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Considerations for Net Zero Water Installations

A Review of Existing Tools and Measures

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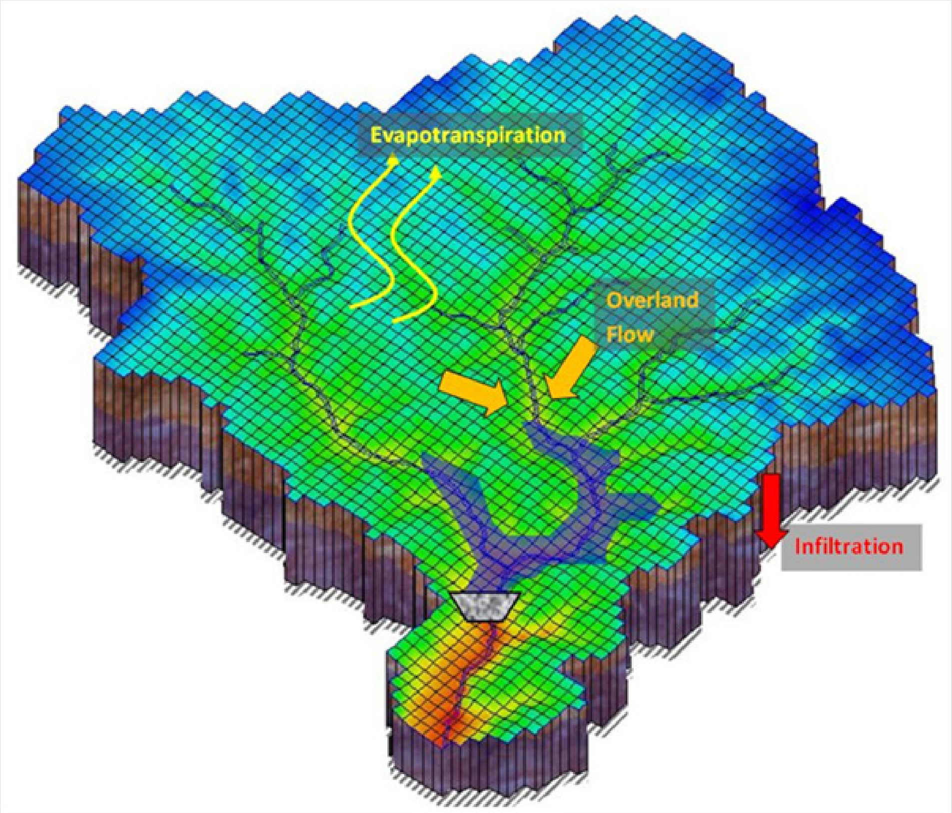

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Abstract

Over the past decade, Federal legislation and executive orders that stipulate increasingly rigorous water conservation requirements have emerged. The Army has adopted these requirements through policy and regulation, and has advanced the concept even further by establishing challenging targets for installations to achieve “net zero water,” an emerging sustainable buildings concept in which an installation limits its consumption of freshwater resources and returns water to the same watershed from which it is drawn so as to not deplete the groundwater and surface water resources of that region in quantity or quality. This work was undertaken to select and/or develop tools to support integrated modeling of energy, water, and waste for Army installations. The first year’s water effort involved reviewing, demonstrating, and developing water models and tools at a variety of spatial scales. Water conservation and efficiency measures were evaluated and documented to enable life cycle costing. The tools and models described in this work were documented for Fort Carson, CO, but the concepts developed here will benefit all Army installations which are working to achieve mandated water conservation targets, to minimize utility costs, and to preserve finite natural resources.

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Preface

This study was conducted for Headquarters, US Army Corps of Engineers (HQUSACE) under Research, Development, Test and Evaluation (RDT&E) project, “Integrating Installation Energy, Water, and Waste Modeling,” via work item codes 8609C7 and BH01K8, Integrated Installation Energy, Water and Waste (EW2) Modeling and work item code LG7452, Computational Framework for Energy, Water, and Waste.

The work was managed and executed by the Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL), Engineer Research and Development Center (ERDC). The CERL program manager was Dr. Michael P. Case. Special appreciation is owed to the installation and other local points of contact for providing information that was invaluable to this study and for reviewing this report. These individuals are: Vince Guthrie and Scott Clark , Fort Carson; Lyle Fogg, Larry McVay, and Stephanie Smith, Joint Base Lewis-McChord (JBLM); Cynthia Skinner, Fort Hunter Liggett; and Kate McMordie-Stoughton, Pacific Northwest National Laboratory (PNNL). Appreciation is also owed to Dr. Marc Kodack, Office of the Assistant Secretary of the Army, Installations, Energy and Environment for policy and technical information on many aspects of water sustainability and for his review of this report. At the time of publication, the Chief of the Energy Branch was Franklin H. Holcomb (CEERD-CF-E), the Chief of the Facilities Division was L. Michael Golish, (CEERD-CF), and the Technical Director for Installation was Martin J. Savoie (CEERD-CV-ZT). The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

The Commander and Executive Director of ERDC is COL Kevin J. Wilson, and the Director of ERDC is Dr. Jeffery P. Holland.

1 Introduction

1.1 Background

1.1.1 Army Net Zero Water

The US Army is vulnerable to the same issues of water supply and demand that jeopardize water security globally. Throughout the world, providing the required amount of clean fresh water in the location where it is needed is increasingly difficult. The conditions that exacerbate water availability are the aging condition of water infrastructure, generalized population growth, especially in regions containing key Army installations, increased water demands for energy, and uncertain, but generally agreed on, regional effects of global climate change. The complexity of water rights, compacts, treaties, and agreements is another challenge for Army installations. It is anticipated that the effects of water scarcity will be more severe in certain locations in the coming years, where diminished water supply will be reflected in increasing costs. These global drivers that threaten to compromise water security (i.e., the capacity of a population to ensure that they continue to have access to potable water) have driven an increasing interest in preserving this finite resource.

Over the past decade, Federal legislation and executive orders that stipulate increasingly rigorous water conservation requirements have emerged. The Army has adopted these requirements through policy and regulation, and has advanced the concept even further by establishing challenging targets for installations to achieve net zero water." Net zero water is an emerging sustainable buildings concept analogous to net zero energy" (NZE). The Army's net zero water installation vision states that

> A net zero water installation limits the consumption of freshwater resources and returns water back to the same watershed so not to deplete the groundwater and surface water resources of that region in quantity or quality.

Meeting net zero water targets can be especially difficult to achieve at Army installations which are often located in regions characterized by a broad spectrum of conditions that affect water availability, quality, security, cost, and the applicability of water-efficient technologies. For installations to achieve large reductions in water use will require a holistic approach that includes policy, technology, behavior change, partnering, and a strong command emphasis. For example, a suite of technologies that includes aggressive conservation, rainwater harvesting, and water recycling/reuse, can enable buildings to achieve independence from the water grid. However, there is no one size fits all solution; an installation's net zero water program should be uniquely tailored to the installation's characteristics. While some policies, programs, and technologies will be applicable Army wide, others will be unique to a region, facility, or system.

1.1.2 DASA (IE&E) net zero installations

The Office of the Deputy Assistant Secretary of the Army Energy and Sustainability (ODASA [E&S]), is the Army lead for the net zero water program. Its accomplishments include developing and executing the net zero program, which includes establishing the initial installation selection process, and which has sponsored many projects, some specifically in support of net zero water, including:

- Water Goal Attainment Policy, which brings together, in one place, the water requirements of executive orders and laws
- Water balance assessments and project roadmaps for each of the net zero water pilots(PNNL)
- Energy and water security/vulnerability assessments (Concurrent Technologies Corporation)
- Current and future water availability at net zero water installations (CERL)
- Net zero water training/monthly phone calls for the net zero water pilots.

1.1.3 Pacific Northwest National Laboratory support

Pacific Northwest National Laboratory (PNNL) is working for ODASA(E&S) to create installation water balances and road maps for the eight net zero water pilots, some which are also energy and/or solid waste pilots. The water balances were completed in Fiscal Year 2012 (FY12). The road maps were completed in FY13. A publically releasable net zero water programmatic summary will provide the results of all the water balance assessments and project road maps. It will be available in October 2013.

1.1.4 Army-USEPA Memorandum of Understanding

The Army and U.S. Environmental Protection Agency (USEPA) signed a Memorandum of Understanding (MOU) on 28 November 2011. The stated intent of the MOU is for "EPA and Department of the Army … to carry out joint activities to advance the development and/or demonstration of new applications and technologies that can be used to achieve Net Zero Water, Waste, Energy, and related goals." The USEPA is initially focusing net zero water efforts at Fort Riley, KS.

1.1.5 RDT&E project overview

The Integrated Installation Energy, Water and Waste Modeling work package is part of the FY12 RDT&E program of the Environmental Quality and Installations Business Area. This work package extends over 4 fiscal years. Generally, the first year involves researching currently available models, the next 2 years focus on adapting/developing new models, and the final year completes the technology transfer process.

The purpose of this work package is to develop an integrated modeling capability to support Army and installation master planning for energy, water, and solid waste (EW2) resource optimization. EW2 is being built on the existing net zero energy modeling capability, a project that is in its final year in FY13.

1.2 Objectives

The objectives of this project were to assess the current state of research and technology in the areas of water demand/efficiency modeling, watershed modeling, and water conservation and efficiency planning, methods, and technologies.

1.3 Approach

The objectives of this work were completed by conducting a series of literature reviews. Previous modeling efforts were reviewed as a means to select/develop the models to be used to support modeling of energy, water, and waste. The scale of models reviewed includes installation/city scale, regional scale, and watershed scale. Additional reviews were conducted to document the range of water conservation/efficiency measures that could be used to achieve net zero. Several of the selected models were applied to the Fort Carson region, using a set of identified measures and associated assumptions, to demonstrate and document their effectiveness for this project. It is anticipated that additional models will be demonstrated over the coming year to comprise a suite of potential tools.

1.4 Scope

The tools and models described in this report are documented for Fort Carson, CO, one of the Army's net zero installations. The life cycle costing assumptions included with each measure were developed for application to the Fort Carson demonstration site and users should use locally specific assumptions for their own economic calculations. Some of the models reviewed are unique to certain physical or hydrologic conditions, and are suitable for broader, although not universal, application. Similarly, the water measures documented in this report may not be applicable at all sites. Nevertheless, the concepts described here can be beneficial to any Army installation. All Army installations are working to achieve water conservation targets and to minimize water, energy, and waste costs.

1.5 Mode of technology transfer

This report will be made accessible through the World Wide Web at URL: http://libweb.erdc.usace.army.mil

2 Analytic Framework for Net Zero Water (NZW) Decision Making

Decision makers charged with implementing effective NZW programs often face challenges in identifying and evaluating those actions and investment alternatives that are most likely to deliver greatest value. From a decision making perspective, allocating scarce resources for NZW-related efforts and initiatives is problematic, largely because of competing objectives, together with difficulties inherent to rationally evaluating the risks, costs, and benefits associated with these potential investments.

Chapter 1 outlined many of the issues and challenges that installation planners must structure and evaluate for net zero installation projects. The role and use of information in this planning process is an important issue in the larger planning context. This chapter explores the question of how this information, some of which is derived from models such as those described in Chapters 4 and 5 of this report, might best inform these decisions. The following sections discuss how decision analytic frameworks can be used in a planning context to help structure and evaluate complex NZW-related decisions. First, the various decision contexts relevant to NZW planning are described. Insofar as NZW planning is almost invariably situated in a broader planning context, such as master planning, there is a need for ways to determine/define the value of NZW efforts, initiatives, and strategies. A simple case study will illustrate this concept.

2.1 Background

As with any complex, real-world problem, there are many possible ways to frame the net zero planning problem. Typically, the framing of options focuses on identifying strategic alternatives for potential NZW investments. The formal evaluation of NZW investment options focuses on three main issues:

- the *economic costs* of pursuing specific NZW-related investment strategies
- the *economic benefits* of pursuing these strategies
- the *uncertainty* concerning potential risks, costs and benefits, and the potential efficacy or effectiveness of chosen strategies.

Situations like this, where NZW choices must be made among alternative courses of action with uncertain consequences, are referred to as *decision problems under uncertainty*. Following Leonard Savage's classic formulation, a decision problem under uncertainty consists of four basic elements:

1. A set $A = \{a_1,...,a_m\}$ of alternative *policy options*, one of which will be selected
2. For each policy option $a_i \in A$, a set $U_j = \{X_1, ..., X_n\}$ of *uncertain events* that describe the possible outcomes associated with the selection of policy option a_i
3. Corresponding to each set U_j is a set of *consequences* $C_j = \{c_1,...,c_r\}$
4. A *preference order* $\leq$, defined as a binary relation between some of the elements of A.

Having chosen a policy action $a_i \in A$, one can observe the occurrence of uncertain events in the set U_j. Each uncertain event in U_j has associated with it a corresponding consequence set C_j. In this way, the set of uncertain events U_j forms a partition of the total set of possibilities, with each investment option a_i mapping elements of U_j to the elements $c_k \in C_j$. As mentioned earlier, scientific knowledge and professional judgment both play pivotal roles in defining the set A of possible policy options. Similarly, risk assessors focus much of their activity on characterizing and evaluating the sets U_j and C_j. These concepts are illustrated below using an example of how multi-criteria decision analysis can be used to prioritize net zero installation projects.

2.2 Multi-Criteria Decision Analysis (MCDA) framework

The MCDA framework presented here is intended to enable installation planners to evaluate strategic options or decision alternatives on the basis of specified objectives and evaluation measures. Ultimately, the framework seeks to provide planners with an instrumental means by which to *integrate* the best available knowledge and information —including subject matter expert opinion and judgment— about potential NZW investment alternatives and to provide a framework for exploring fundamental *tradeoffs* between key dimensions or facets of the problem (e.g., economic, environmental, or social).

To illustrate this MCDA approach, consider the case of an installation planner who must evaluate several potential projects. Each potential project represents a substantial investment in both time and money, and each alternative is characterized by different risks, costs, and benefits, as discussed below. The MCDA model formulation proceeds in three parts: (1) specification of the planners' objectives and evaluation measures, (2) numerical specification of an additive value model, and (3) evaluation of the MCDA model, applied to an illustrative set of net zero installation projects.

2.2.1 Specification of objectives and evaluation measures

Any effort to confront the decision making and resource allocation challenges described above must address a few basic questions. It is important to begin by asking, "What is it that matters most to the installation planners in their evaluation of the nanomaterials in question?" To put the matter succinctly, "*What do the planners care about and why?"* Moreover, since net zero initiatives hold the potential to affect numerous stakeholders, along many possible dimensions (geospatial, temporal), what different kinds of perspectives and viewpoints might they bring to the evaluation process? Finally, how might they assign meaningful metrics to how they measure the degree to which each their key objectives is met or achieved?

Within MCDA, these basic questions are addressed, first, by clarifying the *objectives* to be achieved (attempted) in the analysis and, second, by identifying appropriate *evaluation measures* for gauging the degree to which these objectives are achieved. In the case of the net zero installation projects evaluation, it is assumed that the planners are interested in achieving three fundamental, "high-level" objectives, defined as:

- Maximize Benefits Derived from NZW Investments (X_1)
- Minimize Costs Incurred (X_2)
- Minimize Risks (X_3).

Collectively, these high-level objectives speak to a desire on the part of the installation planners to formally consider a broad range of factors, by looking at potential NZW projects in terms of their overall risks, costs, and benefits.

The three high-level objectives specified above are, by themselves, too broad and general to be useful for characterizing and evaluating potential net zero installation projects. As a consequence, it is necessary to identify and define evaluation measures for each objective.

The terms “evaluation measure,” “performance metric,” “criterion,” and “attribute” are often used synonymously within the realm of MCDA (e.g., Keeney and Raiffa 1993, Keeney 1992, Von Winterfeldt and Edwards 1986). An illustrative set of evaluation measures were defined for this project evaluation. The evaluation measures used here as part of the model formulation span a wide conceptual range, from direct measurement of costs, benefits, to qualitative ratings, indirect measures, and proxies. For objective X_1, the focus is on three evaluation measures: Direct Economic Benefits (X_{11}), Indirect Benefits (X_{12}), and Societal Benefits (X_{13}). For objective X_2, three evaluation measures are specified: Direct Costs (X_{21}), Indirect Costs (X_{22}), and Societal Impacts (X_{23}). Finally, for objective X_3, the focus is on three types of risk: Implementation Risks (X_{31}), Potential Environmental Health and Safety (EHS) Risks (X_{32}), and Technology Risks (X_{33}).

This process of top-down decomposition can continue ad infinitum, with additional evaluation measures similarly defined. Ultimately, the goal for the installation planners at this problem structuring stage of the analysis is to arrive at a hierarchical representation that accomplishes three things. First, it should make clear and explicit the installation’s fundamental mission, goals, and objectives. Second, it should provide some degree of transparency as to how measurement and valuation come together to form the basis of the overall project evaluation. Third, it should provide some degree of clarity about the nature of the competing objectives that lie at the heart of the evaluation, especially the value tradeoffs that exist between the model’s high-level objectives, in this case, fundamental tradeoffs between risks, costs, and benefits.

The foregoing characterization permits a structuring of high-level objectives and evaluation measures in the form of a value tree or objectives hierarchy (Figure 1). (Keeney and Raiffa [1993, pp 31-65] discuss a number of criteria that can be used to guide the construction of objectives hierarchies.)

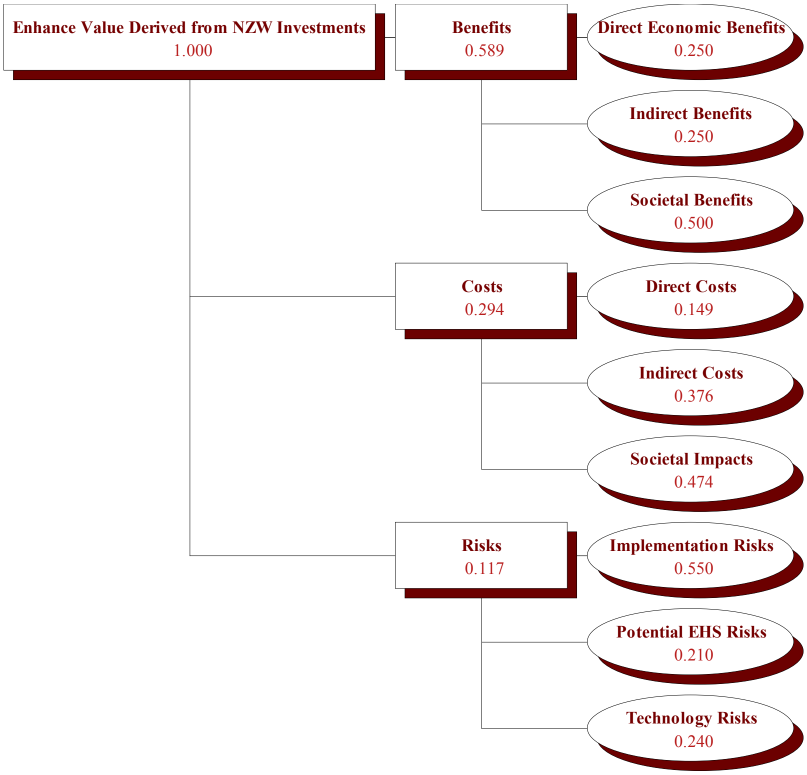


Figure 1. Objectives hierarchy for selection of best NZW project.

In Figure 1, the top objective is the overall goal of the evaluation exercise, i.e., the selection of those NZW projects that enhance overall value, and that explicitly balance key risks, costs, and benefits. The successive decomposition of the hierarchy allows the problem to be broken down, first, in terms of "what matters," and then in terms of "what can be measured or quantified." As discussed below, organizing the objectives and evaluation measures in this manner ultimately facilitates efforts to score each potential NZW project on the basis of each evaluation measure specified in a hierarchy.

2.2.2 The additive value model

Having specified the objectives hierarchy for the MCDA framework, the problem of how to combine and evaluate this information in a meaningful way must now be addressed. As already discussed, a key feature of MCDA methods is the ability to evaluate alternative or options on the basis of how well they perform against specified criteria or measures of performance. For the purposes of this work, it is of interest to use the objectives hierarchy as a starting point for defining individual value functions for each of the evaluation measures identified earlier. Having defined these values, the next step is to seek rational and consistent means by which to *aggregate* these functions into a single, overall value or score.

In choosing an aggregation method, the planners seek a requisite balance between transparency, ease of use, and ease of communication. If the planners' preferences are consistent with a special class of independence assumptions, then the value $V(\cdot)$ of NZW project *r* is simply the weighted sum of its evaluation measure-specific values. This model is valid if the planners' preferences are consistent with certain independence assumptions, the most important being that their preferences display mutual preferential independence. In informal terms, what this means is that the strength-of-preference for an option on one evaluation measure is independent of its judged strength-of-preference on another measure. (See Keeney and Raiffa [1993] for a technical discussion of this issue.)

This is the essence of the so-called *additive value model*. In this model, the main idea is to construct *scales* representing the decision maker's preferences for the consequences of interest, to weight these scales for their relative importance, and to compute weighted averages across these preference scales. Of course, other functional forms requiring consistency or congruence with different sets of independence conditions can be specified, e.g., multiplicative, multilinear, etc. (See von Winterfeldt and Edwards [1986] for examples and illustrative case studies that explore a variety of preference structures.)

Figure 2 shows the overall structure of the model as hierarchical, consisting of three levels or tiers. The first tier represents the overall objective of the analysis, in this case, the selection of NZW projects that enhance overall value. The second tier consists of high-level objectives X_1, X_2, and X_3. The third tier contains the model's evaluation measures. Focusing on the second and third tiers, note that this model formulation consists of $n = 9$ evaluation measures, partitioned into $m = 3$ clusters or groups. Let the vector xj contain the levels or scores for the evaluation measures in Group j for a particular nanomaterial. If Xjk is the level or score for evaluation measure k in Group j, then:

$$\mathbf{x}_j = (x_{j1}, x_{j2}, x_{j3}),\ j = 1,2,3.$$

Similarly, let x^{*}_{jk} and X_{jk^*} denote the "best/most preferred" and "worst/least preferred" levels, respectively, of evaluation measure X_{jk}. Thus, let:

$$x_j^* = (x_{j1}^*, x_{j2}^*, x_{j3}^*) \text{ and } x_{j^*} = (x_{j1^*}, x_{j2^*}, x_{j3^*}),\ \ j = 1, 2, 3$$

In this way, $\boldsymbol{x}^{*}_{j}$ represents the best levels of all the evaluation measures in Group *j,* and $\boldsymbol{x}_{j^*}$ represents the worst levels.

For a given NZW project *r,* its Group *j* value is, according to the additive value model, given by:

$$V_j(x_j) = \sum_k w_{jk}\, v_{jk}\,(x_{jk}) \tag{1}$$

Where: v_{jk} is a single-attribute measurable value function over X_{jk}, scaled from 0 to 1; the w_{jk} are the positive scaling constants or weights associated with evaluation measure *k* in Group *j*. The scaling of each single-attribute value function is accomplished by assigning a score of 0 to the worst level of an evaluation measure, x_{jx^*}, and a score of 1 to its best level, x^{*}_{jk}. Between these worst/best extremes, one can use a number of different methods —including direct scoring, specification of assumed functional form, etc.— to assign scores to intermediate levels of performance for a given evaluation measure. By convention, for each Group *j,* $\Sigma_k w_{jk} = 1$.

To compute the overall value, $V(\boldsymbol{x})$, for a given project *r,* one must factor in weights associated with the high-level objectives in the objectives hierarchy, i.e., the weights associated with X_1,X_2, and X_3. These values may be seen as weights, g_j, assigned locally to each Group *j*. As before, it is assumed that $\Sigma_j g_j = 1$. The overall value for NZW project *r* is then given by:

$$Vx = \sum_{j=1}^{3} g_j \sum_{k=1}^{3} w_{jk} v_{jk}(x_{jk}) \tag{2}$$

Equation 2 therefore requires several pieces of information from the installation planners. First, the determination of an appropriate set of evaluation measures, X_{jk}, together with an understanding of the least preferred and most preferred levels for each attribute. Second, an empirical or theoretical justification for the use of the additive value model. If attempts to verify the independence conditions are unsuccessful and the additive model's use is thereby unjustified, the installation planners can either attempt to simplify their multi-criteria framework to effect some semblance of theoretical congruence, or they can select an alternative value model with a different, more complex, preference structure. Third, determination of the scaling constants or weights, g_j and w_{jk}. And finally, specification of the single-attribute measurable value functions, v_{jk}.

If the decision maker is satisfied that the first two of these concerns are adequately dealt with, the next step in the model formulation process involves assessing weights for the high-level objectives and evaluation measures that comprise the objectives hierarchy. This begins with the weights, gj, associated with high-level objectives X_1, X_2, and X_3. Many methods exist to assess or elicit these weights. For these purposes, this work uses the so-called *swing weighting* method; this method is often favored by practitioners because, as shown below, it derives weights from observed choices among alternatives, as opposed to asking directly for numerical weights, whose meaning may be ambiguous or difficult to interpret. Edwards and Barron [1994] give an insightful discussion of swing weights.

As the name implies, the swing weighting method focuses the decision maker's attention on value or strength-of-preference "swing" differences that exist between evaluation measures. Specifically, how does a swing from least preferred to most preferred on one preference scale compare to the same swing on another scale? In this way, the decision maker is asked to consider the relative importance of changes from the worst to the best levels for each objective and evaluation measure in this model.

The concept of swing weighting is made operational here by using an elicitation approach that makes use of *indifference judgments* provided by the decision maker. To this end, begin by first looking at the high-level objective X_1. It is of interest to presenting the decision maker with a specific choice situation where the goal is the elicitation of an indifference probability. In describing the decision situation, suppose that the installation planners face a situation where they must choose between one of two options. The first option is *riskless* and is characterized by the least preferred level on all evaluation measures except those associated with the 1st measure, X_1, which are characterized by their most preferred level, i.e., x^*_{11}, x^*_{12}, and x^*_{13}; using the notation introduced earlier, this riskless outcome is represented by ($\mathbf{x}^*_1, \mathbf{x}_{2*}, \mathbf{x}_{3*}$). Unlike the first option, the second option is *risky,* and it presents the decision maker with the prospect of winning, with probability p_1, an alternative characterized by the most preferred level in *all* evaluation measures, $\mathbf{x}^*$, and a probability (1 - p_1) of winning an alternative characterized by the least preferred level in all measures, $\mathbf{x}_*$.

Together with its lower-level evaluation measures, each high-level objective in this model constitutes a distinct group or cluster within the hierarchy. The procedure described must therefore be repeated for the two remaining high-level objectives in the hierarchy, X_2 and X_3. In total, the installation planners are presented with three choice situations, each of which seeks a unique indifference probability for the choice setup described above:

$$(x_1^*, x_{2*}, x_{3*}) \sim [x^*, p_1; x_*, (1-p_1)] \tag{3}$$

$$(x_{1*}, x_2^*, x_{3*}) \sim [x^*, p_2; x_*, (1-p_2)] \tag{4}$$

$$(x_{1*}, x_{2*}, x_3^*) \sim [x^*, p_3; x_*, (1-p_3)] \tag{5}$$

Since the weights, g_j, must sum to one, this elicitation need only be done once for two of the three high-level objectives. Still, it is often useful to elicit all three values as a means of enhancing judgmental consistency.

Using Equations 3, 4, and 5 as the basis for a structured elicitation exercise yields the indifference probabilities p_1, p_2, and p_3, which correspond to the needed weights, g_j. Elicitation of these indifference probabilities from the installation planners yields the following weights for three high-level objectives: $g_1 = 0.117$, $g_2 = 0.294$, and $g_3 = 0.589$. The indifference probabilities can be found by employing the lottery equivalent/probability method using bracketing. See de Neufville (1990) for a more detailed example.

Next is the task of eliciting the weights, w_{jk}, associated with the evaluation measures, X_{jk}, in the objectives hierarchy. As before, it is of interest to use swing weights to elicit these values. To do so requires decision makers to use their imaginations and to engage in a Gedanken experiment that proceeds in two stages. The first stage yields the rank order of the weights and the second stage yields the individual weights themselves. Begin by focusing on the high-level objective X_1 and the lower-level evaluation measures X_{11}, X_{12}, and X_{13} associated with it; collectively, this objective and this set of evaluation measures are referred to as Group 1. In the first stage of this thought experiment, the installation planners are asked to imagine a fictitious NZW project that scores worst or least preferred on all of the evaluation measures in Group 1. In this way, for the planners, this situation represents their "worst possible project, relative to objective X_1. In continuing the thought experiment, the planners are presented with the option of improving, e.g., from worst to best", one of these attributes. Suppose that the planners select evaluation measure X_{13}. At this point, the experiment is repeated, this time excluding X_{13} from consideration. Suppose that this time they choose X_{11}. Since there are only three evaluation measures in Group 1, the available measures have been exhausted and the procedure has yielded the following rank order for the evaluation measure weights of interest, w_{1k}: w_{13}, w_{11}, and w_{12}.

In possession of this rank ordering, return to the beginning hypothetical situation described above, in which all of the evaluation measures associated with Group 1 are set at their worst level, an outcome denoted by (x_{11*}, x_{12*}, x_{13*}). Now, modify this situation slightly and improve the evaluation measure that matters least, again, in the context of X_1, to the decision maker, X_{12}, from its worst level to its best level. Envision this full swing — from 0 to 100 on the strength-of-preference scale— which yields $(x_{11*}, x^*_{12}, x_{13*}) \cong H_1$. The initial use of an arbitrary 0 to 100 single-dimensional utility scale was adopted for ease of exposition and elicitation.

Now posit another set of outcomes, where X_{11},which decision makers deemed to be more important than X_{12}, is improved *somewhat* from its worst level, but that X_{13} and X_{12} remain set at their worst levels. This new situation is denoted by $(x^+_{11}, x_{12*}, x_{13*}) \cong H2$. Clearly, the intuition here is that H_2 need not have X_{11} improved to 100 to be *exactly* as attractive to the planners as H_1, since they collectively judged X_{11} to be more important, to X_1, than X_{12}. Now juxtapose H_1 and H_2 and ask the planners the following question: "*For what utility or value of X_{11} would they be indifferent between the hypothetical outcomes H_1 and H_2?*"

Using Equation 1, the value that these three evaluation measures contribute to the overall valuation is given by:

$$V_1(x_1) = \sum_{k=1}^{3} w_{1k} v_{1k}(x_{1k})$$

To answer the question posed above, consider the following situation:

$$V_1(H_1) = V_1(H_2) = 100w_{12} = S w_1 \tag{6}$$

where S denotes the amount of swing in X_{11} necessary to equal in attractiveness a full swing —from least preferred to most preferred— in X_{12},the defining characteristic of H_1. From Equation 6, the weights may be expressed in ratio form as:

$$\frac{w_{11}}{w_{12}} = \frac{100}{S}$$

which can be elicited directly from the decisionmaker. Since there are only three evaluation measures in Group 1 of the objectives hierarchy, to complete the exercise, one must now elicit the amount of swing in X_{13} that is as desirable as a full swing in X_{12}. For this situation, let $(x_{11*}, x_{12*}, x^{+}_{13}) \cong H_3$, in which case:

$$V(H_1) = V(H_3) = 100w_{12} = T w_{13}$$

where T denotes the amount of swing in X_{13} necessary to equal in attractiveness a full swing in X_{12}. As before, it follows that the corresponding weight ratio is given by

$$\frac{w_{13}}{w_{12}} = \frac{100}{T}$$

Now, let $R_1(1/2) \cong w_{11} / w_{12}$ and $R_1(3/2) \cong w_{13}/w_{12}$ denote the weight ratios thus derived. Note that, since the weight of the more important evaluation measure is placed over the weight of a less important measure, the values elicited from the decision maker will be greater than or equal to unity. Since $w_{11} + w_{12} + w_{13} = 1$, it follows that

$$R_1(1/2) + R_1(3/2) = \frac{w_{11}}{w_{12}} + \frac{w_{13}}{w_{12}} = \frac{1 - w_{12}}{w_{12}}$$

Solving for w_{12} yields

$$w_{12} = \frac{1}{R_1(1/2) + R_1(3/2) + 1}$$

In this example, assume that the installation planners provide the following elicited weight ratios:

$$R_1(1/2) = 1 \quad \textit{and} \quad R_1(3/2) = 2$$

This set of values yields w_{12} = 0.250, in which case w_{13} = 0.500 and w_{11} = 0.250. Repeating this elicitation procedure for the set of evaluation measures associated with Groups 2 and 3 of the objectives hierarchy, respectively, yields the weight values listed in Table 1.

2.3 Model evaluation

As discussed above, the MCDA framework requires an assessment of the expected performance of each NZW project *r* on each of the evaluation measures in the objectives hierarchy. Within MCDA, this step is often referred to as scoring-the-options on the evaluation measures contained in the objectives hierarchy. An elicitation exercise with the installation planners yields the scaled strength-of-preference values listed in Table 2 for three illustrative NZW projects. For purposes of illustration, Table 2 lists only how each account scores on each evaluation measure and omits the details of how each function is numerically characterized. In every instance, the value functions, vjk, are assumed to be linear in X_{jk}.

Using Equation 2, each single-dimensional value shown in Table 2 is, in the first instance, multiplied by the appropriate evaluation measure weight, w_{jk}, and then by its corresponding high-level weight, g_j. These weighted single-dimensional values are then summed to determine the overall value for each of the three illustrative NZW projects. Figure 2 shows these totals and their associated high-level objective subtotals.

Table 1. Elicited weights for the high-level objectives and the lower-level evaluation measures of the MCDA NZW project evaluation framework.

High-Level Objectives (X_j)	Objective Weights (g_j)	Evaluation Measures (X_{jk})	Measure Weights (w_{jk})
Benefits (X_1)	0.589	Direct Economic Benefits (X_{11})	0.250
		Indirect Benefits (X_{12})	0.250
		Societal Benefits (X_{13})	0.500
Costs (X_2)	0.294	Direct Costs (X_{21})	0.149
		Indirect Costs (X_{22})	0.376
		Societal Impacts (X_{23})	0.474
Risks (X_3)	0.117	Implementation Risks (X_{31})	0.550
		Potential EHS Risks (X_{32})	0.210
		Technology (X_{33})	0.240

Table 2. Preference scores, with subtotals and totals, for the MCDA NZW project evaluation framework.

Selection of Best NZW Project	Project 1	Project 2	Project 3
Benefits	0.248	0.509	0.244
• Direct Economic Benefits	0.253	0.545	0.202
• Indirect Benefits	0.265	0.590	0.145
• Societal Benefits	0.236	0.450	0.314
Costs	0.499	0.347	0.154
• Direct Costs	0.297	0.540	0.163
• Indirect Costs	0.528	0.333	0.140
• Societal Impacts	0.540	0.297	0.163
Risks	0.491	0.332	0.177
• Implementation Risks	0.594	0.249	0.157
• Potential EHS Risks	0.500	0.250	0.250
• Technology Risks	0.249	0.594	0.157
Overall Score	0.350	0.440	0.210

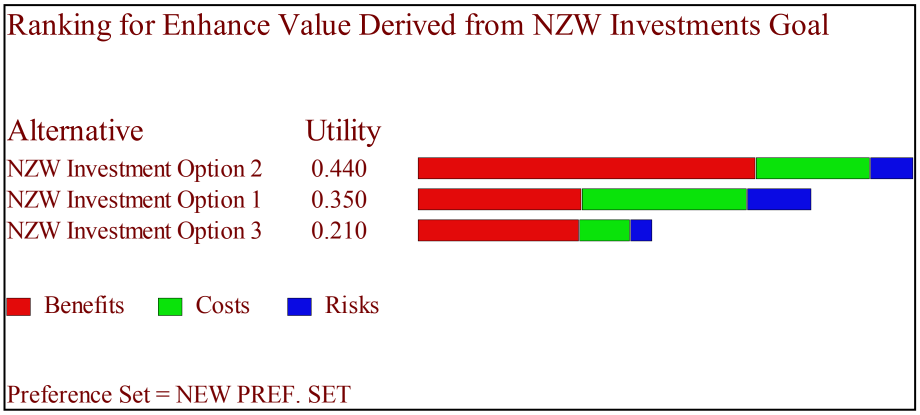


Figure 2. Ranking for the selection of the best NZW project, broken down in terms of the contribution that each high-level objective makes to the overall score of each project.

Figure 3 shows that NZW Project 2 scores the highest, followed by Projects 1 and 3, respectively. As the value breakdown shown in Figure 3 illustrates, although Project 1 scores well on Societal Impacts and Stakeholder Preferences, Project 2 maintains an overall better score because of its high benefits. The installation planners will, of course, want to test the robustness and sensitivity of these rankings to changes in various model assumptions and value characterizations. Ultimately, in using an MCDA framework like the one proposed here, what the decision maker seeks is the ability to prioritize options on the basis of diverse, and oftentimes disparate, sources of knowledge and information about the scope and character of the net zero efforts under consideration.

3 Army Water Background

Army installations are vulnerable to the same issues of water supply and demand that jeopardize the national and indeed the global water supply. Providing the required amount of water in the location where it is needed is increasingly difficult. The use of water and the applicability of conservation and efficiency measures at installations are influenced by several primary factors that are subject to change over time.

Water scarcity can be a consideration in regions already feeling the effects of competition for a finite or decreasing supply. Water scarcity is no longer limited to arid stretches of the United States. Periodic droughts are common in otherwise water-rich regions. The long history of plentiful water left many regions ill-prepared for recent flood-drought cycles. Distribution can also be an issue, e.g., farmers vs. cities in contrast to scarcity.

To a great extent, mandated use constraints are the main motivation for installation personnel to reduce water consumption. Federal mandates range from prescriptive —with established water ratings for equipment and devices— to performance-based, with standards for overall water reduction and an increased emphasis on alternate water sources.

The conditions that exacerbate water availability include continued use in agriculture, increased demand from the energy sector, cost disincentives, and an archaic system of water rights established during a time of low demand and plentiful supply. Energy demands include requirements for new power generation as well as fuel extraction needs and even renewable technologies.

Water cost does not typically enter into the picture except as a constraint for funding water efficiency/ conservation projects. Widespread low pricing of water produces economically unacceptable payback periods. However, there is a trend of rising water rates across the United States. In the coming years, the effects of water scarcity are likely to be more severe. Combined with the need for large investments in infrastructure, this will be reflected in increasing costs.

The complexity of water compacts, treaties, and agreements is another challenge for Army installations. Regional water rights can have some (typical indirect) bearing on Army water use, although Federal reserved water rights are protected from non-use.

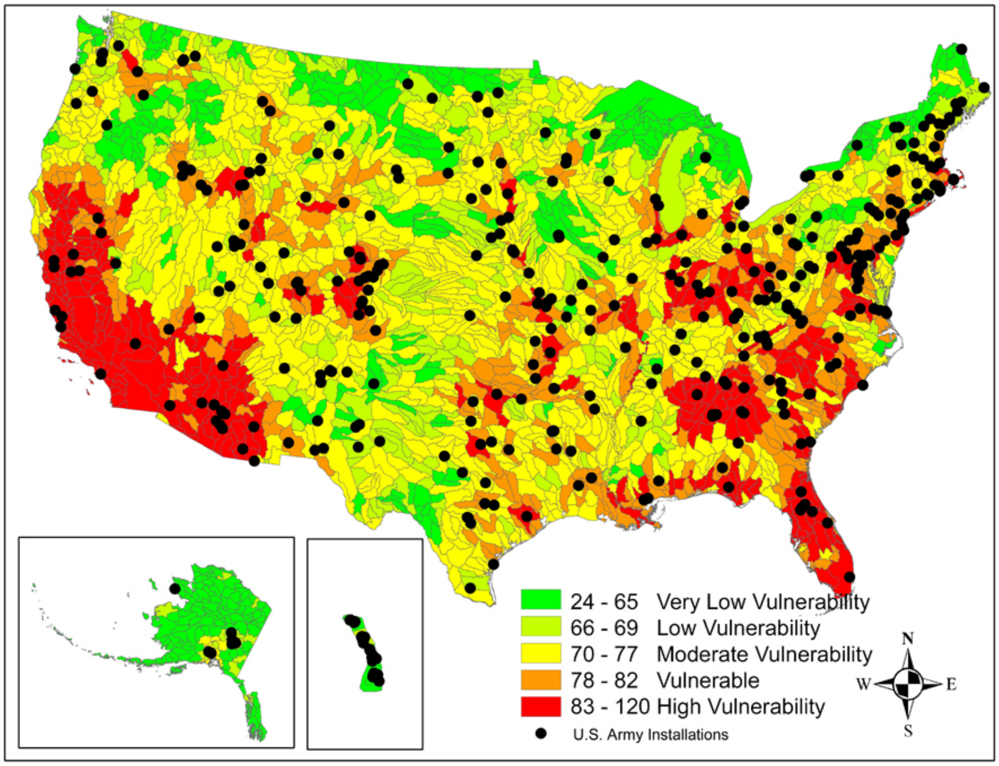
3.1 Water availability

Water availability is one of the main threats to water security. Scarcity can compromise a population's capability to ensure continued access to potable water. The effects of water scarcity are most noticeable for installations living in drought-prone regions. However, concerns with water supply, demand, and quality are more widely spread across the United States. Whether self-supplied or customers of public utilities, installations experience the consequences of insufficient availability of the right quality of water in locations where it is needed.

Increasing demand, degraded supply, uneven distribution, and aging infrastructure are a few of the issues influencing availability. The amount of fresh water globally is finite, whereas human demand for this life-sustaining resource continues to grow. The human pressures affecting water resources are most often related to factors such as demographics, economic trends, legal decisions, and climatic fluctuations. The U.S. population has doubled since 1950. This resulted in increased direct human demand and also influenced water requirements to meet increased food and energy production.

Army installations were historically sited away from settled areas. Over time, the economic drivers inherent in military base operations attracted settlement in proximity to installations. Drawn by employment and commerce, neighbors of installations now compete for limited resources that include water. Water is a resource that recognizes no boundaries, installation, municipal, county, region, state, or national, other than its own, that of watershed or subsurface aquifer. Water supplies that were at one time adequate to meet installation demands are increasingly at risk.

Figure 3 shows the locations of Army installations in the 50 states in relation to watershed boundaries. The watersheds have been rated for overall health based on 17 indicators related to water supply and 10 indicators related to water demand. Twenty-four percent of Army installations are located in watersheds rated vulnerable or highly vulnerability (Jenicek et al. 2009).



Source: Jenicek et al. (2009)

Figure 3. Army installations overlay on a map of watershed health.

3.2 Reactivity to water scarcity (ref. Australia)

An emerging concept is that of embedded water or the water footprint. Recent studies quantify the amount of green water (rainwater), blue water (surface and groundwater), and graywater (water required to assimilate pollutants) by country, end-use, and by import/export. For example, the United States leads the world in embedded water exports. However, the United States is a net exporter of water through various products with a net external water dependency of 20% (Hoekstra and Mekonnen 2012). Exporting virtual water exacerbates conditions of limited supplies, localized droughts, deterioration of freshwater bodies, and disputes over water. As world population grows —estimated to reach more than 8 billion by 2030— the risk to water security will multiply.

