 2 or item 3.

1) The utility should strive to reach 10 percent of students in grades 1 to 6 with a presentation or curriculum each year by the third year of implementation, following the schedule above, and
2) The utility should strive to reach at least 10 percent of students in grades 7 to 12 with a presentation or curriculum each year by the third year of implementation following the schedule above. Or,

3) Alternatively this BMP will be met if the utility only focuses on grades 1 to 6 or 7 to 12. The program would be developed in the first year and implemented in the second year for either alternative. The utility should strive to reach either 15 percent of students in grades 1 to 6 each year by the third year of implementation or 15 percent of students in grades 7 to 12 by the third year of implementation.
4) The utility can count as participants students reached through clubs and educational events; and students impacted by utility sponsored program outside the utility service area.
5) For smaller utilities, or those in which service area boundaries overlap school district boundaries with another water utility, jointly operated or funded programs should be considered.

F. Documentation

To track the progress of this BMP, the utility should gather and have available the following documentation:

1) Number of school presentations made during reporting period;
2) Number and type of curriculum materials developed and/or provided by water supplier, including confirmation that curriculum materials meet state education framework requirements and are grade-level appropriate;
3) Number and percent of students reached by presentations and by curriculum;

4) Number of students reached outside the utility service area;
5) Number of in-service presentations or teacher's workshops conducted during reporting period;
6) Results of evaluation tools used, such as pre- and posttests, student surveys, teacher surveys;
7) Copies of program marketing and educational materials; and
8) Annual budget for school education programs related to conservation.

G. Determination of Water Savings

Water savings for school education programs are difficult to quantify and therefore estimated savings are not included in this BMP. If the retrofit kit is distributed, water savings can be calculated as described in the Residential Retrofit BMP**.** A 1991 study conducted for The Harris Galveston Coastal Subsidence District found an average savings of 18 percent or 1,400 gallons per month[1] in homes where the student and parent had installed efficient showerheads and aerators on bathroom and kitchen sinks.

H. Cost-effectiveness Considerations

A true cost-effectiveness analysis cannot be determined without a measure of water savings. By implementing this BMP, the utility will enhance its public image, increase customer goodwill, and increase the viability of its overall water conservation efforts.

School education costs vary widely due to the varying types of programs. Curriculum units can be developed and implemented for $1 to $3 per student. Educational entertainment programs can be developed or contracted out for $2 to $5 per student. There are prepackaged contractor programs with extensive features that cost up to $35 per student. Most programs will require utility staff oversight and outreach efforts to schools and students.

If showerhead and faucet aerator kits are distributed as part of this BMP, the costs for the kits will be similar to those described in the Residential Retrofit BMP.

I. References for Additional Information

1) *Effectiveness of Retrofit in Single Family Residences,* Prepared for Harris Galveston Coastal Subsidence District, Roger Durand, University of Houston , 1992.
2) *Water Savings and Beyond: A Multi-Resource Conservation Collaboration in the Seattle School District,* Broustis, D., et al, Water Sources Conference Proceedings, AWWA, January 2002.
3) *'Water in our World' and 'Down the Drain' Programs Close the Water Curriculum Gap for 5th and 6th Graders*, Jefferson, C., et al, Water Sources Conference Proceedings, AWWA, January 2002.
4) *Water Sourcebook,* Tennessee Valley Authority, Environmental Education Section, Knoxville, Tennessee, May 1994.

5) *Effectiveness of Retrofit in Single Family Residences and Multi-Family Projects,* Texas Water Development Board**,** Roger Durand, University of Houston-Clear Lake, 1993.
6) *Texas Essential Knowledge and Skills.* http://www.tea.state.tx.us/teks/
7) *Major Rivers,* Texas Water Development Board & Lower Colorado River Authority.
8) *Learning to be WaterWise.* http://www.getwise.org/wwise/
9) *Project Wet.* http://www.water-ed.org/projectwet.asp
10) *Conservation Curriculum Resources,* EPA. http://www.epa.gov/teachers/curriculumconservation.htm
11) *Gulf Coast Curriculum Resources,* EPA. http://www.epa.gov/gmpo/edresrc.html
12) *National Project for Excellence in Environmental Education***,** North American Association for Environmental Education (NAAEE). http://www.naaee.org/npeee/
13) *H2O House Water Saving Home,* California Urban Water Conservation Council and EPA. http://www.h2ouse.org/
14) *TWDB Education and Public Awareness Page.* http://www.twdb.state.tx.us/assistance/conservation/Education.asp
15) *What Education Program is Right for your Community,* Vogel, C., Water Sources Conference Proceedings, AWWA, January 2002.

2.8 Water Survey for Single-Family and Multi-Family Customers

A. Applicability

This BMP is intended for a Municipal Water User Group ("utility") that has 20 percent of homes and apartments constructed before 1995 and/or more than 10 percent of landscapes with automatic irrigation systems. If the utility is unaware of the number or percentage of customers using automated irrigation systems, a drive-by survey can be conducted of a sample of customers to develop an estimate of how many have automatic systems. Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

A Water Survey Program can be an effective method of reducing both indoor and outdoor water usage. Under this BMP, the utility conducts a survey of single-family and multi-family customers to provide information to them about methods to reduce indoor water use through replacement of inefficient showerheads, toilets, aerators, clothes washers, and dishwashers. If the customer has an automatic irrigation system, the survey includes an evaluation of the schedule currently used and recommends any equipment repairs or changes to increase the efficiency of the irrigation system.

Surveys should be offered based on water use starting with the highest single-family and multi-family accounts, respectively. Multi-family accounts should be analyzed based on gallons per unit, although almost all multi-family customers would benefit by this survey if they have not already retrofitted plumbing fixtures. The irrigation component of the single-family survey should target single-family customers using more than a certain amount of water per billing period that could be considered excessive for the particular geographic area and other characteristics of the service area. Typically, this is around 20,000 gallons per month in summer since that could represent an outdoor use of more than 12,000 gallons per month. Surveying outdoor water use in homes with water use below 20,000 gallons per month does not usually provide as significant an opportunity for water reductions. Customer water use records can give the utility a snapshot of which neighborhoods have higher than average water use. The drive by survey should note which lawns have monoculture of a turfgrass species and/or visible irrigation heads indicating an automated sprinkler system.

Once the scope of services is determined, there are three options for conducting the survey: train utility staff to conduct an onsite survey; hire an outside contractor to conduct the onsite surveys; or provide a printed or online survey for customers to complete on their own. When conducting an onsite survey for a customer with an automatic irrigation system that is managed by an irrigation or maintenance contractor, it is beneficial to have the contractor present for the irrigation system survey.

For the indoor water use survey, a form can be used to provide the information on water reductions that would be achieved with each type of equipment change and the length of the payback period, taking into account any utility incentives that may be available. If it is an onsite survey, showerhead and faucet aerators can be changed during the survey.

A leak check should be conducted to determine if there are any toilet leaks occurring and any dripping faucets. If 1.6 gallons per flush toilets have already been installed, the flush volume should be checked and, if needed, the water level in the tank should be adjusted to restore the flush volume to 1.6 gpf. If after the water level in the tank is adjusted, the flush volume is still well above 1.6 gpf, it is likely that the toilet originally had an early closure flapper. Using the model number on the inside of the tank and the Flapper Table (see References for Additional Information), the flapper required to restore the flush volume to 1.6 gpf can usually be determined. If the flapper is one of several early models of closure flappers, the flapper should be replaced during the survey and the information on the correct replacement flapper should be provided to the customer.

Information on water use habit changes such as shorter showers, for example, should also be provided at the time of the survey. The customer should be provided information on climate-appropriate landscaping and about any programs the utility has for incentives to replace inefficient landscaping.

The survey of automatic irrigation systems should include a check of the entire system for broken, misdirected or misting heads and pipe or valve leaks. The customer's service line and meter box should also be checked for leaks. The system should be run to determine precipitation rates for typical zones. Each zone should be checked to be sure that rotors and spray heads are not on the same zone since they have greatly different precipitation rates. Head spacing should be checked to determine if proper heads are installed. The schedule on the irrigation controller should be checked and the customer queried about how the schedule is adjusted during the year. A schedule should be provided based on evapotranspiration ("ETo")-based water-use budgets equal to no more than 80 percent of reference ETo per square foot of irrigated landscape. The statewide Texas Evapotranspiration Network (http://texaset.tamu.edu/) should be consulted for historical evapotranspiration data and methodology for calculating reference evapotranspiration and allowable stress. More aggressive landscape conservation programs can utilize stress coefficients lower than 80 percent (*See* website). For larger water users, a uniformity analysis can be conducted. The customer should be provided a written report on the system repairs and equipment changes needed and the appropriate efficient irrigation schedule by month. The controller should be reset with the efficient schedule. If the system does not have a rain sensor, it should be installed as part of the survey if feasible or provided to the customer to be installed by a contractor. Information should be provided on the installation of dedicated landscape meters for multi-family customers if offered by the utility.

C. Implementation

The utility should develop and implement a plan to market these surveys to both single-family and multi-family customers. Marketing should be done by ranking single-family customers according to water use on a monthly average and offer the program starting with those with the highest water use as a means of increasing cost effectiveness and water savings rapidly. Multi-family customers should be ranked by water use per unit. The survey can be offered by mail, telephone calls, email or through utility bill stuffers or other appropriate methods of communication. The Showerhead, Aerator, and Toilet Flapper Retrofit BMP outlines a method for determining the number of homes and apartments constructed before 1995.

The customer incentive to participate can be reduced utility costs and also recognition as a water efficient customer. If the utility has incentive programs for 1.6 gpf toilets, efficient clothes washers, irrigation systems upgrades, or water efficient landscape, the survey should include this information in the report to the customer.

Once a customer agrees to participate, the utility should collect the following information in the survey:

1) Calculation of the ratio of summer to winter use based on a review of the customer water bills;
2) Pressure on the customer's side of the meter;
3) Number and flush volume for each toilet;
4) If any 1.6 gpf toilets are flushing at greater than 1.6 gpf due to replacement of early closure flapper with standard flapper;
5) If any toilets are leaking around the flapper or over the overflow tube;
6) Showerhead and aerator flow rates in gallons per minute ("gpm") when valve is fully open;
7) Estimated capacity of current clothes washer. If it is a top loading inefficient model, use 41 gallons per load as an estimate;
8) If customer has a swimming pool, the frequency and duration of backflow. Check fill valve and float to determine if working properly. Turn fill valve off at the start of survey to see if any drop in water level is noticed. Ask customer if they have noticed any leakage from pool;
9) Irrigation schedule as indicated on the controller. Ask customer who is responsible for changing the schedule and how often that occurs, if the system is turned off in winter months and if turfgrass areas are over seeded in winter.

The changes that can be made immediately at the time of the survey include:

1) If needed, installation of showerheads using 2.0 gpm or less; kitchen faucet aerators using 2.2 gpm or less and bathroom faucet aerators using 1.5 gpm or less;
2) Resetting the toilet tank water levels to the correct level. Replacement of leaking flappers or flappers that cause the toilet to flush above the design flush volume.
3) Determination of irrigation system precipitation rate for representative zones or all zones if needed;
4) Resetting controller with efficient schedule based on ET and measured precipitation rates;
5) Providing the customer a copy of the twelve months irrigation schedule and attach a copy near the controller;
6) Showing the customer how to use the controller so they can adjust controller throughout the year;
7) Installing a rain sensor on the irrigation system if needed and feasible;

8) Explaining to customer any incentives that the utility offers and how to take advantage of these incentives; and
9) Providing customers a brief report on estimated savings for each item listed in the report and the estimated payback for each item.

The changes that may need to be done after the survey by either a contractor for the utility or by the customer include:

1) Replacing inefficient toilets with 1.6 gpf models;
2) Restoring correct flush volume of existing 1.6 gpf toilets by installation of early closure flapper correctly matched to the model of toilet;
3) Fixing faucet leaks;
4) Replacing the inefficient clothes washer with a new efficient model;
5) If needed, repairing the fill valve on the swimming pool;
6) Replacing damaged portions of the irrigation system;
7) Installing a new controller if warranted such as an ET based irrigation controller;
8) Installing a rain sensor; and
9) Installing a pressure reduction valve if needed.

To assure that the water savings measures recommended during and after the survey are achieved, the utility should follow up with the customer to determine which were actually implemented. The utility should begin a notification program to remind customers of the need for maintenance and adjustments in irrigation schedules as the seasons change and to check toilets and faucets for leaks.

D. Schedule

1) The scope of this BMP should be realized within five years of the date implementation commences.
2) Develop and implement a plan to target and market water-use surveys to all residential customers using more than 20,000 gallons per month in summer months and all multi-family customers in the six months of the first year after implementing this BMP.
3) Repeat marketing efforts until the goals are reached.

E. Scope

To accomplish this BMP, the utility should:

1) In the first year, implement the program and complete a survey of at least 1 percent of eligible single-family customers and 1 percent of multi-family customers;
2) In years two through five, complete a survey of at least 5 percent of eligible single-family customers and at least 5 percent of multi-family customers;
3) Within 5 years, complete water-use surveys for at least 25 percent of eligible single-family customers and 25 percent of multi-family customers; and

4) Follow up on each survey completed within three months of completion and then annually thereafter to encourage implementation of survey recommendations.

F. Documentation

To track this BMP, the utility should gather the following documentation:

1) Number of residential customers,
2) Number of single family customers using more than 20,000 gallons per month in summer months;
3) Number of multi-family customers;
4) Number of surveys offered and number of surveys completed by customer type; and
5) Measures installed during the customer surveys or completed after the survey and verified through a follow-up phone call.

G. Determination of Water Savings

Saving should be based on measures implemented by each customer. Savings are calculated by multiplying the number of each type of measure implemented by the savings for that measure as listed below.

1) Single-Family Home
   - Irrigation Audit: Actual utility survey results or 26 gallons per day ("gpd")[1] per house.
   - Showerhead and aerator replacements: 5.5 gpd per person
2) Multi-Family Community
   - Irrigation Audit: Actual utility survey results or 15 percent[2] of outdoor water use or 208 gpd[1]
   - Showerhead and aerators: 5.5 gpd per person

Savings for resetting toilet tank levels, toilet leak repair, flapper replacement and installation of rain shut-offs should be estimated during the water survey. The rain shut-off savings depend both on the ET of the customer as well as the setting on the rain shut-off switch which can be set to shut off after rainfall of ¼ to 1 inch. If the survey results in toilet and clothes washer replacements, these savings can be included in either this BMP or the Toilet Retrofit or Efficient Clothes Washer BMP if the utility has adopted those BMPs.

H. Cost-Effectiveness Considerations

Surveys can be performed by utility staff or by contractors. The labor costs range from $50 to $150 for a SF survey and start at $100 for a MF survey and go up from there depending on the efficiency in scheduling and the scope of the survey.

If water efficient plumbing fixtures are distributed during the survey, the costs of that equipment should be considered. High quality showerheads purchased in bulk are available starting at less than $2 each with aerators costing less than $1 each. Flappers range in cost from $3 to $10.

There may be other one-time costs such as purchase of leak detection equipment and meters. Marketing and outreach costs range from $5 to $15 per survey. Administrative and overhead costs range from 10 to 20 percent of labor costs.

I. *References for Additional Information*

1) *Project Review of the Irvine ET Controller Residential Reduction Study*, Irvine Ranch Water District, November 2003. http://www.irwd.com/Conservation/R3ProjectReview.pdf
2) *CUWCC BMP No. 5: Large Landscape Program and Incentives*. http://www.cuwcc.org/m_bmp5.lasso
3) *WaterWise Council of Texas.* http://www.waterwisetexas.org/
4) *Austin Green Gardening Program.* http://www.ci.austin.tx.us/greengarden/
5) *Texas Cooperative Extension for El Paso County*. http://elpasotaex.tamu.edu/horticulture/xeriscape.html
6) *San Antonio Water System Conservation Program.* http://www.saws.org/conservation/
7) *City of Corpus Christi Xeriscape Landscaping.* http://www.cctexas.com/?fuseaction=main.view&page=1047
8) *EWEB Home Water Survey Database: PowerPoint Presentation,* Jill Hoyenga, Eugene Water and Electric Board, Water Sources Conference Proceeding, 2004.
9) *CUWCC Cost Effectiveness Models, BMP 1 Water Surveys*. http://www.cuwcc.org/ce_spreadsheets.lasso
10) *Toilet Flappers: A Weak Link in Conservation in Water Conservation,* John Koeller, http://www.cuwcc.org/Uploads/product/Flappers_Weak_Link.pdf
11) *Tampa Bay Water List of Toilets and Replacement Flappers,* Dave Bracciano, Tampa Bay Water, Tampa, Florida
12) *CUWCC BMP No. 5: Large Landscape Program and Incentives.* http://www.cuwcc.org/m_bmp5.lasso
13) *Turf and Landscape Irrigation Best Management Practices*, Water Management Committee of the Irrigation Association, February 2004. http://www.irrigation.org/gov/pdf/IA_BMP_FEB_2004.pdf
14) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf

2.9 Landscape Irrigation Conservation and Incentives

A. Applicability

This BMP is intended for use by a municipal water user group ("utility") with a substantial percentage of customers using automated landscape irrigation systems and is targeted to customers who have automated irrigation systems. If data on the number of customers with irrigation systems are lacking or absent, the summer peak/winter average ratio can be used as an evaluation tool to determine whether to proceed with this BMP. A ratio of 1.6 or greater indicates the potential for substantial water savings with implementation of this BMP. For maximum water-use efficiency benefit, the utility should adhere closely to the measures described below.

B. Description

Landscape irrigation conservation practices are an effective method of accounting for and reducing outdoor water usage while maintaining healthy landscapes and avoiding run-off. Using this BMP, the utility provides non-residential and residential customers with customer support, education, incentives, and assistance in improving their landscape water-use efficiency. Incentives include rebates for purchase and installation of water-efficient equipment. Four approaches are outlined below. Successful implementation of this BMP will be accomplished by performing one or a combination of the approaches listed.

1) ETo-Based Water Budgets
If the utility chooses the water budget approach, the utility also develops reference evapotranspiration ("ETo")-based water-use budgets equal to no more than 80 percent of ETo per square foot of irrigated landscape area for customers participating in its Landscape Irrigation Conservation Program. More aggressive landscape conservation programs can utilize stress coefficients lower than 80 percent.

Evapotranspiration is the combined amount of the water transpired by plants and the water evaporated from the soil. ETo is defined as the estimate of evapotranspiration that occurs from a standardized reference crop of well-watered, clipped, cool-season grass. The amount of supplemental irrigation water needed is the shortfall between plant water need (which is a fraction of ETo) and precipitation.

The statewide Texas Evapotranspiration Network (http://texaset.tamu.edu/) should be consulted for historical evapotranspiration data, historical precipitation, and methodology for calculating reference evapotranspiration and allowable stress. (Communities located in the North Plains areas may find local historical data on potential evapotranspiration at: http://amarillo2.tamu.edu/nppet/whatpet.htm.

2) Water-Use Surveys, Metering, and Budgeted Water Use

If the utility chooses the survey approach, the utility develops and implements a plan to promote landscape water-use surveys to industrial/commercial/institutional ("ICI") and residential accounts with mixed-use meters. The water-use surveys, at a minimum, include: measurement of the landscape area; measurement of the total irrigable area; irrigation system checks and distribution uniformity analysis; review of irrigation schedules or development of schedules as appropriate; and provision of a customer survey report and information packet. When cost-effective, the utility should offer the following: landscape water-use analyses and surveys; voluntary water-use budgets; installation of dedicated landscape meters; acceptance of site conservation plans; and follow-up to water-use analyses and surveys.

At the start and end of the irrigation season, irrigation systems should be checked, and repairs and adjustments made as necessary. Notices should be included in bills to remind customers of seasonal maintenance needs. For accounts with water-use budgets, the utility should provide notices with each billing cycle showing the relationship between budgeted water usage and actual consumption. When soil conditions allow, and landscape managers are familiar with the use and maintenance of soil moisture sensors, water budgets can be allocated based upon soil moisture status, thereby providing a closer estimate of actual evapotranspiration.[3]

Many utilities require dedicated irrigation meters for all commercial and/or industrial accounts with automatic irrigation systems or if the lot is above a minimum size. For municipalities with ordinance-making powers, this can be accomplished by ordinance. Otherwise, dedicated meters may be implemented as a new customer policy.

3) Landscape Design

If the utility chooses the landscape design approach, the utility provides information on climate-appropriate landscape design and efficient irrigation equipment and management for new customers and change-of-service customer accounts (*See* the Landscape Design and Conversion Programs BMP for more detail). To serve as a model, the utility should install climate-appropriate, water-efficient landscaping at water agency facilities and landscape meters where appropriate. Municipalities with ordinance-making powers should consider adopting ordinances that require all new apartment complexes and commercial buildings to install a water conserving landscape. This can often be accomplished by amending an existing commercial landscape ordinance.

4) Minimum Standards and Upgrades

If the utility chooses the landscape standards approach, the utility should require new commercial and industrial customers to install separate irrigation meters and consider retrofitting current commercial and industrial customers with irrigation meters. The utility should consider this requirement for new residential customers installing automatic irrigation systems. For municipalities with ordinance-making powers, this can be accomplished by ordinance. Otherwise, this may be implemented as a new customer policy.

Irrigation system design and maintenance components and landscape design may be systematically upgraded through use of municipal ordinance-making powers where possible. Minimum water efficient design features can be mandated for new construction, while existing systems or landscapes are offered incentives to upgrade. Rainwater sensors, soil moisture sensors, irrigation controllers, pipe specifications, and hydrozone specifications are all potential elements of an irrigation systems ordinance. Total turf grass areas, buffer zone plant material, and hydrozones are all potential elements of landscape design ordinances. Buffer or median areas represent additional savings when all landscaped areas less than five feet in any dimension are restricted to drip or other surface or subsurface (non-spray) irrigation system or no irrigation system.

C. Implementation

The utility should consider offering the Landscape Irrigation Program to customers with large landscapes first as a means of rapidly increasing cost-effectiveness and water savings. Marketing the Program to the customer via bill inserts will allow the utility to target the largest summer peak users first. The utility should consider also approaching local weather announcers, radio gardening show hosts, and newspaper columnists for assistance in notifying the public about the program. Public/private partnerships with non-profits such as gardening clubs, Cooperative Extension offices and/or with green industry businesses such as landscape and irrigation maintenance companies are potential avenues to market the program and leverage resources.

Incentives can include rebates for irrigation audits and systems upgrades, recognition for water-efficient landscapes through signage and award programs, and certification of trained landscape company employees and volunteer representatives who can promote the Program. Utility staff can also be trained to provide irrigation audits which can include resetting irrigation controllers with an efficient schedule.

Approximately one year after conducting an irrigation audit, the utility should consider conducting a customer-satisfaction survey. The objective of the customer-satisfaction survey is to determine the implementation rate of recommended modifications and to gauge customer satisfaction with the program.

The initial step in assisting customers with landscape irrigation systems is a thorough evaluation of the existing landscape area and irrigation systems. This includes:

1) A list of landscape areas, measurements, plant types, irrigation system hydrozones, and controller(s);
2) A list of existing irrigation policies or procedures including maintenance and irrigation schedules;
3) A distribution uniformity analysis on irrigated turf areas;

4) A review of water bills with attention to the ratio of summer to winter use; and
5) An initial report summarizing the results of the evaluation.

The water customer who participates in this program needs to maintain and operate its irrigation systems in a water-efficient manner. Maintenance programs include pre-irrigation system checks, adjustment of irrigation timers when necessary, installation of rain sensors, and regular review of irrigation schedules and visual inspection of the irrigation system. When landscape management companies are utilized, contracts should include a required report showing regularly scheduled maintenance and seasonal adjustments to irrigation systems controllers. A more advanced form of contracting would be to build into the contract a dollar amount based on 80 percent of ET and require the contractor to pay for any water use above that amount. The utility should consider implementing a notification program to remind customers of the need for maintenance and adjustments in irrigation schedules as the seasons change.

When appropriate, the utility should consider offering the following services:

1) Training in efficiency-focused landscape maintenance and irrigation system design;
2) Financial incentives (such as loans, rebates, and grants) to improve irrigation system efficiency and to purchase and/or install water efficient irrigation systems;
3) Financial incentives to replace high-water use plants with lopw water use ones;
4) Rebates and incentives to purchase rain sensors or soil-moisture sensors; and
5) Notices at the start and end of the irrigation season alerting customers to check irrigation systems and to make repairs and adjustments as necessary.

The utility should need to ensure that landscape irrigation system specifications are coordinated with local building codes.

Evaluations and/or rebate processing could be done by the utility staff or be outsourced. If a utility chooses to perform the evaluations using in-house staff, they may take advantage of irrigation evaluation training programs provided by the Texas A&M School of Irrigation or the Irrigation Association.

An outsourcing option for the non-residential sector is to use or recommend a water-based performance contractor. Performance contracting is a financing technique that uses cost savings from reduced utility (water and sewer) consumption to repay the cost of installing water conservation measures. This technique allows for the development of a water-savings program without significant up-front capital expenses on the part of the customer. Instead, the costs of water-efficiency improvements are borne by either the contractor or a third party lender who recoups cost and shares water savings profits with the user.

D. Schedule

1) Realize the Scope of this BMP within ten years of the date implementation commences.

2) Develop ETo-based water-use budgets for all accounts with dedicated irrigation meters by the end of the second year from the date implementation commences.
3) Develop and implement a plan to target and market landscape water use surveys to ICI accounts with mixed-use meters by the end of the first year from the date implementation commences.
4) Develop and implement a customer incentive program by the end of the first year from the date implementation commences.
5) Follow up with the participating customer approximately one year after a water use survey has been conducted and/or a rebate processed.

E. Scope

To accomplish the goals for this BMP, the utility should do the following:

1) Landscape Irrigation System Management Programs
   a. Within one year of implementation date, develop and implement a plan to market water-use surveys to ICI accounts with mixed-use meters;
   b. Within one year of implementation date, develop and implement a customer incentive program;
   c. Within two years of implementation date, develop ETo-based water-use budgets for 90 percent of ICI accounts with dedicated irrigation meters;
   d. Within ten years contact and offer landscape water-use surveys to 100 percent of ICI accounts with mixed-use meters;
   e. Within ten years complete landscape water-use surveys for at least 15 percent of ICI accounts with mixed-use meters.
   f. Within ten years contact and offer landscape water-use surveys to 100 percent of residential accounts with summertime monthly use of greater than four times annual average; and
   g. Within ten years complete landscape water-use surveys for at least 15 percent of residential accounts with summer monthly use of greater than four times annual average.

2) Ordinance Approach

   In the first twelve (12) months: Plan a program, including stakeholder meetings as needed. Consider offering rebates for all or a portion of the time this program is in place. For example, offer rebates for only the first five years to encourage customers to take advantage of rebates and retrofit early in the program. Develop a plan for educating real estate agents, landscape companies, and irrigation installers about this requirement. Plan a follow-up inspection program after retrofit. Develop and pass ordinance. Implement ordinance and tracking plan for number of units retrofitted.

   In the 2nd year and all subsequent years: Continue implementation; continue outreach program for real estate agents, landscape companies, and irrigation system installers; and continue verification inspections.

F. Documentation

To track this BMP, the utility should gather the following documentation:

1) Number of dedicated irrigation meter accounts;
2) Number of dedicated irrigation meter accounts for which water budgets have been developed;
3) Aggregate water use for dedicated landscape accounts with budgets;
4) Aggregate budgeted water use for dedicated landscape accounts with budgets;
5) Number of mixed-use accounts;
6) Number of surveys offered and number of surveys accepted and completed;
7) Number, type, and dollar value of incentives, rebates, and loans offered to and accepted by customers;
8) Estimated water savings achieved through customer surveys; and
9) Estimated landscape area converted and water savings achieved through low water landscape design and conversion program.

G. Determination of Water Savings

Landscape surveys as described in this document are assumed to result in a 15 percent reduction in water demand for landscape uses by surveyed accounts. The utility should provide estimates of water savings from landscape irrigation survey programs based upon actual metered data. The water budget calculation is as follows:

80 percent ETo calculation: I = (ETo x Kc x AS) where I is the irrigation amount to be applied for a given period (daily, twice weekly, weekly, etc.), in inches or centimeters

ETo is the measured reference evapotranspiration over the irrigation period
Kc is a turf coefficient for turf grasses, and can be found at http://texaset.tamu.edu/
AS is allowable stress of 0.8 (or less if the landscape manager wishes)
For those wishing to convert inches of irrigation to gallons, multiply landscape area by 0.62. Irrigation Volume (gals.) = I (in.) x LA (sq ft) x 0.62

When applying irrigation, the equation should be modified to gain greater water savings by accounting for precipitation: I = (ETo x Kc x AS) – Pe where P is precipitation in inches or cm. In calculating an irrigation amount, it is important to consider effective precipitation (Pe). Effective precipitation is less than natural precipitation since some rainfall runs off or percolates below the root zone. The amount of effective precipitation will vary with region and rainfall trends. Each rainfall event will have a unique characteristic, and a good source for estimating Pe is the county office of the Texas Cooperative Extension Service.

H. Cost Effectiveness Considerations

Surveys can be performed by utility staff or by contractors. The labor costs range from $50 to $100 for a SF irrigation survey and start around $100 and go up from there for an ICI irrigation survey, depending on the efficiency in scheduling the surveys, the size of the landscape, and the scope of the survey.

There may be other one-time costs such as purchase of leak detection equipment and meters. Marketing and outreach costs range from $5 to $15 per survey. Administrative and overhead costs range from 10 to 20 percent of labor costs.

I. References for Additional Information

1) *Landscape Irrigation Scheduling and Water Management.* Water Management Committee of the Irrigation Association, September 2003. http://www.irrigation.org/PDF/IA_LIS_AND_WM_SEPT_2003_DRAFT.pdf
2) *Turf and Landscape Irrigation Best Management Practices*, Water Management Committee of the Irrigation Association, September 2003. http://www.irrigation.org/PDF/IA_BMP_SEPT_2003_DRAFT.pdf
3) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
4) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May. 2001.
5) *ET and Weather Based Controllers CUWCC Web Page.* http://www.cuwcc.org/Irrigation_Controllers.lasso
6) *Smart Water Technology Initiative Web Page.* http://www.irrigation.org/swat1.asp
7) *Soil moisture instrumentation: Sensors & strategies for the 21st century*, Richard Mead, in Irrigation Journal, Sept/Oct 1998.
8) *San Antonio Water System Conservation Program.* http://www.saws.org/conservation/
9) *WaterWise Council of Texas.* http://www.waterwisetexas.org/
10) *Texas Evapotranspiration Network*. http://texaset.tamu.edu/
11) North Plains areas of Texas may find local historical data on potential evapotranspiration at: http://amarillo2.tamu.edu/nppet/whatpet.htm.

2.10 Water Wise Landscape Design and Conversion Programs

A. Applicability

This BMP is intended for a Municipal Water User Group ("utility") that has 20 percent or more residential customers that have landscapes consisting of high water use landscape materials that consume more than 20,000 gallon per month or use more than twice as much water in the summer as in the winter. Under this BMP, the utility would offer financial assistance as an incentive to customers to convert to a water wise landscape. Utilities impacted by repeated drought may also consider this BMP as a means of reducing outdoor water demand overall in their service area as a step toward long-term change of water use patterns. Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

The utility offers financial incentives for landscape conversion to a water wise landscape or requires by ordinance that all new landscapes incorporate water wise principles. Water wise landscaping involves not only plant selection but also follows optimum landscaping principles listed below. Financial incentive programs that promote water wise landscaping contain an educational component involving the seven principles of water wise landscaping. Water wise landscaping material often consumes whatever quantity of water the customer supplies, so careful follow up is necessary to ensure that excess irrigation does not take place. Incentives should be designed to be rescinded if water use returns to previous levels or exceeds the projected water budget for the new landscape.

For new customers and change-of-service customer accounts, the utility should provide information on water wise landscape design and efficient irrigation equipment and management (*See* the Landscape Irrigation Systems Conservation and Incentives BMP for more detail on efficient irrigation equipment and management). The utility should install water wise landscaping at water agency facilities. Encouraging the use of rainwater capture and limiting irrigation to the quantity of water captured are also included.

Some cities with ordinance-making powers have adopted ordinances to define water-conserving landscapes to be installed in buffer areas, new commercial buildings, new homes, and apartment complexes. Any ordinance for new homes should incorporate requirements for water wise principles, specifically requiring only water efficient landscaping materials to be used. Irrigated turf areas can be reduced or eliminated in this BMP. Limiting turf areas can be accomplished by any number of means including reducing turf as a percent of total landscaped area, restricting irrigation systems to a portion of the landscaped area, encouraging shade tolerant species under trees, or encouraging the use of turfgrasses which have low water use rates.

In the typical landscape, turfgrass occupies the largest area and, when managed incorrectly, receives the largest amount of irrigation. Installing practical turf areas and irrigating only the turf in high impact, highly visible areas of the landscape, achieve water savings. Practical turf areas mean locating turfgrass in areas of the landscape where it provides the most functional benefit, such as recreational areas or on slopes to prevent erosion. In the case of irrigation of sloped turf grass areas adjacent to a sidewalk and needed for erosion control, the use of drip or subsurface irrigation and not sprinklers is recommended.

Grasses available for use in Texas lawns vary significantly in water requirements. This BMP may require limiting irrigated turf area within the landscape and/or requiring the lowest water use turfgrass adapted to the region and use in the landscape. Shrub beds, low water use groundcover, or hardscape in the landscape design should replace irrigated turfgrass in areas that are long and narrow or small and odd-shaped. Turfgrass requirements for new construction should include specifications for soil depth.

Soil improvement is an effective method for reducing irrigation water usage while maintaining healthy soils. Soil improvement programs on high visibility areas can demonstrate to the public the effectiveness of this method. For most landscapes, compost applications of 1/4 to 1/2 inch annually on turf areas, and one inch annually on flower beds are recommended. Compost is most beneficial when applied in the fall.

Water Wise Landscape programs follow the seven principles of Xeriscape™, from the Texas A&M Horticulture Website (*See*, Section I, References for Additional Information, 2), listed below and explained in greater detail in resources listed in the reference section:

- Planning and design
- Soil analysis and improvement
- Appropriate plant selection
- Practical turf areas
- Efficient irrigation
- Use of mulches
- Appropriate maintenance.

C. Implementation

Initially, the utility should consider offering the Water Wise Landscape Design and Conversion Program to customers with educational missions such as schools, universities, botanical gardens, and museums with large public landscapes. A focus on buffer areas and small landscaped areas that are inefficient to irrigate has also proven effective in some communities. The utility should consider also approaching local weather announcers, radio gardening show hosts and newspaper columnists for assistance in notifying the public about the program. Public-private partnerships should be pursued with gardening clubs, Cooperative Extension offices, landscape designers, maintenance companies and nurseries.

Calculation of rebates for landscape conversion or as incentives for new landscape installation should be based on careful consideration of the net present value of the water saved versus the size of rebate that helps motivate customers to install such a landscape. For new construction, another type of incentive would be a discount on the water capital recovery fee.

Careful design of the program is necessary to prevent overwatering after the water wise landscape is installed. Signed agreements with customers receiving rebates can assist the utility in recovering funds if water use does not decline after installation of the water wise landscape. Incentives including rebates should be rescinded if water use returns to previous levels within two years.

Awards programs can both reward the customer who has converted the landscape and help motivate others in the community to convert to low water use landscaping materials.

D. Schedule

1) The scope of this BMP, should be realized within ten years of the date implementation commences.
2) Develop and implement a plan to target and market landscape conversions to Industrial/Commercial/Institutional ("ICI") & Residential accounts with dedicated meters by the end of the first year from the date implementation commences.
3) Develop and implement a plan to target and market landscape conversions to all accounts by the end of the second year from the date implementation commences.
4) Develop and implement a customer incentive program by the end of the first year from the date implementation commences.

E. Scope

1) <u>Rebate and Incentive Approach</u>
   a. Within one year of implementation date, develop and implement a plan to market low-water requiring landscape design and conversion program;
   b. Within one year of implementation date, develop and implement a customer incentive program.
   c. Rescind incentives, including rebates, if water use returns to previous levels within two years.

2) <u>Ordinance Approach</u>
   In the first twelve (12) months: Plan a program including stakeholder meetings as needed. Consider offering rebates for all or a portion of the time this program is in place. For example, offer rebates for five years and publicize this so customers will take advantage of rebates and retrofit early in the program. Develop a plan for educating realtors and landscape companies about this requirement. Plan a follow up inspection program after retrofit. Develop and pass ordinance. Implement ordinance and tracking plan for number of units retrofitted.

   In the second year and after: Continue implementation and outreach program for realtors and landscape companies. Continue verification inspections.

F. Documentation

To track this BMP, the utility should gather the following documentation:

1) Number of dedicated irrigation meter accounts;
2) Number, type, and dollar value of incentives, rebates, and loans offered to and awarded to customers;
3) Estimated water savings based on customer surveys; and
4) Estimated landscape area converted and water savings achieved through low water landscape design and conversion program.
5) Customer water use records prior to and after conversion of the landscape. This data is best compared in years of similar rainfall and after sufficient time has passed for the landscape to establish itself.

G. Determination of Water Savings

Provide estimates of water savings from landscape conversions based upon actual metered data.

H. Cost-Effectiveness Considerations

The primary costs to implement this BMP are the incentives or rebates to customers for conversion to water wise landscape. Current incentives for landscape conversion range from \$0.05 to \$1.00 per square foot in Texas. Depending on program design and whether pre and postconversion inspections are required, staff labor cost should range from \$50 to \$100 per conversion.

Marketing and outreach costs range from \$20 to \$50 per conversion. Administrative and overhead costs range from 10 to 20 percent of labor costs.

I. References for Additional Information

1) *EARTHKIND™ Environmental Landscape Management*, http://aggie-horticulture.tamu.edu/earthknd/earthknd.html 2004.
2) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
3) *Water Savings from a Turf Rebate Program in the Chihuahuan Desert*, El Paso Water Utilities, City of El Paso Water Utility, 2003.
4) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
5) *Xeriscape Handbook*, American Waterworks Association, Denver, 1999.
6) *Xeriscape Plant Guide*, American Waterworks Association, Denver, 1996.
7) *Xeriscape Color Guide - 100 Water-wise Plants for Gardens and Landscapes,* American Waterworks Association, Denver, 1998.

8) *City of Austin Landscape Regulations.* http://www.amlegal.com/austin_nxt/gateway.dll/Texas/Austin/code00000.htm/volume00157.htm/title00158.htm/chapter00160.htm?f=templates$fn=altmain-nf.htm$3.0#JD_25-2-981
9) *City of Austin Environmental Criteria Manual: Section 2 Landscape.* http://www.amlegal.com/austin_nxt2/gateway.dll?f=templates&fn=default.htm&vid=alp:austin_environment
10) *California Model Landscape Ordinance 1993.*http://www.owue.water.ca.gov/docs/WaterOrdIndex.cfm
11) *Austin Green Gardening Program* (http://www.ci.austin.tx.us/greengarden/)
12) *City of Corpus Christi Xeriscape Landscaping.* http://www.cctexas.com/?fuseaction=main.view&page=1047
13) *San Antonio Water System Conservation Program.* http://www.saws.org/conservation/h2ome/landscape/
14) *Texas Cooperative Extension for El Paso County.* http://elpasotaex.tamu.edu/horticulture/xeriscape.html
15) *WaterWise Council of Texas.* http://www.waterwisetexas.org/

2.11 Athletic Field Conservation

A. Applicability

This BMP is intended for all Municipal Water User Groups ("utility") which manage irrigated athletic field(s) and/or serve a customer with irrigated athletic field(s). Athletic fields often involve a visible use of water during the day, which comes under scrutiny by the public and water resource managers both because of large water demand to maintain an athletic field, and because of the perception that the water use may be excessive. The specific measures listed as part of this BMP can be implemented individually or as a group. Utilities may already be implementing one or more these elements and they may want to adopt additional elements outlined in this document.

Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

Athletic field conservation is an effective method of reducing system water demands. The athletic field manager implements a watering regimen that uses only the amount of water necessary to maintain the viability of the turf and maintain the turf adequately to maintain the health of users. Water is only applied to areas that are essential to the use of the field.

The utility provides the customer, by staff or a third party, a large landscape water-use survey and develops reference evapotranspiration ("ETo")-based water-use budgets equal to no more than 100 percent ETo per square foot of landscape area. The survey includes the following elements: measurement of landscape area; measurement of total irrigable area; irrigation system checks and distribution uniformity analysis; and review or development of monthly irrigation schedules. If landscape use is determined to exceed 20 percent of total water use by the customer, the athletic facility should install a dedicated landscape meter. Alternatively the utility may allow customers to perform their own survey by properly trained staff and provide documentation of the survey to the utility. Proper athletic field management emphasizes precise nutrient management, soil preparation techniques, and regular watering as compared to simply using more water to ensure a dense turf.[1,2,3]

At a minimum, the athletic field BMP should require the replacement of all manual controlled or quick couple irrigation systems with automatic irrigation systems and controllers. The automatic controllers should be able to shut off flow when a sudden pressure loss occurs from a broken system. It is important that access to such controllers be limited to the authorized landscape manager or be designed to shut off flow automatically if the irrigation system is activated manually. The authorized landscape manager should be trained in good soil management and cultural practices such as proper aeration, nutrient management, mowing and soil testing as well as in irrigation management. The utility implementing this BMP should consider offering training for athletic field managers or co-sponsoring training with qualified agronomy program(s). Documentation of cultural practices and soil management measures should be included in a successful program. Although expensive, replacement of natural turf grasses with artificial turf is becoming more popular in some areas of Texas.

When cost-effective, the athletic field user should be required to provide methods for achieving enhanced water conservation through computer controlled irrigation systems ("CCIS") or similar technology. In order to achieve maximum efficiency a CCIS should include at least the following components: computer controller ("digital operating system"), software, interface modules, satellite field controller, soil moisture sensors, and weather station. A CCIS should be designed so as to prevent overwatering, flooding, pooling, evaporation, and run-off of water, and should prevent sprinkler heads from applying water at a rate exceeding the soil holding capacity. School districts or park systems with a number of remotely located athletic fields should consider a CCIS with satellite systems. Subsurface irrigation systems are also becoming more reliable and are an option. The utility may choose to offer incentives for athletic field management in direct relation to the size and sophistication of the system.

It is recommended and encouraged to use reclaimed, reused, and/or recycled water by athletic fields, however, such use must meet TCEQ water quality standards for treated effluent and human contact. When utilizing reclaimed water or water with high levels of total dissolved solids ("TDS") or hardness, the water budget will need to be adjusted to permit leaching of salts below the root zone of the turfgrass. Consultation with local extension agents can assist athletic field managers in properly managing the use of lower quality water for irrigation.

Soil improvement is an effective method for reducing irrigation water usage while maintaining healthy soils. Soil improvement programs on high visibility areas such as athletic fields can demonstrate to the public the effectiveness of this method. For athletic fields, compost applications of 1/4 to 1/2 inch annually are recommended. Compost is most beneficial when applied in the fall.

C. Implementation

The utility should consider stakeholder information meetings. Working with stakeholder groups is important to achieving "buy in" from the athletic field managers. Also a number of voluntary environmental management programs exist in which athletic fields may already be participating. There are two approaches to be considered: an incentive or voluntary approach and an ordinance or other enforceable requirement approach.

1) Incentive or Voluntary Compliance Approach
The utility may provide staff or contract with a third party to provide a water audit of the athletic field. The water-use surveys, at a minimum, include measurement of the irrigated turf areas; determination if hydrozones within the irrigation system are proper for the type of turf present; irrigation system checks and distribution uniformity analysis; review of irrigation schedules or development of schedules as appropriate; and provision of a customer survey report and information packet.

If indicated by survey results and if cost-effective, the utility may offer incentives to the athletic field user for upgrading of irrigation systems, installing or upgrading controllers, changing hydrozones to eliminate irrigation of areas that do not receive high foot traffic, or reducing the amounts of potable water used on the athletic fields. For athletic field managers that agree to manage water efficiently, variance procedures may assist them with watering schedules on large systems with many hydrozones. Utilities may consider assisting athletic field managers in developing an individualized conservation plan, which accounts for turf type, soils, and irrigation system constraints.

When cost-effective, the utility should offer workshops by trained professionals on pesticide and soil and nutrient management for optimal water use efficiency. To ensure that water savings goals are met, the utility should be explicit about the efficiency expectations of voluntary programs.

2) <u>Ordinance or Enforceable Requirements Approach</u>

a. For utilities with ordinance-making powers, in the first twelve (12) months plan develop, and pass an ordinance, including stakeholder meetings as needed. Develop a plan for educating customers, especially those directly affected by the requirements of the ordinance. Plan customer follow-up compliance and education after ordinance passage. Implement ordinance and tracking plan for violations, compliance notifications, and enforcement.