3.3 Policy overview

Global drivers of water conservation have driven increasing interest in preserving this finite resource. On the Federal level, legislation and executive orders with increasingly rigorous water conservation requirements have emerged over the last decade. The Army has promulgated these requirements through policy and regulation and has taken it a step further in establishing challenging targets for installations to achieve NZW. Additionally, industry standards, codes, and specifications play a key role and are often included as requirements in Army water policy.

Policy areas that affect water include conservation targets for both potable and industrial, landscape and agriculture; new construction and major renovation performance standards; technology standards; and metering and monitoring requirements often tied to measurement and verification.

3.3.1 Federal policy

Two recent pieces of Federal policy currently govern water, Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy, and Economic Performance* (White House 2009) and the *Energy Independence and Security Act of 2007* (EISA 2007). EO 13423, *Strengthening Federal Environmental, Energy and Transportation Management* (White House 2007), was largely superseded by EO 13514 although some of the provisions remain in effect. The *Energy Policy Act of 2005* (EPAct 2005) required building-level energy metering in all covered facilities by 2016. (Covered facilities are defined based on size and/or amount of water used.) This requirement also remains in effect though other provisions of EPAct 2005 have been strengthened by newer requirements. Water meters are required by DODI 470.11 and Department of Defense (DoD) metering policy (Table 3 lists legislative and regulatory water mandate requirements as of November 2011.)

EO 13514 superseded the requirements of EO 13423 (White House 2007) in the development of water management plans and implementation of Best Management Practices (BMPs) for water efficiency as identified by the Federal Energy Management Program (FEMP 2011b). EO 13423 requires a 2% annual reduction in water consumption intensity (gal/sq ft) from a 2007 baseline through the end of FY15, or 16% by the end of FY15. It further requires water audits at Federal facilities of at least 10% of facility square footage at least once every 10 years. Finally, it encourages the procurement and use of water-efficient products and services, specifically identifying the USEPA's WaterSense® program as a source of guidance.

Table 3. Water mandates: Legislative and regulatory requirements as of November 2011.

Federal Mandate	Water Topic	Water Performance Target
EO 13423	Water Consumption	Reduce consumption by 2% annually for 16% total by FY15 (FY07 baseline)
	Water Audits	At least 10% per year every 10 years
	Products and Services	Procurement of water efficiency products and services, WaterSense®
EISA 2007	Covered Facilities (75%)	Comprehensive evaluations, project implementation, and follow-up
	Post-Construction Stormwater	Restore to pre-development hydrology
EO 13514	Water Consumption	Reduce consumption by 2% annually for 26% total by FY20 (FY07 baseline)
	Industrial, Landscape, Agricultural	Reduce consumption by 2% annually for 20% total by FY20 (FY10 baseline)
	Water Reuse	Identify, promote, and implement water reuse strategies
	Stormwater Management	Implement and achieve objectives from USEPA
EO 13514 Implementation Instructions	Water Reporting	Defines reporting requirements to comply with reduction and reuse
Army Sustainable Design and Development Policy	New Construction and Renovation	Achieve 30% reduction compared to baseline IAW ASHRAE 189.1-2009 (ASHRAE 2009) Outdoor use achieve a 50% reduction

FEMP developed supplemental guidance to help achieve the water goals and to meet the reporting requirements of EO 13423 (White House 2007) in the *Instructions for Implementing EO 13423* (GPO 2007). This guidance, *Establishing Baseline and Meeting Water Conservation Goals of Executive Order 13423* (USDOE 2008) was developed to assist in the interpretation of, and ultimate compliance with, EO 13423. Specifically, three key elements of compliance were identified and presented: (1) water use intensity baseline development, (2) reduction of water use intensity, and (3) reporting.

Additionally, BMPs were originally developed by FEMP in response to the requirements set forth in the previous EO 13123, *Greening the Government through Efficient Energy Management* (White House 1999), which required Federal agencies to reduce water use through cost-effective water efficiency improvements. In response to EO 13423 and to account for recent changes in technology in water use patterns, the USEPA WaterSense®

Office updated the original BMPs. The updated BMPs, which were developed to help agency personnel achieve water conservation goals of EO 13423 (FEMP 2011b)

EISA 2007 amends Section 543 of the *National Energy Conservation Policy Act (NECPA)* (1978), the foundation of most current energy requirements. It adds further water conservation requirements and provides guidance for benchmarking. Under EISA 2007, agencies are required to categorize groups of facilities that are managed as an integrated operation and to identify "covered facilities" that constitute at least 75% of the agency's facility energy and water use. Each of these covered facilities will be assigned an energy manager responsible for completing comprehensive energy and water evaluations, implementing efficiency measures, and following up on implementation. EISA 2007 also addresses post-construction stormwater management for Federal projects, requiring that:

> The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5000 sq ft (465 m^2) shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the pre-development hydrology of the property with regard to the temperature, rate, volume, and duration of flow.

EO 13514 (White House 2009) expands the water efficiency and conservation requirements of EO 13423 (White House 2007) and EISA (2007). This mandate extends the 2% annual water consumption intensity reduction requirement promulgated by EO 13423 into FY20, resulting in a total water reduction requirement of 26% from the baseline year of 2007. Additionally, the new rules require a 2% annual reduction for agency industrial, landscaping, and agricultural water consumption through 2020, for a total of 20% water consumption reduction relative to the 2010 base year. EO 13514 also encourages agencies to identify, promote, and implement water reuse strategies that reduce potable water consumption, and to support objectives identified in the stormwater management guidance issued by the USEPA. Guidance on reporting compliance with the water requirements of EO 13514, released in July 2013, contains definitions for the various water categories (White House 2013).

3.3.2 Army policy

The 2012 *Army Campaign Plan* is the driver for energy and water security for the Army and addresses water sustainability under Campaign Objective 8, “Achieve Energy Security and Sustainability Objectives.” Major Objective 8-3, “Enhance water security,” has the desired strategic outcome: “Assured access to reliable supplies of water and the ability to protect and deliver sufficient water to meet mission essential requirements.” Major subtasks currently relate to reduction of potable water consumption intensity at permanent installations; reduction of industrial, landscaping and agricultural water consumption; and increased use of alternative water sources.

The *Army Energy Security Implementation Strategy* (AESIS), signed 13 January 2009 (AESC 2009), addresses energy security. This policy stresses the enhanced operational capability that is supported through achievement of the Army’s energy and water goals.

The Department of the Army’s *Sustainable Design and Development Policy Update (Environmental and Energy Performance)* (Hammack 2013) includes incorporation of sustainable development and design principles, following guidance as detailed in American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Standard 189.1-2009 (ASHRAE 2009). All facility construction projects shall achieve a 30% reduction in indoor potable water use as compared to a baseline using guidance from ASHRAE. In addition, outdoor potable water consumption shall achieve a reduction of 50% from the baseline.

US Army Corps of Engineers (USACE) Engineering and Construction Bulletins (ECBs) are used to promulgate changes in requirements or processes related to building design and are contained on the Whole Building Design Guide website as part of the Construction Criteria Base, at URL: http://www.wbdg.org/ccb/browse_cat.php?o=31&c=214

Army Regulation (AR) 420-1, effective February 2008, calls for water supply and wastewater services to be provided at the lowest Life Cycle Cost (LCC) consistent with installation and mission requirements, efficiency of operation, reliability of service, and environmental considerations. The costs for these services are to be held to a minimum through comprehensive water resource planning, management, and an effective water conservation program, all of which rely heavily on the adoption of sustainable water technologies. Furthermore, AR 420-1 also requires compliance with the Safe Drinking Water Act (SDWA).

3.3.3 Standards and codes

Plumbing and building codes influence the adoption of water-efficient products and processes. DoD adopts the International Code Council (ICC) International Plumbing Code (IPC) as the primary standard for DoD facility plumbing systems. The code has a 3-year development cycle for updates. The process of amending codes is long and labor intensive and requires the support of water stakeholders. Any additions, deletions, and revisions to the IPC are listed in Appendix A "Supplemental Technical Criteria" of Unified Facilities Criteria (UFC) 3-420-01, 25 October 2004. Although the ICC also produced the International Green Construction Code, the Army has not adopted it.

WaterSense® is a USEPA partnership program that certifies water fixtures that meet rigorous criteria in both performance and efficiency. Specifications and criteria are available for bathroom sink faucets, shower heads, toilets, urinals, pre-rinse spray valves, and landscape irrigation controls.

The US Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED®) Green Building Rating System is a voluntary standard for high performance sustainable buildings. LEED® certification validates that a building is a high performing, sustainable structure. Certification also benchmarks a building's performance to support ongoing analysis over time to quantify the return on investment of green design, construction, systems, and materials. All Military Construction, Army (MCA) projects meeting the Minimum Program Requirements for LEED® certification are to be planned, designed, and built to be Green Building Certification Institute (GBCI) certified at the Silver level or higher. WE 1, the Water Efficient Landscaping credit and WE 3, the water use reduction (30% reduction) credit are required in all MCA projects. This requirement is contained in the SDD policy.

ASHRAE developed Standard 189.1-2009 in conjunction with the USGBC and the Illuminating Engineering Society (IES). This standard is intended to provide minimum requirements for sustainable or green buildings through the general goals of reducing energy consumption, addressing site sustainability, water efficiency, occupant comfort, environmental impact, materials, and resources. The Army adopted the energy and water standards of *ASHRAE 189.1-2009* (ASHRAE 2009) for all new construction and major renovations through the *Sustainable Design and Development Policy* (Hammack 2013).

3.4 Army water consumption

The Army's water use is reported along with installation energy data through the Army Energy and Water Reporting System (AEWRS). AEWRS is a common access card (CAC) enabled web-based system that collects quarterly installation data reports can be generated for installations, MACOMs, and the Army or active Army. Water reports include potable water, water reuse, or total water. Water cost is also included as is building square footage and installation population.

The Army achieved a 10.3% reduction in water intensity during FY11 in comparison to the baseline year of FY07 (Figure 4). This exceeds the EO 13514 (White House 2009) reduction target of 8% (DA 2012).[1]

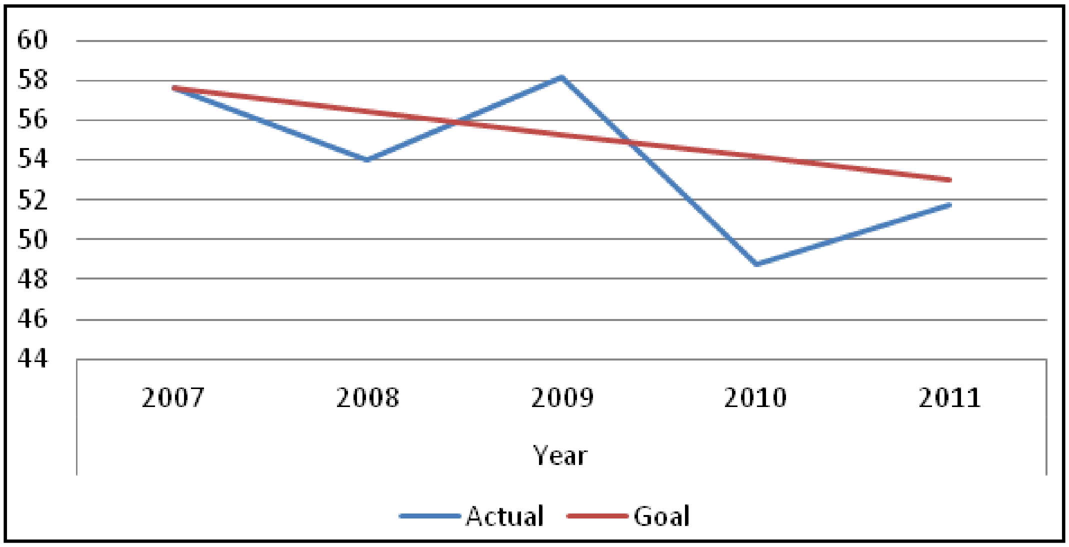


Figure 4. Army historical water consumption compared to goal.

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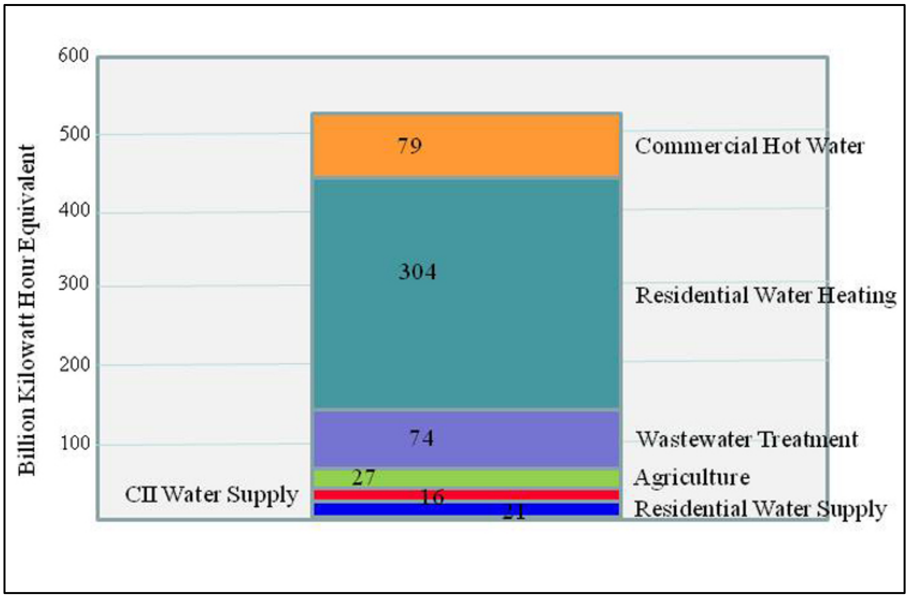
[1] FY2012 Army water use, available at time of publication, was an additional 3.4% lower with a cost that was 12.8% higher (DA 2014)

3.5 Energy-water nexus

The energy-water nexus is an important issue that has taken on new urgency as concerns have grown about competing demands for this limited resource (AWE 2008). Key organizations in both water and energy have mobilized to develop solutions to the historic clashes between these critical resources. The Alliance for Water Efficiency (AWE) and the American Council for an Energy Efficient Economy (ACEEE) developed *A Blueprint for Action and Policy Agenda* (AWE and ACEEE 2011). The World Energy Council and the World Water Council announced their commitment to cooperation for efficiency in both sectors during World Water Week 2012 (Water Efficiency 2012). The River Network developed The Carbon Footprint of Water, examining both embedded energy in water and embedded water in energy (River Network 2009). Numerous efforts have focused on renewable energy trying to ensure that clean energy does not contribute to water scarcity. A comprehensive list of energy-water studies can be found at: http://en.openei.org/wiki/Water_and_energy_studies.

Energy can account for 60 to 80% of water transportation and treatment costs and 14% of total water utility costs (Figure 5). Much of water resources development occurred during the 20th century in an era of both low energy and water prices. Subsidized rural electricity increased agricultural production in irrigated areas and encouraged the use of irrigation in areas without direct access to surface water. Energy-related uses of water include thermoelectric cooling, hydropower, minerals extraction and mining, fuel production (fossil, non-fossil, and biofuels), and emission controls. Energy demands in potable water systems include that required for pumping, transport, treatment, and desalination of water in addition to end-use energy such as water heating.

The links between energy and water may seem problematic. However, there are several beneficial outcomes to addressing these resources together. Executing programs and projects that achieve both energy and water savings can support attainment of both program goals. Best use of resources is made when project funding can be used to reduce both energy and water consumption. Including energy savings in water projects will improve the project's economics, producing a shorter payback and a higher return on investment.



Source: River Network (2009)

Figure 5. Embedded energy in the water use cycle, 2005.

Any time energy consumption is reduced, greenhouse gas (GHG) reduction follows, making water projects contributors to climate goals. Lastly, ignoring the water impact of energy or the energy impact of water may provide a solution to one resource problem while exacerbating other resource issues.

Increasing water demands for energy, prompted by population growth and economic development, are poised to collide with a finite water supply already subject to degradation and vulnerable to climate change. How one plans or fails to resolve the competition between water and energy needs will become one of the defining issues of this century (Institute of Electrical and Electronic Engineers 2010).

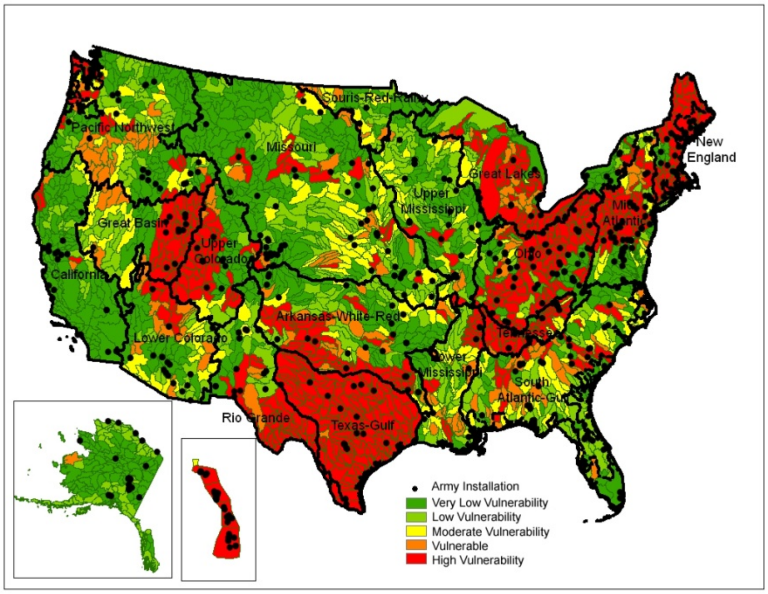
3.5.1 Embedded water

Water is required for the extraction, transformation, and delivery of energy. Some of the end-uses of water include pumping crude oil, removing exhaust gas pollutants, generating steam, flushing away combustion residue of fossil fuels, and thermoelectric cooling. Water is also required for many renewable energy technologies. Hydropower, biofuel feedstock, biofuel production, geothermal power, and concentrating solar power all demand water. Even photovoltaics require some amount of water to clean solar cells. Carbon capture and storage (CCS) technologies also have water needs.

3.5.1.1 Thermoelectric power

Approximately 40% of water use in the United States is for energy production, the number two use behind agriculture (Figure 6). This is largely non-consumptive cooling water for power generation plants. The total consumptive use is 3%. Trends away from once-through cooling and toward closed-loop cooling have reduced the ratio of total water withdrawals to energy produced from 63 gal/kWh (238 m^3/MWh) during 1950 to 23 gal/kWh (87 m^3/MWh) in 2005 (Kenney et al. 2009).

Construction of new power plants has been flat for 20 years, but that is changing. Within the next 10 years, approximately 131,000 megawatts (MW) of new generation resources are planned (NERC 2010). If new power plants are constructed with today's technologies, water use for power generation could more than double by 2030, from 3.3 billion gallons per day (BGD) in 1995 to 7.3 BGD. Water required for power generation may compete with other demands such as agriculture and sanitation. Alterations in water temperature, quality, volume or seasonally available flow, and other factors are important to both human and ecological needs.



Source: Jenicek et al. (2009)

Figure 6. Thermoelectric power water withdrawals, 10-year change

Reduced surface water flows can also affect energy production. The August 2007 drought in the southeastern United States caused several nuclear power plants to reduce their output by up to 50% due to low river levels. Hoover Dam's 17 turbines generating 2080 MW cannot operate at full capacity when the waters of Lake Mead drop. (Lake Mead water levels below 320 m can damage Hoover Dam's turbo generators.) Lake Mead has not been full (372 m) in 10 years due to drought conditions that began in 1999 (IEEE 2010). The Browns Ferry, AL nuclear plant reduced power production in 2007 and 2010 due to insufficient cooling water (UCS 2010). Elevated source water temperatures also affect the operation of nuclear power plants.

3.5.1.2 Oil and gas

Many steps in the fossil fuel extraction, refining, and transportation industries require significant amounts of water. Tar sands, shale gas, hydraulic fracturing, and even coal carry water burdens that need to be considered along with the other environmental effects of these fuel sources. Processing coal into liquid coal or oil is a water intensive process, mirroring the water use required for gasoline. Additional water is used to mine and wash the coal before refining (UCS 2010). Potable water supplies are at further risk from contamination by arsenic, mercury, and lead found in coal plant waste.

The use of water to extract natural gas from shale deposits by injecting large quantities of water to break up deep rock formations has become controversial both for its enormous water demand and for its effect on water quality. In hydraulic fracturing or fracking, water is mixed with sand and chemicals, and blasted at high pressure to release oil and natural gas supplies far below the earth's surface. Technological advances in horizontal drilling and fracking have expanded access to oil and natural gas from shale formations during the past decade. A boom in fracking in Texas has led to accelerated well drilling (TWSJ 2011). Local water districts are adding fracking to a list of pumping restrictions for farmers and small towns (Lee 2011). Fracking poses a threat to public water quality long after development occurs and is not regulated by the Clean Water Act. Documented drinking water contamination due to fracking has occurred in Pennsylvania, Wyoming, Colorado, and Texas (Food and Water Watch 2012). Fracking led to a rash of 12 earthquakes in the Youngstown, OH area between March and December 2011 (Ohio DNR 2012).

3.5.1.3 Renewable energy

The implementation of renewable energy technologies is a way to meet rising energy demand and to allay concerns regarding US dependence on imported oil and the climate impacts of fossil fuel combustion. Solving one resource problem can affect another if all implications are not considered through systems analyses. Examples of conflicts between renewable energy and water are not difficult to find. For example, exploiting a fault line beneath the Salton Sea in California to produce 2300 megawatts of geothermal power requires pumping water from the over allocated Colorado River (IEEE 2010).

The Army shares the DoD renewable energy consumption goal that seeks 25% total renewable energy use by 2025. In addition, the Army seeks to deploy 1 gigawatt of renewable energy projects during this time period. Other pressures can be felt from state targets. California has set the ambitious goal of generating 33% of its electricity from renewable sources by 2020. Some renewable energy options require little, if any water. However, the water requirements should be considered for each renewable energy development.

Globally, many countries are exploring the effect of substituting biofuels for transportation fossil fuels. This includes setting targets by the United States and the European Union. Worldwide, approximately 86% of fresh water is used in agriculture. Increasing biofuel production requires careful consideration to avoid conflicts with the water needed for food and fiber production. Potential effects of increased biofuel production on water quality include pollution from fertilizer runoff and sedimentation from soil erosion. The demand for ethanol-based fuels varies with the price of oil. At the peak price in 2008, many new ethanol production plants were in planning stages. Not all of those plants were constructed following the subsequent drop in the oil price. The water demand of ethanol production varies among crops. Another variable is regional. Local conditions such as soil and climate determine whether crop irrigation is a required. Operating a typical car in the United States (24 mpg) on corn ethanol contains a water footprint of ½ to 20 gal of water per mile (UCS 2010). Production of biofuels from irrigated crops can consume 15 to 30 times more water than it takes to produce a gallon of gasoline (Rogers and Spanger-Siegfried 2010).

Researchers recommend seeking optimal production regions for each crop based on water consumption and climate data. Selective agricultural practices, alternative water sources, and technology innovations can mitigate the effects of biofuel production on water resources. Improved crop varieties and careful location of biofuel production facilities, close to sustainable water resources, are additional considerations (Gerbens-Leenes et al. 2009).

Changing energy sources to minimize GHG emissions should be done in ways to minimize the strain placed on water resources. Renewable energy technologies have varying water footprints. Without careful selection of technologies, solving a problem in one sector will exacerbate a problem in another.

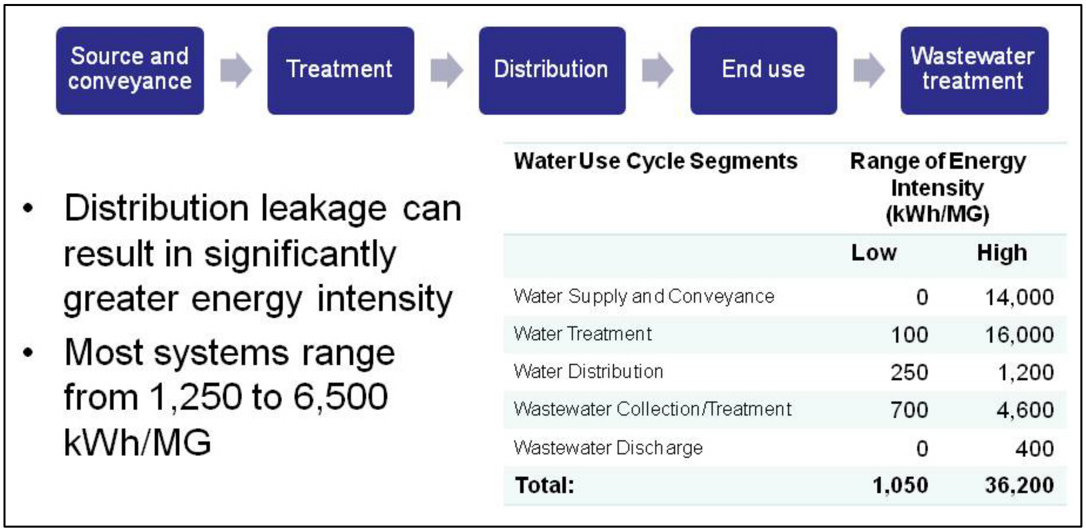
3.5.1.4 Carbon capture and storage

There are also concerns about the water requirements of CCS technologies being employed to address concerns over climate change. CCS technologies capture and store CO_2 deep underground, in oceans, or in mineral form. The heavy water footprint of CCS is derived from the additional water-cooled electricity needed to power the carbon-capture technology. This could be as high as an additional 80% of the water currently used in the electrical sector. Using a wind farm as a power source would reduce that figure to 50% (Moore 2010).

3.5.2 Embedded energy

In the United States, 13% of total energy consumption is water-related. While water uses 521 million MWh of energy each year, water processes are responsible for the production of 290 million metric tons of carbon each year. This is equivalent to emissions of over 62 coal-fired power plants. Several trends are expected to increase the amount of energy embedded in water. Climate change will render many water supplies less than reliable. Water providers will look to remote or alternative sources thereby increasing the energy and carbon cost of water supply. Adoption of higher water treatment standards at the state and Federal level will increase the energy and carbon costs of treating water and wastewater (River Network 2009).

Embedded energy in water can be found throughout the system of water supply, conveyance, treatment, and end-use (Figure 7). There is a range of energy intensities in each segment, however, typical water systems range from 1,250 to 36,200 kWh/million gallons (MG) (River Network 2009).



- Distribution leakage can result in significantly greater energy intensity
- Most systems range from 1,250 to 6,500 kWh/MG

Water Use Cycle Segments	Range of Energy Intensity (kWh/MG)	
	Low	High
Water Supply and Conveyance	0	14,000
Water Treatment	100	16,000
Water Distribution	250	1,200
Wastewater Collection/Treatment	700	4,600
Wastewater Discharge	0	400
Total:	**1,050**	**36,200**

Source: Klein et al. (2005), River Network (2009)

Figure 7. Energy intensity of water cycle segments.

3.5.2.1 Source and conveyance of water

Embedded energy in water supplies relates to the type, quality, and location. The energy required to extract groundwater is related to the pumping depth. In general, groundwater is about 30% more energy intensive than surface water (EPRI 2000). Surface water can also require a great deal of energy if it must be moved over long distances and changes in elevation. Some of the greatest amount of energy is needed to desalinate seawater or brackish groundwater. Seawater desalination is about seven times more energy intensive than groundwater extraction (Cooley and Gleick 2006). Other variables that affect energy are system leakage and pump efficiencies. Table 4 lists the generic range in energy intensities of water supply types.

Table 4. Energy intensity of water supply types.

Source Types	Energy Intensity (kWh/MG)
Surface Water (Gravity Fed)	0
Groundwater	2000
Brackish Groundwater	3200
Desalinated Seawater	13800
Recycled Water	1100
Source: Pacific Institute	

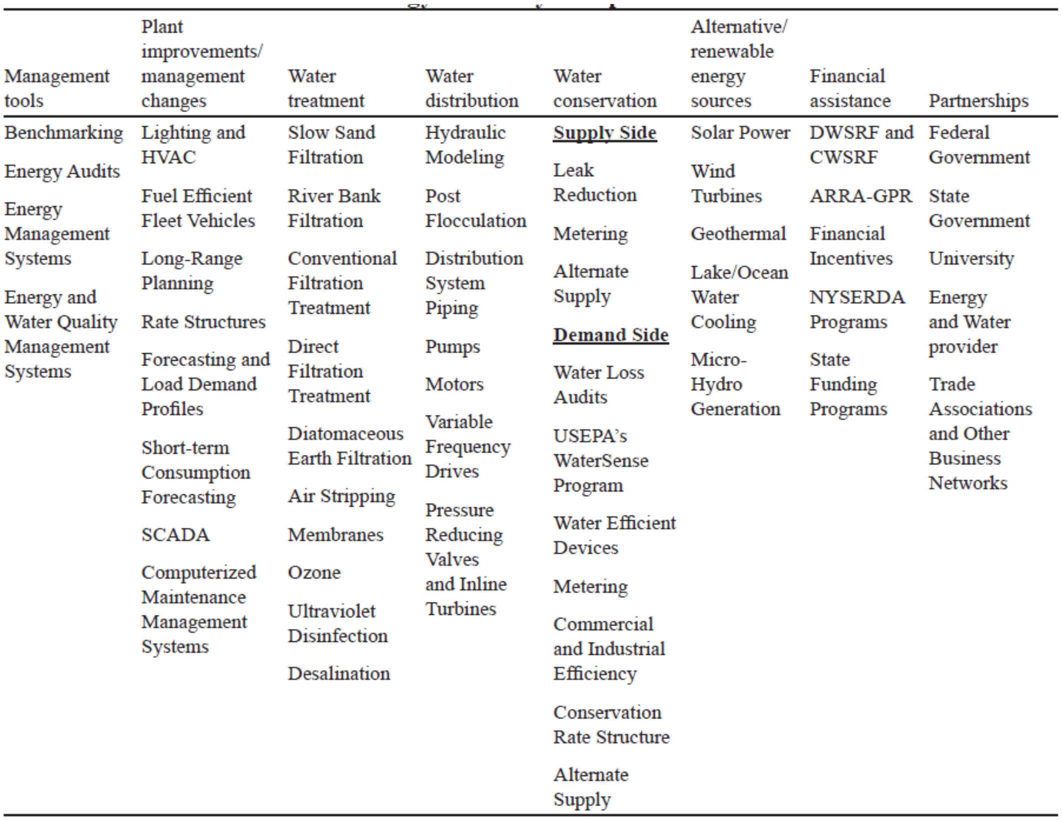
3.5.2.2 Drinking water and wastewater treatment

The USEPA estimates that the bill for operating the nation's wastewater and drinking water systems is about $4 billion each year. Energy demand for drinking water and wastewater services is estimated at 3 to 4% of national energy use although energy demands of individual systems vary by location. This energy excludes end-use energy required to circulate, pressurize, and heat water for use inside households and businesses. In addition, it includes electrical energy only, not natural gas used for some process applications. About 20% of energy use for water is used in treatment plants. Between 10 and 30% savings are achievable by almost all utilities. Some reductions can be achieved with limited investment. Optimizing equipment and operations can provide significant energy reductions. Efforts to improve water efficiency logically lead to energy savings as well as chemicals and treatment supplies (Lelby and Burke 2011, EPRI 2002).

Energy efficient practices can be organized into the following categories: management tools, plant improvements and operational changes, water treatment, water distribution, water conservation, alternative/renewable energy sources, financial assistance, and partnerships (Table 5).

Energy use of wastewater treatment plants depends on the size of plant, type of equipment, and level of treatment. Typical plants range from 1000 to 3000 kWh/MG (River Network 2009). Table 6 lists typical ranges of energy intensity for wastewater treatment plants. There are several trends that are likely to increase the amount of embedded energy in wastewater treatment. As closer, cleaner, and easier sources of water are exploited, there will be a greater reliance on marginal supplies, that is, those that require greater amounts of energy, for example, to transport or treat. New water supplies are likely to include energy intensive alternatives such as desalination, very deep groundwater, or inter-basin transfers. Some expect that regulatory standards will require higher standards for drinking water and wastewater treatment. This is due in part to the presence of emerging contaminants, for example, compounds found in pharmaceuticals and personal care products (PPCPs).

Table 5. Energy efficiency best practices for drinking water systems.



Management tools	Plant improvements/ management changes	Water treatment	Water distribution	Water conservation	Alternative/ renewable energy sources	Financial assistance	Partnerships
Benchmarking Energy Audits Energy Management Systems Energy and Water Quality Management Systems	Lighting and HVAC Fuel Efficient Fleet Vehicles Long-Range Planning Rate Structures Forecasting and Load Demand Profiles Short-term Consumption Forecasting SCADA Computerized Maintenance Management Systems	Slow Sand Filtration River Bank Filtration Conventional Filtration Treatment Direct Filtration Treatment Diatomaceous Earth Filtration Air Stripping Membranes Ozone Ultraviolet Disinfection Desalination	Hydraulic Modeling Post Flocculation Distribution System Piping Pumps Motors Variable Frequency Drives Pressure Reducing Valves and Inline Turbines	**Supply Side** Leak Reduction Metering Alternate Supply **Demand Side** Water Loss Audits USEPA's WaterSense Program Water Efficient Devices Metering Commercial and Industrial Efficiency Conservation Rate Structure Alternate Supply	Solar Power Wind Turbines Geothermal Lake/Ocean Water Cooling Micro-Hydro Generation	DWSRF and CWSRF ARRA-GPR Financial Incentives NYSERDA Programs State Funding Programs	Federal Government State Government University Energy and Water provider Trade Associations and Other Business Networks

Source: Lelby and Burke (2011).

Table 6. Energy intensity of wastewater treatment plants (EPRI 2000).

Treatment Plant Size (million gallons/day, [MGD])	Unit Electricity Consumption (kWh/million gallons)			
	Trickling Filter	Activated Sludge	Advanced Wastewater Treatment	Advanced Waste Water Treatment w/Nitrification
1 MGD	1,811	2,236	2,596	2,951
5 MGD	978	1,369	1,593	1,926
10 MGD	852	1,203	1,408	1,791
20 MGD	750	1,114	1,303	1,676
50 MGD	687	1,051	1,216	1,588
100 MGD	673	1,028	1,188	1,558

3.5.2.3 End-uses of water

Approximately 80% of the energy in water is embedded by the end user. This includes energy to heat, cool, pressurize, or purify water. Army installations have the most potential to reduce embedded energy in the end-uses of water. Nearly 80% of the energy in water is embedded during the end-use segment. Many of the existing FEMP BMPs will reduce embedded energy along with water use (Figure 8). Those BMPs shaded green in the figure offer the greatest opportunity for energy savings.

Energy intensities for commercial end-uses range from 0 to 207,800 kWh/MG (Pacific Institute and Natural Resources Defense Council [NRDC]). Though not included in the referenced study, industrial water uses for chilling, process water use, and plant cleaning are substantial and are worth consideration (Table 7).

Residential water uses carry a range of energy intensities. The intensity varies with the mix of hot and cold water, and the efficiency and cost of the heating source. Army installations have, and should consider these end-uses. Table 8 lists energy intensities of residential end-uses.

Figure 8. FEMP BMPs contribute to energy reduction as well as water savings.

Table 7. Estimated energy intensity of commercial end-use.

Water Use Category	Energy Intensity (kWh/MG)
Kitchen Dishwashers	83,500
Pre-rinse nozzles	21,000
Laundries	35,800
Water-cooled Chillers	207,800
Single-Pass Cooling	0
Landscape Irrigation	0

Source: River Network 2009.

Table 8. Estimated hot water requirements and energy intensity of residential end-use.

Water Use Category	Hot Water	Energy Intensity (kWh/MG)
Bath	78.2%	159,215
Clothes Washers	27.8%	56,600
Dishwasher	100%	203,600
Faucet	72.7%	148,017
Leaks	26.8%	54,565
Shower	73.1%	148,832
Toilet	0%	0
Landscape Irrigation	0%	0
Source: River Network 2009		

3.5.3 How this information will be included in the EW2 Project

Each possible system or equipment in the NZE architecture carries with it a water burden. This water is included in the Net Zero Installation (NZI) Tool to calculate an overall water footprint of the recommended measures.

The water measures being included in the NZI project were evaluated for their energy demand. This information is being captured in the NZI Tool to calculate both water and energy savings achieved by the recommended measures.

The NZE model currently employs EnergyPlus to model each building type included in an installation assessment. EnergyPlus incorporates water requirements as part of its analysis. The water footprint of each energy measure can be considered and used to compare it against or among the set of potential measures.

3.6 Financial considerations

The cost of water at Army installations varies widely. Installations obtain water by purchase from utilities, by self-supply through either surface water permits or groundwater extraction, or by a combination of both. Other water sources may include rainwater capture, condensate collection, and graywater reuse. Army installations may have several water rates depending on the source and level of treatment and will calculate a separate water rate for non-Army reimbursable customers.

It is widely thought that the cost of water will continue to rise as demand continues to grow, especially in regions already water-stressed. Globally, business is investing in water planning to ensure sustained supplies. Fresh water presents business opportunities through a myriad of water market mechanisms for fielding technologies that minimize water use and offer reuse opportunities

3.6.1 Global/national cost of water

There is a wide variation in water costs across the United States, which is reflected in Army water rates. Army installations are subject to the local market for water prices. The large backlog of water system upgrades in the United States is starting to be felt through increasing water rates as projects proceed. Water utilities must defend decisions to increase rates to Public Utility Commissions. Installation water purchase contracts are supported by the Huntsville Division of the Army Corps of Engineers, which can negotiate and participate in rate interventions if requested. Water cost is a lagging indicator and often not subject to price signals. Artificially low water prices do not support quick payback of water efficiency/conservation projects. It can take years to implement projects once rates become high enough to justify the investment.

Although there is not generally a link between the scarcity of water and its cost, water prices are beginning to rise. This is fueled at least in part by the need for infrastructure investments throughout much of the United States. With industrial and agricultural water consumption on the decline since its peak in 1980, system improvements are being largely funded by raising rates for existing customers. Water use has been on the decline for several reasons: loss of industry, increased efficiency in irrigation, decrease in new home construction, migration, and weather, both droughts, which spur conservation; and rains, which reduce the need to irrigate. The rising trend in public supply withdrawals is expected to overcome the decline in other use sectors as will the water needs of an increasing energy demand.

The American Water Works Association (AWWA) documents a 13% increase in cost for the average residential water customer from 2008 to 2010, or 6.5% annually. This compares to the consumer price index (CPI) rate *decrease* of 0.91%, or 0.46% annually. The average utility rate change was an increase of 15.9%, or 7.9% annually. Of the utilities surveyed, 12 utilities decreased their rates, 17 utilities maintained their rates and 152 utilities increased their rates between 2008 and 2010. The average calculated rate was $3.68 per thousand gallons ($0.97/m^3) based on the survey of 308 water utilities. Water charges reflected in the results of this survey are highest in the Northeast and lowest in the Midwest (AWWA 2011).

One factor that is expected to drive the rate of water cost increase is the need for massive infrastructure improvements, both of drinking water and wastewater systems. The latest predictions (March 2012) forecast cost increases of at least $1 trillion over the next 25 years to maintain existing levels of water service. Infrastructure condition varies regionally. These improvements are expected to triple household water bills in some communities (AWWA 2012).

3.6.2 Cost of water to the Army

The cost of water to the Army varies regionally and also by source. Army installations calculate the cost of self-supplied water annually based on operations and maintenance (O&M) costs. AR 420-41, *Acquisition and Sale of Utilities*, addresses billing of utilities to reimbursable customers. Paragraph 3-3 of AR 420-41 discusses establishing utility rates.

Rates for Federal government activities and family housing will equal the cost to the Government, including O&M costs plus transmission losses. All other customers located on an installation will be charged the total cost to the Government including transmission losses, O&M costs, capital charges, and administrative overhead. Customers located off-installation will be charged the local prevailing rate of the closest utility company. However, the rate will not be less than the total cost to the Government including transmission losses, O&M costs, capital charges, and administrative overhead.

DA installations consumed over 129 million m^3 (34.3 billion gallons) of potable water at a cost of $84.4M in FY13 (AEWRS 2014). This is an average unit cost of $2.46/Kgal. Although the cost on average is quite low, installation water rates vary regionally and sometimes seasonally. Higher rates are found in California and in the National Capital Region, where some seasonal rates apply. Table 9 lists a range of reported installation water costs for FY13 (AEWRS 2013).

Table 9. Installation water costs for the 3d quarter FY12.

Installation	Cost of Water* $/Kgal
Aberdeen Proving Ground	$9.10
Fort Belvoir	$3.54
Fort Benning	$10.36
Fort Bliss	$1.32
Fort Bragg	$1.60
Fort Buchanan	$15.62
Fort Carson	$3.82
Fort Detrick	$5.42
Fort Hood	$0.80
Fort Irwin	$0[2]
Fort Leonard Wood	1.38**

* Source: AEWRS 2012

**Fort Leonard Wood water rate is the rate for other agencies "B"

Army installations report both water consumption and water cost to the AEWRS. The AEWRS database is used by ACSIM to assess installation progress toward water reduction goals and to report upward to DoD on overall Army water use and cost. The rates at many installations reflect only the cost to pump and treat the water to potable standards if the installations are self-supplied, usually from groundwater. Even so, water cost is not uniformly calculated or entered into AEWRS.

3.6.3 Water pricing and Net Zero Installations

The pricing of water directly affects cost effectiveness of water efficiency and conservation projects. Indirectly, a low price for water devalues its preciousness and encourages disregard for the importance of a comprehensive water planning program. The NZI Tool will incorporate the full price of water in LCC assessments wherever possible.

3.7 Water rights

The property right to water can be a constraint for installations planning for net zero energy, water, and waste. Insufficient quantities of water can inhibit day-to-day operations and limit the amount and types of energy

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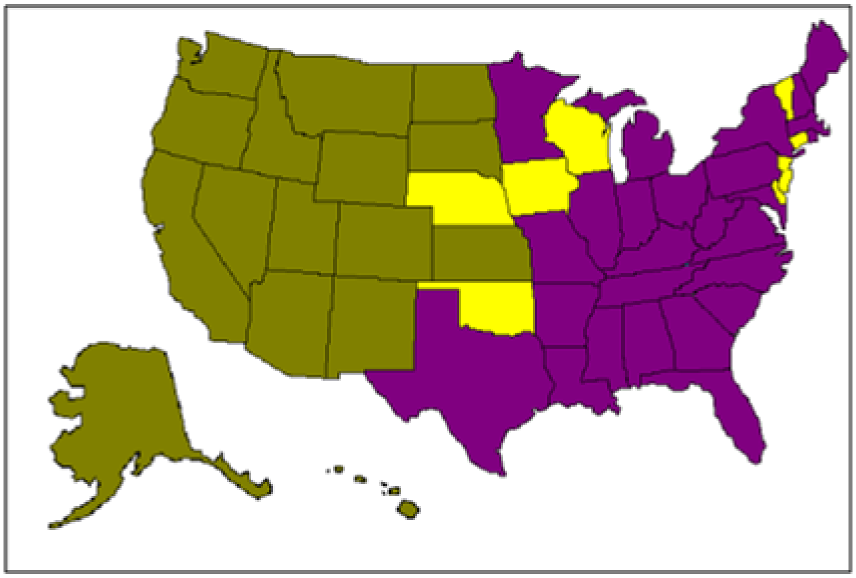
[2] There is no water cost reported for Fort Irwin in the AEWRS system.

generated on post. In addition, water rights may affect implementation of some measures such as graywater reuse.