After ordinance passage (in the 2nd year and on), continue implementation and outreach program for customers. Continue compliance education and initiate enforcement programs. Enforcement can include citations with fines for repeat offenders. Or,

b. For utilities that lack ordinance-making powers, in the first twelve (12) months plan a program including stakeholder meetings as needed. Develop a plan for educating customers, especially those directly affected, about the requirements of an athletic field conservation program. Plan follow-up compliance and education program. Implement water conservation program and tracking plan for violations and compliance notifications. Consider passing excess-use rates as a disincentive to athletic fields that do not stay within a budgeted amount of water (*See* Conservation Pricing BMP).

D. Schedule

1) The utility should adopt an incentive program, an ordinance or rules within twelve (12) months of commencing this BMP.
2) The utility should implement the incentive plan or commence enforcement upon adoption of the ordinance or rule.

E. Scope

To accomplish this BMP, the utility should adopt athletic field conservation policies, programs or ordinances consistent with the provisions for this BMP specified in Section C.

F. Documentation

To track the progress of this BMP, the utility should gather and have available the following documentation:

1) Copy of incentive plan or athletic field conservation ordinances or rules enacted in the service area;
2) Copy of compliance or enforcement procedures implemented by utility, if applicable;
3) Records of enforcement actions including public complaints of violations, and utility responses, if applicable;
4) Number of customers completing the incentive plan;
5) Tracking mechanism developed to determine customer water use before and after implementation of BMP;
6) Water savings attributable to changes implemented; and
7) Costs of incentive plan(s) or ordinance if applicable.

G. Determination of Water Savings

Estimating total water savings for this BMP may be difficult, however, water savings can be estimated from each water-wasting measure eliminated through the actions taken under this BMP. For the replacement of inefficient equipment, the water savings are the difference in use between the new or upgraded equipment and inefficient equipment. For landscape water waste, the savings can be calculated based on estimated savings from each water waste incident. For an irrigation survey, water savings can be expected in the range of 15 percent to 25 percent for athletic fields that do not have a CCIS and where the efficiency measures recommended by the results of the survey are implemented. Switching to artificial turf, reuse or other nonpotable alternatives can save up to 100 percent of the potable water supply used in irrigation. These savings should be determined by measuring water use before and after the conversion to the new water supply.

H. Cost-Effectiveness Considerations

The labor costs for irrigation survey of an athletic field range from $250 to more than $1000 for an irrigation survey depending on the efficiency in scheduling the surveys, the size of the facility, and the scope of the survey. Surveys can be performed by utility staff or by contractors.

Marketing and outreach costs range from $5 to $15 per survey. Administrative and overhead costs are in the range of 10 to 20 percent of labor costs. Costs for upgrades to irrigation systems and controllers can be much more extensive depending upon the scale of changes needed. Costs for incentive programs for system upgrades will need to be evaluated on a case-by-case basis.

I. References for Additional Information

1) *Athletic Fields and Water Conservation*, Texas Agricultural Extension Service. http://soilcrop.tamu.edu/publications/pubs/b6088.pdf
2) *Maintaining Athletic Fields*, J. A. Murphy. http://www.rce.rutgers.edu/pubs/pdfs/fs105.pdf
3) *Managing Healthy Sports Fields: A Guide to Using Organic Materials for Low-Maintenance and Chemical-Free Playing Fields*, by Paul D. Sachs, John Wiley & Sons, January 2004.
4) *Managing Bermudagrass Turf: Selection, Construction, Cultural Practices, and Pest Management Strategies*, L. B. McCarty, Grady Miller, John Wiley & Sons, July 2002.
5) *Irrigation System Design and Management Courses*, Irrigation Technology Center, Texas A&M. http://irrigation.tamu.edu/courses.php
6) *Water Management Stretches Irrigation Water,* E. K. Chandler. http://www.txplant-soillab.com/page32.htm

2.12 Golf Course Conservation

A. Applicability

This BMP is intended for all Municipal Water User Groups ("utility") that serve a golf course customer. Golf courses often involve a visible use of water, which comes under scrutiny by the public and water resource managers both because of large water demand to maintain the course, and because of the perception that the water use may be excessive. Golf courses are often good candidates for reuse water or other alternative sources of water. The specific measures listed as part of this BMP can be implemented individually or as a group. Utilities may already be implementing one or more of the elements of this BMP and they may want to adopt additional elements outlined below.

Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

Golf course conservation is an effective method of reducing water demands. Under this BMP, the utility requires each golf course to develop a conservation plan that includes the elements described in this section. The golf course manager conducts a landscape and irrigation survey to determine water needed to efficiently irrigate the course. A water budget should be developed using reference evapotranspiration ("ETo"). The manager implements a watering regimen that uses only the amount of water necessary to maintain the viability of the course. In addition to commercially available information from irrigation controller equipment companies, the Texas Evapotranspiration Network (http://texaset.tamu.edu/) has information to assist golf course managers and utility planners with proper management of large turf areas. Golf course managers should be encouraged to limit their water use to areas essential to the use of the golf course. An example of a use that has been eliminated on some golf courses is irrigation of the roughs.

The golf course plan utilizes methods of achieving enhanced water conservation such as a Computer Controlled Irrigation Systems ("CCIS") or similar technology. In order to achieve maximum efficiency a CCIS should include at least the following components: computer controller ("digital operating system"), software, interface modules, satellite field controller, soil sensors, and weather station. A CCIS should be designed so as to prevent overwatering, flooding, pooling, evaporation, and run-off of water and should prevent sprinkler heads from applying water at an intake rate exceeding the soil holding capacity. The golf course plan provides an analysis of the cost-effectiveness of utilizing a CCIS.

If potable water is used and if non-potable water is available, the golf course converts to use of non-potable water as soon as is practicable. The golf course plan should include projected implementation dates to convert to alternative water supplies. Use of reclaimed, reused, and/or recycled water by golf courses must meet TCEQ water quality standards for treated effluent and human contact.

Soil improvement is an effective method for reducing irrigation water usage while maintaining healthy soils. Soil improvement programs on high visibility areas such as golf courses can demonstrate to the public the effectiveness of this method. For golf courses compost applications of 1/4 to 1/2 inch annually on turf areas and one inch annually on flower beds are recommended. Compost is most beneficial when applied in the fall.

C. Implementation

The utility should consider stakeholder information meetings. Working with stakeholder groups will be important to achieving “buy in” from golf course businesses. Also a number of voluntary environmental management programs exist in which golf courses may already be participating. There are two approaches to be considered to implement the golf course conservation plan described in Section B: an incentive or voluntary approach and an ordinance or other enforceable requirement approach.

1) <u>Incentive or Voluntary Compliance Approach</u>
The utility may provide staff or contract with a third party to provide a water audit of the golf course. The water-use surveys should, at a minimum, include measurement of the irrigated turf areas; measurement of the greens, tee boxes and fairways; determination whether hydrozones within the irrigation system are proper for the type of turf present; irrigation system checks and distribution uniformity analysis; review or development of irrigation schedules; and provision of a customer survey report and information packet.

If indicated by survey results and if cost-effective, the utility may offer incentives to the golf course user for upgrading irrigation systems, installing or upgrading controllers, changing hydrozones to eliminate irrigation of rough, or reducing the amount of fairway watering.

When cost-effective, the utility should offer golf course management and staff workshops by trained professionals on pesticide and nutrient management for optimal water-use efficiency. An advantage to working with programs like the Audubon Cooperative Sanctuary Program (“ACSP”) for Golf program is that the third party can assist in implementation at no cost to the utility. To ensure that water-savings goals are met, the utility should be explicit about the efficiency expectations of voluntary programs.

2) <u>Ordinance or Enforceable Requirements Approach</u>
a. For utilities with ordinance-making powers, in the first twelve (12) months plan, develop, and pass an ordinance that requires development and implementation of the golf course conservation plan, including stakeholder meetings as needed. Develop a plan for educating customers, especially those directly affected by the requirements of the ordinance. Plan customer follow-up compliance and education after ordinance passage. Implement ordinance and tracking plan for violations, compliance notifications, and enforcement.

In the second year and on (after ordinance passage): Continue implementation and outreach programs for customers. Continue compliance education and initiate enforcement programs. Enforcement can include citations with fines and service interruption for repeat offenders.

b. For utilities that lack ordinance-making powers, in the first twelve (12) months plan a program including stakeholder meetings as needed. Develop a plan for educating customers, especially those directly affected, about the requirements of a golf course conservation plan. Develop follow-up compliance and education program. Implement water conservation program and tracking plan for violations and compliance notifications. Consider passing excess-use rates as a disincentive to golf courses that do not stay within a budgeted amount of water (*See* Conservation Pricing BMP).

D. Schedule

1) The utility should adopt an incentive program or an ordinance or rules within twelve (12) months of commencing this BMP.
2) The utility implements the incentive plan or commences enforcement upon adoption of the ordinance or rule**.**

E. Scope

To accomplish this BMP, the utility adopts golf course conservation policies, programs or ordinances consistent with the provisions for this BMP specified in Section C.

F. Documentation

To track the progress of this BMP, the utility should gather and have available the following documentation:

1) Copy of incentive plan or golf course conservation ordinances or rules enacted in the service area;
2) Copy of compliance or enforcement procedures implemented by utility, if applicable;
3) Records of enforcement actions including public complaints of violations and utility responses, if applicable;
4) Water savings from implemented changes; and
5) Number of customers completing the incentive plan.

G. Determination of Water Savings

Estimating total water savings for this BMP may be difficult, however, water savings can be estimated from each water-wasting measure eliminated through the actions taken under this BMP. For an irrigation survey, water savings can be expected in the range of 15 percent to 25 percent for courses without a CCIS that choose to implement the efficiency measures recommended by the results of the survey. There will be additional savings from the education of customers about golf course watering efficiency, which will be difficult to calculate but will encourage public goodwill toward the golf course water user and the utility. Switching to reuse or other non-potable alternatives can save up to 100 percent of the potable water supply used in irrigation. These savings are determined by measuring water use before and after the conversion to the new water supply.

H. Cost-Effectiveness Considerations

The one-time labor costs for producing golf course conservation plan guidelines and meeting with golf course stakeholders are dependent upon the level of staffing, the number of meetings, and time allotted to the planning process. Costs for annual review of golf course water use and conservation plan updates should be less than $100 per plan.

Marketing and outreach costs range from $5 to $15 per plan. Administrative and overhead costs are approximately 10 to 25 percent of labor costs. The costs to the golf course facility for an irrigation system survey and CCIS or other systems upgrades or switching to reuse water are highly variable. Costs are dependent upon the efficiency in scheduling the surveys, the size of the course, and the scope of the survey. Surveys can be performed by golf course staff or by contractors.

I. References for Additional Information

1) *Audubon Cooperative Sanctuary Program (ACSP) for Golf.* http://www.audubonintl.org/programs/acss/golf.htm
2) *Environmental Principles for Golf Courses in the United States*, United States Golf Association, 1996. http://www.usga.org/green/download/current_issues/print/environmental-principles.html
3) *Golf Course Irrigation: Environmental Design and Management Practices*, James Barrett, et al., Wiley & Sons Publishers, 2003.
4) *Irrigation Information Packet*, Golf Course Superintendents Association of America. http://www.gcsaa.org/resource/infopacks/pdfs/irrigation.pdf
5) *Turf Management for Golf Courses, 2nd Edition*, James B. Beard, United States Golf Association, 2002.
6) *U.S. Air Force Golf Course Environmental Management Program*, Air Force Center for Environmental Excellence, San Antonio, Texas. http://www.afcee.brooks.af.mil/ec/golf/default.asp
7) *Wastewater Reuse for Golf Course Irrigation*, edited by James T. Snow, United States Golf Association, 1994.

2.13 Metering of All New Connections and Retrofit of Existing Connections

A. Applicability

This BMP is intended for all Municipal Water User Groups ("utility") that do not have 100 percent metering of all customer connections. Improved accuracy of meters resulting from increased maintenance efforts should result in increased revenue and reduced "water loss." Metering of all new customer connections and retrofit of existing connections are effective methods of accounting for all water usage by a utility within its service area.

B. Description

Proper installation of meters by size and type is essential for good utility management. Using and maintaining the most accurate meter for each type of connection will generate adequate revenues to cover the expenses to the utility, equity among customers, reduce water waste and reduce flows to wastewater facilities. The American Water Works Association (AWWA) provides a number of resources listed in the reference section of this BMP. The purpose of this BMP is to ensure that all aspects of meter installation, replacement testing and repair are managed optimally for water use efficiency.

For a utility's meter program to qualify as a BMP it should have several elements:

1) Required metering of all new connections and existing connections.
2) A policy for installation of adequate, proper-sized meters as determined by a customer's current water use patterns. The use of compound meters for multi-family ("MF") residential connections or other industrial and commercial accounts is recommended.
3) Direct utility metering of each duplex, triplex, and fourplex unit whether each is on its own separate lot or whether there are multiple buildings on a single commercial lot.
4) Metering of all utility and publicly owned facilities, as well as customers.
5) Use of construction meters and access keys to account for water used in new construction.
6) Required separate irrigation meters for all new commercial buildings with a site plan area of more than 10,000 square feet and for all duplexes, triplexes and fourplexes.
7) Implementation of the State requirements in HB 2404, passed by the 77th Legislature Regular Session and implemented through Texas Water Code 13.502, that requires all new apartments to be either directly metered by the utility or submetered by the owner.
8) Review of capital recovery fees to determine whether the fees provide any disincentive to developers to use utility metering of apartment units.
9) Annual testing and maintenance of all meters that are larger than two inches since a meter may underregister water use as the meter ages.
10) Regular testing and evaluation of 5/8 and ¾ inch meters which are 8 to 10 years in service to determine meter accuracy or a periodic, consistent replacement

program based on the age of the meter or cumulative water volume through the meter. This program should be based on testing of meters at each utility to determine the optimal replacement/repair period since it depends both on the quality of water and the average flow rate through the meter versus the capacity of the meter.

11) An effective monthly meter-reading program where readings are not estimated except due to inoperable meters or extenuating circumstances. Broken meters should be fixed within 7 days or a reasonable time frame.
12) An accounting of water savings and revenue gains through the implementation of the Meter Repair and Replacement Program.

C. Implementation

To accomplish this BMP, the utility should do the following:

1) Conduct a Meter Repair and Replacement Program following the methodology and frequency currently recommended in industry practices and specified by the AWWA.
2) Develop and perform a proactive meter-testing program and repair identified meters.
3) Notify customers when it appears that leaks exist on the customer’s side of the meter. An option would be to repair leaks on the customer’s side of the meter.

D. Schedule

To accomplish this BMP, the utility should do the following:

1) The utility should develop procedures for implementation of this BMP within the first twelve months.
2) The procedures should include annual or more frequent benchmarks for measuring implementation.
3) The program participant should develop procedures for and maintain a proactive Leak Detection and Repair Program (*See*, Water Loss BMP) within the first twelve months.

E. Scope

To accomplish this BMP, the utility should do the following:

1) Develop and implement a metering program based on current AWWA practices and standards.
2) Produce a regular schedule for the utility meter repair and replacement program based upon total water use and the consumption rates of utility accounts.
3) Effectively reduce real water losses though implementation of the meter replacement and repair programs.

F. Documentation

To track the progress of this BMP, the utility should gather the following documentation:

1) Copy of meter installation guidelines based upon customer usage levels.
2) Copy of meter repair and replacement policy.
3) Records of number and size of meters repaired annually.
4) Report on the method used to determine meter replacement and testing intervals for each meter size.
5) Estimate of water savings achieved through meter replacement and repair program.

G. Determination of Water Savings

Every year the utility should estimate its annual water saving from the BMP. Savings can be estimated based upon a statistical sample analyzed as part of the meter-testing program. Project potential savings into future years and include in utility water savings targets and goals.

H. Cost-Effectiveness Considerations

Capital costs to the utility in implementing this BMP may include the costs of installing new meters and retrofitting older ones, as well as one-time or periodic costs such as purchase of meter testing and calibration equipment. A replacement meter can run from as little as $50 for a residential meter to several thousand for larger compound meters. Meter testing and repair can be done by utility staff or by outside contractors. Smaller utilities could consider sharing testing facilities. A typical residential meter test can be done from $15 to $50. There also may be administrative costs for additional tracking and monitoring of meter replacements.

I. References for Additional Information

1) *Water Loss Control Manual,* Julian Thornton, McGraw-Hill, 2002.
2) *M6 Water Meters – Selection, Installation, Testing and Maintenance,* AWWA 4th Edition, 1999.
3) *Applying Worldwide BMPs in Water Loss Control,* AWWA Water Loss Control Committee, Journal AWWA, August 2003.
4) *HB 2404 2001 Session.* http://www.capitol.state.tx.us/cgi-bin/tlo/textframe.cmd?LEG=77&SESS=R&CHAMBER=H&BILLTYPE=B&BILLSUFFIX=02404&VERSION=5&TYPE=B
5) *Texas Water Code, Submetering Rules for Apartments, Subchapter M, Section 13.502.* http://www.capitol.state.tx.us/statutes/docs/WA/content/htm/wa.002.00.000013.00.htm#13.502.00

2.14 Wholesale Agency Assistance Programs

A. Applicability

This BMP is intended for Wholesale Municipal Water User Groups ("agency") supplying potable water. The specific measures listed as part of this BMP can be implemented individually or as a group. Upon review, an agency may find that it is already implementing one or more of these elements and may want to adopt additional elements outlined below.

Once an agency decides to adopt this BMP, the agency should follow the BMP closely in order to achieve the maximum benefit from this BMP.

B. Description

Wholesale agency assistance program measures are designed to deliver assistance to its wholesale utility customers who purchase water and provide retail water service to customers. Under this BMP, the wholesale agency will provide financial and/or technical support to wholesale purchasers to advance water conservation efforts both for the wholesale customer and its retail water customers. Financial support should consist of incentives or equivalent resources as appropriate and beneficial. All BMP programs that target retail water customers should be supported when they can be shown to be cost-effective in terms of avoided cost of water from the wholesaler's perspective.

Financing for water conservation programs can be built into the rate structure as a dedicated fund available to wholesale customers who are retail purveyors. The wholesale agency can offer its BMP programs either to the wholesale customer or directly to its retail customers and should provide technical assistance to implement them. When mutually agreeable and beneficial, the wholesale agency may operate all or any part of the conservation-related activities for one or more of its retail customers.

Wholesale agencies should work in cooperation with their wholesale customers to identify and remove potential disincentives to conservation that are created by water management policies including, to the extent possible, when considering the nature of wholesale water service, its water rate structure. Wholesale rate structures should be designed upon the basic principal of increased cost for increased usage. Incentives to conserve can be built into the base rate/volumetric rate ratio with greater emphasis on volumetric rates or with a seasonal increment.

C. Implementation

Agencies are encouraged to consider stakeholder group information meetings, especially for those affected by this BMP. Working with stakeholder groups will be important to achieving "buy in" from the stakeholders. Implementation of this BMP will exceed the requirements of §TAC 288.5, Water Conservation Plans for Wholesale Water Suppliers. To implement this BMP, the following elements and strategies should be included:

1) Wholesale agency baseline profile: A description of the wholesaler's service area, including population and customer data, water use data, water supply system data, and wastewater data;
2) Wholesale agency goals: Specification of quantified five- and ten-year targets for water savings including, where appropriate, target goals for municipal use in gallons per capita per day (Total "GPCD") for the wholesaler's service area, maximum acceptable water loss and the basis for the development of these goals;
3) Wholesale water system accounting and measurement:
   a. A description as to which practice(s) and/or device(s) will be utilized to measure and account for the amount of water diverted from the source(s) of supply;
   b. A monitoring and record management program for determining water deliveries, sales, and losses;
   c. A program of metering and leak detection and repair for the wholesaler's water storage, delivery, and distribution system;
4) A requirement in every wholesale water supply contract that each successive wholesale customer develops and implements a water conservation plan that meets TAC 288 rule requirements for public water suppliers. Because no state mechanisms are in place to enforce implementation of these plans, the wholesale agency should consider developing and adopting penalties for non-compliance of this requirement.
5) Conservation-oriented water rates. During the process of contracting for water service, either new or renewed, the wholesale agency should implement wholesale water rate structures that provide incentives to conserve.
6) Wholesale customer assistance. A program to assist customers, which could include, but not be limited to, the following:
   a. Technical assistance with the development of plans and program implementation;
   b. Development of consistent methodologies for accounting and tracking water loss and gallons per capita per day;
   c. Development of procedures for calculating program savings, costs and benefits;
   d. Coordination of conservation incentive activities. Examples of pooling funds and providing grants; offering bulk purchase of equipment such as ULF toilets;
   e. Implementation of wholesale service area-wide education and outreach programs, such as school education programs, public information programs, etc. (*See* BMP for school education and public information);
   f. Cost-sharing, including joint management of retrofit and education programs and partial funding of rebates for specific conservation measures.
7) A program for reuse and/or recycling of wastewater and/or gray water and
8) Any other water conservation practice, method, or technique which the wholesaler shows to be appropriate for achieving the stated goal or goals of the water conservation plan.

9) A means for implementing this BMP, which will be evidenced by official adoption of the wholesale agency's BMP initiatives by the wholesale customers.

D. Schedule

Program participants should begin implementing this BMP within twelve (12) months of official adoption.

E. Scope

To accomplish this BMP, the agency should adopt wholesale agency assistance policies, programs or rates consistent with the provisions for this BMP as specified in Section C.

F. Documentation

To track the progress of this BMP, the agency should gather the following documentation:

1) Copy of wholesale agency assistance BMP enacted in the service area;
2) Copy of Conservation Plan pursuant to §TAC 288.5;
3) Annual report of measures accomplished; and
4) Copies of progress reports of BMPs implemented by wholesale customers that are done in conjunction with the wholesaler or which are cost-shared through this BMP.

G. Determination of Water Savings

Using historical records as appropriate, calculate water savings due to implemented BMPs, such as water loss programs or programs delivered to retail customers. Calculated savings should be based upon equipment changes, quantified efficiency measures, or alternative water sources as appropriate.

H. Cost-effectiveness Considerations

The labor costs for technical services to retail customers are dependent upon the type of conservation BMPs which the wholesale agency decides to implement. Wholesale providers should evaluate each of the BMPs to determine the appropriate costs associated with technical assistance. Cost-share costs also depend upon the cost of the BMP and the percentage of BMP implementation the wholesaler determines is appropriate. It is recommended that the wholesaler determine the NPV of avoided costs for new supply projects to determine the appropriate level of financial support to offer retailers for cost-share programs.

I. References for Additional Information

1) *A Water Conservation Guide for Public Utilities,* New Mexico Office of the State Engineer, March 2001.

2) *Pulling Utilities Together: Water-Energy Partnerships*, Home Energy Magazine Online July/August 1993. http://hem.dis.anl.gov/eehem/93/930709.html
3) *Memorandum of Understanding*, California Urban Water Conservation Council, 1999.

2.15 Conservation Coordinator

A. Applicability

This BMP is intended for all Municipal Water User Groups ("utility"). A common element in successful conservation programs[1] is a conservation coordinator who is responsible for implementing and maintaining the conservation program.

B. Description

A Conservation Coordinator is an individual designated to oversee and coordinate conservation efforts within a utility's service area. A regional supplier may have a coordinator that works with all of its wholesale customers. Under this BMP, the utility designates a Conservation Coordinator to be responsible for preparation and implementation of the utility's water conservation and drought contingency plans, preparation and submittal of annual conservation status reports to utility management, and implementation of the utility's conservation program. Other duties should include preparation of the annual conservation budget, promotion of water conservation programs, developing marketing strategies for conservation programs, coordination with other utility staff and promoting the value of conservation programs within the utility, participation in regional water planning conservation and drought period initiatives and management of conservation staff, consultants and contractors when appropriate.

The Conservation Coordinator may have other duties and job titles within the utility. Small utilities may share costs with other small utilities by jointly hiring a Conservation Coordinator. Wholesale suppliers may hire a Conservation Coordinator to serve the retail utilities that receive water from them.

C. Implementation

Implementation should consist of identifying a Conservation Coordinator and support staff (when needed), whose duties can include the following:

1) Manage and oversee conservation programs and implementation;
2) Document water conservation program implementation status as this relates to state requirements and BMPs adopted;
3) Communicate and promote water conservation to utility management;
4) Coordinate utility conservation programs with operations and planning staff;
5) Prepare annual conservation budget
6) Manage consultants and contractors assisting in implementing the water conservation program;
7) Develop public outreach and marketing strategies for water conservation; and
8) Participate in regional water conservation planning and drought planning initiatives

Often, the Conservation Coordinator is the spokesperson for the utility on conservation issues. For small utilities, the Conservation Coordinator may have other responsibilities. Utilities that jointly operate regional conservation programs are not expected to staff duplicative and redundant Conservation Coordinator positions.

D. Schedule

Utilities pursuing this BMP should begin implementing this BMP within six (6) months of adoption of the official resolution to initiate the program. Implementation should be completed in a timely manner.

E. Scope

A utility should staff and maintain the position of Conservation Coordinator and provide support staff as necessary. This includes providing the Conservation Coordinator with the necessary resources to prepare and implement the water conservation program. Depending upon the size of the utility or opportunity to collaborate with neighboring utilities or wholesale agencies within its region, this BMPs objective may be achieved by sharing resources and implementation efforts with other utilities.

F. Documentation

To track this BMP, the utility should gather the following documentation:

1) Description of the Conservation Coordinator position.
2) The date the Conservation Coordinator was hired.
3) Annual or more frequent reports on progress of water conservation program implementation, costs and water savings.

G. Determination of Water Savings

Water savings are not quantified for this BMP. The Coordinator assists in the implementation of other BMPs and this additional effort can be considered as essential to the savings accrued by the implementation of the whole range of conservation program(s) which are offered by the utility.

H. Cost-Effectiveness Considerations

Without specific water savings, it may be difficult to do a true cost-effectiveness analysis for this BMP. However, this BMP is essential to the successful implementation of other BMPs the utility chooses to undertake. There will be non-financial benefits as a result of implementing this BMP such as enhanced public image through increased outreach and visibility in emphasizing conservation programs. The salary and associated overhead expenses for the Coordinator would be the primary costs that would be incurred in implementing this BMP. Depending on size and scope of the water conservation programs, the Coordinator position could be full-time, part-time, shared with others, or contracted out.

I. References for Additional Information

1) Texas utilities and regional suppliers with conservation coordinators include (but are not limited to) Austin, Corpus Christi, Dallas, El Paso, Lower Colorado River Authority, San Antonio,San Marcos, Post Wood Municipal Utility District, and Harris Galveston Coastal Subsidence District.
2) *Memorandum of Understanding*, California Urban Water Conservation Council, 1999.
3) *Groundwater Conservation Plan*, Edwards Aquifer Authority, 2000.

2.16 Water Reuse

A. Applicability

This BMP is intended for Municipal Water User Groups ("utility") that may have potential applications for reusing water within its system. The utility may be a producer of reclaimed water or may work to bring in reclaimed water from outside sources. Reuse can be direct with reclaimed water substituted in end uses to replace potable water or raw water. Another method of reuse is indirect water reuse which involves the intentional planned use of system return flows.

Both direct and/or indirect reuse should be implemented as a supplement to other methods of reducing per capita water use or increasing the efficient use of water.

Upon review, utilities may find that they are already implementing one or more elements of this BMP and may want to adopt additional elements outlined below. Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum benefit from this BMP.

B. Description

1) Direct Reuse

The direct use of reclaimed water is an effective method of reducing potable water usage. Reclaimed water is defined inTexas Administrative Code ("TAC") §210.3(24) as "Domestic or municipal wastewater which has been treated to a quality suitable for a beneficial use, pursuant to the provisions of this chapter and other applicable rules and permits." Direct use of reclaimed water is appropriate for a number of domestic, industrial and irrigation needs where the potential for human contact is limited. Some possible uses for reclaimed water are landscape irrigation, non-contact recreational use, cooling tower make up water, toilet or urinal flushing water, or manufacturing process water. Although differences in water quality between potable and non-potable water may change the quantity needed for a particular task, users of reclaimed water should view it as a valuable water resource and use it as efficiently as possible. Direct use of reclaimed water is regulated by the Texas Commission on Environmental Quality ("TCEQ") under Chapter 210 of the TAC (2) and Safe Drinking Water Act standards. Included in these rules are provisions that require permission from that agency before providing reclaimed water for beneficial use and design guidelines for reclaimed water systems.

Under this BMP, the utility should identify and rank industrial, commercial, and institutional ("ICI") customers according to volume of water use and investigate the feasibility of replacing some of potable water uses with reclaimed water. Municipalities should investigate reclaimed water opportunities within their own accounts or with third parties outside their service area. The utility provides a description of effluent treatment facilities and distribution systems including the amounts and quality of effluent expected to be available for reuse. The utility should implement programs to provide as much reclaimed water to approved non-potable uses as is available and cost-effective to the utility.

2) Indirect Reuse

Indirect reuse can provide substantial water conservation by replacing or delaying the development of additional raw water resources for water supply. Indirect reuse can be for potable or non-potable uses. Indirect potable reuse is defined as follows by the Water Reuse Association[1] "A particular application where the recycled water (generally having received a substantial degree of treatment) is blended into a community's water supply (via groundwater recharge or surface water augmentation) prior to final treatment and distribution to the customer in the existing water distribution system."

The use of reclaimed water for augmentation of potable supplies as a BMP involves the intentional planned use of the reclaimed water for this purpose. Use of reclaimed water for augmentation of potable supplies must take into consideration the following:

- TCEQ Surface Water Quality Standards for the receiving water body.
- State laws and regulations directly applicable to authorizing water reuse, including those that consider the impact of reuse on instream uses, freshwater inflows to the bays and estuaries, and existing water rights under circumstances that the regulatory agency deems appropriate.

A water rights permit is required to withdraw reclaimed water that has been discharged to the waters of the state.

C. Implementation

Implementation should consist of at least the following actions:

1) Direct Reuse

a. Identify Potential Reuse Accounts

b. Identify and rank ICI accounts according to water use. Proximity to a reclaimed water distribution system, an existing wastewater treatment plant, or possible locations for new wastewater treatment plants should be considered in ranking potential reuse customers. A wastewater interceptor could be designed to divert wastewater flows from a wastewater line for treatment and use in the nearby area. Careful consideration should be given to the water quality needs of the end user. For purposes of this BMP, potential direct reuse accounts are defined as:

1. Irrigation Accounts: any water user that uses potable water to irrigate large turf, shrubs, trees or other landscaped area. Care should be taken to ensure that such irrigation is in compliance with the human contact

standards in TAC Chapter 210 and that the plant material can tolerate the water quality of available reclaimed water

2. ICI Accounts: any water users that are defined as ICI in the Conservation Programs for Industrial, Commercial, and Institutional Accounts BMP. Care should be taken to ensure that identified potential uses are in compliance with the human contact standards in TAC Chapter 210.
3. New Construction: Reclaimed water can be used for toilet and urinal flushing if it meets TCEQ standards. This would only be feasible in new construction of an office building or adult residential facility such as a dormitory. For new subdivisions, dual distribution systems could be installed to use reclaimed water to irrigate common areas, medians, parks and home landscapes. The utility could also adopt an ordinance and regulations requiring all or specific customers to use reclaimed water for irrigation and other suitable purposes if reuse water is available.

c. Implement a Reclaimed Water Customer Incentives Program. Financial incentives can be offered on a dollar amount per acre-foot of potable water use replaced. Another potential incentive is to offer discount rates or grants to assist a reuse end user in connecting to the reclaimed water system and replumbing facilities from potable to non-potable water use. Purple pipe is required for all reuse water to prevent cross connections. Proper backflow prevention measures must be implemented when a facility has both potable and non-potable water uses or has an irrigation system installed.

2) Indirect Reuse

a. Identify indirect reuse opportunities for augmentation of potable supply.

b. Identify the source of reclaimed water that could be used to augment the potable raw water supply.

c. Identify the potential water body that would receive the reclaimed water. Careful consideration should be given to the water quality requirements for the augmented water supply to be suitable for potable use. The augmentation of a potable supply should involve multiple barriers to ensure compliance with applicable regulatory standards, including high levels of treatment of the reclaimed water, blending with substantial amount of natural water, retaining the reclaimed water in the receiving water body for significant amounts of time, high degree of treatment of the potable water, and monitoring (sampling and testing) to ensure compliance with applicable regulations.

d. Determine potential impacts on instream uses, freshwater inflows to bays and estuaries, and existing water rights with regulatory agency input.

D. Schedule

Utilities pursuing this BMP should begin implementing this BMP within twelve (12) months of adoption of the official resolution to initiate the program.

E. Scope

In order to accomplish this BMP, the utility should perform the following:

1) Direct Reuse
To the extent that reclaimed water is available for reuse, replace the use of potable water on golf courses, in large cooling plants, and in other industrial or landscape processes identified by the municipal utility.

2) Indirect Reuse
To the extent that reclaimed water is available, that a receiving water body is available, and a water rights permit is obtained from the TCEQ, augment the potable water supply sources with reclaimed water in a manner determined by the utility to be financially and technically feasible.

F. Documentation

To track this BMP, the utility should gather the following documentation based on whether direct and/or indirect reuse is selected:

1) Direct Reuse
   a. Description of wastewater treatment facilities and reclaimed water distribution systems.
   b. Documentation of its efforts to find reuse opportunities within its customer base, including lists of potential users.
   c. Number of gallons or acre-feet of water use replaced by reclaimed water or new water demands served by reclaimed water since implementation of this BMP.

2) Indirect Reuse
   a. Description of indirect reuse project(s).
   b. Number of gallons or acre-feet of previous potable water use replaced by reuse water or new water demands served by reuse since implementation of this BMP.

G. Determination of Water Savings

Water savings are estimated at up to 100 percent of total amount of water replaced by reuse. Changes in operating parameters or water balance calculations which depend upon water quality parameters, such as the impact of TDS in irrigation water, may require different quantities of reuse water to be applied for the same end uses.

H. Cost-Effectiveness Considerations

The costs for direct or indirect reuse include capital costs of facilities, engineering, regulatory costs, and operations costs. There will also be outreach costs to gain public acceptance. The benefits will be the avoided costs for water supply acquisition and additional potable water treatment capacity.

These benefits of direct reuse can be taken into account when setting the reclaimed water rate. If a utility can adopt a regulation requiring reclaimed water use for certain purposes within the proximity of a reclaimed water supply line, more customers will tie on to the reclaimed water system and the utility will be able to charge a rate that recovers its costs.

I. References for Additional Information

1) *Water Reuse Association: Fact Sheets and Studies.* http://www.watereuse.org/Pages/information.html
2) *Recycled Water Users' Handbook, San Antonio Water System.* http://www.saws.org/our_water/recycling/handbook/recycle_water_hb.pdf
3) *Chapter 210 Rules, Texas Commission on Environmental Quality.* http://www.tnrcc.state.tx.us/oprd/rules/pdflib/210a.pdf through 210e.pdf
4) *AWWA M24 Manual: Dual Water Systems.* http://www.awwa.org/bookstore/product.cfm?id=30024
5) *Using Reclaimed Water to Augment Potable Water Resources,* Water Environment Federation and American Water Works Association, 1998. (2.16c)

2.17 Public Information

A. Applicability

Any Municipal Water User Group ("utility") can adopt this BMP. A program for providing water conservation information to the public is an effective means of both promoting specific water conservation programs and practices and educating the public about the importance of using water efficiently. A utility may have already accomplished this BMP if it has a current public information program that meets the criteria of this BMP.

Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

Public information programs, even though they may not be directly related to any equipment or operational change, can result in both short and long-term water savings. Behavioral changes by customers will only occur if a reasonable yet compelling case can be presented with sufficient frequency to be recognized and absorbed by customers. There are many resources that can be consulted to provide insight into implementing effective public information programs. Like any marketing or public information program, to be effective, water conservation public information should be planned out and implemented in a consistent and continual manner.

The goal is education of customers about the overall picture of water resources in the community and how conservation is important for meeting the goals of managing and sustaining existing water supplies and avoiding or delaying building of new facilities. An equally important part of the program is to provide data and information on specific actions and measures the customers should take to implement these community goals. Showing customers that the results of those actions have made a difference encourages greater participation in conservation efforts.

There are a variety of tools that can be effectively used to communicate water conservation public education. These include use of print, radio, and television media; billboards; direct distribution of materials; special events such as exhibits and facilities tours; and maintenance of an informative website.

Print media activities can include press conferences, articles and news releases. Regular columns and contributions to gardening and environmental reports are also good ways to reach a wide audience. Electronic media efforts include talk shows, news conferences, press releases, public service announcements, and even paid commercials.

Besides media, utilities can use direct distribution of materials such as inserts or messages on the utility bill, a newsletter, flyers, direct mail, and door hangers. Direct distribution allows targeting of specific messages to specific target audiences.

Special events provide excellent opportunities for direct interaction with the public. These events include facility tours, exhibits, participation in community events, trade shows, presentations to groups, water efficient landscape judging and competitions, and classes and seminars. Development of demonstration gardens and permanent exhibits are also effective.

Websites are now an essential element of public information. Much of the same printed material made available to the media and through direct distribution can be put on a website. Electronically delivered newsletters should include links to the utility's website.

An early step in development of the public information program is to identify the target audiences and what messages need to be conveyed. Themes should be selected that both convey the importance of water conservation and provide customers an opportunity to act. Thematic messages that stress the importance of water as a natural resource can be linked with specific tips or water conserving activities. The most successful public information campaigns also promote or "market" opportunities for customers to participate in utility sponsored conservation programs such as rebate and/or retrofit programs described in other BMPs.

Each public information program should be tailored to the utility and the community. The types of communication methods most effective for the target audience should be identified. Certain media outlets will be more effective than others. For example, television may be effective for large city utilities where it would not be for suburban or rural utilities. In those areas, a local newspaper or direct distribution of materials would likely be better choices.

There are many publications, brochures, videos, DVDs, etc. already available on water conservation that can be used as published or modified to meet the goals of the utility. The TWDB has brochures and guidebooks available at cost as well as TV and radio public service announcements. A statewide public awareness program is an additional resource anticipated for future years.

Some of the most effective education initiatives involve the participation of customers in the planning process. Creation of stakeholders committees, task forces, or advisory groups have proven effective for utilities in both defining the message and in recruiting allies in the community for promotion of water conservation. Such participatory programs should be well planned and may require an extensive process with numerous meetings or could be a relatively shorter process with representatives of key community organizations. The representative approach could involve neighborhood associations, business groups (i.e. nursery/landscape or other water-related businesses), academic institutions, not-for-profit agencies and environmental organizations among the mix of groups invited to participate. This process will be most successful if public input is sought not only for the public information plan but also for the entire Conservation Plan.

Partnership programs are another effective means of expanding the utility's public information efforts. Numerous not-for-profit agencies include environmental education among their goals. Integrating the utility's public information efforts with programs of other local agencies expands the impact of utility efforts. Other State agencies with offices around the state that include water conservation among their information programs include Texas Cooperative Extension offices, Texas Parks & Wildlife, Texas Soil & Water Conservation Board, Texas Commission on Environmental Quality, and Texas Forest Service.

Some business associations, neighborhood associations or not-for-profit groups may also provide partnering opportunities for the overall utility conservation program or specific BMPs. Together with these partners utility staff may be able to develop a speaker's bureau to offer adult education about specific water efficiency related topics such as Water Wise landscaping, irrigation system management, and retrofit and behavioral changes available to reduce water bills.

Another important marketing tool for successful conservation programs is public recognition of water-conserving customers. This is often used to focus attention on commercial customers as an incentive to promote greater efficiency by providing positive coverage of company conservation efforts. Awards or certification programs exist in a number of utility programs in Texas and across the nation[1]. These programs have also been used to recognize water-saving landscape designs.

For utilities that are pursuing a number of BMPs, it is important that the public information efforts be integrated with the promotion of implementation of the other conservation BMPs. Promotional efforts or "marketing" of rebates, retrofits, surveys, or educational events should be tied together in the Public Information Plan, much like commercial entities develop a marketing plan.

C. Implementation

The first step in implementation is to develop a Public Information Plan with goals and objectives and a schedule of activities for the first year and a tentative second year schedule. Forming a committee composed of customers and community leaders can help with the development of an effective plan. Committee members may be directly involved in implementing the plan, such as partnership programs with other agencies promoting water conservation, businesses or residents which implement BMPs and receive public recognition, or providing non-utility volunteers to promote conservation through a speakers bureau. Utilities should take advantage of and coordinate their efforts with State programs on conservation[2]. Another option is using firms that specialize in marketing and public information to develop a public information program.

The goal should be, at a minimum, to provide information to each customer at least four times each year on each action that the utility would like the customer to take. The plan should be updated every year continuing with a two-year time horizon. Every other year, the utility should survey a sample of customers or consider the use of focus groups to determine if the utility messages are reaching customers and how effective the messages are in terms of customer actions.

The Public Information Plan should be a substantial part of the utility's overall Conservation Plan. Implementation of the Public Information program should be integrated with the implementation of specific BMPs included in the Conservation Plan. A successful public information effort will promote participation in other BMPs

D. Schedule

1) Utilities pursuing this BMP should begin implementing this BMP according to the following schedule: The utility should complete the Public Information Plan within six (6) months of adopting this BMP.
2) In the second year and each year thereafter, the utility should complete a revised Public Information Plan.
3) In the second year and every other year thereafter, the utility should conduct and complete a survey of customers to determine the effectiveness of its message and actions that customers have taken.
4) Every other year, the utility should survey customers or convene focus groups to assist in determining the effectiveness of materials used or to be used in the public information campaign.

E. Scope

The Public Information Plan should provide conservation information on each BMP being implemented to customers at least four times per year. For utilities focused on reducing summertime peak usage, themes and scheduling of message should be repeated numerous times during the late spring and early summer, rather than being spaced evenly throughout the year.

F. Documentation

To track the progress of this BMP, the utility should gather and have available the following documentation:

1) Number of activities and pieces of information and how many customers were at that activity or received each piece of information;
2) Number and schedule of activities or information pieces related to promoting specific BMPs adopted by the utility;
3) Number of news programs or advertisements that featured the utility message and how many customers had the opportunity to receive each message;
4) Total population in the utility service area;
5) Total budget by category for public information; and
6) Results of annual or biannual customer survey and/or focus groups to determine the reach and impact of the program.

G. Determination of Water Savings

Water savings due to public information efforts are difficult to quantify. If the public information effort was for a specific action such as a showerhead distribution, the savings can be calculated under this BMP if the utility did not implement the BMP containing the product or action. Water savings for other public information programs that result in specific actions by customers such as changes in irrigation scheduling or reduction in water waste occurrences could also be quantified through surveys or analysis of water waste reporting.

H. Cost-effectiveness Considerations

The costs for implementing this BMP depend on the scope of the public information effort. There may be costs for administration and materials. A comprehensive program would range in costs starting at $0.50 to $3.00 per customer per year depending on the size of the utility. Larger utilities should have lower unit costs due to economies of scale. The public information program can be developed and managed by utility staff or outside contractors. Media purchases with TV, radio and print media may be done directly by utility staff.

I. References for Additional Information

1) Texas Award Program Examples
   a. City of Austin Excellence in Conservation Award Program. http://www.cityofaustin.org/water/wwwssd_iw_award10.htm
   b. San Antonio Water System Annual Water Saver Awards for ICI Customers and Water Saver Landscapes. http://www.saws.org/conservation/
2) Texas Water Smart Program. http://www.watersmart.org
3) Educational Material on Outdoor Water Conservation, *Does Print Material Translate into Water Conservation Savings?* Kate Soroczan, Canadian Mortgage and Housing Corporation, AWWA Water Sources Conference, 2004.
4) *If They Help Write it, They'll Help Underwrite It*, Haring, T., AWWA Conserv 99, 1999.
5) *People are Watching – Public Participation in a Reuse Project*, Richardson, A.W., Janga, R.G., AWWA Water Sources Conference, 2002.
6) *Providing Incentives for Environmental Performance*, Brown, C., AWWA Water Sources Conference, 2004.
7) *Public Participation Methods to Increase Non-Residential Conservation*, Brown, C., AWWA Conserv 99, 1999.
8) *Stretching Your Marketing Dollar*, Mark Wieland, AWWA Water Sources Conference, 2004.
9) *Tuna Cans, Rain Gauges, and Soil Probes: High-Visibility Campaigns to Reduce Water Use*, DelForge and Platt, AWWA Water Sources Conference, 2002. http://www.awwa.org/waterwiser/references/abstract.cfm?id=53276&start=1&kw=public%20information
10) *Water Wise Awards: Incentive Based Conservation*, Bracciano, D., Holland, N., and Brown, S.P., AWWA Conserv 99, 1999.
11) *TWDB Education and Public Awareness Page.* http://www.twdb.state.tx.us/assistance/conservation/Education.htm
12) *A Consumer's Guide to Water Conservation (video and DVD),* AWWA, 1999. http://www.awwa.org
13) *Conserve Everyday Video,* AWWA, 2001. http://www.awwa.org

14) *H2O House Water Saving Home*, California Urban Water Conservation Council and EPA. http://www.h2ouse.org/

2.18 Rainwater Harvesting and Condensate Reuse

A. Applicability

This BMP is intended for use by a municipal water user group ("utility") concerned with reducing outdoor irrigation demands on the potable water system. Calculation of potential savings will depend upon regional climate patterns. Rainwater harvesting and condensate reuse are applicable to ICI buildings, while private homes can benefit from rainwater harvesting. Utilities may benefit by targeting this BMP to help shave peak demand through customer education. For maximum water-use efficiency benefit, the utility should adhere closely to the measures described below.

B. Description

Rainwater harvesting and condensate reuse ("RWH/CR") conservation programs are an effective method of reducing potable water usage while maintaining healthy landscapes and avoiding problems due to excessive run-off. Using this BMP, the utility provides customers with support, education, incentives, and assistance in proper installation and use of RWH/CR systems. RWH/CR systems will be most effective if implemented in conjunction with other water efficiency measures including water-saving equipment and practices. Rainwater harvesting is based on ancient practices of collecting – usually from rooftops – and storing rainwater close to its source, in cisterns or surface impoundments, and using it for nearby needs. Industrial, Commercial, and Institutional ("ICI") users have found it to be cost effective to collect the condensate from large cooling systems by returning it into their cisterns as well. Facilities with large cooling demands will be in the best position to take advantage of condensate reuse, which due to its quality can potentially be used in landscape irrigation, as cooling tower makeup water, or in some industrial processes. The variability in rate and occurrence of precipitation events requires that rainwater or condensate be used with maximum efficiency. Incentives may include rebates for purchase and installation of water-efficient equipment.

Several factors should be considered in the design of rainwater harvesting and condensate reuse systems. System components include the collection area, a first flush device, a roof washer, an opaque storage structure with the capacity to meet anticipated demand, and a distribution system. Design consideration should be given to maintaining the highest elevations feasible for collection and storage systems for the benefit of gravity flow to storage or distribution. When using drip irrigation systems, filters are necessary to prevent particulates from clogging drip nozzles. For potable water uses, a higher degree of filtration and disinfection is needed to ensure water quality adequate for human consumption. Regular maintenance of RWH/CR systems includes changing filter media on a regular basis and cleaning the first flush filter. The utility should consider providing participants with reminders of regular maintenance requirements for their RWH/CR systems. Maximum expected daily demand, and knowledge of historical precipitation patterns, including amount, frequency and longest time between rainfall events, is important in designing the system. The Texas Water Development Board's *Texas Manual on Rainwater Harvesting, 2004,* should be used as a resource, as well as technical assistance from professional installers and manufacturers of RWH/CR equipment for proper design and implementation of RWH/CR program guidelines.

In some parts of the state of Texas, RWH/CR has been used as a private water supply for both potable as well as nonpotable uses. Using rainwater for potable supply creates a responsibility on the part of the owner/operator of the system to operate and maintain the system to a higher level than nonpotable use. For this reason most RWH/CR programs run by utilities are likely to focus on non-potable water uses. Successful implementation of this BMP is accomplished by performing one or a combination of the approaches outlined below.

While residential cooling systems are unlikely to provide significant flows of condensate, Industrial/Commercial/Institutional ("ICI") installations with large cooling demands can produce significant amounts of condensate and should be evaluated for the dual RWH/CR system. Large ICI installations can implement rainwater harvesting (from roofs) as well as capture of stormwater for irrigation or other non-potable uses. New commercial developments are often required to have either stormwater detention ponds or water quality treatment structures. In either case, permanent storage can be added beyond that required and this storage can be used to retain runoff for later irrigation use. Large buildings that have or need French drain systems for foundation drain water should evaluate the potential for recovery of this resource as well.

The utility should consider sponsoring one or more demonstration sites. Potential partners include customers with educational missions such as schools, universities, botanical gardens, and museums with large public landscapes.

Although rainwater is recommended for all irrigation uses, it is most appropriate for use with drip or micro irrigation systems. Utilities implementing this BMP should consider offering a landscape water-use survey (*See*, the related BMP) to help customers ensure that RWH/CR systems are properly designed and sized.

The water-use surveys, at a minimum, include: measurement of the total irrigated area; irrigation system checks, review of irrigation schedules or development of schedules as appropriate; provision of a customer survey report and information packet. The utility should provide information on climate-appropriate landscape design and efficient irrigation equipment and management for new customers and change-of-service customer accounts (*See*, the Water Wise Landscape Design and Conversion Programs BMP for more detail).

C. Implementation

Programs should consider the following elements:

1) <u>Retrofit or Rain Barrel Program</u>
Marketing the program to the customer via bill inserts will allow the utility to target the largest summer peak users first. The utility should consider also approaching local weather announcers, radio gardening show hosts, and newspaper columnists for assistance in notifying the public about the program. Public/private partnerships with non-profits such as gardening clubs,

neighborhood associations, Cooperative Extension offices and/or with green industry businesses such as rainwater harvesting companies and local sustainable building groups are potential avenues to market the program and leverage resources.

Incentives can include rebates for RWH/CR systems, recognition for RWH/CR systems through signage, award programs, and certification of trained landscape company employees and volunteer representatives to promote the program. Utility staff can also be trained to provide irrigation audits, which can include resetting irrigation controllers with an efficient schedule.

The initial step in assisting customers with landscape irrigation systems is a thorough evaluation of the potential water capture of a RWH/CR system.

The water customers who participate in this program will need to maintain and operate their irrigation systems in a water-efficient manner. The utility should consider implementing a notification program to remind customers of the need for maintenance and adjustments in irrigation schedules and to system filters as the seasons change.

The utility needs to ensure that RWH/CR system specifications are coordinated with local building and plumbing codes.

The American Rainwater Catchment Systems Association lists evaluation training for RWH/CR programs. ICI customers may want to consider performance contracting as an option for financing retrofitted RWH/CR systems.

2) <u>New Construction</u>

a. In addition to retrofitting existing homes and buildings with RWH/CR systems a utility may also choose to support implementation focused on new construction. Under this approach, the utility could:

b. Adopt regulations requiring all new ICI properties to install a RWH/CR system that collects and stores rainwater and condensate from all eligible sources and distributes it to irrigation and/or a cooling tower make-up system or

c. Implement an incentive program to encourage builders and owners of new ICI properties to install a RWH/CR system that collects and stores rainwater and condensate from all eligible sources and distributes it to irrigation and/or a cooling tower make-up system. In large ICI buildings requiring cooling towers, design consideration should be given to returning condensate flows from air conditioning coils to cooling tower make-up. It may be effective for this BMP to be part of a Green Builder type rating system that also includes WaterWise landscaping and adequate soil depth;

d. Implement an incentive program to encourage homebuilders and homeowners to install a RWH system for landscape use to reduce potable water consumption from the utility in the summer season or

e. Adopt regulations requiring all new homes and/or multi-unit properties to install plumbing that separately collects and stores rainwater from all eligible sources and distributes the rainwater through a subsurface irrigation system either around the foundation of the residence or building or for other landscape use.

Such programs would need to be carefully coordinated with stormwater collection programs and meet all applicable regulations for stormwater collection and reuse.

D. Schedule

Depending on the option(s) selected, the corresponding schedule should be followed.

1) <u>Incentive Approach</u>
In the first six months, plan the program including stakeholder meetings as needed. Develop a plan for educating potential homebuyers, developers, plumbers, green industry trade groups, landscape architects and realtors about this program. After six months, implement the program.

2) <u>Ordinance Approach</u>
In the first six months, hold stakeholder meetings to develop the ordinance. Consider offering incentives for the first year of implementation. Propose the ordinance or rules to local City Council or Board for approval. Develop a plan for educating potential homebuyers, developers, plumbers, and realtors about this program. After six months, implement the program.

E. *Scope*

To accomplish the goals of this BMP, the utility should do one or more of the following:

1) Develop and implement an incentive program to encourage RWH/CR in new multi-unit properties and certain new commercial developments such as office parks. Or,

2) Develop and implement an incentive program to encourage RWH/CR in existing multi-unit properties and certain existing commercial developments such as office parks. Or,

3) Develop and implement an incentive program to encourage residential customers to install rainwater systems and rain barrels. Or.

4) Develop and implement an ordinance requiring condensate recovery in new non-residential construction as applicable.

F. Documentation

To track this BMP, the utility should gather and have available the following documentation for each year of operation:

1) The number of new RWH/CR developments for which design planning started after adoption of this BMP;
2) The number and type of RWH/CR installations completed each year;
3) The estimated rainwater and condensate use in each RWH/CR installation;
4) Aggregate water capacity of RWH/CR sites;
5) Number, type, and dollar value of incentives, rebates, or loans offered to and accepted by customers; and
6) Estimated water savings achieved through customer surveys.

G. Determination of Water Savings

Water savings from a RWH/CR program is determined by water volume harvested and used to replace other water sources. In programs which target new construction, the water savings should be estimated based upon known water consumptions for the proposed end use. A number of sources, including other BMPs, can be helpful in estimating potential water savings. A method for estimating potential water catchment and a monthly water balance equation for estimating water storage capacity are:

1) <u>Catchment Potential</u> (gals) = Area x 0.62 x 0.8 x Rainfall
   Where Area = total area of catchment surface in square feet
   0.62 = coefficient for converting inches per ft^2 to gallons (unit conversion from 7.48 gallons per ft^3)
   0.8 = collection efficiency factor
   Rainfall = average rainfall in inches.
   Note: median and lowest recorded rainfall can also be calculated in order to develop a range of expected values.

2) <u>Storage Capacity</u>
   A simple assumption is that up to three months may elapse without significant rainfall. So a storage capacity to provide for a three-month period of water demand may be desired.

   More precise methods of estimating needed storage capacity or additional information for estimating water balance of RWH/CR systems and of accounting for the variability in seasonal rainfall pattern is available in the *Texas Manual on Rainwater Harvesting.*

   For condensate recovery, storage should be based on the anticipated maximum holding time before the condensate is reused for irrigation or other purposes.

H. Cost-Effectiveness Considerations

The costs of this BMP to the utility will include both administrative program management costs and incentives to customers for implementing rainwater harvesting or condensate reuse projects. Depending on program design and whether project inspections are required, staff labor cost should range from $50 to $100 per project. Current incentives provided by the City of Austin for complete rainwater harvesting system are up to $500 per SF home and for commercial customers, the incentive for condensate reuse is up to $1 per gallon per day recovered. Marketing and outreach costs range from $20 to $50 per project. Administrative and overhead costs range from 10 to 20 percent of labor costs.

The incentive for bulk purchase rain barrels in Austin is a $20 discount from the actual costs of the rain barrel. Labor costs range from $8 to $12 per rain barrel and warehouse storage costs may be an additional consideration.

I. References for Additional Information

1) American Rainwater Catchment Systems Association. http://www.arsca-usa.org/
2) City of Austin Water Conservation Program. http://www.ci.austin.tx.us/watercon/rainwaterharvesting.htm
3) *First American Rainwater Harvesting Conference Proceedings*, Gerston, J. and Krishna, H., editors, ARCSA, August 2003.
4) *Rainwater Harvesting Design and Installation,* Save the Rain. saverain@gvtc.com
5) *Texas Guide to Rainwater Harvesting*, Texas Water Development Board and Center for Maximum Potential Building Systems, 2nd Edition, 1997.
6) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf

2.19 New Construction Graywater

A. Applicability

This BMPis intended for a Municipal Water User Group ("utility") that has new development in its service area where use of graywater can be an option for an additional water supply. This BMP does not include on-site wastewater treatment and reuse. Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

Graywater has always been used in Texas. The most common example is using washing machine water for lawn or garden irrigation. Until 2003, Texas statutes contained very restrictive provisions for using graywater, primarily due to concerns about public health. In 2003, the Texas Legislature adopted House Bill ("HB") 2661 which provides a more comprehensive definition of graywater and provisions for facilitating the use of graywater in a safe manner.

Graywater is defined in Texas as wastewater from clothes washers, showers, bathtubs, handwashing lavatories and sinks not used for the disposal of hazardous or toxic ingredients. Graywater cannot include water from clothes washers used for washing diapers, sinks used for food preparation, toilets, nor urinals.

HB 2661, passed by the 78th Legislature Regular Session, added a provision that allows graywater use without treatment of up to 400 gallons per day at a private house for landscape irrigation, gardening or composting as long as the graywater:

1) Is used by the occupants of the residence for gardening, composting, or landscaping;
2) Is collected using a system that overflows into a sewage collection system or on-site wastewater treatment and disposal system;
3) Is stored in tanks that are clearly labeled and that have restricted access;
4) Uses purple pipe or purple tape around the pipe;
5) Is not allowed to pond or run off across property lines; and
6) Is distributed by a surface or subsurface system that does not spray into the air unless the graywater receives additional treatment.

HB 2661 also encourages builders of new homes to install dual piping that provides the capacity to collect graywater from allowable sources and to install subsurface graywater systems around the foundation of new houses to minimize foundation movement and cracking. This approach can also provide irrigation for landscaping planted up to four feet from the foundation.

New duplexes, triplexes, fourplexes, town homes, condo units and apartments can all be designed for utilization of graywater. Graywater generated from office buildings and other commercial buildings, primarily through faucet use, can be used for landscape irrigation. HB

2661 requires the Texas Commission on Environmental Quality to adopt rules for graywater use for commercial purposes as well as for industrial purposes and these rules are expected to be released for public comment sometime in 2004.

In many cases the quantity of water available as graywater is declining due to water efficiency gains from water conserving showerheads, faucet aerators and clothes washers. In a new home, which would have efficient plumbing fixtures, the amount of graywater produced will range from 22 to 30 gallons per person per day[1]. For an average size household of 2.7 persons that would be sufficient in most cases for both foundation stabilization and landscape irrigation in a four-foot strip around a 2,500 square foot house.

The suitability of graywater for irrigation will vary, and if graywater is the primary source for irrigation, a low water use landscape should be used. Irrigation systems should consider soil depth, soil permeability and flooding characteristics. Application options include drip, flood and subsurface irrigation. It is not appropriate to use spray irrigation unless the graywater is highly treated. Pumps may be required for pressure dosing and uniformity of flow.

C. Implementation

Implementation of this BMP includes following rules pertaining to graywater adopted by TCEQ (expected 2004) as well as any local City or County Health Department rules. To promote this BMP, stakeholder meetings should be held with builders, developers, realtors and other impacted groups.

Due to the high cost of retrofitting existing homes and buildings for collection and use of graywater, that option is not included in this BMP. A utility choosing to support such retrofits should include design standards as a component of its public information programs.
Under this BMP, the utility should:

1) Implement an incentive plan to encourage builders and owners of new homes and/or multi-unit properties to install plumbing that separately collects graywater from all eligible sources and distributes the graywater through a subsurface irrigation system around the foundation of the residence or building or for other landscape use. It may be effective for this BMP to be part of a Green Builder type rating system that also includes WaterWise landscaping, adequate soil depth and rainwater harvesting; or
2) Adopt regulations requiring all new homes and/or multi-unit properties to install plumbing that separately collects graywater from all eligible sources and distributes the graywater through a subsurface irrigation system either around the foundation of the residence or building or for other landscape use; or
3) Adopt regulations and/or incentives requiring new commercial properties to reuse graywater.

D. Schedule

The schedule for accomplishing this BMP depends upon the utility's choice of approach:

1) Incentive Approach: In the first six months, plan the program including stakeholder meetings as needed. Develop a plan for educating and training potential homebuyers, developers, plumbers, landscape professionals and realtors about this program. After six months, implement the program.
2) Ordinance Approach: In the first six months, hold stakeholder meetings to develop the ordinance. Consider offering incentives for the first year of implementation. Propose the ordinance or rules to local City Council or Board for approval. Develop plan for educating potential homebuyers, developers, plumbers, and realtors about this program. After six months, implement the program.

E. Scope

To accomplish this BMP, the utility should do the following:

1) Develop and implement an incentive program to encourage graywater use in new homes and/or multi-unit properties and/or certain new commercial developments such as office parks; Or,

2) Adopt an enforceable ordinance or rules requiring use of graywater on all new homes and/or multi-unit properties and/or certain new commercial developments such as office parks.

F. Documentation

To track the progress of this BMP, the utility should gather and have available the following documentation for each year of implementation:

1) Depending on which sectors the utility has decided to focus on, the number of new homes and/or multi-unit properties and/or certain new commercial developments such as office parks, started and completed after adoption of this BMP;
2) The number and type of graywater installations completed each year; and
3) The estimated graywater use in each graywater installation.

G. Determination of Water Savings

Water savings will vary depending on the type of installation and will likely be unique to each customer installing a graywater system. There may also be some cases where graywater use will provide more water for a purpose than is currently being met with potable water. Only the reduction in potable water use should be calculated as the actual savings. In general, calculate water savings as follows:

- For single-family units, calculate gallons of potable water use replaced by graywater and multiply this estimated potable water savings per house times the number of houses installing a graywater system.

- For commercial and other properties, calculate gallons of potable water use replaced by graywater. In some cases, water savings for commercial developments can be calculated based on the number of employees and graywater discharge per employee.

H. Cost-Effectiveness Considerations

The costs to the utility will center around the administrative costs of working with existing and potential graywater projects, including review of plans and inspection of construction. Utilities may also consider offering incentives. Depending on program design and whether project inspections are required, staff labor cost should range from $50 to $100 per project. Marketing and outreach costs range from $20 to $50 per project. Administrative and overhead costs range from 10 to 20 percent of labor costs.

I. References for Additional Information

1) *Graywater System Guidelines, Green Building Program Sustainable Building Sourcebook.* http://greenbuilder.com
2) *Impacts of Demand Reduction on Water Utilities,* AWWA Research Foundation, 1996.
3) *Residential End Uses of Water,* AWWA Research Foundation, 1999.
4) *Quantifying the Effectiveness of Various Water Conservation Techniques in Texas,* Texas Water Development Board, May 2002.
5) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
6) *Texas HB 2661.* http://www.capitol.state.tx.us/tlo/78R/billtext/HB02661F.HTM
7) *City of Austin Green Builder Program.* http://www.ci.austin.tx.us/greenbuilder/

2.20 Park Conservation

A. Applicability

This BMP is intended for all Municipal Water User Groups ("utility") which manage parks or serve customers with parks which consume water. These include facilities such as irrigated parks, recreation centers, fountains or pools at which the visible use of water often comes under scrutiny by the public and water resource managers both because of large water demand to maintain a park and because of the perception that the water use may be excessive.

The specific measures listed as part of this BMP can be implemented individually or as a group. Utilities may already be implementing one or more these elements and they may want to adopt additional elements outlined in this document. Once a utility decides to adopt this BMP, the utility should follow the BMP closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

Park irrigation conservation practices as well as the careful use of water in operation and maintenance of park facilities can effectively reduce water demands. Under this BMP, the utility requires the management of each park with an irrigation system to develop a conservation plan that includes the elements described in this section. A Municipal Park Department should develop comprehensive written water conservation policies and procedures that cover all irrigated parks under its jurisdiction. Maintenance and operations of park facilities such as pools are also addressed. All park facilities should be metered and water use billed as means of reinforcing the importance of water use efficiency to park management.

Under the plan the park manager implements a watering regimen that uses only the amounts of water necessary to maintain the viability of the turf and landscape material appropriate for the use of the park. Water should only be applied to areas that are essential to the use of the park. For parks with athletic fields, the fields should be irrigated in accordance with the guidelines of the Athletics Fields BMP. Utilities should consider methods to encourage park managers to cease irrigation of areas that do not affect the use of the park by the public.

The utility should coordinate with Park Department or customer staff to ensure implementation of a large landscape water-use survey of irrigated areas and develop reference evapotranspiration ("ETo")-based water-use budgets equal to no more than 80 percent ETo per square foot of landscape area. The landscape survey should include the following elements: measurement of landscape area; measurement of total irrigable area; irrigation system checks and distribution uniformity analysis; and review or development of irrigation schedules. Alternatively, the utility may allow individual customers to perform their own surveys with properly trained staff or consultants and provide documentation of the survey to the utility.

The statewide Texas Evapotranspiration Network (http://texaset.tamu.edu/) should be consulted for historical evapotranspiration data, historical precipitation, and methodology for calculating reference evapotranspiration and allowable stress. Communities located in the North Plains areas

may find local historical data on potential evapotranspiration at
http://amarillo2.tamu.edu/nppet/whatpet.htm

At a minimum, compliance with this BMP should require the replacement of all manually controlled or quick couple irrigation systems with automatic irrigation systems and controllers. The automatic controllers must be capable of shutting off flow when a sudden pressure loss occurs from a broken system. It is important that access to such controllers be limited to the authorized landscape manager, or be designed to shut off flow automatically if the irrigation system is activated manually. The authorized landscape manager should be trained in good soil management and cultural practices such as proper aeration, nutrient management, mowing and soil testing as well as in irrigation management.

When cost-effective, the park irrigation user should be required to provide methods for achieving enhanced water conservation through computer controlled irrigation systems ("CCIS") or similar technology. In order to achieve maximum efficiency a CCIS should include at least the following components: computer controller (digital operating system), software, interface modules, satellite field controller, soil moisture sensors, and weather station. A CCIS should be designed so as to prevent overwatering, flooding, pooling, evaporation, and run-off of water, and should prevent sprinkler heads from applying water at an intake rate exceeding the soil holding capacity. Park organizations with a number of remotely located park irrigation systems should consider a CCIS with satellite systems. The utility may choose to offer incentives for park irrigation management in direct relation to the size and sophistication of the system.

The utility implementing this BMP should consider offering training for park irrigation management or co-sponsoring training with qualified horticulture or park management programs. Documentation of cultural practices and soil management measures should be included in a successful program.

Water wasting practices during park irrigation should be eliminated, including water running in gutter, irrigation heads or sprinklers spraying directly on paved surfaces, operation of automatic irrigation systems without a functioning rain shut off device, operation of an irrigation system with misting or broken heads, and irrigation during summer months between the hours of at least 10 a.m. and 6 p.m.

Use of reclaimed, reused, and/or recycled water for park irrigation offers excellent opportunities for conservation of potable water. However, specific uses must meet Texas Commission on Environmental Quality ("TCEQ") water quality standards for reclaimed water and human contact and must be appropriate for the specific use of the park. Reclaimed water should be applied based on the appropriate water budget.

1) <u>Park Facilities</u>
   Playground equipment and facilities such as recreational facilities, tennis courts, basketball courts, and park and pool buildings should be swept for regular sanitary purposes and only cleaned with the amounts of water needed for human health and safety purposes. Showerheads, faucets and toilets in park facilities should be retrofitted with efficient fixtures.

All public swimming pools should be equipped with recirculation and chlorination equipment. While not common, there are pools that are filled and drained everyday with potable water and that practice should be discontinued. Overflow drains should be plumbed back into the recirculation system. Swimming pools should be managed to minimize operational losses due to evaporation, splashing and filter backwashing. Proper design, optimal backwash scheduling, and use of a pool cover can help limit all these losses. Regular maintenance during the off-season should include testing for water loss and repair of leaks. Use of pool covers is also an important consideration for reducing water losses due to evaporation, although safety concerns where pools are accessible after hours require careful implementation.

Decorative water features at parks including fountains and augmented streams should use recirculation systems. During high temperature seasons reduced operating procedures and use of covers can reduce evaporation losses. Reuse of non-potable water such as reclaimed water should also be considered where available. Rainwater harvesting is also an option for many park facilities with large roof areas.

2) Botanical Gardens

Botanical Gardens or other related areas in parks are usually run by staff trained in proper water management techniques to meet plant needs. However, water saving opportunities should be explored in leak detection and repair, installation of low-water-use demonstration gardens, and the use of rainwater harvesting or alternative water supplies as conservation techniques. The planting and maintenance of low-water-use demonstration gardens can assist the utility in the implementation of the WaterWise Landscaping, School Education, and Public Information BMPs.

Soil improvement is an effective method for reducing irrigation water usage while maintaining healthy soils. Soil improvement programs on high visibility areas such as public parks can demonstrate to the public the effectiveness of this method. For parks, compost applications of 1/4 to 1/2 inch annually on turf areas and one inch annually on flower beds are recommended. Compost is most beneficial when applied in the fall.

C. Implementation

Prior to development of a specific park conservation plan, the utility should consider a series of planning meetings with park irrigation personnel and management to discuss water conservation issues and to prepare an adequate scope of action for the plan. Additionally, a number of voluntary environmental management programs exist in which park irrigation staff could participate. There are two approaches to be considered for implementing the park irrigation conservation plan: an incentive or voluntary approach and an ordinance or other enforceable requirement approach.

1) Incentive or Voluntary Compliance Approach
The utility may provide staff or contract with a third party to develop the conservation plan, including a water audit of the park irrigation system and practices. The water-use survey, at a minimum, includes measurement of the irrigated turf areas; determination if hydrozones within the irrigation system are proper for the type of turf present; irrigation system checks and distribution uniformity analysis; review of irrigation schedules or development of schedules as appropriate; and provision of a customer survey report and information packet.

If indicated by survey results and if cost-effective, the utility may offer incentives to the park irrigation user for upgrading irrigation systems, installing or upgrading controllers, changing hydrozones to eliminate irrigation of areas that do not receive high foot traffic, or for reducing the amounts of potable water used.

When cost-effective, the utility should offer workshops by trained professionals on pesticide, soil and nutrient management for optimal water use efficiency. An advantage to using third parties is that assistance in implementation can be provided at minimal cost to the utility.

To ensure that water savings goals are met, the utility should be explicit about the efficiency expectations of any voluntary or incentive programs. Park facilities and operations other than irrigation systems should also be included in the incentive or voluntary compliance approach.

2) Ordinance or Enforceable Requirements Approach
For utilities with ordinance or rule making powers:
In the first twelve (12) months: Plan, develop, and pass an ordinance that requires development and implementation of the conservation plan, including stakeholder meetings as needed. Develop a plan for educating customers, especially those directly affected by the requirements of the ordinance. Plan customer follow-up compliance and education after ordinance passage. Implement ordinance and tracking plan for violations, compliance notifications, and enforcement.

After ordinance passage (in the 2nd year and on): Continue implementation and outreach program for customers. Continue compliance education and initiate enforcement programs. Enforcement can include citations with fines and service interruption for repeat offenders.

For utilities that lack ordinance or rule making powers:
In the first twelve (12) months: Plan a program including stakeholder meetings as needed. Develop a plan for educating customers, especially those directly affected, about the requirements of park irrigation conservation plans. Develop follow-up compliance and education program. Implement water conservation program and tracking plan for violations and compliance notifications. Consider passing excess-use rates as a disincentive to park irrigation operations that do not stay within a budgeted amount of water (See Conservation Pricing BMP).

D. *Schedule*

To accomplish this BMP, the water user should do the following:

1) The utility with ordinance or rule making powers should adopt an incentive program or an ordinance or rules within twelve (12) months of commencing this BMP.
2) The utility with ordinance or rule making powers should implement the incentive plan or commence enforcement upon adoption of the ordinance or rule.

E. *Scope*

To accomplish this BMP, the utility should adopt park irrigation conservation policies, programs or ordinances consistent with the provisions for this BMP specified in Section C.

F. *Documentation*

To track the progress of this BMP, the utility should gather and have available the following documentation:

1) Copy of incentive plan or park irrigation conservation ordinances or rules enacted in the service area;
2) Metered water readings before and after any changes are implemented.
3) Copy of compliance or enforcement procedures implemented by utility, if applicable;
4) Survey of public swimming pools and actions taken to increase the efficiency of the pools.
5) Records of enforcement actions including public complaints of violations and utility responses, if applicable;
6) Where incentives are used, the number of park facilities completing the incentive plan;
7) Changes to irrigation systems, retrofits, or upgrades, regular leak detection and maintenance policies, and estimated water savings from conservation practices.
8) Water savings attributable to changes implemented; and
9) Costs of incentive plan(s) or ordinance if applicable.

G. *Determination of Water Savings*

Estimating total water savings for this BMP may be difficult; however, water savings can be estimated from each water-wasting measure eliminated through the actions taken under this BMP. For the replacement of inefficient equipment, the water savings are the difference in use between the new or upgraded equipment and the inefficient equipment. For landscape water waste, the savings can be calculated based on estimated savings from each water waste incident. For an irrigation survey, water savings can be expected in the range of 15 percent to 25 percent for park irrigation operations that do not yet have a CCIS and which choose to implement the efficiency measures recommended by the survey.

Switching to reuse or other nonpotable water or other alternatives can save up to 100 percent of the potable water supply used in irrigation. The savings are determined by comparing water use before and after the conversion to the new water supply. The savings for swimming pools that have been modified or repaired can be measured in the same way.

H. Cost-Effectiveness Considerations

The labor costs for an irrigation survey of a park range from $250 to more than $1000 for an irrigation survey depending on the efficiency in scheduling the surveys, the size of the facility, and the scope of the survey. Surveys can be performed by utility staff or by contractors.

Marketing and outreach costs range from $5 to $15 per survey depending upon whether parks are owned by the same municipality as the utility. Administrative and overhead costs are in the range of 10 to 20 percent of labor costs. Costs for upgrades to irrigation systems and controllers can be much more extensive depending upon the scale of changes needed. While less expensive, costs for pool leakage repair and other water efficient equipment are also very site specific. Incentive programs for park conservation equipment upgrades or maintenance will need to evaluate costs on a case-by-case basis.

I. References for Additional Information

1) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
2) *Maintaining Park Irrigation,* J. A. Murphy. http://www.rce.rutgers.edu/pubs/pdfs/fs105.pdf
3) *Managing Bermudagrass Turf: Selection, Construction, Cultural Practices, and Pest Management Strategies*, L. B. McCarty, Grady Miller, John Wiley & Sons, July 2002.
4) *Managing Healthy Sports Fields: A Guide to Using Organic Materials for Low-Maintenance and Chemical-Free Playing Fields*, by Paul D. Sachs, John Wiley & Sons, January 2004.
5) *Water Management Stretches Irrigation Water*, E. K. Chandler. http://www.txplant-soillab.com/page32.htm
6) *Park Irrigation and Water Conservation,* Texas Agricultural Extension Service. http://soilcrop.tamu.edu/publications/pubs/b6088.pdf
7) *Irrigation System Design and Management Courses*, Irrigation Technology Center, Texas A&M, http://irrigation.tamu.edu/courses.php

2.21 Conservation Programs for Industrial, Commercial, and Institutional Accounts

A. Applicability

This BMP is intended for all Municipal Water User Groups ("utility") which serve industrial, commercial, and institutional ("ICI") customers. Conservation programs for ICI accounts are essential for increasing water efficiency among ICI users. For many utilities, consumption in the ICI sector is a significant proportion of total consumption, and average water use by ICI customers is higher than average water use by residential customers. In these circumstances significant overall reductions in water demand can be more rapidly achieved by developing a Conservation Program for ICI Accounts. Additional information regarding specific processes is found in the industrial section of the BMP guide.

B. Description

Under this BMP, the utility identifies ICI customers and sorts them according to water usage. The utility should focus its ICI Conservation Program toward the higher use customers and those sectors with the highest conservation potential. In addition to domestic water use by employees and customers, many industry-specific processes are captured in this BMP. Differences in this industry-specific category of water use result in unique opportunities for significant water savings within each utility service area. Similarities in overall water use by ICI customers create the opportunities for an ICI Water Conservation Program which is the subject of this BMP.

Utilities wishing to pursue efficiency among their ICI customers should consider programs which offer incentives for specific activities such as: retrofits of inefficient water cooled equipment with air cooled equipment (*See,* Cooling Systems BMP), cooling tower upgrades (*See,* Cooling Tower's BMP), installation and operation of internal recycling equipment, or conversion to reclaimed water from the local water treatment plant in processes where nonpotable water can be used (*See,* Industrial Alternative Sources and Reuse of Process Water BMP). In addition to process changes and cooling tower upgrades, incentives can be offered for condensate collection and reuse, using water quality ponds for permanent storage for irrigation or use of process water for irrigation. Efficient landscape water use should be evaluated and implemented by using appropriate elements of the Landscape Irrigation Conservation and Incentives BMP and the Rainwater Harvesting and Condensate Reuse BMP. For clothes washers in common area laundry rooms in apartment communities and for self-service laundromats, a clothes washer incentive program could be offered.

The incentive programs should start with direct communications through newsletters or direct mail to introduce the program and give examples of successful efficiency efforts (*See* Industrial BMP for Management and Employee Programs).

While a significant portion of conservation savings for industrial customers comes from modifications to water using equipment and processes, additional savings for the commercial and institutional customers comes from water used for domestic purposes. Programs and incentives for plumbing fixture retrofits and reduction in water wasting practices should be considered. Several municipal BMPs such as Prohibition of Wasting Water; Showerhead, Aerator, and Toilet Flapper Retrofit; and Residential Toilet Replacement Programs provide good guidance for the development of programs for ICI customers in these areas.

A water use survey program (*See,* Industrial Water Audit for guidance) is another program that can educate ICI customers about potential water savings. To accurately track water usage by ICI accounts, the utility should develop and market an ICI water-use survey. Water-use surveys should include a site visit; an evaluation of all water-using equipment and processes; a report identifying recommended conservation measures and their expected payback; and available agency incentives. The utility should conduct periodic follow-up visits to evaluate the status of recommended water-saving improvements.

In lieu of customer incentives programs and water-use surveys, the utility may choose to implement other efforts to reduce water usage in the ICI sector. All ICI customers should be encouraged to become familiar with BMPs that may be appropriate to their facilities including those related to fixture retrofits, landscape management, submetering, employee education, and reuse. The utility can also set goals for the ICI sector in relation to the utility's own gallons per capita per day ("GPCD") targets and goals from its overall conservation plan.

C. Implementation

Implementation should consist of at least the following actions:

1) <u>Identify ICI Accounts</u>
Identify and rank commercial, industrial, and institutional accounts (or customers if the agency chooses to aggregate accounts) according to water use and highest conservation potential. For purposes of this BMP, ICI accounts are defined as follows:
    a. <u>Commercial Accounts</u>: any water user that provides or distributes a product or service, such as hotels, restaurants, office buildings, commercial businesses or other places of commerce. These do not include multi-family residences, agricultural users, or customers that fall within the industrial or institutional classifications.
    b. <u>Industrial Accounts</u>: any water users that are primarily manufacturers or processors of materials as defined by the Standard Industrial Classifications (SIC) Code numbers 2000 through 3999 or the North American Industry Classification System.
    c. <u>Institutional Accounts</u>: any water-using establishment dedicated to public service. This includes schools, courts, churches, hospitals, and government facilities. All facilities serving these functions are to be considered institutions regardless of ownership.

After ranking ICI accounts by water use, identify priority customers for incentives based upon cost-effectiveness or ease of program implementation.

2) 5-Year ICI Ultra Low Flush Toilet (“ULFT”) Program
Implementation should consist of at least the following actions:
a. A retrofit program to replace 50 percent of existing high-water-using toilets with ultra-low-flush (1.6 gallons or less) toilets in commercial, industrial, and institutional facilities within 5 years.
b. Other programs that may be at least as effective as facilitating toilet replacements over a 10-year implementation period sufficient to produce cumulative water savings to 5 percent of total water savings potential per year for ULFT retrofits by the ICI sector.

3) ICI Customer Incentives Program and Water-Use Surveys
Implement an ICI and Customer Incentives Program. Develop a customer targeting and marketing strategy to provide customer incentives to ICI accounts such that each ICI sector’s average annual water demand, after considering growth in demand that may occur from new ICI customers, is reduced 10 percent within 10 years of the date implementation is to commence. Directly contact (via letter, telephone, or personal visit) and offer water use surveys and customer incentives to at least 10 percent of each ICI sector on a recurring basis.

Financial incentives can be offered on a dollar amount per piece of equipment retrofitted such as toilets, clothes washers or cooling tower conductivity meters. Another option for determining the amount of potential incentives is offering an open-ended incentive per gallon per day saved so that facility managers propose the projects. This approach places utility staff in the role of evaluating such proposals.

For utilities which choose to offer water-use surveys, the surveys include a site visit, an evaluation of all water-using apparatus and processes, a customer report identifying recommended efficiency measures with their expected payback period, and available agency incentives. The Industrial Water Audit BMP can provide good guidance for development of the survey.

Within one year of a completed survey, there should be follow-up via phone or site visits with customers regarding facility water use and water-saving improvements. The utility should track customer contacts, accounts (or customers) receiving surveys, follow-ups, and measures implemented. Develop a customer targeting and marketing strategy to provide water-use surveys to ICI accounts such that 10 percent of each ICI sector’s accounts are surveyed within 10 years of the date implementation is to commence. Directly contact (via letter, telephone, or personal visit) and offer water use surveys and customer incentives to at least 10 percent of each ICI sector on a repeating basis.

4) ICI Conservation Performance Targets
Utilities may choose an alternative approach based upon local customer base and specific circumstances. To be effective as a BMP, they should implement programs designed to achieve annual water-use savings by ICI accounts of an

amount equal to or exceeding 10 percent of the baseline use of ICI accounts in the utility's service area over a ten-year period, accounting for growth. The target amount of annual water-use reduction in ICI accounts is a static value calculated from the baseline amount of annual use. Baseline use is defined as the average annual use by ICI accounts in the five years prior to implementing the BMP.

D. Schedule

1) Within the first twelve (12) months of implementing this BMP, identify industrial, commercial, and institutional accounts and sort them by water use;
2) Replace at least 10 percent of existing high-water-using toilets with ultra-low-flush (1.6 gallons or less) toilets each year for 5 years;
3) By the end of year 5 contact and offer water-use surveys and customer incentives to 100 percent of ICI accounts;
4) By the end of year 10 complete water-use surveys for 10 percent of ICI accounts; and
5) If utilizing other programs in lieu of the water-use survey and customer incentives program: by the end of year 10, reduce ICI water usage by 10 percent of baseline ICI usage.

E. Scope

To accomplish this BMP, the utility should adopt ICI conservation policies, programs or ordinances consistent with the provisions for this BMP specified in Section C.

F. Documentation

To track this BMP, the utility should provide the following documentation:

1) The number of customers and amount of water used within the commercial, industrial, and institutional customer classes;
2) Number of toilets replaced each year;
3) A description of the plan to market water-use surveys to ICI accounts;
4) The number of ICI customers offered water-use surveys during the reporting period and the number of water-use surveys completed during the reporting period;
5) The number of follow-ups completed during the reporting period;
6) The type and number of water-saving recommendations implemented; and
7) If utilizing other programs in lieu of the water-use survey and customer incentives program, a description of the programs and estimated water-use reductions achieved through these programs. The utility should document how savings were realized and the method and calculations for estimating savings.

G. Determination of Water Savings

Calculate water savings as follows:

Using historical records and manufacturer data as appropriate, calculate water savings due to implemented operating procedures, equipment changes or alternative water sources.

Specific water savings calculations for cooling tower efficiency improvements can be found in the Cooling Tower BMP for industrial users.

For Water Surveys
Water Savings = Number of Surveys x Estimated Savings x Water Used

Where: Estimated Savings = 20 percent or percentage determined through survey results
Water Used = Average (5 year) annual water use by ICI customers receiving the survey

Source: A&N Technical Services, Inc. (1999)

H. Cost-Effectiveness Considerations

1) Toilet Rebates

If the rebate cost for the toilet is set too low, only those customers planning to retrofit will do so. If the rebate is set too high, the utility will be overpaying for customers to retrofit. Most utilities have found a rebate to work effectively if set between $75 and $130 for the toilet and flush valve.

Some utilities find it is more cost effective to provide toilets free of charge to their customers. Flush valve bowls and the flush valves can be purchased in bulk for approximately $50 to 60 and $35 to 40 respectively. Administration of the program can be conducted by utility staff or contracted out. There will be labor costs for application processing and inspections to verify installation. Labor costs range from $10 to $20 per toilet. Marketing and outreach costs range from $5 to $10 per toilet. Administrative and overhead costs range from 10 to 20 percent of labor costs. To calculate the total cost per unit, total all costs and divide by the number of units being retrofitted.

2) General ICI Rebate

The rebate can be based on a set amount such as $1 per gallon per day reduction up to a certain percentage of the actual customer costs of implementing the project. Often the cap for the rebate is 50 percent of the actual costs of the project.

I. References for Additional Information

1) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*, New Mexico Office of the State Engineer, July 1999. (http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf)
2) *Commercial and Institutional End Uses of Water*, AWWA Research Foundation, Summer 2000.
3) *Commercial Conservation Rebates & Audits*, San Antonio Water System. http://www.saws.org/conservation/commercial/
4) *Commercial/Industrial Rebate Program,* Metropolitan Water District of Southern California. http://www.mwd.dst.ca.us/mwdh2o/pages/conserv/program02.html
5) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
6) *Waste Not, Want Not: The Potential for Urban Water Conservation in California*, Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
7) *Water Efficiency Guide for Business Managers and Facility Engineers*, State of California Department of Water Resources, October 1994.

2.22 Cost-Effectiveness Analysis for Municipal Water Users

A. Discussion

The decision whether to implement a water conservation program should be based on some type of benefit-cost or cost-effectiveness analysis. The underlying concept is a comparison of the inputs of any action with the outcomes, usually expressed in dollars. In evaluating water conservation efforts, the decisions center around comparison of the costs of implementing a program against the "costs of conserved water" or the "avoided costs" of acquiring new sources of water. In the strictest sense, if the analysis shows that the water user will gain positive value (benefit-cost) or that the costs of one option are less than the costs of another (cost effectiveness), then the conservation program should be implemented. In reality, there are external factors that are also considered such as public perception, long term environmental considerations, or political factors that may affect the decision.

A variety of analytical processes are used in making these types of decisions. One of the most common is use of present value techniques to evaluate expenditures or income incurred at different times. Present value takes into account the time value of money. Basic principles that are part of making valid present value analyses include:

- Selection of the appropriate discount rate.
- Consistency in the consideration of inflation.
- Matching the time period for the analysis.
- Ensuring that all appropriate cost and benefits are considered.

There are many studies, models and worksheets that have been developed to guide the decisions for implementing water conservation programs using present value analysis. For these decision models to be more accurate and consistent, they may be quite detailed in the assumptions made, statistical smoothing of data, and consideration of influencing parameters such as weather or natural replacements. (*See* Section D References for Additional Information, 1 and 2 for good examples)

The challenge is to make an analysis that reflects real life situations and is complete, but still comprehensible and usable. It is important that in an analysis that consistently compares the costs of implementing a conservation program to the costs of water saved or deferred, that the costs themselves be consistently developed.

1) Program Costs

   To determine the program costs of a BMP it is important to include those costs associated with both administration and implementation. They can be categorized generally along the lines of:

   - Capital expenditures for equipment or conservation devices.
   - Operating expenses for staff or contractors to plan, design, or implement the program.
   - Costs to the customers.

Program costs should be measured in reference to the opportunity costs of a program – that is, what must be foregone in order to provide the service. The costs should be realistic costs, both direct and indirect, that would be incurred above and beyond those the entity would normally incur if the program were not implemented. The timing of the costs is extremely important, whether up front, one time only, intermittently recurring, or ongoing on a periodic basis. The analysis should use all of the costs incurred over the life of the program. Specific program considerations for the different BMPs will be developed.

Each BMP has one or more of the costs and benefits categorized below. Cost considerations specific for BMPs are summarized in Section H under the individual BMPs.

- Start up: Any equipment necessary to initiate a BMP such as a computer for database tracking, software, specialized equipment, etc.
- Staff and administrative costs: Water conservation staff or contractor costs for implementing the BMP on an ongoing basis.
- Marketing and promotion: Costs for bill stuffers, media advertising, direct mail, etc., to let customers know about the BMP program. In many cases, marketing and outreach costs and expenses can be reduced or spread out when multiple BMPs are implemented by an entity.
- Materials: Costs for education and other materials provided to customers such as student workbooks and plant guides, etc.
- Incentive: Cost of incentives or rebates and/or any free equipment provided to customers.

2) <u>Costs of Saved Water</u>
If a conservation program will result in less water used (saved water) from existing supplies or less water needed from a wholesale supplier, then the benefits to the user are developed along the lines of:

- Direct avoided costs of treatment and delivery of water, including labor, energy, and chemicals.
- Costs of water not purchased from a wholesale supplier.
- Other expenses associated with the cost of providing water.

These costs are sometimes known as marginal operating costs. In the case of saved water, the costs that are to be compared to the costs of implementing the program are those directly saved by the provider, and not always the same as the lost revenues at the retail rate that would have been charged to the consumer.

Other benefits that may be considered include:

- Direct benefits: reductions in hot water use, energy use, and landscape labor costs when the frequency of watering and fertilizing is reduced.

- Indirect benefits: better air quality when energy use is decreased; and improved runoff water quality when fertilizer and herbicide use is reduced in landscape related BMPs.
- Environmental: One example would be reduced water withdrawals from rivers due to implementation of BMPs, resulting in more inflows to bays and estuaries.

3) Avoided Costs of Supply

Avoided water supply costs are those total costs, both capital and operational associated with new water supply that is deferred, downsized, or eliminated because of the conservation effort. These include:

- Capital costs of construction of production, treatment, transportation, storage, and related facilities.
- Costs of obtaining water rights and permits.
- These costs may also include avoided costs of additional wastewater treatment facilities if significant.
- Directs avoided costs of treatment and delivery of water, including labor, energy, and chemicals.