Allocation of water in the United States is determined on the state level and is often based on decisions made during times of more plentiful supply and lower demand. While regulated riparian and prior appropriation are the basic surface water doctrines, they should be viewed as templates from which each state developed its own laws. Figure 9 shows the state surface water doctrines; riparian is predominant in the east where water was historically abundant (shown as purple). The prior appropriation doctrine dominates in the western states (shown as green). A few state have a hybrid approach to regulating water rights (shown as yellow).

Disputes over water are becoming all too common in the United States. Over 95% of available freshwater resources in the United States cross state boundaries and are affected by compacts. Although there are 39 interstate freshwater compacts in the United States, some areas, such as a part of the Mississippi River Basin, do not have compacts in place (Hall 2010). Many existing compacts base water allocation on an overly optimistic forecast of water availability, particularly given regional warming trends. Water rights also ignore the hydrologic connection between surface and subsurface water.



Source: ASDWA (2009)

Figure 9. Water rights in the United States.

3.7.1 Riparian water rights

The riparian doctrine, with its origin in English common law, allocates water among those who own land adjacent to a body of water. This system dominates in the eastern United States and grants the right to make reasonable use of water. In addition to the use of water for domestic purposes, riparian rights include access for swimming, boating, and fishing; the right to erect structures; the right to wharf out to navigable waters; and the right to accretions caused by water level fluctuations (ASDWA 2009). The use of water by a non-riparian land owner is illegal.

3.7.2 Prior appropriation doctrine

Water rights in the western United States generally follow the prior appropriation doctrine. This doctrine was derived from Spanish law and treats water as a resource separate from land that can be sold like other property. This doctrine is commonly referred to as first in time, first in right. In states where this doctrine is recognized, the oldest or most senior water rights belong to the first person to beneficially use water regularly from a particular source. They retain the right of continued use of that quantity of water for that purpose subject to availability. Each water right has a yearly allocation and appropriation date. During times of insufficient supply, those holding lower water rights might not receive their allocation. The appropriation doctrine typically requires the holders to exercise their full appropriations or risk losing them under the doctrine of abandonment. Adjudications may or may not have been performed that explicitly assign specific volumes of water to each rights holder.

3.7.3 Groundwater rights

Groundwater doctrine is also established on the state level. Mixed doctrine states have typically developed different regulations for percolating groundwater and underground streams. There are five legal doctrines that govern conflict between competing groundwater users: (1) the rule of absolute ownership, (2) the reasonable use rule, (3) the correlative rights rule, (4) prior appropriation, and (5) the restatement of torts rule (Table 10).

Table 10. State water policy and administering agencies.

State	Surface Water Right System	Groundwater Right System	Permit Required		Court Approval		Buying/ Selling	Disputes	Administering Agency	Number of Compacts or Treaties
			Surface Water	Groundwater	Surface Water	Groundwater				
Alabama	R	U	No	No	No	No	No	Gc	None	0
Alaska	A	A	Yes	Yes	No	No	Yes	Wa, Gc	Dept. of Natural Resources	0
Arizona	A	Mixed	Yes	Yes	No	No	Yes	Wa, Gc	Dept. of Water Resources	3
Arkansas	R	U	No	No	No	No	Yes	Gc	None	0
California	Mixed	A	Yes	No	No	No	Yes	Gc	Water Resources Control Board	4
Colorado	A	A	No	Yes	No	No	Yes	Sc	Div. of Water Resources	12
Connecticut	R	O	Yes	Yes	No	No	No	Gc	Dept. of Environmental Protection	2
Delaware	R	U	Yes	Yes	No	No	No	Wa, Gc	Dept. of Natural Resources	4
Florida	Mixed	U	Yes	Yes	No	No	No	Wa	Regional Water Management Districts	0
Georgia	R	Mixed	Yes	Yes	No	No	No	Gc	Dept. of Natural Resources	0
Hawaii	Mixed	Mixed	No	Yes	No	No	No	Wa, Sc	State Water Commission	0
Idaho	A	A	Yes	Yes	No	No	No	Gc	Dept. of Natural Resources	2
Illinois	R	O	No	No	No	No	No	Gc	Div. of Water Resources	1
Indiana	R	Mixed	No	No	Yes	No	No	Wa, Gc	Dept. of Natural Resources	1
Iowa	Mixed	U	Yes	Yes	No	No	No	Wa, Gc	Dept. of Natural Resources	0
Kansas	A	U	Yes	Yes	No	No	No	Gc	Div. of Water Resources	4
Kentucky	R	Mixed	Yes	Yes	No	No	No	Wa, Gc	Div. of Water	2
Louisiana	R	U	No	No	No	No	No	Gc	None	2
Maine	R	Mixed	No	No	No	No	No	Sc	None	1
Maryland	R	U	Yes	Yes	No	No	No	Wa, Gc	Water Resources Administration	3
Massachusetts	R	O	Yes	Yes	No	No	No	Gc	Div. of Water Supply	0
Michigan	R	U	No	No	No	No	No	Gc	Dept. of Natural Resources	2
Minnesota	R	U	Yes	Yes	No	No	No	Wa, Gc	Dept. of Natural Resources	2
Mississippi	Mixed	Mixed	Yes	Yes	No	No	No	Wa, Gc	Dept. of Natural Resources	0
Missouri	R	U	No	No	No	No	No	Gc	None	0
Montana	A	A	Yes	Yes	No	No	No	Wa	Water Resources Div.	4

State	Surface Water Right System	Groundwater Right System	Permit Required		Court Approval		Buying/ Selling	Disputes	Administering Agency	Number of Compacts or Treaties
			Surface Water	Groundwater	Surface Water	Groundwater				
Nebraska	A	A	Yes	No	No	No	Yes	Wa, Sc	Dept. of Water Resources	5
Nevada	A	A	Yes	Yes	No	No	Yes	Wa, Gc	Div. of Water Resources	1
New Hampshire	R	U	No	No	No	No	Yes	Gc	Water Resource Div.	0
New Jersey	R	U	Yes	Yes	No	No	No	Wa, Gc	Div. of Water Resources	1
New Mexico	A	A	Yes	Yes	No	No	Yes	Gc	State Engineer's Office	11
New York	R	U	Yes	Yes	No	No	Yes	Gc	Dept. of Environmental Conservation	4
North Carolina	R	U	Yes	Yes	No	No	Yes	Gc	Div. of Water Resources	0
North Dakota	A	A	Yes	Yes	No	No	Yes	Gc	State Water Commission	2
Ohio	R	U	Yes	Yes	No	No	No	Gc	Dept. of Natural Resources	4
Oklahoma	A	U	Yes	Yes	No	No	Yes	Wa, Gc	Water Resources Board	3
Oregon	A	A	Yes	Yes	Yes	Yes	Yes	Wa, Sc	Dept. of Natural Resources	2
Pennsylvania	R	U	Yes	No	No	No	No	Gc	Dept. of Environmental Resources	7
Rhode Island	R	U	No	No	No	No	No	Gc	Water Resources Board	0
South Carolina	R	Mixed	Yes	Yes	No	No	No	Gc	Water Resources Commission	0
South Dakota	A	A	Yes	Yes	No	No	Yes	Wa, Gc	Dept. of Water And Natural Resources	1
Tennessee	R	U	No	No	No	No	Yes	Gc	Dept. of Health And Environment	2
Texas	A	A	Yes	No	No	No	Yes	Wa, Gc	State Water Commission	8
Utah	A	A	Yes	Yes	No	No	Yes	Wa, Gc, Sc	Dept. of Natural Resources	4
Vermont	R	Mixed	No	No	No	No	Yes	Gc	None	2
Virginia	R	U	No	Yes	No	No	No	Gc	State Water Control Board	4
Washington	A	A	Yes	Yes	No	No	Yes	Wa, Gc	Dept. of Ecology	2
West Virginia	R	U	No	No	No	No	Yes	Gc	Div. of Natural Resources	3
Wisconsin	R	U	Yes	Yes	No	No	Yes	Wa, Gc	Dept. of Natural Resources	5
Wyoming	A	A	Yes	Yes	No	No	Yes	Gc	State Engineer's Office	10

A = Appropriation; R = Riparian

Source: Wright 1990

A = Appropriation; O = Absolute Ownership; U = Reasonable Use

Wa = Water Agency; Gc = General Courts; Sc = Special Courts

The absolute ownership rule allows landowners to pump groundwater under their land to use anywhere without any responsibility to adjacent owners (10 states, all eastern except Texas). The reasonable use rule is the same except that waste is prohibited and water must be used on the overlying land unless using it elsewhere does not harm other overlying landowners (Arizona and about a dozen eastern states). The correlative rights rule allocates water among overlying landowners by determining the most beneficial use and degree (California and some eastern states). In prior appropriation states the permitting process is administered by a state agency for some or all of the groundwater in the state (most states in the west; exceptions are Texas and Nebraska). The restatement of torts rule allows an overlying landowner to use water on- or off-site as long as it does not unreasonably interfere with a neighbor's use through well interference, pumping more than one's share, and interference with stream and lake levels that are dependent on groundwater (Wisconsin).

3.7.4 Federal water rights

Historic water rights are limiting factors for some installations. Army installations may have Federal reserved water rights as well as other kids of water rights. Federal reserved water rights holds that when the United States sets aside or reserves public land for uses such as Indian reservations, military reservations, national parks, forests, or monuments, it also implicitly reserves sufficient water to satisfy the purpose for which the reservation was created (Federal Reserved Water Rights Doctrine, USDOJ 2013). In terms of Army guidance on water rights, a DA memorandum was issued in 1995, in response to Army Science Board recommendations, to "set forth instructions on how water rights information should be documented and protected at Army installations" (Johnson and Stockdale 1995). The Army is currently updating the 1995 policy.

3.7.5 A recent history of Federal water rights

Army installation water rights are poorly understood. Federally recognized tribes struggle with the same water issues as the Army. For example, the Choctaw and Chickasaw tribes of southeastern Oklahoma are fighting for state recognition of their Federal reserved rights to the waters of Sardis Lake, which date from 175 years ago. The reservation land has been divided among individual tribe members, but the tribe at large is looking for quantification of water rights that belonged to the original land (Barringer 2011).

3.7.6 Water rights and NZIs

Water rights can be a constraint for installations for several reasons. First, installations require water to perform their mission. There is no substitute for water and the capability to reach absolute net zero water does not exist in the open water systems where, minimally, evaporation removes water. The nature of water rights for each state will be included in the NZI model (**Error! Not a valid bookmark self-reference.**). However, note that to know the water rights for an installation requires considerable background research if in a prior appropriation state. Secondly, provisions in some water statutes, compacts, and agreements serves to limit the some water use For example, in some states it is illegal to capture rainwater if one does not possess the legal right to the water. Reclamation of wastewater can also be prohibited due to water rights.

The NZIEW2 modeling system will include water rights as a modeling constraint. For the purpose of the beta tool, the following table details installation-specific information related to water supply, demand, cost, and related water rights, laws and compacts for the eight net zero water installations.

Table 11. Installation water sources.

	Water Data			Water Rights	
		2011 Water Cost ($/KGal)			
Net Zero Water Installation	**2011 Water Use (MGal)**	**AEWRS**	**Point of Contact**	**Source**	**Laws, Compacts**
Aberdeen Proving Ground	687.8	$3.96	$1.21/$7.15	EA-Winters Run AA-Privatized (Deer Creek, Aberdeen & Harford Co. wells)	SRBC†
Fort Bliss	2,205	$1.34	$1.00	Own wells & EPWU*	Rio Grande Compact
Fort Buchanan	70.7	$14.11	$3.50/m^3 $15.91/KGal	Purchase: PRASA	N/A
Fort Carson	835.2	$2.75	$3-5/KGal $8.13–CSU**	Purchase: Colo Spgs Util	Law of the River
JBLM	1,627.9	$1.29	N/A	Own wells	
Fort Riley	580.5	N/A	$1.47	Own wells	
Camp Rilea	135.8	$0.83	N/A	Own wells & reuse	Prior Appropriations
Tobyhanna AD	73	N/A	$3.00	Own wells	DRBC‡

Source: AEWRS 2012 and NZW POCs

* El Paso Water Utilities

**Colorado Springs Utilities (CSU)

†Susquehanna River Basin Commission

‡Delaware River Basin Commission

4 Planning for Net Zero Water Installations

4.1 Planning on Army installations

4.1.1 Master planning

Army installation master planning is based on the Real Property Master Plan (RPMP), which consists of five major components: (1) the Vision Plan, (2) Long Range Component (LRC), (3) Installation Design Guide (IDG), (4) Capital Investment Strategy (CIS), and (5) the Real Property Master Plan Digest (RPMPD). The major policy driving the master planning process is AR 210-20 (HQDA 2005), although the regulation is currently in flux as the guidance transitions toward a more flexible form-based approach.

The Vision Plan provides a broad context for the entire scope of the master plan. It is a statement of intent for the general goals of the master plan and the resulting physical form of the installation. It is meant to look ahead to the point that cannot be completely anticipated. Missions, activities, and technologies change over time. Therefore, the vision cannot be tied directly to any of these driving factors. There is a difference between the installation's mission and the installation's vision. A vision should literally be something one can visualized. It is difficult to know what a world class facility would look like, but quite easy to see pedestrian oriented or architecturally compatible (Gillem 2012).

The LRC provides a more detailed set of plans meant to drive development of land and facilities on the installation, typically with a projected timeframe of 20-50 years. The LRC contains the Future Development Plan, focused on citing of facilities so that they do not conflict spatially in the CIS; Area Development Plans, focused on providing details on the form, function; and land use for each District and the Installation Development Plan, providing installation-wide locations of current and planned networks such as streets, sidewalks, parks, open space, and primary utilities (HQUSACE 2011).

The IDG lays out the specific design guidelines for installation development. It spells out the basic physical form for new and retrofit projects, both site design and more specific architectural details. The IDG is a guide for all individuals involved in decision making, design, construction, and/or maintenance of facilities on the installation. The primary users include the Senior Mission Commander, Garrison Commander and personnel, installation facility planning and design personnel, installation facility maintenance personnel, USACE project managers, design and construction personnel, consulting planners, architects, engineers, and landscape architects (HQUSACE 2011).

In the past, the IDG has been based primarily on common Army-wide standards with some customization at each installation. Since development of the UFC, the IDG has gained greater attention as installations begin to transition toward the *UFC Installation Master Planning* document. The UFC was developed between the Army, Navy, Air Force, and Marine Corps to create a consistent approach to planning throughout the Office of the Secretary of Defense (OSD). It was published 15 may 2012. The document outlines Master Planning values and strategies that are consistent with philosophies such as New Urbanism, Smart Growth, and Sustainable Urbanism, which promote compact, infill, and mixed use development on a human scale to encourage both pedestrian access and the efficiency of the overall built environment. Furthermore, the UFC-based process dictates that the IDG play a central role in the preparation of plans for new construction (Military Construction [MILCON]/MCA), renovations, maintenance, and repair projects (HQUSACE 2011). The form-based criteria and design guidance approach contained in the UFC Master Planning document will be reflected in the currently ongoing update to AR 420-1, which has absorbed the previously controlling AR 210-20 as the primary regulation for installation master planning (Zekert 2012).

Implementation of the UFC will effect multiple areas across installations as well as the way HQDA uses master planning to shape installation activities. . The CIS will become much more important to HQDA and will explicitly include major restoration and modernization (R&M) projects. Furthermore, HQDA will make programming decisions based partially on Real Property Planning and Analysis System (RPLANS) and Installation Status Report (ISR) systems and will require more justification for new construction. Of particular note, plan-based programming is a major tenet of the UFC Installation Master Planning. As a result of actions at the HQDA level, master planning will no longer be just an installation exercise. There will be more feedback and interaction between the installations and the headquarters level where programming decisions are made (Haught 2012).

The CIS works to match current demands with the installation's anticipated needs in the long term. The product is a prioritized list of real property actions on a time line that provides details about how short- and long-term needs will be addressed. The development of the CIS should be a collaborative process, in the same manner that the installation owns the master Plan and so too they should own the CIS. If CIS development includes across-the-board collaboration between garrison leadership and those throughout the Directorate of Public Works (DPW) (Master Planning, Business Operations), it will not be necessary for any group to sell the plan because everyone will already be behind it (Haught 2012). In the past, the CIS has been based almost entirely on the expectation of MILCON projects, a pattern that will not be carried into the future as the funding for MILCON projects drastically decreases (Carroll 2012).

The RPMPD functions as an executive summary of the RPMP. It describes the overall thrust of the document and the goals contained in the various components and plans.

The Real Property Master Planning Technical Manual (MPTM) currently stands as the primary technical guidance for the RPMP planning process. The document guides a user through the entire process in great detail from the visioning process to the many issues that might be encountered along the way. Due to its length and detail, the MPTM is best used a reference document (HQUSACE 2011). With the adoption of the UFC and its tenets into Army regulations, the MPTM will become somewhat obsolete in the future (Zekert 2012).

Each installation has a strategic planning cell primarily focused on strategic planning considerations, including stationing, mission, and business operations, over a 4–8 year time horizon. Included in this cell is the Installation Planning Board (IPB), whose responsibilities include the strategic planning of the overall installation (Zekert 2012).

The Real Property Planning Board (RPPB) is a subcommittee of the IPB and acts as the installation's "city planning council to ensure orderly development and management of installation real property …" (AR 210-20). The RPPB exerts a large amount of influence over planning decisions, since it holds the responsibility for overseeing and approving all actions related to real property or master planning. The Garrison Commander chairs the board. The remaining board members are drawn from the "chief of each principle and special staff section of the garrison," especially the Chief of DPW, and the commander of each other major unit or independent activity on base (AR 210-20). In addition, the Garrison Commander may assign various others to non-voting positions and may invite a variety of guests to attend meetings. The UFC, on which updates to Army master planning regulations will be based, specifies that the RPPB will continue to play an important role in the preparation and approval of master plans. The power of the RPPB and the influence wielded by the Garrison Commander over the board illustrates the vital importance of support for master planning by the commander and senior leadership of the installation.

Most often, the master planning and operational planning personnel work on programming that originates from separate funding sources. Master planning departments have been involved primarily with MCA projects in which stationing requirements drive project selection and funding is pursued through the completion of DoD Form 1391s submitted up the hierarchy to Installation Management Command (IMCOM) and ultimately the ACSIM who then designates funding for approved projects. USACE then acts as a construction agent and manages the project from design through completion. Implementation is either taken on in-house at USACE or contracted out to an architecture and engineering firm (McVay 2012).

As described in greater detail later, ACSIM is the primary decision making organization for programming funds; it prepares a Future Years Development Plan (FYDP) that identifies projects submitted by installations for funding. ACSIM provides the approved/funded project list to the installations, which then begin the work of executing those funds. At the time of this writing, ACSIM is changing the process of project approval/funds allocation to ensure greater adherence to previous planning efforts. Once the change is in place, ACSIM will not program funds unless the project has gone through the installation master planning process. This policy shift is a large step in the right direction as it will ensure that loopholes in the process are closed and projects will not be able to slip through without considerable guidance from the master plan. This is a shift toward invigorating the relationship between programming and planning, in which programming is the execution of a plan (Haught 2012).

Projects with an execution cost of $750,000 or less are usually funded and managed through the Sustainment, Restoration, and Modernization (SRM) program. Projects requiring more than $750,000 most often fall under the MILCON or MCA programs and consequently must go through the DD 1391 process (McVay 2012). Accordingly, ACSIM is working to put language in the legislation that would make it easier to use SRM rather than MILCON funds (Haught 2012).

4.1.2 Operational planning

Operational Planning is a term used in this chapter to describe one of the two principal types of planning that occur within the DPW. It differs from master planning temporally. Operational planning is focused on the short term and is often associated with the maintenance or short-term improvement of existing systems. Also, as opposed to master planning which operates in a specific department, operational planning is decentralized and performed across the DPW. For example, at JBLM, a majority of the operational planning is completed in the Business Operation and Integration Division (BOID) where systems managers for water, energy, and solid waste monitor their respective systems and continually update plans based on current and projected needs.

It is important to consider the difference between planning and programming. Planning refers to the act of charting out a general course for the future built environment at a broad spatial and temporal scale. Much of what is deemed planning on installations is better described as programming, the process of defining specific buildings or projects and the pursuit of funding for those projects. The 1 to N list, SRM list, and other prioritization documents fall under programming.

For example, in the recent development of installation Area Development Plans (ADPs), Fort Hunter Liggett planned the location and use for various buildings of future unprogrammed construction to identify potential capacity and to make a claim on vacant real estate so any future development will occur in the best, most efficient way. This planning precedes any programming. If future stationing decisions site a new battalion at Fort Hunter Liggett, ad hoc programming will not occur (Skinner 2012).

4.1.3 Project programming process

At the installation level, the prioritization of all projects (MILCON, MCA, SRM.) occurs often and requires input from a variety of sources and decision makers. It is a continuous process based on the evaluation of needs and funding decisions. Stationing decisions are primarily based on the Base Realignment and Closure (BRAC) program, Congressional Adds to the annual Pentagon Spending Bill, and more local decisions using Unspecified Minor Military Construction, Army (UMMCA) projects. UMMCA projects are those with a planned cost under $1.5 million and include an expedited time frame, but they are not listed on the FYDP passed down from ACSIM. The process works faster than the typical MCA project, but has a very similar set of required meetings (McVay 2012).

The primary documents for project prioritization at an installation are the 1- to N-lists, which are prioritized project lists to be completed. There are several versions of the list within the DPW. At installations, the BOID provides a variety of services. Most important to this report, the BOID acts as the operational planning arm Public Works (Appendix B). At JBLM, BOID systems' managers for water, waste, and energy, , compose a list of needs for their relevant systems that are eventually merged to become the Public Works plan, which is unrelated to any Master Planning lists (Figure 10) This plan directs SRM funds for the current and upcoming year (2 years total). The 2-year plan is consistently updated because once it is complete, installation personnel begin to execute the first year of the plan. The Garrison Commander reviews and reorganizes that plan twice annually. Until this review is done, the list is not owned by the installation. The first annual review results in marching orders for the DPW, which consist of a prioritized application of funds to projects. The marching orders consist of a spreadsheet developed through cooperation between BOID and the Garrison Headquarters. The commander's final review in a given fiscal year is parsed into an "unfinanced requirements list" (UFR) from which the commander directs funding as SRM money becomes available from other unfinished work (Fogg 2012).

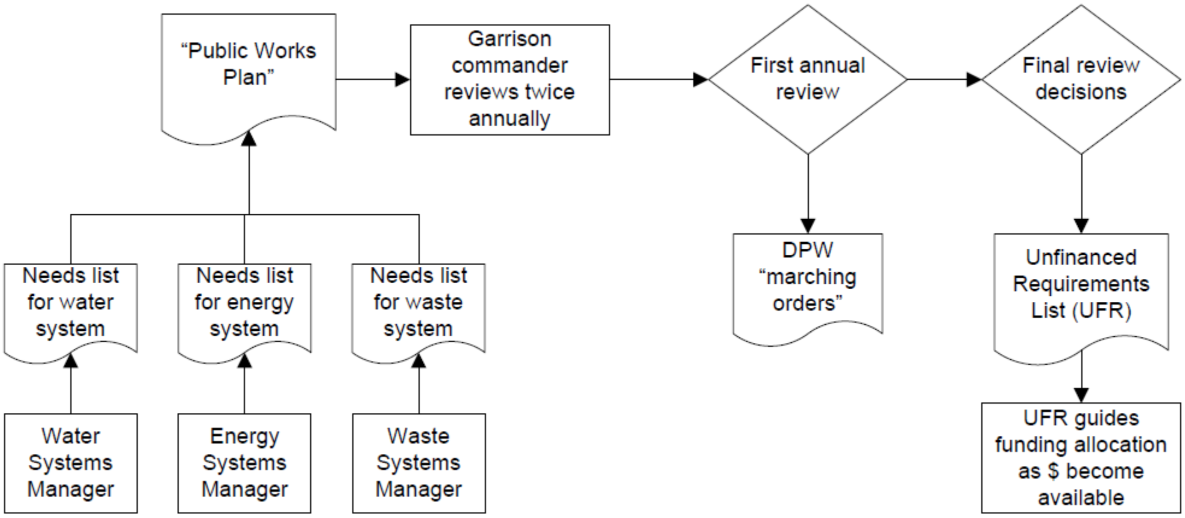


Figure 10. BOID prioritization process.

The RPMP acts to guide the overall process, but often the RPMP does not function entirely as intended. The ADPs and the IDG are often the most effective tools in the RPMP to shape development. The master plan does not necessarily determine *what* gets built, but it determines *where* and *how* facilities are built.

HQDA defines the Army-wide design criteria for installations. The USACE then takes those criteria and creates standard designs for Army construction through its Centers of Standardization (COS), which conform to the square footage requirements for a multitude of building types set by HQDA. An installation or USACE District does have some opportunity for adaptation of the standard designs, but traditionally neither has been given much leeway to conform to local needs or desires. The USACE also works as a contracting agent for MCA. ACSIM establishes the design criteria and the USACE consequently produces standard building designs based on those criteria. In some instances, installations or USACE districts use the standard designs with little alteration. Those installations/districts that want to build something different are able to adapt the standardized designs somewhat, but there is not a great deal of leeway for localities to change things according to their needs/desires. The Secretary of the Army is working to make it easier for installations to obtain waivers from the criteria to provide more opportunities for adaptability at individual installations (Haught 2012).

The 1 to N lists also play an important role in the development of high-level Army FYDP. The local 1-to-N" list is submitted through the chain of command, IMCOM to the office of the ACSIM that creates its FYDP and the President's Budget Estimate Plan. There are multiple levels of the FYDP reaching from ACSIM-wide down to the individual installation level. The FYDP passed down to an installation informs the top priorities of the "1 -to-N" list, which consequently feeds back into the FYDP process the next year.

ACSIM approves the Army FYDP, which then passes through the Army's major commands and IMCOM until it has worked its way down to each installation. The installation then works on the projects from their 1-to-N list that are included in the FYDP. In the project implementation process, the USACE District supporting an installation dictates a project code that determines whether that specific project will require planning charrettes, a detailed Project Development Report (PDR) or in some cases, a pared down version of the PDR with few details (PDR lite). A full PDR is equivalent to a 65% design and can still make changes to the DD1391 (McVay 2012). (Section 4.1.3.2 explains the DD1391 process more.)

Installations use a computer program called RPLANS, which allows master planners to quickly determine the type and size of facilities that are required/allowed by the Army. The primary application of RPLANS is to balance the Tabulation of Existing and Required Facilities (TAB), a spreadsheet of buildings defined by category code used to understand installations' real property excess and deficits. The TAB is meant to assist in managing changes in the most efficient manner possible by identifying the positive and negative effects of significant changes. It involves analyzing asset data, the Force and criteria.

Army standard guidelines provide the number of square feet suitable for each individual building type and use. Through the presence of ADPs and the IDG, master planning sites a project from which point potential funding sources are identified based on funding level required or project type.

4.1.3.1 The role of the USACE

Any approved funding flows directly to the USACE District acting as construction agent. As the manager of the project, USACE chooses to either manage the project in-house, complete the work through a contractor, or a mixture of the two (McVay 2012). The DPW often possesses its own engineering services divisions that provide in-house engineers for design of some projects. These projects are typically on the smaller scale, such as repairing a water line by replacement. When a project becomes complicated, DPW uses consultants for design work. The local USACE District is used for design, using their own engineers or consultants, and as project managers when workload or project size requires. The USACE provides technical expertise, but it also has contracting relationships that can often work better than the DPW contract mechanisms. There are two ways that a project would use USACE. The first is through the large MCA projects covered throughout Section 4.2.The second would occur if the local work load for SRM project requirements (for engineering, management, contracts) were unable to be fulfilled locally (Fogg 2012).

There are two procedures through which the programming of an MCA project might occur (Figure 11). For perspective of how the procedures fit in the larger MCA programming process (Appendix C). Installation planners can pursue a design-bid-build project, which is designed in-house by USACE using their own engineers or a design-build, and for which a Request for Proposal (RFP) is advertised. The winning contractor completes both the design of the project and the actual construction. There is an existing perception that the design-build process saves time, but it carries the complication that every piece of the project has to be defined ahead of time because the contract cannot be changed after it is awarded. The design-bid-build process allows the installation/USACE District to make changes as the design progresses (McVay 2012).

DoD uses the DD Form 1391 to submit requirements and justification to Congress to support funding requests for military construction in accordance with AR 415-15, Military Construction, Army Program Development. The 1391 can be submitted for a large variety of projects, the most significant of which at JBLM is MCA. This is the primary programming document for MILCON project and the preparation of necessary components of 1391s comprises an important function of DPW and master planning (Rubicon Planning 2012, McVay 2012) (Appendix C).

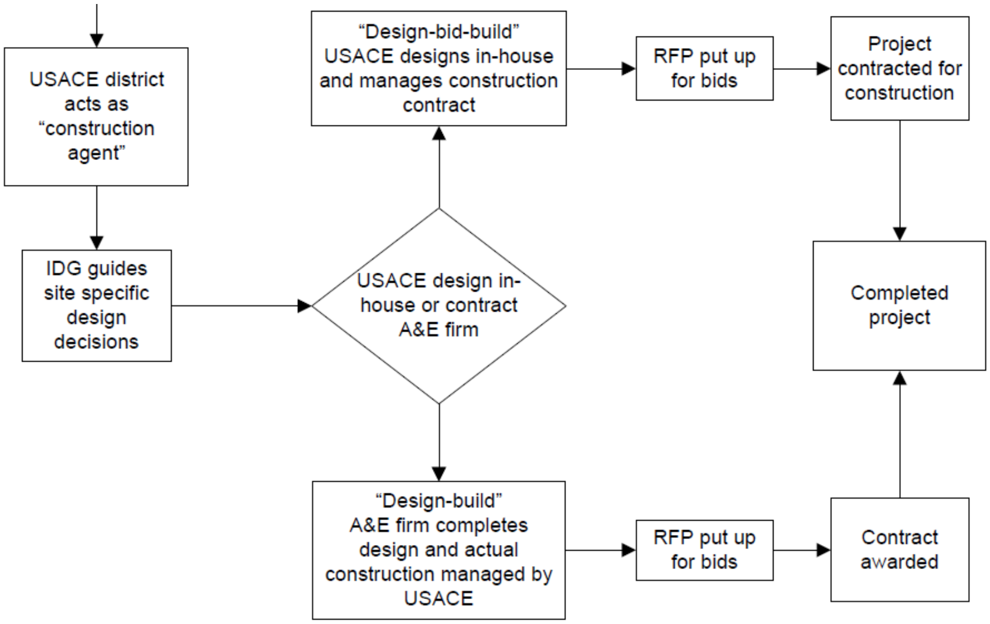


Figure 11. Design and build process.

4.1.3.2 DD 1391 process

Charrettes are intended as a key component of the DD1391 process (Figure 12). In fact, all MCA projects are required to have a programming charrette and design charrette completed at the beginning and later stages of project development respectively. The planning community has actually misnamed the programming charrette: programming occurs when dealing with a single project or proposal; planning occurs during the development of ADPs and other master planning guidance (Zekert 2012). The programming charrette provides a conceptual design and the design charrette is completed later in the process once it is determined whether the project will be completed as a design-bid-build or a design-build (McVay 2012).

For the initial planning charrette, installation personnel must prepare for an on-site meeting by gathering all necessary data: spatial/Geographic Information System (GIS) data, prior site approvals, related regulations, design guides. The on-site meeting requires site visits and the development of consensus and validation between the various stakeholders. In general, attendees of the on-site meetings vary depending on the buy-in and enthusiasm of the leadership at a given installation and the associated USACE District. Projects are generated from the RPMP, which is a result of a collaborative process involving the entire installation community.

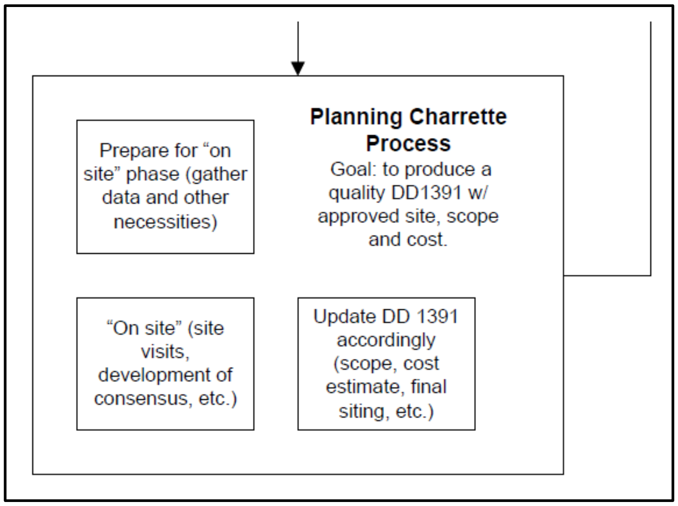


Figure 12. Planning charrette process.

Therefore, that same community would be involved in the programming process. A well-attended meeting would include the presence of the senior installation leadership (Garrison Commander, Senior Mission Commander), members of the RPPB, Director of Public Works, the Anti-Terrorism/Force Protection (AT/FP) officer, environmental and sustainability representatives from master planning, BOID, and strategic planning areas such as natural and historic preservation. It is important that the charrette process be carried out conscientiously because there is no single formula that can be applied everywhere. A small SRM project likely will not warrant the collective process used for an installation-wide initiative (Zekert 2012).

Products of the on-site meeting include validation of the project scope, an updated draft 1391, estimated preliminary costs, a site plan with constraints, and a floor plan, along with setting relevant timelines for completion of the final products. Final products include the final DD 1391, including the scope and cost estimate, and a summary of the results of the charrette (McVay 2012).

Operational planners commonly submit 1391s to IMCOM's Project Priority System, which is managed by the DPW's Business Operations. Through this system, an installation may have submitted 30 or more projects to be funded in the next 5 years. For example, an installation may request funds for a base-wide leak detection survey for FY14 and also request for funds for FY15 to go toward fixing the leaks found. This may be the extent of long-term planning that occurs for most installations while working toward net zero (Clark 2011).

Development of a DD1391 requires an engineering background or construction experience. The project site is determined by the corresponding ADP in the master plan– it is then necessary to locate the buildings, calculate the appropriate size of utilities and infrastructure including water, storm sewer, natural gas, communications, electrical, sidewalks, curbs and gutters, evacuation, construction fill, demolition, depth and composition of streets and parking lots, AT/FP measures, energy management. The remainder of the form consists of a justification that can sometimes be copied from another DD1391 and edited to fit the new project. Throughout the process, it is necessary to coordinate with the Directorate of Information Management (DOIM) Network Enterprise Center, the Environmental Office, AT/FP, and Physical Security. After completion, the front pages (summaries) and a site sketch must be submitted to IMCOM for approval (McVay 2012).

To receive funding consideration for large projects, 1391s make up the majority of the 1-to-N list,. For example at JBLM, the 1-to-N list is submitted to IMCOM and then forwarded to ACSIM for final review and decision (McVay 2012). alternatively, for an Army Reserve installation such as Hunter Liggett an additional approvals are required (Skinner 2012). While most installations have many projects on their 1-to-N list, only a very small fraction are funded, even in the cases of the few installations that are currently growing. However, DD 1391 is not only applicable to MILCON projects; it is also a key part of the UMMCA process.

4.1.3.3 Imminent changes

Funding for future MILCON projects is anticipated to be very limited. Informal guidance has been issued to Army planners to refocus on the appropriate pursuit and application of more short-term, lower cost projects using SRM funds. Installations have also been encouraged to look toward alternative sources for funds such as Environmental Security Technology Certification Program (ESTCP), which is DoD’s environmental technology demonstration and validation program, third-party financing, Energy Conservation Investment Program (ECIP) funds, or water purchase agreements for new ways to fund larger projects. Installations need to fundamentally change how they look at the long-term component of the RPMP and take an expectation of MILCON funding out of the equation. A MILCON project might still be funded, but the likelihood and frequency of such funding will be scarce enough that any significant planning for it would be wasted. Funding is certainly not limited to SRM. The UMMCA may also be a good option for such projects (Carroll 2012).

Full facility replacement and repair by replacement are two more funding mechanisms separate from MILCON. Such projects often exceed the $750,000 statutory limit and thus require a waiver from higher commands, but approvals stop short of those necessary for full-fledged MILCON projects. For these projects, funding comes from the same sources as SRM (Skinner 2012).

A lot of planning has to do with balancing excesses and deficits in terms of building types/uses and the changing needs of the installation mission. To do this well, planners must be fully integrated into the operational component of the DPW. A great deal of change can be affected on the urban landscape using sustainment funding for replanting, street realignments, or façade improvements. It is anticipated that installation planners will be busier in the future than they were during periods of rapid growth because leadership will look to them to help creatively deal with the absence of MILCON projects (Carroll 2012).

A future emphasis on SRM projects suggests that master planners will need to work much more closely with operational planners, specifically systems managers, in BOID. Each system manager has the authority to coordinate input and make final decisions and approvals on system plans, project management, repairs, replacements, upgrades, Public Works (PW) design standards, equipment, and other system issues. At JBLM, coordination between systems managers and their counterparts in master planning already frequently occurs. The water systems manager is in contact with the facilities master planner on almost daily (Fogg 2012).

4.1.4 Planning case studies

4.1.4.1 Fort Carson

Fort Carson has experienced extreme growth over the past 10 years. It has grown from a base sized to accommodate approximately 15,000 Soldiers to one that serves approximately 28,000 troops. Additional major expansion is being planned while repurposing of buildings is ongoing. Although there is an additional combat air brigade slated for reassignment to Fort Carson, the 3rd Brigade is expected to be removed and personnel reassigned. With this shuffling, anticipated population should remain around 27,000 troops for the foreseeable future. With recent announcements from DoD estimating an 80,000 troop reduction, Fort Carson planners and commanders have little insight on what could be on the horizon after 2016. Reduction scenarios are already being considered for existing facilities for either repurposing, leasing, or demolition. Master planners are attempting to stay informed about ongoing MILCON construction projects while anticipating elimination or repurposing existing facilities.

Due to this state of flux, acquiring timely and up-to-date information regarding the future of Fort Carson is essential for applying the NZI modeling tool. Fort Carson is a net zero pilot in all three focus areas. They are also willing to be a test-bed for new technologies and strategies. Several agencies are stepping up to support Fort Carson in their efforts. PNNL has already performed a water audit, which formed the basis of an installation water balance, a baseline and end-use modeling map of water use throughout the post. The National Renewable Energy Laboratory (NREL) also been supported Fort Carson with help building water and energy nexus matrices to help guide and inform their own energy and water planning. The Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) is coordinating with the Department of Energy labs to tailor the NZI modeling tools to serve Fort Carson's needs.

Feedback from installation master planning regarding net zero specifically suggests, however, that it is not a priority in their planning processes in new or existing projects. Much of Fort Carson's planning policies are established and do not include incorporation of the operational planning initiatives regarding NZI. There is room in the process to incorporate the goals of NZI, but it has yet to be communicated or set as a priority. Additionally, the master planning process and goals are separate from the operational planner goals (Christensen 2012).

4.1.4.2 Joint Base Lewis-McChord

JBLM also experienced great growth in the past decade as stationing changes and base realignments kept a continuous stream of new facilities requirements streaming into the base. The 16th Combat Aviation Brigade (CAB) is the most recent unit moved to JBLM and by the summer of 2012 will result in 44 helicopter and 1,100 additional troops on the installation (Levering 2011). As a result of this rapid growth, the installation struggles to provide the required facilities for everyone and find themselves attempting to catch up with the requirements of units that are already on base (McVay 2012).

4.1.4.3 Fort Hunter Liggett

Fort Hunter Liggett is designated net zero pilot in energy and waste. They are mentioned in this chapter to highlight a different set of challenges than occur at either Fort Carson or JBLM. Although it is officially an Army Reserve installation, it supports year-round training for every branch of the military on its very large land holdings. The high cost of energy in California and the remoteness of the installation were primary factors in the decision to volunteer to be a NZEW pilot. The climate provides significant solar resources, but due to the heavy training demand for undeveloped lands and the presence of sensitive habitat, renewable energy projects must be constructed within the cantonment area and close to where the energy will be consumed (Skinner 2012).

4.2 Planning for NZI projects

The implementation of water conservation projects revolves around analysis of LCC and the process involved in filling out various programming documents. Planning in an academic or civil sense does not necessarily come into play, though comprehensive, traditional utility systems plans do play a role. Even in cases when operational and master planners are collaborating and have solid support from the Garrison Commander, long-term planning for NZIs involves many unique challenges. Unless garrison commanders and the chiefs within DPW make operational/master planning collaboration a priority and policy, significant interaction will likely occur only through the processes necessary to complete the forms and reports necessary to pursue funding. Without policy to enforce long-term sustainable planning priorities, DPW operators and master planners are subject to the potentially different priorities of a new Garrison Commander every 2 years. In addition, long-term tracking of performances and upgrades may be documented using independent systems and personnel. Some of the processes involved in planning for conservation projects are outlined in the following section. The goal is to examine how existing processes can be used to integrate the NZI model into existing installation planning practices.

4.2.1 The 4283 work order process

The 4283 work order process is essential to the planning and tracking of improvement projects by Army installation personnel. Several installation agencies use the work order process to improve existing facilities after the completion of MILCON projects. Use of the 4283 work order is limited to projects up to$750,000. Anything greater requires approval by US Army Materiel Command, US Army Installation Management Command, the Army National Guard and the Army Reserve. More costly projects must be routed through the 1391 fund process (see Section 4.1.3.2). The 4283 work order process is meant to be used for minor installation improvements. Building-by-building upgrades are often funded through this process. Incremental, piecemeal upgrades to facilities by different occupying units through separate work orders create an as-built environment that challenges operational planners to keep track of all the upgrades over decades. As a result, it is very difficult for operation planners to know the actual existing condition of all the buildings on their installation. When planners cannot establish a solid as-is baseline, it is especially difficult to set goals for conservation projects.

4.2.1.1 Business operation integration division

One of the BOID's duties within the DPW is handling the 4283 work order process. This office keeps track of completed facility improvement projects. Project database management may differ between installations. At Fort Carson improvement project tracking is retained by the originating office. This practice can limit coordination and information flow required for effective master planning. The BOID could be a potential site for project tracking that could incorporate aspects of NZI planning into their long-term process. The challenge may be establishing the policy that requires units to provide data on building upgrades to create a baseline database.