The Texas Water Development Board has very detailed cost guidelines for determining the values of the water management strategies in Section 4.2.9 of its Guidelines for Regional Water Plan Development. In making the comparisons it is very important that costs for water supply facilities still needed, but deferred until some point in the future, are discounted properly in the present value analysis.

B. Determination of Water Savings

Besides development of the costs themselves, the next most important number in a cost effectiveness analysis is the actual volume of water saved associated with a particular conservation BMP. Careful efforts should be made to ensure that the volumes of water savings are associated with the costs incurred. In some BMPs, the water savings associated with a conservation measure may be continual or permanent, where in other cases they can be determined over a defined life.

In some cases there can be an easy correlation. For example, each toilet retrofit measure is estimated to save 10.5 gallons per day per person. The total amount of water saved by the measure can then be estimated from the number of measures to be implemented. A toilet has an average life of 25 years so the savings due to the program would be estimated over the total life, even though the period of program implementation may be less than that.

In other cases, due to the nature of the BMP, there really are not easy ways to predict water savings. In reality, when BMPs such as these are included along with other water conservation activities, there will be a complementary or synergistic effect that should enhance the overall success of the initiatives.

C. Cost-Effectiveness Considerations

To make valid cost effectiveness decisions, costs must be presented on a comparable basis. In comparing the costs of conservation programs, the costs of saved water, or avoided costs of water, the costs are usually condensed down to terms of dollars per acre ft ($/ac ft) or dollars per measure ($/unit).

Two levels of comparison costs can be developed from the analyses. At the first level, for general comparison purposes, costs are given as an annualized or amortized value, which is the equivalent to an equal payment per time period over the life of the program for a one-time cost or stream of costs. The second level of costs for specific measures is the present value of all costs for a specific scenario, usually calculated and expressed in $/ac ft.

1) Example Cost Effectiveness Models

Two models have been developed to provide examples of how the cost effectiveness of conservation programs can analyzed. The example BMP Cost Analysis Spreadsheet is designed for use to evaluate the costs of implementing a BMP. The example Supply Analysis Spreadsheet allows future expenditures to obtain water supply over a period of time to be valued in the present. Then these expenditures can be compared with the present day costs of implementing conservation programs.

Cost of BMP versus New Water Supply: The cost per acre-foot of new water supply and treatment capacity can be compared to the cost per acre-foot achieved by implementing the BMP. The Municipal Supply Analysis Table provides an example of the water supply cost savings that can be achieved by implementing one or more BMPs.

2) Notes on Present Value and Discount Rate

In order to compute net present value, it is necessary to discount future benefits and costs. This discounting reflects the time value of money. Present value analysis allows a comparison of alternative series of estimated future cash flows – either costs or income. To do a present value analysis we use a “discount rate” which by general definition reflects the minimum acceptable rate of return for investments of equivalent risk and duration.

Benefits and costs are worth more if they are experienced sooner. The higher the discount rate, the lower is the present value of future cash flows. For typical investments, with costs concentrated in early periods and benefits following in later periods, raising the discount rate tends to reduce the net present value.

What discount rate should be used? In constant dollar analyses the real discount rates used reflect the treatment of inflation and the adjustment of future costs for real price escalation. In the private sector, discount rates can vary significantly from investor to investor. We are using the TWDB recommended discount rate of

6 percent that is in line with current economic expectations and those frequently seen used in energy and water conservation projects.

By comparison, the Office of Management and Budget in its Circular A-94 Update (2004) recommends a base rate for Federal project evaluations to be determined using a nominal discount rate of 5.5 percent for 30 year projects. This rate is supposed to approximate the marginal pretax rate of return on an average investment in the private sector in recent years. The Federal Energy Management Program uses life cycle costing for project decision making for potential energy and water conservation projects and has established a nominal rate (includes a general price inflation factor) of 4.8 percent for 2004. The TWDB Planning group periodically uses an EPA recommended 6.38 percent in water infrastructure cost effective analyses.

3) Example Spreadsheet for BMP Cost Effectiveness Analysis

Municipal conservation programs typically involve the implementation of a combination of several BMPs. In this spreadsheet example are models based upon existing state plumbing code which will account for expected changes in demand due to natural replacement of less efficient plumbing fixtures over the next several decades. These anticipated changes are accounted for in the Cost Savings Analysis and Program Planning sheets that the conservation analyst will use to determine cost-effectiveness. This model can be expanded to include additional BMPs in a scenario-building model that can be used in conjunction with the Supply Analysis Needs worksheet.

Utility baseline information is required to be put in, as well as confirmation of assumptions for program implementation. Information required to be input for these BMPs includes:

	Example
2000 SF Population	752,791
2000 MF Population	248,658
Institutional Population	0
2000 SF Units	270,788
2000 MF Units	207,215
1995 SF Units	63,294
1995 MF Units	203,574
SF Growth Rate (Calc Ann Avg)	0.6%
MF Growth Rate (Calc Ann Avg)	0.4%
No. of ICI Customers	20,000
SF Household Size	2.78
MF Household Size	2.44
No. of Bathrooms per SF House	2.0
No. of Bathrooms per MF Unit	1.2

The following data is used by default, unless the user has more accurate data.

Category:	**Default**
No. of Bathrooms per SF House	2.0
No. of Bathrooms per MF Unit	1.2
No of Irrigation Months	6
% of High Use SF customers	10%
No. of MF Units per Washer	18
No. of MF Units per Complex	50
Additional Data:	
Toilet Natural Replacement Rate	2.0%
Showerhead Natural Replacement Rate	6.7%
Annual SF Program Goal (Housing Turnover Rate)	6.7%
Annual MF Program Goal (MF Housing Turnover Rate)	10%
Percent of SF Units with CWs	95%
Discount Rate	6.0%
Projected Inflation Rate	2.0%

These models also use net free ridership assumptions, a very real consideration in plumbing fixture program analysis. This considers the number of measures receiving an incentive that would have done the program anyway less the number of measures that were done because of the publicity about the conservation program without any incentives (free drivers).

The resulting information can be used in decisions to select cost effective BMPs to meet the water saving goals of the utility.

TABLE 1 EXAMPLE BMP COST SAVINGS MODEL

	Selected Length of Program (years)	Life of Measure (years)	Savings per Residential Capita (gpd)	Savings per Living Unit (gpd)
Residential	1	2	3	4
SF Toilet (ULFT) Retrofit BMP	10	25.0	10.5	29.2
SF Showerheads and Aerators BMP	10	15.0	5.5	15.3
MF Toilet (ULFT) Retrofit BMP	10	25.0	10.5	25.6
MF Showerheads and Aerators BMP	10	15.0	5.5	13.4
SF Irrigation Survey	10	10.0	18.0	50.0
ICI Irrigation Survey	10	10.0	NA	NA

	No. of Measures / Living Unit	Savings per Measure (gpd)	Natural Penetration Rate	Program Penetration Goal
Residential	5	6	7	8
SF Toilet (ULFT) Retrofit BMP	2.0	14.6	18%	80%
SF Showerheads and Aerators BMP	2.0	7.6	53%	80%
MF Toilet (ULFT) Retrofit BMP	1.2	21.4	20%	80%
MF Showerheads and Aerators BMP	1.2	11.2	53%	80%
SF Irrigation Survey	1.0	50.0	0%	50%
ICI Irrigation Survey	NA	470.0	0%	25%

	Number of Measures at Penetration Rate	Estimated Annual Savings (at Penetration Rate) (gpd)	Estimated Annual Savings (at Penetration Rate) (acre-ft/yr)	Number of Years to Reach Penetration Goal
Residential	9	10	11	12
SF Toilet (ULFT) Retrofit BMP	275,761	4,024,725	4,508	22
SF Showerheads and Aerators BMP	110,990	848,518	950	11
MF Toilet (ULFT) Retrofit BMP	138,200	2,950,563	3,305	15
MF Showerheads and Aerators BMP	64,077	716,600	803	8
SF Irrigation Survey	13,539	676,970	758	10
ICI Irrigation Survey	5,000	2,350,000	2,632	10

TABLE 1 cont.

Residential	Penetration Estimated at 10 Yr	Program Costs per Measure	Estimated Net Free Ridership	Net Program Costs per Measure
	13	14	15	16
SF Toilet (ULFT) Retrofit BMP	61%	$ 85	10%	$ 94
SF Showerheads and Aerators BMP	79%	$ 7	50%	$ 14
MF Toilet (ULFT) Retrofit BMP	70%	$ 75	10%	$ 83
MF Showerheads and Aerators BMP	82%	$ 4	50%	$ 8
SF Irrigation Survey	NA	$ 50	1%	$ 51
ICI Irrigation Survey	NA	$ 200	1%	$ 202

Residential	Cost per AF of Water Saved (Amortized)	Total Program Costs (at Penetration Rate)	Present Value of Program Costs (year 1 = 2005)	Estimated Water Saved over Life of Measure (acre ft)
	17	18	19	20
SF Toilet (ULFT) Retrofit BMP	$ 452	$ 26,044,051	$ 19,112,751	101,436
SF Showerheads and Aerators BMP	$ 168	$ 1,553,858	$ 634,306	7,128
MF Toilet (ULFT) Retrofit BMP	$ 273	$ 11,516,638	$ 9,117,548	74,364
MF Showerheads and Aerators BMP	$ 66	$ 512,620	$ 371,221	6,020
SF Irrigation Survey	$ 123	$ 683,808	$ 540,425	7,583
ICI Irrigation Survey	$ 52	$ 1,010,101	$ 980,392	26,323

Residential	Present Value Per Acre Foot Saved	Standard Delivery Description	Other Delivery Options
	21	22	23
SF Toilet (ULFT) Retrofit BMP	$ 188	free or rebate	direct install
SF Showerheads and Aerators BMP	$ 89	kits picked up by customer	door to door dist or direct
MF Toilet (ULFT) Retrofit BMP	$ 123	free or rebate	direct install
MF Showerheads and Aerators BMP	$ 62	kits picked up, installed by apt.mgmt	
SF Irrigation Survey	$ 71	audits performed by utility staff	contractor performs audits
ICI Irrigation Survey	$ 37	audits performed by utility staff	contractor performs audits

TABLE 1 cont.

Notes to Municipal cost Savings Model

SF=single-family, MF=multi-family *Population figures are from 2000 Census

Column 1 - user selects the length of time the program will be implemented for.

Column 2- assumed useful life of the measure

Column 3 - savings per person in gallons per day

Column 4 - savings per housing unit in gallons per day (Col 3 x No.of persons per living unit, input page)

Column 5 - the number of measures needed for each living unit

Column 6 - gallons saved per day for each measure

Column 7- estimated percentage penetration of efficient measures already accomplished: either defined or calculated from models

Column 8 - the potential number of customers who could be expected to implement the program with substantial marketing and outreach- includes natural replacements and retrofits

Column 9 - estimated number of measures ultimately accomplished by program (no. of MF or SF units x no. of measures per unit)

Column 10- potential savings in gallons per day (column 10 x column 7)

Column 11- potential savings for the region in acre-feet [(column 11 x 365) / 325,851]

Column 12- years to reach penetration goal selected in Column 9

Column 13- actual penetration achieved during life of program (Column 1) and desired retrofit goal per year (turnover rate, input page)

Column 14- program costs including rebates, staff time and marketing

Column 15- percentage of free ridership, or those that would participate even without incentive

Column 16- net program costs after adjusting for net free ridership

Column 17 - amortized cost per acre foot of water saved each year [(column 17 x 325,851 gallons/AF) / (column 6 x 365 days)]) amortized at discount rate over the life of the measure

Column 18 - total program cost (column 7 x column 10)

Column 19 - net present value of costs of program incurred each year

Column 20 - total acre feet of water expected to be saved over expected life of measure (col 7 x col 10 x col 2)

Column 21 - net present value of program per acre ft saved (col 20 divided by col 21)

Column 22 - delivery option(s) for which costs are estimated

Column 23 - other possible delivery options

4) Municipal Cost Effectiveness Example

This example shows a straight forward example of a midsize utility that is growing and that anticipates that it will have to purchase water rights or develop additional water supply. The utility would prefer to delay purchasing these additional rights if one of more BMPs would achieve the required savings to delay the purchase. This analysis does not take into account the reduced operating cost benefit to the utility of implementing the conservation measures.

A simple Example Municipal Supply Analysis spreadsheet has been set up for use by the utility to *Find the Benefit to the Utility of a Delay in Purchasing Water Supply*. The utility enters:

- increase in annual water demand (AF),
- number of AF to be purchased,
- number of years until the purchase will be made,
- cost for the additional water rights,
- years of the new supply contract,
- number of years of delay desired, and
- discount rate.

The Example Municipal Supply Analysis spreadsheet set up for this example contains the following assumptions (region-specific data from the State Water Plan or utility generated data should be used when performing this analysis for a particular conservation program):

- The utility water demand is increasing by 1000 AF per year.
- In 10 years, the utility anticipates being at 90 percent of its existing water supply and plans to purchase an additional 25,000 AF of water.
- The new water supply will cost $400 per AF and will be a 50-year contract.
- Water costs are anticipated to rise 2 percent per year.
- The utility hopes to delay the purchase by 3 years.
- The assumed discount rate is 6 percent.

Based on these assumptions, the utility would have to conserve 3000 AF of water. The Municipal Supply Analysis spreadsheet shows the present value of water saved ($/AF). To get to this number the spreadsheet includes several calculations. First the value of a 50-year water contract starting in 2015 is determined. It has been calculated using Microsoft Excel's NPV function. In this case, the NPV function is used to calculate the total amount that a series of future payments is worth in 2015.

The syntax of the Microsoft NPV function is NPV(rate,nper,pmt1,pmt2, pmt3,…);

- Rate is the interest rate per period. For simplicity this is presented as 6 percent per annum;
- Pmt1, Pmt2, Pmt3, …, are the annual payments for the time period selected. For this example the contract is 50 years, starting at $400 per AF in year 1 and increasing by 2 percent per year.

Next the NPV function is used to calculate the value of the 50-year water contract if it started after a 3-year delay, which would be 2018.

To determine the present value of the water saved, the difference in the present value in 2005 for the 2015 NPV value and the 2018 NPV value is determined. This is done using the appropriate discount factor. The difference between the 2015 and the 2018 PV values in 2005 dollars is the value of the conserved water.

Energy and chemical deferred cost savings are calculated in a separate tab and entered in this tab.

The present value of the delay and deferred chemical and water savings is $930 per AF that could be compared to the cost of implementing the water saving BMPs.

TABLE 2 EXAMPLE MUNICIPAL SUPPLY ANALYSIS WORKSHEET

Utility Entered Variables

1	Cost per AF	$	400	
2	No. of AF Purchase		25,000	
3	No.of Years until Purchase: No Conservation		10	
4	Annual Increase in Water Demand (AF)		1,000	
5	No of Years of Contract		50	
6	Delay Projected Due to Conservation		3	
7	Discount Rate		6.0%	
8	Increase in Water Costs per Year		2.0%	
9	Annual Cost per AF for Energy and Chemicals	$	65.00	
10	Estimated Annual Inflation in Energy and Chemical Costs		2.0%	
11	Water Savings Required (AF)			**3,000**
12				

13	Present Value of Contract if Purchased in 2015	Present Value of Contract if Purchase Delayed Until 2018	PV Value of Conservation per AF
14		642.36	
15	$8,538.78	$9,061.42	
16	0.538615114	0.447365096	
17	$4,599.12	$4,053.76	**$545.35**
18			**$384.91**
19			$\boxed{\textbf{\$930.26}}$

Notes

1 Negotiated or anticipate cost per AF
2 Amount of water to be purchased in AF
3 Anticipated date when water will be purchased without conservation
4 Projected annual increase in water demand without conservation
5 Length of supply agreement
6 Desired delay due to conservation
7 Rate that will be used to discount future cost back to present value in todays' dollars
8 Projected annual increase in user rates during the period of delay
9 Actual costs for Energy and Chemicals for water treatment per AF
11 This is the total water savings needed based on the annual growth in water demand and the length of delay selected
15 Cost per AF: This amount is the value for the 50 years of payment for 1 AF in 2015 and 2018.
16 Discount to Present: The calculated discount amount from 2015 to 2005; and 2018 to 2005
17 Present Value of Delay: The difference in the discounted value from 2015 to 2005; and 2018 to 2005
18 PV of Energy and Chemical Savings: From Energy and Chemicals tab
19 Total Present Value of Delay

D. References for Additional Information

1) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003.
2) *BMP Costs and Savings Study,* prepared for The California Urban Water Conservation Council, by A & N Technical Services, July 2000.
3) *Cost-Effective Cost Effectiveness: Quantifying Conservation on the Cheap,* David L. Pekelney, Thomas W. Chesnutt, and David L. Mitchell, Abstract of Paper presented at AWWA National Conference June 26, 1996.
4) Office of Management and Budget Circular No. A-94 Revised, October 29, 1992.
5) OMB Circular No. A-95, Appendix C (revised February 2004).
6) *Life-Cycle Costing Manual for the Federal Energy Management Program,* prepared for the U.S. Department of Energy, Sieglinde K. Fuller and Stephen R. Petersen, February 1996.
7) *Energy Price Indeces and Discount Factors for Life-Cycle cost Analysis – April 2004*, prepared for U.S. D.O.E, by U.S. Department of Commerce.

3.0 BMPs for Industrial Water Users

BMPs for industrial water users are a combination of proven management, educational, and physical practices that a water user can use to achieve efficient and economical conservation of water. Water consumption by industries, whether supplied by others or self-supplied from surface or groundwater sources, can be varied in amount of use, rate of use, and opportunities for efficiency. For many industrial water users in Texas, water is an integral part of a product or a process. Another major use of water is for cooling, either removing heat from processes or providing a comfortable safe environment through air conditioning. Some industries use water as a conveyance or for rinsing and cleaning products and containers. Numerous industrial facilities use water for landscape irrigation. The quality of water used by industries in different processes varies widely from ultra-pure treated water to water which does not meet potable water standards.

The wide variety in the types of water uses, the size of facilities and the types of activities at different industrial facilities makes it difficult to compare one water user to another, although there are certain overall comparisons that can be made. In many industries, the water used to produce a product may be divided by the output to calculate the gallons per unit of production. Each industrial water user should evaluate water use and efficiency potential at its own facility(s). As a result, the initial recommended Best Management Practice for all industrial water users is the Industrial Water Audit BMP where the user identifies the relationships between all water coming into the facility and the various uses of water within.

The next Industrial BMP that should be considered is the Industrial Water Waste Reduction BMP, which focuses on the most economical changes to improve efficiency. By implementing the Industrial Submetering BMP, an industry may be able to identify significant opportunities for monitoring ongoing water use within specific parts of its facility.

Additional Industrial BMPs focus on the water uses most common among Texas industries and in which cost-effective measures for increasing water use efficiency are well understood. The Cooling Systems and Cooling Tower BMPs deal with specific measures for reducing water use in cooling.

Many water uses in industrial settings can use water of lower quality than that necessary for human consumption. The Industrial Alternative Sources and Reuse of Process Water BMP addresses reuse of water both within processes of the facility and from other sources that may be available near the facility.

For industrial users who rinse or clean products in their facilities numerous opportunities arise for water conservation through controlling flow rates and reusing water as outlined in the Rinsing/Cleaning BMP. Those with more sophisticated water treatment processes should consider the Water Treatment BMP as a means of increasing efficiency.

For industrial users which use steam as a motive force or in high temperature processes, the Boiler and Steam Systems BMP is provided. The Refrigeration (including Chilled Water) BMP provides a template for those with large cooling operations of greater sophistication than typical cooling towers. For large industrial plants using bays or lakes for cooling, the Once-Through Cooling BMP offers guidance on efficiency for their operations.

All industrial users can benefit from the Management and Employee Programs BMP that includes guidelines for increasing employee support and participation in conservation efforts. Many industrial users also irrigate a large landscaped area. The Industrial Landscape BMP presents approaches for reducing water use or irrigating with alternative sources of water.

For industrial users that do not find their specific process covered among the other BMPs, the Site-Specific Conservation BMP is offered to help in developing a BMP to address their unique needs.

Best-management practices contained in the BMP Guide are voluntary efficiency measures that save a quantifiable amount of water, either directly or indirectly, and can be implemented within a specified timeframe. The BMPs are not exclusive of other meaningful conservation techniques that an entity might use in formulating a state-required water conservation plan. At the discretion of each user, BMPs may be implemented individually, in whole or in part, or be combined with other BMPs or other water conservation techniques to form a comprehensive water conservation program. The adoption of any BMP is entirely voluntary, although it is recognized that once adopted, certain BMPs may have some regulatory aspects to them (e.g. implementation of a local city ordinance).

3.1 Industrial Water Audit

A. Applicability

This BMP is intended for industrial water users and should be thought of as the initial BMP for industrial water users to increase water efficiency at their facility. Under this BMP, the water user collects information about all water that enters a facility and an understanding of how that water is used within a facility. Once an industrial water user decides to adopt this BMP, the water user should follow the BMP process closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

Water audits are effective methods to account for all water usage within a facility in order to identify opportunities to improve water use efficiency. Benefits from implementation of this BMP may include lower utility costs, energy savings, and reduced process costs. It will also provide information helpful in the implementation of related Industrial BMPs such as Water Waste Reduction BMP, the Industrial Submetering BMP, the Industrial Landscaping BMP, the Cooling Towers BMP, Cooling Systems (other than Cooling Towers) BMP, and the Industrial Alternative Sources and Reuse of Process Water BMP.

Facility water audits include accurate measurement of all water entering the facility, the inventory and calculation of all on-site water uses, any unused water sources or waste streams that may be available, calculation of water related costs, and identification of potential water efficiency measures. The information from the water audit should then form the basis for a comprehensive conservation program to implement specific water saving measures throughout the facility. The conservation program may consist of one or more projects in different areas of the facility.

The steps to conduct a water audit are listed sequentially in Section C. The order can be altered if it would be more effective at a particular facility. This BMP is the first step in implementing industrial water conservation. As the water user identifies opportunities for conservation, other BMPs will be indicated as listed below:

1) After completing this BMP, if unaccounted water is greater than 5 percent, the Water Waste BMP should be considered. At facilities, where no system of internal water measurement has been established, the determination to implement the Water Waste BMP should be delayed until the Submetering BMP is implemented.
2) The next step is to determine if the Submetering BMP needs to be implemented in order to be able to account for all water use within the facility.
3) If water use for irrigation represents a significant portion of demand, then the Landscape BMP should be considered and more detailed information on landscape irrigation and outdoor water use should be collected.
4) If the facility has a cooling tower, then the Cooling Towers BMP should be considered.

5) If there are cooling processes, then the Cooling Systems (other than Cooling Towers) BMP should be considered.
6) Finally, if there are opportunities to reuse water within the facility or reclaimed water is available from a utility provider, the Reuse of Process Water BMP should be considered.

C. Implementation

Generally following the guidelines as outlined in this section, the industrial water user should conduct a facility audit. References that provide more detailed audit procedures are listed in Section I.

1) <u>Preparation and information gathering</u>
The material collected should be used to implement this BMP and should be useful for other BMPs as well. Information that should be collected before beginning the audit includes maps of facilities with building sizes and locations of main water supply meters and any submeters, numbers of employees and work schedules, inventories of plumbing fixtures, inventories of water using equipment and processes including water quality limitations, and outdoor water use information including irrigation schedules and types and square footage of landscape materials. Also, water use and water quality data for the past three years should be collected such as utility records of water used and wastewater generated, actual water use on site including submetered use, and non-utility water use such as wells or storm water. Additionally, any prior water use surveys or energy audits should be obtained and reviewed since these reports may include useful and relevant information to determine the most appropriate water saving measures to implement. If the plant has a water right of greater than 1000 acre-feet per year, then it should have a water conservation plan submitted to the Texas Commission on Environmental Quality. If the plant has a waste discharge permit, the water balance diagram included with the permit should be obtained. All possible alternative sources of water should be inventoried.

2) <u>Conduct facility survey</u>
The on-site physical examination and water use survey should identify and verify all equipment that uses water, noting discrepancies to update the inventory. Equipment information should be verified or measured for hours of operation, meter calibrations, and manufacturers' listed flow rates. If appropriate, water quality should be analyzed so that reuse of water can be assessed. Daily water usage for each major water use area should be determined and, when added together, total facility usage calculated on a monthly basis and compared with the utility measured sales to the facility. The quantity of water used by specific processes should be considered in developing the priority list of facility areas for the audit.

If water use for irrigation represents a significant portion of demand more detailed information on landscape irrigation and outdoor water use should be collected.

When applicable, a determination of irrigation schedules from irrigation controllers should be made along with a run of the irrigation system to measure the distribution efficiency as well as to identify leaks, overpressurization, and broken heads. The Landscape BMP should be considered if it is determined that improvements in irrigation practices may offer opportunities for significant water savings.

3) Prepare a facility audit report
The data gathering and the facility survey should be incorporated into a facility audit report that includes an updated set of facility diagrams and water flow charts broken down by water use areas, a current list of all water using equipment including actual and manufacturer recommended flow rates, a current schedule of operations for all manufacturing or process areas and equipment, a monthly landscaping irrigation schedule based on no more than 80 percent of historical ETo with recommended landscaping equipment repairs and upgrades, water use observations revealed by the walk-through of the facility, an analysis of water costs by operating area and for the entire facility, identification of waters that have the potential for conservation and reuse and calculations of the difference between water coming into the facility and a list of identified water uses throughout the facility. (Note: This is the amount of water that is potentially being lost by leaks, which could be underground.)

4) Prepare a cost-effectiveness analysis
The cost-effectiveness analysis should determine the water efficiency opportunities that are cost effective to implement. The analysis may also identify water efficiency opportunities that should be implemented even if not cost effective due to high visibility, ease of implementation, or general employee and customer goodwill. If landscaping water use is a large component of water use, or if high quality effluent from processes is available, consideration should be given for reuse water on the landscape. After confirming the cost effectiveness of the BMP, the action plan should then be prepared based on the water users' own decision criteria which may include considerations for available resources, safety, compatibility with manufacturing facilities, and management priorities.

5) Prepare recommendations for action
The facility audit report should contain proposals and a timetable to implement selected water efficiency measures. The report is the first step in preparing a water conservation plan. In addition to other BMPs which are indicated through the audit results, the plan should address a leak detection program if needed, installation of submeters if needed, a regular water audit checkup schedule (i.e., weekly during the spring and summer, and monthly during the cooler months) to check flow rates for specific equipment, and to identify leaks, to adjust irrigation equipment and schedules, communication of the action plan to employees, communication of successful implementation of plan to the public, and procedures and policies to repeat audit process on an annual basis.

D. Schedule

1) The audit should be completed in a timely manner. Very large or complex audits should be completed within the first twelve (12) months of implementing this BMP.
2) The recommendations should be implemented within the first normal budget cycle following the conclusion of the audit. For most facilities, this should be a reasonable time period to implement the recommendations. Major projects may take additional time for audit and implementation. Obvious water leaks and problems found during the course of the audit should be repaired as soon after discovery as possible.
3) If determined to be necessary for very large or complex facilities or for more comprehensive conservation plans, the schedule can be extended. BMPs should be initiated in the second year and continued until the targeted efficiency is reached.

E. Scope

To accomplish this BMP:

1) Industrial water users with one facility, or several facilities with the same or very similar industrial processes, should conduct a water audit following the schedule outlined in Section D.
2) For industrial water users with multiple facility sites, or multiple industrial processes, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until all facilities have been audited and conservation measures implemented. Conservation measures implemented at one facility may not be applicable or cost-effective at another location.
3) Cost effectiveness considerations may result in partial implementation of this BMP at one or several of a large number of facilities.

F. Documentation

To track the progress of this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) The audit report;
2) Cost-effectiveness analysis;
3) The action plan;
4) Schedule for implementing the action plan;
5) Documentation of actual implementation of water efficiency measures contained in the action plan; and
6) Estimated water savings and actual water savings for each item implemented.

G. *Determination of Water Savings*

In order to calculate water savings, the industrial water user should use the methodology appropriate to the identified water efficiency opportunities. Estimated overall water savings for implementing the recommendations from the audit should be in the range of 10 percent to 35 percent if a similar audit process has not previously taken place .[1]

H. *Cost-Effectiveness Considerations*

The industrial water user should determine the cost effectiveness to implement each identified replacement or equipment upgrade, utilizing its own criteria for making capital improvement decisions. The facilities survey and audit report may be conducted and prepared by either the industrial water user's own staff or by specialized outside consultants. There may be additional one-time costs for equipment such as flow meters and additional costs for periodic inspections and audit updates. Some of the water savings opportunities found by the audit may require only minor capital expenditures and should be done simply as a matter of good practice.

I. *References for Additional Information*

1) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
2) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*. New Mexico Office of the State Engineer, July 1999. http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf
3) *Water Efficiency Guide for Business Managers and Facility Engineers*, State of California Department of Water Resources, October 1994.
4) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
5) *Commercial and Institutional End Uses of Water*, AWWA Research Foundation, Summer 2000.

3.2 Industrial Water Waste Reduction

A. Applicability

This BMP is intended for industrial water users that could increase water use efficiency at facilities by prohibiting specific wasteful activities such as wasteful irrigation practices and scheduling, single-pass cooling, non-recycling decorative fountains, discharge of process water and use of inefficient water softeners. In addition, if the facility has a substantial amount of unaccounted-for water, a leakage survey may need to be conducted. Once an industrial water user decides to adopt this BMP, the water user should follow the BMP process closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

A comprehensive program to reduce water waste is an effective method of improving water use efficiency. Benefits from implementing this BMP include lower utility costs, energy savings, reduced process costs and an enhanced public image. If the Water Audit BMP has been completed, some of the information needed for this BMP will already be available.

The industrial water user should first conduct a pre-survey, which is a walk-through of the facility to find out if there are any obvious wasteful activities taking place. Then a facility survey should be conducted and the following questions should be addressed:

1) How much water is being used?
2) Where is the water being used?
3) When and for how long is water being used?
4) How is water being used?
5) Who is using water?
6) Why is water being used?
7) Do we need to be using water at all?
8) Can the water quality of a process discharge be matched with the water quality of another process or equipment need?

In addition, depending on the type of facility being surveyed, water wasting practices should be identified, including, but not limited to, water waste in single pass cooling systems or equipment; non-recirculating systems in all new conveyer or inbay automatic vehicle wash and commercial laundry systems; non-recycling decorative water fountains; discharge of process water that could potentially be reused within the facility for another process use or for irrigation; and use of inefficient water softeners. Other water waste practices may include wash and rinse processes which run for longer time periods or at greater flow rates than needed or processes in which water is used as a conveyance.

Irrigation use can also be a source of water waste. Water waste during irrigation includes water running down the gutter; irrigation heads or sprinklers spraying directly on paved surfaces such as streets, parking lots, and driveways; operating an automatic irrigation system without a functioning rain shut off device; operating an irrigation system that has misting heads due to broken heads or failure to install pressure reduction device; irrigating between 10 a.m. and 6 p.m. during seasons with high evapotranspiration; and irrigating more than required by actual or reference evapotranspiration.

Proper controls can limit water use to the minimum necessary in many facility processes. Limiting or eliminating the use of water in facility wash down operations is also another potential means to reduce water waste. Significant water savings can also be achieved through a proactive and frequent facility leak detection and repair program that addresses all facility pipes, valves, plumbing fixtures, and process equipment.

C. Implementation

The industrial water user should conduct a facility water use survey. References that provide more detailed audit procedures are listed in Section I below.

1) Conduct a facility water use survey of all equipment, processes and practices to determine all places where there could be wasting water, use of water inefficiently or possible sources of water lost to leakage. Next, possible remedial actions should be ranked, in ascending order of efficiency value. These include
   a. Adjust equipment or process to use less water,
   b. Modify equipment or install water saving devices,
   c. Replace with more efficient equipment,
   d. Recycle water within the process or plant by matching the water quality of a process discharge with the water quality of a process or equipment need, and
   e. Change to waterless equipment or process.
2) Preparation of a report that details the results of the facility water use survey with calculations and costs of replacing water wasting equipment, processes and practices. For some practice changes, such as irrigation scheduling, the actual costs may be minimal.
3) Prepare a cost-effectiveness analysis for each type of equipment and each process or practice change. The cost-effectiveness analysis determines water efficiency opportunities that are cost-effective to implement. The analysis may also identify water efficiency opportunities that should be implemented even if not cost-effective due to high visibility, ease of implementation, or general employee and customer and community goodwill. After analyzing the cost-effectiveness of each potential action to eliminate a water wasting practice, the industrial water user should proceed to develop an Action Plan.
4) Prepare an Action Plan: The action plan contains proposals and a timetable to implement the selected equipment, processes and practices.

D. Schedule

1) The facility water use survey, report, cost-effectiveness analysis and action plan should be completed in a timely manner. Very large or complex facilities should

complete the facility water use survey, report, cost-effectiveness analysis and action plan within the first twelve (12) months of beginning this BMP.

2) The action plan should be implemented in the normal business cycle. Major projects may take additional time for implementation.
3) If determined to be necessary for very large or complex facilities, the schedule can be extended. BMPs should be initiated in the second year and continued until the targeted efficiency is reached.

E. Scope

To accomplish this BMP:

1) Organizations with one facility, or several facilities with the same or very similar industrial processes, should conduct a facility survey following the schedule outlined in Section D.
2) For organizations with multiple facility sites, or multiple industrial processes, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until all facilities have been surveyed and wasteful equipment, process and practices changed.

F. Documentation

To track the progress of this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) The facility survey report;
2) Cost-effectiveness analysis;
3) The action plan;
4) Schedule for implementing the action plan;
5) Documentation of actual implementation of items contained in the action plan; and
6) Estimated water savings and actual water savings for each item implemented.

G. Determination of Water Savings

The industrial water user should calculate water savings based on the calculation methodology appropriate to the identified water efficiency opportunities.

H. Cost-effectiveness Considerations

The industrial water user should determine the cost effectiveness to implement each identified replacement or equipment upgrade, utilizing its own criteria for making capital improvement decisions. Obvious water wasting practices should be corrected as soon as possible without a cost-effectiveness analysis. The water waste reduction survey and report may be conducted and prepared by either the industrial water user’s own staff or by specialized outside consultants.

There may be additional one-time costs for equipment such as flow meters or leak detection equipment.

I. References for Additional Information

1) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*. New Mexico Office of the State Engineer, July 1999. http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf
2) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
3) *Water Efficiency Guide for Business Managers and Facility Engineers*, State of California Department of Water Resources, October 1994.
4) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
5) *Commercial and Institutional End Uses of Water*, AWWA Research Foundation, Summer 2000.

3.3 Industrial Submetering

A. Applicability

This BMP is intended for industrial water users that do not already have submeters on all significant water uses. Submeters are an effective method to account for all water usage within a facility in order to determine the amount of water used in specific processes and lost to leakage and to identify water efficiency opportunities. Before deciding to adopt this BMP, the applicant may want to determine the relative flow volumes to be measured by using estimation methods to determine the potential cost-effectiveness of installing a particular submeter.

B. Description

Submeters are an effective method for measuring all major water uses including but not limited to each process, subprocess or piece of equipment using water. Other methods of flow measurement that may be effective are engineering estimates, heat balance, installing a temporary meter, volumetric measurement and other intuitive methods. Meters should be installed permanently where the meters should be regularly read and the data used for water management purposes. Information from submetering can improve the effectiveness of leak detection methods and equipment inspections.

In addition to process equipment, submeters provide reliable water use data for cooling towers, boilers, rinsing or cleaning equipment, fountains, and irrigation systems. For new facilities or when cost-effective for existing facilities, sanitary uses should be submetered so that leaks and malfunctioning equipment can be identified and promptly repaired. Proper sizing of submeters is an important consideration. Many industrial facilities require large meters that do not accurately measure water usage during low-flow periods. In order to have more accurate accounting for low flow rates in a high water use system, the water user should determine the feasibility of installing compound water meters or similar technology so that periods of low flow are accurately metered. Compound water meters have two water meters, one for high flow rates and the other for low flow rates. Cooling systems that use evaporation ponds should calculate a potential water balance on the system to determine the value of using submeters for determining evaporation and other losses. Submetering data can be used to identify water use patterns and variability within a facility and relative consumptive and non-consumptive uses of water. As water efficiency measures are implemented, the user can monitor the impact and resulting water savings. For industrial water users who discharge to sanitary sewer systems, submetering data can often be provided to the utility to reduce sewer fees by documenting evaporation losses on the cooling tower and other processes and equipment that consumes or evaporates water.

C. Implementation

Generally following the guidelines as outlined below, the industrial water user should conduct a facility survey and cost-effectiveness analysis.

1) Conduct a facility survey: Conduct a survey of the facility to identify all major water use areas and locate all existing submeters (if any) for the major water use

areas. Determine sizing and locations for submeters for major water use areas that are not currently submetered.

2) Complete a cost-effectiveness analysis for installation of submeters: Determine if installing the submeters is cost-effective by estimating the cost of installing submeters compared to the value of water conserved using appropriate benchmarks. For example, determine if it would be cost-effective if submeters resulted in a 10 percent, 20 percent, 30 percent, etc. savings. Amortize the cost of installing submeters over the life of the equipment or other appropriate time period.
3) Complete and implement an action plan: The action plan should include a timetable to install submeters as well as a plan to use the data from the installed submeters to do a comparative analysis of all major water use areas and determine the cost-effectiveness of switching to a more efficient process, changing to more efficient equipment, and/or reducing water lost or wasted.
4) Update internal audit as necessary.

D. Schedule

1) The facility survey and cost-effectiveness survey should be completed in a timely manner. Surveys of very large or complex facilities should be completed within the first twelve (12) months of implementing this BMP. This is considered a reasonable time period to complete the survey.
2) The action plan should be completed and implemented in the normal business cycle immediately following the completion of the facility survey and cost-effectiveness analysis. For most facilities, twelve (12) months should be a reasonable time period to implement the action plan. Major facilities may need additional time for completion and implementation of the action plan.
3) If determined to be necessary for very large or complex facilities the schedule can be extended. BMPs should be initiated in the second year and continued until the targeted efficiency is reached.

E. Scope

To accomplish this BMP:

1) An industrial user should conduct surveys for each of its facilities following the schedule outlined in Section D.
2) For industrial water users with multiple facilities, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until submeters have been installed in all facilities.
3) Cost-effectiveness considerations may result in partial implementation of this BMP at one or more of the facilities.

F. Documentation

To track the progress of this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) The facility survey report;
2) The cost-effectiveness analysis;
3) The action plan;
4) Schedule for implementing the action plan;
5) Schedule of actual installation of submeters in the action plan; and
6) Estimated potential water savings for each major water use area for each submeter installed.

G. Determination of Water Savings

Industrial water users should use the installed submeters to determine a baseline level of water use for each major water use area. The water use should be linked to a performance measure, production level, production curve or other output. For facilities with a significant seasonal demand, it may take a longer period of time to determine baseline use. Use the data collected to determine the cost-effectiveness of equipment and process changes in the other Industrial BMPs. Regular record keeping and analysis of submetering data can also help identify the occurrence and quantity of water saved from early repair of unobserved leaks.

H. Cost-Effectiveness Considerations

The industrial water user should determine the cost effectiveness to implement each identified replacement or equipment upgrade, utilizing its own criteria for making capital improvement decisions. Both the capital costs of installation of identified meters and the ongoing expenses for reading and maintaining the meters should be considered. In some cases, meters installed within an industrial site may be considered as part of implementation of other specific BMPs. Costs for meters generally range from $50 to $100 for those with smaller flow rates to several thousand for larger compound meters. Meters can be retrofitted for automatic or remote reading capability for a moderate additional expense which can be compared to savings in reading and data collection costs. Water meters have a typical design life of 10 to 15 years.

I. References for Additional Information

Resources that can assist an industrial water user in implementing this BMP:

1) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*. New Mexico Office of the State Engineer, July 1999. http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf
2) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.

3.4 Cooling Towers

A. Applicability

This BMP is intended for any water user which employs cooling towers to remove heat by the evaporation of water. Cooling towers are used extensively from relatively small facilities such as office buildings, schools, and supermarkets to large facilities such as hospitals, electric power generation plants, and manufacturing and industrial plants.

B. Description

Cooling towers can be among the largest water using systems in industrial and commercial settings. A cooling tower uses evaporation to lower the temperature of water that conveys heat from mechanical equipment such as air conditioning systems, heat exchangers, condensers, or process machinery. Although recirculated within the system, water is lost due to evaporation, “blowdown”, and drift or other losses. Water is added through “make-up water.” This BMP centers on the practices for water-use efficiency of cooling towers by optimizing the water quality and the amount of blowdown.

Four general types of measures can reduce the amounts of water used in cooling towers: improved system monitoring and operation, optimal contaminant removal from cooling water, use of alternative sources for make-up water, and reducing heat load to evaporative cooling by either good energy management or by combining air and water cooling.

As water evaporates, the concentrations of dissolved solids become greater, affecting the operation and integrity of the facility. The most significant opportunity for water savings in cooling tower operation is by reducing the amount of highly concentrated water removed from the system as blowdown. One measure of water-use efficiency in a cooling tower is the concentration ratio, also known as cycles of concentration, which indicates the number of times water is used before being released as blowdown. There have been significant recent advances in both chemical treatment and monitoring technology which allow the concentration ratios in cooling towers to be increased, thus minimizing the amount of required make-up water needed to replace blowdown.

Other operating efficiency techniques may include careful use of acid or other pH lowering agents to reduce scale formation, sidestream filtration to filter out sediment and suspended particles that may clog lines, prevention of biogrowth by use of biocides and limiting exposure to sunlight, and use of ozonation to reduce chemical use. The entire heat transfer process should be kept in good order including, as applicable, coils, fans, condensers, and feed equipment.

Optimum concentration ratios for operation are highly dependent on the quality of the make-up water used, which can vary significantly from region to region. For evaporative cooling towers that use potable quality water, the minimum cycles of concentration should be at least four (4). With the modern water treatment chemical and monitoring technology available today, the potential exists for systems to be operated continuously at six (6) to eight (8) cycles or even greater, contingent upon system metallurgy and allowable corrosion rates. In cases where reuse and other non-potable sources are used for cooling tower water, a lower goal for cycles of concentration may be used since these nonpotable sources typically have higher TDS or hardness than potable water. However, using reuse water or alternative sources is encouraged in that it reduces potable water use.

C. Implementation

Implementation of this BMP should consist of the following actions:

1) Perform a water efficiency evaluation on each cooling tower system within a facility to identify areas of improvement for water savings and optimization of heat loads. The evaluation should review all aspects of cooling tower operations including heat load requirements, sources and amounts of water used for make up and released as blowdown, concentration ratios, treatment techniques and chemicals used, metering, use of automated monitoring and controls, repair and maintenance schedules and procedures, and water quality characteristics.
2) Cooling towers should be operated in a water efficient manner with consideration for:
    a. Calculation of and monitoring of cycles of concentration in order to optimize the blowdown rate;
    b. Optimal use of chemical additives and automatic blowdown techniques to optimize the cycles of concentration based on water quality. Use of contractors and vendors that specialize in cooling tower operations efficiency should be considered;
    c. Installation of meters to measure both make-up and blowdown water and daily monitoring of use;
    d. Location of blowdown points away from make-up supply and preferably in dead spots that have a minimal amount of circulation;
    e. Appropriate use of automated control procedures such as continuous blowdown, conductivity metering to control blowdown, pH monitoring, corrosion monitoring and automatic shutdown when the system is not use;
    f. Recovery for reuse of water that passes through cooling water instrumentation;
    g. Use of shielding or other equipment to minimize drift;
    h. Use of cooling water sequentially to cool a number of processes prior to being returned to the cooling tower;
    i. Evaluation of and utilization of alternative sources of water such as saline water, reclaimed water, harvested rainwater, graywater, or water used in other on-site processes; and
    j. Evaluation of the opportunities for reuse of the blowdown water for other processes on site. In many cases the reuse of cooling tower blowdown may require additional treatment of the water by processes such as lime softening or reverse osmosis. Exceptions to that general rule would apply to waters used for dust suppression or plant wash down.

D. Schedule

1) The industrial water user should complete the efficiency evaluation of the cooling towers in a timely manner. Very large or complex evaluations should be completed within six (6) months of initiating this BMP.
2) The industrial water user should implement the opportunities for water savings from the efficiency evaluation within the normal budget cycle after completion of the efficiency evaluation in order that the maximum water efficient benefit can be achieved in a reasonable time frame. Water saving measures for very large or complex systems should be implemented within twelve (12) months of completing the evaluation.
3) If determined to be necessary for very large or complex facilities the schedule can be extended. BMPs should be initiated in the second year and continued until the targeted efficiency is reached.

E. Scope

To accomplish this BMP, the industrial water user should do the following:

1) Industrial water users with one cooling tower, or several towers which are operated with the same or very similar parameters, should perform an efficiency evaluation and perform upgrades or replacements as outlined in the schedule of Section D.
2) For industrial water users with multiple cooling towers, or multiple sites with cooling towers that have significantly different operational parameters, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until all facilities have been evaluated and conservation measures implemented.
3) Cost-effectiveness considerations may result in partial implementation of this BMP at one or several of a large number of facilities.