The BOID also focuses on work classification and, if within the garrison, the authority to do this type of work. The BOID collaborates with customers throughout the installation and other pertinent agencies that the requested work may affect.

The Installation Management Application Center (IMARC) website serves as a single access point to all of Office of the Assistant Chief of Staff for Installation Management (OACSIM) Business systems. It includes access to AEWRS, Army Mapper, Army Stationing and Installation Plan (ASIP), Headquarters Information System (HQIIS), Integrated Facilities System (IFS), RPLANS, and SWARWeb. None of these systems, despite their extensive tracking, contain information about water-consuming fixtures or equipment at the building level within installations.

4.2.1.2 Fort Carson

At Fort Carson, base-wide work order tracking occurs using several different systems. SharePoint is used for individual customer work order tracking, but the tracking is not part of a networked system. The SharePoint work space contains a document library where projects are organized and tracked by brigades, directorates, and tenants using MS Access software. SharePoint works as a collection box for customers to create and track work orders. The SharePoint system is a temporary tracking system that will be replaced with an Army-wide Project Management System (Collaborative Projects or cProjects), with implementation expected by the beginning of FY14?. cProjects is a web-based application linked to the General Fund Enterprise Business System (GFEBS) program which is the replacement for IFS (Thompson 2012).

4.2.1.3 JBLM

At JBLM, completion of the 4283 work order process and tracking of project progress are both handled by the BOID. Once the 4283 is sent for execution, either in-house or through contract, the project manager is responsible for updating the progress, but BOID will also track the progress as it is updated. Furthermore, if a repair or upgrade results in an amortized increase in value to a facility, the increase is reported to the Real Property Branch within Master Planning. A DD 1354-Transfer and Acceptance of DoD Real Property form is used for the receipt (Fogg 2012).

4.2.2 Case Studies for project initiation between DPW and Master Planning

4.2.2.1 Fort Carson

Fort Carson is in the midst of updating their IDG to reflect low impact development, but that is still a work in progress. Until the IDG is revised, the master planners continue to rely on current regulations with the expectation that the USACE District office will integrate LEED Silver criteria as required.

4.2.2.2 Joint Base Lewis-McChord

Since 2007, JBLM has been working on an update of their master plan to integrate the master plans for the former Fort Lewis and McChord Air Force Base. The focus is on creating a living RPMP which is linked to the installation's GIS (Smith 2012). The RPMP is integrated into the installation's planning process with endorsements from the Garrison Commander and Senior Mission Commander. In drafting the plan, JBLM personnel conceived of a unique system to measure the success of the plan's five key goals. The goals were broken down into 39 design principles and assigned a rating system which measured the degree to which the principles had been realized, varying from the current state to complete build out (HQUSACE 2011).

4.2.2.3 Fort Hunter Liggett

Since 2010, Fort Hunter Liggett has been actively updating its key master planning documents. Significant revisions to the Blackhawk Hills, Mission Valley, and Hacienda Heights ADPs involved capacity analysis and planned build outs to prepare for any potential development which might occur in the future. In addition, a new IDG set a new standard for such documents in the future and outlined the planning/design standards for streets, buildings and landscapes (HQUSACE 2011). Previous IDGs, which were several hundred pages long, were drafted so that their detail would allow them to be transited easily into the RFP (Section 4.1.3.1). In practice, however, the length made the documents simply too cumbersome and they were not used often. Consequently, the new IDG was drafted to provide specific design guidance in as few pages as possible.

4.2.2.4 Fort Carson Operational Planning

The project planning process between offices is dependent on the type of project initiated and who initiated the project. Personnel in the DPW's energy and water branches may coordinate and complete LCC analyses before submitting their proposals to the 4283 work order system or IMCOM's Project Priority System (PPS). The 4283 system is accessible throughout the base and allows other unit offices to view these proposals, insert additional coordination requirements, or make suggestions for changes. Though other units may see current proposals, they cannot view past projects or their outcomes.

Operational planning and master planning personnel work typically on projects using separate funding streams. Master planning works primarily with MCA projects for future development on the installation. Proposals for refurbishments to existing infrastructure or buildings are primarily handled by other departments, while master planning checks to make sure that the new or updated designs or technologies are acceptable and should be funded with O&M funds . For example, if an untested technology which is very difficult to support were to be installed in an existing building, master planning would try to determine if the installation could support the additional requirements for that new technology compared to the status quo maintenance. If new maintenance requirements are considered unfeasible over time, then master planning would request other types of updated technology from the project originator (Weirsma 2012).

4.2.2.5 JBLM

As is the case at Fort Carson, the planning and programming processes at JBLM may take several paths from planning to completion depending on several project variables. For example, Medical Command (MEDCOM), Special Operations Command (SOCOM), and Reserve components from multiple military services, are currently working on real property projects on JBLM. These projects are guided in siting and design by the RPMP, but are otherwise independent from the DPW. However, from a master planning perspective, MCA is funding these construction projects.

Aside from the COS mandates for total square footage, the RPMP holds a great deal of power over the built environment on an installation. ADPs provide guidance about the location of a given facility, whereas the IDG provides specifics on the site and architectural design (McVay 2012). By the time that USACE becomes involved in a project, the 1391 process ,and all major siting decisions, have already been made. Therefore, the influence of USACE can only be felt in site-level design considerations (Skinner 2012).

The CIS is meant to provide a prioritized list of projects toward which the installation should work to meet current and future needs. In theory, the CIS would drive development on the installation. Often, though, the CIS does not act as a driver because the installation is attempting to backfill needs necessitated by past action. When installations are behind in providing mandated facilities, the CIS functions as a prioritization exercise. Master planners and others are required to think critically about their real property needs (McVay 2012).

4.2.2.6 Fort Hunter Liggett

As an Army Reserve installation, the relationship between Hunter Liggett and the Army Corps of Engineers is somewhat different. USACE still works as a contracting agent, but because of the Reserve structure, the installation works almost exclusively with the Louisville District, which retains an A&E firm for contracting work. The primary difference in the relationship is that the Army Reserve Installation Directorate (ARID) assigns a project manager who tracks the project. In this instance, the ARID provides very close direction to USACE's management of the project and brings a great deal of technical and contractual expertise to the table in support of Fort Hunter Liggett (Skinner 2012).

At Fort Hunter Liggett, master planning and operational planning tend to operate separately. Master planning assures that renovations, infrastructure projects/improvements, and other operational projects are consistent with the various components of the master plan. Otherwise, the master planning office is primarily concerned with large new MCA projects, or in the case of Hunter Liggett, Military Construction, Army Reserve [MCAR] projects) (Skinner 2012).

4.3 Planning for water - Installation Sustainability and Water Management Plans

4.3.1 Fort Carson

Fort Carson has no installation level water management plan. However, PNNL recently completed a water balance assessment and a project roadmap. Fort Carson does have a Sustainability Master Plan which focuses on incorporating not only sustainable aspects in local planning, but takes into account the installation's effect on the region. The intent is to coordinate with area planners to support a sustainable region.

The Sustainability Master Plan's number one goal is energy and water conservation. The plan sets targets for both stormwater management and purchased potable water. The 2027 targets are to reduce total water purchased from outside sources by 75% from the 2002 baseline and to reduce total volume of wastewater and stormwater treated by 75% from the 2002 baseline. Fort Carson anticipates a 60% reduction by FY17. The strategies planned to support attainment of these objectives include implementation of a landscaping master plan that incorporates no water and low water use alternatives (Fort Carson 2010b). Fort Carson is pursuing these strategies. Smart irrigation and xeriscaping has been incorporated on a larger scale. Their second initiative, to increase recycling of treated wastewater, is in progress and made possible to due to the 2 MGD capacity available from their wastewater treatment plant (WWTP). However, storage for this retreated water is an issue that limits further irrigation application in place of potable water. A recent reclaimed water expansion study identified additional irrigation demands for this excess graywater: Iron Horse Park, Sports Complex, Pershing Field, Founders Parade Field, and other irrigated areas (Guthrie 2012).

The goals of the sustainability plan do not match with the operational planning goals. Further collaboration is required if both the operational net zero water planning goals and the sustainability energy and water planning goals are to be met. Additionally, both unit plans need to be incorporated in the overall master planning process and decision processes.

4.3.2 JBLM

PNNL completed a water balance assessment and a project roadmap at JBLM. Phase 1 of JBLM's sustainable water goals is represented by the completion of a new wastewater treatment facility. Another of the installation's net zero water project's is the installation of a purple pipe system designed to return treated water to the installation for use in irrigation or other needs. JBLM has mapped out a long range plan to locate these reclaimed distribution system corridors. This plan is being fed into other planning efforts for buildings and utilities. This long range plan allows JBLM to complete the system through snowflake development during which they install pieces of the system when it is most efficient and funding is available. The short-term product is unconnected and dispersed, but as the system continues to fill in, it can be connected and will eventually form a complete wastewater treatment and reuse system. The planned location of the reclaimed water corridors heavily influences layout planning and trench placement. Electrical utilities in particular are problematic because they are laid at nearly the same depth as the pipes. The decision to pursue a reclaimed water system meant a conscious decision to abandon a building-centered, site recycling approach and work instead toward the longer term district system (Fogg 2012). This approach indicates an awareness of the long-term benefits of such district systems and a willingness to pursue projects with a longer planning horizon and payback period.

This type of district planning is precisely the area in which the NZI Tool can be most useful. If available when they were planning the reclaimed water system, NZI modeling could have been applied at two key planning junctures: first, to determine whether a district-wide reclaimed water system was the most desirable and feasible technological solution or whether another option or set of options might have been worth pursuing; and, second, in determining the specific spatial and technical configuration that would be optimal for implementing a reclaimed water reclamation system. The decision by JBLM to pursue the district system appears to be an excellent solution to current and future water needs, but the decision making process would have certainly benefited from the availability of a tool such as NZI.

4.3.3 Water systems and planning

Inspection and analysis of current water system needs occur based on regular monitoring and will result in the identification of necessary projects. After projects have been identified, the required funding determines the funding source. Most often the projects are within the statutory limit required for the SRM program (less than $750,000), since the upkeep and restoration of installation facilities are the primary purpose for that funding stream. Once SRM funds are obligated and sent to the garrison, the funds become local. If some funding is left after project completion or due to unfinished or unobligated work, it becomes available to complete other tasks in the Public Works Plan (Fogg 2012).

Operational plans at JBLM include:

- a comprehensive plan submitted to the State Department of Health
- a project list for USEPA National Pollutant Discharge Elimination System (NPDES) permits
- an energy goals project list
- Sustainability and net zero (Army internal initiatives) lists
- PPS (Project Prioritization List): Headquarters, Installation Management Command (HQIMCOM) projects, usually large or grouped projects listed for Sale In – Lease Out (SILO) or program funds managed by HQIMCOM or its Central Region.

The local building standards take care of 90% of the stormwater compliance so they are an incredibly important component of the overall water program. For potable, non-potable, and sewer systems, national standards are more applicable and require only slight modification. At JBLM the local standards and the USACE Section 6 modifications for MCA projects, are written by the system managers who oversee each system and act as the primary subject matter expert. Note that Section 6 is also known as Chapter 6 or Paragraph 6, of the Project-Specific Requirements Joint Base Lewis-McChord (JBLM), WA. It is intended for use at the USACE level in putting together requests for proposal during project contracting. The document is separate from the JBLM IDG, but coordination occurs to make sure the two do not conflict with each other (Smith 2012).

Technical systems managers at JBLM work in the BOID, but work closely with master planning to create and maintain comprehensive plans. At

JBLM, the comprehensive water plan and discharge permits, submitted to the State Department of Health (drinking water) and USEPA (wastewater) respectively, include a capital improvement section that is closely synchronized with the short-term BOID water plan and also the long-term water component in the RPMP (Fogg 2012).

4.4 Recommendations

4.4.1 General

To achieve the current net zero goal, the IDG and ADPs *must* be written to include the necessary elements of overall net zero and *must* apply to any and every project undertaken on an installation. This will refocus the shaping of the built environment into the hands of the installation personnel.

The USACE COS need to be integrated into the net zero process for requirements and design templates developed by the COS to correspond with the net zero-related design guidelines already included in installation IDGs.

Load reduction should always be the first net zero strategy on any installation. System load reduction is appropriately cited in the Army's concept of net zero, but no matter the importance it is given, one cannot accurately reduce a system's load without first understanding status quo demands/use. Accurate, building-level energy use data are rare. Water use and waste generation is even more so. It is expensive to retrofit a building with the appropriate metering technology, but it is essential if the Army wants to reach net zero in the most efficient way possible. For example, when JBLM designed its new wastewater treatment facility, it was designed to treat a specific load. If the current use data is incorrect or estimators failed to take into account significant future decreases in water use, the plant might be dramatically oversized within 10 years which leads not only to wasted construction costs, but to inefficient operation as well. Perhaps planning for a modular system that could be ramped up or down with need would be a better option. These types of systems do not sacrifice efficiency with variation in loads. They also do not require all of the costs to be front-end loaded.

There are many excellent and committed professionals working in master and operation planning on Army installations. However, the lack of coordination between different planning efforts makes it easy for significant disconnects to occur. Certain plans are required by legislation or Army mandate and are completed, but never implemented. This is not a problem limited to the Army or even the DoD. It is intrinsic to the practice of planning. Steps must be taken to eliminate irrelevant planning by enhancing mandated planning studies and increasing their relevance. This can be accomplished by taking steps to require adherence to the most essential and important plans, especially the RPMP.

The importance of leadership support cannot be overstated. Performance evaluations for those in leadership positions on installations e.g., garrison commanders should include a section in which they are held responsible for supporting sustainability efforts in general and master planning efforts. Responsibility and accountability must also be applied to the planners who must be inclusive both within and outside the DPW and work to include all possible installation interest groups .

Fundamental change to a reliance on SRM or similar funding will require that the DPW rethink the relationships between master and operational planning practices that have traditionally addressed restoration, maintenance, and other short-term projects. Even on installations with a relatively high level of communication within the DPW, such as JBLM, it will be necessary to more fully integrate master planning with operational planning sections like BOID to ensure a better connection between a long-term vision and the planning activities practiced to implement shorter term projects. For this to occur, the RPMP will need to become part of operational planning practice. Rather than the current process, which identifies needs and subsequently checks projects for conformation with the RPMP, projects must be strategically planned to achieve RPMP-level goals for the quality of the built environment while also meeting critical mission needs. This will require effort across DPW and will be well served if leadership recognizes the importance of integration.

By emphasizing installation-wide involvement and buy-in during the master planning process, from the development of a vision to the ADPs, installations will be able to closely follow the guidance provided in the RPMP and thus cut back drastically on the amount of time, effort, and funding spent on programming charrettes and other project-specific activities later in the project programming process.

4.4.2 Specific to the NZI Tool

4.4.2.1 Master planning

There is a great deal of confusion between the practices of planning and programming. In many cases, programming —which often takes the form of documents discussed at length in this chapter, such as DD1391s and 1-to-N lists— is mislabeled as planning. The significance of the distinction for NZI is its intended use during the planning process. It has been suggested that NZI provide outputs that would assist in the completion of DD1391s and other programming documents. This is certainly an admirable aim and would be valuable to installation personnel, but should be understood to be part of the programming process, which ideally represents the execution of a plan rather than the creation of one.

The NZI Tool, including and especially the optimization component, would be best applied during the development of planning alternatives for a RPMP. At this point, according to the UFCs for Installation Master Planning Master Planning, the stakeholders will have already defined their vision, goals, and planning objectives. During the development of alternatives, planners and stakeholders will be able to identify multiple strategies to reach their desired goals. They will be able to understand the effects of various scenarios and explore the best possible mix of technologies and practices.

4.4.2.2 Operational planning

By its nature, operational planning is focused primarily on the fulfillment of the shorter term needs necessary to support the installation mission. The emphasis on results across a shorter time frame does not preclude operational planners from using a tool like NZI early in their process. Like their counterparts in master planning, operational planners would be best served by using NZI while considering possible solutions after the needs assessment step. Some needs are fairly straight forward and require little consideration, but others, such as a higher capacity for treating wastewater, would be an ideal application for NZI.

If a project tracking mechanism of any sort is included in NZI, it will need to tie into the installations' existing tracking processes. At JBLM, project tracking is handled by the BOID from the initiation of the 4283 work order to project completion. At the time of completion, any project that adds value, which is nearly all projects, will be recorded in the records of the Real Property Branch, a branch of master planning within the DPW. Thus, an NZI project tracking component will require coordination and integration with both the operational and master planning components within an installation’s DPW.

5 Installation Level Water Modeling

NZI water planning models at an installation are meant to model measures that affect an entire or large part of an installation. However, not all installations have projects that affect every building or building type. The challenge is to identify a model that is flexible enough to address both small specific and large general projects while remaining accurate for an installation scale analysis. This evaluation considered water planning models from AWWA, AWE, Maddaus Water Management, and the Pacific Institute.

The final modeling review is complete. The evaluation method compared above mentioned models with the same data from Fort Carson and PNNL, and determined the product that is most effective at meeting the NZI water planning goals. Additional evaluation includes a comparison of installation model output to the existing NZI energy optimization model, as this model is the basis for integrating energy, water, and waste. Ideally, the model chosen for integration in the optimization model will work within the framework established immediately. If this is not feasible, the water planning model will be modified or a bridge tool created to transfer relevant information between the models.

The water planning models that address water planning at an installation most comprehensively are the Demand Side Management Least Cost Planning Decision Support System model (DSS), the AWE Tracking Tool, the Pacific Institute Cost Effectiveness of Water Conservation and Efficiency (CE2) model, and the Installation Demand Tool created by CERL in 2009 (USACE 2010). The input and output matrices of the models will be discussed briefly, but the results will not yet be presented here. The intent of this chapter is to compare and determine compatibility. Detailed result comparisons will be discussed in a later report.

Each of the models require localized utility rates along with as much organized and disaggregated use data that is available. This evaluation includes data provided by PNNL that was developed during its water balance and road-mapping work at net zero water installations. In addition, Fort Carson personnel provided data and information to fill out the picture of data required to run the models.

Each model was populated with the same water conservation and efficiency measures from which the models will optimize and calculate life cycle cost analysis (LCCA) based on Fort Carson data. None of the models evaluated for this work currently perform a LCCA, but these models do require or calculate almost all of the information needed to make simple payback calculations. The economic information required for the optimization model, savings-to-investment ratio [SIR] and LCCA data, will be added to the model found to be most appropriate to support the NZI effort.

5.1 The demand side management least cost planning DSS Model

The DSS model breaks down total water production (water demand in the service area) to specific water end-uses such as toilets, faucets, or irrigation. The end-use approach allows for detailed criteria to be considered when estimating future demands, such as the effects of natural fixture replacement, plumbing codes, and conservation efforts. The model has been used in several case studies to forecast both urban and agricultural water demand and has the ability to adapt and capture a wide range of measures and account types.

The DSS model is a labor-intensive, Excel-based model, rich with complex macros, that strives to provide long-term planning information that is only as accurate as the data used. As a result, the time taken to create and tailor the model for individual use is greater than the other models evaluated for this effort. The effort and programming required for the DSS model does eventually provide a more realistic outcome as it has internal indicators that keep the operator from making accounting mistakes, such as saving more water than the baseline consumption. The key aspect of interest to this project is how the DSS model takes multiple projects into account concurrently and how it relates or bundles their affect collectively instead of modeling each measure separately. The model takes the water saved from one measure and calculates the overall remaining available water from which other measures can potentially be used to save water.

5.1.1 Drivers for water demand

As described in the Maddaus's DSS water manual: "customer billing data are obtained from the water agency being modeled. The billing data are reconciled with available demographic data to characterize the water usage for each customer billing category in terms of number of users per account and per-capita water use. The billing data are further analyzed to approximate the split of indoor and outdoor water usage in each customer billing category. The indoor/outdoor water usage is further divided into typical end-uses for each customer billing category." Published (Water Research Foundation [WRF]) data on average per-capita indoor water use and average per-capita end-use are combined with the number of water users to calibrate the volume of water allocated to specific end-uses in each customer billing category (Maddaus Water Management 2012).

5.1.2 Water use data inputs

Adjustments to the basic DSS model takes place during input of baseline data and before measure analysis can be done. The number and types of consumer categories will influence how effective the selected measures are and if their cost-benefit ratio is viable. In addition, the breakout between consumer types, accounts per consumers, and end-use, e.g., fixtures, is defined here. The baseline data are tied to fixture assumptions which factor efficient technology, policy evolution, and also cross-check the average per-capita use with the amount of water available to ensure that the allocation is logical. Despite the details for account users and forecasting, environmental data such as evapotranspiration and rain data are not required. The model relies primarily on customer billing data and account growth derived from demographic forecasts.

5.1.3 Cost analysis and planning results

The DSS model captures cost-benefit parameters in two ways. One way is from the custom-made measure, i.e., a water conservation/efficiency technology or practice, library that summarizes all available measures and their simple payback. A comparative table is available from which an operator can review the implementation parameters and screen for out-of-range water savings or unlikely cost-benefit ratios. Summary cost-benefit data, calculated by the operator independent of the model, is a required input.

Another means to factor in cost savings is through a “water and wastewater energy savings” table. This table captures the savings created by avoiding or delaying any capital improvement costs through implementation of measures. An example of this is an installation that grew in population, but was able to delay expanding its WWTP. The model is able to capture these delayed cost savings that were responsible for reduced demand resulting from the implementation of bundled measures.

5.1.4 Water outputs

Chapter 8 of this report discusses the measures considered for planning and what data were collected for not just these models, but also for the overall NZI model. However, when the model is run for an installation, it will be tailored specifically to that installation’s needs. Much of the baseline water demand data are based on PNNL’s water balance assessments . Based on these assessments, PNNL recommended specific measures for an installation to implement to reach the current net zero water goal. Some of these measures, such as irrigation and graywater projects, were not included by PNNL for Fort Carson because the measures were already being implemented. For the DSS model, the measures will be put together in bundled programs. The interactions are accounted for by multiplying end-use water use reduction factors together. DSS model’s results are typically more conservative than other models that do not bundle measures interactions, but this makes achieving the planned results more likely (Maddaus 2012). The DSS model output calculates cost-benefit ratio, annual water savings, and total water savings for 30 years, and simple payback. It does not do an LCCA.

5.2 AWE Water Conservation Tracking Tool

The AWE Water Conservation Tracking Tool is an Excel-based spreadsheet for evaluating the water savings, costs, and benefits of urban water conservation programs. The tracking tool includes a library of pre-defined, fully parameterized conservation activities from which users can develop conservation programs. This set of activities meets the needs for the most basic operator planning. This model allows portfolios of up to 50 separate conservation program activities (AWE 2011).

The tracking tool is relatively easy to use and is intended for operators to navigate using the provided user guide. It is more user friendly for day-today interactions than the DSS model because it is less labor intensive . DSS is better for annual or quarterly updates. Although the AWE model is easier to operate than the DSS model, it has the capability to become more complex as the measure input can be extensive and the account types can be customized.

The tracking tool has been used extensively by municipal operators as it is focused on calculating consumption based on typical types of municipal use including single-family, multi-family, commercial, industrial, institutional, and irrigation. Residential and barracks breakdown on Army bases are not typical municipal housing. Force fitting Army real property cat codes into the tracking tool classifications may incur errors.

The strength of the tracking tool is that it can be used as an accounting system for tracking the implementation, water savings, costs, and benefits of actual conservation activities over time. Its weakness is that it focuses on the utility operator level and not on integrated planning. It does not integrate water reduction factors that may result in double counting of savings skewing the water savings which may actually have occurred.

All family housing was classified as single-family and all barracks were classified under the multi-family housing to see how the model would capture consumption based on the plumbing code and assumptions. Both single and multi-family assumptions were required to be used for the model to work at all. The baseline input limit does allow the multi-family housing to be allocated between family housing multi-family homes and barracks.

5.2.1 Drivers for water demand

Factors that calculate water demand in the tracking tool are plumbing codes, population, and unit factored derived consumption. One possible drawback to this model for the NZI modeling effort is the unit factor model. The demand assumptions are based on plumbing codes, assumed water efficiency of fixtures, and consumption demand of households. This may be fine if billing data are not available and it does make the model more user friendly, but multiple model versions are required due to the differing plumbing codes in Texas and Georgia. The unit factor assumption works well for indoor use, but errors may be introduced for outdoor use because of regional climate variability. Evapotranspiration and precipitation rates are part of the input data, but cannot account for operational practices of individual irrigation managers.

5.2.2 Water use data inputs

The tracking tool requires 30-year population estimates from the base year. Users can also input time periods for peak season rates. However, dual rate input is not possible for individual customer classes. Energy, gas, and sewer rates are required. The model allows entry of forecasted water consumption, GHG emissions, average number of bathrooms per household, and potential avoided capital improvement costs. Alternately, the model will assume values for these items based on the geographic region. Additional required inputs are regional data for evapotranspiration rates and average rainfall.

5.2.3 Cost analysis and planning results

Cost analysis and savings are required to be filled in and pre-calculated. The information is broken down between the utility and the participant, or the home owner. As most installation residents do not pay utility bills, all the costs and savings can be classified under utility inputs. The prefilled Activity Library is a good sample of the general types of conservation measures most operators should use for high-efficiency fixtures, leak detection, surveys, and efficient irrigation. The model can take up to 50 activities (or measures) and run them as part of the overall output. The actual costs of the activities should be localized to become more accurate. Once the library is populated, the AWE model works well for daily operator interaction to check on a project’s status and water savings, but does not capture accurately the overall bundling effects of multiple projects in the long run and how one activity’s effect influences another. The output data shows overall water, gas, electricity, and GHG savings both in dollar and respective units.

5.3 AWWA

The AWWA has several documents to help in conducting water audits and planning, including tools directed at utility engineers to help them include economic cost-benefit, risk, and energy savings into the analysis. However, the AWWA does not have a comparable tool that runs planning scenarios or models activities included in the AWE and the DSS models.

5.4 Installation Water Demand Tool (CERL)

The Installation Water Demand Model uses customer disaggregation for its projections. Customer classes are residential (family housing, Unaccompanied Personnel Housing (UPH)/barracks, and transient/lodging facilities), dependent schools, industrial and maintenance, medical, administrative and moderate users, community and commercial (food and non-food related), storage, high water use facilities, pools and vehicle wash facilities, irrigation and improved lands, and losses. Categories can be combined depending on the availability of installation data (USACE 2010).

Sectoral demands were developed based on typical water consumption values and are calibrated to the installation footprint, population, and op-tempo.

5.4.1 Drivers for water demand

The key drivers for the water model are the installation real property data, installation permanent population (barracks, multi-family, single-family, transient quarters), commuting population, industrial tempo, deployment tempo, rainfall and evapotranspiration data, and planned construction.

5.4.2 Water use data

Installation water use data are reported monthly by the utility contract operator. Data are available for the entire installation. Reimbursable customers are metered separately for billing purposes. These data are aggregated quarterly and entered into AEWRS. Initial per-capita water use is typically about 69.3 gallons per capita per day (gpcd) and applies to resident population (family housing, multi-family housing. Irrigation water use is calculated as:

[acreage x (summer evapotranspiration rate)] – [0.60 x (summer precipitation rate)]

The model assumes no restrictions on irrigation. The seasonal variation in installation consumption can also be used as a check on the irrigation rate.

The model assumes an initial rough breakout by sector as follows: 50-60% for residential, 25% for non-residential, and 10-15% for losses. These figures are then aligned based on the fact that many installations have a large population that commutes onto the installation so the non-residential sectors may exceed the typical city's profile ratio for commercial/industrial/institutional buildings and use. Landscape irrigation may also be a much larger consumer than in a typical community due to large parade fields, commons, and golf courses. The factors for the consuming sectors of the model were taken from *Forecasting Urban Water Demand* (Jennings and Jones 2008). The model works on the premise that there are several basic using categories of consumers on the installation. These are residents, commuters, and processes. The residential consumption is in the housing, barracks, and transient facilities. The commuting population is represented by the square footage of the different types of buildings and their consumption factors. The processes are represented by the irrigation loads, losses, and high water uses. These are more unique consumers and are evaluated for each installation (Jenicek et al. 2010).

5.4.3 Water output data and testing

The steps in initial development of the water model were: (1) collect data on water use and drivers for water demand including 10 years of monthly data and 20 years of annual data, (2) analyze key drivers and disaggregate data, (3) develop and test of the model, (4) augment data if required, (5) test and calibrate the model for several installations, (6) develop forecast for the drivers (independent variables), and (7) develop the water demand and consumption forecasts.

The model is installation-specific and the baseline is calibrated to the installation. CERL's model also provides guidance in disaggregating the installation water consumption to several key using sectors. To date this model has been applied to 16 domestic Army installations and three overseas (Jenicek et al. 2009, 2013).

6 Hydrologic Models

6.1 Role of hydrologic models in NZW planning

The role of the hydrologic models in NZW planning will be to assess the regional scale water balance for Fort Carson in southern Colorado. This portion of the project will include the overall water-related inputs and outputs to the regional system, to include: infiltration, evapotranspiration, inflow from streams, outflow to streams, outflow to sewer, consumption, groundwater flow inputs, municipal flow inputs, and water reuse. Of these system inputs and outputs, cost per volume of water is associated with groundwater flow input, municipal flow input, and water reuse. Local, state, and national laws will likely restrict the amount of water that is released to the stream system from the base and how much water may be pumped from the groundwater system. This chapter discusses the typical water inputs and outputs to the system, and the economic cost to maintain a water balance that meets the needs of the installation while satisfying all the flow constraints.

6.2 Description of literature review findings

The modeling for this project is divided two sections: regional hydrologic model and the regional water balance model. The regional hydrologic model must determine the amount of water that is lost due to infiltration, evapotranspiration, and overland flow. These losses must be determined for the entire area of interest, in this case Fort Carson. The water balance model must incorporate these losses with the inputs and outputs to the system to make sure the system's water balance is stable. The water inputs, outputs, and reuse within the system all have fixed costs, requiring this model to incorporate economic considerations as well.

6.2.1 Regional hydrologic model

There are numerous regional hydrologic models available, so determining the best one to use depends on the available input data, required accuracy of results, pertinence of results, and versatility of the model. The requirements of the model are to produce accurate estimates of infiltration, evapotranspiration, and how much water leaves the basin through overland flow (Figure 13). This model will be of the natural system only, therefore it will not include any water pumped from or piped into the system. These water volumes will be accounted for in the regional water balance model. Regional hydrologic models are commonly referred to as watershed models because they capture the hydrologic aspects of the entire watershed. To determine the most appropriate model to use, the available watershed models can be differentiated using two criteria: how the hydrologic characteristics, such as infiltration, evapotranspiration, runoff are calculated, and the platform on which these hydrologic characteristics are modeled and spatially interact. The calculations of hydrologic characteristics are typically grouped into two categories, empirical and physically-based. The platform used to model watershed systems typically falls into one of three categories: lumped parameter, semi-distributed, and fully distributed. Further discussions of these types of classifications are provided below.

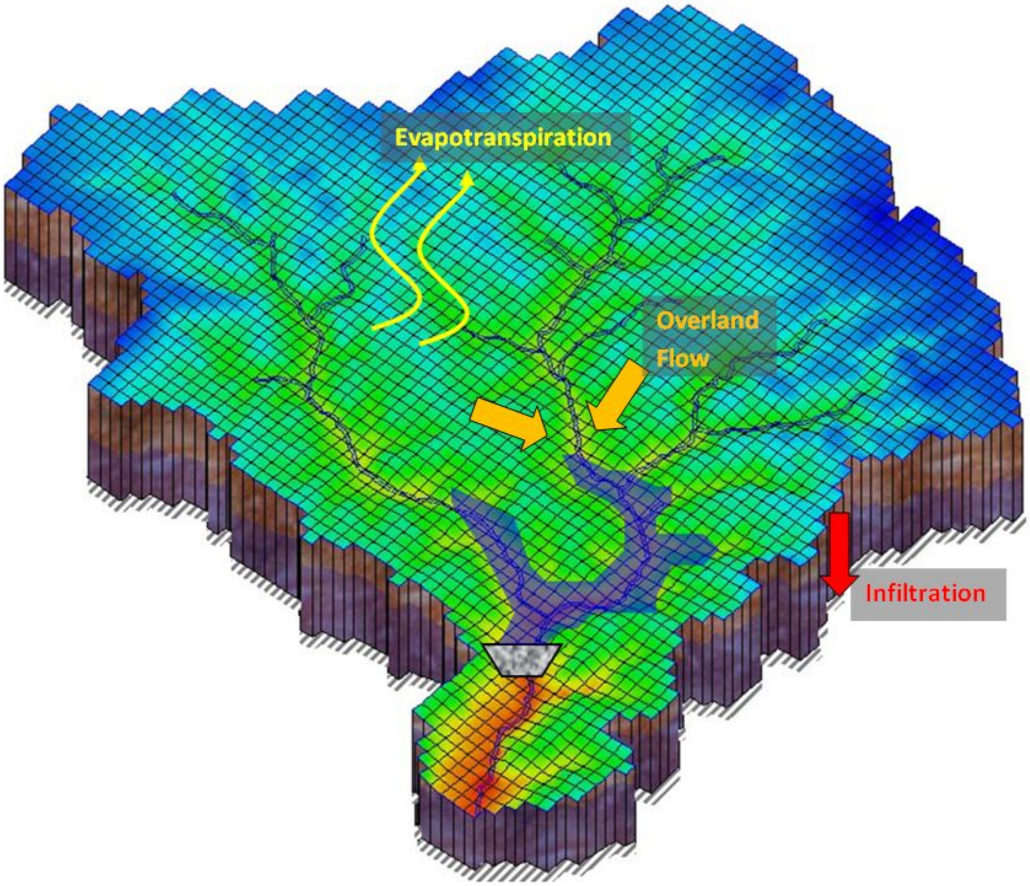
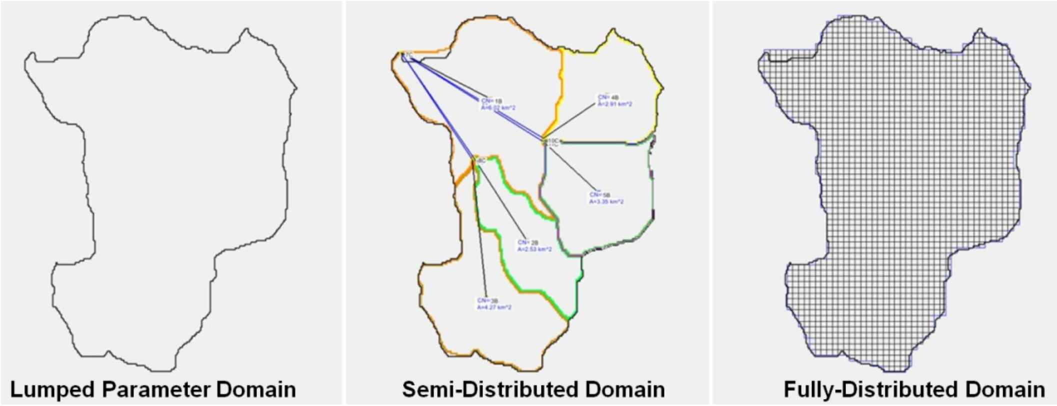


Figure 13. Example regional hydrologic model

6.2.1.1 Domain platforms for regional/watershed hydrologic models

Lumped parameter models treat the entire watershed as a single unit, therefore having one value per time step for precipitation, evapotranspiration, infiltration, and outflow. Semi-distributed models combine several lumped parameter models of sub-basins to simulate the entire watershed. The links between these sub-basins are nearly always one-dimensional, i.e., only one value is transferred between adjacent sub-basins. A fully distributed model subdivides the watershed into individual cells where the individual physical processes of precipitation, infiltration, evapotranspiration, and flow are calculated. Each cell represents a small two-dimensional unit of area of the watershed. By combining all the cells together in a two-dimensional grid or mesh, an entire watershed is simulated. A fully distributed model is capable of simulating many types of hydrologic modeling applications, but is particularly suited to simulating applications where soil, land use, elevation, and hydrometeorological (HMET) data are not uniform over the area of interest and simulation time frame (Figure 14)



Lumped Parameter Domain **Semi-Distributed Domain** **Fully-Distributed Domain**

Figure 14. Three most common types of hydrologic modeling domains.

6.2.1.2 Empirical and physically-based modeling strategies

The purpose of a watershed model is to capture the hydrologic processes within the watershed. Two predominant methods are available for calculating these processes. Empirical models assume that the basin-scale models capture the overall net effect of all the processes occurring in the domain whereas the physically-based models attempt to actually simulate the processes as they occur. The advantage of the empirical models is to quickly reproduce expected behavior of the system given that there are no changes to the underlying processes. The advantage of the physically-based models is that they model the underlying processes and thus can more appropriately simulate the effect of changes to the underlying processes, such as the changes from watershed management practices. Overall, empirical methods are easier to calibrate and require less forcing of the data, whereas physically-based methods require more forcing of the data, but perform better when calibration data are lacking. As indicated above, the main physical processes that will be investigated in this project are infiltration, evapotranspiration, and surface runoff. A brief description of these physical processes as well as the effect of using empirical or physically-based methods to calculate them is discussed below.

Evapotranspiration (ET) is the combination of the natural evaporation and plant transpiration that occurs over a land surface. Depending on location and a variety of conditions, ET can have a significant role in the water budget of a system. ET occurs naturally, but can also be increased through irrigation. In many irrigation systems much of the water used to irrigate is lost to infiltration into the groundwater, evaporation, or to surface runoff. At Fort Carson, advanced irrigation systems are in place to reduce the amount of water lost to infiltration and runoff, therefore this effort will assume that all irrigation is lost through ET alone. Typically, ET values used in watershed modeling are either measured or calculated using equations based on the work of Penman (1948).

For the modeling done as a part of this work, it is assumed that run-on overland flow from outside the Fort Carson boundaries is minimal, making precipitation the only source of water lost to infiltration that occurs within the base boundaries.

Empirical methods for calculating infiltration rely on a parameterized, empirically derived equation to determine the amount of precipitation that infiltrates verses the amount that runs off the surface. One such method is the runoff curve number. The runoff curve number was developed from an empirical analysis of runoff from small catchments and hillslope plots monitored by the US Department of Agriculture (USDA) (Cronshey 1986). A single curve number represents the infiltration verses runoff characteristics of the entire watershed, lumping together all of the spatial variability into a single, calibrated, value. It is a widely used and efficient method for determining the approximate amount of infiltration and direct runoff from rainfall for a watershed where ample amounts of calibration data are available and where spatial variability across the watershed can be ignored.

Physically-based methods for calculating infiltration, such as those proposed by Green and Ampt (1911) and Richards (1931), use parameters of the physical characteristics of the soil and a physical process equation to calculate the amount of infiltration and direct runoff. Because of the critically important mediating effect of infiltration, and the central role of soil moisture in infiltration models, a critical need for long-term simulations with multiple storms is an infiltration method with redistribution of soil wetting fronts, such as proposed by Ogden and Saghafian (1997) or Talbot and Ogden (2008). Although these methods require more parameters than the curve number method, they are able to capture the initial conditions for runoff generation from storms. These methods are often preferred where little to no calibration data is available because measured ranges for the parameters are available and can be used to produce a reasonable estimate of infiltration amounts.

Surface runoff and infiltration are tightly coupled processes. As mentioned before, water that does not infiltrate then becomes part of the surface water system. In the absence of manmade stormwater structures, surface runoff (overland flow and stream flow) and ponding are the dominant processes considered in the surface water system. Empirical methods have been developed that essentially delay the timing of the water as it travels to the stream network and eventually to the outlet of the watershed model. These methods require a long record of flow calibration data and are not suited for the comparison of various scenarios, such as land use change, because of the underlying assumptions of stationarity in the underlying processes captured in the empirical equation. Physically-based methods use the surface roughness and topography of the land to simulate the flow of water, both temporally and spatially, over the land surface and through the stream network. Although they still require calibration, physically-based methods are better suited for areas lacking in observed data. Physically-based methods for calculating surface runoff are well suited for watershed management scenarios involving land use change or the addition or removal of engineered water conveyance systems.

6.2.1.3 Hydrometeorological data

Temporal data are required to drive any regional hydrologic model. Because this project is concerned with water balance over an entire year, it was determined to simulate the basin using a statistically average year of HMET data. At minimum, temperature and precipitation data are required, but more options for physically-based infiltration and ET models are available when pressure, relative humidity, radiation, wind, and cloud cover data are included. At least two separate methods for calculating a statistically average year of hourly HMET data are available. Work completed by Wilcox and Marion (2008) has produced the TMY3 dataset while methods described in Lee and Byrd (Submitted) could be applied to existing data to create the required input dataset. The TMY3 dataset currently exists, but would need holes filled in the precipitation data. Using the work by Lee and Byrd (2013) would require obtaining historical HMET data for the area. Both datasets can be derived from data collected near Fort Carson at Colorado Springs International Airport. The datasets provide a statistically average year of hourly HMET data, which can be used in nearly all regional hydrologic models.

6.2.2 Potential regional hydrologic models

there are numerous hydrologic models available for use. Due to the size of Fort Carson as well as the objectives of the modeling effort, lumped parameter models are not being considered for this project. Also, in an effort to reduce project costs, only freely available models are considered. The following sections discuss the four models chosen for consideration.

6.2.2.1 Hydrologic Engineering Center (HEC)—Hydrologic Modeling System (HMS)

The Hydrologic Engineering Center has produced the HEC-HMS, which uses a semi-distributed approach to solving watershed-scale problems. HEC-HMS (Scharffenberg and Fleming 2010) uses a dendritic watershed domain to simulate precipitation-runoff processes. It is widely used by both public and private entities. Because it has few calibration parameters it is easily calibrated and it is computationally efficient. HMS uses three methods for infiltration, one of them being the Green and Ampt method, but without redistribution. Among other processes, the model calculates infiltration, ET, outflow, and snowpack melting.

6.2.2.2 Hydrological Simulation Program-FORTRAN (HSPF)

The HSPF was developed by the USEPA to model water quality within a watershed scenario. Among other processes, HSPF models infiltration, evapotranspiration, runoff, and groundwater (Bicknell et al. 1996 and 1997). HSPF uses both empirical and physically-based methods to calculate these hydrologic processes. HSPF is considered a semi-distributed watershed model and has been shown to be useful in analyzing long-term hydrological effects (Choi and Deal 2008).

6.2.2.3 tRIBS

The TIN-based Real-Time Integrated Basin Simulator (tRIBS) is a fully distributed hydrologic model originally developed at the Massachusetts Institute of Technology. The tRIBS model (tRIBS User Manual, Ivanov et al. 2004) is a physically-based hydrologic model that runs on a triangulated irregular network (TIN). The advanced methods used to calculate infiltration, soil moisture, and evapotranspiration are discussed in detail in Ivanov et al. (2004). The model also calculates runoff routing and interaction with a variable groundwater surface through a simplified coupled system (Ivanov et al. 2004).