F. Documentation

To track the progress of this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) Operating information on the cooling towers, including cooling capacity design heat loads for each tower, description of the process the cooling tower is used for, system requirements for cooling including temperature, volume, and duration of flows (hours/day). Operating information should also include cooling system metallurgical design information for maximum levels of contaminants that can be tolerated while maintaining an acceptable corrosion rate.
2) Water use records for each tower that include the number of gallons of blowdown and the number of gallons of make-up water used daily.
3) Number of cycles of concentration and calculation data.

4) Descriptions, operating manuals and procedures of any automatic controls used such as automatic meters and conductivity or pH sensors used to control blowdown.
5) Description of chemical compounds and amounts used to improve water quality for efficient cooling tower use to maximize cycles of concentration and optimize make-up requirements. Consideration must be given to system corrosion rates and scale forming potential.
6) Description of and amounts used of any alternate water source or system used or considered for composing make-up water, including an evaluation of both beneficial and detrimental effects.

G. Determination of Water Savings

Using historical records and manufacturers' data as appropriate, water savings due to increased concentration ratio and other implemented operating procedures can be calculated.

The concentration ratio (CR) is determined from the dissolved solids (or alternatively the conductivities) in the make-up water (CM) and blowdown water (CB):

$$CR = CB / CM$$

The percent of water expected to be conserved = (CR2 – CR1) / (CR2 x (CR1 – 1)

Where CR1 is concentration ratio before and CR2 is concentration ratio after increasing cycles. Source: Handbook of Water Use and Conservation (Vickers, 2001).

The chart below gives a graphic representation of water use at different cycles of concentration.

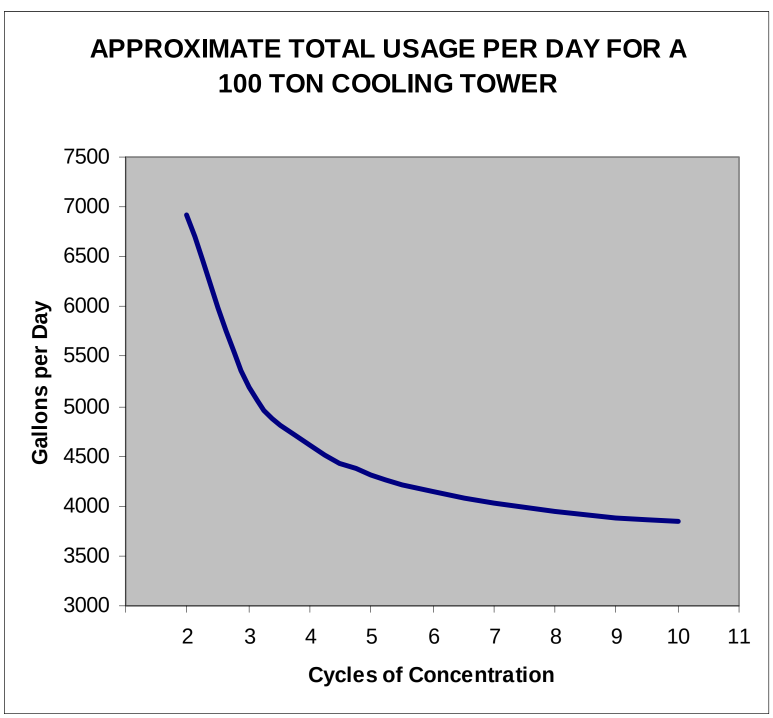

Figure 3.1 Cooling Tower Water User versus Cycles of Concentration

H. Cost-Effectiveness Considerations

A cost effectiveness analysis under this BMP should consider capital equipment costs, changes in staff and labor costs, chemical and treatment costs, additional costs or savings in energy use, costs for waste disposal, and potential savings in wastewater treatment costs. Many industries regularly use outside specialized consultants with fees starting at a few hundred dollars per month depending on the size and scope of the operation. Or the water treatment chemical suppliers may provide consulting services as part of the chemical costs.

The industrial water user should determine the cost effectiveness to implement each identified equipment replacement, upgrade, or change to its cooling tower operations, utilizing its own criteria for making capital improvement decisions. Many operating procedures and controls that improve the water use efficiency of cooling towers should be implemented simply as a matter of good practice.

I. References for Additional Information

There are many chemical vendors, equipment manufacturers, and consultants that specialize in industrial cooling towers. They can be an excellent source of information related to specific cooling tower applications. Many vendors have published literature available to assist an industry in optimizing its cooling water treatment systems.

1) Cooling Technology Institute, P. O. Box 73383, Houston, TX 77273 http://www.cti.org. The Cooling Technology Institute is a nonprofit self-governing technical association dedicated to improvement in technology, design, performance, and maintenance of evaporative heat transfer systems.
2) *Process Cooling & Equipment,* magazine published by BNP Media. http//www.process-cooling.com
3) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*, New Mexico Office of the State Engineer, July 1999. http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf

3.5 Cooling Systems (other than Cooling Towers)

A. Applicability

This BMP is intended for industrial water users that use circulated water to convey heat generated from industrial equipment and mechanical devices such as heat exchangers, condensers, process machinery, tools, air conditioning systems, appliances, vacuum pumps, x-ray or similar medical and dental equipment, welding machines, icemakers, and aircompressors. This BMP is not targeted to larger, once-through cooling systems on bodies of water such as lakes and bays that use and may recirculate water from within the same or adjacent water bodies or large once-through cooling systems that typically consume water by forced evaporation only.

B. Description

Cooling involves the removal of process energy in the form of heat. This BMP centers on the practices for optimizing the water-use efficiency of cooling systems other than large-scale evaporative cooling towers or large systems that typically consume water through forced evaporation (*See* Cooling Towers BMP). Water-cooling systems using single-pass water in a variety of industrial applications can use large amounts of water.

The single most significant opportunity for water reduction comes from eliminating or limiting the use of single-pass cooling systems. The use of single-pass cooling systems is prohibited by ordinance or legislation in numerous municipalities and states. Options for replacement of single-pass water cooling include the use of air cooling, the use of non-aqueous fluids and the use of recirculating and recycling water systems. If single-pass cooling cannot be eliminated, then opportunities should be explored for reuse of the cooling water for other on-site purposes.

C. Implementation

After identification of water-cooled equipment, implementation should consist of the following actions:

1) Performance of a water efficiency evaluation on each water-cooled system or process to identify areas or opportunities for reduction of water use. Information gathered should include types of equipment and processes, estimated or measured water use, water quality requirements, heat load and identification of opportunities to optimize the removal of heat within the process.
2) Replacement or upgrades of water-cooled systems with equipment that uses closed loop recirculating equipment.
3) Replacement or upgrades of water-cooled systems with equipment using alternative cooling modes such as air-cooling or non-aqueous systems.
4) Elimination of single-pass water cooling in facilities which have small evaporative coolers, sometimes known as “swamp coolers.” Swamp coolers are only effective in areas of low relative humidity and need recirculating systems in order to operate efficiently. Operating efficiency of recirculating evaporative

coolers should be optimized by regular replacement of pads and maintenance of equipment.

5) When practical, installation of individual meters on all water-cooled systems and daily monitoring of use.
6) An evaluation of and use, if possible, of alternative sources of cooling water such as condensate, saline water, reclaimed water, harvested rainwater, graywater, or water used in other onsite processes.
7) Evaluation of opportunities for reuse of the cooling water for other processes on site.
8) Operation of the water-cooled processes and equipment in an efficient manner at all times and keeping equipment in optimal operating condition. This includes maximization of external air-cooling opportunities and optimization of heat exchange equipment.
9) Use of solenoid valves or other methods for shutting down of systems when not in use.

D. Schedule

The industrial water user should identify and complete an efficiency evaluation of water-cooled systems in a timely manner. Evaluations of very large or complex systems should be completed within six (6) months of beginning this BMP.

1) The industrial water user should eliminate or upgrade all single-pass cooling systems within a normal budget cycle to implement the BMP in order to achieve the maximum water efficiency benefit in a reasonable time frame.
2) If determined to be necessary for very large or complex facilities, the schedule can be extended. BMPs should be initiated in the second year and continued until the targeted efficiency is reached.

E. Scope

To accomplish this BMP, the industrial water user should do the following:

1) Industrial water users with one facility, or several facilities with the same or very similar industrial processes, should perform an efficiency evaluation and perform upgrades or replacements as outlined in Section D.
2) For industrial water users with multiple facility sites or multiple industrial processes, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until all facilities have been evaluated and conservation measures implemented.
3) Cost-effectiveness considerations may result in partial implementation of this BMP at one or several of a large number of facilities.

F. Documentation

To track this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) List of water-cooled devices or systems and description of the process the cooling is used for, type of cooling process, water use stream, and heat load;
2) System requirements for cooling including temperature, volume, heat load and duration of flows (hours/day);
3) Where meters exist, the daily water use records for each system as appropriate for make-up water, discharge, and flow through the system;
4) Written details and records of all facility replacements, modifications, and upgrades of cooling systems made to meet the requirements of this BMP; and
5) Details of alternate water sources or water reuse opportunities considered.

G. Determination of Water Savings

Based on historical records, manufacturers' performance data, or observations and measurements, calculated water savings due to implemented changes in operating procedures or equipment replacements and upgrades can be estimated. For example, it is estimated that retrofitting of single-pass cooling equipment such as x-rays to recirculating water systems can cut water use by 90 percent (*See* Section I. References for Additional Information, 4).

H. Cost-Effectiveness Considerations

The industrial water user should determine the cost effectiveness to implement each identified replacement or equipment upgrade to its cooling systems operations, utilizing its own criteria for making capital improvement decisions. A cost effectiveness analysis under this BMP should consider capital equipment costs, changes in staff and labor costs, additional costs or savings in energy use, costs for waste disposal, and potential savings in wastewater treatment costs. Many operating procedures and controls that improve the water use efficiency should be implemented simply as a matter of good practice.

I. References for Additional Information

1) *Process Cooling & Equipment*, monthly magazine published by BNP Media focuses specifically on cooling equipment, materials and supplies used during the manufacturing process. http//www.process-cooling.com
2) *Commercial and Institutional End Use of Water*, published by AWWA Research Foundation and American Water Works Association, 2000 (ISBN 1-58321-035-0).
3) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
4) *Water Efficiency Guide for Business Managers and Facility Engineers*, State of California Department of Water Resources, October 1994.

5) *Waste Not, Want Not: The Potential for Urban Water Conservation in California (Appendix D),* Pacific Institute, November 2003.
http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf

3.6 Industrial Alternative Sources and Reuse of Process Water

A. Applicability

This BMP is intended for industrial water users that have the opportunity to reuse process water or other sources of nonpotable water such as treated effluent, rainwater collected on site, condensate, graywater, storm water, sump pump discharge or saline sources as a substitute for potable or raw water.

Once an industrial water user decides to adopt this BMP, the water user should follow the BMP process closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

Replacing potable water use with an alternative water supply is an effective way to improve water use efficiency. The industrial water user should survey all water uses on site and determine if process water or other sources of nonpotable water such as treated effluent, rainwater collected on site, condensate from cooling, graywater, storm water, sump pump discharge or saline sources could be substituted for potable water uses. A feasibility analysis should be conducted to determine the cost-effectiveness of conversion to each potential alternative source of reuse water. Benefits from implementation of this BMP may include lower utility costs, energy savings, and reduced process costs. Water quality necessary for the intended end use should be understood as well as the engineering technology necessary for treatment of reuse water prior to use.

For an industrial water user within close proximity of a utility reclaimed water line, purchase of treated effluent or reuse water may also be an option for completing this BMP.

C. Implementation

To determine if the potential exists for using nonpotable water as an alternative source the industrial water user should conduct a facility survey and feasibility analysis generally following the guidelines outlined below. References that provide more detailed information are listed in Section I below.

1) Preparation and information gathering
   Types of information that should be collected before beginning the survey include water use and water quality data for the past three years including utility records of water used and wastewater generated, actual water use on site including submetered use, and existing non-utility water use such as wells or storm water.

   Any alternative sources that may be available such as municipal effluent, effluent from other industrial water users in the area, high quality process water that is being discharged, or brackish groundwater and storm water should be identified. Chapter 210 Reclaimed Water Rules of the Texas Commission on Environmental Quality should be reviewed. TCEQ authorization is required when industrial reclaimed water is received from or sent to others, but these rules may not apply if the reuse system is internal to the facility and not discharging to surface waters. This information is necessary for completing the facility alternative water use report as described below in C.3.

2) Conduct facility survey
The water use survey should include identification and verification of all equipment and processes that use water and the required water quality and quantity for the equipment or process. Water quality should be measured so that the water quality of a process discharge can be matched with the water quality of a process or equipment need. It should be noted whether the equipment or process consumes water or is a nonconsumptive use. All sources of water that could be potentially be reused such as process rinse water, water used for equipment cooling, rainwater, etc., should be catalogued for water quality and water quantity. If reclaimed water is available from the local utility, another plant, or from another source such as seawater or brackish water, the cost to bring alternative water to the facility should be determined and included in the facility alternative water use report described next.

3) Prepare a facility alternative water use report
After the survey data is collected, the alternative water use report should analyze the reliability of the alternative supply and the equipment and processes that have been identified that could use an alternative source of water. The cost of piping, storage and any additional treatment that would be required for the alternative source of water should be calculated. When poorer quality source water is substituted, careful evaluation of effluent water quality is important to ensure that water quality discharge constraints are met.

4) Prepare a cost-effectiveness analysis
The cost-effectiveness analysis should determine if each alternative source of water can replace water used from other sources and should be based on equipment costs and any treatment that might be required. Additional guidance is provided in Chapter 3.15.

5) Prepare an action plan
The facility evaluation action plan should contain the alternative reuse project proposals and a timetable for implementation.

D. Schedule

1) The survey, alternative water use report and cost-effectiveness analysis should be completed in a timely manner. Very large or complex surveys, reports and analyses should be completed within the first twelve (12) months of initiating this BMP.
2) The action plan should be implemented in the normal business cycle. For very large or complex facilities, the action plan should be implemented within twelve (12) months immediately following the completion of the cost-effectiveness

report in order that the maximum water efficiency benefit can be achieved in a reasonable time frame. Major projects may take additional time for implementation.

3) If determined to be necessary for very large or complex facilities, the schedule can be extended. BMPs should be initiated in the second year and continued until the targeted efficiency is reached.

E. Scope

To accomplish this BMP:

1) Organizations with one facility, or several facilities with the same or very similar industrial processes, should conduct a facility survey following the schedule outlined in Section D.
2) For organizations with multiple facility sites, or multiple industrial processes, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until all facilities have been surveyed and alternative water sources implemented.
3) Cost-effectiveness considerations may result in partial implementation of this BMP at one or several of a large number of facilities.

F. Documentation

To track the progress of this BMP, the industrial water user gathers and maintains following documentation and can utilize industry accepted practices:

1) The facility survey report;
2) Cost-effectiveness analysis;
3) The action plan;
4) Schedule for implementing the action plan;
5) Documentation of actual implementation of alternative water sources contained in the action plan; and
6) Estimated potable water savings and actual potable water savings for alternative water source implemented.

G. Determination of Water Savings

The industrial water user should calculate potable and/or raw water savings based on metering of the alternative water sources implemented. Water savings estimates can be calculated based upon the percentage of water estimated to be replaced by reuse water:

$S = R \times Wp$

Where S = Savings in Acre-feet/year

Wp = water use prior to implementing BMP for specific processes targeted for reuse water, and

R = percentage efficiency of reuse system.

An industrial water user interested in implementing this BMP can get reasonable estimates of potential reuse efficiencies from manufacturers' estimates, comparisons with similar facilities, or the list of references in Section H of this BMP.

H. Cost-Effectiveness Considerations

The industrial water user should determine the cost effectiveness to implement each identified replacement or equipment upgrade, utilizing its own criteria for making capital improvement decisions. A cost effective analysis under this BMP should consider not only the capital costs of any equipment or process changes and improvements, but also the one-time costs of the reuse opportunity survey and feasibility study, any water quality sampling and testing, and regulatory costs. Additional ongoing costs may include staff and labor, chemical and treatment costs, additional costs or savings in energy use, and potential savings in wastewater treatment costs.

I. References for Additional Information

1) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*. New Mexico Office of the State Engineer, July 1999. http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf
2) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
3) *Water Efficiency Guide for Business Managers and Facility Engineers*, State of California Department of Water Resources, October 1994.
4) *Waste Not, Want Not: The Potential for Urban Water Conservation in California*, Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
5) *Texas Guide to Rainwater Harvesting,* Texas Water Development Board, 1997. http://www.twdb.state.tx.us/assistance/conservation/Cons-image/Downloads/RainHarv.pdf NOTE: To be updated Fall 2004.
6) *Commercial and Institutional End Uses of Water*, AWWA Research Foundation, Summer 2000.
7) *TCEQ Chapter 210 Rules on Reclaimed Water*. http://www.tnrcc.state.tx.us/oprd/rules/pdflib/210a.pdf
8) *TCEQ Application to Use Industrial Reclaimed Water*. http://www.tnrcc.state.tx.us/permitting/forms/20094.pdf

3.7 Rinsing/Cleaning

A. Applicability

This BMP is intended for industrial water users that use rinsing or cleaning in processing, production or finishing operations.

B. Description

Rinsing and cleaning are important operations for a number of industries. Water conservation opportunities arise in improvements in flow rates, pressure, or timing. Many operations can also increase efficiency by recirculating water or by filtering contaminants and reclaiming water for reuse internally.

Specific processes in which this BMP can be implemented will have been identified in the Industrial Water Audit BMP. Each process requires careful evaluation to determine the most economical and efficient measures to implement. Initial cost-effectiveness analysis should begin with the simplest measures including adjusting operating parameters on existing equipment. Often reductions in water pressure, changes in timing or adjustments to nozzles can achieve measurable results in water savings. In container rinsing for reuse or disposal, immediate rinsing before products solidify or gel can reduce the amount of time and water required for cleaning. In multiple rinse processes, reducing the amount of “dragout” or contaminated rinse water carryover from one container to the next can reduce the total amount of water needed for the process.

Equipment upgrades can also be cost-effective, including use of smaller rinse or cleaning sinks and tanks, changes in pumps, nozzles, and pipes, and in the machinery that controls the timing of rinse or cleaning processes. Mechanical mixing, agitating rinse water in tanks, and counterflow rinsing processes have also been shown to improve effectiveness of cleaning and water use.

Reuse of water within a rinse or cleaning process is one of the most effective means of saving water. Sequential rinsing can often make use of spent water from one process in another. Filtering final rinse water for use in cleaning processes is also often done with minimal filtration.

When filtering of water is necessary, the simplest process is often just recirculation of water with dust or other solids removed in settling tanks. More sophisticated filtration may include oil/water separators, centrifugal separation, sand filters, bag filters, or even more sophisticated membrane filtration. In processes where ultra-pure or very high quality water is needed, careful engineering of treatment processes is necessary to ensure removal of organics and other materials which can damage membrane filters.

Adjusting the chemical requirements of the process can also lead to significant water savings. Often solids can be filtered from a cleaning process, leaving some detergents in the filtered water, thus reducing the addition of new cleaning chemicals while reusing the water. Some processes can be adjusted to use higher levels of chemicals in a process, reducing water pressure and flow volumes used to scour a product. In these cases careful evaluation of the effluent water quality is important to ensure that water quality discharge constraints are met.

In facilities that filter rinsing and cleaning water for reuse, the water used to backwash the filter or RO reject water should be considered for use in other processes where lower quality water can be utilized.

C. Implementation

Implementation of this BMP should consist of the following actions:

1) Perform a water efficiency evaluation of each rinsing/cleaning process within a facility to identify areas of improvement for water savings. The evaluation should review amounts of water used, use of automatic controls, repair and maintenance schedules and procedures, and water quality characteristics. Where manufacturers' specifications or industry specific information is not available, company engineers or third party contractors should perform an empirical evaluation of existing equipment. Based on the requirements and uses of the system, alternative water supplies should be considered.
2) Water-using rinsing/cleaning processes should be operated in a water efficient manner with consideration for:
    a. Optimal repair and maintenance of rinsing/cleaning equipment and facilities to keep rinsing/cleaning equipment, lines and related equipment in good repair;
    b. Timing of existing equipment, reduction in flow rates by changes in nozzles, changes in sizing of rinse or cleaning tanks, the installation of positive shutoff valves;
    c. Upgrades of apparatus including tanks or sinks, nozzles, valves, pumps, and timing equipment;
    d. Optimal use of chemical additives to minimize water use; and
    e. Use of water quality instrumentation for more accurate determination of when rinsing baths should be replaced or recharged.
3) Within the water user's budget cycle, install or upgrade to the most cost-effective reuse and reclamation equipment system, with highest water efficiency.
4) When cost effective, reuse and reclamation equipment should be operated in a water efficient manner with consideration for:
    a. Optimal repair and maintenance to keep reuse and reclamation equipment, lines and related equipment in good repair; and
    b. Potential use of filter backwash or reject water in other operations.

D. Schedule

If the water user chooses this BMP, the following is a recommended schedule:

1) The efficiency evaluation of the rinsing/cleaning systems should be in a timely manner, generally within three (3) months of beginning this BMP.
2) The opportunities for water savings indicated by the efficiency evaluation should be implemented in a normal business cycle, and it is recommended within twelve (12) months after completion of the evaluation in order that the maximum water efficient benefit can be achieved in a reasonable time frame.
3) Water using rinsing/cleaning equipment should be operated optimally at all times following the guidelines of this BMP.

E. Scope

To accomplish this BMP, the industrial water user should do the following:

1) Industrial water users with water-using rinsing/cleaning systems which are operated with the same or very similar parameters should perform an efficiency evaluation and perform upgrades or replacements as outlined in the schedule of Section D;
2) For industrial water users with multiple systems, or multiple sites that have systems with significantly different operational parameters, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until all facilities have been evaluated and conservation measures implemented; and
3) Cost-effectiveness considerations may result in partial implementation of this BMP at one or several of a large number of facilities.

F. Documentation

To track this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) Operating information on the rinsing/cleaning systems, including capacity design, description of the process the rinsing/cleaning system is used for, system requirements for temperature, volume, and duration of flows (hours/day). Operating information should also include design information for maximum levels of contaminants that can be tolerated while maintaining an acceptable cleaning rate.
2) Water use records for each rinsing/cleaning system that include the frequency and number of gallons of make-up water used;
3) Description of chemical compounds and amounts used to affect water quality; and
4) When applicable, description of reclaim and reuse system and water savings achieved.

G. Determination of Water Savings

The industrial water user should calculate water savings based on the calculation methodology appropriate to the identified water efficiency opportunities. Estimated overall water savings for implementing rinsing/cleaning efficiencies have been in the range of 10 percent to 15 percent for process adjustments and 50 percent to 85 percent for installing various reclaim systems. Actual water savings should be measured by comparing water use prior to implementation to water use after the measures are implemented.[1]

H. Cost-Effectiveness Considerations

The industrial water user should determine the cost effectiveness to implement each identified replacement, equipment upgrade, or change to its rinsing/cleaning operations, utilizing its own criteria for making capital improvement decisions. Many operating procedures and controls that improve the water use efficiency of rinsing/cleaning processes should be implemented simply as a matter of good practice. A cost effectiveness analysis under this BMP should consider capital equipment costs, staff and labor costs, chemical and treatment costs, additional costs or savings in energy use, costs for waste disposal, and potential savings in wastewater treatment costs.

I. References for Additional Information

1) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
2) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*. New Mexico Office of the State Engineer, July 1999. Available in PDF at http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf
3) *Water Efficiency Guide for Business Managers and Facility Engineers*, Sate of California Department of Water Resources, October 1994.

3.8 Water Treatment

A. Applicability

This BMP is intended for those industrial water users that use water treatment systems in processing, production or finishing operations. Water treatment is used to produce improved quality water such as softened or ultra-pure water to produce water of a specific quality necessary for a certain production process, to improve water quality for reuse within a facility, or for a second use within a facility. Industrial users who treat water for a rinsing or cleaning process should refer to the Rinsing/Cleaning BMP; users that treat water for cooling tower use should follow the Cooling Towers BMP; and those using boilers to produce steam should consult the Boiler and Steam Systems BMP.

B. Description

Most major industries and power plants and many commercial operations need water purity higher than that provided by the local municipal water supply. In addition, many industries use raw water directly from lakes, streams, or wells and require additional treatment before use in the process. The focus of this BMP is water efficiency in the provision of additional treatment of water for use within the facilities.

In addition to treatment for boiler feed, rinsing/cleaning processes, and cooling tower water, common examples of water treatment in industries include softening of water to prevent scaling and preparation of ultra-pure water. Specialized water treatment is important in such industries as metal finishing and plating, food and beverage, chemicals, pharmaceuticals, electronics and micro-chip production, and most other process industries requiring especially clean water.

On the commercial and institutional side, examples include soft water for the laundry industry, spot free car wash water for commercial car washes, hospital needs such as kidney dialysis, and high purity water for injection fluids in medical facilities.

Water conservation opportunities arise in increased efficiency through improvements in flow rates, pressure, temperature, chemistry, filtration or timing. Metering both inflow and outflow from the system provides the operator information to determine if the system is meeting design efficiencies. Process control is often an area where increased efficiency can be obtained. Many operations can also increase efficiency by recirculating water or by filtering contaminants and reclaiming water for reuse internally.

Specific processes in which this BMP can be implemented will have been identified in the Industrial Water Audit BMP. Each process requires careful evaluation to determine the most economical and efficient measures to implement. The initial cost-effectiveness analysis should begin with the simplest measures such as adjustment of operating parameters on existing equipment. Often reductions in water pressure, changes in timing, repair of leaks or other adjustments to plumbing can achieve measurable results in water savings.

Equipment upgrades can also be cost-effective, including use of smaller sinks and tanks, changes in pumps, nozzles, pipes, solenoid switches, and instrumentation or machinery that control the timing and volume of rinsing or cleaning processes. Reuse of water within a water treatment process is one of the most effective means of saving water.

When filtering of water is necessary, the simplest process is often just recirculation of water, with dust or other solids removed in settling tanks. Filtration may include oil water separators, centrifugal separation, sand filters, bag filters, or even more sophisticated membrane filtration. In processes where ultra-pure or very high quality water is needed, careful engineering of pre-treatment and treatment processes is necessary to ensure removal of organics and other materials which can damage membrane filters. Flocculation or coagulation can help prevent fouling of membranes.

Careful balancing of cost-effectiveness considerations should be considered when choosing between reverse osmosis ("RO"), nanofiltration, electrodialysis, ultrafiltration, microfiltration or other treatment processes. Issues such as membrane fouling, multiphase processes, organic and inorganic constituents in the feed stream, pressure levels, and discharge levels should all be considered. Careful evaluation of filter media should take into account the relative efficiency of the process in terms of the ratio of filter backwash to through-put and reject water to product water.

Adjusting the chemical requirements of the process can also lead to significant water savings. Coagulation should be optimized by adjustments to pH, coagulant type, and feed rate to achieve the most effective removal of turbidity, particulates, precursors and/or disinfection byproducts. Some processes can be adjusted to use higher levels of chemicals in a process, reducing water pressure and flow volumes used to scour a product. Corrosion control is another area where proper water treatment process selection can result in greater water use efficiency.

Where treated water is used for potable purposes, all applicable Texas Commission on Environmental Quality ("TCEQ") rules and regulations for design and operation of public drinking water systems must be followed. Although the underlying mission is to protect the public health, the TCEQ has the Texas Optimization Program ("TOP"), a voluntary, non-regulatory program designed to dramatically improve the performance of existing surface water treatment plants without major capital improvements.

Additionally, discharged effluent water quality must meet all TCEQ water quality discharge constraints. Instead of discharge, in facilities that use filters for treatment processes, filter backwash water or RO reject water should be considered for use in other processes where lower quality water can be utilized. (*See* the Industrial Alternative Sources and Reuse of Process Water BMP)

The level and type of treatment are dependent on the purity of water required and the end use needs, but reuse opportunities for the waste streams generated by treatment should be evaluated. Other than cartridge type filtration, almost all treatment processes produce both a product water and waste stream.

C. Implementation

Implementation of this BMP should consist of the following actions:

1) Perform a water efficiency evaluation on each water treatment process within a facility to identify areas of improvement for water savings. The evaluation should review amounts of water treated and produced, amounts and types of chemicals used, use of automatic controls, repair and maintenance schedules and procedures, and water quality characteristics. The efficiency evaluation should review the end use needs of the specific processes for which the treated water is used. Where manufacturers' specifications or industry specific information is not available, company engineers or third party contractors should perform an empirical evaluation of existing equipment.
2) Water treatment processes should be operated in a water efficient manner with consideration for:
    a. Optimal repair and maintenance of water treatment equipment and facilities to keep water treatment equipment, lines and related equipment in good repair.
    b. Timing of existing equipment, reduction in flow rates by changes in nozzles, changes in sizing of filters or holding tanks.
    c. Use of proper filters and settings for water quality necessary for end-use, including optimal timing of and amount of backwash water.
    d. Use of reject or backwash streams in other uses, where water quality is appropriate.
    e. Upgrades of apparatus including tanks or sinks, nozzles, valves, pumps, and control equipment.
    f. Optimal use of chemical additives to minimize water use.
    g. Use of water quality instrumentation to control when to recharge or regenerate the water treatment process.
3) Water softening processes should be operated in a water efficient manner with consideration for:
    a. Optimal repair and maintenance of water softening equipment and facilities to keep water treatment equipment, lines and related equipment in good repair.
    b. Timing for efficient use of existing equipment for optimal flow rates.
    c. Full knowledge of the chemistry of the water to be softened as well as the application uses of the softened water (laundry, boiler feed, process water, condensate polishing, etc.).
    d. Optimum design for maximum water use efficiency, minimum pressure drop, minimum regeneration waste water discharge and lowest capital cost.
4) When cost-effective, reuse and reclamation equipment should be installed or upgraded.
    a. Optimal repair and maintenance of reclaim equipment and facilities to keep rinsing/cleaning equipment, lines and related equipment in good repair.

b. Install most cost-effective system, with highest water efficiency.
c. Consider potential use of filter backwash or reject water in other operations.

5) Based on the requirements and uses of the system, alternative water supplies should be considered.

D. Schedule

If the water user chooses this BMP, the following is a recommended schedule:

1) The industrial water user should complete the efficiency evaluation of on site water treatment systems in a timely manner. Most site evaluations should be completed within three (3) months of beginning this BMP.
2) The industrial water user should implement the opportunities for water savings identified in the efficiency evaluation during the normal business cycle or within twelve (12) months after completion so that maximum water efficiency benefits can be achieved in a reasonable time frame.
3) Water treatment equipment should be operated optimally at all times following the guidelines of this BMP.

E. Scope

To accomplish this BMP, the industrial water user should do the following:

1) Industrial water users with one or more water treatment systems operated with the same or very similar parameters should perform an efficiency evaluation and perform upgrades as outlined in the schedule of Section D.
2) For industrial water users with multiple systems, or multiple sites that have systems with significantly different operational parameters, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until all facilities have been evaluated and conservation measures implemented.
3) Cost-effectiveness considerations may result in partial implementation of this BMP at one or several of a large number of facilities.

F. Documentation

To track this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) Operating and design information on all on site water treatment systems, including capacity design, descriptions of the end use processes the water from the treatment system is used for, system requirements for temperature, volume, and duration of flows (hr/day). Operating information should also include design information for maximum levels of contaminants that can be tolerated while maintaining an acceptable water quality rate.

2) Water use records for each treatment system that include the volume of water treated and produced.
3) Description of chemical compounds and amounts used to improve water quality and the costs of chemical treatment before and after efficiency measures are implemented.
4) When applicable, description of reclaim and reuse system and water savings achieved.

G. Determination of Water Savings

The industrial water user should calculate water savings based on the calculation methodology appropriate to the identified water efficiency opportunities. For example, estimated overall water savings for implementing water treatment efficiencies have been in the range of 10 percent to 15 percent for process adjustments and 50 percent to 85 percent for installing some reclaim systems. Actual water savings should be measured by comparing water use prior to water use after the measures are installed.[1]

H. Cost-effectiveness Considerations

The industrial water user should determine the cost effectiveness to implement each identified replacement or equipment upgrade to its water treatment processes, utilizing its own criteria for making capital improvement decisions. Many operating procedures and controls that improve the water use efficiency should be implemented simply as a matter of good practice. A cost effectiveness analysis under this BMP should consider capital equipment costs, increased staff and labor costs, chemical and treatment costs, additional costs or savings in energy use, costs for waste disposal, and potential savings in wastewater treatment costs.

I. References for Additional Information

1) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
2) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*. New Mexico Office of the State Engineer, July 1999. Available in PDF at http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf
3) Water Efficiency Guide for Business Managers and Facility Engineers, State of California Department of Water Resources, October 1994.
4) *Rules and Regulations for Public Water Systems* (30 TAC Chapter 290, Subchapter D), Texas Commission on Environmental Quality.

3.9 Boiler and Steam Systems

A. Applicability

This BMP is intended for any water user that employs boiler and steam generators for heating or process steam. Commercial boiler and steam systems are primarily found in larger buildings, multiple-building institutions such as campuses, commercial cooking facilities, or in some cases where process steam is required. Large industrial steam boiler and steam systems typically use high pressure saturated or superheated steam for electric power generation or for processes or manufacturing needs. Due to their complexities large power boilers and large industrial steam systems are beyond the scope of this document to deal with in detail. Operators of such systems should use best operating practices specific to the process to achieve thermal and water use efficiency.

Frequently, the primary driving force for improving the efficiency of commercial boiler and steam systems is energy savings. Industrial steam generating systems are generally already designed to optimize overall thermodynamic efficiency. In most cases however, the measures taken to improve energy savings also result in water savings, and likewise water efficiency measures can also improve the energy efficiency of steam systems.

B. Description

A steam boiler system transfers energy from a fuel source such as natural gas, coal, lignite, nuclear, or fuel oil to water in a steam generator or process equipment. The heated water as steam is circulated through a distribution system to the manufacturing process, heat exchanger, or heating coil where it reverts back to liquid phase called condensate. Water is added through “make-up water” to replace lost steam and “blowdown water” that is periodically released to remove contaminants and reduce the level of dissolved solids in the boiler water. This BMP centers on the practices for optimizing the water-use efficiency of boiler and steam systems.

Three general types of measures can reduce the amounts of water used in boiler and steam systems:

1) optimized condensate recovery;
2) improved water treatment and monitoring to minimize boiler blowdown; and
3) good operation and maintenance programs for steam lines, steam traps, feed pumps, condensers, heat exchangers, and boilers.

Use of appropriate industrial standards for water chemistry is necessary both for equipment upkeep and for efficient water use. Operators of boiler and steam systems should also consult the Water Treatment BMP for possible interlocking efficiencies related to demineralizer or softener operations.

A major opportunity for water savings in boiler and steam systems is through improving the efficiency of condensate water return to the boiler. As more condensate is returned, less make up water is needed. The reuse of high purity condensate water reduces the amount of water required from the water treatment process. Insulating and maintaining return lines ensures that the higher temperature of the water will require less energy for reheating within the system. Maximizing the return of condensate must be carefully balanced with the potential for carryback of contaminants and scale particles.

In many smaller commercial and institutional steam systems "flash steam", which occurs when saturated condensate is reduced to some lower pressure and some flashes off to steam again, is vented to the atmosphere. Flash tanks should be used to recover and return flash steam to the system along with the condensate.

Minimizing blowdown can be accomplished through use of chemicals and treatment to reduce scale buildup and minimize scale deposition. Automatic chemical feed and automatic control systems based on water quality are recommended as good options to reduce the amount of water released through blowdown. Another recommended practice where possible is installation of automatic controls that shut down boiler units when not in use for extended periods of time. Blowdown should be matched to meet the water quality standards required to minimize corrosion and scaling.

Most large industrial users should already have in place good maintenance practices to maintain boiler and steam systems and related equipment and facilities. It is recommended that commercial boiler steam system operators have an organized preventative maintenance program. Significant amounts of steam can be lost through leaking steam traps, holes in coils or steam lines, and faulty pressure release valves.

Water users considering replacement or retrofit options for boiler and steam systems should consider opportunities to optimize heat requirements within the facility and to determine the appropriate size of the system. Many institutional boiler and steam needs can be met through use of individual systems for different buildings or processes instead of central systems or through installation of secondary small load boilers for low use periods.

Opportunities should also be explored for internal reuse of steam or condensate within a facility or complex. Cogeneration facilities are becoming more widespread where industrial steam can also be used to generate electricity or where lower pressure steam can be extracted for process use.

C. Implementation

Implementation of this BMP should consist of the following actions:

1) Perform a water efficiency evaluation on each boiler and steam system within a facility to identify areas of improvement for water savings and optimization of heat loads. The water user may want to perform the water efficiency evaluation in conjunction with an energy efficiency audit. The evaluation should review all aspects of boiler and steam operations including end use of steam requirements, sources and amounts of water used for make-up, blowdown, condensate recovery, concentration ratios, treatment techniques and chemicals used, metering, use of

automated monitoring and controls, repair and maintenance schedules and procedures, and water quality characteristics.

2) Boiler and steam systems should be operated in a water efficient manner with consideration for:
   a. Maximizing condensate return;
   b. Optimal use of chemical additives and automatic blowdown techniques to minimize the required blowdown rates;
   c. Appropriate use of automatic shutdown when the system is not use; and
   d. Regular inspection and maintenance of steam lines, steam traps, condensate feed pumps, boilers, and other associated equipment. Contaminants should periodically be removed from boiler and steam units by cleaning the boiler chemically or mechanically.
3) Overall efficient operation of the steam delivery system including analysis of the end use requirements to optimize required heat loads; and cost-effectiveness evaluation of boiler and steam system replacement and retrofit options.

D. Schedule

If the water user chooses this BMP, the following is a recommended schedule:

1) The industrial water user should complete the efficiency evaluation of its boiler and steam systems in a timely manner or within twelve (12) months of beginning this BMP.
2) The action plan should be completed and implemented in the normal business cycle immediately following the completion of the facility survey and cost effectiveness analysis. For most facilities, twelve (12) months will be a reasonable time period to implement the action plan. Major facilities may need additional time for completion and implementation of the action plan.
3) Boiler and steam systems will be operated optimally at all times following the guidelines of this BMP.

E. Scope

To accomplish this BMP, the industrial water user must do the following:

1) Industrial water users with one or more boiler and steam systems should perform an efficiency evaluation and perform upgrades or replacements as outlined in the schedule of Section D.
2) Cost-effectiveness considerations may result in partial implementation of this BMP at one or several of a large number of facilities.
3) Have in place an organized preventive maintenance program that includes regular inspection and repair of all equipment and facilities associated with the boiler and steam system.

F. Documentation

To track this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) Operating information on the boiler and steam systems including boiler and steam efficiencies and end use load information for each system;
2) System operating hours;
3) Energy and water use records for each boiler and steam system that include the number of gallons of blowdown water and the number of gallons of make-up water used monthly;
4) Number of cycles of concentration and calculation data;
5) Documentation of appropriate steam system water chemistry standards and controls that are used. There are several resources for standards related to boiler and steam systems included in Section I; and.
6) Descriptions of equipment or process changes, equipment operating manuals and procedures for any controls used such as automatic meters and conductivity or pH sensors used to control blowdown and automatic shut down equipment.

G. Determination of Water Savings

Using operating observations, historical records and manufacturers' data as appropriate, water savings due to increased condensate return and increased concentration ratios can be calculated.

1) Water use in boiler and steam systems, where temperatures and pressures vary, is typically accounted for in units of pounds (lbs) per hour. When condensate return is implemented or improved and operating hours are known, the amount of water saved in gallons can be found by:
   = (condensate load in lbs/hr) x (operating hours) / 8.34
   If flash steam is not recovered, adjustments must be made for "flash steam loss" which can be 10 percent or more of the condensate load depending on the temperature and pressure differential.
   Source: U.S. Department of Energy
2) The percent of water expected to be conserved through increased concentration ratio (CR) is $= (CR2 - CR1) / (CR2 \times (CR1 - 1))$
   Where CR1 is concentration ratio before and CR2 is concentration ratio after increasing cycles.
   The CR is determined from the dissolved solids (or alternatively the conductivities) in the makeup water (CM) and bleed-off water (CB):
   $CR = CB / CM$

H. Cost-Effectiveness Considerations

The industrial water user should determine the cost effectiveness to implement each identified replacement or equipment upgrade to boiler and steam equipment, utilizing its own criteria for making capital improvement decisions. A cost effectiveness analysis under this BMP should consider capital equipment costs, staff and labor costs, chemical and treatment costs, and additional costs or savings in energy use. Many industries regularly use outside specialized water quality consultants at fees starting at a few hundred dollars per month depending on the size and scope of the operation. Or the water treatment chemical suppliers may provide consulting services as part of the chemical costs.

Many operational procedures and controls that improve both water and energy use efficiency in boiler and steam systems should be implemented simply as a matter of good practice. In addition to water savings, increasing the amount of condensate returned to the boiler saves significant amounts of energy. Heat energy remaining in the condensate can be more than 10 percent of the total steam energy content of a typical steam system.

I. Resources

1) There are many equipment manufacturers, chemical vendors, and consultants that specialize in manufacturing and operating boiler and steam systems. They can be an excellent source of information related to specific applications. Many vendors and boiler equipment manufacturers have published standards and other literature available to assist an industry in optimizing its steam boiling systems.
2) Office of Industrial Technologies Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington, D.C. 20585-0121. www.oit.doe.gov
3) Steam Boiler Practices and Standards have been developed by The American Society of Mechanical Engineers www.asme.org
4) The Electric Power Research Institute (EPRI), a non-profit energy research consortium which provides science and technology-based solutions to the energy industry, has developed standards for operation and has conducted or has ongoing several projects that address all aspects of boiler and steam systems in electric power generation. www.epri.com
5) The American Boiler Manufacturers Association (ABMA) is a national, non-profit trade association of manufacturers and users of commercial/institutional, industrial and power-generating boilers and boiler and steam-related equipment, 4001 North 9th Street, Suite 226, Arlington, VA 22203-1900 www.abma.com
6) The National Association of Corrosion Engineers (NACE) is an association dedicated to the control and prevention of corrosion. NACE has standards prepared by the Association's technical committees to serve as voluntary guidelines in the field of prevention and control of corrosion. www.nace.org
7) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*, New Mexico Office of the State Engineer, July 1999. http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf

3.10 Refrigeration (including Chilled Water)

A. Applicability

This BMP is intended for any water user which utilizes water as a primary refrigerant fluid to remove heat. Water conservation practices for cooling towers that use evaporation of water to remove the heat at the "condenser" where the refrigerant is changed from high temperature to a lower temperature are described in the Cooling Towers BMP. Additionally, the Cooling Systems (other than Cooling Towers) BMP covers processes that use a circulating flow of water at ambient temperatures as a coolant medium to convey heat away from machinery or a process. Examples of refrigeration processes that this BMP is intended for are primarily chilled water facilities that circulate refrigerated water for use in precision cooling of process units or large scale air conditioning systems of buildings or campuses.

B. Description

Using the latent heat properties of the refrigerant, mechanical refrigeration removes heat from a colder medium and rejects it to a warmer medium. A chilled water system is for all intents a refrigeration system that cools water. Most chillers are used as closed loop systems with the heat removed by air-cooling or through a cooling tower, and water consumption can be reduced. All chilled water systems require a reservoir for the returned fluid to act as a heat sink, but very little water is lost due to evaporation.

The major water use in these systems, other than at the cooling towers, occurs when water is replaced due to leaks or equipment problems. The primary maintenance recommendations for the closed chilled water loop include treatment of the water periodically with rust inhibitor and biocides, use of strainer screens and filters, and regular inspection and maintenance of pipes, valves, and pumps. For larger systems condensate water from the condenser coils can potentially be collected as an alternative to potable water for cooling tower make up or for some other use. Water is not the only fluid that can be used as a liquid refrigerant. For example, direct cooling of deionized water, hydraulic oil, glycol solutions, and water soluble oils is possible in refrigerated systems.

C. Implementation

Implementation of this BMP should consist of the following actions:

1) Perform a water efficiency evaluation on each water-using refrigeration process within a facility to identify areas of improvement for water savings. The evaluation should review amounts of water used, use of automatic controls, repair and maintenance schedules and procedures, and water quality characteristics. Based on the requirements and uses of the system, alternative refrigerants should be considered.
2) Institute a routine schedule of optimal repair and maintenance measures for all equipment, such as using chemical additives to minimize corrosion. Make-up water to all closed loop systems should be metered to assist in evaluation for

leaks. Chilled water systems or other refrigeration systems that use cooling towers should be operated following the guidelines of the Cooling Towers BMP.

D. Schedule

If the water user chooses this BMP, the following is a recommended schedule:

1) The facility survey and cost-effectiveness survey should be completed in a timely manner. Surveys of very large or complex facilities should be completed within the first twelve (12) months of implementing this BMP. This is considered a reasonable time period to complete the survey.
2) The action plan should be completed and implemented in the normal business cycle immediately following the completion of the facility survey and cost effectiveness analysis. For most facilities, twelve (12) months should be a reasonable time period to implement the action plan. Major facilities may need additional time for completion and implementation of the action plan.
3) Water-using refrigeration equipment should be operated optimally at all times following the guidelines of this BMP.

E. Scope

To accomplish this BMP, the industrial water user should do the following:

1) Industrial water users with one or more chilled water or water-using refrigeration systems which are operated with the same or very similar parameters should perform an efficiency evaluation and perform upgrades or replacements as outlined in the schedule of Section D.
2) For industrial water users with multiple systems, or multiple sites that have systems with significantly different operational parameters, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until all facilities have been evaluated and conservation measures implemented.
3) Cost-effectiveness considerations may result in partial implementation of this BMP at one or several of a large number of facilities.

F. Documentation

To track the progress of this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) Operating information on the chilled water systems, including cooling capacity design heat loads, description of the process utilizing the refrigeration system, system requirements for cooling including temperature, volume, and duration of flows (hr/day). Operating information should also include cooling system metallurgical design information for maximum levels of contaminants that can be tolerated while maintaining an acceptable corrosion rate;

2) Water use records for each refrigeration system that include the frequency and number of gallons of make-up water used;
3) Description of chemical compounds and amounts used for corrosion control; and
4) Description of and amounts used of any alternate refrigerant used or considered.

G. Determination of Water Savings

Using historical records and manufacturers' data as appropriate, water savings can be estimated.

H. Cost-Effectiveness Considerations

The industrial water user should determine the cost effectiveness to implement each identified replacement or upgrade to refrigeration equipment and operations, utilizing its own criteria for making capital improvement decisions. Many operating procedures and controls that improve the water use efficiency, such as repair of leaks, should be implemented simply as a matter of good practice. A cost effectiveness analysis under this BMP should consider capital equipment costs, staff and labor costs, chemical and treatment costs, and additional costs or savings in energy use.

I. References for Additional Information

1) There are many chemical vendors, equipment manufacturers, and consultants that specialize in refrigerated systems and chilled water systems. They can be an excellent source of information related to specific refrigeration applications. Many vendors have published literature available to assist an industry in optimizing its cooling water treatment systems.
2) *Process Cooling & Equipment,* magazine published by BNP Media. http//www.process-cooling.com
3) American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is an international membership organization founded to advance the arts and sciences of heating, ventilation, air conditioning, refrigeration and related human factors. www.ashrae.org

3.11 Once-Through Cooling

A. Applicability

This BMP is intended for those industrial water users that circulate water from a lake or bay to remove heat generated from industrial equipment and mechanical devices such as heat exchangers, condensers, or process equipment. Water is consumed in the process by forced evaporation on the lake or bay. In addition a number of facilities with cooling lakes or ponds supplement the dependable yield of the plant reservoir by pumping water from another water source such as a lake or river.

B. Description

Cooling involves the removal of process energy in the form of heat. This BMP centers on the practices for optimizing the water-use efficiency of the once-through cooling systems and the makeup to the cooling reservoir from other sources.

The Environmental Protection Agency ("EPA") defines once-through cooling as water passed through the main condensers in one or two passes for the purpose of removing waste heat. This definition would also apply to other types of large heat exchangers that utilize cooling water to remove heat in one or two passes. Typically, large volumes of water at ambient temperatures are pumped from one arm of a lake or bay, through the heat exchange equipment where heat is transferred, and then are discharged to another arm of a lake or to a separate bay system. After the warm water is discharged to the receiving water body, heat is liberated from the once through cooling water primarily by evaporating a small portion of the total volume pumped. The cooled water then circulates back to the plant intake where it is again pumped back through the plant to provide cooling. For cooling reservoirs, the natural evaporation from the pond surface must also be made up or replenished.

Once-through cooling is the favored choice for cooling needs in electric power plants and many other large facilities such as petrochemical complexes, primarily for overall economical, operational, and reliability factors. Alternatives to once-through cooling in large facilities are recirculating evaporative cooling towers, dry cooling by induced air flow, and combination wet/dry (hybrid) cooling systems. Because of the significant amounts of capital investments and variability of operating expenses associated with each, cost effectiveness decisions on the type of cooling process to be used will generally be made during the planning and development of new facilities.

Water efficiency measures that should be implemented for existing once-through systems include:

1) sizing of pumps with cooling equipment to optimize heat transfer,
2) proper maintenance and repair of pipelines, intake and discharge structures, and
3) optimization of heat loading to the system.

For those plants that have an additional makeup supply to the cooling reservoir, the plant must carefully balance the makeup requirements to the cooling lake with the need to pump the additional water from the other sources. The cooling ponds should be optimally sized for efficient cooling with consideration for minimization of evaporative losses. For plants on cooling lakes that do not supply potable water, the use of alternative make-up water sources such as treated wastewater or reuse of water from other processes should be considered. At coastal locations, the use of saline water should be evaluated to provide complete or partial cooling for high heat load areas of the plant or as a replacement for higher quality water.

C. Implementation

After identification of water-cooled equipment, implementation should consist of the following actions:

1) Perform an equipment efficiency evaluation on each water-cooled system to optimize the effective heat transfer to the cooling water which thereby results in the optimum amount of cooling water being force evaporated.
2) Replacement or upgrades of small water-cooled systems with equipment using alternative cooling modes such as air-cooling or non-aqueous systems to reduce the heat load placed on the cooling reservoir.
3) Evaluate the cooling pond makeup requirements to optimize the amount of water required to be pumped to the plant reservoir.
4) Evaluate alternative sources of cooling pond makeup water such as reclaimed water from mining activities, wastewater from other industrial facilities, or wastewater from publicly owned treatment works.
5) Operation of the water-cooled processes and equipment in an efficient manner at all times. This includes maximization of external air-cooling opportunities, optimization of heat exchange equipment, use of solenoid valves or other methods for shutting down of systems when not in use, proper sizing of pumping equipment including consideration for variable speed drives, and keeping all structures and equipment maintained in optimal operating condition.
6) For industrial facilities located adjacent to coastal areas, consider utilizing saline water as a cooling source. Typically such a decision would be made during the design phase for a new process unit.

D. Schedule

If the water user chooses this BMP, the following is a recommended schedule:

1) The industrial water user should identify water cooled equipment and complete an efficiency evaluation in a timely manner. Evaluations of very large or complex systems should be completed within twelve (12) months of beginning this BMP.
2) The industrial water user should upgrade identified systems within a normal planning and budget cycle to implement the BMP in order to achieve the maximum water efficiency benefit in a reasonable time frame. For changes

implemented over multiple budget cycles, changes should be implemented in a progressive manner to increase efficiency.

3) Once-through cooling systems should be operated optimally at all times following the guidelines of this BMP.

E. Scope

To accomplish this BMP, the industrial water user should do the following:

1) Industrial water users with one facility, or several facilities with the same or very similar industrial processes, should perform an efficiency evaluation and perform upgrades or replacements as outlined in Section D.
2) For industrial water users with multiple facility sites, or multiple industrial processes, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until all facilities have been evaluated and conservation measures implemented.
3) Cost effectiveness considerations may result in partial implementation of this BMP at one or several of a large number of facilities.

F. Documentation

To track this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) Number of once-through cooled devices or systems and description of the process the cooling is used for, type of cooling process, and water use stream;
2) System design requirements for cooling including temperature, volume, and duration of flows (hr/day);
3) Where meters exist, the daily water use records for each system as appropriate for make-up water, discharge, and flow through the system. If discharge permits are held, these records should be kept in conformance with the requirements of the Texas Commission on Environmental Quality or other appropriate regulatory authorities.
4) Written details and records of all facility replacements, modifications, and upgrades of cooling systems made to meet the requirements of this BMP; and
5) Details of alternate water sources opportunities considered.

G. Determination of Water Savings

Water savings should be calculated based upon a quantified water balance for the entire cooling lake and plant water use systems. Changes in cooling lake volumes resulting from historic inflows, surface evaporation, forced evaporation, return flows from plant operations, seasonal differences in evaporative demand, seepage, and rainfall contributions to the water in storage should all be evaluated in the water balance analysis. Based on this analysis the industry should optimize the amount of makeup water needed to properly operate their reservoir. While it is recognized that each site will have unique circumstances for water conservation, opportunities may exist to reduce surface evaporation or percolation losses from the lake and increase potential return flows from the plant. These water saving opportunities should be included as terms in the water balance.

H. Cost-Effectiveness Considerations

The industrial water user should determine the cost effectiveness to implement each identified replacement or equipment upgrade in its once-through cooling facilities or operations, utilizing its own criteria for making capital improvement decisions. A cost effective analysis under this BMP should consider not only the capital costs of any equipment or process changes and improvements, but also the one-time costs of any feasibility studies, water quality sampling and testing, and regulatory costs. Additional ongoing costs to be considered may include staff and labor, chemical and treatment costs, additional costs or savings in energy use, purchased water supply costs, and potential savings in wastewater treatment costs.

I. References for Additional Information

1) The Electric Power Research Institute ("EPRI"), a non-profit energy research consortium which provides science and technology-based solutions to the energy industry, has conducted or has several ongoing projects that address water use, water availability, and water utilization.
2) The U.S. Department of Energy's Office of Fossil Energy has ongoing research in multiple aspects of water management issues for industry. www.fossil.energy.gov/programs/powersystems/
3) *Process Cooling & Equipment,* monthly magazine published by BNP Media focuses specifically on cooling equipment, materials and supplies used during the manufacturing process. http//www.process-cooling.com
4) *Water Efficiency Guide for Business Managers and Facility Engineers*, State of California Department of Water Resources, October 1994.

3.12 Management and Employee Programs

A. Applicability

This BMP is intended as a supplemental BMP for the other Industrial BMPs and could apply to all industrial water users. The successful implementation of any of the Industrial BMPs requires the joint efforts of both management and employees. This BMP describes the process for involving both management and employees in accomplishing the water conservation efforts of the industrial water user. Once an industrial water user decides to adopt this BMP, the water user should follow the BMP process closely in order to achieve the maximum water efficiency benefit from this BMP.

B. Description

For any Industrial BMP to be successful, the employees should be involved in the development and implementation of the BMP. A joint management/employee committee should be formed to determine the water conservation BMPs that will be beneficial to the user and this committee should guide the implementation of the BMPs that are adopted.

1) Set Goals & Obtain Management Support
   Goals should be established depending on the set of Industrial BMPs adopted by the industrial water user. Costs drive business decisions so cost savings are very important in the goal setting process and in obtaining strong management commitment for implementing the specific BMPs. For purposes of this BMP, the set of BMPs that the industrial water user has decided to adopt should be called the water conservation program (program).

   As with many other aspects of business management, ownership of the program by a member of the management team and routine management review of the results achieved are absolutely critical to successful implementation. A water conservation program will generate cost savings but will require funding and a time commitment to make the program work. It is very important that the funding and commitment are in place before the program is initiated.

2) Employee Education & Participation
   Employees can have a major effect on the success (or failure) of a water conservation program. Therefore, it is imperative that they be an integral part of all water conservation efforts and are kept informed about the program. The following steps can serve as guidelines for effectively enlisting employees' full support, keeping employees informed of the progress being made, and seeking their participation on an ongoing basis.
   a. Communication to all employees from a key management leader of the organization. The communication should announce the water conservation program, introduce the Water Conservation Manager on the leadership team, detail specific goals, ask for employee support, and invite feedback.

b. Establish an employee water use education program. The education program should communicate information about
   - the importance of and need for water conservation in Texas, the local region of the state, and the industry;
   - the overall aspects of the company's water conservation program, including specific goals and incentives;
   - the importance of each individual's contribution to the success of the water conservation goals of the entire organization and, if appropriate, the region of Texas;
   - how specific water-saving measures by individuals can reduce overall consumption;
   - how specific water-saving measures by employees working together as a team can result in major water use reductions; and
   - new procedures and water conservation equipment that should be implemented.

c. Use a wide variety of communication media to help keep the water conservation message current and to reinforce the importance of the organization's water conservation efforts. Potential communication vehicles include
   - company newsletter
   - internal website
   - memos
   - paycheck stuffers
   - email
   - posters and signs
   - water conservation "progress reports" and "score cards"
   - new and/or revised operating guides and manuals that describe changes made to implement water-saving measures

d. Establish a schedule for regular communication with employees about the water conservation program. The initial excitement of a new program will begin to fade unless the importance of the program is regularly communicated. Ensure that employees are kept abreast of the specific water reduction measures as they are being implemented as well as the associated water, energy and cost savings generated by those measures. Information about water and cost savings are especially useful to help tie water conservation to business results.

e. Get employees involved.
   - Establish incentive programs to encourage and reward participation. One example could be offering employees a percentage of the first year's direct savings resulting from water and energy conservation;
   - Create a "Water Conservation Ideas" box where employees can submit suggestions on how the organization can save water;
   - Promote slogan and poster contests;

- Create friendly team competition between shifts, operating areas, divisions, and/or locations;
- Reward employees with a pizza party or similar celebration when water conservation plan goals are met; and
- Reward employees who spot leaks and other instances of water waste.

f. Implement effective new ideas submitted by employees. Recognize and reward the contributions made by individual employees, groups, and the organization as a whole.

Benefits from implementing this BMP include lower utility costs, energy savings, reduced process costs and an enhanced public image.

C. Implementation

The industrial water user should follow these steps to implement this BMP:

1) Form a combined management/employee committee and determine which of the Industrial BMPs will be implemented.
2) Incorporate the selected BMPs into a water conservation program using the schedules and scope from the individual BMPs. The program should include a component to involve all employees in implementation of the program as described in Section B.

D. Schedule

If a water user chooses to implement this BMP, the following is a recommended schedule:

1) The employee conservation team should be completed in a timely manner, within approximately three (3) months of implementing this BMP.
2) The water conservation program should be implemented based on the timelines of the individual Industrial BMPs adopted and in the normal business cycle.

E. Scope

To accomplish this BMP, the industrial water user should do the following:

1) Organizations with one facility, or several facilities with the same or very similar industrial processes, should organize a management/employee conservation committee and implement the program following the schedule outlined in Section D.
2) For organizations with multiple facility sites, a progressive implementation schedule should be followed, implementing the BMP in successive facilities until all facilities have established employee conservation teams and implemented the water conservation program developed by the team.

3) Organizations with multiple facilities should consider organizing conservation teams to include representatives from all facilities where the tasks are similar and where such cross-facility teams are feasible.

F. Documentation

To track the progress of this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) List of members of employee conservation team and team minutes;
2) List of actions taken to educate all employees about the importance of water conservation and involve them in implementing the program;
3) Copy of the water conservation program;
4) Documentation of actual implementation of each item contained in the water conservation program; and
5) Estimated water savings and actual water savings for each item implemented and associated cost savings if appropriate.

G. Determination of Water Savings

The industrial water user should calculate water savings based on the calculation methodology appropriate to the identified water efficiency opportunities.

H. Cost-Effectiveness Considerations

It may be difficult to determine direct water savings and cost effectiveness of this BMP on its own. Costs that should be considered in this BMP include labor and staff costs, materials, and overhead. By implementing an employee water conservation program, the industrial water user will improve the efficiency of its overall water conservation efforts, ensure the success of other BMP efforts it may choose to undertake, enhance its public image, and increase employee goodwill. Some employee suggestions resulting from the program could be implemented with minimal cost impact. For suggestions with significant cost impacts, each industry should utilize its own criteria for making capital improvement decisions.

I. References for Additional Information

1) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*. New Mexico Office of the State Engineer, July 1999. http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf
2) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
3) *Water Efficiency Guide for Business Managers and Facility Engineers*, State of California Department of Water Resources, October 1994.
4) *Waste Not, Want Not: The Potential for Urban Water Conservation in California*, Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf

5) *Commercial and Institutional End Uses of Water*, AWWA Research Foundation, Summer 2000.

3.13 Industrial Landscape

A. Applicability

This BMP is intended for industrial water users that irrigate landscape areas or use a significant amount of water in outdoor irrigation. Water conservation in the landscape can reduce water demands overall, reduce peak stress on water delivery systems, save energy, and reduce fuel and water costs. Landscape irrigation also offers the opportunity for water reclamation and reuse or useful disposal of water sometimes considered waste, such as air conditioning condensate.

For industrial water users, reducing water used for irrigation as an efficiency measure has the benefits of reduced water bills and landscape maintenance costs. Studies have shown that many plants that have undergone the stress of water constraints become more drought resistant and require less irrigation. Once an industrial water user decides to adopt this BMP, the water user should follow the process closely to achieve maximum water efficiency and other benefits this BMP offers. This BMP is not intended for cases where irrigation water is applied to mining reclamation projects, landfill closeouts, or other similar revegetation projects, but those projects should be done in an efficient manner with attention to water conservation.

B. Description

Under this BMP, the industrial water user with an irrigated landscape area will conduct a landscape water-use survey of its site and facilities. The water-use survey should at a minimum include measurement of the landscape area; measurement of the total irrigable area; irrigation system checks and distribution uniformity analysis; and review or development of irrigation schedules. In addition, the survey should identify currently irrigated areas where irrigation could be discontinued because such areas are not highly visible or the plant materials in these areas do not need supplemental irrigation. The survey should also identify areas in which return flow reuse, stormwater reuse, and use of treated wastewater effluent for irrigation might be environmentally, legally, and agronomically feasible.

If the water user has an automated irrigation system to irrigate turf grass, it will develop reference evapotranspiration (ETo)-based water-use budgets equal to a maximum of no more than 80 percent of reference evapotranspiration per square foot of irrigated landscape area. The statewide Texas Evapotranspiration Network (http://texaset.tamu.edu/) should be consulted for historical evapotranspiration data and methodology for calculating reference evapotranspiration and allowable stress. As the website indicates, those desiring greater water savings can utilize stress coefficients lower than 80 percent. If irrigated landscape area exceeds one (1) acre, the water user should install a dedicated irrigation meter or submeter.

Some industrial users have found that ceasing all irrigation and allowing native groundcovers to grow amidst an existing turf grass landscape is an effective means of reducing water use. Others have used rainwater harvesting, condensate reuse, cooling tower blowdown, RO reject water or stormwater recovery to irrigate landscape areas. These approaches could be considered a substitute means to accomplish the water saving goals of this BMP.

At the start and end of the irrigation season, irrigation systems should be checked and repaired and adjustments made as necessary. For companies with landscape managers on staff, training in landscape maintenance and irrigation system design should be required. In accordance with Texas law, individuals responsible for installing irrigation systems must be licensed by the State of Texas.

Large managed landscapes and commercial operations should prepare a written irrigation management site plan that clearly identifies responses and priorities during water-limited situations such as various stages of drought. The plan should be part of a comprehensive landscape management plan that addresses other management practices such as mowing, fertilizing, etc. On large sites, written landscape plans that include specifications for soil preparation, plant materials, irrigation design, mulch, and maintenance instructions are particularly important.

A landscape conservation program might also incorporate systematic upgrades to reduce water use, including irrigation system components, design and maintenance programs, and landscape design. Rainwater sensors, irrigation controllers, pipe specifications, and hydrozone specifications are all potential elements of an irrigation systems upgrade.

Landscape design emphasizing low-water-use plants should also be considered. Plants appropriate to the region in which they are being planted and with documented low water requirements should be given priority in the landscape design. All designs should be based on the seven principles of WaterWise landscaping (also known as Xeriscape principles).[1] Careful follow-up is essential to ensure that water is not applied in excess of plant needs. In addition to the references noted below, many landscape management companies in Texas now offer water-efficient landscape design and maintenance services.

Landscape design for new construction should use low-water-use plants appropriate to the region of Texas. For large landscape areas, an evapotranspiration (ET) controller or soil moisture sensors should be installed in order to use real-time input to determine plant water stress and needs. A new irrigation system will include a rain sensor shutoff mechanism and use drip or low-pressure irrigation heads in hydrozones where appropriate in order to achieve maximum water efficiency.

Soil improvement is an effective method for reducing irrigation water usage while maintaining healthy soils. Soil improvement programs on high visibility areas can demonstrate to the public the effectiveness of this method. For most landscapes, compost applications of 1/4 to 1/2 inch annually on turf areas and one inch annually on flower beds are recommended. Compost is most beneficial when applied in the fall.

[1] Water Wise Landscape programs follow the seven principles of Xeriscape™, from the Texas A&M Horticulture Website (2), listed below and explained in greater detail in resources listed in the reference section:
1. Planning and design; 2. Soil analysis and improvement; 3. Appropriate plant selection; 4. Practical turf areas; 5. Efficient irrigation; 6. Use of mulches; and 7. Appropriate maintenance.

C. Implementation

The initial step is an efficiency evaluation of the existing landscape area and irrigation systems. Recommended changes to the irrigation system will come from the evaluation report.
The evaluation should include:

1) a list of landscape areas, measurements, plant types, irrigation system hydrozones, controller(s);
2) a list of existing irrigation policies including maintenance and irrigation schedules;
3) a distribution uniformity analysis on irrigated turf areas; and
4) an initial report summarizing the results of the evaluation.

Based on the results of the evaluation, the water user develops and implements a program to maintain and operate its irrigation systems in a water-efficient manner. Maintenance programs include seasonal system checks, adjustment of irrigation timers when necessary, installation of rain sensors, and regular review of irrigation schedules. Internal reporting should be done to confirm that regular seasonal maintenance of the irrigation systems is achieved. When landscape management companies are utilized, contracts should include a required report showing regularly scheduled maintenance and seasonal adjustments to irrigation systems controllers.

In its landscape management programs, the water user should consider installation of climate-appropriate water-efficient landscaping; installation of an ET-based irrigation controller; and dual metering. Another measure to consider is the training of personnel in landscape maintenance, irrigation system maintenance, and irrigation system design. Implementation of Integrated Pest Management strategies can also result in reduced use of pesticides and fertilizers, thereby reducing the amount of water required.

For users that do not have an ET-based controller collecting real-time data, evapotranspiration data is available for numerous parts of the state from the Texas Evapotranspiration Network (Network). This Network will expand over time, as more weather stations are added. If the water user is located in a part of the state not covered by the Network, then it can use the methodology on the Network Website (http://texaset.tamu.edu/) and weather data available from federal agencies such as the National Oceanic and Atmospheric Administration ("NOAA") or the United States Geological Survey ("USGS"). While this BMP sets 80 percent ETo as the minimal allowable stress ("AS") to achieve water conservation, lower irrigation amounts are achievable by reducing the AS coefficient further. A preferred alternative approach is to utilize the methods for reducing irrigation quantities as outlined in this BMP and on the Network, but collect evapotranspiration data on site by purchasing a weather station.

If significant changes to irrigation systems or landscape design are implemented, these should be planned with a licensed irrigation professional or a professional landscape designer for optimal water savings. Ceasing irrigation of the landscape and allowing native groundcovers to flourish or converting to an alternative water source are also acceptable means of implementing this BMP.

D. Schedule

If the water user chooses this BMP, the following is a recommended schedule:

1) The irrigation systems evaluation should be completed in a timely manner. Efficiency evaluations of very large or complex systems should be completed within the first twelve (12) months of implementing this BMP. This is a reasonable time period to complete a thorough evaluation.
2) Develop ETo-based water-use budgets for all landscape zones no more than two years after the implementation start date.
3) Within two years of the implementation start date, install a dedicated landscape meter if landscape use is determined to exceed one (1) acre.
4) If irrigation systems upgrades are indicated or new landscape designs are planned, the changes should be initiated immediately after the landscape report is concluded and be completed within twelve (12) months.
5) The Landscape BMP shall be fully implemented within two years of the start date. If determined to be necessary for very large or complex facilities, the schedule can be extended. BMPs should be initiated in the second year and continued until the targeted efficiency is reached.

E. Scope

To accomplish this BMP:

1) Industrial water users with several facilities with the same or very similar landscape irrigation systems should conduct a landscape evaluation following the schedule outlined in Section D.
2) Industrial water users with several facility sites with very different landscape irrigation systems at the various sites should follow a progressive implementation schedule, implementing the BMP successively until all facilities have been audited and conservation measures implemented.
3) Cost-effectiveness considerations may result in partial implementation of this BMP at one or several of a large number of facilities.

F. Documentation

To track the progress of this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) Summary report of the initial landscape survey;
2) Estimated ETo-based budget and annual water savings using the method described in Section G below;
3) Records of monthly landscape water use, personnel training, and changes to equipment and performance specifications;
4) Demonstrated water use reduction in targeted landscapes; and
5) Data on program progress, water savings, and expenditures.

G. *Determination of Water Savings*

Estimated water savings should be based on the assumption that a landscape survey and resulting programs will result in a 15 percent reduction in the amount of water used for landscape purposes. Calculating savings can be more accurately achieved after implementing the BMP.

Water savings calculation: $S = I_{(h)} - I_{(BMP)}$

Where S is savings in acre-feet/year
$I_{(h)}$ is annual irrigation average prior to implementing BMP
$I_{(BMP)}$ is annual irrigation after implementing BMP

80 percent ETo calculation: $I = ETo \times Kc \times AS$

Where I is the irrigation amount to be applied for a given period (daily, twice weekly, weekly, etc.) in inches or centimeters
ETo is the measured reference evapotranspiration over the irrigation period
Kc is a turf coefficient for turf grasses, and can be found at http://texaset.tamu.edu/
AS is allowable stress of 0.8 (or less if the landscape manager wishes)

When applying irrigation, the equation should be modified to gain greater water savings, by accounting for precipitation: $I = (ETo \times Kc \times AS) - P$
Where P is precipitation in inches or cm.

H. *Cost-Effectiveness Considerations*

The industrial water user should determine the cost effectiveness to implement each identified replacement or upgrade to its landscape irrigation equipment and procedures, utilizing its own criteria for making capital improvement decisions. Many operating procedures and controls that improve the water use efficiency should be implemented simply as a matter of good practice. A cost effectiveness analysis under this BMP should consider capital equipment costs and changes in staff and labor costs.

I. *References for Additional Information*

1) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*. New Mexico Office of the State Engineer, July 1999. http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf
2) *EARTHKIND™ Environmental Landscape Management* http://aggie-horticulture.tamu.edu/earthknd/earthknd.html 2004.
3) *Landscape Irrigation Scheduling and Water Management,* Water Management Committee of the Irrigation Association, September 2003. http://www.irrigation.org/PDF/IA_LIS_AND_WM_SEPT_2003_DRAFT.pdf

4) *Turf and Landscape Irrigation Best Management Practices*, Water Management Committee of the Irrigation Association, September 2003. http://www.irrigation.org/PDF/IA_LIS_AND_WM_SEPT_2003_DRAFT.pdf
5) *Waste Not, Want Not: The Potential for Urban Water Conservation in California*, Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
6) *WaterWise Council of Texas.* http://www.waterwisetexas.org/
7) *San Antonio Water System Conservation Program.* http://www.saws.org/conservation/
8) *ET and Weather Based Controllers CUWCC Web Page.* http://www.cuwcc.org/Irrigation_Controllers.lasso
9) *Smart Water Technology Initiative Web Page.* http://www.irrigation.org/swat1.asp
10) *Austin Green Gardening Program.* http://www.ci.austin.tx.us/greengarden/
11) *City of Corpus Christi Xeriscape Landscaping.* http://www.cctexas.com/
12) *Texas Cooperative Extension for El Paso County.* http://elpasotaex.tamu.edu/horticulture/xeriscape.html

3.14 Industrial Site Specific Conservation

A. Applicability

This BMP applies to any industrial water user with facility or product-specific water-using processes. While other BMPs address most water uses in industrial facilities, this BMP is offered to assist the industrial water user in designing a BMP for process which is not covered by other industrial BMPs. The industrial water user can use the guidelines of this BMP to develop a site-specific BMP using appropriate elements from other BMPs. This BMP would also be useful for an industrial user that may be required to submit a conservation plan to a wholesale provider or other entity.

B. Description

Industrial conservation practices are essential for reducing water usage in the industrial sector. Under this BMP, the water user should conduct an industrial water-use survey as defined in BMP 3.1 (Industrial Water Audit). The water-use survey includes an evaluation of all water-using equipment and processes and will result in a report identifying potential conservation measures and their expected payback based on a cost-effective analysis. From the results of the survey a water conservation program should be developed that identifies performance goals, actions to meet the goals, and methods of measuring success and estimating water savings.

Those facilities which operate an Environmental Management System ("EMS") may already have water conservation as an environmental aspect and may have already adopted a conservation program. Facilities that have adopted ISO 14000 or other systems with a "Plan-Do-Check-Act" framework may already meet several of the elements of this BMP.

Because each facility is unique, the scope and formality of its conservation program will vary according to its size, sector, and complexity. Once all water uses are identified through a survey and potential conservation goals are identified, other industrial BMPs should be reviewed for applicability and those BMPs that would be beneficial to the water user should be selected.

If there are specific measures that should be implemented that fall outside already existing BMPs, a BMP can be developed following the Best Management Practice outline. All selected and developed BMPs should then be incorporated into the conservation program. A qualifying conservation program and site specific BMP should include the following essential elements:

1) Clear description of goals and implementation steps
2) Implementation schedule
3) Scope
4) Documentation
5) Information used to determine water savings
6) Cost-effectiveness analysis

For new facilities, design and construction should be accomplished with conservation in mind, and measures implemented should be documented to demonstrate efficiencies achieved, and water savings potential of such measures.

C. *Implementation*

Any industrial site specific water conservation program must have a fundamental starting point: to understand the water use at the facilities. The initial step is to perform an industrial water-use survey as described in BMP 3.1 (Industrial Water Audit). The water-use survey should include an evaluation of all water-using equipment and processes and identification of potential conservation measures along with their expected payback based on a cost/benefit analysis.

1) Access Information and Resources
   There are many sources of information available on all aspects of water conservation. Water conservation districts, water planning groups, industry trade associations, and the Texas Water Development Board ("TWDB") are all good sources for specific conservation guidance materials. A water user should first attempt to find available resources that will greatly reduce the time and cost of developing a site specific BMP. The easier and quicker the practice can be prepared the sooner implementation can commence and results can be obtained.

2) Define Performance Measures
   In order to set goals and monitor conservation success it is necessary to derive performance measures. Each facility audit should identify the appropriate performance measure of water usage. Examples of performance measures are gallons per unit of product, per employee, per process, per cycle, per unit of energy consumption, per unit of manufacturing area, or per time period. Those performance measures should be used in tracking the success of this Industrial Site-Specific Conservation Program BMP. Two examples are gallons per pound or ton produced and gallons per kWh of power produced.

3) Employee Education & Participation
   Employees can have a major effect on the success of a water conservation practice and the overall conservation program. Employees will be responsible for implementing efficient practices and are usually the first to notice a problem and/or identify changes that can make the process more efficient. Therefore, it is imperative that they be kept informed about the program and made an integral part of all water reduction efforts. The steps outlined in BMP 3.12 (Management and Employee Programs BMP) can serve as a guideline for effectively informing employees of the BMPs in your program and enlisting their full support and participation on an ongoing basis.

4) Measure Results & Publicize Success
   The site-specific water conservation practice should include specific metrics on water use and water conservation strategies. Goals should be approved by management and be specific and measurable, and a timetable for compiling and

reviewing information should be defined. Direct management involvement in the goal setting process should facilitate acceptance and improve the likelihood of success. The specifics of the conservation practice will dictate how quickly it can be implemented and how quickly water savings can be achieved. Generally, a conservation practice should not take more than one year to develop and implement. Water conservation should become a regular parameter that the management team reviews just as they regularly review revenue, costs, financial performance, safety, and environmental compliance. Toward that end, just setting expectations of water conservation without regular review or monitoring of the results will not result in a more water-use efficient facility.

In addition to saving water, energy and money, positive public opinion is an extremely important benefit. Because Texas is a very diverse state with a variety of climatic conditions, water conservation is of ongoing public interest. News media throughout the state routinely cover "good news" stories about companies, institutions, and industrial facilities that take a proactive stand on water conservation. Incorporating conservation efforts into qualifying for TCEQ's Environmental Excellence Program or Clean Texas Program are excellent methods of achieving this objective.

D. Schedule

If the water user chooses this BMP, the following is a recommended schedule:

1) The water-use survey should be conducted in a timely manner. Audits of very large or complex systems should be completed in the first three (3) months after initiating this BMP.
2) The selection and development of BMPs, cost-effectiveness analysis of water efficient alternatives, and the development of the conservation practice should be completed by the end of the first year. If determined to be necessary for very large or complex facilities, the schedule can be extended. BMPs should be initiated within the normal business cycle and continued until the targeted efficiency is reached.
3) Regular monitoring of water use and annual evaluation of water-use efficiency should be maintained.

E. Scope

To accomplish this BMP, the industrial applicant should:

1) Conduct an industrial water-use survey consistent with the guidelines and schedule above, and
2) Implement the site specific conservation practice.

F. Documentation

To track the progress of this BMP, the industrial water user gathers and maintains the following documentation and can utilize industry accepted practices:

1) Water-use survey results and potential conservation measures identified through the survey;
2) A description of each BMP implemented;
3) A description of the measures implemented and estimated water use reductions achieved through these measures. The water user should document how savings were realized and the method and calculations for estimating savings; and
4) A copy of the site specific conservation practice and the conservation program, which includes all BMPs planned, estimated potential water savings and schedule for completion.

G. Determination of Water Savings

The industrial water user should calculate water savings based on the calculation methodology appropriate to the identified water efficiency measures adopted. Each industrial process will have its own potential for water savings. Studies have shown estimated overall water savings for implementing water audits have been in the range of 10 percent to 35 percent on average. Efficiency measures which included changing from high quality or potable water to recycling water have shown savings in the range of 50 percent to as high as 95 percent.[1]

H. Cost-effectiveness Considerations

The industrial water user should determine the cost effectiveness to implement each identified water savings opportunity, utilizing its own criteria for making capital improvement decisions. A cost effectiveness analysis under this BMP should consider, as appropriate, capital equipment costs, staff and labor costs, administrative materials and overhead, chemical and treatment costs, additional costs or savings in energy use, costs for waste disposal, and potential savings in wastewater treatment costs. The one-time-only costs of developing and implementing the facility evaluation survey and recommendations should also be included.

I. References for Additional Information

There are significant resources that have already been developed that should assist an industrial water user in implementing this BMP.

1) *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, May 2001.
2) *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*. New Mexico Office of the State Engineer, July 1999. http://www.seo.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf

3) Millwater Pumping System Optimization Improves Efficiency and Saves Energy at an Automotive Glass Plant, Office of Industrial Technology, Department of Energy, March 2003. http://www.oit.doe.gov/bestpractices/factsheets/gl_cs_visteon_nashville.pdf
4) *Water Efficiency Guide for Business Managers and Facility Engineers*, Sate of California Department of Water Resources, October 1994.
5) *Commercial and Institutional End Uses of Water*, AWWA Research Foundation, Summer 2000.
6) *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* Pacific Institute, November 2003. http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
7) *Water Efficiency Manual for Commercial, Industrial and Institutional Facilities*, State of North Carolina, August 1998. http://www.p2pays.org/ref/01/00692.pdf

3.15 Cost Effectiveness for Industrial Water Users

A. Introduction

The industrial water user should determine if implementation of each identified BMP measure to achieve water savings would be cost effective. The analysis should determine the cost effectiveness to the industrial water user of the lower direct costs of the saved water and other cost savings that may also accrue. Many operating procedures and controls that improve water use efficiency should be implemented simply as a matter of good practice. In other cases the industrial user may decide to implement BMPs based on non-cost factors such as public good will or political reasons. In evaluating equipment and process additions or changes, each industry should utilize its own criteria for making capital improvement decisions.

B. Cost Effectiveness Example

The following gives a simplified example of the process that an industrial water user can use to evaluate the cost effectiveness of making water savings investments and decisions under any applicable BMP. Each industry should utilize its own financial criteria for making capital improvement decisions.

A cooling tower efficiency audit of a small industrial facility resulted in three recommendations for water savings: increase the cycles of concentration in the cooling tower, improve the overall cooling system efficiency with regard to repairing facilities and overall system operations, and look for opportunities to reuse the cooling tower blowdown.

The system currently uses approximately 20,000 gallon per day (14 gpm). Increasing the cycles of concentration from two (2) to six (6) will reduce the amount of blowdown water by about 8,000 gallons per day. To effectively do that the system will require new monitoring and controls for pH and conductivity, automatic blowdown controls, chemical feed systems, and related piping and equipment modifications. Also, to maintain that level of operation, the industry will utilize the service of a professional water treatment firm to monitor the operation and supply appropriate chemicals to keep the facilities in good repair.

Estimated capital costs of retrofitting and installing conductivity controller, probes, valves, chemical injectors, relays, etc., will be about $7,500. For a medium size facility the cost of using a monthly water management consulting and chemicals firm would increase by approximately $250 per month ($3,000 per year). In this example, the water source is the company's own wells, and the overall average cost of supplying water and disposing of wastewater is $2 per 1000 gallons.

Estimated water savings = 8,000 x 360 days = 2,880,000 gal (8.84 ac ft)
Or $5,760 a year ($480 per month) or $652 per acre foot per year

1) The simple payback analysis for capital expenditures =

   $7,500 / ($5,760 - $3,000) = 2.7 years

The payback method does not take into account the time value of money.

2) A simple present worth analysis, with the assumptions of a 6 percent rate over the estimated life of the controls of ten (10) years shows that it would be cost effective to implement the measure.

6%, 10 years		Amount	Years	P V
Capital Costs	$	7,500	0	($7,500)
O & M Contractor	$	250	per mo	($22,518)
Water Savings	$	480	per mo	$43,235
Net Present Value				$13,217

3) The second water savings recommendation is to increase the overall efficiency of the cooling system by such measures as coil cleaning, reducing heat load, making operations more efficient with variable speed fans and pumps, adjusting belts, replacing fill, repairing and replacing shielding, and generally keeping the system in good repair. Estimated water savings from these measures could be up to an additional 15 percent (Pacific Institute, 2003), which is about 1,800 gallons per day. If the company spends $5,000 in cleaning up the cooling tower operation initially, and then spends $1,000 every other year for a ten year period, the cost effective analysis shows that the measure would be effective, again assuming a ten (10) year life of the measure.

6%, 10 years		Amount	Years	P V
Capital Costs	$	5,000	0	($5,000)
Periodic cleaning, etc	$	1,000	every 2 yrs	($3,573)
Water Savings	$	108	per mo	$9,728
Net Present Value				$1,155

4) The next recommended water savings measure was to investigate opportunities for reuse of the blowdown water for other purposes within the facility. After savings from increasing the cycles of concentration, the quantity of water is relatively small, and quality of the water will not be suitable for every purpose. This facility requires relatively good quality of water for reuse in its manufacturing processes, so in order to use the approximately 2,000 gallons per day of blowdown, collection facilities, a tank, additional pumping, and a small membrane treatment unit will be needed for a cost of $10,000. Then operating costs are conservatively estimated to be approximately $100 per month. If the facilities have a useful life of 10 years, then the analysis shows that the measure is not cost effective.

6%, 10 years	Amount	Years	P V
Capital Costs	$ 10,000	0	($10,000)
Treatment costs	$ 100	per mo	($9,007)
Water Savings	$ 108	per mo	$9,728
Net Present Value			($9,279)

C. *Additional Considerations:*

The analyses in these examples are fairly straightforward and some assumptions to simplify the example were made. In a detailed, case by case evaluation of the water users facilities, there are additional cost components associated with the water savings measures that may be taken into consideration, including:

1) Initial efficiency evaluation and engineering costs.
2) Administration and other increased labor costs if significant.
3) Estimated energy savings.

The cost of water is also a very significant component of the analysis. In this example it was assumed to be the same for the entire period, and the production facilities were already in place. If the industry would have to consider the additional expansion of its water facilities, or obtaining alternate water supplies at some point in the future, the costs of water saved would be even greater. These costs would include:

1) Costs of water or contract purchase of water.
2) Construction of treatment or production facilities.
3) Operating costs.
4) Increased or alternative costs of waste disposal.

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4.0 BMPs for Agricultural Water Users

BMPs for agricultural water users are combinations of site-specific management, educational, and physical practices that have proven to be effective and are economical for conserving water. BMPs have been developed which focus on increasing the water use efficiency of water users such as producers of agricultural crops and of water suppliers such as irrigation districts. BMPs have been developed which focus on conserving rainwater, such as land owners managing and controlling brush species. BMPs provide a means of measuring the success of agricultural water conservation programs, their costs, and schedules of implementation. Good agricultural water conservation practices can provide benefits to wildlife resources.

Irrigation of crops accounts for the great majority of agricultural water use in Texas. The amount of water used in irrigation of a specific crop or in an agricultural practice varies with the location, climate, type of crops grown, local cropping practices, type of irrigation systems, and institutional constraints. Likewise, the amount of water conserved by implementing a BMP for such crop or practice will also vary.

Agricultural Water Use Management BMPs may include Irrigation Scheduling to determine when to irrigate crops, Volumetric 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 and Nursery Production Systems, which improve the efficiency of water use in the production of nursery crops.

The quantity of water and cost savings provided in each BMP are estimates, and actual values vary with location and site specific conditions.

Best-management practices contained in the BMP Guide are voluntary efficiency measures that save a quantifiable amount of water, either directly or indirectly, and can be implemented within a specified timeframe. The BMPs are not exclusive of other meaningful conservation techniques that an entity might use in formulating a state-required water conservation plan. At the discretion of each user, BMPs may be implemented individually, in whole or in part, or be combined with other BMPs or other water conservation techniques to form a comprehensive water conservation program. The adoption of any BMP is entirely voluntary, although it is recognized that once adopted, certain BMPs may have some regulatory aspects to them (e.g., implementation of a local city ordinance).

4.1 Agricultural Irrigation Water Use Management

4.1.1 IRRIGATION SCHEDULING

A. Applicability

This BMP is used to determine when to irrigate a crop and is intended for agricultural producers that have access to irrigation water in adequate quantities and at times required by the producer. Advanced irrigation scheduling methods are particularly applicable to nursery/floral irrigation systems that have an adequate water supply and delivery system.

B. Description

Irrigation scheduling is a generic term for the act of scheduling the time and amount of water applied to a crop based on the amount of water present in the crop root zone, the amount of water consumed by the crop since the last irrigation, and other management considerations such as salt leaching requirements, deficit irrigation, and crop yield relationships. Irrigation scheduling is a water management strategy that reduces the chance of too much or too little water being applied to an irrigated crop. Extensive publications exist regarding irrigation scheduling, many of which are documented in "Evapotranspiration and Irrigation Water Requirements" by the American Society of Civil Engineers, Manual No. 70. The most common irrigation scheduling methods are:

1) Direct measurement of soil moisture content, soil water potential, or crop stress including: soil sampling, tensiometers, gypsum blocks, infrared photography of crop canopy, time domain reflectrometry, plant leaf water potential, and other methods.
2) Soil Water Balance Equations: Irrigation methods based on soil water balance equations. These equations range from very simple "checkbook" accounting methods to complex computer models that require input of climatic measurements such as temperature, humidity, solar radiation, and wind speed. The Texas Cooperative Extension Service maintains a network of weather stations that are used to determine the "Reference Evapotranspiration" in agricultural regions throughout the state.

C. Implementation

Each type of Irrigation Scheduling method has specific steps required for implementation. The manufacturers of soil moisture measurement equipment typically provide detailed instruction on how to operate their equipment. Soil Water Balance implementation information can be obtained from the Texas Cooperative Extension Services – Texas Evapotranspiration Network web site (texaset.tamu.edu) ET User's Guide for Growers. This guide has step-by-step instructions for using evapotranspiration for scheduling irrigations. Other evapotranspiration networks include North Plains ET Network and the South Plains ET Network.

D. Schedule

Irrigation scheduling can be implemented at any time during crop production, but normally an irrigation scheduling program is established prior to the first irrigation of the crop.

E. Scope

All agricultural producers, to one degree or another, schedule their irrigations. However, only a small percentage of producers use advanced irrigation scheduling methods. The producer has to balance when a crop is irrigated with both the demand by the crop for water and the amount of labor and water supply that the producer has available to irrigate. In many cases in western Texas where there is little rainfall, the producers have a limited water supply and limited capacity to deliver water to the field. Under these conditions the producer is continually using 100 percent of his water supply to irrigate, and most, if not all, of the producer's fields are under-irrigated (deficit irrigation). Another issue to many producers is the economics of scheduling. Yield and/or quality of many irrigated crops can be very dependent on adequate soil moisture at one or more critical periods in crop growth. Often, a producer will balance the cost of irrigation with the risk of reducing crop yield and/or quality if the irrigation is delayed or no water is applied. Depending on the producer's investment in the crop ($200 to $1,200 per acre) and the cost of water ($10 to $50 per acre per irrigation), the producer may choose to irrigate independently of any irrigation scheduling program.