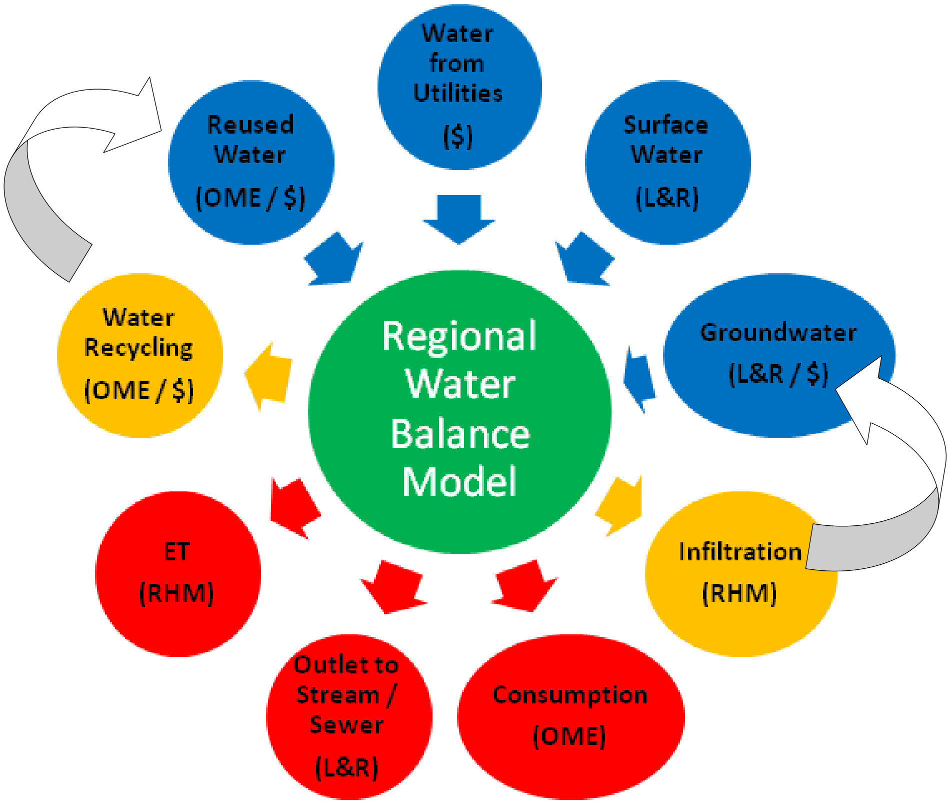
6.2.2.4 Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model

The GSSHA is a fully distributed, physics-based, hydrologic model used for a wide array of hydrologic problems. Among other processes, GSSHA (Downer and Ogden 2004 and 2006) simulates infiltration, evapotranspiration, overland runoff, streamflow, groundwater, surface-groundwater interaction, and snow melt/accumulation. The GSSHA Wiki (www.gsshawiki.com) outlines the most current capabilities within the model. The amount of water infiltrated, lost through evapotranspiration, and lost through surface flow can easily be quantified through a long-term simulation. GSSHA can use several methods for calculating infiltration, one of them being Green and Ampt with redistribution that is beneficial for long-term simulations in areas with little calibration data.

6.2.3 Regional water balance model

There are numerous water balance models from which to choose. Harou et al. (2010) describes several of the more established. Some models are specific to certain areas, whereas others are useful in numerous scenarios. These models also range in effort and complexity. The main goal of this project is to determine the most cost-effective means to balance the water budget. This means that the model of choice must have both economic cost and water budget built in. As is the case in most areas, the amount of water demanded depends on the climate and season, therefore the model must also be able to run under changing water demand scenarios. It is imperative that the model runs in conjunction with the regional hydrologic model used in this project.

The inputs to the model will be the cost and volume limits of the groundwater, cost and volume of water purchased from CSU, and reused water volume in the Fort Carson system (Figure 15). In addition, the volume of water lost to ET, outlets, and infiltration will also be inputs into the model. The volume of water lost to ET and infiltration will be provided by the regional hydrologic model.



RHM = Data input from Regional Hydrologic Model
OM = Data input from Other Modeling Efforts within this Project
L&R = Laws and Regulations may apply

Figure 15. Regional water balance model -$cost associated with source.

The volume of water delivered to the system by groundwater and CSU will be controlled by demand, price, laws, and regulations. The volume of water discharged from the installation through outlets to streams/sewer will also be regulated by laws and agreements. The overall cost of water to the system and meeting water demands are the main considerations of the regional water balance model, therefore the model outputs will be overall cost, the associated volume demands, and volume requirements needed to satisfy the system. The cost will be based on the volumes of water brought into the system from groundwater, CSU, and the volume of water reused. There is a cost associated with water reuse because CSU charges Fort Carson to reuse water.

6.2.4 Potential regional water balance models

As indicated above, there are numerous regional water balance models available. These types of models are also referred to as DSS. For large-scale projects with a high degree of uncertainty, models and methods have been built to solve these complex issues (Rosenberg and Lund 2009). For the issues concerning water balance for Fort Carson, a simpler DSS model is used. Two appropriate DSS models are examined below.

6.2.4.1 Confluence

Confluence is a proprietary model that helps water resource planners manage available water resources. The link-and-nod” setup of the Confluence model represents the relationships between water supplies, demands, and transmission networks. It uses these relationships with inputted data to determine water balance as well as the costs. The model also can be configured to existing conditions within nearly any water distribution system and then allows the user to test various water management scenarios. A climate change feature allows the user to simulate various climate change scenarios. Time can be set to monthly to sub-daily. The model enables the user to detail specific current and future conservation programs within the system. Confluence also has a complete financial and cost accounting module for outlining future system capital and operating costs (www.confluence-water.com).

6.2.4.2 Water Evaluation and Planning (WEAP)

The WEAP system is a software tool that helps water resource planners manage available water resources. The spatial boundary of the WEAP model is typically on a watershed or a region. WEAP uses a link and node system to represent the relationships between water supplies, demands, and transmission networks. It uses these relationships with input data to determine water balance as well as cost analysis. The model uses month-to-month time scale and balances the water demands within the system. The WEAP model takes a holistic approach to water balance by incorporating natural losses due to infiltration and by including reclaimed wastewater, a major concern of this project. The model can also do cost-benefit analyses as well as include information such as water rights and allocation priorities (www.weap21.org).

6.3 Water collection and stormwater measures

As part of the net zero initiative, finding intuitive ways to optimally use existing water that naturally occurs on the installation is the paramount goal. Two methods of capitalizing on natural water resources within the installation boundaries are described below.

6.3.1 Water detention ponds

Collection and use of stormwater is a practical and efficient means of using water in many parts of the country. In Colorado however, depending on water rights, it is generally illegal to permanently detain water for use. However, temporarily detaining the water before it passes through natural drainage to reduce flooding and erosion is not prohibited. As discussed in Stogner (2000a, 2000b), Fountain Creek, which runs along Fort Carson and drains part of the installation (Figure 16), has experienced significant flooding and caused erosion in the past. Although water may not be permanently detained on-site at Fort Carson, water which is temporarily delayed will cause more infiltration to occur, thus providing more water to the groundwater system. Based on conversations with installation personnel, Fort Carson does have the right to use this groundwater. Although different methods were used, Stephens et al. (2012) demonstrated that stormwater can be an effective means of recharging the groundwater system. The delay in runoff will also likely have a mutually beneficial effect of replenishing the groundwater while reducing flooding affects and erosion in Fountain Creek. If actions are taken to slow water runoff, the effects on infiltration, and therefore the groundwater system, can be quantified using the regional hydrologic model in future work.

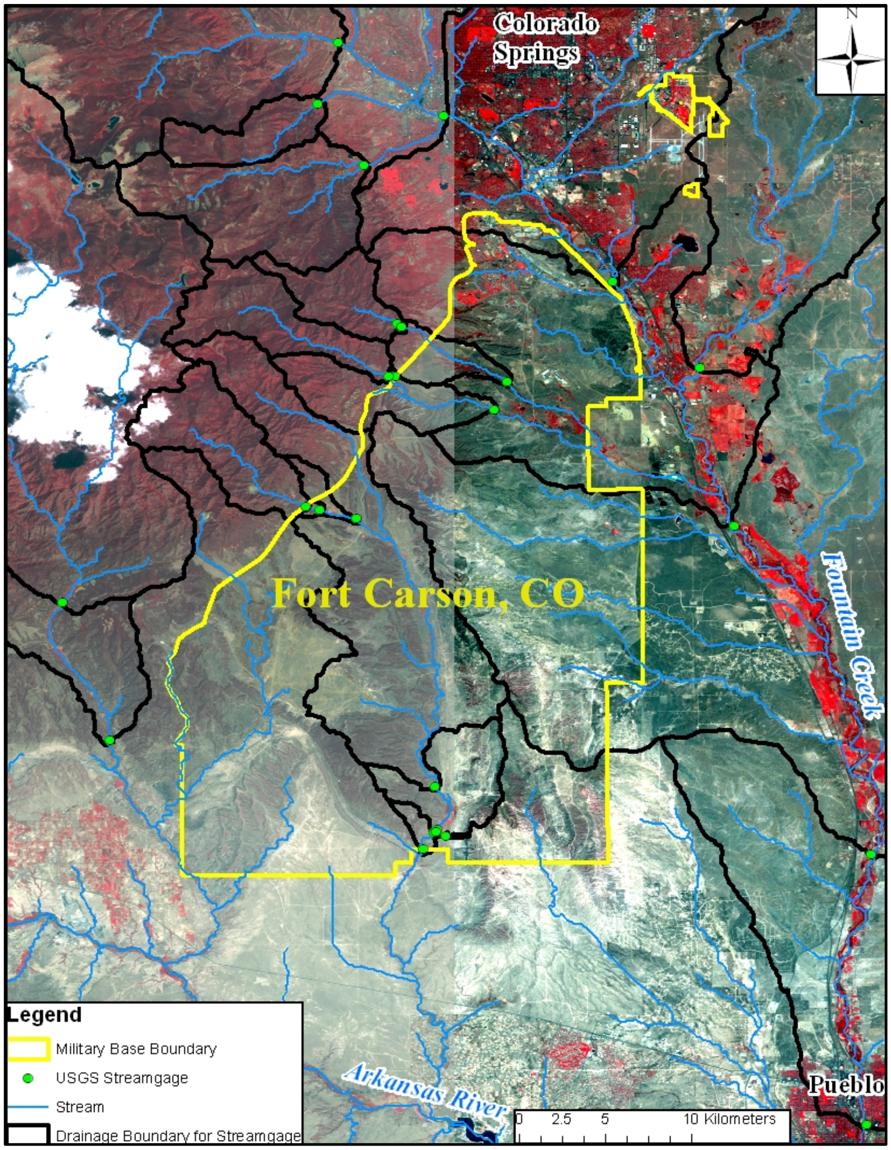


Figure 16. Fort Carson, CO with stream gages and drainage basins.

6.3.2 Rainfall collection system

Water enters the system through precipitation at an average rate of 15.21-in/yr (NOAA 2011), but due to local laws and restrictions, most of this water is unavailable for use (Waskom and Kallenberger 2009). If it became legal for Fort Carson to harvest rainwater, the collection of this water would likely only occur on large buildings and could be accounted for in the regional water balance model. The estimated effect of this loss in infiltration potential is small when compared to the size of Fort Carson, but could be calculated using the regional hydrologic model.

6.4 Case study: Fort Carson, CO

Fort Carson is a contributor to two major drainages, the Arkansas River to the south and Fountain Creek to the east. Fifteen U.S. Geological Survey (USGS) stream gages around and within Fort Carson will enable a partial calibration of the drainage system. The calibration exercise will calibrate the physical characteristics of the soil and land use, which then can be used in similar areas where calibration is not possible due to a lack of appropriate gauging systems. By proceeding in this fashion, the infiltration, overland flow, and evapotranspiration of the entire base can be effectively estimated.

6.4.1 Recommended regional hydrologic model for Fort Carson

To proceed with the plan above, a physically-based infiltration model that uses the individual characteristics of the soil (porosity, hydraulic conductivity) and land use (albedo, roughness) is required. Therefore, it is recommended that a version of Green and Ampt or Richards Equation be used, limiting the hydrologic model selection to GSSHA, HMS, and tRIBS. Furthermore, since a long-term simulation is required with multiple events, HMS is eliminated because it does not include an infiltration method that includes multiple soil wetting fronts. Therefore either GSSHA or tRIBS can be used for the regional hydrologic modeling. The modeling effort will consist of running the hydrologic model for 1 year using a statistically-derived annual average of hourly HMET data. The water volumes calculated for evapotranspiration, infiltration, and runoff by the hydrological model will be used as inputs to the regional water balance model.

6.4.2 Recommended regional water balance model for Fort Carson

The main objective of the regional water balance model is to account for volumes and costs associated with:

- input from CSU (cost associated)
- input from groundwater wells (cost associated)
- input from surface water (negligible)
- consumption of water (output from other modeling efforts)
- outlet to stream (controlled by laws/regulations)

- outlet to sewer (possibly controlled by laws/regulations)
- evapotranspiration (output from regional hydrologic model)
- infiltration (output from regional hydrologic model)
- reuse of water (output from other modeling efforts).

Because the regional water balance has nine factors, in lieu of a proprietary model, a programming script will be written that balances the water budget as well as determine the present value cost of the water balance. This model will be based on daily changes and consider seasonal changes in water use and prices. The script will also incorporate inputs and outputs from future net zero pilot studies. A customized model will facilitate the connection of input and output data from the water balance model to the other modeling efforts within this project.

6.5 Recommendations

6.5.1 Current legal considerations

It is highly recommended that Fort Carson personnel learn what, if any, water rights they currently possess and what volume of water these rights confer on Fort Carson. It is also recommended that minimal effort be spent on rain water harvesting and more effort be placed on the legality of slowing surface runoff water as it moves across the base. The amount of water that Fort Carson is required to output to the sewer or natural system will also need to be determined.

6.5.2 Modeling mentality

It is recommended that an ensemble of regional hydrologic model runs be compiled to serve as the evapotranspiration, infiltration, and runoff amounts to be used in the regional water balance model. By having an ensemble, the installation need not run the regional hydrologic model every time an optimization measure, e.g. updated toilets, updated faucets, is used in the overall net zero simulation. The ensemble will capture a diversity of potential hydrologic scenarios, e.g., high precipitation, low precipitation) and will greatly reduce computational time.

7 Infrastructure Models

7.1 Role of water and wastewater models in NZW

Water and wastewater models can serve as a key piece in the approach to NZW. This chapter reviews the role of models in reducing water use, and gives a conservative estimate of potential water savings between 37 and 44% even when using surprisingly simple models.

Models can range from very simple representations of the system plan in a map view to more complex models that can use more detailed information on pipe diameter, pipe elevation, tank water levels, and metering data. Applications vary from facilitating leak detection to comprehensive diurnal modeling of water quality, water use, and energy use. Even with a simple model, there are two principle ways to reduce water use. First, given the age of the water distribution system infrastructure, almost all water distribution systems lose between 25 and 33% of transported water due to leakage (Olsson 2012, Farley and Hamilton 2008, Charalambous and Hamilton 2012). Second, metering key locations in the water distribution system can create actionable information for the various tenant organizations regarding their individual water use. Recent studies conducted in the private sector indicate that creating such actionable information for end users decreases water use by approximately 16% (LeChevallier 2012).

More complete models that capture information regarding pipe-sizes and elevations can be used to modify distribution system parameters and operations, e.g., pump usage, tank levels, flushing operations, fire-fighting capacity, water quality. More sophisticated models can also yield important information that helps clarify complex boundary conditions that linear modeling, for example, an installation level model, would not predict. These models can also capture energy use information due to pipe roughness and pumping.

Water and wastewater systems on military installations are typically not amenable to a one-size-fits-all approach to NZW. Terrain, weather, and state and local regulations play a large role in how NZW is defined and implemented. Therefore, any sophisticated computer model implementation must be flexible in its approach and evaluation metrics to accommodate locale-specific constraints.

7.1.1 Water distribution system modeling

It is critical to understand that water distribution system models can vary from simple to complex. Models can vary from very simple map view representations of the system plan, to more complex models that require pipe diameters, and elevation data, and that can incorporate data such as water quality, tank levels, pump curves, and diurnal usage.

7.1.1.1 Simple water distribution system model usage

Up to 33% of potable water is presently lost due to leaks in water distribution systems (Olsson 2012, Farley and Hamilton 2008, Charalambous and Hamilton 2012). In the private sector, where individual users all have their own water meters, this lost water is referred to as non-revenue water. Installations, by contrast, may only have a single water meter for an entire installation monitoring water use on a main near the installation's fence line. Therefore, all losses within the installations' distribution system are paid by the installation.

In FY13, the Army spent $84 million for potable water, suggesting that savings of as much as $27 million per year might be attainable. EO 13514 (White House 2009) requires significant reduction in water use across all Federal agencies. These reductions in water use can be more easily met if leaks can be identified and repaired promptly.

The current approach for leak detection and repair requires annual leak detection surveys, along with water meters that evaluate district metering areas to direct and enhance leak surveys. However, these surveys and evaluations are labor intensive, expensive, and thus in practice, often deferred or not performed at all (AWWA 2007).

All leak detection surveys require a basic model of the water distribution system's layout. Temporary placement of acoustic recording devices at two adjacent above ground fixtures, hydrants, inlets, backflow preventers, , can determine the acoustic recordings of a leak's position between the fixtures and estimate severity. A leak in a pipe reveals itself by the sounds generated when the water inside the pipe makes a turbulent escape. The leak-created, liquid-borne, acoustic waves can be detected hundreds of feet away from the leak by using special sensors, by which the sound is converted into electrical signals and processed. Leak *detection* occurs when the presence of a leak signal is definitively established. More recent systems can also determine leak *location* by comparing the leak signal from two sensors on either side of a leak by then performing a time difference calculation based on the leak signal.

Simple map-based models also give actionable information on optimal placement of water meters. Historically, installations may only have a single water meter located on a water main near the fence line. The original intent was to avoid the cost of individual water meters on each structure in an era when water was not considered a potentially scarce resource.

A simple map-based model that shows the individual installation tenant organizations and their physical layout can inform planners regarding placement of meters at key locations so that individual tenants of the installation can be informed of their water use. Recent studies conducted in the private sector indicate that when end users are provided with such information, water usage drops an average of 16%, even when there is no direct remuneration to the individual end user.

7.1.1.1.1 Meeting goals and requirements

At some installations, leak location and repair has the potential to meet all reduction mandates, even if it is the only measure implemented. This is a major component in the NZIs Initiative. It has been shown that the use of simple layout models and suitable planning for water meters can achieve aggregate savings somewhere between 37 and 44% of current water use.

7.1.1.1.2 Water, energy, and repair savings

If a leak goes undetected for years, large and costly water and energy losses occur. The amount of time a leak runs is the primary determinant of water lost due to leakage (AWWA 2007).

7.1.1.2 Complex water distribution system model usage

Higher fidelity hydraulic models, e.g., EPANet, WaterGEMS, can assist in water conservation. Such models can, for example, provide more realistic and non-linear bounds on linear estimates used for installation-wide planning, and assist in optimizing day-to-day operations of the water distribution system.

Information easily captured and analyzed within hydraulic models include energy savings due to pipe re-surfacing, e.g., pigging, relining, pipe replacement, pump replacement, and installation of motor controllers for large pumps. Such changes can have beneficial effects on energy consumption. This interaction is termed the *water-energy nexus*. At 8.3 lbs/gal, and with a typical installation requiring millions of gallons per day, the energy consumed by pumping is considerable.

Recent experience (Ferguson and Field 2003) has shown that when military units deploy from an installation, the demand profile for users changes radically and can cause water quality problems requiring more aggressive flushing programs, especially in hotter weather or hot climates. Hydraulic models can give water distribution system operators a useful tool to optimize flushing programs to minimize lost water.

In view of the full range of net zero water initiatives, most installations will benefit from having access to a hydraulic computer model of their water distribution and storage systems. Hydraulic modeling is considered an energy efficiency best practice. Benefits also extend to improved water conservation performance (Lelby and Burke 2011). Most of the Army's eight net zero water pilot installations do not have such a model. In fact, five of them report that they do not model their water distribution system.

Hydraulic models have been in use for decades. They are proven and trustworthy predictors of flows and pressures when properly constructed, operated, and calibrated. Today's models are also capable of modeling many aspects of water quality and energy consumption of the water distribution system. These newer versions of hydraulic models link and simulate the hydraulic and water quality aspects of the system.

Further refinement of water system modeling incorporates continuous monitoring of parameters such as pH, turbidity, TOC, and chlorine residual. Continuous monitoring produces large quantities of data, and requires sophisticated and intensive analysis, which is an active field of study. Likewise, water system modeling that incorporates continuous monitoring allows for real-time analysis and can inform system operations. This is a developing and emerging field with applications including water security, basic operational troubleshooting, and event detection (Speight 2008).

7.1.2 Water distribution modeling—software review and findings

Many software products are available for hydraulic modeling of water distribution and storage systems. Several leading software packages were reviewed, with attention to specific features to meet the needs of the NZI initiative. The factors considered were:

- wide use and acceptance in the industry, with support available in the United States
- a full range of industry standard built-in features for efficient analysis of operational scenarios
- flexible user interface for analysis of non-standard scenarios
- open-source computer code for possible integration with net zero software being developed as part of this project
- the ability to make use of data within existing hydraulic models and GIS at the selected installations, possibly including models created in other software.

The vast majority of water distribution system models fit into a surprisingly simple taxonomy (Figure 17). Within the United States, there are many different vendors of water distribution system models. Almost all of these models base their predictions on EPANet. To understand this, it is important to understand that EPANet is a computational engine that is distinct from its user interface. In this way, many different vendors either customize the EPANet engine or leave it as is, and then provide a user interface that can keep track of supplemental information not used by EPANet itself.

There are hydraulic modeling systems that each use a one-off modeling engine entirely different from EPANet. Previous experience has shown that these models are unusable, not due to their scientific or engineering fidelity, but simply because DPWs that have attempted to make such models work cannot interact with the model's manufacturer when questions arise. Sharing information with a foreign company represents a potential operational security leak, and in practice, has proven too difficult.

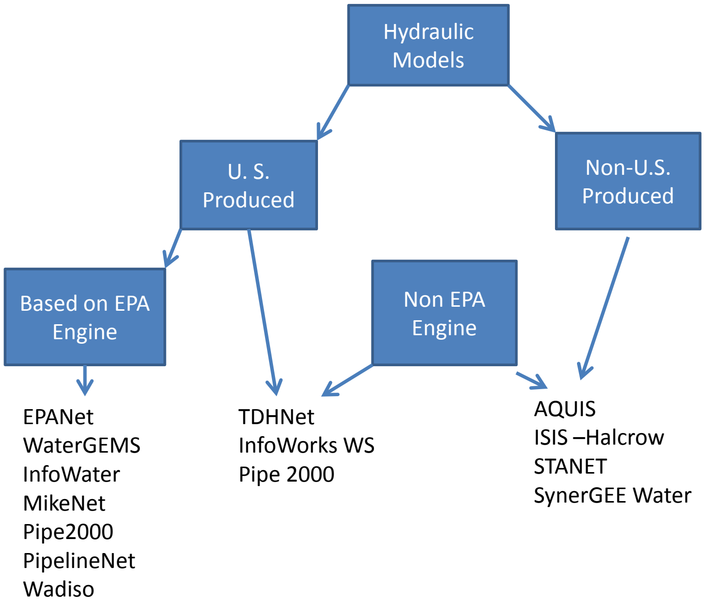


Figure 17. Taxonomy of hydraulic water distribution simulation software.

As work begins to customize a hydraulic modeling engine, or even to adapt the computational wrapper to the DoD's future needs, it would make little sense to work with proprietary software when the USEPA makes its engine's source code readily available. Furthermore, since most domestic hydraulic modeling engines are based on EPANet, the EPANet representation of a water distribution system is the lingua franca for data sharing among different parts of the Federal government. For these reasons alone, EPANet is usually the model of choice for further development in DoD and other Federal applications (Table 12).

Table 12. Representative list of hydraulic and network modeling software packages.

Network Modeling Software	Company	EPANet-Based?	Web Site
AQUIS	Seven Technologies	No	www.7t.dk/aquis
EPANet	USEPA	Yes	www.epa.gov/ord/nrmrl/wswrd/epanet.html
InfoWater H2ONet	Innovyze	Yes	www.innovyze.com
InfoWorks WS	Innovyze	No	www.innovyze.com
MikeNet	DHI, Boss International	Yes	www.dhisoftware.com/miknet
Pipe 2000	University of Kentucky	No	www.kypipe.com
PipelineNet	SAIC, TSWG	Yes	www.tswg.gov/tswg/ip/pipelinenettb.htm
STANET	Fisher-Uhrig Engineering	No	www.stanet.net
SynerGEE Water	Advantica	No	www.advantica.biz
WaterCAD/WaterGEMS	Haestad Methods	Yes	www.haestad.com

Current versions of hydraulic models offer a variety of built-in analysis features that will be of use in net zero water efforts. Because EPANet is the foundation of most water modeling software, its capabilities, which are particularly relevant to NZW, are listed here for reference:

- Hydraulic modeling capabilities:
    - place no limit on the size of the network that can be analyzed compute friction headloss using the Hazen-Williams, Darcy-use Weisbach, or Chezy-Manning formulas to include minor headlosses for bends, fittings, etc.
    - model constant or variable speed pumps
    - compute pumping energy and cost
    - model various types of valves including shutoff, check, pressure-regulating, and flow control valves
    - consider multiple demand categories at nodes, each with its own pattern of time variation
    - model pressure-dependent flow issuing from emitters (sprinkler heads or leaks)
    - can base system operation on both simple tank level or timer controls and on complex rule-based controls.
- Water quality modeling capabilities:
    - model the age of water throughout a network
    - model the age of water throughout a system
    - model the loss of chlorine residuals.

Using such capabilities, water distribution system models allow assessment of the effects on the overall system of proposed conservation measures or changes in operation. It is important to understand and mitigate potential negative effects of conservation measures. Such effects might include low- or high-pressure areas or problems with water quality including low disinfectant residual or problems related to water age in the distribution system. Hence, the model allows system operators optimize the system for energy consumption at lower water use without compromising water quality.

It is also important to be able to quantify cost/benefit parameters for proposed system improvements. For example, any EPANet-based system can incorporate leakage. That capability would simplify the analysis of a proposed measure to reduce leakage, such as advanced pressure management or allow assessment of the future affect of leakage increases if maintenance is deferred. Any EPANet-based system would also be able to predict energy use benefits due to operational changes such as adjustments to pressure or timing of pumping, e.g., to decrease on-peak electrical demand.

The cost of creating a complex model will vary greatly with the size and complexity of the system. Another factor affecting the cost of modeling is the availability of drawings and detailed information about the system. The basic information needed is the horizontal layout, the elevation of all pipes and structures, and, the age and material of each pipe and structure. Finally, the cost of a model will be affected by the intended use of the model and the needed methods and degree of calibration.

Of particular note for Army installations is the typical lack of building-level metering information. As stated above, metering can be carried out using a simple model to provide individual installation tenant organizations actionable information on their water use. Previous studies indicate that this visibility reduces water usage by about 16%.

While the installation will know its overall water use, detailed demand information about distribution will be sparse. The NZI Tool may offer a partial remedy for this problem because it models demand at a building and fixture level. Even without meters, the NZI Tool will provide better resolution for demand allocation in hydraulic modeling than would otherwise be available without building meters.

Based on information from consultants and vendors, and in very broad terms, smaller, easier, and less detailed model implementations at Army installations might cost as little as $70K, whereas larger and more complete system models could cost roughly $250K to create. The Army and the Army Corps of Engineers have enterprise license agreements with Bentley for the use of *WaterGEMS* software. The EPANET software from the USEPA is available free of charge.

7.1.3 Wastewater collection and treatment

Wastewater collection (sanitary sewer) system modeling is available, but is less widespread than potable water system modeling. It is not recommended to create sanitary sewer system hydraulic models for each installation unless special circumstances require one.

As described in Chapter 2, wastewater collection, treatment, and discharge can consume as much as 5000 kWh/MG (kilowatt-hour of electricity per million gallons of wastewater treated). It may be possible to incorporate evaluation of WWTP efficiencies and metrics into the net zero planning tool. Work will continue to explore the ways this planning model can make specific recommendations for practices within a WWTP. However, the measure to be considered may be somewhat specific, such as "install automation systems for energy optimization." Or, recommendations may be as general as to call for an engineering energy efficiency study of the system. The cost could be a factor of the plant's average daily flow and the expected benefit as an improvement of energy across a variety of uses.

7.2 Infrastructure conservation and efficiency measures

For the NZI water infrastructure modeling effort, one need is to identify specific measures for adoption by installations. This section discusses the idea of measures associated with water and wastewater infrastructure such as treatment plants, water distribution systems, and wastewater collection systems.

As a single example, consider leak detection. One approach is to reduce modeling output-recommendations for a given measure to a limited number of options such as: (1) status quo ("Do nothing."), (2) strongest response ("Do everything possible."), or (3) a middle ground recommendation. For the example of distribution system leak repair measures, options could be expressed as: (1) low option ("Repair leaks only in emergencies."), (2) high option ("Annually locate and immediately repair every detectable leak."), or (3) one or more middle ground options. However, cost-benefit information will need to be very general for this approach to modeling water infrastructure.

Another approach for analysis of measures is to assume the recommendation will be a best practice program or individual measure. For example, distribution system leak detection and repair can be thought of this way. The variable needed to determine and recommend to the installation will be the frequency of surveys, i.e., continuously." However, to follow the

AWWA approach for this kind of recommendation, the installation will need to have several years of data quantifying their leakage percentage. The resulting information would be a rate of change of leak occurrences, from which it is then possible to calculate an optimal interval of survey/repair efforts. If the installation has not completed a water balance, it would be recommended as a best practice.

7.2.1 Water distribution systems

Various measures can be considered for improving water and energy efficiencies in water distribution systems. A few of the more promising and accessible are part of the AWWA four-pillar approach to the control of real losses. These four measures include advance pressure management, speed and quality of repairs, active leak control, and, pipeline and asset management (AWWA 2007). Another promising measure for which cost can be quantified is hydraulic modeling. As discussed previously, the value of the benefits of hydraulic modeling are varied and significant, but are very dependent on situation. Hydraulic modeling can enable evaluation of other measures, such as improvements to the pumping system operations and advanced pressure management. Measures should aim not only to reduce, but to sustain lower real loss levels in the distribution system continuously.

Fort distribution system leakage, cost-benefit could be approached with a generalized parameter such as Infrastructure Leakage Index (ILI)

This kind of information can be collected in a water audit.

The ILI can be calculated as:

(Current Annual Real Losses [CARL]) / (Unavoidable Annual Real Losses [UARL]).

The ILI offers the advantage of allowing inter-utility comparisons. A possible disadvantage is that the formula for assessing unavoidable leaks is rigid (Dziegielewski and Kiefer 2010).

Before the year 2000, most utilities used the imprecise “unaccounted-for water percentage.” The target range for ILI will depend on the characteristics of the installation. ILI target values range from 1.0 -3.0 for systems with water limited resources and up to greater than 8.0 for systems with extremely ample water resources (AWWA 2009).

CARL is calculated as part of a water audit/water balance. CARL is calculated as system input volume minus authorized consumption minus apparent losses. UARL can be estimated in gallons per day according to the following equation (Dziegielewski and Kiefer 2010):

$$\text{UARL} = (5.41L_m + 0.15N_c + 7.5L_p).\ P$$

where:

L_m = length of water mains, miles
N_c = number of service connections

L_p = total length of private pipe, miles. This is normally obtained by multiplying the average distance from the curbstop to the meter. In cases where private pipe is not applicable, L_p might be assumed as zero, or an estimate might be made of the length of service laterals if those laterals are not included in L_m. Table 5-2 of AWWA Manual m36 (AWWA 2009) lists target ILI ranges and descriptions.

In many cases, the cost of ILI benchmarking will be low, provided the utility has a recent water audit/water balance. The remainder of the required information will be available to the utility or can be estimated with moderate effort.

Benchmarking enables the utility to understand the performance of their system in a way that enables reasonable goal-setting. The avoided cost associated with this measure could be estimated as the difference between current and target leakage quantities, multiplied by the incremental cost of water for the given utility. Of course, benchmarking alone will not save water unless followed up with other loss reduction actions. However, similar to water metering for end users, awareness of use and comparison to other utilities could result in benefits.

Hydraulic modeling also captures actionable information which is part of the water-energy nexus. Rough pipe surfaces impose head-losses and hence pressure drop in the distribution system. All pumps consume energy and can be upgraded by replacement and/or the application of motor controllers. All pump improvements decrease peak energy demand, and increase expected service life. These types of improvements can be accessed via hydraulic modeling.

Another measure under consideration is advanced pressure management. Information about water losses and use can be gathered during the water audits and from other sources. If it appears that an installation could reduce leakage significantly as a result of advanced pressure management, a water distribution system hydraulic model could be required.

7.2.2 Wastewater treatment

The performance of a WWTP can be evaluated based on energy use and unit quantities of treated wastewater. One must consider that wastewater arrives at treatment plants with varying characteristics and that disinfection processes vary from plant-to-plant. In addition, treatment plant equipment varies by age and type. Effective benchmarking would involve monitoring influent qualities, effluent permit requirements, other treatment plant parameters, and processing characteristics. One benchmarking effort, which looked at secondary treatment processes, calculated three parameters: (1) energy used per pound of biological oxygen demand (BOD) removed (kWh/lb BODr), (2) energy used per million gallons of wastewater treated (kWh/MG), and (3) oxygen transfer efficiency (OTE) (PG&E 2002).

Pumping and aeration are usually the largest energy users and these are often the target of energy savings analysis. One can think of energy conservation measures as conventional, being proven by use in the United States. One can also consider innovative technologies, which may be established overseas, but which are in being tested in the United States. Such technologies can be divided for analysis into pumping systems, aeration systems, blower and diffuser technology, solids processing, and special advanced treatment processes. For example, wastewater pumping system efficiencies range widely from 5% to 80%. System efficiency can be analyzed as the result of three components including pump, flow control, and motor, where each has its own efficiency (USEPA 2010).

The ability to model the efficiencies within a WWTP will likely be limited by the availability of plant electrical and water use information at the subsystem or process level. If the plant wastewater flow and electrical use is available, it is possible to make a general assessment at the plant level. Proposed measures could then remain general or might be more specific if based on surveys of the exact process being used at the plant and the measured performance of the equipment.

Another issue related to wastewater treatment is water reuse. If wastewater treatment effluent is to be reclaimed and used on an installation, it will require a dedicated transmission and distribution system. A hydraulic model will enable a quick assessment of the energy required for pumping and of the approximate pipe sizing and configuration. Such modeling is underway by the Omaha District at Fort Carson, CO. Each state has its own laws governing the treatment levels required and the allowable uses for reclaimed wastewater and any proposed wastewater reuse must be carefully explored (USEPA 2004).

7.3 Case study: Fort Carson

Fort Carson’s stated definition for “net zero” is that non-potable water use will equal potable use. Using Fort Carson’s definition, water use reduction and water reuse are of equal value in reaching net zero. Current targets include reducing potable use by 20% by 2014, 35% by 2017, and 50% by 2020, from the baseline year of 2007.

The Fort Carson utility personnel stated they are aware of many ideas for improving the water system, but they did not clearly indicate which ideas should be attempted first.

As of January 2012, Fort Carson has contracted with the Army Corps of Engineers Omaha District to provide a significant update to an existing, outdated, water distribution system model. The new model will be built on WaterGEMS software from Bentley. The District is evaluating two general areas in their study. The first is the potable water distribution system, including peak and average daily use for the system’s 9-12 pressure zones and 20+ pressure-reducing valves (PRVs). The District may divide the model into segments, probably by pressure zones, to make it more directly usable by the Fort Carson personnel. While these personnel are experienced and competent, it is as yet clear what modeling work Fort Carson staff personnel want to perform in-house.

The Omaha District contract will also include assessment of a piping system for expansion of irrigation using non-potable water from the WWTP. They will specifically irrigate the new parade field and running track area, and other athletic fields. The District has expressed the opinion that it may be possible to reuse 100% of the wastewater treatment plant effluent. If it is found that there is not enough effluent to irrigate all desired areas, then sensitive areas including housing will not be irrigated with WWTP effluent.

Fort Carson conducted a leak detection survey that identified 13 areas of leakage at an estimated rate of 40 gallons per minute for a total water loss of 57 kgal/day (Kenneth Hahn Architects 2012). However, not all leaks can be detected. It also may be deemed uneconomical to repair the smallest leaks, or leaks in difficult locations. Fort Carson has not used its water system model in the past to estimate leakage or the potential reduction in leakage from operational changes including pressure management. It should be feasible to perform field testing on representative mains that can be isolated. The results, including pipe parameters such as age, size, material, and operating pressure, would be used along with hydraulic modeling to predict installation-wide potential leakage benefits of pressure management.

In general, Fort Carson has expressed its preference to maintain high visibility areas in a “green” (not brown) condition, which requires irrigation. However, Fort Carson has also expressed also interest in xeriscape opportunities.

7.4 Recommendations

Significant water conservation measures can be based on simple models of water distribution system layout. By facilitating leak detection, simple models can reduce water use, typically by 25%-33%. By facilitating the placement of meters so that each individual tenant organization can be informed of its water use, private sector experience indicates such a measure will drop water usage by another 16%.

Hydraulic modeling is recommended for most installations. It is valuable both as a tool for evaluating the feasibility and benefits of various infrastructure measures. It can also facilitate operator understanding of the system’s dynamic behavior and facilitates operational policies that can decrease energy use. The price of hydraulic modeling varies widely (between $70K, and $250K) based on the detail of information captured and simulated. Given the long service life of the components, the benefits can easily justify the expense.

Another approach for future consideration would be to assess and address water infrastructure at Army installations with best practices. This would mirror various other studies and manuals for operation that are available in the literature, such as *Energy Efficiency Best Practices for North American Drinking Water Utilities* (Lelby and Burke 2011).

An additional area to consider for further research is to focus efforts on integrating subject matter expert knowledge into other net zero modeling by embedding EPANet-MSX (a Multi-Species eXtension of EPANET) as a hydraulic transport engine to measure water quality and residual chlorine levels. This model should be augmented by GIS information on building type and likely diurnal use monthly and should possibly be implemented under maximal (peacetime) and minimal (deployment) use to check if proposed changes to the system meet customer standards for water quality. The resulting simulations can be used as a decision support tool to help an installation prioritize system upgrades.

8 Conservation and Efficiency Measures

This chapter provides a brief description of water efficiency and conservation measures that are being considered for inclusion in the Net Zero Planner tool. Note that a tremendous variation exists in efficacy of any specific measure, the amount of water used or saved and energy requirements. Each measure should be investigated to determine its applicability for a specific installation. Fort Carson was referenced as a case study for some of the water measures. Policies, regulations, and technical guidance for each conservation measures are included with brief technology descriptions and recommendation for the measures implementation.

8.1 Distribution system strategies

The condition of water distribution systems on Army installations is similar to that of the United States at large in design and pipe age. This is because adjacent municipalities typically expanded at the same pace as the installation. Privatized distribution systems on post offer special challenges. Contractors are bound by the specific language of each contract. The utility privatization process has evolved over time and contract language varies. ACSIM documents a water reduction of 28% more at 20 privatized installations as compared to Army-owned systems (OACSIM undated).

Improvements in metering and leak detection are necessary to reduce water loss. The cost of unaccounted-for water includes wasted energy and treatment chemicals, liability from damage, loss of infrastructure capacity, increased flows to sewer collection systems and wastewater treatment, and wasted water. While standards for technical performance, increased efficiency, and reduced use have been implemented, no such Army standards exist for leak detection or repair.

8.1.1 Leak detection

A comprehensive assessment of Army installation water distribution systems has not been completed. Recent water sustainability assessments determined that many installations were unaware of unaccounted-for water rates. The water loss was estimated at 15%, the target established by the AWWA for unaccounted-for water (Jenicek et al. 2011). Historic surveys of

Army installations report 9% unaccounted-for water where it was possible to measure (Bandy and Scholze 1983). It is likely that leakage rates on post are presently the same as those for similar-aged systems in local communities, where water loss over 30% is reported. Proactive detection through methodical field work is the best solution for reducing water loss. Several methods and technologies are available to detect and control leaks.

Acoustic detection is the most common and diverse method for detecting leaks. Hydrophones, leak noise loggers, leak noise correlators, streaming cable inline acoustic leak detectors, free-floating inline acoustic leak detectors, acoustic fiber optics, and/or electromagnetic field detection can be used to detect the sounds that pipe leaks make. Thermal detection uses infrared radiation to find temperature differences in the surrounding ground caused by water saturation from leaking water. Electromagnetic systems that have been used to detect buried utilities can also be used to detect leaks. Ground-penetrating radar (GPR) locates subsurface leaks using a rolling unit going back and forth across the pipeline. Finally, the use of chemical tracers relies on the method of introducing a unique gas or liquid to a system. Leaks are detected if the chemical is found outside the system. The use of a tracer gas requires that pipelines be dewatered whereas trace liquids can simply be added to the water. It is recommended that installation personnel consult with the local drinking water regulatory agencies before implementation of liquid tracers (USEPA 2010b).

8.1.2 Leak repair

The techniques now available for leak repair help limit, but do not eliminate the need for excavation. Trenchless methods do not require a full excavation of the surrounding soil to fix or stop leaks. The reduction of required manpower and labor at inaccessible jobsites results in lower maintenance costs. The extent of open-trench replacement depends on the amount of pipe deterioration and availability of pipe in stock. Other remedies include wrapping, clamping, and slip-lining. Wrapping is usually limited to pipes with diameters of 4 in. (10 cm) or less, with rated services up 300 psi (2,068.20 kPa). Wraps are adapted for different environments and pipe materials above and below the ground. Clamps are metal collars with gaskets that compress the leakage site on the surface of the pipe. Slip-lining pulls a plastic liner filled with epoxy resin through a previously existing cleaned pipe to seal its leaks (USEPA 2010b).

8.1.3 Metering

The lack of building water meters at most Army installations makes it difficult to assess water loss (Jenicek et al. 2009). The DoD Advanced Meter Policy mentions the installation of advanced meters on all water intensive buildings and facilities by the end of FY20 (Conger 2013). Available meter types include propeller, ultrasonic, electromagnetic flow, differential pressure gauges, positive displacement, compound, proportional, and open channel meters (USEPA 2010b). Meter reading can be done manually or automatically. If a comprehensive building-level metering system is constrained by cost, then strategies which identify critical locations at an installation should be employed. Critical meters should be installed where use is greatest, most critical, and where conservation and leak repair may have the most benefit to the entire system. The draft Army Metering Policy (AMP) mentions that water metering should be based on: (1) water use intensity, (2) regional water supply versus demand, (3) available opportunities to reduce water consumption/water, and (4) (where effective) water main leak detection (Whitaker 2006, Valine 2013, HQDA 2011c).