F. Documentation

To document this BMP, the agricultural water user shall document and maintain one or more of the following records:

1) Records of the amount of rainfall, irrigation dates, and volumes of water applied during each irrigation and the method;
2) Records of the location and information collected from direct measurement of soil moisture; and/or
3) Copies of irrigation scheduling program reports or printouts.

G. Determination of Water Savings

The amount of water saved by implementing advanced irrigation scheduling is difficult to quantify, likely varies from year to year, and is strongly influenced by climatic variation, cropping practices, irrigation water quality, and total amount of water used to irrigate. The Pacific Northwest Laboratory (1994) attempted to verify estimates of reduction in the amount of irrigation water pumped in the Grand County Public Utility District resulting from the implementation of irrigation scheduling. The Public Utility District estimated savings of 0.3 to 0.5 acre-feet per acre, but actual savings could not be confirmed or disproved by the Pacific Northwest Laboratory's review.

H. Cost-Effectiveness Considerations

The cost for implementing advanced irrigation scheduling methods depends on the method of scheduling used and the number of fields scheduled, the type of scheduling program, and the cost for technical assistance.

I. References for Additional Information

1) *Evapotranspiration and Irrigation Water Requirements, Manuals and Reports on Engineering Practice No. 70*, 332 p., American Society of Civil Engineers, 1990
2) Texas Cooperative Extension Service, Irrigation and Water Management. http://farwest.tamu.edu/text/watermgt/et.html
3) Texas Evapotranspiration Network, Texas A&M University-College Station, Department of Biological and Agricultural Engineering. http://texaset.tamu.edu/
4) *Applicability and Limitation of Irrigation Scheduling Methods and Techniques*, Iteier, B. *et al.*, United Nations, Food and Agricultural Organization. http://www.fao.org/docrep/W4367E/w4367e04.htm
5) North Plains PET network: http://amarillo2.tamu.edu/nppet/whatpet.htm

4.1.2 VOLUMETRIC MEASUREMENT OF IRRIGATION WATER USE

A. Applicability

This BMP is applicable to agricultural irrigation systems and agricultural producers that irrigate. The requirements and applicability of volumetric measurement of irrigation water use varies between specific geographic regions and political subdivisions in the State.

B. Description

The volumetric measurement of irrigation water use provides the water user with information needed to assess the performance of an irrigation system and better manage an irrigated crop. There are numerous types of volumetric measurement systems or methods that can be used to either directly measure the amount of irrigation water used or to estimate the amount of water from secondary information such as energy use, irrigation system design, or mechanical components of the irrigation system.

1) Direct Measurement Methods
Direct measurement methods usually require either the installation of a flow meter or the periodic manual measurements of flow. Several common direct measurement systems for closed conduits (pipelines) are:

- Propeller meters
- Orifice, venturi or differential pressure meters
- Magnetic flux meters (both insertion and flange mount)
- Ultrasonic (travel time method)

Several common methods for direct measurement of flow in open channels are:

- Various Types of Weirs and Flumes
- Stage Discharge Rating Tables
- Area/Point Velocity Measurements
- Ultrasonic (Doppler and travel time methods)

2) Indirect Measurement Methods
Indirect measurement methods estimate the volume of water used for irrigation from the amount of energy used, irrigation equipment operating or design information, irrigation water pressure, or other information. Indirect measurements require the correlation of energy use, water pressure, system design specifications, or other parameters to the amount of water used during the irrigation or to the flow rate of the irrigation system when irrigation is occurring.

Several common indirect measurements for irrigation systems are:

- Measurement of energy used by a pump supplying water to an irrigation system
- Measurement of end-pressure in a sprinkler irrigation system
- Change in the elevation of water stored in an irrigation water supply reservoir
- Measurement of time of irrigation and size of irrigation delivery system

Estimating irrigation water use from an indirect method can be as accurate as a direct measurement. For example, to estimate the volume of water pumped by a new electric powered irrigation pump based on kilowatt-hours of energy used during the billing period of the electric service provider, the following equation can be used:

$$\text{Acre-Feet per Billing Period} = \frac{\text{(Kilowatt Hours/Billing Period) x Pumping Plant Efficiency (\%)}}{\text{236.6 x Pump Pressure (psig)}}$$

Where the pump pressure is the total dynamic head (ft) of the pump converted to pressure, and Pumping Plant Efficiency (typically 55 percent to 75 percent) equals the pump efficiency (usually obtained from the pump manufacturers pump curves, typically 60 percent to 80 percent) multiplied by the motor efficiency (typically 90 percent-95 percent for 3 phase motors greater than 20 horsepower). The total dynamic head for a turbine pump installed in a water well includes the head required to lift the water from the well and head lost to friction.

C. Implementation

When implementing this BMP it is important to be aware that the installation of a flow meter or indirect measurement varies significantly with each site, type of measurement being made, desired accuracy of the measurement, and the volume or flow rate of the water being measured. Each type of direct measurement flow meter should be installed according to the recommendations of the manufacturer of the meter. Indirect measurement methods require the water user to determine the correlation between the indirect measurement (kilowatt hours, gallons, or ccf of fuel) and the volume of water used. Typically, the indirect measurement is correlated to the amount of water used by an engineer or technician using a portable flow meter or information from the irrigation system design. Both direct and indirect measurement methods should be periodically evaluated for the accuracy of volume or flow rate of the water being measured.

D. Schedule

For direct measurement systems, the time required to install a flow meter can vary from an hour or two for a saddle mount or insertion meter to several days for the construction of a metering vault and fabrication of associated piping or the construction of a weir, flume, or open channel metering station. For indirect measurement, once the indirect measurement (such as energy usage) is correlated to the volume of water used, no additional installation or construction is required. However, the indirect measurement correlation may need to be repeated periodically to verify pumping capabilities due to normal wear on irrigation equipment.

E. Scope

The methods for volumetric measurement of irrigation water and the associated scope vary from site to site, and each site and method may have unique limitations or requirements. The scope for volumetric measurement ranges from very simple (recording the amount of energy used per month from an energy bill), to complex (installation and management of a large open channel flow measurement station). Furthermore, metering requirements vary by geographic region and by political subdivision (River Authorities, Irrigation Districts, Water Improvement Districts, Groundwater Conservation District, etc.).

F. Documentation

The water user should record the total quantity of water used per site, field, or system on a periodic basis as determined by the water user to be necessary for implementing other BMP practices. At a minimum, recording of the volume of irrigation water used should be done every year. Indirect measurements, such as energy use, are often documented by a monthly bill or statement from the supplier of the energy (i.e. the electric service provider), which becomes the record of the amount of water used during such billing period.

G. Determination of Water Savings

This BMP is used in coordination with other BMPs and in itself does not directly conserve any water. However, the information gained helps better inform the user of costs associated with water use and will assist the user in implementing voluntary conservation measures.

H. Cost-Effectiveness Considerations

Cost for volumetric measurement of irrigation water use varies greatly from application to application. Typical impeller meter installations for irrigation pipelines with diameters between 4 inch and 15 inch cost between $600 and $1,000 per meter. Cost for installation of a large open channel flow meter (flume, weir, or metering station) can be in the tens of thousands of dollars. Cost for indirect measurements, such as energy use, depends on the amount of time required to correlate the indirect measurement to the amount of water used and the time required to compile and record such information. The cost and the benefits of statewide implementation of this BMP are significant. The TWDB’s 2001 *Survey of Irrigation in Texas* reported that there were approximately 6.4 million acres of land irrigated in 2000 in Texas and 115,857 irrigation wells.

Most of these wells do not have flow meters, and the exact number of unmetered irrigation wells is unknown.

I. References for Additional Information

1) *Water Measurement Manual,* U.S. Bureau of Reclamation, 1997, U.S. Government Printing Office, Washington, D.C. 318 p.
2) *Techniques of Water Resource Investigation Reports, Book 3 Application of Hydraulics*, U.S. Geological Survey.
3) *Energy Use for Pumping*, Center for Irrigation Technology, California State University at Fresno. http://www.wateright.org/site2/advisories/energy.asp
4) *Buying an Energy-Efficient Motor*, Office of Industrial Technologies, U.S. Dept. of Energy, Best Practices. http://www.oit.doe.gov/bestpractices/motors/factsheets/mc-0382.pdf
5) *Survey of Irrigation in Texas*, Report 347, 102 p., Texas Water Development Board, August 2001.

4.1.3 Crop Residue Management and Conservation Tillage

A. Applicability

This BMP is applicable to irrigated crops and most agricultural producers using irrigation water. Conservation tillage in general is applicable to both irrigated and dryland farming and can be used to preserve soil moisture in areas where there is significant winter precipitation to allow conversion of irrigated land to dryland farming.

B. Description

This BMP includes tillage methods such as no till, strip till, mulch tillage, and ridge till. Residue management and conservation tillage allow for the management of the amount, orientation and distribution of crop and other plant residue on the soil surface year-round on crops grown where the entire field surface is tilled prior to planting. Conservation tillage improves the ability of the soil to hold moisture, reduces the amount of water that runs off the field, and reduces evaporation of water from the soil surface.

C. Implementation

The number, sequence and timing of tillage and planting operations and the selection of ground-engaging components shall be managed to achieve the planned amount, distribution and orientation of the residue after planting or at other essential time periods. Loose residue shall be uniformly distributed on the soil surface. Tillage implements shall be equipped to operate through plant residues to maintain residue on or near the soil surface by undercutting or mixing. Planting devices shall be equipped to plant in the distributed residue on the soil surface or mixed in the tillage layer.

D. Schedule

Residue management and conservation tillage may be practiced continuously throughout the crop sequence or may be managed as part of a residue management system that includes other tillage methods such as no till.

E. Scope

For furrow irrigation, crop residue in furrows can impede the flow of water down the field and cause problems with irrigation uniformity and application efficiency. Conservation tillage is more appropriate with some types of irrigation systems than others. For example, conservation tillage works well with low-pressure center pivot irrigation and subsurface drip irrigation.

F. Documentation

Establishment and operation of this practice shall be prepared for each field and recorded using jobs sheet, narrative statements in the conservation plan or other acceptable documentation.

G. Determination of Water Savings

The amount of water saved by conservation tillage will vary by climate and irrigation method. Increased spring soil moisture content resulting from conservation tillage may allow a farmer to conserve one or more irrigation applications per year (typically 0.25 to 0.50 acre-feet per acre). Reduction in soil moisture loss during the irrigation season may save an additional 0.5 acre-foot per acre.

H. Cost-Effectiveness Considerations

The cost of conservation tillage depends on the type of field operation used to manage crop residues. Some conservation tillage programs are less expensive than conventional tillage.

I. References for Additional Information

1) *Conservation Practice Standard for Residue Management, No Till/Strip Till (Acre), Code 329A*, Natural Resources Conservation Service, March 1999.
2) *Conservation Practice Standard for Residue Management, Mulch Till (Acre), Code 329B*, Natural Resources Conservation Service, March 1999.
3) *Conservation Practice Standard for Residue Management, Ridge Till (Acre), Code 329C*, Natural Resources Conservation Service, November 2002.

4.1.4 ON-FARM IRRIGATION AUDIT

A. Applicability

This BMP is applicable to agricultural producers that currently use on-farm irrigation and should be thought of as the initial BMP for agricultural water users to increase water efficiency in irrigation. Under this BMP the water user will collect information about water that is used to irrigate farm crops.

Once an agricultural water user decides to adopt this BMP, the water user should follow the BMP process in order to achieve the maximum benefit from this BMP.

B. Description

Water audits are an effective method of accounting for all water usage for on-farm irrigation and to identify opportunities to improve water use efficiency. Benefits from implementation of this BMP may also include energy savings and reduced chemical costs.

On-farm irrigation audits include measurement of water entering the farm or withdrawn from an aquifer, the inventory and calculation of on-farm water uses, calculation of water-related costs, and identification of potential water efficiency measures. The information from the on-farm irrigation audit forms the basis for implementing measures to increase efficiency of current farming practices and the basis for deciding which additional BMPs to implement. The conservation program may consist of one or more projects in different areas of the agricultural operation.

The audit will consist of gathering information on the following (source: NRCS):

- Field size(s) and shape, obstructions, topography, flood vulnerability, water table, and access for operation and maintenance;
- Type of pump equipment and energy source and pumping efficiency, if any;
- Type of irrigation equipment, age and general state of repair;
- Records of previous and current crops and water use; and
- Human assets - Available technical ability and language skills of laborers. Time and skill level of management personnel.

C. Implementation

The agricultural water user should conduct an on-farm irrigation audit that generally follows the guidelines as outlined in this section. NRCS procedures for an on-farm irrigation audit will result in the same or similar results. References that provide more detailed audit procedures are listed in Section I below.

1) <u>Preparation and information gathering</u>
The material collected to implement this BMP will be useful for other BMPs as well. Information that should be collected before beginning the audit includes

maps of the agricultural operation with field sizes and locations of main water supply, meters or measuring points, inventories of irrigation equipment, and irrigation schedules. Also, information about crop types, field slope, soil types and textures, and infiltration rates should be collected. Water use data for the past year should be collected. Additionally, any prior water use audits should be obtained and reviewed since these reports may include useful and relevant information to determine the most appropriate water saving measures to implement.

2) Conduct on-farm irrigation audit
The on-site physical examination and water use audit should identify and verify all equipment that uses water. Water usage for each major water use area should be determined. If possible during the audit, the performance of the irrigation equipment should be evaluated while it is being used to irrigate farmland.

3) Prepare a cost-effectiveness analysis
The cost-effectiveness analysis should determine the water efficiency opportunities that are cost-effective to implement. The analysis may also identify water efficiency opportunities that should be implemented even if not cost effective due to high visibility, ease of implementation, or general goodwill. After confirming the cost-effectiveness of the BMP, the action plan should then be prepared.

4) Prepare an action plan
The action plan should identify the conservation goals and recommend specific technology or actions that must be implemented by the agricultural producer to meet such goals. The plan should include estimates of the time required to implement the proposed technology or actions and list any governmental or non-governmental programs or services needed to implement the plan.

5) Preparation of an on-farm irrigation audit report
The data gathering and the on-site audit should be incorporated into an audit report that includes an updated set of field diagrams and water flow charts broken down by water use areas, a current list of all water using equipment including actual and manufacturer recommended flow rates, a current schedule of irrigation for all areas and equipment, an analysis of water costs by each field and for the entire farm, and calculations of the difference between water coming into the agricultural operation and a list of identified water uses throughout the operation. (Note: This is the amount of water that is potentially being lost by leaks and other losses.) The on-farm irrigation audit report should contain a proposed timetable to implement selected water efficiency measures.

D. Schedule

1) The audit will be completed in a timely manner.
2) The recommendations should be implemented within the first normal budget cycle following the conclusion of the audit. For most farms, this should be a reasonable time period to implement the recommendations. Major projects may take additional time for implementation.
3) If determined to be necessary for very large or complex agricultural operations or for more comprehensive conservation plans, the schedule can be extended. BMPs will be initiated in the second year and continued until the targeted efficiency is reached.

E. Scope

To accomplish this BMP:

1) Agricultural water users with one farm, or several farms with the same or very similar irrigation practices, should conduct a water audit following the schedule outlined in Section D above.
2) For agricultural water users with multiple farms sites, or multiple types of agricultural operations, a progressive implementation schedule should be followed, implementing the BMP at successive farms until all farms have been audited and conservation measures implemented.

F. Documentation

To track the progress of this BMP, the agricultural water user should gather and have available the following documentation:

1) The audit report;
2) Cost-effectiveness analysis;
3) The action plan;
4) Schedule for implementing the action plan;
5) Documentation of actual implementation of water efficiency measures contained in the action plan; and
6) Estimated water savings and actual water savings for each item implemented.

G. Determination of Water Savings

This BMP in and of itself does not save any water but helps identify other agricultural water conservation BMPs that may be implemented by the agricultural water user to save water.

H. Cost-Effectiveness Considerations

The cost of a farm audit varies from minimal to significant with the extent of the audit and if the audit is done internally, by a consultant, or using assistance from a governmental entity. The Texas State Soil and Water Conservation Board ("TSSWCB") prepares Water Quality Management Plans which often address water conservation measures for agricultural land, and the NRCS can assist agricultural water user in implementing conservation plans.

I. References for Additional Information

1) Edwards Aquifer Authority, Groundwater Conservation Plan, September 2000, Rev. January 2004, *Appendix F- Water Savings Assumptions*.
2) Texas State Soil and Water Conservation Board, *Water Quality Management Plans*, http://www.tsswcb.state.tx.us/programs/wqmp.html
3) Natural Resources Conservation Service, September 1997, Irrigation - Handbooks and Manuals - National Engineering Handbook Part 652 - Irrigation Guide, *Estimated Efficiency Improvements Expected from Irrigation System Improvements*, http://www.wcc.nrcs.usda.gov/nrcsirrig/irrig-handbooks-part652.html
4) Natural Resources Conservation Service, March 1999, *Irrigation Management*, National Conservation Practices Standards, Code 449, 2 p.

4.2 Land Management Systems

4.2.1 FURROW DIKES

A. Applicability

This BMP is used to reduce water runoff from agricultural row crops and is intended for use by agricultural producers that plant row crops.

B. Description

Furrow dikes are small earthen dams formed periodically between furrow ridges. Furrow dikes reduce runoff from the soil surface and increase infiltration of rain or water applied by sprinkler irrigation. Furrow dikes can be used on gently sloping land in arid and semiarid areas.

C. Implementation

Furrow dikes should be implemented in fields with row crops to capture rainfall, reduce runoff from fields, and improve uniformity of low pressure sprinkler irrigation applications.

D. Schedule

Furrow dikes are typically first installed in non-wheel traffic rows at the time the crop bedding is prepared and reinstalled or maintained as necessary during portions of the crop growing season with high irrigation demand or high probability of rainfall occurring.

E. Scope

Furrow dikes are installed using a tractor-drawn implement in non-wheel traffic rows and can be used in the following agricultural practices:

1) In conjunction with a conservation tillage practice, furrow dikes are installed in rows when the crop bedding is prepared to facilitate capture of rainwater or water from preplant low-pressure sprinkler irrigation and may remain in place during the entire growing season.
2) In conjunction with conventional tillage, furrow dikes can also be installed after the crop bed is prepared and prior to planting or after a crop is planted and prior to the crop height being such that the installation would damage the crop. The dikes must be removed prior to and replaced after mechanical cultivation of weeds.
3) Furrow dikes are typically removed when additional moisture from rainfall would be detrimental to production or harvest of the crop.

F. Documentation

To document this BMP, the agricultural water user shall document and maintain one or more of the following records:

1) Photographs of the furrow dikes installed;
2) Any USDA Farm Service Agency or other governmental agency evaluation and assistance reports that may relate to the project; and
3) Water measurement records from both the periods before and after conversion to the water efficient irrigation system.

G. Determination of Water Savings

The amount of water conserved using furrow dikes is difficult to estimate and is dependent on when the furrow dikes are installed, the amount of rainfall, rainfall intensity, the infiltration rate of the soil, the slope of the furrow, and the application rate of the sprinkler irrigation system. Measured data for a row crop field without furrow dikes in the High Plains Region of Texas showed that the quantity of runoff was equal to 12 percent of the gross quantity of water applied using sprinkler irrigation. The runoff was eliminated for the same field when the furrow dikes were installed.

H. Cost-Effectiveness Considerations

The cost for purchasing or constructing a furrow diking implement ranges from less than $2,000 to several thousand. Cost estimates per crop season per acre range from $5 to $30 per acre. The quantity of water saved by installation of such varies from field to field and season to season, but a conservative estimate would be three inches per season (0.25 acre-feet per acre).

I. References for Additional Information

1) *The Impact of Furrow Dike, Terracing, and Contour Cultivation on Water Conservation in Texas Agriculture*, Tucker, Kevin and Sam Feagley, 1998.
2) *Water management studies in the Rolling Plains,* TAES, B-1321. 19 p., Gerard, C.J., D.G. Bordovsky, and L.E. Clark, 1980.
3) *Furrow diking to conserve moisture,* J. of Soil Water Cons. 44: 271-273. Harris, B.L., and J.H. Krishna, 1989.
4) *Off-Season Manager Tips Pre-Plant Irrigation Management*, S5-02/03, Texas Agricultural Extension Service, 5 p., Porter, Dana, 2003.

4.2.2 LAND LEVELING

A. Applicability

This BMP is applicable to agricultural producers that use furrow, border, or basin irrigating of agricultural crops.

B. Description

This BMP is used to increase the uniformity with which water is applied to an irrigated field. The term "Land Level" generally applies to mechanized grading of agricultural land based on a topographic survey. In only a few special situations does the final product of land leveling result in a level field. Most land leveling is done using a laser controlled scraper pulled by a tractor. The laser is set to predetermined cross and run slopes, and the scraper automatically adjusts the cut or filled land over the plane of the field as the tractor moves.

C. Implementation

All leveling work should be designed based on measurement of land elevations (topography). If more than one irrigation method or more than one kind of crop is planned, the land must be leveled to meet the requirements of the most restrictive irrigation method and crop. The leveling work must be designed within the slope limits of the water application method used, provide for removal of excess surface water and control erosion caused by rainfall.

D. Schedule

Land leveling work falls into two general categories: 1) large scale land shaping typical to newly irrigated land or land that has never been graded, and 2) land level or floating of a field prior to preparation of seed beds or borders. The time required per acre of land to grade a field depends on the size of the land grading equipment and the quantity and distance that soil must be moved. Typically, the time required to "touch-up" a field prior to planting is measured in hours per acre, whereas initial grading of a field may take one or more days per acre.

E. Scope

Land leveling is typically used on mildly sloping land. Contour farming is used to farm on modest slopes and terrace farming is used for steeply sloping land. Land leveling is primarily used by agricultural producers using surface methods (furrow, border, or basin) to irrigate their fields or by those wishing to improve surface drainage of their non-irrigated field.

F. Documentation

The documentation may consist of the following items:

- Copies of the topographic survey of the land prior to land leveling.

- Drawings that show the design slopes and field layout after the land leveling work is complete.
- Annual records of “touch-up” land leveling work by field.

G. Determination of Water Savings

The quantity of water that may be saved from land leveling is difficult to estimate. Land leveling is critically important to improving surface irrigation uniformity and application efficiencies.

H. Cost-Effectiveness Considerations

The cost of land leveling for new irrigation fields is usually estimated based on the soil type, the cut to fill ratio, and the total number of cubic yards which must be cut. Touch-up land leveling is usually based on a “per acre” or “per hour” rate. Cost per yard of cut varies from approximately $1.00 to $2.00 per cubic yard depending largely on diesel fuel costs. Initial costs per acre for land leveling can range from $50 to $400. Touch up land leveling usually costs less than $50 per acre and most commonly less than $25 per acre.

I. References for Additional Information

1) *Irrigation Land Leveling*, Natural Resources Conservation Service, United States Department of Agriculture, National Conservation Practice Standards No. 464.

4.2.3 CONTOUR FARMING

A. Applicability

This BMP applies to agricultural users where crops are irrigated on moderately sloping lands.

B. Description

Contour farming is the practice of tillage, planting and other farming operations performed on or near the contour of the field slope. This method is most effective on slopes between two (2) and ten (10) percent. Tillage and planting operation follows the contour line to promote positive row drainage and reduce ponding.

C. Implementation

The steps necessary for implementing contour farming are

1) Topographic survey of field.
2) Layout of a baseline contour with markers, an untilled crop row paralleling the contour, or other method of marking a baseline contour.
3) Prepare field borders to allow room for farm implements to turn.
4) Perform all farming activities parallel to baseline contour(s).

D. Schedule

Contour farming can be implemented at the time the field is being prepared for farming.

E. Scope

Minimum and maximum row grade, ridge height, slope lengths and stable outlets must be determined. Obstruction removal and changes in field boundaries and shape should be considered to improve the effectiveness of the practice and ease of farming operations. Agricultural operations with slopes exceeding 10 percent will find this practice less effective. Rolling topography having a high degree of slope irregularity is not well suited to contour farming.

F. Documentation

Specifications for this BMP shall be recorded using specification sheets, job sheets, narrative statements or other acceptable documentation.

G. Determination of Water Savings

The amount of water savings resulting from implementing contour farming is site specific and dependent on how the field was previously farmed and irrigated.

H. Cost-Effectiveness Considerations

The cost for preparing contour rows as compared to conventional rows is minimal. The primary cost per acre for contour farming is for the field layout and surveying of the contours. The cost for surveying varies from $1 to $3 per acre. Secondary costs for contour farming may include additional farming and harvesting costs for small row lengths in corners and ends of the field.

I. References for Additional Information

1) *Conservation Practice Standard, Contour Farming (Acre)*, Natural Resources Conservation Service, February 2000, NRCS, NHCP Code 330.

4.2.4 CONVERSION OF SUPPLEMENTAL IRRIGATED FARMLAND TO DRY-LAND FARMLAND

A. Applicability

This BMP is applicable to agricultural producers that currently use ground or surface water as a supplement to rainfall to irrigate agricultural lands that are located in geographic areas where agricultural crops can be produced without irrigating. This BMP is not applicable to geographic areas of the state of Texas that have insufficient rainfall to produce an agricultural crop. This BMP is not applicable to the conversion of farmland to non-farmland.

B. Description

Dry-land farming produces agricultural crops using precipitation as the source of soil moisture. Many geographic parts of Texas receive sufficient precipitation to produce some types of crops. Typically the crop yields produced by dry-land farming are significantly lower than yields produced by irrigated farming. Crop yields from dry-land farming vary season to season depending on the amount and timing of precipitation.

Permanent pasture is the most common type of dry-land farming and is popular as a dry-land crop because pasture can survive longer periods of no rainfall compared to typical row crops such as milo, corn, or cotton. In the High Plains and Lower Rio Grande Valley regions of Texas, low water use crops such as cotton have been successfully grown without irrigation. However, irrigation of such crops in those regions reduces the risk of crop failure due to lack of soil moisture and increases crop yield.

Some crops such as sugar cane, rice, and many vegetable crops cannot be grown in Texas without irrigation regardless of the geographic location of the crop.

C. Implementation

The effect of conversion from irrigated farming to dry-land farming on crop yields, crop production costs including the costs of irrigation, and farm profits should be evaluated by comparing information from dry-land farming in the same geographic and climatologic area in which the irrigated land is located. After the agricultural water user has evaluated the increased risks associated with dry-land farming, the water user should then convert an amount of previously irrigated land to dry-land farming that is acceptable to the user based on the amount of increased risk.

D. Schedule

Conversion from supplemental irrigated farmland to dry-land farmland can be implemented at the beginning of the crop growing season on a field by field basis.

E. Scope

This BMP should be used with other BMPs that can improve the water use efficiency of dry-land farming such as conservation tillage and furrow diking.

F. Documentation

To track this BMP, the agricultural water user shall gather and maintain the following documentation:

1) Copies of records of crop yields and crop production expenses;
2) Any USDA Farm Service Agency or other governmental agency evaluation and assistance reports documenting that specific fields were not irrigated; and
3) Irrigated water use and rainfall measurement records from the periods before conversion to dry-land farming.

G. Determination of Water Savings

The quantity of water saved by conversion from supplemental irrigated farmland to dry-land farmland can be estimated based on historical water use records for the crop type and geographic location where the crop was grown.

H. Cost-Effectiveness Considerations

The cost-effectiveness of conversion to dry-land farming requires complex economic and climate analysis. Dry-land farming can be significantly less costly than irrigated farming. However, since crop yields are often less, and the risk of crop failure may be significantly increased, the amount of profit per acre of dry-land is usually less than irrigated land. Texas Agricultural Extension Service estimated that crop yields grown in Bexar, Medina, and Uvalde Counties for dry-land farming are one-third to one-half less than for irrigated farming.

I. References for Additional Information

1) P. W. Unger, T. V. Sneed, W. R. Jordan, R. Jensen (eds.) *"Proc. Intl. Conf. on Dryland Farming, Challenges in dryland Agriculture - a Global Perspective"*, Aug. 1988, Amarillo/Bushland, Texas. TAES, p. 965.
2) Pena, Jose, 1997, *"Texas Crop Enterprise Budgets"*, Southwest Texas District, Texas Agricultural Extension Service, Uvalde, Texas.

4.2.5 BRUSH CONTROL/MANAGEMENT

A. Applicability

This BMP, where appropriately based on regional factors and site location characteristics, is a potential means of reducing evapotranspiration by brush species (such as ashe juniper, mesquite, and salt cedar) in order to improve soil conservation, water quality and water yield. It is intended for use by agricultural producers in riparian areas or on upland areas (rangeland, native or naturalized pasture, pasture, and hay lands) where sufficient rainfall or water exists as determined by a feasibility study prepared by the Natural Resource Conservation Service ("NRCS"), the Texas State Soil and Water Conservation Board ("TSSWCB"), or the project manager. This BMP is intended for use with governmental cost-share programs.

B. Description

Brush Control/Management includes the removal, reduction or manipulation of non-herbaceous plants by mechanical methods, chemical treatment, biological methods, prescribed burning, or combinations of these methods to achieve the desired plant community. Prescribed grazing shall be applied to ensure desired response from the above treatments. Chemical treatments should be applied in accordance with NRCS and TSSWCB recommendations and in a manner consistent with the product label so as to protect water quality and non-target plant or animal species.
To be considered a water conservation BMP a Brush Control/Management project should:

1) Demonstrate water savings. The project should be able to provide probable and measurable water benefits, and the project manager should establish reasonable hydrologic goals considering local conditions before implementation.
2) Be cost-effective.
3) Be compatible with the natural soil profile and conditions. Excessive removal of brush or removal of brush in areas that have thin soil profiles or steep slopes can lead to severe erosion. This can negatively impact water quality downstream and remove important soil microorganisms from the site.
4) Be compatible with natural vegetation. Before removal of brush, a project manager should identify the vegetation appropriate for restoration of the area. A manager should assess whether or not the restoration can occur naturally or if it needs to be augmented with planting.
5) Maintain or promote affected wildlife. A properly designed brush management project can provide habitats for a variety of wildlife species, including endangered species.
6) Incorporate an effective maintenance plan. Maintenance of the brush management area is critical to ensure continuance of water production.

C. Implementation

A Brush Control/Management plan should be developed for each pasture, field, or management area where Brush Control/Management will be applied. The Brush Control/Management plan should include the following information:

1) Brush canopy or species count and percent canopy or number of target plants per acre.
2) Maps or drawings showing areas to be treated and areas to be left undisturbed.
3) For mechanical treatment methods:
    a. Types of equipment to be used
    b. Dates of treatment
    c. Equipment operating instructions
    d. Techniques or procedures to be followed
4) For chemical methods:
    a. Herbicide name
    b. Rate of application or spray volumes
    c. Acceptable dates of application
    d. Mixing instructions (if applicable)
    e. Application techniques, timing considerations or other factors that must be considered to ensure safe, effective application, including available manufacturer's literature and/or instructions and NRCS or TSSWCD guidelines. The chemical will be used in a manner consistent with the product label so as to protect water quality and non-target plant or animal species.
5) For biological treatment methods:
    a. Kind of biological agent or grazing animal to be used
    b. Timing, duration and intensity of grazing or browsing
    c. Desired degree of grazing or browsing used for control/management of the target species
    d. Special precautions or requirements when using insects or plants as control/management agents

Brush Control/Management will be planned and applied in a manner to meet wildlife habitat requirements and consider wildlife concerns.

D. Schedule

Brush Control/Management projects are typically multi-year in scope to achieve initial removal levels and then require follow-up treatments every three to five years. A Brush Control/Management project can be scheduled over several years to reduce the cost of the project.

E. Scope

Brush Control/Management for water conservation is typically applicable to non-irrigated land in areas with sufficient rainfall, as determined by feasibility studies, for brush to become established and to present a problem or in riparian areas (land adjacent to water courses).

F. Documentation

To document this BMP, plans and specifications for each field scheduled for Brush Control/Management will be prepared and may include narratives, maps, and/or drawings. These documents may contain the following items:

1) Maps or aerial photographs of the field prior to brush treatment;
2) Maps or aerial photographs of the field one or more years after brush treatment;
3) Method used for Brush Control/Management and receipts for materials or contract work;
4) For chemical treatments, records should be kept of specific names and types of chemicals used, application rates, and total amounts used;
5) Estimates of the number of target plants per acre or percent canopy cover prior to treatment; and
6) Estimates of the number of target plants per acre or percent canopy cover one or more years after treatment.

G. Determination of Water Savings

Accurate determination of the quantity of water salvaged by Brush Control/Management requires expert analysis. In general, control/management of salt cedar in riparian areas has the potential to salvage significantly more water per acre treated than control/management of brush on uplands. However, there is significantly more land in Texas with brush infestation in upland areas as compared to riparian areas. The NRCS in cooperation with the Texas Agricultural Experiment Station through the TSSWCB reported that expected water yields for various levels of control/management of brush in upland areas range from 0.34 to 0.55 acre-feet per year per acre (net).[1] It was estimated that the annual amount of water salvaged from salt cedar control/management in riparian areas along the Pecos River in West Texas at 5 to 8 acre-feet per acre treated.[2]

H. Cost-Effectiveness Considerations

Texas A&M University at College Station, Department of Agricultural Economics, found that "present values of total upland brush control costs per acre range between $35.57 and $203.17" for a time period of ten years, and the cost of "added water" between $14.83 and $35.41 per acre-foot averaged for the same time period. The United States Natural Resources Conservation Service Environmental Quality Incentives Program for Texas provides partial funding for eligible mechanical brush control and management projects at rates per acre based on the "established county average cost of the practice". The county average costs range from $150 to $200. It was reported that the cost for chemical treatment of salt cedars on the Pecos River in

West Texas using aerial application of between \$183 and \$189 per acre and a resulting cost for the salvaged water of \$7.90 to \$8.22 per acre-foot using a conservative estimate of the effective life of the treatment of 3 years.[2] The cost of salvaged water per acre-foot in other locations may be significantly different.

I. References for Additional Information

1) *Brush/Water Yield Feasibility Studies II"*, USDA Natural Resources Conservation Office, Texas Agricultural Experiment Station, USDA- Agricultural Research Service. Bednarz, S., *et al.*, no date.
3) *The Pecos River Ecosystem Progress Report*, Texas Cooperative Extension Service, http://farwest.tamu.edu/rangemgt/Saltcedar/2002_Progress_Reports.pdf, Hart, Charles, 2002.
4) *Assessing the Economic Feasibility of Brush Control to Enhance Off-Site Water Yield*, Department of Agricultural Economics, Texas A&M University, College Station. Dumke, L, *et al.*, no date.
5) *Conservation Practice Standard, Brush Management*, Natural Resources Conservation Service, April 1995, Code 314.
6) *Brush Management, "Myths and Facts",* Environmental Defense, 2003, 17 p. Ball, Laura and Melinda Taylor.
7) Technical Resources, USDA-NRCS, www.nrcs,usda.gov/technical

4.3 On-Farm Water Delivery Systems

4.3.1 LINING OF ON-FARM IRRIGATION DITCHES

A. Applicability

This BMP is applicable to agricultural producers that use open channels to convey irrigation water to fields.

B. Description

This practice is accomplished by installing a fixed lining of impervious material in an existing or newly constructed irrigation field ditch. The three most commonly used impervious liners for irrigation canals in Texas are Ethylene-Propylene-Diene Monomer (EPDM), urethane, and concrete. Each type of liner has benefits and detriments specific to the liner. EPDM is the least expensive and concrete the most expensive. Reinforced concrete liners have the longest durability but may have the largest seepage rate. Urethane has low seepage rates but uses hazardous chemicals during installation. The U.S. Bureau of Reclamation report titled "Canal Lining Demonstration Project Year 7 Durability Report" provides a detailed description of these and other liners.

C. Implementation

The specific steps required to implement this BMP depend on the type of ditch liner used and the existing conditions of the ditch to be lined. Installation specifications, material specifications and detailed installation instructions for most types of ditch liners are available from liner manufacturers and governmental agencies. In general, most ditch lining projects require the following steps:

1) A site survey of the proposed ditch being lined which includes the length of ditch and one or more typical cross-sections of the ditch;
2) Development of a plan that details the installation and materials specifications;
3) Preparation of the ditch bed, including removal of any vegetation, bed compaction, and bed shaping;
4) Installation of liner; and
5) Finish work including inlets and outlets to lined ditch.

D. Schedule

The time required to line a farm irrigation ditch depends on the size of cross-sectional perimeter of the ditch, the amount of work needed to prepare the ditch for lining, and the type of liner used to line the ditch. EPDM liners are usually the easiest and quickest to install. For a typical farm ditch with a top width of five feet, between 500 and 1,000 feet of EPDM liner can be installed per day with a crew of five persons. Slip form concrete lining of the same ditch with the same number of workers can line between 200 and 500 feet per day.

E. Scope

Replacement of on-farm ditches with low-pressure pipelines is an alternative to lining the ditch. Typically, small ditches with flow capacities less than 5 cubic feet per second are candidates for replacement with a buried pipeline. Each type of liner has advantages and disadvantages. EPDM should not be used in a location where the ditch is subject to large animal or other traffic that might tear the liner. Concrete liners handle most traffic well, but are subject to crack formation due to soil heave, tree root pressure, or thermal expansion.

F. Documentation

To document this BMP, the agricultural water user shall gather and maintain the following documentation:

1) Copies of equipment invoices or other evidence of equipment purchase and installation;
2) Any USDA Farm Service Agency or other governmental agency evaluation and assistance reports that may relate to the project.
3) Water measurement records from the period both before and after conversion to the water efficient irrigation system.

G. Determination of Water Savings

The seepage rate of a farm ditch can be estimated by conducting a ponding test with a typical section of the ditch prior to the ditch being lined. A ponding test measures the rate at which the level of water ponded behind an earthen dam placed in the ditch drops over two to twenty-four hours. The amount of the ditch that is wetted by the pond behind the dam must be measured. The seepage rate can be calculated as acre-feet per mile of ditch per day. The total quantity of water lost to seepage from the ditch is estimated by multiplying the seepage rate times the number of days per year the ditch is used to convey water. For example, a small farm ditch with a wetted perimeter of 5 feet and a length of 1/2 mile is found to have a seepage rate of 1.0 acre-feet per mile per day, assuming the ditch is used to carry irrigation water 40 days per year. The total seepage from the ditch is 20 acre-feet per year (1/2 x 1.0 x 40). Lining the ditch with an EPDM liner would result in minimal or no seepage. Seepage loss from a concrete lining depends on how the liner was constructed and the amount of water that seeps through cracks and expansion joints in the concrete. A conservative estimate would be that concrete lining salvages 80 percent of the original seepage, or for the example, 16 acre-feet.

H. Cost-Effectiveness Considerations

U.S. Bureau of Reclamation in June of 2001 published “Construction Cost Tables – Canal Lining Demonstration Project.” The cost table included material and installation costs for approximately thirty-five different types of liners or coatings. The cost for an installed EPDM liner was approximately $0.85 per square foot and $1.43 per square foot for urethane. The cost for concrete lining ranges from $2.50 to $3.50 per square foot. For the example above the cost per acre-foot of water salvaged in the first year for the EPDM liner would be $11,220 ($561 per acre-foot), for urethane liner $18,876 ($944 per acre-foot) and for concrete $33,000 ($1,650 per acre-foot). Because each of these types of liner has a different life expectancy a present value analysis of cost should be performed. For example, while the concrete liner may have the most expensive installation cost, it also has the longest life expectancy.

I. References for Additional Information

1) *Conservation Practice Standard, Irrigation Water Conveyance, Flexible Membrane Ditch and Canal Lining*, 9 p. Natural Resources Conservation Service, October 1980.
2) *Canal Lining Demonstration Project Year 7 Durability Report*, 156 p. U.S. Bureau of Reclamation, Pacific Northwest Region, September 1999.
3) *Canal Lining Demonstration Project,- 2000 Supplemental*, 46 p. U.S. Bureau of Reclamation- Pacific Northwest Region, January 2000.
4) *Construction Cost Tables – Canal Lining Demonstration Project*, 5 p U.S. Bureau of Reclamation, Pacific Northwest Region, June 2001.

4.3.2 REPLACEMENT OF ON-FARM IRRIGATION DITCHES WITH PIPELINES

A. Applicability

This BMP is applicable to irrigated farms that use an open ditch to convey irrigation water and as an alternative to lining the ditch. In general, pipelines are used to replace on-farm ditches with less than 2,000 gpm (4.5 cubic feet per second) capacity.

B. Description

This practice is the replacement of on-farm irrigation ditches with buried pipeline and appurtenances to convey water from the source (well, irrigation turnout, farm reservoir) to an irrigated field. On-farm pipelines can be used to replace most types of farm ditches. In general, on-farm pipelines are 24 inch in diameter or less, with 8 inch through 15 inch pipelines being common. Most farm pipelines use either PVC Plastic Irrigation Pipe (“PIP”) or Iron Pipe Size (“IPS”) PVC pipe. PIP is available in diameters from 6 inch to 27 inch with pressure ratings from 80 psi to 200 psi. IPS PVC pipe is available in diameters from 6 inch to 12 inch with pressure rates from 63 psi to 200 psi.

C. Implementation

Installation of any pipeline requires design and field engineering. The pipeline location must be surveyed and the size, installation procedures, pipe type, bedding and compaction details, and other engineering considerations should be addressed in engineering drawings and a design report. Planning considerations include working pressure, friction losses, flow velocities, and flow capacity. Systems shall be designed with appurtenances to deliver water from the pipe system to the irrigated field, check valves to manage backflow, and pressure relief stands to manage air entrapment and pressure issues.

D. Schedule

The time required to replace an open ditch with a buried PVC pipeline depends on the site conditions, depth of the pipeline trench, size of the pipeline, and number of outlets or connections in the pipeline, and the type of equipment used. Typical installation times range from 100 feet per day to more than 500 feet per day for a 6 inch to 12 inch diameter pipeline installed in a sandy loam soil with few or no rocks, using a four person crew with mechanical excavation of the pipe trench to a depth less than 4 feet, minimal site preparation, and mechanical backfill. Most on-farm pipeline projects are constructed during a time when no irrigation water is required for crops and are typically designed and installed during the winter or early spring.

E. Scope

The two primary limitations for replacement of a farm ditch with pipelines are cost and capacity. Construction of an unlined farm ditch can typically be done using farm equipment common to farming and at minimal cost. Installation of pipeline usually requires the farm to rent trenching or excavating equipment or contract for the installation of the pipeline at significant costs. In general, a farm ditch has the capacity to carry significantly more irrigation water than a farm pipeline. The decision to line a farm ditch or replace the ditch using a pipeline is often made based on how much water is conveyed in the ditch. The smaller the capacity of the ditch, the more likely it is a candidate for replacement using a pipeline.

F. Documentation

To document this BMP, the agricultural water user shall gather and maintain the following documentation:

1) Copies of equipment invoices or other evidence of equipment purchase and installation;
2) Any USDA Farm Service Agency or other governmental agency evaluation and assistance reports that may relate to the project.
3) Water measurement records from both the period before and after conversion to the water efficient irrigation system.

G. Determination of Water Savings

The seepage rate of ditch can be estimated by conducting one or more ponding tests with a typical section of the ditch prior to the ditch being lined. A ponding test measures the rate at which the level of water ponded behind an earthen dam placed in the ditch drops over two to twenty-four hours. The amount of the ditch that is wetted by the pond behind the dam must be measured. The seepage rate can be calculated as acre-feet per mile of ditch per day. The total quantity of water lost to seepage from the ditch is estimated by multiplying the seepage rate times the number of days per year the ditch is used to convey water. For example a small farm ditch with a wetted perimeter of 5 feet and a length of ½ mile is found to have a seepage rate of 1.0 acre-feet per mile per day. The ditch is used to carry irrigation water 40 days per year. The total seepage from the ditch is 20 acre-feet per year (1/2 x 1.0 x 40). Replacement of the ditch with a buried PVC pipeline would result in minimal or no seepage.

H. Cost-Effectiveness Considerations

The cost for low pressure PVC PIP or IPS pipe is dependant on the pipe diameter and the distance between the pipe factory and the installation site. PIP 80 psi PVC pipe with a 15 inch diameter costs approximately $5.00 delivered to most parts of Texas. The cost for pipeline design, site preparation, trenching, bedding materials, backfill, compaction, and finish work are is site and project specific.

I. References for Additional Information

1) *Conservation Practice Standard, Irrigation Water Conveyance, Low Pressure, Underground, Plastic Pipeline*, 5 p. Natural Resources Conservation Service, December 1988.

4.3.3 LOW PRESSURE CENTER PIVOT SPRINKLER IRRIGATION SYSTEMS

A. Applicability

Low Pressure Center Pivot ("LPCP") Sprinkler Irrigation Systems are applicable to both arid and humid locations, most soil types, and land with flat to modest slopes and can be used for irrigating a wide variety of crops. LPCP systems are typically used in Texas by agricultural producers of cotton, alfalfa and other hays, pasture, chile, corn, silage, and other non-orchard crops.

B. Description

The four types of Center Pivot Sprinkler Irrigation Systems that are commonly considered to be low-pressure systems and BMPs are:

1) Low Energy Precision Application ("LEPA")
2) Low Pressure In-Canopy ("LPIC")
3) Low Elevation Spray Application ("LESA")
4) Medium Elevation Spray Application ("MESA")

All four systems are low-pressure sprinkler systems (with typical pressures at the outer end of the center pivot ranging from 10 to 25 psig) and use fixed sprinkler applicators or nozzles or drop tubes or a combination of both to apply water. Center Pivots equipped with high or medium pressure (greater than 25 psig) impact sprinkler heads have lower water application efficiencies than low-pressure systems. Care should be taken to match water application rates to soil intake rates to minimize water runoff. Each of these LPCP systems can be combined with cultural practices necessary to prevent runoff during irrigation or moderate rainfall events. LEPA systems combine the LPCP system BMP with the Furrow Dikes BMP and the practice of farming with the row direction perpendicular to the direction of travel of the center pivot (i.e. farming in a circle).

C. Implementation

Conversion of a high or medium pressure center pivot to a low-pressure system is relatively inexpensive and can be completed in one to five days. Installation of a new center pivot on land that was previously irrigated using surface irrigation can take several weeks to several months and has significant cost. Implementation should be completed within one growing season of commencement of the BMP in order to achieve the maximum water efficiency benefit.

D. Schedule

To accomplish this BMP, the agricultural water user should, within two years of the implementation date, install and maintain a low-pressure center pivot sprinkler irrigation system.

E. Scope

The scope for MESA, LESA, and LPIC systems is complete when the system is installed or the conversion from a high or medium pressure system to a low-pressure system is complete. LEPA systems require installation of additional conservation practices (such as farming in a circle and use of furrow dikes) before the scope of the BMP is complete.

F. Documentation

To document this BMP, the agricultural water user shall gather and maintain the following documentation:

1) Copies of equipment invoices or other evidence of equipment purchase and installation;
2) Any USDA Farm Service Agency or other governmental agency evaluation and assistance reports that may relate to the project.
3) Water measurement records from both the period before and after conversion to the water efficient irrigation system.

G. Determination of Water Savings

The amount of water saved from converting a conventional center pivot sprinkler irrigation system to a BMP center pivot sprinkler irrigation system (i.e. LPCP system) can be estimated using the following equation:

$$\text{Water Saved (acre-feet per year)} = A_1 \times (1 - E_1/E_2)$$

Where A_1 is the annual amount of water pumped or delivered to the inlet of the non-BMP center pivot sprinkler system, E_1 is the application efficiency of the non-BMP center pivot sprinkler system, and E_2 is the application efficiency of the BMP center pivot sprinkler system. E_1 and E_2 can be directly measured or obtained from the estimated values in the table below.

Estimated Application Efficiency Percent

System Type	New Condition	Fair Condition	Poor Condition
Non-BMP Systems			
Spray	78	60	40
Regular Angle Impact	65	50	30
Low Angle Impact	80	60	40
BMP Systems			
MESA	80	85	70
LESA	90	85	75
LPIC	90	85	75
LEPA (Drop Tube to Furrow Dike, concentric rows)	95	90	80

The amount of water saved is also affected by environmental conditions during irrigation, the amount of runoff that occurs during irrigation (soil slopes, soil texture, cropping practices), and the time of irrigation (i.e. pre-plant irrigation versus irrigation once the crop canopy is established).

H. Cost-Effectiveness Considerations

The cost for purchase and installation of center pivot systems is typically $300 to $500 per acre. The cost per acre-foot can be estimated by dividing the estimated quantity of water conserved (acre-feet per acre) by the cost per acre of the system ($ per acre-foot).

I. References for Additional Information

1) *LEPA Conversion and Management*, B-1691, Texas Agricultural Extension Service, New, Leon, and Guy Fipps.
2) *Comparison of Spray, LEPA, and Subsurface Drip Irrigated Cotton*, Texas Agricultural Experiment Station, Bordovsky, James.
3) *Optimal Performance from Center Pivot Sprinkler Systems*, B-797, Idaho Cooperative Extension System, King, Bradley and Dennis Kincaid.
4) *Comparison of SDI, LEPA, and Spray Irrigation Efficiency*, Paper No. 12019, American Society of Agricultural Engineering, 2001 International Meeting, Schneider, A.D., T.A. Howell, S.R. Evett, July 2001.

4.3.4 DRIP/MICRO-IRRIGATION SYSTEM

A. Applicability

There are numerous variations of types of drip or micro-irrigation, and each type has its limitations in application to production of agriculture. In general, this BMP is applicable to agricultural producers of crops which have been proven to be irrigable using drip or micro-irrigation in the geographic region of the producer and when the producer has available a water supply of sufficient quality to make drip or micro-irrigation feasible.

B. Description

Drip or micro-irrigation is a generic term for a family of irrigation equipment that provides for distribution of water directly to the plant root zone by means of surface or sub-surface applicators or emitters. TWDB's 2001 "Surveys of Irrigation in Texas" reported approximately 77,000 acres of micro-irrigated land within Texas for 2000. This amounts to approximately 1.2 percent of the total of 6.4 million acres irrigated in 2000. The three most common types of micro-irrigation used in Texas are:

1) Micro-spray or bubblers
2) Sub-Surface (buried) Drip
3) Orchard Surface Drip or Microspray Irrigation

Micro-irrigation is typically used on high value crops (vegetables, orchard, and nursery). Recently, sub-surface drip irrigation has begun to be used on cotton, chile, and other row crops.

C. Implementation

The system shall be designed to uniformly apply water directly to the plant root zone to maintain soil moisture without excessive water loss, erosion and reduction in water quality or salt accumulation. The depth of application shall be sufficient to replace water used by the plant in peak use periods without depleting soil moisture in the root zone and to maintain a steady state salt balance.

D. Schedule

Typical design and construction of a drip irrigation system takes approximately 3 to 6 months for large fields (40 acres or greater) and less time for small applications. Typically, it takes one year from planning to operation of a system.

E. Scope

Considerations must be made for situations where natural precipitation or stored soil water is not sufficient for germination and systems must have the ability to provide enough water to properly germinate the seed. The amount of dissolved salts, suspended solids, and particulate (typically sand from irrigation wells or surface water) in the irrigation water must be tested to determine whether a micro-irrigation system is feasible. The following maintenance and monitoring issues must be addressed by the system manager on a nearly daily basis:

1) Cleaning and backflushing of filters;
2) Flushing lateral lines;
3) Measurement of applicator discharge and replacement of applicators as necessary;
4) Monitoring of operating pressures;
5) Injection of chemicals to prevent biological growth; and
6) Injection of chemicals to prevent precipitation of salts.

F. Documentation

To document this BMP the agricultural water user shall document and maintain one or more of the following records

1) Copies of the design drawings and specifications for the irrigation system;
2) Photographs of micro-irrigation pumping and filtration plant; or
3) Receipts or other documentation of purchase and installation of system.

G. Determination of Water Savings

Micro-irrigation can be the most efficient form of irrigation and typically requires the most capital expense per acre of irrigated land. It is the preferred irrigation method for high value crops, including many nursery trees, small fruit trees, grapes, melons, and other vine plants. Determination of the water saved by conversion from surface irrigation to drip irrigation depends on many parameters. The primary reasons for converting from conventional irrigation to drip irrigation is for crop yield and crop quality reasons rather than reduction in water use.

H. Cost-Effectiveness Considerations

Micro-irrigation is typically the most capital expensive type of irrigation. Installation costs for subsurface drip irrigation range from $800 to $1,200 per acre. The operation and maintenance costs vary depending on the value of the crop being irrigated and the quality of the irrigation water supply. The high capital and operational cost for micro-irrigation is the primary reason that micro-irrigation is limited to only 1.2 percent of the irrigated land within Texas.

I. References for Additional Information

1) *Irrigation System, Micro Irrigation*, Natural Resources Conservation Service, United States Department of Agriculture, National Conservation Practice Standards No. 441.

4.3.5 GATED AND FLEXIBLE PIPE FOR FIELD WATER DISTRIBUTION SYSTEMS

A. Applicability

This BMP is applicable to agricultural producers that currently use unlined ditches to distribute water to furrow or border irrigated fields.

B. Description

Gated pipe or flexible pipe (commonly called poly-pipe) is used to convey and distribute water to the furrow and border irrigated fields. Gated pipe is made of aluminum or PVC and ranges in diameters from 6 inch to 12 inch and lengths of 20 or 30 feet. Ports or gates are installed in the side of the pipe at 20 inch, 30 inch, 36 inch, or 40 inch intervals. The flow rate out of each gate is controlled by the percent opening of the gate.

Flexible pipe is a very low pressure (less than 5 psi) thin wall (less than 25 mil) pipe that is unrolled and can have ports installed after the pipe is pressurized. Flexible pipe is available in 12 inch through 21 inch diameters in roll lengths of 1,320 feet. Flexible plastic pipe can also be used as a surface pipeline to convey water between fields and can improve the application efficiency of furrow irrigation by allowing the delivery of larger stream sizes of water per irrigated row.

C. Implementation

This BMP is often implemented simultaneously with the replacement of an on-farm ditch with a pipeline. The steps required to implement this BMP are:

1) Selection of the diameter of the gated pipe or flexible pipe to match the desired flow rate to the irrigated field, and
2) Purchase and installation of the gated or flexible pipe.

D. Schedule

This BMP can be implemented in one or two days if the on-farm water delivery system is adaptable to gated or flexible pipe.

E. Scope

Both gated pipe and flexible pipe are laid out after the rows or borders are prepared and removed after the last irrigation of the season. Gated pipe has a long life cycle (10 to 40 years), whereas flexible pipe is typically used only one or two seasons before it must be replaced. Both gated pipe and flexible pipe are easy to install and remove. Flexible pipe installs faster than gated pipe and can be purchased in larger diameters than gated pipe. The larger diameter pipe will deliver more water per acre to the field and can facilitate the farmer improving irrigation application efficiency. Both gated pipe and flexible pipe are typically connected to a buried pipe via a pipeline riser with a hydrant. The hydrants for gated pipe and flexible pipe are different and are not interchangeable. Typically gated pipe uses a “bonnet” type hydrant and flexible pipe uses a “duck’s nest” type hydrant. Surge irrigation is commonly used in conjunctions with gated pipe.

F. Documentation

To document this BMP, the agricultural water user shall document and maintain one or more of the following records:

1) Photographs of the gated or flexible pipe installed; and
2) Receipts or other documentation.

G. Determination of Water Savings

The amount of water saved by switching from an unlined ditch to gated or flexible pipe can be estimated by the amount of water that was lost to seepage from the unlined ditch. Seepage rates vary with soil type and local conditions. The information in the Lining of On-Farm Irrigation Ditches BMP can be used to estimate the amount of water saved from seepage. Gated and flexible pipe can also increase the amount of water delivered to each row and reduce deep percolation of irrigation water near the head of the field. Estimation of the amount of water saved from increasing the irrigation application efficiency can be made by measuring the amount of water delivered to the field prior to installing gated or flexible pipe and comparing it to the amount of water delivered to the field using gated or flexible pipe. Under most situations, the water saved by increasing irrigation application efficiency will be significantly greater than water savings from reducing the amount of water lost to seepage.

H. Cost-Effectiveness Considerations

The cost for 12 inch diameter PVC gated pipe ranges from $2.00 to $2.50 per foot and flexible pipe between $0.15 and $0.20 per foot. For a field length of 1300 feet with a row spacing of thirty-six inches it takes approximately 34 feet of gated or flexible pipe per acre. Because the life cycle for gated pipe is significantly longer than that of flexible pipe, the annualized price of PVC gated pipe is similar to flexible pipe. Assuming that 0.25 acre-foot per acre per year of water is saved by using gated or flexible pipe, the annual cost per acre-foot of water saved ranges from $20 to $25.

I. References for Additional Information

1) *Irrigation Water Conveyance, Rigid Gated Pipe*, Natural Resources Conservation Service, United States Department of Agriculture, October 1985, National Conservation Practice Standards No. 430HH.

4.3.6 SURGE FLOW IRRIGATION FOR FIELD WATER DISTRIBUTION SYSTEMS

A. Applicability

This BMP is applicable to agricultural producers that currently use gated pipe or flexible pipe to distribute water to furrow irrigated fields and who have soil types that swell and reduce infiltration rates in response to irrigation.

B. Description

A surge irrigation system applies water intermittently to furrows so as to create a series of on-off periods of either constant or variable time intervals. Surge flow can also increase the amount of water delivered to each row and reduce deep percolation of irrigation water near the head of the field. Surge irrigation is typically applicable to agricultural fields with medium soils. Surge irrigation may have limited applicability to fields with heavy clay soils or light sandy soil. If improperly used, surge irrigation can increase the volume of water that runs off the tail of a field during irrigation. Under this BMP, the agricultural water user will install and maintain a surge irrigation system. The system will, at a minimum, include butterfly valves or similar equipment that will provide equivalent alternating flows with adjustable time periods and a solar or battery-powered timer. The agricultural producer should consider field slope, soil type, texture, and infiltration rates to maximize effectiveness of the system. Surge flow has also been shown to reduce runoff in some fields by increasing the uniformity of infiltration and by reducing the duration of flow as the water reaches the end of the field.

C. Implementation

This BMP is often implemented simultaneously with replacement of an on-farm ditch with a gated pipeline. The steps required to implement this BMP are:

1) Selection of the timer and valve equipment for the system based upon the type of gated pipe and soil type;
2) Purchase, installation and use of the surge flow equipment; and
3) Use of soil probes and trialing set times to determine optimal use for each field.

D. Schedule

This BMP can be implemented in one or two days if the on-farm water delivery system is adaptable to gated or flexible pipe. If the surge flow system is installed at the same time the gated or flexible pipe BMP is implemented, it should add less than one day to the installation time of the new irrigation system.

E. Scope

The surge flow system is integral to the gated pipe or flexible pipe systems which are laid out after the rows or borders are prepared and removed after the last irrigation of the season. Surge flow valves have a life cycle of between 5 and 15 years; this results in different life cycle costs based upon the use of gated versus poly pipe and should be considered when doing a cost-effectiveness analysis. Surge irrigation is commonly used with gated pipe rather than with flexible pipe.

F. Documentation

To document this BMP, the agricultural water user will maintain one or both of the following records:

1) Photographs of the surge flow system installed; and
2) Receipts or other documentation.

G. Determination of Water Savings

The amount of water saved by switching to surge flow is estimated to be between 10 percent and 40 percent and is dependent upon soil type and timing of operations. The savings from installing the surge flow at the same time as replacing an unlined ditch with gated or flexible pipe should be considered separately as a factor in implementing that BMP. Experience has shown that differences in soil texture and field slope have a significant impact on actual water savings. Estimation of the amount of water saved from increasing the irrigation application efficiency can be made by measuring the amount of water delivered to the field prior to installing surge flow and comparing it to the amount of water delivered to the field by using surge flow.

H. Cost-Effectiveness Considerations

Cost for a surge valve with an automated controller will range between \$800 and \$2,000 depending on the size of the valve and the controller options. If installed at the same time as gated pipe, the cost for those systems is outlined in the Gated or Flexible Pipe BMP. Assuming that 0.25 acre-foot per acre per year of water is saved by using a surge valve, the annual cost per acre-foot of water saved ranges from \$20 to \$25.

I. References for Additional Information

1) Irrigation Water Conveyance, Rigid Gated Pipe, Natural Resources Conservation Service, United States Department of Agriculture, October 1985, National Conservation Practice Standards No. 430HH.
2) Estimated Efficiency Improvements Expected from Irrigation System Improvements, Natural Resources Conservation Service, United States Department of Agriculture, September 1997, Natural Conservation Practice Standards No. 210-vi-NEH.
3) Surge Irrigation, Yonts, C.D., et al., Nebraska Cooperative Extension NF. 94-176, January 1994. http://ianrpubs.unl.edu/irrigation/nf176.htm

4.3.7 LINEAR MOVE SPRINKLER IRRIGATION SYSTEMS

A. Applicability

Linear Move Sprinkler Irrigation (linear move) Systems are an adaptation of center pivot sprinkler systems for use on fields which are not appropriate for center pivot systems due to shape or elevation changes (*See* Low Pressure Center Pivot Sprinkler Irrigation Systems BMP). Linear move systems are applicable for both arid and humid locations, for most soil types with flat to minimal slope, and for producing a wide variety of crops. Texas agricultural producers typically use linear move systems to irrigate cotton, alfalfa and other hays, pasture, chile, corn, silage, and other row type crops.

B. Description

The linear move sprinkler irrigation system is composed of a series of towers that suspend the irrigation system and move laterally in the direction of the rows. Water can be supplied to the towers from a open ditch adjacent to the 1st tower and parallel to the director of travel or by a flexible hose typically 100 to 200 feet in length. The flexible hose is supplied through risers connected to a buried pipeline. Use of a linear move system is normally limited to irrigating rectangular shaped fields. The four types of Linear Move Sprinkler Irrigation Systems that are addressed in the best management practices document and are commonly considered to be low-pressure system include:

1) Low Energy Precision Application ("LEPA")
2) Low Pressure In-Canopy ("LPIC")
3) Low Elevation Spray Application ("LESA")
4) Medium Elevation Spray Application ("MESA")

All four systems are low-pressure sprinkler systems (with typical pressures at the farthest end of the sprinkler from the water source ranging from 10 to 35 psi) and use fixed sprinkler applicators/nozzles or drop tubes or a combination of both to apply water. Linear Move Sprinklers equipped with high or medium pressure (greater than 35 psi) impact sprinkler heads have lower water application efficiencies than low-pressure systems. Each of these linear move systems can or must be combined with cultural practices necessary to prevent runoff during irrigation or moderate rainfall events. LEPA systems can be combined with the Linear Move Systems BMP and with the Furrow Dikes BMP (*See* Section 4.3.1).

C. Implementation

Conversion of a high or medium pressure linear move to a low-pressure system is relatively inexpensive and can be completed in one to five days. Installation of a new linear move system on land that was previously irrigated using surface irrigation can take several weeks to several months. Implementation should be completed within one growing season after commencement of this BMP in order to achieve the maximum water efficiency benefit.

D. Schedule

To accomplish this BMP, the agricultural water user should, within two years of the implementation date, install and maintain a low-pressure linear move sprinkler irrigation system in order to achieve the maximum water efficiency benefit.

E. Scope

The agricultural water user with multiple fields can implement the Linear Move Sprinkler BMP or other irrigation BMPs on each field in different years or growing seasons, if such timing is more cost-effective.

F. Documentation

To track this BMP, the agricultural water user shall gather and maintain the following documentation:

1) Copies of equipment invoices or other evidence of equipment purchase and installation;
2) Any USDA Farm Service Agency or other governmental agency evaluation and assistance reports that may relate to the project; and
3) Water measurement records from the period both before and after conversion to the water efficient irrigation system.

G. Determination of Water Savings

The amount of water saved from converting from a conventional linear move sprinkler irrigation system to a BMP linear move sprinkler irrigation system can be estimated using the following equation:

Water Saved (acre-feet per year) = $A_1 \times (1 - E_1/E_2)$

Where A_1 is the annual amount of water pumped or delivered to the inlet of the non-BMP center pivot sprinkler system, E_1 is the application efficiency of the non-BMP linear move sprinkler system, and E_2 is the application efficiency of the BMP (linear move) sprinkler system. E_1 and E_2 can be directly measured or obtained from the estimated values in the table below.

Estimated Application Efficiency Percent

System Type	New Condition	Fair Condition	Poor Condition
Non-BMP Systems:			
Spray	78	60	40
Regular Angle Impact	65	50	30
Low Angle Impact	80	60	40
BMP Systems:			
MESA	85	80	70
LESA	90	85	75
LPIC	90	85	75
LEPA (Drop Tube to Furrow Dike)	95	90	80

The amount of water saved is also affected by environmental conditions during irrigation, the amount of runoff that occurs during irrigation (soil slopes, soil texture, cropping practices) and the time of irrigation (i.e. pre-plant irrigation versus irrigation once the crop canopy is established).

H. Cost-effectiveness Considerations

The cost for purchase and installation of linear move systems is typically \$300 to \$700 per acre. The cost per acre-foot can be estimate by dividing the estimated quantity of water conserved (acre-feet per acre) by the cost per acre of the system (dollars per acre-foot).

I. References for Additional Information

1) New, Leon, and Guy Fipps, *"LEPA Conversion and Management"*, B-1691, Texas Agricultural Extension Service.
2) Bordovsky, James, *"Comparison of Spray, LEPA, and Subsurface Drip Irrigated Cotton"*, Texas Agricultural Experiment Station.
3) King, Bradley and Dennis Kincaid, *"Optimal Performance from Center Pivot Sprinkler Systems"*, B-797, Idaho Cooperative Extension System.
4) Evans, R.O., et al., Center Pivot and Linear Move Sprinkler Systems, AG-553-3 North Carolina Cooperative Extension, 1997.

4.4 Water District Delivery Systems

4.4.1 LINING OF DISTRICT IRRIGATION CANALS

A. Applicability

This BMP applies to any water district and serves as an integral part of the water distribution system designed to facilitate the conservation and efficient conveyance of water to a group of water users.

B. Description

A fixed lining of impervious material is installed in an existing or newly constructed irrigation canal or lateral canal. The three most commonly used impervious liners for irrigation canals in Texas are Ethylene-Propylene-Diene Monomer (“EPDM”), urethane, and concrete. Each type of liner has benefits and detriments specific to the liner. EPDM is least expensive and concrete the most. Reinforced concrete liners have the longest durability but may have the largest seepage rate. Urethane has low seepage rates but uses hazardous chemicals during the installation. The U.S. Bureau of Reclamation report titled “Canal Lining Demonstration Project Year 7 Durability Report” provides a detailed description of these and other liners.

C. Implementation

The canal considered for lining shall be of sufficient capacity to meet its requirement as part of a planned irrigation water conveyance system without overtopping, but with enough capacity to deliver the water needed to meet the peak consumptive use. The specific steps required to implement this BMP depend on the type of canal liner used and the existing conditions of the canal to be lined. Installation specifications, material specifications and detailed installation instructions for most types of canal liners are available from liner manufacturers and governmental agencies. In general, most canal lining projects require the following steps:

1) A site survey of the proposed canal being lined including length of canal and one or more typical cross-sections of the canal.
2) Development of a plan that details the installation and materials specifications.
3) Preparation of the canal bed, including removal of any vegetation, bed compaction, and bed shaping.
4) Installation of liner.
5) Finish work including inlets and outlets to lined canal.

D. Schedule

The time required to line a canal depends on the size of the cross-sectional perimeter of the canal, the amount of work needed to prepare the canal for lining, and the type of liner used to line the canal. EPDM liners are usually the easiest and quickest to install. For a small canal with a top width of 15 feet, between 500 and 1,000 feet of EPDM liner can be installed per day with a crew of eight persons.

E. Scope

Each type of liner has advantages and disadvantages. EPDM should not be used in a location where the canal is subject to large animal or other traffic that might tear the liner. Concrete liners handle most traffic well but are subject to crack formation due to soil heave, tree root pressure, or thermal expansion.

F. Documentation

To document this BMP, the water district shall document and maintain one or more of the following records:

1) As-built drawings or photographs of the lined canal; and
2) Water measurement records from both the period before and after conversion to the water efficient irrigation system.
3) Copies of equipment invoices or other evidence of equipment purchase and installation; and
4) Any USDA Farm Service Agency or other governmental agency evaluation and assistance reports that may relate to the project.

G. Determination of Water Savings

The seepage rate of a canal can be estimated by conducting a ponding test with a typical section of the canal prior to the canal being lined. A ponding test measures the rate at which the level of water ponded behind an earthen dam placed in the canal drops over two to twenty-four hours. The amount of the canal that is wetted by the pond behind the dam must be measured. The seepage rate can be calculated as acre-feet per mile of canal per day. The total quantity of water lost to seepage from the canal is estimated by multiplying the seepage rate times the number of days per year the canal is used to convey water. For example, a small farm canal with a wetted perimeter of 20 feet and a length of 1 mile is found to have a seepage rate of 1.5 acre-feet per mile per day assuming the canal is used to carry irrigation water for 270 days per year. The total seepage from the canal is 405 acre-feet per year (1 x 1.5 x 270). Lining the canal with an EPDM liner would result in minimal or no seepage. Seepage loss from a concrete lining depends on how the liner was constructed and the amount of water that seeps through cracks and expansion joints in the concrete.

H. Cost-Effectiveness Considerations

The U.S. Bureau of Reclamation in June of 2001 published "Construction Cost Tables – Canal Lining Demonstration Project." The cost table included material and installation cost for approximately thirty-five different types of liners or coatings. The cost for an installed EPDM liner was approximately $0.85 per square foot and $1.43 per square foot for urethane. The cost for concrete lining ranges from $2.50 to $3.50 per square foot. For the example above the cost per acre-foot of water salvaged in the first year for the EPDM liner would be $89,760 ($222 per acre-foot), for urethane liner $151,008 ($373 per acre-foot) and for concrete $316,800 ($782 per acre-foot). Because each of these types of liner has a different life expectancy a present value analysis of cost should be performed. For example, while the concrete liner may have the most expensive installation cost, it also has the longest life expectancy.

I. References for Additional Information

1) *Conservation Practice Standard, Irrigation Water Conveyance, Flexible Membrane Canal and Canal Lining*, 9 p. Natural Resources Conservation Service, October 1980.
2) *Canal Lining Demonstration Project Year 7 Durability Report*, 156 p. U.S. Bureau of Reclamation- Pacific Northwest Region, September 1999.
3) *Canal Lining Demonstration Project - 2000 Supplemental*, 46 p. U.S. Bureau of Reclamation- Pacific Northwest Region, January 2000.
4) *Construction Cost Tables – Canal Lining Demonstration Project*, 5 p. U.S. Bureau of Reclamation, Pacific Northwest Region, June 2001.

4.4.2 REPLACEMENT OF IRRIGATION DISTRICT CANALS AND LATERAL CANALS WITH PIPELINES

A. Applicability

This BMP is applicable to Water Districts that use open canals and lateral canals to convey irrigation water and as an alternative to lining the canals or lateral canals. In general, pipelines are used to replace district canals or lateral canals with less than 44,900 gpm (100 cubic feet per second) capacity.

B. Description

This practice is the replacement of district irrigation canals or lateral canals with buried pipeline and appurtenances to convey water from the source (well, river, reservoir) to a farm or irrigation turnout. District irrigation pipelines can be used to replace most types of small canals or lateral canals. In general, district irrigation pipelines are 72 inch in diameter or less, with 12 inch through 48 inch diameter pipes being common. Most district irrigation pipelines use either PVC Plastic Irrigation Pipe ("PIP") or Reinforced Concrete Pipe ("RCP") with gasketed joints. PIP is available in diameters from 6 inch to 27 inch with pressure ratings from 80 psi to 200 psi. RCP is typically available in diameters between 24 inch and 72 inch. It is common practice in the irrigation districts in the Lower Rio Grande Valley to use PIP for 24 inch or less diameter pipe and RCP for pipe diameters greater than 24 inch. On a limited basis, 36 inch and 42 inch diameter PVC pressurized sewer pipe is being used to replace open canals.

C. Implementation

Installation of any pipeline requires design and field engineering. The pipeline location must be surveyed and the size, installation procedures, pipe type, bedding and compaction details, and other engineering considerations should be addressed in engineering drawings and a design report. Planning considerations include working pressure, friction losses, flow velocities, and flow capacity. Systems will be designed with appurtenances to deliver water from the pipe system to the farmer and open pipe stands to allow for air release and surge (water hammer) protection.

D. Schedule

The time required to replace an open canal with a buried PVC or RCP pipeline depends on the site conditions, depth of the pipeline trench, size of the pipeline, number of outlets or connections in the pipeline, and the type of equipment used. Most district pipeline projects are constructed during a time when no irrigation water is required for crops, which is typically during the winter or early spring.

E. Scope

The two primary limitations for replacement of canals with pipelines are cost and capacity. In many cases the length and engineering of existing canal systems will require a number of years to replace with pipeline. In such cases, a program for progressively replacing canals and lateral canals should be developed with a focus on replacing those canals and lateral canals with larger potential for water conservation. The decision to line a canal or replace the canal using a pipeline is often made based on how much water is conveyed in the canal. The smaller the capacity of the canal, the more likely it is a candidate for replacement using a pipeline.

F. Documentation

To document this BMP, the water district shall gather and maintain the following documentation:

1) Copies of equipment invoices or other evidence of equipment purchase and installation;
2) Any USDA, NRCS or other governmental agency evaluation and assistance reports that may relate to the project.
3) Water measurement records from both the period before and the period after the installation of the pipeline.

G. Determination of Water Savings

The seepage rate of a canal can be estimated by conducting a ponding test within a typical section of the canal or lateral canal prior to the canal and lateral canal being lined. A ponding test measures the rate at which the level of water ponded behind an earthen dam in a canal drops over two to twenty-four hours. The amount of the canal that is wetted by the pond behind the dam must be measured. The seepage rate can be calculated as acre-feet per mile of canal per day. The total quantity of water lost to seepage from the canal is estimated by multiplying the seepage rate times the number of days per year the canal is used to convey water. For example, a canal with a wetted perimeter of 50 feet and a length of 1 mile is found to have a seepage rate of 1.0 acre-foot per mile per day. The canal and lateral canal are used to carry irrigation water 270 days per year. The total seepage from the canal is 270 acre-feet per year per mile (1.0 x 1.0 x 270). Replacement of the canal with a buried PVC pipeline would result in minimal or no seepage.

H. Cost-Effectiveness Considerations

The cost for low-pressure PVC PIP pipe is based on the pipe diameter and the distance between the pipe factory and the installation site. PIP 80 psi PVC pipe with a 24 inch diameter costs between $15 and $21 delivered to most parts of Texas. Because of the heavy weight and associated transportation costs, reinforced concrete pipe is usually manufactured in the area in which the pipe is being installed. The cost for pipeline design, site preparation, trenching, bedding materials, backfill, compaction, and finish work are all site and project specific. The cost per acre-foot can be estimated by dividing the estimated quantity of water conserved (acre-feet per acre) by the cost per acre of the system ($ per acre-foot).

I. References for Additional Information

1) Natural Resources Conservation Service, December 1988, “Conservation Practice Standard, Irrigation Water Conveyance, Low Pressure, Underground, Plastic Pipeline”, 5 p. Code 430EE.

4.5 Miscellaneous Systems

4.5.1 TAILWATER RECOVERY AND REUSE SYSTEM

A. Applicability

Tailwater recovery and reuse systems (tailwater systems) are applicable to any irrigated agricultural system (typically flood or furrow irrigation) in which significant quantity of irrigation water, as a result of the irrigation method, runs off the end of the irrigated field. Tailwater systems are typically implemented by agricultural producers that use flood or furrow irrigation.

B. Description

A Tailwater System consists of ditches or pipelines to collect tailwater and deliver water to a storage reservoir (typically below the grade of the irrigated land) and includes a pumping and pipeline system that conveys the water to irrigated fields for reuse. Most tailwater systems also collect rainfall that may run off of the irrigated field. Natural reservoirs, such as the playa lakes located in the High Plains region of Texas, may serve to both capture irrigation runoff and rainfall runoff and may be used as part of a tailwater system. Also, capture and reuse of tailwater can improve the water quality of downstream reaches of rivers, streams, or waterways. Conservation through reduction in field runoff may reduce agricultural drain flow and the amount of water in downstream reaches of rivers, streams, or waterways. In the irrigated agricultural areas of Texas supplied by groundwater, reduction or reuse of field runoff is a common practice and can provide secondary benefits such as an open water source for wildlife (tailwater ponds). Also, capture and reuse of tailwater can improve the water quality of downstream reaches of rivers, streams, or waterways. Conservation through reduction in field runoff may reduce agricultural drain flow and the amount of water in downstream reaches of rivers, streams, or waterways.

C. Implementation

The steps required to implement a tailwater system are:

1) Construction of the tailwater collection system.
2) Construction of the storage reservoir.
3) Construction of the tailwater irrigation water delivery system.
4) Application of the tailwater for irrigation of crops or other uses.

D. Schedule

The time required to construct and install a tailwater system varies from several days to over a month.

E. Scope

The most common limitation on the installation of a tailwater system is the availability of land for construction of the storage reservoir such that the tailwater can be conveyed to the reservoir by gravity. Secondary concerns include water quality and disease problems that result from the reuse of irrigation water. Some agricultural users of tailwater systems have the systems designed so that reused irrigation water is kept separate from virgin irrigation water, and the reused water is applied to crops that are more resistant to the problems that may exist with use of tailwater for irrigation.

F. Documentation

To document this BMP, the agricultural water user shall gather and maintain one or more of the following:

1) Photographs of the installed storage reservoir and pump back system;
2) Reports or receipts that document the purchase and installation of reservoir and pump back system;
3) Any USDA, NRCS or FSA or other governmental agency evaluation and assistance reports that may relate to the project; or
4) Water measurement records from both the period before and after conversion to the water efficient irrigation system.

G. Determination of Water Savings

Both direct and indirect measurements of the volume of water captured and reused by the Tailwater System can be used to determine the annual volume of water saved. The amount of runoff from a surface irrigated field varies significantly from site to site, but it is not uncommon for runoff to be 15 percent or greater of the gross volume of water applied to the field. Typical tailwater systems can reuse 0.5 to 1.5 acre-feet per acre of irrigated crop per year.

H. Cost-Effectiveness Considerations

The cost of constructing a tailwater system varies significantly from site to site and with land costs. The cost to construct a small storage reservoir (assuming the water user owns the land) ranges from $800 to $2,000 per acre-foot. Construction of the tailwater collection system varies from little cost (adapting an existing surface drainage system) to as much as $15 per foot of installed pipe. The cost of the pump back system is also site specific and typically costs several thousands of dollars.

I. References for Additional Information

1) *Irrigation System, Tailwater Recovery*, Natural Resources Conservation Service, United States Department of Agriculture, National Conservation Practice Standards No. 447.

4.5.2 NURSERY PRODUCTION SYSTEMS

A. Applicability

This BMP is applicable to irrigation of nursery crops and agricultural producers that grow nursery crops.

B. Description

This BMP considers the design of the irrigation system used for distribution and application of irrigation water to field, container, and greenhouse grown nursery plants. Improved efficiency of water use in the production of nursery crops includes the following practices:

1) Irrigation System Design and Management
   a. Scheduling irrigation according to crop needs and growing-medium water depletion. Watering requirements will vary and should be adjusted based on time of year, weather, methods of storage and type and stage of the plant (e.g., dormancy). Plants need less water during cool, rainy weather than during hot, dry, windy weather.
   b. Upgrading irrigation equipment to improve application efficiency. For example, a computerized irrigation scheduler using a drip system can reduce overwatering and excessive leaching compared to an overhead system.
   c. Plugging sprinkler heads that are not watering plants, keeping sprinkler heads as low as possible to the plants, and use of the largest appropriate water droplet size to reduce irrigation time.
   d. Use of drip tubes or spray tanks for each individual container, when reasonably practical.
   e. When using programmable irrigation booms, travel rate and flow rates should be adjusted to specific crop needs.
   f. Use of sub-irrigation systems where appropriate, using ebb and flood or capillary mat irrigation technologies with water capture and reuse systems.

2) Plant Media and Management
   a. Grouping plants together that have the same water requirements (i.e., use hydrozoning).
   b. When ball-and-burlapped stock and containerized stock are received, they should be kept out of the wind and sun. Ideally, balls should be covered with moisture-retaining materials such as sawdust or wood chips if stock will be stored for a long time.
   c. Knowing characteristics of the application site, including soil type and depth to groundwater under the greenhouse or nursery.
   d. Spacing containers under fixed overhead irrigation to maximize plant irrigation and reduce waste between containers.
   e. Minimizing leaching from containers or pulse-irrigate containers. Many textbooks recommend leaching greenhouse and nursery crops to 10

percent excess. This rate can be reduced to close to zero by reducing fertilizer rates and closely monitoring the electrical conductivity or the root substrate.

C. Implementation

Many operational procedures and controls to improve water use efficiency of the nursery operations should be implemented simply as a matter of good practice. Implementation of this BMP consists of the following actions:

1) Perform a water efficiency audit of the nursery facility to identify areas of improvement for water savings and optimization of water use. The audit should review all aspects of operations including types of plants and specific water requirements, growing medium characteristics, and the irrigation system.
2) Implement appropriate water efficiency practices, including:
   - Design of the irrigation system such that water can be delivered to different zones at different application rates and for different durations.
   - Upgrading or modernization of irrigation system.
   - Organization of plants by water use.
   - Programming of irrigation system controllers for optimal water use.

D. Schedule

The time required to implement one or more of the above practices depends on the size and extent of the nursery operation and which conservation practices are to be implemented. Implementation of some of the above practices can be done in less than a week (programming of irrigation controllers, replacement of sprinkler nozzles, scheduling irrigations, etc.) to several months (installation of a new irrigation system or water recovery and reuse system).

E. Scope

Nursery production systems vary in extent from small (less than 1 acre) operations to multi-acre farms and greenhouses. The applicability of each of the above practices must be customized for the specific requirements of each Nursery Production System. Some of the above practices may be not be cost effective for smaller operations. Larger operations may select to implement all of the above practices.

F. Documentation

The following information can be used to document implementation of this BMP:

- Description of irrigation techniques and water zones;
- Description of mulching practices and soil amendments used;
- Description of the irrigation and water recovery and reuse system; and
- Water use records for the periods both before and after implementation of water efficient practices.

G. Determination of Water Savings

Determination of the quantity of water saved by implementing this BMP must be determined specific to each nursery production system and is dependent on the amount of water used by the existing system and which conservation practices are currently implemented by the producer. Water use records prior to and after implementation of one or more of the above practices can be used to determine the amount of water saved.

H. Cost-Effectiveness Considerations

The cost-effectiveness of implementing one or more of the above practices must be analyzed for each nursery production system. The cost ranges from minimal (for reprogramming irrigation controllers, changing sprinkler heads, etc.) to significant (installation of water recovery and reuse system, upgrading or replacement of irrigation system, etc.). Some basic operational practices should be corrected without a cost-effectiveness analysis.

I. References for Additional Information

1) Colorado Springs Utilities, Water Conservation Program, *"Hydrozoning-Irrigation Definitions and Requirements"*, www.csu.org/files/general/2656.pdf, 2 p.
2) Southern Nursery Association, *"Production Practices for Nurseries, Greenhouses, and Growers"*, www.sna.org
3) Texas Nursery Landscape Association, www.txnla.org.
4) Department of Horticulture, Texas A&M University-College Station, Texas Greenhouse Management Book, www.aggie-horticulture.tamu.edu.

4.6 Cost Effectiveness for Agricultural Water Users

The table on the next page shows a simplified example that estimates the annual cost that an agricultural producer will incur to replace an earthen ditch used to convey water to an irrigated field with a buried PVC pipe. It lists the information and calculations needed to determine the annual cost per acre-foot of water saved from installing the proposed pipeline. Narrative information regarding each item in the table is included.

For this example the Net Annual Cost per Acre-Foot of Water Saved equals $11.51. The actual cost per acre-foot of water savings could be smaller or larger depending on actual cost information. Under conditions of high water loss in the existing ditch and/or high energy cost for well water, the Net Annual Cost per Acre-Foot of Water Savings could be a negative value (the cost of the proposed pipeline would both save water and increase the agricultural producers net revenue).

Cost Effectiveness Evaluation for Replacement of an Earthen Ditch with Buried PVC Pipeline.

Item	Description		Units
1	Water Source:	Irrigation Well	
2	Typical Irrigated Crop:	Alfalfa	
3	Gross Water Application for Crop:	4.00	ac-ft/yr
4	Energy Cost per Acre-Foot of Water from Irrigation Well:	$20.00	$/ac-ft
5	Irrigated Area:	120	ac
6	Design Flow Rate for Pipeline:	800	gpm
7	Gross Annual Water Application:	480	ac-ft
8	Time Required to Apply Irrigation Water:	136	days/yr
9	PVC Pressurized Irrigation Pipe (Class 100) Pipe Diameter:	10	inches
10	Pipeline Length:	5,280	ft
11	Assumed Capital Recovery Period for Project:	20	yr
12	Assumed Interest Rate for Capital:	6.00%	%
13	Annual Water Savings:	136	ac-ft
14	Capital Cost for Pipeline:	$10.00	$/ft
15	Capital Cost for Pipeline:	$52,800	$
16	Annual Change in Maintenance Cost (Earthen Ditch to PVC Pipeline):	-$1,500	$/yr
17	Energy Cost for Pipeline Friction (@0.10 $/kwhr, and 70% Pumping Efficiency, 0.32 ft/100ft headloss):	$1,182	$/yr
18	Change in Annual Energy Cost for Well Water:	-$2,720	$/yr
19	Change in Annual Energy Cost (Earthen Ditch to PVC Pipeline):	-$1,538	$/yr
20	Total Change in Annual Energy and Maintenance Costs:	-$3,038	$/yr
21	Annual Capital Recovery Cost:	$4,603	$/yr
22	Net Annual Cost of Pipeline:	$1,565	$/yr
23	Net Annual Cost per Ac-Ft of Water Savings:	$11.51	$/yr

1) **Water Source.** The source of water for this example is from an irrigation well. The source of water is important in determining the amount of energy savings from reduced pumping requirements as a result of the water conservation effort.

2) **Typical Irrigated Crop.** The type of crop proposed to be grown on the irrigated area. Crop type can be used to estimate the annual irrigation water requirement.

3) **Gross Water Application for Crop** is the annual amount of water anticipated to be applied to the field per acre of irrigated area and includes any water that may run off the field or infiltrate past the crop root zone.

4) **Energy Cost per Acre-Foot of Water from Irrigation Well**. The energy cost per acre-foot of water pumped from the irrigation well can be estimated based on the total pumping depth, discharge pressure, energy loss in the pump column, pump efficiency, motor or engine efficiency, and fuel or energy cost. (*See* Texas Agricultural Extension Service Publication L-2218).

5) **Irrigated Area** is the irrigated acreage of the field for which water will be supplied by the proposed pipeline.

6) **Design Flow Rate for Pipeline**. The design flow rate of the pipe is typically matched to amount of water available from the supply source (in this case an irrigation well) and the requirements of the irrigation system. For this example the design flow rate was assumed to be 800 gpm.

7) **Gross Annual Water Application** is the product of the items 3 and 5.

8) **Application Time** is the amount of time required to delivery the Gross Annual Water Application (item 7) using the Design Flow Rate of the Pipeline (item 6).

9) **PVC Plastic Irrigation Pipe Diameter** is commonly calculated as the commercially available pipe diameter that results in a water velocity in the pipeline of approximately 3 feet per second for the Design Flow Rate (item 6).

10) **Pipeline Length** is the length of the earthen ditch being replaced with pipe.

11) **Capital Recovery Period for Project.** The Capital Recovery Period is assumed to be either the cost of borrowing money for the project or the value of the lost opportunity that might have been realized had the capital funds been invested.

12) **Interest Rate for Capital Investment** was assumed to be 6 percent per year.

13) **Annual Water Savings** equals the amount of water lost to evaporation and seepage in the earthen canal. Losses from a properly installed PVC pipeline are approximately zero. The earthen ditch in the example was assumed to lose water at 1 acre-foot per mile per day the ditch is used to convey water.

14) **Installed Capital Cost** (including valves, air release, and other items). The cost of installing the proposed pipeline per linear foot. The cost includes all mobilization, equipment, labor, material, and other construction costs.

15) **Project Capital Cost** (including valves, air release, and other items) equals the product of item 14 and item 10.

16) **Annual Change in Maintenance Cost** (Earthen Ditch to PVC Pipeline): Earthen ditch usually requires periodic maintenance to remove vegetation and wind blown

sediments. Buried PVC pipe usually requires minimal maintenance but can require the occasional repair of leaks. The net decrease in cost was assumed.

17) **Energy Cost for Pipeline Friction**. Typically, there is minimal energy cost for using an open ditch to convey water. Energy loss in pipelines is proportional to the velocity of the water in the pipeline and the type of pipe material. Converting from an earthen ditch to a buried pipeline will increase the amount of energy needed to convey the water from the irrigation well to the field.
18) **Change in Energy Cost for Well Water.** The annual amount of water pumped by the irrigation well to be delivered to the field is reduced by the amount of water saved by installing the pipeline. The water savings results in a proportional reduction in energy cost for water supplied by the irrigation well.
19) **Change in Annual Energy Cost** (Earthen Ditch to PVC Pipeline) equals the sum of items 17 and 18.
20) **Total Change in Energy and Maintenance Costs** equals the total of items 16 and 19.
21) **Annual Capital Recovery Cost** equals the annual payment that would be required to service a loan for the amount of capital required to construct the proposed project (item 15).
22) **Net Annual Cost of Pipeline** equals the sum of items 20 and 21.
23) **Net Annual Cost per Ac-Ft of Water Savings** equals item 22 divided by item 13.

I. References for Additional Information

1) Texas Agricultural Extension Service, L-2218, “Pumping Plant Efficiency and Irrigation Costs.”
2) University of Tennessee, Agricultural Extension Service, “Irrigation Cost Analysis Handbook.”