8.2 Power plants, district plants, heating, ventilating, and air-conditioning (HVAC) systems and equipment

Power plants, district plants, HVAC systems, and other utility equipment account for a significant percent of water loss on an installation. Criteria for new buildings and major renovations include water-efficient technologies. Great strides in water loss prevention can be made through adopting a comprehensive and rigorous inspection and maintenance program. The following paragraphs summarize BMPs that can help attain NZW in power plants, district plants, HVAC systems, and equipment.

New water technologies that are required in new construction and major renovation should be considered for all existing buildings. These include retrofitting or replacing single-pass cooling systems, evaporative coolers, and humidifiers; collecting condensate from air-handling units for reuse; installing condensate receivers with pumps and piping back to condensate return lines for all condensate draining to wastewater systems; and equipping cooling towers and evaporative coolers with makeup and blowdown meters, conductivity controllers, overflow alarms, and efficient drift eliminators. BMPs for maintenance and repair include:

- Monitor and repair water distribution system leaks.
- Establish a steam trap inspection and replacement program.
- Establish a boiler inspection program, to include piping connections, deaerator, malfunctions, and neglected maintenance.
- Optimize the deaerator vent rate. Insulate the deaerator section and storage tank and all hot water and steam piping to avoid water and heat losses from condensation.
- Implement a water treatment program for boiler water systems.

8.2.1 Cooling towers

Cooling towers are often the largest end-use of water in commercial and institutional facilities, using between 20 and 50% of the facility's total water consumption. Cooling towers are used by a large variety of facilities to remove excess heat from the cooling fluids used in on-site chillers, air-conditioners and many other processes. While it is already mandated that cooling tower water be recirculated, cooling tower water is lost in two ways, including evaporation and blowdown (DUSD[I&E] 2005).

8.2.1.1 Policy

It is mandatory that all cooling towers and evaporative coolers be equipped with makeup and blowdown meters, conductivity controllers and overflow alarms. In addition, cooling towers must be equipped with drift eliminators that reduce drift to a maximum of 0.003% of the recirculated water volume for counterflow towers and 0.005% of the recirculated water flow for cross-flow towers.

ASHRAE (2009) provides specific guidelines on water quality, including the quality of water being discharged from cooling towers for air-conditioning systems such as chilled-water systems:

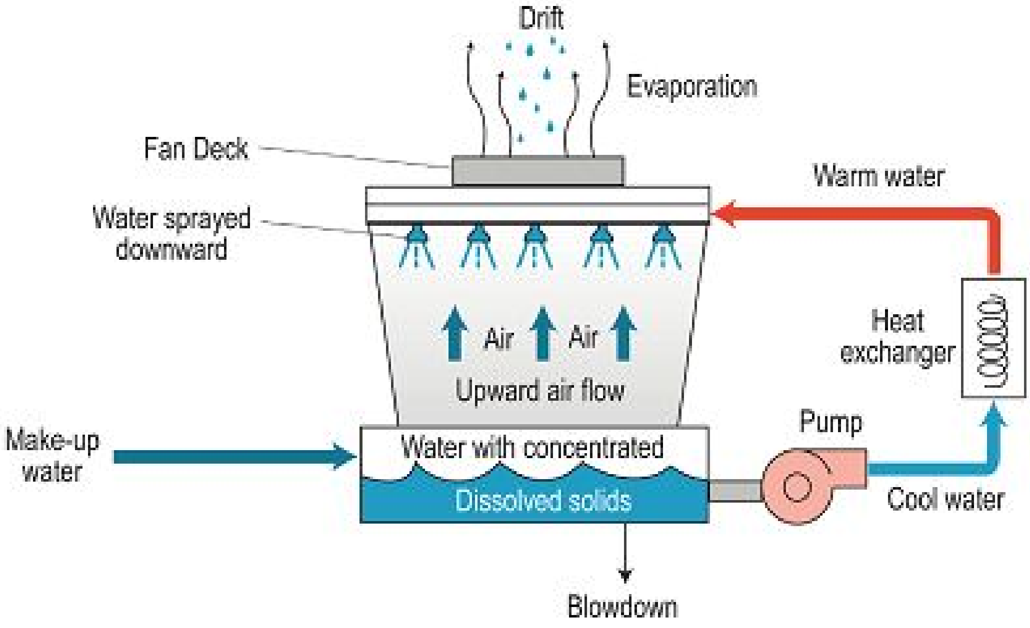
- For makeup waters having less than 200ppm (200 mg/L) of total hardness expressed as calcium carbonate, by achieving a minimum of five cycles of concentration
- For makeup waters with more than 200 ppm (200 mg/L) of total hardness expressed as calcium carbonate, by achieving a minimum of 3.5 cycles of concentration.

One exception to these guidelines occurs when the total dissolved solids concentration of the discharge water exceeds 1500 mg (1500 ppm/L), or when the silica exceeds 150 ppm (150 mg/L) measured as silicon dioxide before the above cycles of concentration are reached.

Additional water efficiency BMPs are available from the Federal Energy Management Program (FEMP 2011b).

8.2.1.2 Technology description

Cooling towers (Figure 18) help to dissipate heat from systems such as air-conditioners, chillers, and other building appliances. Cooling towers function by first collecting warmed water, e.g., water that runs through the coils of a heat exchanger, and carrying this warmed water via pipes to the top of the tower. Once this warmed water arrives at the top of the tower, the cooling process involves spraying or dripping the water through an internal fill (the large surface area of the fill aids in the heat transfer), often with fans forcing air through the tower in the opposite direction. This process causes some of the water to evaporate, which cools all of the water in the tower. After the water has been allowed to cool, it collects (typically at the bottom of the tower) and is ready to be recirculated again.



Source: Van Goor (2012)

Figure 18. Cooling tower schematic.

Conservation efforts do not generally try to decrease the amount of water lost to evaporation, because the evaporation is a critical part of cooling tower operation (USEPA 2012b). In general, for every 10 degrees Fahrenheit that the cooling tower decreases the temperature of the recirculated water, the tower will evaporate approximately 1% of the recirculating flow.

This evaporation causes a buildup of dissolved solids, often calcium, magnesium, chloride, and silica. If this buildup becomes too large, scaling will form, possibly leading to corrosion. As such, mineral buildups can be removed by replacing water that has built up excess dissolved solids with new makeup water. This process, known as blowdown or bleeding, may provide the best opportunity for installations to maximize water efficiency.

Treating cooling tower water may prove cost effective and help installations to meet water savings goals (HQUSACE 2012a). Chemical treatment is becoming a standard consideration in many steam and evaporative systems for both cooling and heating. Improvements to the quality of the water supplied to the cooling tower will minimize the need for blowdown because blowdown is an intentional response to water quality challenges. Non-chemical treatments are also a current area of research and development for cooling tower efficiency. While guidance on non-chemical treatment of cooling tower water has yet to be formalized, ERDC-CERL has found that such processes can greatly decrease the amount of flushing and refilling required when the dispersed particles in cooling tower water are charged. With initial system costs ranging between $21,000 and $32,000, the study found payback periods between 19 and 43 months with annual savings of $2,700 to $20,599 (HQUSACE 2012a).

8.2.1.3 Applicability

The opportunity to reduce blowdown depends heavily on the water quality of the cooling water. Waters with higher concentrations of dissolved solids are likely to cause more frequent scaling. In addition, the operating environment, such as temperature, may influence the sedimentation rate. As such, it is important that installations be aware of the quality of their incoming water. Many concerns an installation may have about dissolved solids are likely shared by local water infrastructure. Thus, best practices or additional needed treatment types can be learned from other users in the surrounding area.

8.2.1.4 Recommendations

The most significant opportunity for water savings from cooling towers is reducing the amount of water used for blowdown. The saturation point for the dissolved solids may be increased by chemically treating the water as it is recirculated. In other words, treating the water may allow the cooling tower water to build up more dissolved solids before those solids settle out and cause scaling. Any such improvement is likely to decrease the number of blowdowns that must occur, greatly decreasing wasted water.

The actual level and type of treatment may vary. However, considering treatments to increase the saturation point of dissolved solids is common engineering practice and occurs in many other areas, it is likely that installations will be able to find relevant local guidance on the quality of water in steam and evaporative systems. It is recommended that facility’s incorporate locally appropriate practices, as such practices are expected to enhance water conservation efforts. Installations considering acid treatments of the water should ensure that proper safety precautions are followed.

Facilities with cooling towers should install conductivity controllers to automate blowdown. Flow meters should also be installed on the makeup and blowdown lines. Both flow meters and conductivity sensors should be read regularly.

Options for retrofit include the construction of sidestream filtration systems, typically either cartridge filters or rapid sand filters, which are shown to be particularly helpful in dusty areas. Commercial water softening for makeup water systems should be considered when calcium and magnesium are causing scaling.

8.2.2 Boilers and water heating

Boilers and steam generators are common, and serve many different facility needs. Such systems may provide heated water and heated air to heat facilities, to run large kitchens, and to power steam-driven equipment.

8.2.2.1 Policy

EO 13423 (White House 2007) mandates the application of BMPs for boiler systems. Example best practices for steam boilers can be found in *BMP #8 – Boiler/Steam Systems* (FEMP 2011b).

Many steam and hot water boiler regulations and suggestions will also be found in guidelines covering their use, such as boilers for hot water systems and steam boilers for commercial kitchens. Installations should consult applicable policies for the facility under consideration.

In addition, installations are encouraged to supplement their hot water supplies from alternative sources. Department of Defense Instruction (DODI) 4170.11 (DoD 2009a) instructs facilities in areas with high solar radiation to consider cost-effective means to meet 30% of their hot water demand in newly constructed or renovated buildings with solar water heaters.

8.2.2.2 Technology description

In recirculating boilers, water is lost through two processes, evaporation and blowdown (DUSD[I&E] 2005). Impurities left behind by the water can cause a buildup of minerals in the recirculating water. Once this buildup exceeds its saturation point, the mineral begins to settle out as scaling. Blowdown is the engineered response to prevent these deposits. Minimizing scaling reduces the need for blowdown and prevents unnecessary water use. Options for decreasing scaling include the introduction of chemical treatment, which allows the concentration of the specified minerals to increase beyond their normal saturation points without settling. As such, blowdown would have to be performed less frequently, realizing water savings.

8.2.2.3 Applicability

The feasibility of upgrading or modifying boilers and steam systems depends highly on the size of the system, on the use patterns of the building, which may also be highly related to local climate, and on cost considerations. In general, one may expect the cost savings resulting from these system upgrades would come principally from energy savings. Water savings are an important added benefit.

8.2.2.4 Recommendations

An obvious way to decrease both energy and water use is to decrease the size of boiler systems. Reducing the demands of facilities served by boilers will decrease the amount of water required and thus the amount of energy required to heat the water. Facilities with existing boilers can undertake a wide range of modifications and management strategies to improve the water and energy efficiency of boilers and steam systems, including: leak prevention, improvement of steam trap integrity, addition of boiler system deaerators, treatment of system feed waters, and collection of condensate.

Water leaks and losses are an obvious inefficiency to be repaired in boiler and steam *systems*. Systems should be monitored for leaks and any necessary repairs should be performed. Particular areas to monitor for leaks include gaskets, fittings, valves, and pump seals (Jenicek 2011). Any piping systems used to distribute water to the boilers should likewise be inspected for leaks.

Steam condensate can be very corrosive and can thus damage the steam system plumbing and fixtures. Many steam systems are equipped with steam traps to alleviate such damage. Steam traps are devices that remove condensate removal while maintaining the flow of steam to heating coils, heat exchangers, and other heating elements. Steam traps are attached to these devices to discharge condensate while minimizing steam loss. Because of the corrosive nature of steam condensate, steam traps may often fail, resulting in either interrupted or continuous flow. As such, steam traps should be inspected at least twice a year. This inspection can be performed several ways (IEA 2009):

- Measure the pipe temperature downstream of the trap and compare it to the incoming steam temperature. If the two are approximately equal, then steam is escaping because the trap is stuck in the open position.
- Experienced testers can help to identify the proper operation of traps from the sound of their operation.
- Devices are available that can be installed with the trap, providing maintenance personnel with an indication of whether or not the trap is functioning as desired.

Boiler system deaerators should be inspected for malfunctions and regularly maintained. The deaerator vent rate should be optimized and all tanks and connections should be insulated to avoid heat losses. The connection of the suction-side of pumps should be tightened and inspected. PRVs may be added to avoid sudden steam losses.

The treatment of boiler water requires careful review by professionals. The incorporation of automatic treatment systems will help to appropriately add chemicals that maintain the correct pH, dissolved solids, and other required parameters (IEA 2009). Properly treating heating system water will help to prevent corrosion and fouling of pipes, fixtures, and heat transfer devices.

Condensate return systems will prevent condensate from being sent to wastewater streams. Systems with existing condensate returns should be inspected and properly maintained, whereas systems lacking such returns should be studied for possible retrofits. Condensate return systems could reduce water supply, chemical use, and operating costs up to 70% (HQDA 2011a).

Further energy BMPs should be considered. Large boilers should take advantage of blowdown heat exchangers to transfer some of the energy contained in blowdown water into the incoming boiler feed water. Many such systems also produce low-pressure steam, which may be used in other processes.

8.2.3 HVAC systems and cooling equipment

8.2.3.1 Policy

Overall guidance for HVAC systems is found in UFC 3-410-01, *Heating, Ventilating, and Air-Conditioning* (DoD 2013). Recent efficiency initiatives have stressed the importance of minimizing the water and energy losses associated with facility-level climate control. Unless specified in UFC 3-410-01FA or other applicable standards, HVAC designs are expected to comply with standards prepared by ASHRAE.

Single-pass, once-through cooling equipment is forbidden in most applications. *BMP #9 – Single-Pass Cooling Equipment* details water-efficient technologies and practices for eliminating or retrofitting single-pass cooling equipment (FEMP 2011b).

8.2.3.2 Technology description

The composition and uses of HVAC and cooling systems will vary widely. Such systems could be used to provide climate control for an entire facility, or to cool individual pieces of equipment from medical, industrial or commercial facilities. In addition, cooling equipment is often a critical component of HVAC machinery such as air-conditioners.

Single-pass systems use water only once for heat exchange, and then discharge the water into a wastewater stream. Compared to closed-loop systems that recirculate the water, single-pass systems are very wasteful. In cooling tower applications (Section 8.2.1) a single-pass system can use 40 times more water than a five-cycle cooling tower (HQDA 2011a).

8.2.3.3 Applicability

Because HVAC and cooling equipment span large and diverse uses, installations are expected to consult applicable codes and perform life cycle cost assessments to determine the technical and financial appropriateness of replacements and retrofits. In addition, the needs of the area being controlled must be considered. It is likely that HVAC quality and operations will be very different for industrial areas, computer server rooms, medical facilities, and areas requiring specific climate or cooling conditions.

8.2.3.4 Recommendations

Climate control and cooling systems are very diverse, and must reflect the needs of specific installations, climates, and facilities. Although recent trends in the United States have been toward facility-level heating, at locations overseas and in domestic institutions such as universities, it is common to find district level heating. When combined with power cogeneration, such plants may be far more efficient than facility-level planning. However, installations are encouraged to consider the high capital costs of such systems and to assess the appropriateness of centralized or decentralized heating case-by-case.

Recommendations that are applicable to specific end-uses may be found in their associated section. At the level of facility climate control, UFC 3-410-01 (DoD 2013) recommends that small, remote facilities that are occupied less than 168 hrs/wk adjust their temperature to a maximum of 50 °F during periods of disuse. Condensate collection should be considered for air-conditioning systems, especially those with a capacity greater than 65,000 Btu/hour), as discussed in Section 8.4.3.

8.3 Treatment plants

Central treatment plants offer opportunities to support NZW on Army installations. Advanced water treatment systems can enable the use of water that is otherwise unfit for consumption, for example, brackish or saline water. Wastewater treatment plants provide the opportunity to reclaim tertiary treated effluent for reuse for irrigation and other non-potable uses. Locating decentralized wastewater treatment plants close to point of wastewater generation reduces the need for extensive infrastructure.

8.3.1 Drinking water treatment

The primary role of drinking water treatment in NZW is the potential for emerging technologies to bring otherwise undrinkable water up to drinking water standards. Water purification removes unwanted solids, chemicals, and biological contaminants from source water for human consumption and other uses. Out of 84 water treatment plants documented on Army installations in 2008, 21 were privatized, 39 were exempted, two were being privatized, and 12 were to be evaluated (IMCOM 2008). In addition, 33 water systems have been privatized and 19 water systems are pending evaluation for privatization (ACSIM 2012).

Centralized water treatment plants work by extracting water from a source, treating in a centralized plant, and then pumping water to all system customers at a range of distances from the plant. Typical steps in the purification process include pre-treatment (screening, storage, pre-conditioning, and pre-chlorination), pH adjustment, flocculation, sedimentation, filtration (by rapid sand, membrane, or slow sand methods), and disinfection (using chlorine, chlorine dioxide, chloramines, ozone, ultraviolet methods).

Point-of-use/point-of-entry water treatment systems are a type of decentralized system. These water treatment methods are intended for use at the point of consumption, and are appropriate for small-scale application, e.g., on a small community or household level. They can be useful where safely storing water is a challenge. These systems are most often used in under-developed regions due to infrastructure constraints and in developed regions as a supplement to water treatment or to safeguard against particular contaminants of concern. Components of a point-of-use system include boiling, ceramic pot filtration, chlorination, cloth filtration, natural or chemical coagulation, pasteurization, sand filtration, and/or solar disinfection.

Other water treatment systems include membrane filtration, ultrafiltration, and reverse osmosis. Microfiltration (pore size of 0.01 micron) removes many micro-organisms, but viruses remain. Ultrafiltration (pore size of 0.01 micron) removes some viruses, but not dissolved substances. Nanofiltration (pore size of 0.001 micron) removes most organic molecules, nearly all viruses, most of the natural organic matter, and a range of salts. Reverse Osmosis (pore size of 0.0001 micron) removes virtually all organic and inorganic matter (including minerals), producing essentially pure water (SDWF 2011).

In November 2008 ERDC-CERL partnered with the Strategic Environmental Research and Development Program, the Army Research Office, the Army Environmental Policy Institute, and the WaterCAMPWS to sponsor the Military Applications for Emerging Water Use Technologies workshop. The workshop served as a platform for Government, academia, and trade associations to share information; to increase visibility of current efforts; to explore the potential of existing, emerging, and future technologies and other options for military installations; and to identify potential thrust areas where demonstrations and future research could be focused. The summary report contains a number of recommendations for both forward operating and fixed facilities (Scholze et al. 2009).

8.3.2 Wastewater treatment

The primary role of wastewater treatment in NZW is the potential use of treated wastewater as an alternate water source. Treating and reusing wastewater is becoming an acceptable solution to water scarcity. Sewage treatment is required to meet the Clean Water Act of 1972, which requires municipal wastewater treatment plants to meet secondary treatment level. Secondary treatment level requires the removal of dissolved and suspended biological matter, typically done with micro-organisms or aeration stations. Out of 84 sewage treatment plants documented on Army installations in 2008, 31 were privatized, 40 were exempted, one was in process, and 12 were to be evaluated (IMCOM 2008). In addition, 33 wastewater systems have been privatized and 18 wastewater systems are pending evaluation for privatization (ACSIM 2012).

Centralized wastewater treatment plants collect sewage through a conveyance system from a range of sources including residential, commercial, and industrial, and then treat the sewage in a centralized plant. The objective is to produce environmentally-safe treated effluent/treated sludge suitable for disposal or reuse. Combined systems may include stormwater runoff with the sewage.

Typical steps in the treatment process include pre-treatment (screening, grit removal, and fat and grease removal), primary treatment (sedimentation), secondary treatment (aerobic biological processes), sludge digestion, and sludge drying and finishing. Other treatment components may include activated sludge plants and surface-aerated basins.

Constructed wetlands are intended to mimic natural wetlands. These systems provide a high degree of biological improvement and can act as primary, secondary, and sometimes tertiary treatment. Alternatives include surface flow or subsurface flow, and horizontal or vertical flow. Unlike conventional treatment plants, the systems are robust; treatment capacity improves with time. Space limitation may be an obstacle to widespread adoption. A demonstration project is currently underway at Marine Corps Recruit Depot San Diego as part of the ESTCP program (Tertiary Treatment and Recycling of Waste Water, Engineer Regulation [ER] 201020). This project is demonstrating the Living Machine system. The system is currently operating at about 7,000 gallons per day with an end-state performance of 10,000 gallons per day. The Naval Facilities Engineering Command (NAVFAC) is currently engaged in the permitting process that will allow them to use the treated wastewater for sub-terrain irrigation (Maga 2013).

Reclaimed water is effluent generated by a WWTP that is treated to a level appropriate for reuse. Allowable uses vary by state. State agencies in charge of regulating water reuse are contained in the USEPA's *Guidelines for Water Reuse* (USEPA 2004). For installations that do not treat wastewater on-site, purchasing reclaimed water from a local source may be the more practical choice. Reclaimed water is generally lower in cost than potable water purchased from a utility. Installations with sewage treatment plants, whether contractor or Army-operated, may generate their own reclaimed water. The Federal Energy Management Program provides guidance for using reclaimed water (FEMP 2011a). Federal guidance encourages installations to combine conservation with reuse and to employ water reuse strategies where potable water would otherwise be used (CEQ 2013).

Decentralized systems are sometimes an option to eliminate septic systems or as an alternative to a centralized system, which may be more costly. Decentralized treatment to complement or replace central plants can provide the added benefit of reducing energy consumption of these processes. Cluster systems serve two or more dwellings and less than an entire community. One example of such a system uses watertight effluent collection pipes, sand-gravel filter treatment, and effluent disposal by subsurface drip irrigation. Decentralized systems may be cost effective and enable better watershed management by keeping water within the watershed from which it was withdrawn.

8.4 Alternate water sources

Alternate water sources are a major factor in attaining NZW. Atmospheric water is available as rain or stormwater, condensate capture, and water from air. Graywater is derived from sinks, showers, and clothes washers and can be collected locally or obtained as reclaimed or recycled water from a centralized treatment plant. Factors that affect the applicability and success of alternate water sources include technology, regulations, and maintenance. Public acceptance of reused water must be addressed through public outreach/education.

Naturally occurring water in the form of rainwater, stormwater, and condensate from water vapor are all available for non-potable use. Rainwater is typically collected from roof runoff into gutters and stored in rain barrels and cisterns. Stormwater is collected from storm drains and therefore tends to gather more debris and is exposed to different pollutants than rainwater. Consequently, stormwater is more likely to need treatment before use (Hoffman 2008). Condensate water is water that condenses on a surface that holds a temperature below dew point. Water vapor is regularly collected in air-conditioning and refrigeration units that operate in warm, moist places. Condensate water is generally clean enough to be put to either of these uses without treatment (Chesnutt, et al. 2007) (Hoffman 2008). The capacity to collect water is regionally dependent and laws that govern collection vary from state to state (Johnson 2009)

8.4.1 Rainwater harvesting

Climate change is not only affecting global temperatures; it also affects the amount of precipitation and available water. As global water supplies become more variable, the need to conserve water is becoming more apparent. Rainwater harvesting offers an opportunity to decrease water and wastewater cost and can be most effective when coupled with water conservation. The system requires collecting, storing, and conserving rainwater runoff as part of the design for later usage such as landscaping and irrigation. Installation for rainwater harvesting can also encourage water efficiency and saving energy.

8.4.1.1 Policy

There is no specific Army regulation or policy that addresses rainwater harvesting. Rainwater harvesting system installation is a voluntary effort for buildings. Some of the requirements for water management systems and wastewater treatment can be applied to rainwater harvesting. Water efficiency guidance often recommends installation and management of rainwater harvesting systems. Useful guidelines for potable and non-potable rainwater harvesting systems are published by The American Rainwater Catchment Association (ARCSA). Some states in the United States are developing rules on rainwater harvesting. For example, Texas passed legislation requiring any new state building with a footprint greater over 10,000 sq ft to install rainwater harvesting equipment. Albuquerque-Bernalillo county also passed new standards that require rainwater harvesting system for new homes that need to capture the runoff from at least 85% of the roof area. Ohio also has codes and rules for rainwater harvesting systems (HQUSACE 2010).

8.4.1.2 Technology description

Rainwater harvesting components usually include a catchment surface, gutters and downspouts, leaf screens, first-flush diverters, filters, storage tanks, pumps, and disinfection equipment. The size of catchment and storage containers typically depend on climate and demand. Designs may be above or below ground. Factors such as outside temperature ranges, soil, available space, and budget usually determine what type of tank should be used. Tank materials may include fiberglass, polypropylene, galvanized metal, or concrete (TWDB 2005).

Rainwater can pick up roof debris and organic material en route that need to be filtered before entering storage. Bacteria levels in untreated rainwater should be tested routinely. Additional treatment of rainwater, using ultraviolet (UV) radiation or ozone, for example, can usually achieve levels of water quality high enough to be potable (TWDB 2005).

8.4.1.3 Applicability

Rainwater harvesting can be implemented and is applicable to most types of Army buildings and facilities from residential to commercial of any size. The most common type of rainwater harvesting is collecting rainwater from the roof. Storage capacity varies by installation, depending on the building size and amount of rainwater being collected. Different types of materials are available for the storage tank, pumps, disinfection equipment and the pipes needed for the rainwater harvesting.

8.4.1.4 Recommendation

Rainwater harvesting is an excellent way to conserve water and practice water reuse. The amount of rainwater collected can be significant depending on the climate where the buildings and facilities are located. Fort Carson, CO, has a semi-arid climate with annual rainfall of about 16 in. (Fort Carson 2010) mostly during April to September. The annual rainfall is relatively low compared to other Army facilities in different regions in the United States, but for regions such as Fort Carson, rainwater harvesting can be implemented seasonally. Besides seasonality, legal issues must also be considered before rainwater harvesting can be installed. Many installations hesitate to install rainwater harvesting due to the aesthetically unpleasing design of the rainwater collecting tanks. However, rainwater catchment tanks can be designed to accommodate the amount of local rainfall and to complement a facility’s roof catchment size.

8.4.2 Stormwater

Rainwater is naturally absorbed quickly by vegetation and trees, infiltrated into the soil, or evaporated back into the atmosphere. However, when the precipitation amount is large or the ground is an impermeable surface, the rainwater quickly becomes stormwater runoff. Heavy stormwater runoff can scour streambeds, erode stream banks, overfill stormwater systems, and transport polluted sediment downstream to pollute water bodies at a lower elevation. Section 438 of the EISA 2007 is intended to address the inadequacies of the historical detention approach to managing stormwater and promote more sustainable practices that have been selected to maintain or restore redevelopment site hydrology (USEPA 2009).

8.4.2.1 Policy

Section 438 states that any development or redevelopment project involving a Federal facility with a footprint greater than 5000 sq ft must use site planning, design construction, and maintenance strategies to maintain or restore, to the maximum extent technically feasible, the pre-development hydrology of the property with regard to the temperature, rate, volume, and duration of flow.

8.4.2.2 Technology description

Based on the design water volume calculated, the design options must meet the maximum extent technically feasible (METF). Technical constraints also need to be considered and implemented when considering on- and off-site design options. Green infrastructure/low impact development (GI/LID) tools are preferred practices. Some of the GI/LID practices include green roof, planting trees and tree boxes, rain garden, vegetated swales, pocket wetlands, infiltration planters, porous and permeable pavements, vegetated medium strips, reforestation and revegetation, and protection of riparian buffer and floodplains (USEPA 2009).

8.4.2.3 Applicability

Any Army facility with a footprint greater than 5000 sq ft is a candidate for development or redevelopment for stormwater management system. Any development or redevelopment of Federal facilities should consider the hydrologic response to the development and follow Section 438 guidelines (USEPA 2009).

8.4.2.4 Recommendation

Stormwater management can be implemented at Fort Carson during the summer season, when the installation receives 80% of its annual rainfall. Although the area does not get amounts of rainfall significant enough to create stormwater management problems, it is important to understand that development and redevelopment can still have negative effects on hydrology. Facilities with large impervious surface area such as parking lots should stormwater control practices that can effectively reduce the volume of stormwater discharge. Designers can plan buildings and facilities in developing (or redeveloping) areas that incorporate stormwater management simply by including and implementing more green space.

8.4.3 Air-conditioning condensate

Many Army installations can successfully apply condensate capture and reuse technologies that match their local climate, building type, and building use patterns. For example, cooling towers make up one of the highest water demands in many buildings. At the same time, condensate generated from air-handling units (AHUs) is treated the same as wastewater. It is diverted to drains which incurs costs for both treatment and disposal.

Cooling towers, which are often located close to AHUs, draw on potable water supplies for makeup water required to replace water lost to evaporation. Connecting these water-producing and water-using components within the same building system will preserve potable water for required uses, reduce energy required to process and pump potable water, reduce cost for purchased water and condensate disposal, and support sustainable water supplies for the future. Other opportunities for water reuse include toilet or urinal flushing, makeup for water features, or landscape irrigation. Use of condensate for other purposes may require additional treatment, especially if the water will be exposed to the atmosphere in open containment.

8.4.3.1 Policy

EO 13514 (White House 2009) directs agencies to identify, promote, and implement water reuse strategies that reduce potable water consumption. ASHRAE 189.1-2009 (ASHRAE 2009) addresses water reuse within buildings and provides requirements for condensate collection in new construction and SRM. Mandatory provisions include recovering condensate from air-conditioning units with a capacity greater than 65,000 Btu/h (19 kW). ASHRAE also mandates water reuse for landscaping. The USGBC (2009) standards for Existing Buildings: Operations and Maintenance (LEED-EBOM) recognizes the use of alternate water sources for cooling tower makeup through water efficiency credits.

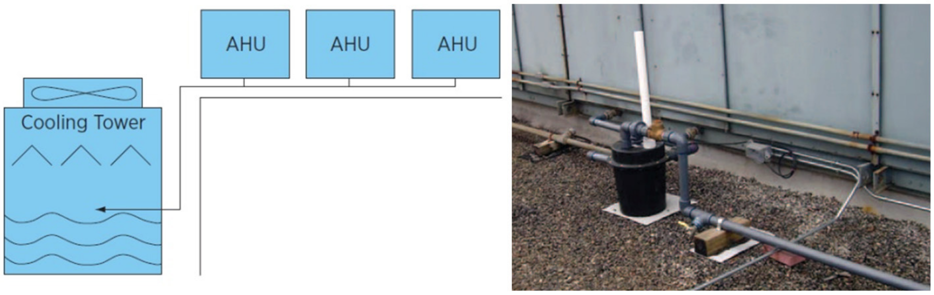
8.4.3.2 Technology description

Heating and cooling AHUs are typically located on facility roofs. During cooling, air passes through the chilled cooling coils before entering the building. In regions with a hot and humid summer, condensate forms rapidly as air passes over the cooled coils. The amount of condensate that drips into the collection pan below the unit can range from between 3 to 10 gal/day/1000 sq ft of air-conditioned space. Condensate drains through lines routed to sewers through floor drains or piping, or simply to the outdoors. Condensate is typically high quality water with low mineral content that is suitable for reuse in cooling towers with little to no treatment.

Condensate capture systems can be inexpensive to install and can reduce demand for potable makeup water for cooling towers between 5 and 15% (Figure 19). Case studies realized paybacks ranging from 6 months to 6 years. Based on the literature reviewed for this report, installations with water costs of $1.66/kgal, the calculated Army average cost of potable water for FY2011, will realize an 18-month payback.

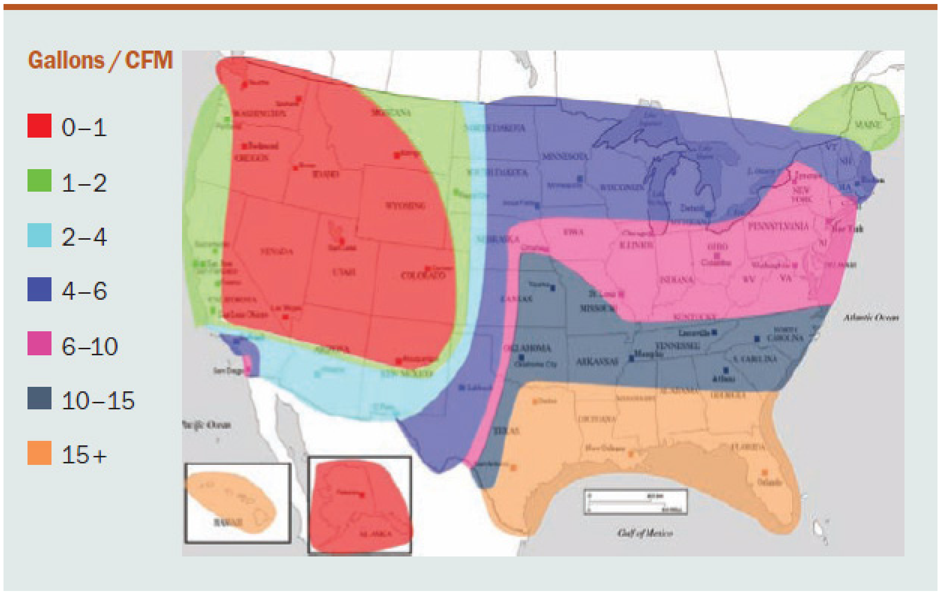
8.4.3.3 Applicability

Many Army installations can successfully apply condensate capture and reuse technologies that match their local climate, building type, and building usage patterns. The availability of adequate amounts of condensate for collection depends on ambient humidity and the number of hours per year of mechanical cooling required. The southeastern United States is an obvious locale for effective condensate collection (Figure 20).



Source: FEMP (2010a)

Figure 19. Schematic of AHU condensate recovery system and collection manifold from three AHUs at USEPA in Athens, GA.



Source: Lawrence and Perry (2010)

Figure 20. Map of condensate collection potential.

Other marginal areas will depend on building occupancy, type, and outdoor air requirements (Lawrence and Perry 2010).

Recent research efforts (SDWF 2011) have developed and validated estimating guidelines for determining the amount of condensate available for reuse more precisely than previous calculators and rules of thumb. The condensate prediction and correlation studies used only three values average dew point, cooling degree days, and April–October rainfall to develop the correlation equation:

Condensate (gal/dfm) = 0.4777 x Avg. DP + 0.00204 CDD + 0.32596 x [April through October Rainfall] – 22.5 Equation 1

Table 13. Economics for some documented condensate reuse projects.

Location	Building	Project Cost	Condensate	Savings ($)	Payback
San Antonio	Rivercenter Mall	$32,057	1.1 MG/month	$49K/yr	8 mos.
San Antonio	Public Library	$21,500*	1440 GPD*	?	?
San Antonio	Sony Semiconductor	$5,777	5198 GPD	$4,371/yr	16 mos.
San Antonio	HEB Grocery Dist Ctr	$19,000		$20K/yr	11 mos.
Houston	Memorial City Plaza	$1,300	1506 GPD	$2,775/yr	6 mos.
Athens, GA	UGA Vet Med	$3,200	1233 GPD	$3,375/yr	2 yrs.
Athens, GA	USEPA SESD Division	$24,500	2250 GPD	$5,250/yr	< 6 yrs.

*GPD=gallons per day; MG=million gallons

These values were calculated for 47 locations throughout the United States. The figures were then validated with recorded condensate data for existing collection systems in those locations. The study validated the map in Figure 20, finding locations in the southeastern United States produced the greatest amount of condensate (Lawrence, Perry, and Alsen 2012)

The overall cost of a condensate collection system depends on the size of the system, the intended reuse, and whether the system will be a retrofit installation or included in new construction. Other variables include whether the system should be configured to include rainwater collection as well. Table 13 lists the economics of some documented retrofit projects. The building design or layout of existing structures may preclude some condensate collection and reuse schemes. The demonstration shown in Figure 19 required minimal retrofit.

The second phase of the condensate correlation project (SDWF 2011) was to evaluate the economics of condensate collection and reuse. This evaluation assumed a simple system with a low first cost. The study concluded that the cost of water was a major factor affecting whether retrofit projects could achieve a quick payback. Additionally, reuse of water for toilets requires cisterns, pumps, and some degree of filtration/treatment. Including rainwater collection in the project would require filtration/treatment and storage.

8.4.3.4 Recommendation

Harvesting air-conditioning condensate for non-potable water supplementation can save water, energy, and funding and help installations meet water reduction goals. Conserving highly treated drinking water also supports water security by providing a locally-controlled water supply.

Environmental benefits include decreasing wastewater discharges and decreasing diversion of water from sensitive ecosystems. Additional benefits include relieving stress on water infrastructure by reducing water volumes. Army installations in water-stressed regions compete with local communities for resources. Therefore, by reducing the Army's consumption, the Army fosters good community relations.

Condensate capture and reuse in cooling towers is the most cost-effective water reuse technology placing a high quality supply adjacent to a continuous demand. Cooling towers typically operate at the same time as do ventilation cooling coils. Case studies indicate that collected AHU condensate can provide up to 15.9% of cooling tower makeup water.

Installations with condensate collection potential of at least 3 gal/CFM should evaluate cooling systems for applicability of this measure. The final decision should be based on the results of an LCC assessment that shows the potential to generate and collect condensate, the potential to use collected condensate, the cost of the retrofit, and the local cost of water. This specific retrofit is applicable to any building-level AHU-cooling tower system that generates enough condensate to be cost effective. Moreover, under certain circumstances, e.g., in times of drought, water reuse may be beneficial to installations even when the strategy cannot be justified on the basis of savings alone.

8.4.4 Filter and membrane reject water recovery

Principles of sustainability and water conservation also apply to the practice of water treatment; sustainable water practices should be incorporated into the water treatment infrastructure. Drinking water treatment membrane plants can produce a large wastewater stream, up to 8–10% of the plant's capacity (Christensen 2012). Although most of the reject water from filter and membrane is commonly discarded to the sanitary sewer system due to its high concentration of pollutants, this water can be repurposed for such uses as landscaping, irrigation, and even for other processes within the treatment plant.

8.4.4.1 Policy

Current policies and regulations do not address the recovery of reject water from drinking water treatment infrastructure for reuse. Installations should review local laws and ordinances, the drinking water treatment methods, and the amount of water treatment required to determine whether recovery and reuse of reject water is feasible.

8.4.4.2 Technology description

The main technologies needed to recover filter and membrane reject water are treatment systems for the reject water. Treatment systems can vary depending on the desired use of the recovered water. The amount of treatment of the recovered water can also vary depending on the type of filter used. For example, microfiltration can increase the recovery in reverse osmosis system (Shen 2011).

8.4.4.3 Applicability

Reject water can be used for landscaping, irrigation, cooling tower makeup, swimming pools, and even for other processes within the plant. Recent examples in which filter backwash and membrane reject water have been recovered for use include:

- In Texas, backwash water from several swimming pools has been used to irrigate nearby park land.
- A major microelectronics manufacturing plant in Austin, TX has used reverse osmosis reject water combined with stormwater for landscape irrigation.
- Many industries use reverse osmosis reject water for cooling tower makeup (AWE 2010a).

8.4.4.4 Recommendation

It is recommended to conduct a feasibility study before implementing a new reject water recovery project, especially one that will employ filtration and membrane processes. Water treatment plants that create a large amount of reject water may be likely candidates for recovery water treatment. However, plants in which most of the reject water is blackwater (rather than graywater) will need to implement further treatment for the reject water recovery.

8.4.5 Foundation drain water

Foundation drains remove water that could potentially harm the foundation and use gravity flow to direct it away from the building to some low spot in the landscape. Building codes require perimeter drains around the foundation of the building to protect the base of the building from water that has seeped through the soil. A traditional foundation drain system does not concern itself with the water after it leaves the drain outlet. However, depending on the regional climate, the quantity of water captured through foundation drainage can be significant and may be a considerable resource for reuse.

8.4.5.1 Policy

Every building is required to have a foundation drainage system to prevent moisture and water from damaging the building foundation. Depending on the building's elevation, drain tile, typically a corrugated plastic pipe (Figure 21) placed along with the footing, is one means of draining foundations. There is no specific Army guidance for installing a system to capture foundation drainage water.

8.4.5.2 Technology description

A foundation drainage collection system includes a pump, a storage tank to hold the drain water, and, if needed, a simple treatment system. Proper use of filter cloth and drain tiles is necessary to prevent clogging and corrosion of the drain lines. Depending on the intended use of the recovered water and the nutrient concentration in soil, recovered water might have to be treated before reuse.

Figure 21 shows a drain tile with a protective filter cover that keeps silt and sand from clogging the system. Drain tile like this can be used to transport the drained water to the desired storage tank (USDOE undated).

8.4.5.3 Applicability

Foundation drains can be designed to connect with subsurface pipe systems allowing water to be distributed over large areas. The landscape and climate of the area is important when developing foundation drain water catchment systems. Foundation drains can retrieve significant amounts of water that can be used for irrigation during the dry season.

Source: USDOE (Undated)

Figure 21. Drain tile with protective cover.

8.4.5.4 Recommendation

Buildings or facilities with large rainwater catchment areas in wet climates can benefit from installing foundation water drains. Unlike stormwater runoff, foundation drain water goes through the soil, allowing drains to be installed underground.

Foundation drain technologies are fairly simple. The technology can be incorporated during building construction when developing the foundation. It is important to install filters or drain tiles along the piping and the drain to prevent clogging. The drain material should be resistant to corrosion.

8.4.6 Cooling tower blowdown

The reuse of cooling tower blowdown faces some technological impediments. However, substituting alternative sources for potable makeup water used to replace blowdown losses does represent a significant area for installations to realize water savings.

8.4.6.1 Policies

Due to the challenges with reusing blowdown water, there is little policy guidance or relevant precedence. Facilities should consider their water quality needs before incorporating an alternative water source such as blowdown water. When properly treated, blowdown waters can be used in accordance with policies for the reuse of treated graywater from industrial sources as opposed to other policies regarding recycled water (HQAFCESA 2008). Alternative sources of makeup water should be encouraged and evaluated case-by-case. The use of potable water in building systems should be minimized when cost effective (DoD 2013).

8.4.6.2 Recommendations

Cooling tower blowdown is typically disposed of directly into wastewater systems. Because cooling towers often replace large quantities of water with blowdown, the potential to reuse such a source is of interest to any installation attempting to increase water reuse. There are, however, significant obstacles to the reuse of cooling tower blowdown.

The obstacle of particular concern is the mineral content of cooling tower blowdown. Blowdown is an engineered process used to replace low quality water, in this case, water with a buildup of dissolved solids, before it can cause damage to plumbing and mechanical systems. Because of this, blowdown water is already considered to be of too low quality for cooling tower use.

One exception to quality concerns is a systems that replaces water too often and thus discharges blowdown that is still of suitable quality for cooling tower operation. However, in these systems it is more advisable to reduce the blowdown rate, and thus worsen the quality of blowdown water, than it is to waste large quantities of usable water through inefficient blowdown schedules.

Installations should also consider the chemical composition of blowdown water when evaluating for possible reuse. The high salt and mineral content in blowdown water may make it unacceptable for irrigation purposes, and could additionally risk damage to machinery and plumbing. However, this water may be used for purposes where quality is not paramount such as dust suppression or vehicle washing.

It is advisable that installations consider using alternative water sources for cooling tower operation. These sources are likely to require additional treatment before the water may be used as makeup water to minimize cooling tower blowdown and maintenance. While it would be ideal to cool systems using non-potable water, installations must consider the capabilities of their treatment infrastructure when making such decisions. Treatment is a specialized and technical field. Installations are encouraged to seek professional guidance from both cooling tower experts and experts on water quality.

8.4.7 Atmospheric water generator

Condensate collection may be accomplished using an atmospheric water generator (AWG). An AWG is a device that extracts water from air. Water may be extracted from humid ambient air by cooling or by using desiccants. Historical methods include air wells in Middle Eastern deserts 2000 years ago and water-collecting fog fences.

8.4.7.1 Policy

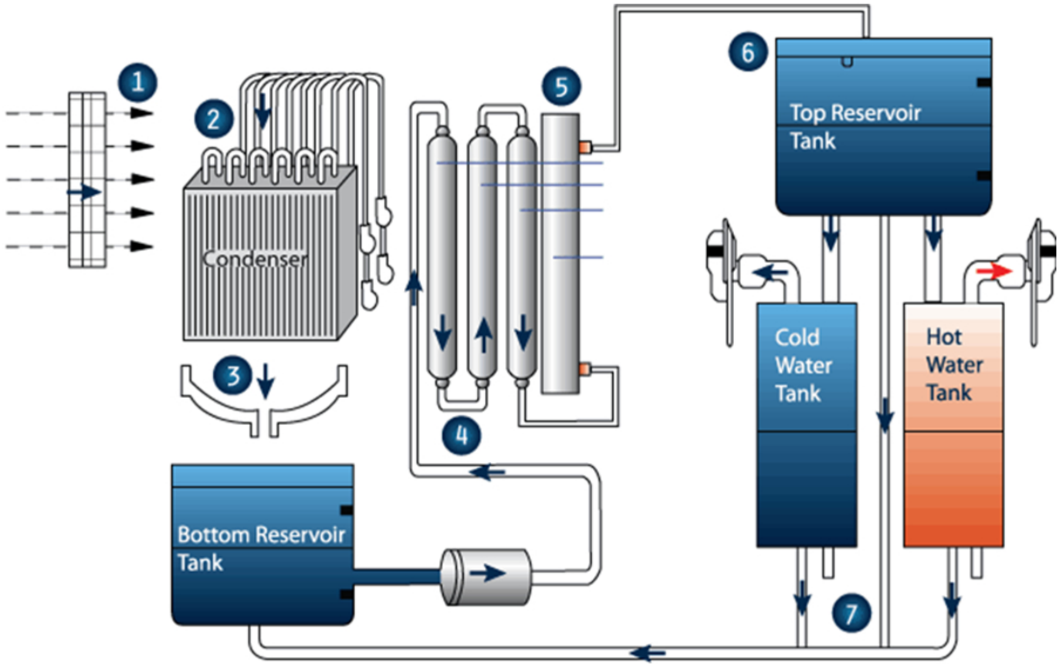
The use of an AWG can be helpful in regions where water is scarce. This technology is recommended if possible. If condensate water is to be used as drinking water, the water quality must meet the USEPA drinking water standards. Any AWG system that produces drinking water must have a filter in the system to meet these standards (HQUSACE 2008a).

8.4.7.2 Technology description

An AWG extracts water from humid ambient air by condensing the water vapor in air and cooling it below the dew point. Unlike a dehumidifier, an AWG is designed to produce pure water.

Air is passed through a cooled coil allowing the water to condense. The compressor circulates refrigerant through a condenser and then to the evaporator coil. An AWG works most efficiently when the temperature is above 65 °F with relative humidity above 30% (Figure 22) (Atmospheric Water Supply 2012):

1. Air is drawn into the AWG and filtered.
2. Filtered air is passed over a condensing unit.
3. Water is collected.
4. Water is pumped through filters.
5. Water goes through filter and UV light for purification.
6. Purified water is collected.
7. Pure water is dispensed.



Source: Atmospheric Water Supply, LLC (2012)

Figure 22. Typical AWG diagram.

AWG technologies can be applied to many different water end-uses such as residential, commercial, disaster relief, and humanitarian applications. AWG devices vary in size and in the amount of water that they can generate. Depending on the purpose and use, different types can be selected. AWG is more applicable in some regions than others and attention must be paid to the amount of energy that is required to operate these systems.

8.4.7.3 Recommendation

Extracting fresh water from the atmosphere is a sustainable way to generate water especially in areas where surface and ground water are scarce. With the right type of climate, AWG can be a very effective technology for obtaining clean water. AWGs are becoming increasingly popular for generating safe drinking water. The technology can be used on many different scales and is readily available.

8.4.8 Graywater reuse

Graywater is wash water or water discharged from lavatories, showers, bathtubs, clothes washers, and laundry trays. Graywater reuse is a term describing the reclamation, treatment, and recycling of these waters. While irrigation and toilet flushing are two of the most common reuses of water, a variety of other possibilities exist, including groundwater/aquifer recharge, heating/cooling (cooling towers, water-cooled equipment, and boilers), vehicle washing, and some industrial processes. Recycled and reclaimed water must meet quality standards that ensure protection of health and user acceptance (Duffy 2011).

8.4.8.1 Policy

Graywater reuse is generally regulated at the state level. This, in turn, is reflected in building plumbing codes. In addition, counties often have specific health-related requirements. The greatest potential regulatory risk for graywater reuse in general is use in states that do not allow graywater reuse. Army installations planning to use graywater at the building level should work closely with local authorities to establish a standard for processes and/or water quality.

The IPC, the USEPA, and ASHRAE have established some requirements for graywater systems, e.g., purple piping for visibility and backflow controls to prevent cross contamination. Other code provisions may include requirements that govern required treatment level; material, type, and location of locking valves; marking; separation/barriers; and signage. An example of state requirements is in California. Regulatory Framework Title 22 (State of California 2007) requires inspection by an AWWA cross-connection control program specialist before initial operation and annually thereafter.

Two main consensus standards for graywater treatment systems are in place. The first is the NSF350, *On Site Residential and Commercial Water Reuse Treatment Systems*" (NSF 2011). This standard covers systems up to 1500 gpd treatment capacity for restricted and unrestricted potable use. This standard requires a 26-week testing period (Martin 2010). At the time of this publication there were six single-family residential treatment systems that were certified under NSF/ANSI Standard 350 for Water Reuse.

The second standard is the Canadian Standards Association (CSA) B128.3, *Performance of Non-Potable Water Treatment Systems* (CSA 2012). This standard covers packaged non-potable water reuse systems for wastewater and graywater to approximately 2650 gpd treatment capacity. This standard specifies Class A and Class B quality of reclaimed water and requires a 46-week testing period (Martin 2010).

8.4.8.2 Technology description

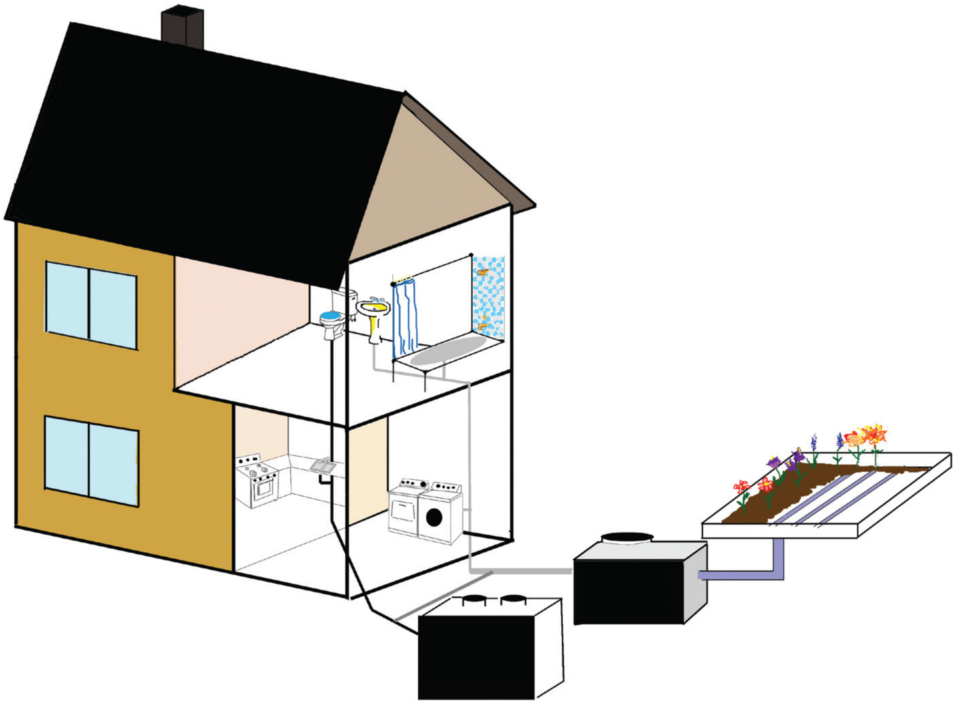
A wide range of technologies have been used to recycle graywater, from simply using laundry rinse water from one load as wash water for the next load, to direct discharge of graywater to irrigation. Many systems are also focused on disposal rather than reuse. Systems can be as simple as collecting graywater without treatment or as complex as including real treatment plants on a miniature scale. Typically, systems designed to provide minimum treatment use coarse filtration or mesh screens to remove large objects such as hair, threads, and lint, and then channel the graywater into an underground irrigation system (HQUSACE 2012b).

More complex systems are used to process graywater for uses other than irrigation (e.g., toilet flushing). Such systems might include living systems that use water plants or sand filtration. At the higher end, many commercial packaged systems produce a filtered, disinfected product (USACE HQUSACE 2012b). When using graywater for irrigation, drip irrigation hoses should have holes with a diameter of at least 3 mm to reduce the potential for clogging from solids present in the graywater or from algae growing in the hose (Figure 23). Possible risks and unfavorable side effects of graywater reuse, such as odor and mosquitoes, can be reduced by eliminating the storage of the graywater. Graywater is suitable for irrigation but should be applied no faster than the rate at which soil can absorb to avoid saturation and pooling of the graywater (HQUSACE 2012b).

8.4.8.3 Applicability

For military applications, the best time to install and design for graywater use is during new construction. The first step is to estimate graywater production and whether there will be enough demand for the volume of graywater generated. A multi-family apartment complex or a large barracks on a small property might generate so much graywater that most of the flow winds up in the sewer system, or a single-family residence may require significant potable makeup water (HQUSACE 2012b).

Planners must first consider whether the regulatory climate allows graywater use either inside or outside the building. As mentioned earlier, some areas welcome and encourage graywater use, whereas others ban it or have onerous requirements for testing and reporting (HQUSACE 2012b).



Source: HQUSACE (2012b)

Figure 23. Graywater system schematic showing subsurface drip irrigation.

Packaged systems

Packaged graywater treatment systems are off-the-shelf and ready for installation. They are widely applicable and not project specific. Systems are generally simple, consisting of a three-way diverter valve, a treatment assembly, such as a sand filter, a holding tank, a bilge pump, and irrigation or leaching system. Building-scale systems are in use overseas and not widely implemented in the United States, but are receiving considerable attention from organizations such as the International Water Association (IWA).

A simpler form of graywater reuse can be implemented in washrooms. The water from the lavatory can be collected under the sink and transported to the flush fixture’s tank to be used for flushing. Such a technique could be retrofitted to existing bathrooms.

8.4.8.4 Reclaimed water

Reclaimed water refers to water that may be regionally available from local or regional water reclamation facilities. Reclaimed water is generally filtered and disinfected. It is then available for use in urban areas.

8.4.8.5 Graywater reuse challenges

The biggest challenges facing graywater are regulatory, though severe droughts have helped to ease those restrictions in some regions. States that have regulations permitting graywater use include Arizona, California, Montana, Nevada, New Mexico, Oregon, Texas, and Utah. This list is anticipated to increase as concerns about water scarcity continue to grow.

Public acceptance is a challenge for the reuse of graywater within buildings. The most common concern is the potential threat to human health. However, demands on operation and maintenance, user perceptions, and water aesthetics can also be strong determinants of user acceptance.

A final barrier to the widespread adoption of graywater reuse is the economic challenge of modifying an existing infrastructure to facilitate the practice. For example, reuse of graywater for flushing toilets is a sensible idea. However, in most buildings, water and wastewater lines extend throughout a complex network of pipes and other utilities that are often not easily accessible for modification. Even if reusable fractions of a building's wastewater were intercepted and centrally treated by a pressurized membrane filtration process, the resulting graywater would still need to be delivered to toilets by pumping through new, independent lines. The associated costs and infrastructure modification make this approach a challenge in many cases. There is a need for more practical, streamlined approaches for reusing graywater.

8.4.8.6 Recommendation

The four factors that present challenges in the near future with implementing graywater reuse are technology, regulation, maintenance, and behavior. Technology consensus standards have been in effect only for a short time meaning that most systems now on the market have not met the rigorous testing that such standards impose. Additionally, technological immaturity and limited market penetration result in relatively high first costs. Different regional regulations and codes emphasize that these technologies must be evaluated case-by-case unique to the locale. Rigorous maintenance is imperative to ensure that health and safety are not compromised. This obstacle can be overcome through the use of maintenance contracts.

Decentralized, building-level graywater reuse poses challenges. An installation must be aware of the economic considerations, installation, management, oversight, monitoring, and maintenance needed to maintain these systems and prevent cross contamination.

8.5 Efficient plumbing fixtures

Water-efficient appliances and fixtures are some of the easiest conservation retrofits to accomplish. EPAct 2005, EISA 2007, EO 13423 (White House 2007), and EO 13514 (White House 2009) require Federal agencies to achieve water reduction targets and improve water efficiency by incorporating BMPs and by using water-efficient products and services.

In addition, the Army now mandates that indoor water consumption in new construction and major renovation shall use technologies that result in at least 30% reduced consumption of potable water as compared to the base case facility. Standards have been established for specific technologies by USEPA WaterSense, ENERGY STAR, and ASHRAE 189.1-2009 (ASHRAE 2009). Army guidance for new construction can be found in the Whole Building Design Guide (NIBS 2013).

While criteria specify a maximum flow, a range of flows are available for some fixtures and appliances. It is important to ensure that user needs are met while achieving the greatest savings possible. WaterSense labeled devices have been tested for efficacy as well as efficiency, that is, shower heads deliver an adequate flow and toilets meet flush criteria with testing medium. Highly efficient fixtures and appliances may be well worth the investment to decrease water use beyond the regulatory requirements particularly if there is little to no price difference. The use of ultra efficient plumbing fixtures in buildings with long horizontal pipe runs should be evaluated for their potential effect on drain line transport.

8.5.1 Toilets

In the residential sector, toilets, which account for nearly 30% of indoor water consumption, are the largest water users. Savings are achieved by reducing the number of gallons per flush (gpf) volumes. ASHRAE 189.1-2009 (ASHRAE 2009) mandates that tank-type toilets shall be 1.28 gal (4.8 L) and shall be certified to the performance criteria of the USEPA WaterSense® Tank-Type High-Efficiency Toilet Specification. Also, urinals in Army facilities will comply with ASHRAE 189.1-2009 as specified in the Sustainable Design and Development Policy Update (Hammack 2013).

8.5.1.1 Technology

Replacement of high water consumption toilet fixtures has been the chief initiative of the water industry's reduction of potable water use campaign since the 1980s. Installation of 1.6 gpf toilets is now standard and it is increasingly rare to encounter older 3.5 and 5.0 gpf fixtures. As market saturation of efficient toilet fixtures occurred, different technologies to achieve lower flush volumes were developed. Currently, two distinct types of toilet fixtures are prevalent in the marketplace today: Ultra-Low-Flush Toilets (ULFTs, aka "low-flow" or "ultra-low-flow") and High-Efficiency Toilets (HETs). The distinction between these fixtures rests in the quantity of water used per flush; ULFTs are defined by an effective flush volume in the range between 1.28-gpf and 1.6-gpf (4.8 L and 6.1L), while HETs are defined as 1.28-gpf or less (4.84 L).

ULFTs first began making their way into residential dwellings in the 1980s, with the first mandated use occurring in Massachusetts in 1989. After 15 other states followed suit, the 1992 Environmental Policy Act extended the requirement to all toilets sold nationally (AWE 2010b).

In the late 1990s, HETs emerged as an improvement over ULFTs, saving 20% more water per flush. Just a few years later (in 2003) the first HET technology fixtures became available in the marketplace. Today, HETs outlive and outperform their predecessor; as a result there are over 200 HET fixture models available from 21 different manufacturers. Four types of HET technologies commonly found on the market are gravity fed single-flush, dual-flush, pressure-assist, and power-assist toilets.

8.5.1.2 Policy

Virtually all toilet models sold in the United States meet both flush volume and performance standards required by the American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME). However, concerns regarding customer expectations and approvals of toilet fixtures led to the development of the Maximum Performance (MaP) testing project in 2003. Now 7 years old, MaP testing provides performance information on over 1,600 different toilet fixtures (AWE 2010b) (Veritec and Koeller 2010). With so many toilet fixtures available, MaP testing provides a roadmap for water managers by distinguishing between good and marginal performers such as those that have earned WaterSense® certification. WaterSense® only certifies toilet fixtures that complete a third-party certification process (USEPA 2010b). For HETs, the USEPA has adopted a 350 gram of MaP media (soy bean paste) as the minimum performance threshold for earning WaterSense® certification (AWE 2010b) (Veritec and Koeller 2010). MaP testing has found that toilet fixtures available in today's marketplace are significantly better performers than those tested when the MaP project began in 2003. Much of this improvement is credited to the wide marketplace acceptance of MaP testing, and to the ongoing dialogue and cooperation between the Steering Committee for Water Efficient Products, the USEPA, and toilet manufacturers (USEPA 2006, 2010b).

8.5.2 Showerheads

8.5.2.1 Technology

Showering represents a significant water use and represents a great target for water savings. Low-flow showerheads are also cheaper to install than low-flow toilet fixtures, making them a good candidate for short-term cost-effective implementation on Army installations. Low-flow showerhead retrofits are one of the most cost-effective BMPs because of the energy savings resulting from reductions in hot water heating. This retrofit alone can pay for itself in less than a year.

8.5.2.2 Policy

Federal guidelines mandate that all showerheads manufactured and sold in the United States after 1 January 1994 must use no more than 2.5 gpm.

The USEPA's WaterSense® has a standard of 2.0 gpm at water pressure of 80 psi. According to the USEPA water-saving calculator, WaterSense® shower heads can help save 900 gal of water annually, which translates to an annual utility bill savings of $7.40 (USEPA 2012a).

8.5.3 Faucets

8.5.3.1 Technology

The best practice for faucet water use varies by faucet type. Generally, kitchen faucets require a relatively high water flow to fill pots and perform other kitchen-related tasks. Maximum water flows of 2.2 gpm at 60 psi are considered appropriate for kitchen faucets. A number of more efficient kitchen faucets are available for those willing to forego quickly filled kitchen sinks; some even have adjustable flow rates to allow for the higher flow when needed. These lower flow kitchen faucets should be considered and installed where appropriate to achieve further kitchen water savings.

WaterSense® has released a more stringent specification for non-public lavatory faucets. To warrant a WaterSense® label, private residential lavatory faucets must have a flow rate no greater than 1.5 gpm at 60 psi. Best practice for public lavatory faucets comes from an ASME code that requires a flow rate of no greater than 0.5 gpm at 60 psi, except for metering faucets that should flow at 25 gallons per cycle (gpc) (ASME 2011). These levels of water flow are achieved with replacement fixtures and with faucet aerators. Faucet aerators restrict water flow while maintaining the feel of higher pressure by mixing air into the flowing water.

There are a variety of different mechanisms for activating faucets beyond the traditional manual method. These include sensors that turn faucets on when triggered by a person's presence and faucets that shut off after a certain amount of time has passed or water has flowed. In theory, many of these mechanisms have the potential to help conserve water. In fact that was the intention behind the development of some. However, a number of empirical studies contest the idea that manual water faucets are less efficient than their competitor. Sensor-activated faucets in particular have been shown to use more water than their manual counterparts (Gauley and Koeller 2010). While more studies are certainly needed to clarify the most water-efficient faucet activation method, caution should be used when considering non-manual faucets and (especially) sensor-activated faucets to ensure that these models are the most efficient option.

Food waste disposers are another aspect of faucet water use in the residential sector. From a pure water perspective, food waste disposers constitute an unnecessary use of water because organic waste can be disposed of in a number of other ways. This perspective is probably best applied in a drought situation. From a broader perspective, there are pros and cons to various methods of food disposal and sometimes using a food waste disposer is preferable to other forms of disposal. When possible, composting is always considered the most efficient and environmentally friendly way to dispose of organic wastes. When composting is not an option, disposal to the sewer via a food waste disposer is generally considered to be environmentally preferable to incineration. When choosing between a sewer system (via a disposer) and a landfill, whichever utility captures waste methane is considered the preferable option for organic waste.

8.5.3.2 Policy

Provisions of ASHRAE 189.1-2009 (ASHRAE 2009) apply to faucets in new construction and renovation (Table 14)

8.6 Efficient appliances

While publicly supplied water only accounts for approximately 10% of water use in the nation as a whole (USGS 2009), many of the water uses of a typical installation use publicly supplied water. Substituting more efficient residential, commercial, industrial, and institutional appliances is an important step toward meeting an installation's water reduction goals.

Table 14. New construction and renovation faucet requirements.

Type	Function	Maximum Flow Rate/Water Use
Public lavatory faucets	Lavatory faucets	Maximum flow rate of 0.5 gpm
Public metering	Self-metering. self-closing faucet	Maximum water use of 0.25 gal per cycle (gpc)
Residential bathroom		Maximum flow rate of 1.5 gpm
Residential kitchen faucet	kitchen faucet	Maximum flow rate of 2.0 gpm

8.6.1 Residential appliances

Nationally, residences use more than half of publicly supplied water (USGS 2009). Reducing residential water use is an important step for installations seeking to reduce water demand. Many residential appliances are continuously becoming more energy and water efficient. Such efficiency can add up to significant savings for an installation's permanent and temporary residents, without decreasing quality of life. Improved appliance efficiency is becoming industry standard, as evidenced by such programs as EnergyStar and WaterSense.

ASHRAE 189.1-2009 (ASHRAE 2009) details a "total building sustainability package" and provides standards for many residential appliances such as clothes and dish washers. These standards are frequently referenced and recommended when constructing or upgrading water and energy efficient buildings.

8.6.1.1 Clothes washers

According to the ENERGY STAR program, the average family in the United States washes about 300 loads of laundry each year (ENERGY STAR 2013a). A typical residential washing machine uses 23 gpc of water, equal to about 6900 gal of water per year per household for clothes washer operation.

8.6.1.1.1 Policy

ASHRAE 189.1-2009 (ASHRAE 2009) mandates that residential clothes washers shall comply with the ENERGY STAR requirements for clothes washers, i.e., they must achieve a maximum water factor of 6.0 gal/cu ft (800 L/m^3) of drum capacity. However, the most efficient washers use 3.1 gal/cu ft (467 L/m^3). A typical ENERGY STAR certified washing machine will use 15 gpc of water, although more efficient machines are available and should be sourced when economical.

8.6.1.1.2 Technology description

As a general rule, washing machines oriented along the horizontal-axis (front-loading washers) are significantly more water efficient saving up to 25% of water, than those oriented along the vertical-axis (top-loading washers) (ODUSD[I&E] 2005). Furthermore, it is important that washers be sized for the expected needs of the household. Washers should only be operated when full and, if the option is available, on low water, short cycle settings. If the washer is too small, excess cycles will be needed. Alternatively, using a larger-than-necessary washer will waste both energy and water. Additional water savings can be realized by following manufacturer recommendations.

8.6.1.1.3 Applicability

The water savings of more efficient clothes washers are not likely to provide the full financial justification for their adoption. Rather, the high associated energy needs of heating the water and running the appliance are likely to dominate any cost estimation. When selecting any compromise between efficiency and up-front cost, installations are advised to consider their costs, local scarcities of energy and water, and also the resident population that will be using the appliances.

8.6.1.1.4 Recommendations

Adoption of ENERGY STAR clothes washers is expected for new construction, and should be considered for installations with large populations that currently rely on older, less efficient models. Even washers using the top permissible ENERGY STAR use of 15 gpc are expected to save 27,000 gal of water over the machine's lifetime (ENERGY STAR 2013a). However, due to the low price of water on most installations, water savings are not likely to be the driving factor behind the adoption of ENERGY STAR clothes washers. Such washers are about 20% more energy efficient than the Federal minimum specifications and are more likely to justify the cost of improved efficiency through both energy and water savings.

8.6.1.2 Dishwashers

In general, newer and more energy efficient dishwashers will use less water than washing dishes by hand. However, significant variations and improvements in newer machines should be considered by installations seeking to decrease water and energy demands.

8.6.1.2.1 Policy

ASHRAE 189.1-2009 (ASHRAE 2009) mandates that residential dishwashers shall comply with the ENERGY STAR program requirements for dishwashers, achieving a maximum water factor of 5.8 gal (22 L)/full operating cycle.

Dishwashers also lack WaterSense® specifications, but (like clothes washers) have ENERGY STAR criteria that include water use. ENERGY STAR-labeled dishwashers come in two sizes – standard (capable of holding eight place settings and six serving implements) and compact (washers with a lower capacity). Standard dishwashers currently use a maximum of 5.8 gpc, whereas compact dishwashers, a maximum of 4.0 gpc. However, the most water-efficient (standard) dishwashers use as little hot water as 1.6 gpc.

8.6.1.2.2 Technology description

According to Federal efficiency standards (and disregarding any additional standards such as ENERGY STAR), all standard-sized dish washers built after 1 January 2010 use no more than 6.5 gpc. The adoption by ASHRAE of ENERGY STAR standards has led to the availability of numerous washers using 5.8 gpc or less. Residential dishwashers built before 1994 may use 10 gpc or more.

The recent focus on water and energy efficiency in residential appliances has led to many new technologies and improvements in dishwashing design. Some residential dishwashers are equipped with soil sensors designed to change the amount of energy and water applied based on the level of cleaning required for a particular load. In addition, improvements in both the layout of interior space (improved dish racks) and the application of water (water jets) have greatly decreased the amount of water required to clean each load. Some models may also include water filtration in the unit to maximize the cleanliness and aesthetics of each load.

As with clothes washers, it is important that dishwashers be sized for the needs of the residence. Dishwashers will be most efficient when operated at their design capacity, as specified by the manufacturer. In addition, newer dishwashers may have multiple wash cycles to allow users to specify the most efficient wash for their needs.

8.6.1.2.3 Applicability

As with clothes washers, the most significant financial savings associated with more efficient dishwashers are likely to be from the energy saved both in machine operation and decreased hot water use. User education is one of the most important steps in decreasing dishwashing water and energy consumption. Residents should be informed of the advantage of scraping dishes as opposed to pre-rinsing, which can save up to 20 gal of water per load (ENERGY STAR 2013b).

8.6.1.2.4 Recommendations

While the financial effects of water savings are likely to vary based on the price and scarcity of water at each individual installation, the energy savings of adopting energy and water-efficient dishwashers are likely to be beneficial. Especially when paired with a culture of conservation, ENERGY STAR certified dishwashers can help installations to meet water and energy savings objectives.

8.6.1.3 Recommendations

The water and energy efficiency of residential appliances are constantly improving. Any new construction should use ENERGY STAR and/or WaterSense® certified appliances. Especially within the United States, such appliances are likely to be readily available and economical. Replacing appliances that are already in use requires additional consideration.

From a financial perspective, it is unlikely that savings only of cold water will justify replacing large appliances, such as dishwashers and clothes washers (ODUSD[I&E] 2005). When water savings are coupled with energy savings, payback periods may significantly improve. However, these appliances consume large amounts of heated water. The savings from incorporating more efficient appliances are expected to be significant, especially in areas with high energy costs.

8.6.2 Commercial appliances

Typical installations have a number of water intensive commercial processes, such as food service, laundry facilities, and vehicle wash operations. These uses consume large amounts of both energy and water. Installations benefit from increasing the efficiency of these services.

8.6.2.1 Food service

Commercial kitchens are one type of Commercial, Industrial, and Institutional (CII) facility for which water efficiency measures are unlikely to vary by facility. In facilities such as restaurants as much as half of water use occurs in the kitchen. Even in facilities where food service is only one part of a facility's water use, such as hospitals, offices, schools, and hotels, kitchens may still account for 10 to 15% of water use (USEPA 2012a).

Water conservation measures usually involve the straightforward retrofit, replacement, or, occasionally, elimination of an appliance or fixture. Most, though not all, of these potential savings exist for dishwashing. Water efficiency measures not related to dishwashing may involve the retrofit or replacement of outdated icemakers and steamers.

Guidance for commercial kitchen equipment are available (FEMP 2011b). Additional requirements for commercial food facilities, are found in ASHRAE 189.1-2009 (ASHRAE 2009).

For dining facilities, specifications are provided in UFC 4-722-01 (DoD 2007). While commercial food service facilities may vary in use, the water efficiency policies and best practices are likely to be very similar.

Since FY08, Army projects have been expected to comply with ECB 2006-02, *Sustainable Design and Development* (HQUSACE 2006), in incorporating LEED for New Construction and Major Renovations, also known as LEED-NC (DoD 2007).

Changes to fixtures in food service facilities require attention to specific plumbing requirements, such as those contained in Technical Instructions (TI) 800-01, *Design Criteria* (HQUSACE 1998). Food service plumbing and equipment should to consider ease of maintenance and cleaning, local jurisdictions for wastewater and solid waste management, and coordination with other building systems, such as HVAC piping and maintenance. Specific considerations for water supply systems include hardness, pressure, and temperature, especially for equipment such as dishwashers and pot and pan washes. Proper safety must also be considered, including the installation of water safety devices, such as temperature limiting devices on hand washing stations, and plumbing safety, such as backflow connections. Some plumbing systems may require special connections or equipment, as specified by the manufacturer.

8.6.2.1.1 Applicability

New construction or major renovations of commercial food service facilities should consider the most current policies, guidelines, and best practices. While the location of the food service may affect the applicability of the best practices and guidelines discussed , they will often prove applicable across most installations and facilities.

As new technologies are introduced, installation personnel considering either new construction or upgrades to existing facilities should look to best practices used throughout DoD, other Federal agencies, and in the private sector.

8.6.2.2 Dishwashers and Dishwashing

Most food service facilities have dish washing equipment to remove food from the surfaces and clean dishes, utensils, and cups. Dishwashers use a large amount of energy, hot water, soap, and rinsing chemicals and may account for one-third of a commercial kitchen's water use (USEPA 2012b).

8.6.2.2.1 Description

Dishwashers come in a variety of designs. Typically, dishwashers are specified as either under-counter, stationary door- or hood-type (Figure 24), conveyor-type or flight-type (Figure 25). It is typical for under-counter dishwashers, which are similar to their residential counterparts, to only be used in smaller facilities that serve fewer than 60 people per day. Slightly larger facilities (those serving up to 150 people per day) often rely on stationary door or hood-type washers, which are often loaded with racks (commonly 20 x 20 in.) of dishes and utensils. Conveyor-type machines may be found in facilities serving up to 300 customers per day and function by conveying pre-loaded racks through the wash cycle. The largest commercial kitchens may use flight-type machines, which are similar in design to conveyor systems, but with the conveyor itself functioning as the rack. Unlike conveyor systems, flight-type machines are often left running, with dishes continuously loaded and removed after the wash cycle.

Source: Electrolux (2008)

Figure 24. Hood-type dishwasher.

Source: Insinger Machine (Undated)

Figure 25. Flight-type dishwasher.

USEPA's ENERGY STAR and WaterSense programs provide Water use recommendations for commercial dishwashers and washing practices ENERGY STAR estimates that using a certified commercial dishwashers may save a typical business an average of $3,000 per year (ENERGY STAR 2013b). Those dishwashers awarded the ENERGY STAR label are on average 40% more energy efficient and use 40% less water. In addition, ENERGY STAR machines must minimize energy and water consumption while "idling between wash cycles" (ENERGY STAR 2013b).

8.6.2.2.2 Recommendations

Inefficient or conventional appliances should be replaced with ENERGY STAR qualified models that have significantly lower gallons per rack and energy consumption rates. Commercial dishwashers must use 1.00/0.95/0.70/0.54 gal of water per dish rack depending on whether they are, respectively, under-counter/stationary, single tank door/single tank conveyor/multiple tank conveyor-type dishwashers.

Dishwashers are most efficient and should only be operated, when full. Any damaged dishwashing racks should be immediately replaced. Employees should fill each rack to its maximum (design) capacity. It is important that the capacity be considered when selecting dishwashers. Dishwashers that are smaller than their expected demand will be used more frequently, whereas dishwashers that are oversized will waste energy and water if they are not completely filled.

Water can be saved by ensuring that the water pressure is adequate and set to the lowest level advised by the manufacturer. If the water pressure is too low, typically below 20 psi, the dishwasher will not function properly and sanitation may be compromised. However, if water pressure is too high, even high-efficiency machines will use more than the rated amount of water. In general, it is important that dishwashers be operated according to the manufacturer's instructions.

8.6.2.3 Pre-rinse spray valves

In typical commercial kitchens, the combination of dishwashers and Pre-Rinse Spray Valves (PRSVs) accounts for over two-thirds of the kitchen's water use. These PRSVs are not the same as those relied on for filling glasses, pots, or kettles or for washing surfaces, requiring consideration for different use and needs (USEPA 2012b).

8.6.2.3.1 Description

PRSVs are typically connected to a hose, allowing the nozzle to be moved while rinsing. Typical valves will contain a squeeze lever, possibly lockable, to control flow.

The Energy Policy Act of 2005 (EPAct05) requires commercial PRSVs sold in the U.S. may output a maximum of 1.6 gal/minute. Older models use between 3 and 4.5 gpm. Models developed since the EPAct05 may reduce water use to as low as 0.65 gpm. WaterSense limits flow to 1.28 gal/minute or less(USEPA 2013c).

8.6.2.3.2 Recommendations

It is vital that personnel be educated about the importance of water efficiency and about the simple measures they can take to improve their water use. Training workers to scrape dishes instead of pre-rinsing before putting them in the dishwasher will help commercial kitchens conserve water. When dishes must be pre-rinsed, water savings can be realized through low-flow PRSVs that use 1.28 gal/minute or less at 60 psi.

Proper kitchen planning will also assist personnel. PRSVs must be properly situated and attached to hoses of proper length to make the device convenient for use. Failure to ensure proper placement may force people to use other fixtures that are not optimally designed for rinsing dishes.

Because of the relatively low cost of PRSVs, USEPA advises replacing older pre-rinse valves with newer, more efficient models when the older valves begin to demonstrate clogs or poor performance, in place of normal maintenance cycles.

8.6.2.4 High-efficiency ice machines

Ice machines produce ice by using refrigeration to freeze water. This is an energy intensive process and produces a significant amount of waste heat, requiring either water or air cooling.

8.6.2.4.1 Policy

Standards for ice machines are set by Energy Policy Act of 2005 (EPAct05). Machines that are issued an ENERGY STAR certification are on average 15% more energy efficient and 10% more water-efficient when compared to standard air-cooled machines.

Installations should purchase choose air-cooled ENERGY STAR/ models with higher production capacity (ASHRAE 2009). Higher capacity machines tend to be more efficient in making ice, measured in kWh/lbs of ice. However, facilities should choose machines that are appropriately sized for their ice needs.

8.6.2.4.2 Description

Three common types of ice machines include: (1) ice-making head units, (2) self-contained units, and (3) remote condensing units. Ice-making head units combine the ice-making mechanism and the condenser unit. Self-contained units combine storage for the produced ice with the ice-making mechanism and the condensing unit. Remote condensing ice machines separate the condenser and ice-making mechanisms.

If perfectly efficient, it takes approximately 12 gal of water to produce 100 lb of ice (USEPA 2012b). However, ice machines require additional water beyond that which is frozen to operate properly and produce suitable quality ice. Depending on the cooling system, many machines use water to remove heat. In addition, machines may require rinsing to remove mineral buildup. The amount of rinsing required dependents highly on the quality, in particular dissolved solids, of water provided to the machine. Ensuring that machines only rinse as needed requires that the rinsing cycles be set to accommodate the incoming water quality. Some machines may have sensors that detect mineral buildup, and are thus able to set their rinse cycles automatically to the most efficient and necessary times.

Ice machines may use as much as 15 to 50 gal water per 100 lb of ice. The least efficient of machines, when accounting for single-pass cooling, may use as much as 100 to 300 gal of water per 100 lb of ice. Single-pass cooling is highly inefficient. Replacing a single-pass cooling machine with air cooling can reduce total water consumption to less than 50 gal per 100 lb of ice production. Despite these water savings, air-cooled machines are typically more energy intensive than comparable water-cooled machines.

However, recent advances have enabled some air-cooled machines to "match or exceed the energy efficiency of water-cooled units while also providing substantial water efficiency" (USEPA 2012b).

Aesthetic requirements for the ice set by the end-use may alter the production process used. For instance, ice that is served to customers may be produced by a more energy and water intensive method of partial thawing and repeated freezing. This produces more uniform and clear ice. Ice of such high aesthetic quality may not be necessary for food storage. As a general rule, ice of higher aesthetic quality, e.g., clearer with fewer bubbles, will require more water and power to produce.

8.6.2.4.3 Recommendations

If an existing ice machine is water cooled, determine if it uses single-pass cooling. Single-pass cooling inefficiently brings in new water for each cooling cycle. If possible, some equipment may be modified to recirculate cooling water, known as a closed-loop system, instead of immediately discharging it. It may also be possible to reuse cooling water for other processes.

Cleaning the machine, whether manually or with a self-clean mode, will help to remove mineral buildup and kill bacteria and fungi. After cleaning, it is important to discard several batches of ice to ensure that the end-use ice is free of cleaning solution. Cleaning of the coils will also help to improve the efficiency of heat exchange.

As is generally important in any heating or cooling process, the lid to the machine should be kept closed as much as possible to prevent heat exchange with the surroundings. One option for machines with timers is to set the machine to produce ice during off-hours, such as overnight. Beyond decreasing a facility's peak energy use, such an option allows the machine to fill the bin with ice without personnel needing to open the doors during the cycle to collect ice for use.

8.6.2.5 High-efficiency steam cookers

Commercial steam cookers are required by ASHRAE 189.1-2009 (ASHRAE 2009) to meet both ENERGY STAR requirements and additional water efficiency requirements. Facilities need to use boilerless/connectionless food steamers that consume no more than 2 gal/hr (7.5 L/hour) during operation.

Installations should choose ENERGY STAR steam cookers that have significantly higher cooking efficiencies. Boilerless (connectionless) steam cookers tend to have lower production capacities than steam generator and boiler-based models. They are best suited to batch-cooking. Where possible, analyze production needs and replace boiler-based steamers that can use up to 40 gal/h and have cooking efficiencies below 30% with boilerless steamers that use little water (<5 gal/h) and have cooking efficiencies up to 85%.

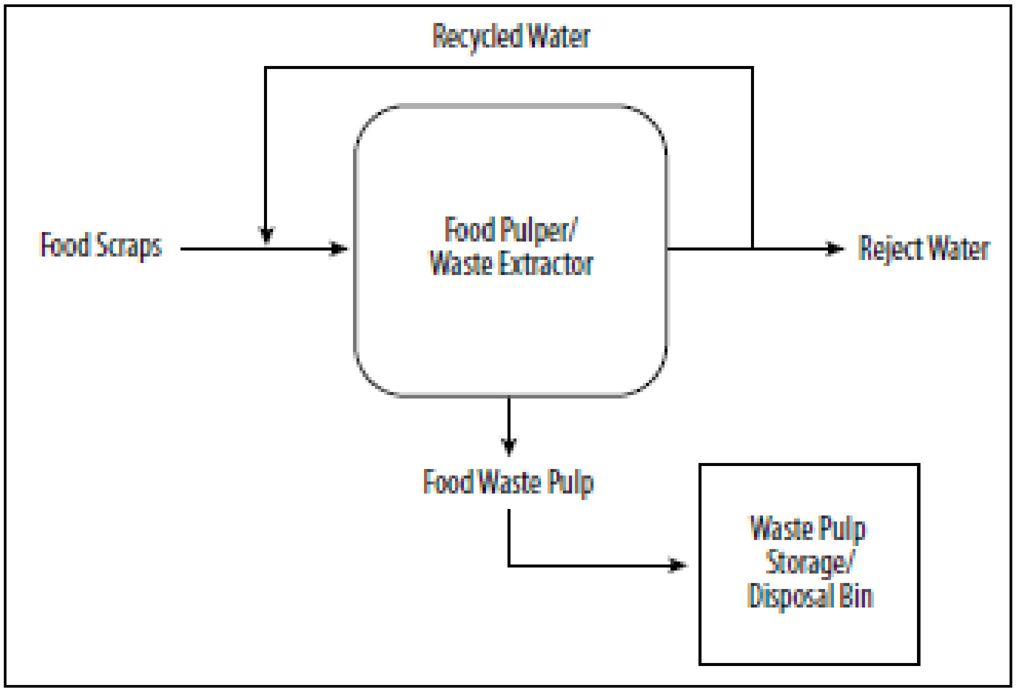
Proper operation of the steam cooker according to manufacturer instructions is very important. In general, water and energy will be saved by cooking in batches as opposed to staged loading of food pans. In other words, it is advised that the steamer be filled to capacity and that the door be opened sparingly to load and unload food pans.

8.6.2.6 Food disposals

8.6.2.6.1 Policy and technology description

Disposal of food waste may simultaneously be energy and water intensive. While traditional commercial garbage disposals do not use water as a means of operation, kitchen personnel often use large quantities of water to protect the equipment from damage, to force food waste through the system, and to prevent overheating. In many commercial kitchen configurations, water is continuously applied through a sluice trough to the garbage disposal at a rate between 2 and 15 gal/minute. Other facilities may use their PRSVs to move waste into the disposal.

While ASHRAE 189.1-2009 (ASHRAE 2009) does not provide guidance on specific food disposal technologies, the WaterSense® program provides several alternatives to water intensive food disposal. One such technology, a pulper (Figure 26), crushes waste rather than grinding it. The water extracted from the waste during this process may be suitable for reuse as pre-rinse water. Such recycling configurations may be able to return between 5 and 15 gal of water per minute back into the system, at an expense of only 2 gal/minute of makeup water (USEPA 2012b).



Source: USEPA (2012b)

Figure 26. Food pulper system diagram.

Facilities could also consider the use of food strainers in their sinks, which require manual action to move or dispose of food waste. Combination devices, such as Salvajors, which combine elements of pulpers and strainers, are also available (Table 15).

Table 15. Four common waste disposal methods.

Parameter*	Grinder	Salvajor	Pulper	Strainer Basket
Solids to sewer	Yes	No	No	No
Recirculate	No	Yes	Yes	No
Strain foods	No	Yes	Yes	Yes
Compost Produced?	No	Yes	Yes	Yes
Solid waste produced?	No	Yes	Yes	Yes
Flow restrictor?	Yes	No	No	N/A
Horse power	1–10	0.75–7.5	3–10	0
Potable water use (gpm)	3–8	1–2	1–2	0
Sluice trough (gpm)	2–15	2–5	2–15	0
*Source: CUWCC (2010)				

8.6.2.6.1Applicability

When selecting a system for food waste disposal, facilities must consider the state of local infrastructure and regulations, as some localities may not allow the discharging of commercial food waste with wastewater. Private facilities in such areas may be subject to bans on garbage disposals or the levying of additional taxes due to the amount of food waste they output to wastewater treatment plants.

8.6.2.6.2 Recommendations

Regardless of the type of disposal used, facilities are advised to only supply water to the disposal mechanism as needed for use. Large food waste that would be difficult for the disposal mechanism to manage should be thrown away rather than disposed of down the sink. Neither grease or hard objects should be discarded down the sink, due to concerns for clogging and damage to pipes and disposal equipment. When water is run through food disposal machinery, USEPA advises that facilities use cold water, which requires less energy to produce and better cools food disposal equipment. Finally, the efficiency of food disposal equipment is preserved with regular maintenance as specified by the manufacturer.

Existing disposals may be retrofit to turn off the water provided either when no food is being disposed of or at a set interval. Also, devices are available which can vary the amount of water applied to the disposal based on the amount of food being sent through it. Such devices may reduce the idle water consumption of commercially available disposals from over 5 gal/minute to approximately 1 gal/minute.

8.6.2.7 General commercial kitchen operations

It is vital that personnel be educated about the importance of water efficiency, and simple measures they can take to improve their water usage. Training workers to scrape dishes instead of pre-rinsing them before putting dishes in the dishwasher will help commercial kitchens conserve water. When dishes must be pre-rinsed, water savings can be realized through low-flow PRSVs that use no more than 1.25 gpm at 60 psi. Additionally, eliminating scraping troughs or using troughs that recycle water, will save water. Replacing food waste disposers with food waste strainers or eliminating them altogether can result in water savings as well. When possible, composting is always considered an environmentally preferable option.

All faucet controllers within a food preparation area need to be equipped with hands-free faucet controllers, such as foot or sensor-activated controllers. This includes faucets used for washing pots.

In general, it is important that all kitchen equipment be operated according to the instructions provided by the manufacturer. Fixing leaks is also an easy way to avoid unnecessary water loss. Employees, including custodial and cleaning crews, should be required to report problems, and should be provided with easy and user-friendly ways to do so.

8.6.2.8 Laundromats

Laundromats provide a centralized location where installation personnel, visitors, and families can clean personal clothing, linens, and other fabric items. Such facilities are often self-service, allowing users to access washing and drying equipment after payment by coins or a payment card. The clothes washers found in such facilities are often sized for a single load, similar to the washers found in residences.

Regardless of the type of facility, water-recycling systems may be available for reuse of the graywater produced by laundry operations. The complexity of such systems is typically dictated by the water conservation goals of an installation. For instance, reusing only the final rinse water from one load for the beginning water of the next may require little treatment, and may reduce water consumption by between 10 and 35% (USEPA 2012b). More advanced water-recycling systems with treatment could reduce total laundry water consumption by as much as 85%. However, such systems will likely require additional plumbing and fixtures and additional maintenance.

8.6.2.8.1 Coin-operated washers

Requirements and best practices for commercial coin- or card-operated washers have much in common with those discussed in Section 0, “Residential Clothes Washers.” However, Federal policy on commercial washers has undergone changes in recent years. Previous standards set by EPAct 2005 have been recently revised by the Department of Energy. Such appliances must now meet one of two water factors, based on the basic machine configuration:

- Top-loading washers must meet a water factor of 8.5 gal/cu ft.
- Front-loading washers must meet a water factor of 5.5 gal/cu ft.

In addition, the ENERGY STAR and WaterSense® programs provide additional specifications for clothes washers. As with residential washers, facilities are advised that choosing more efficient washers and driers will likely yield large water savings and, more financially significant, large energy savings.

None of these standards apply to multi-load washers. While more common for facility use, multi-load washers (which often are capable of washing more than 80 lb of laundry per load, versus 20 lb per load for the washers discussed above) may be found in some coin- or card-operated facilities. While such machines are not subject to the above regulations, facilities are advised that newer models may allow the user to customize the amount of water and energy used by the machine depending on load.

8.6.2.8.2 Common-area washers

Clothes washers installed in publicly accessible spaces (e.g., multi-family, barracks, and hotel common areas) and coin- and card-operated clothes washers of any size used in Laundromats shall have a maximum water factor of 7.5 gal/cu ft (1.0 kL/m^3) of drum capacity-normal cycle. It is important to note, however, that the most efficient available washing machines significantly improve on these specifications, using as little as 3.1 gal/cu ft per cycle (ASHRAE 2009).

8.6.2.9 Tactical vehicle washing

Water conservation during tactical vehicle washing provides an opportunity for installations to reuse water and minimize total water consumption. It is expected that a typical tactical vehicle washed on an Army facility may require between 100 and 3,000 gal of water (HQDA 2011a). Many permanent installations have already had success implementing best practices in tactical vehicle washing.

8.6.2.9.1 Policies

Overall guidance on planning, design, construction, sustainment, restoration, and modernization of central vehicle wash facilities (CVWFs) is provided in UFC 4-214-03, *Central Vehicle Wash Facilities* (DoD 2004). Many installations have strived to improve their CVWFs, providing the Army a number of lessons learned and best practices. Installations seeking guidance on these lessons learned may look to Public Works Technical Bulletin (PWTB) 200-1-55, *Update to UFC 4-214-03 Central Vehicle Wash Facilities* (HQUSACE 2008), which details lessons learned at CVWF's since 1990. In addition, details of BMPs and facility case studies are discussed in *BMP #13 – Other Water Intensive Processes* (FEMP 2011b). USEPA's WaterSense® program provides valuable overviews of best practices in Section 5.5 of *WaterSense® at Work* (USEPA 2012d).

When designing a reclamation system, the USEPA (2012) recommends that facilities consider:

- the nature of the contamination to be removed or treated
- the concentration of contaminants
- the volume of water used per day
- the flow rate per minute of different processes
- the chemicals and procedures used in the wash and rinse processes
- any regulatory discharge limits
- the intended use (and required quality) of the recycled water
- any additional maintenance required for a reclamation system.

When treating reclaimed water, Army best practices have advised consideration of reverse osmosis or nanofiltration.

8.6.3 Landscape irrigation

Irrigation is often the largest single water demand on any installation. Because of this, water conservation can be achieved by improving the water efficiency both of the landscape itself and of the processes used to maintain it. The largest cost and resource savings will likely come from substituting alternate water sources for potable water for landscapes that must be irrigated (Vickers 2001). Irrigation is such an important component of Army water conservation objectives that, of the 14 FEMP BMPs two (*BMP #4 – Water-Efficient Landscaping* and *BMP #5 – Water-Efficient Irriga-*

tion) are dedicated to landscape and irrigation, respectively (FEMP 2011b).

8.6.3.1 Policy

The DoD has recently instituted general efficiency guidelines under UFC 1-200-02, *High Performance and Sustainable Building Requirements* (DoD 2013). Section 2-5.2 of these guidelines set efficiency targets for outdoor water use, including the use of water-efficient landscapes and irrigation strategies, such as water reuse, xeriscaping, and rainwater harvesting, to reduce the use of potable water for irrigation by at least 50%. In addition, irrigation contractors who are WaterSense certified are preferred (DoD 2013).

DoD guidance on landscape architecture is contained in UFC 3-201-02, *Landscape Architecture* (DoD 2009c). UFC 3-201-02 is applicable to “all DoD projects with site improvements regardless of the method of execution or the funding source.” For all construction activities that include at least $250,000 in site improvement, involvement and signing of all plans by a state-licensed landscape architect or similarly qualified and accredited professional is required.

Efforts to minimize irrigation water use are well served by considering the appropriateness of the plants at an installation. Under EO 13148 *Greening the Government through Leadership in Environmental Management* (White House 2000), guidance on landscape management is given by Part 6, “Landscaping Management Practices.” The order specifies compliance with the Presidential Memorandum on “Environmentally and Economically Beneficial Practices on Federal Landscaped Grounds” (White House 1994). This memorandum mandates that, to the greatest extent practical, facilities “use regionally native plants for landscaping,” and implement water-efficient irrigation systems emphasizing recycled or reclaimed water as well as planting practices (such as mulch and efficient organization) to minimize water loss.

Under EO 13423 (White House 2007), landscape architecture in DoD facilities should comply with LEED–New Construction Standards (USGBC 2013). Likewise, projects are subject to EISA 2007, including standards on storm water runoff management. Additional local and installation-specific requirements must be considered. UFC 3-201-02 (DoD 2009c) advises that installations check such standards by contacting and/or studying: their State Historic Preservation Office, installation Natural Resources Management Plan, installation Cultural Resources Management Plan, installation Appearance Plans, Base Exterior Architecture Plans, and the Installation Design Guide (HQDA, NAVFAC, and HQUSAF 1981).

Standards for irrigation of new planted areas are found in ASHRAE 189.1-2009 Sec. 6 (ASHRAE 2009). Outdoor water consumption shall be 50% as compared to the base case landscaping employing conventional means. Guidance is also contained in the 1994 Presidential Memorandum, *Environmentally and Economically Beneficial Practices on Federal Landscaped Grounds* (White House 1994).

ASHRAE 189.1-2009 (ASHRAE 2009) also requires hydrozoning of automatic irrigation systems to water different plant materials, such as turf grass versus shrubs. Landscaping sprinklers shall not be permitted to spray water directly on a building or within 3 ft (1 m) of a building.

Irrigation systems for new sites must be controlled by either: (1) a qualifying smart controller that uses ET and weather data to adjust irrigation schedules and that complies with the minimum requirements, or (2) an on-site rain or moisture sensor that automatically shuts the system off after a predetermined amount of rainfall or sensed moisture in the soil. Q. More recently, WaterSense® standards for smart controllers have come into effect. Such standards stipulate that controllers adequately water the area they serve without overwatering. Installations should seek and use WaterSense® certified controllers as more controllers gain such certification.

Exceptions allowing a temporary irrigation system used exclusively to establish new landscape shall be exempt from this requirement. Temporary irrigation systems shall be removed or permanently disabled at such time as the landscape establishment period has expired.

8.6.3.2 Technology description

Careful attention to reducing water requirements and improving the efficiency of irrigation systems are important to meeting water conservation targets. This is particularly true for installations with large irrigated areas, where outdoor water use can comprise as much as half of an installation's total water demand.

8.6.3.3 General considerations

In general, the most important consideration for decreasing irrigation demands of an installation's landscape is to properly select and control the landscaping itself. This is particularly vital for installations located in water-scarce areas, as even traditional landscaping, such as turf grass, can constitute an unacceptably high water burden in areas experiencing water-stress. Xeriscaping, the use of locally native and appropriate plants, minimizes the need for additional water and chemicals.

Areas that rely on non-native plants should be strictly limited by necessity. While spaces, such as golf courses and parade grounds, may require turf grass, their use for aesthetic reasons in water-scarce areas is not an efficient use of water resources.

Planting techniques such as the use of natural mulches may both improve water use and minimize the need for weeding. Grouping plants by water requirements, referred to as hydrozones, allows for the irrigation systems that serve each group to be adjusted for maximum efficiency. Proper soil preparation is also of importance to irrigation efficiency, as improperly prepared soils, such as the overuse of clays in place of top soils, may cause water to runoff instead of being absorbed to the root zone.

8.6.3.4 Irrigation supply

Irrigation systems may decrease the demand on installation water supplies by using non-potable sources of water. Common sources of irrigation-quality water include captured rainfall, stormwater runoff, graywater collected from the installation itself, untreated groundwater, and recycled water purchased from municipal supplies. Local considerations, policies, and building codes may exist for the use of non-potable water, and should be considered where irrigation is essential to preserve potable water supplies.

Special health and safety concerns may apply to the use of non-treated or minimally-treated waters. In particular, the use of graywater for irrigation should be confined to below ground drip irrigation systems to minimize the risk of human contact (HQAFCESA 2008). In addition, some localities may require maximum storage times for stormwater and graywater.

Water quality concerns may also apply to the plants being grown. Depending on the site, some rainwater, graywater or reclaimed water may contain high concentration of salts or other minerals making the water impractical for irrigation use without additional treatment.

Even without dedicated rainwater systems, site selection and grading can improve the ability of the existing site to harvest rainwater (DoD 2009c). Such improvements can include berming and adjusting site grading to passively direct and store water where needed by the plants.

8.6.3.5 Irrigation controls

Controlling the time and rate of irrigation is important for water conservation and effective landscape management. Smart irrigation controls allow for plant maintenance to be varied with season and climate. This avoids unnecessarily watering when soil moisture is sufficient while also providing moisture as needed at the most efficient times and at the required quantities.

Both turf and non-turf irrigation systems can conserve water by using smart irrigation controllers. These units estimate or measure the depletion of available plant moisture to control an irrigation system. Controllers use input either from soil moisture sensors or from evapotranspiration, rainfall, and solar radiation. Smart controllers require adjustment once they are installed.

The WaterSense® program has recently developed specifications for weather- and sensor-based smart controllers. These WaterSense® certified smart controllers should be sourced when switching to irrigation controller technologies. These specifications are strongly influenced by Irrigation Association's standards, and controllers procured before the development of the certification can be assessed by comparing the two sets of standards. The WaterSense® program also certifies a variety of irrigation professionals.

When properly used, irrigation controls also help to implement best practices. Examples of irrigation best practices include watering in the early morning or at night (when evaporation is lowest), adjusting, and perhaps cycling, irrigation based on hydrozoning, reducing irrigation during droughts (e.g., deficit irrigating), and only providing the amount of water needed. Once installed, irrigation controllers should be monitored and adjusted as the season and weather conditions change.

8.6.3.6 Irrigation systems

UFC 3-201-02 (DoD 2009c) specifies that irrigation efficiency relies on “Irrigat[ing] efficiently by watering slowly, deeply, and infrequently.” By irrigating slowly and deeply, best practices indicate that the efficiency and effectiveness of irrigation systems are directly related to the environment that they are watering. The rate at which the system applies water should never be faster than the rate at which water can infiltrate the soil, requiring “slow and even irrigation” (DoD 2009c). Enough water must be applied that proper soil moisture may be maintained, with enough water reaching the root zone. If such a system is used properly and consistently, plant roots will grow deeper, decreasing irrigation requirements even further.

Losses may also be minimized by choosing the most water-efficient irrigation technologies. For non-turf areas, drip and micro-spray irrigation minimize water losses, especially when compared to surface spray systems. Drip irrigation systems are comprised of tubing, often buried- “to deliver water directly to plant roots at very low pressures.” Such systems minimize water losses due to wind and evaporation (USEPA 2012b). Micro-spray systems differ from surface spray systems in that water is delivered at lower pressures through miniature spray heads. While the water savings are often greater than those of traditional systems, micro-spray systems do tend to lose more water to wind and evaporation. For large areas covered by turf grass, it is important to minimize losses due to evaporation by avoiding misting sprinkler heads. In addition, the trajectory of sprinkler heads should be adjusted to only water the intended area.

While conventional irrigation systems lose as much as 40% of the water delivered, high-efficiency systems can help ensure that up to 95% of the water supplied reaches the plants (DoD 2009) Minimizing system leaks and loss can also result in large water savings, as irrigation systems often constitute a large component of installation demand and typically involve pipeline infrastructure covering a large area.

It is important to strictly adhere to any relevant plumbing codes because irrigation systems are intended to create an exposed interface between waterlines and the environment. For instance, backflow preventers may be required to prevent contamination of water pipes.

Technical Guide Specifications for irrigation systems can be found in Unified Facilities Guide Specification (UFGS) 32-84-24, *Irrigation Sprinkler Systems* (NAVFAC 2011) and UFGS 32-84-23, *Underground Sprinkler Systems* (HQUSACE 2008c).

8.6.3.7 Applicability

Landscape irrigation policies, practicalities, and best practices vary widely by region. As UFC 3-201-02 (DoD 2009c) notes, for large, and if practical, even smaller exterior improvement projects, consultation with local regulatory bodies and local expertise can lead to dramatic improvements in the sustainability, functionality, and aesthetics of installation landscaping.

Policies governing water sources, especially those that use reclaimed, gray, and rain water, are typically set at the state or even local level. When Federal law/regulation trumps these policies, consideration is advised. Likewise, designers and planners should be aware of any requirements for approval from the Department of the Army. In addition, opportunities to retain rainwater may fall under other and potentially contradictory requirements, such as requirements to allow natural flow into the drainage basin and requirements to regulate the impact of development on runoff. Such considerations should be resolved at the local level and may require consideration in an installation’s storm water plans.

The practicality (and necessity) of many irrigation requirements will be determined by the local climate, water availability and the water demands of native plants. Likewise, plant choices may be dictated by the intended site use of the, such as parade grounds and golf courses. Whenever possible, installations are encouraged to select locally appropriate plants and landscaping techniques. Furthermore, the local climate may influence the choice of irrigation technologies. Rainwater catchment is driven by local precipitation. The selection of irrigation type, such as drip or spray, should consider the local climate. Technologies should be selected to minimize weaknesses in the local context. An example of the relationship between irrigation method and climate includes reconsidering micro-spray irrigation in areas highly susceptible to wind and evaporation losses. Likewise, the best practices discussed in this section should be considered in the local context. Often, the introduction of locally appropriate irrigation and landscaping techniques may allow for dramatic water savings.

8.6.3.8 Recommendations

Landscape irrigation may often be the largest individual use of water on an installation. Every installation needs to consider the local climate, policies, and proven best practices in creating an irrigation plan. Sensible irrigation plans should reduce the need for water in the first place (xeriscaping and landscape planning), promote non-potable sources of water (rainwater, graywater), develop an infrastructure of water-efficient irrigation, and control the irrigation to provide the correct amount of water at the correct time. Each of these considerations is mandated by DoD policy and, more importantly, provides a practical way to achieve significant water savings on the majority of installations. Minimizing water use in landscaping requires significant knowledge of local conditions and climate. Local nurseries and the local water utility can provide useful information (ODUSD[I&E] 2005)

8.7 Command emphasis

Of 14 water efficiency BMPs for water conservation established by the Department of Energy a *BMP #1 - Water Management Planning*, and *BMP #2 - Information and Education Programs* detail specific responsibilities to be undertaken by the command structure at installations. These two BMPs are critical for the successful implementation of the other 12 best practices, and to the overall success of installation conservation efforts (FEMP 2011b).

Due to the budget pressures faced by many installations, promoting a culture of water conservation may become an important supplement to the adoption of more efficient technologies. In addition, adoption of technologies, while an important step, is insufficient to meet water conservation goals if personnel are not trained and motivated to properly use these technologies. It is vital that installation commands show that water conservation is not only financially sound, but is also critical to the secure future of installations and to relationships with the surrounding communities.

8.7.1 Command support

Installations are responsible for planning for the secure and economical future of their water use. *BMP #1 – Water Management Planning* (FEMP 2011b) calls for each installation to create a Comprehensive Energy and Water Management Plan (CEWMP), which is the installation's road map to meet local goals and to comply with the EPAct05, EISA 2007, EOs 13423 (USDOE 2008), and 13514. While these policies are discussed in more detail in preceding sections, an overall vision for conservation is laid out in the 2014 Army Campaign Plan

When creating environmental management systems (EMSs), installations are urged to follow the existing "Plan, Do, Check, Act" model. For commands to integrate their efforts with those of the personnel, installations should provide means, for instance hotlines, for personnel to report processes and infrastructure that waste water and energy. The continued success of such hotlines will require that feedback and repairs be made promptly, to encourage confidence that reports are being addressed.

In addition, installations should recognize and publicize achievements in water conservation. Fort Huachuca, discussed in the following section, has implemented systems for recognizing personnel and facilities that meet or exceed their water conservation targets. Sharing successes at Army installations may also serve to inspire surrounding communities that share water resources with the installation and to foster relations by showing that the Army is a responsible steward for its share of local water resources.

8.7.2 Water awareness programs and education

Many studies have shown that the mere addition of water metering helps facilities to decrease their demand. Because many Army installations lack facility-level metering, it is important to provide personnel, employees, and residents with as much information as possible. Installations should provide metering to large water users in compliance with current policies. Water awareness programs and auditing can also help make personnel aware of their individual and collective effect on an installation's water goals.

Installations may have existing experience with awareness campaigns, such as energy awareness. The DoD Instruction, *Installation Energy Management* (DoD 2009) suggests that energy awareness campaigns should “publicize energy conservation goals, disseminate information on energy matters and energy conservation techniques, and emphasize energy conservation at all command levels and relate energy conservation to operational readiness” (DoD 2009a). In addition, the energy management program is instructed to create energy efficiency awards and establish an awareness month. October 2013 is Energy Action Month.

When creating water awareness programs, installations should look to previous success and challenges with other awareness campaigns. Because water is not priced relative to its scarcity, it may be important to emphasize the connection between water conservation and energy savings. In addition, personnel should be informed of the importance of water security to successful operation of the installation and relations with the surrounding communities.

An example water awareness program is at Fort Huachuca, in water-scarce southern Arizona. Created with help from the University of Arizona in 1998, the program provides briefings, presentations, and displays on water conservation goals, reaching approximately 2,500 personnel annually. The program is managed by two part-time employees, and in total is budgeted at approximately $48,000 per year. In addition, the installation established a water awareness month, and a number of festivals and goal-specific days. The progress of the program is noted quarterly in Fort Huachuca’s newspaper, with supplemental information and materials available online. The campaign also established a mascot, named “Wettie the Water Drop” (Figure 27). Readers of the installation newspaper are encouraged by Wettie to engage in competitions for prizes (FEMP 2010).

Fort Huachuca also implements a youth education campaign covering basic water science, aquifers, and, watersheds and conservation. The subjects are taught by installation personnel, both on post and in nearby schools, more than 100 times per year, in 30 different interactive classes. In total, such outreach is estimated to improve the understanding and personal connections to water of more than 2,000 students.

Source: FEMP (2010)
Figure 27. “Wettie” the water drop, Fort Huachuca.

Finally, Fort Huachuca provides services such as a free water audit for commercial facilities. During the audits, trained personnel check fixtures and appliances for many of the technologies and best practices suggested in this report. In addition, the personnel are equipped to help identify system leaks. For low cost changes such as replacing faucet aerators, the auditor may perform the upgrade during the audit. In addition, the facility manager is provided with a written report.

Many of the recommendations contained in this report, and the policy changes that have prompted them, will lead to the introduction of new or modified equipment to facilities. It is critical that users be educated on the proper use and maintenance of such equipment, and that signage near the equipment be updated to provide proper instruction.

8.7.3 Collaboration with other organizations

Water resources challenges are local and often shared between installations and the surrounding communities. It is important that the Army not be seen as being “in competition” with the local community for scarce resources. While few installations have been challenged regarding their water rights, updates to Federal policy show that the DoD is aware of the potential for conflict, and wishes to demonstrate that water used by the Army are being properly used and valued at each installation. It is valuable for installations to practice wise use of water whether water rights are at issue or water is plentiful and available to all.

Because of the local nature of many water resources, it can be valuable for installations to collaborate with local utilities and surrounding communities on issues ranging from water quantity, quality, and infrastructure. Such collaboration is especially important when water is purchased from a local utility or sold from the Army installation to an outside community, as conservation and security concerns become intertwined inside of and outside of the fence line. Installations will benefit from accessing local knowledge and experience, such as Fort Huachuca's success in engaging a local university in its water conservation campaign (see Section 8.7.2). In addition, local populations and local media could be invited to tour the installation and see the water efficiency programs in action.

In addition, installations can learn and benefit from the experiences and knowledge of other Government agencies and industry standards. Such collaboration can already be seen in the Army's adoption of standards from the Green Building Council (ASHRAE 2009), the USEPA (WaterSense®) and the Department of Energy (ENERGY STAR).

9 Conclusions

Threats to water supply and demand at Army installations are accelerating in frequency and reach. The Army responded to escalating water insecurity with increasingly stringent requirements for installation water efficiency and new programs that support efforts to improve resource conservation. One of these programs is the ERDC's Integrated Installation Energy, Water and Waste Modeling (EW2) research project that is developing planning tools for installations.

This report documents the first year's effort in the net zero water element of EW2. Existing water models were screened for their ability to support the needs of the EW2 goals. Useful aspects of the surveyed models will be incorporated in the EW2 tool. These models include watershed scale as well as community scale methods of estimating water supply and demand. Some models are available to any user at no cost and others were purchased in order to complete this review.

Another focus of the year one was to document technologies, programs, and policies that support water efficiency and conservation. These water measures are described generally in this report with reference to primary sources for more detailed information. Any data required for life cycle costing of the measures is contained in Appendix A. Life cycle costing data also includes the energy or waste embedded in water.

The information in this report will be used to develop the NZI modeling system that is the final product of this research effort.

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Acronyms and Abbreviations

Term	Definition
ACEEE	American Council for an Energy Efficient Economy
ACSIM	Assistant Chief of Staff for Installation Management
ADP	Area Development Plan
AECS	Army Senior Energy Council
AESIS	Army Energy Security Implementation Strategy
AEWRS	Army Energy and Water Reporting System
AHU	air-handling unit
ANSI	American National Standards Institute
AR	Army Regulation
ARID	Army Reserve Installation Directorate
ASDWA	Association of State Drinking Water Administrators
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASIP	Army Stationing and Installation Plan
ASME	American Society of Mechanical Engineers
AT/FP	Anti-terrorism/Force Protection
AWE	Alliance for Water Efficiency
AWE	Alliance for Water Efficiency
AWWA	American Water Works Association
BGD	Billion Gallons per Day
BMP	Best Management Practice
BOD	biological oxygen demand
BOID	Business Operation and Integration Division
BRAC	Base Realignment and Closure
CAB	Combat Aviation Brigade
CAC	Common Access Card
CAIOU	California Investor Owned Utilities
CARL	Current Annual Real Losses
CCS	Carbon Capture and Storage
CDD	total Cooling Degree Days
CEE	Consortium for Energy Efficiency
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CFM	Cubic Feet per Minute
CHL	Coastal and Hydraulics Laboratory
CII	Commercial, Industrial, and Institutional

Term	Definition
CIS	Capital Investment Strategy
COS	Centers of Standardization
CPI	consumers price index
CSA	Canadian Standards Association
CSU	Colorado Springs Utilities
CUWCC	California Urban Water Conservation Council
DA	Department of the Army
DAIM	Department of the Army Assistant Chief of Staff for Installation Management
DA PAM	Department of the Army Pamphlet
DASA	Deputy Assistant Secretary of the Army
DC	District of Columbia
DD	Department of Defense
DNR	Department of Natural Resources
DoD	US Department of Defense
DOE	US Department of Energy
DOIM	Directorate of Information Management
DP	Dew Point
DPW	Directorate of Public Works
DSS	Decision Support System
EBG	Efficient Basing-Grafenwoehr
EBMUD	East Bay Municipal Utility District
ECIP	Energy Conservation Investment Program
EHS	Environmental Health and Safety
EISA	US Energy Independence and Security Act of 2007
EL	Environmental Laboratory
EO	Executive Order
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EPWU	El Paso Water Utilities
ERDC	Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
ESTCP	Environmental Security Technology Certification Program
ET	evapotranspiration
EWR	Energy and Water Resources
FEMP	Federal Energy Management Program
FORTRAN	Formula Translation/Translator (high-level programming language)
FSW	Food Service Warehouse
FY	Fiscal Year
FYDP	Future Years Development Plan

Term	Definition
GAO	Government Accountability Office
GBCI	Green Building Certification Institute
GFEBS	General Fund Enterprise Business System
GHG	Greenhouse Gas
GIS	Geographic Information System
GPD	gallons per day
GPR	Ground-Penetrating Radar
GPY	Gallons per Year
GSSHA	Gridded Surface Subsurface Hydrologic Analysis
HE	High Efficiency
HEC	Hydrologic Engineering Center
HET	high-efficiency toilet
HMET	Hydrometeorological
HMS	Hydrologic Modeling System
HQDA	Headquarters, Department of the Army
HQIIS	Headquarters Information System
HQUSACE	Headquarters, US Army Corps of Engineers
HQUSAF	Headquarters, US Air Force
HSPF	Hydrological Simulation Program-FORTRAN
HVAC	heating, ventilating, and air-conditioning
IAMPO	International Association of Plumbing and Mechanical Official
IAW	in accordance with
ICC	International Code Council
ID	identification
IDG	Installation Design Guide
IEEE	Institute of Electrical and Electronics Engineers
IES	Illuminating Engineering Society
IFS	Integrated Facilities System
ILI	Infrastructure Leakage Index
IMARC	Installation Management Application Center
IMCOM	Installation Management Command
IPB	Installation Planning Board
IPC	International Plumbing Code
IPR	Indirect Potable Reuse
IRWD	Irvine Ranch Water District
ISR	Installation Status Report
IWA	International Water Association
IWSA	International Water Supply Association
JBLM	Joint Base Lewis-McChord
LCC	Life Cycle Cost

Term	Definition
LCCA	life cycle cost analysis
LEED	Leadership in Energy and Environmental Design
LEED-EBOM	LEED for Existing Buildings: Operations and Maintenance
LID	Low Impact Development
LLC	Limited Liability Company
LRC	Long Range Component
MCA	Military Construction, Army
MCAR	Military Construction, Army Reserve
MCDA	Multi-Criteria Decision Analysis
MCRD	Marine Corps Recruit Depot, San Diego
MDMS	Meter Data Management System
MEDCOM	Medical Command
MG	Million Gallons
MGD	Million Gallons/Day
MILCON	Military Construction
MIT	Massachusetts Institute of Technology
MOU	Memorandum of Understanding
MPTM	[Real Property) Master Planning Technical Manual
MS	MicroSoft
MW	Megawatt
MWD	Metropolitan Water District
NACE	National Association of Corrosion Engineers
NDWC	National Drinking Water Clearinghouse
NECPA	National Energy Conservation Policy Act
NERC	North American Electricity Reliability Council
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
NZE	Net Zero Energy
NZI	Net Zero Installation
NZW	Net Zero Water
OACSIM	Office of the Assistant Chief of Staff for Installation Management
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
OTE	Oxygen Transfer Efficiency
PBMP	Potential Best Management Practice
PDF	Portable Document Format
PDR	Project Development Report

Term	Definition
PNNL	Pacific Northwest National Laboratory
PPS	Project Priority System
PRSV	Pre-Rinse Spray Valve
PW	Public Works
PWTB	Public Works Technical Bulletin
RFP	request for proposal
RHM	Regional Hydrologic Model
RO	Reverse Osmosis
ROI	Return on Investment
RPLANS	Real Property Planning and Analysis System
RPMP	Real Property Master Plan
RPMPD	Real Property Master Plan Digest
RPPB	Real Property Planning Board
SAIC	Science Applications International Corporation
SDWA	Safe Drinking Water Act
SDWF	Safe Drinking Water Foundation
SESD	Science and Ecosystem Support Division
SF	Standard Form
SILO	Sale In – Lease Out (program)
SIR	savings to investment ratio
SMS	Army Strategic Management System
SOCOM	US Special Operations Command
SR	Special Report
SRM	Sustainment, Restoration, and Modernization
SWAT	Smart Water Application Technologies
TAB	Tabulation of Existing and Required Facilities
TIN	Taxpayer Identification Number
TOC	Table of Contents
TR	Technical Report
tRIBS	TIN-based Real-Time Integrated Basin Simulator
TSWG	Technical Support Working Group
TWSJ	The Wall Street Journal
UARL	Unavoidable Annual Real Losses
UCC	Union of Concerned Scientists
UCS	Union of Concerned Scientists
UFC	Unified Facilities Criteria
UFR	Unfinanced Requirements
UGA	University of Georgia
UK	United Kingdom
UMMCA	Unspecified Minor Military Construction

Term	Definition
UPH	Unaccompanied Personnel Housing
URL	Universal Resource Locator
US	United States
USACE	US Army Corps of Engineers
USDA	US Department of Agriculture
USDOE	US Department of Energy
USDOJ	U.S. Department of Justice
USEPA	US Environmental Protection Agency
USGBC	US Green Building Council
USGS	US Geological Survey
UV	Ultraviolet
WAVS	Water Availability, Variability, and Sustainability
WEAP	Water Evaluation And Planning
WRCC	Western Regional Climate Center
WRF	Water Research Foundation
WWTP	Wastewater Treatment Plant
WWW	World Wide Web

Appendix A: Water Measure Cost Analysis

The following measures reflect an effort to compile and classify possible options for water conservation at military installations and will be used as a resource in developing water analysis capabilities of the Net Zero Planner tool. Much of the investment calculations are based on water data collected from Fort Carson by PNNL and ERDC-CERL. The assumptions for size, volume, and capacity, are stated as much as possible in each measure.

The measures are not meant to reflect actual SIR results for specific projects. They are meant to be used as a starting point for developing net zero water measures. The first three tables in each measure reflect the effort to capture data for two community level water models, DSS and AWE, which are being considered for the NZI optimization tool. The following tables in each measure aim to capture additional input and output data that would be needed to reflect the measure's impact on energy and waste consumption.

This appendix is only a sampling of the possible water measures. New and improved options are becoming available every day and this team understands that the information in the appendix will become dated. However, it is hoped that the effort to bring as many options as possible together for consideration will provide a good reference for future ideas and areas for consideration.

Commonly Used Numbers and Calculations:

Fort Carson: (from PNNL 2012)

On Post irrigation (non-residential): 294,993 kgal/yr (824.4 kgal/acre/yr)

Residential irrigation:106700 kgal/yr

Residential Lawn size: 2160 sq ft.

Number of Residential Lots: 3,368 homes

Costs: (from AWE Conservation Tracking Tool- Fort Carson Region)

Water: $5.12/kgal

Sewage: $2.51/kgal

Electricity: $0.08/kWh

Gas: $6.20/Therm

Water Reuse: $0.8021 (Fort Carson billing data)

Fixtures: (from AWE Conservation Tracking Tool User Guide)

Average of 5200 flushes/yr (20 flushes/day, 260 days/yr)

Average of 7300 flushes/yr (20 flushes/day, 365 days/yr) [High Use]

Appliances

Ice machine (air-cooled)

Activity description

Water-cooled ice machines use single-pass cooling, using around 100 gal of water additionally per 100 lb of ice produced. Air-cooled machines reject heat into the room, and use slightly more electricity to operate. Measure considers the purchase of an air-cooled ice machine to match the capacity of an existing water-cooled machine, with the production of 100 lb of ice per day, 365 days a year.

Another option is retrofitting a water-cooled machine to a closed-loop system. However, this is usually only an option if a chilled-water loop already exists in the building, as in an office building.

Old/existing standards

None.

Efficiency standards

ENERGY STAR does not certify water-cooled ice machines. The range for air-cooled ice machines is 4-16 kWh/100 lb ice. Tables A1–A4 summarize costs and savings.)

Table A1. Costs, ice machine (air-cooled).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2011	$2173*	$652	1.6	0	7**	0	0

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)

* Price based on Manitowoc ID-0322A Indigo Series Ice Maker, includes installation

**Average lifetime (FEMP)

Table A2. Avoided costs, ice machine (air-cooled) (cost of water and recycled water if elected not to use a higher efficiency).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2011	0	0	7	$361(water)+$177(sewer)-$96(elec)=$442	0

Table A3. Model inputs/potential savings, ice machine (air-cooled).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
70,445*	89%	0%	50%	7	0%

*Assuming 100 lb of ice produced per day, 365 days of per year

Table A4. Additional savings, ice machine (air-cooled).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yer	% Reduction GHG	Utility Savings Sewer (GPY*)	Effective Years
617**	-30%	0	0%	0	0%	70,445	7

* gallons per year

** Based on increased use of 1.7 kWh/100 lb of ice because of air cooling and 100 lb/ice produced per day, 365 days/yr

Table A4. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
7.4 kWh/100 lb ice	5.7 kWh/100 lb ice	N/A	N/A	Air-cooled machines require clearance for air flow; filters and vents need to be cleaned, usually need to be placed in cool area. Water-cooled machines require separate water line.

Table A4. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>sewer)	100% (potable water=>sewer	4-16 kWh/100 lb ice*	3.4-6.6 kWh/100 lb ice*	175-450 lb ice/day*	175-450 lb ice/day*

* Based on increased use of 1.7 kWh/100 lb of ice because of air cooling and 100 lb/ice produced per day, 365 days/yr

Plumbing code

Single-pass water-cooled ice machines have been banned in Austin, TX, Seattle, WA, Phoenix, AZ, San Antonio, TX, Denver, CO, and Santa Fe, NM, among other cities.

Constraints

None.

References

FSW. 2012. Part 4: How do air-cooled ice machines compare to water cooled ice machines? *Restaurant Equipment and supplies*. Web page. Accessed 18 July 2012, http://www.foodservicewarehouse.com/restaurant-equipment-supply-marketing-articles/understanding-restaurant-equipment-and-supplies/commercial-ice-machines/how-do-air-cooled-ice-machines-compare-to-water-cooled-ice-machines/c28429.aspx

Ice Machine Life Cycle Cost Calculator. (2012). Accessed 18 2008, July, from Food Service Technology Center, http://www.fishnick.com/saveenergy/tools/calculators/icemachinecalc.php

Parpal, M. (2012). *The Truth About Water-Cooled Ice Machines*. Accessed July 18th, 2012, from Food Service Warehouse, http://www.foodservicewarehouse.com/restaurant-equipment-supply-marketing-articles/going-green/the-truth-about-water-cooled-ice-machines/c28133.aspx

Manitowoc. 2011. *Indigo series 0300 ice cube machine*. Web page. Accessed 15 August 2012, http://www.manitowocice.com/products/ice-beverage/cubers/modular-air-and-water/air-cooled/indigo-series-0300-ice-cube-machine

US Department of Energy (USDOE). Energy Efficiency & Renewable Energy. September 2009. Accessed 18 July 2012, http://www1.eere.energy.gov/femp/pdfs/pseep_icemachines.PDF

USEPA. 2012c. *Commercial ice machines key product criteria*. Web page. Accessed 18 July 2012, http://www.energystar.gov/index.cfm?c=comm_ice_machines.pr_crit_comm_ice_machines

Food steamer (connectionless)

Activity description

High-efficiency steamers reduce water use by using convection fans to distribute steam in the oven and reduce cooking time, using vacuum systems to lower the boiling point of water, heating water as needed instead of using a boiler, recycling condensate, or using microwaves to heat the water in the food without adding additional water.

Connectionless food steamers use 3 gal of water per hour or less, compared with 40 gph for a conventional model. Connectionless steamers have a water reservoir that vents only a small amount of steam with each cycle, and reuses the majority of it. Connectionless steamers can be electric or gas-powered. Tables A5-A12 summarize costs and savings.

Old/existing standards

None.

Table A5. Costs, food steamer (connectionless).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$5000*	$10,457	4.0		10		
*Average self-contained steamer cost (AWE Water Conservation Tracking Tool User Guide), with installation							

Table A6. Avoided costs, food steamer (connectionless) (cost of water and recycled water if elected not to use a higher efficiency).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008		0	10	$415 (water)+ $142 (sewer)+$1,442(elec)=$1999 tot	

Table A7. Model inputs/potential savings, food steamer (connectionless).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
81,500.0*	93%**	0	50%	10	0
* Estimated use of 6hrs/day, 365 days/yr **Standard efficiency of 40 gph vs. ENERGY STAR Connectionless efficiency of 3 gph					

Table A8. Additional savings, food steamer (connectionless).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
18,027kWh/yr*	71%			13†	81% for electric†	56,700‡	10

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years

* Based on Fisher Nickel 2005 ;70 kWh/day used for standard model, 20 kWh/day used for connectionless, 365 days/yr. Daily energy use adjusted for 6 hrs/day of use.

† Based on EPA assumption of 6.8956 x 10^{-4} metric tons CO_2/kWh for electric steamers, http://www.epa.gov/cleanenergy/energy-resources/refs.html

‡ Assuming 30 % evaporation

Table A8. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
7505 kWh/yr	25,532 kWh/yr*	N/A	N/A	N/A

* Based on data from Fisher Nickel study, indicating pressure or pressureless gas steamer with boiler, using 32 kBTU/hr and operated 14 hrs/day

Table A8. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>30% evaporation, 70% sewer)	100% (potable=>30% evaporation, 70% sewer)	50%-70%	Unknown	3-6 pans	3-6 pans

Constraints

None.

References

Accutemp. 2012. Accutemp Products, http://www.accutemp.net/steamer_energy.htm

AWE. 2011. *Water Conservation Tracking Tool User Guide.*

FEMP. April 2007. *FEMP Designated Product: Commercial Steam Cookers*. Accessed 18 July 2012, from US DOE—Energy Efficiency and Renewable Energy: http://www1.eere.energy.gov/femp/pdfs/pseep_steamcookers.pdf

FEMP. September 2011. *Kitchen Appliance Upgrades Improve Water Efficiency at DoD Exchange Facilities*. Accessed 18 July 2012, from US DOE—Energy Efficiency and Renewable Energy: http://www1.eere.energy.gov/femp/pdfs/dodexchange_watercs.pdf

Fisher Nickel. 2005. *Evaluating the water savings potential of commercial "Connectionless" Food Steamers.* Food Service Technology Center.

Metropolitan Water District of Southern California. 2011. *MWD Save a Buck*. Accessed 18 July 2012, from Connectionless Food Steamers: http://www.mwdsaveabuck.com/devices_01.php?id_dvce=1

Parpal, M. 2012. *Steamers: Steam Sensibly in Your Commercial Kitchen*. Accessed 18 July 2012, from Food Service Warehouse: http://www.foodservicewarehouse.com/restaurant-equipment-supply-marketing-articles/going-green/steamers-steam-sensibly-in-your-commercial-kitchen/c28124.aspx

Commercial, Industrial, and Institutional pre-rinse spray valve

Activity description

Pre-rinse sprayers rinse food waste from dishware before it enters a dishwasher. Efficient valves use less water with equal or better rinsing effectiveness. Water savings is calculated from a direct comparison with existing valves. However, it is important to note that the lower flow valves can increase washing time, between 8 to 30% in different studies. Measure savings are based on case studies that specify low-flow models to have a flow rate of 1.6 to 2.65 gpm at 80 psi for PRSVs, where high-flow models have a flow rate of 3 gpm or more. Measure considers replacement of one high-flow valve with the worst-case low-flow model (2.65 gpm).

Old/existing standards

None.

Tables A9–A12 summarize costs and savings.

Table A9. Costs, CII PRSV.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$217*	$150**	$2712	17.5	10		

* Cost includes valve and installation

** Unit Cost without installation

Table A10. Avoided costs, CII PRSV (cost of water and recycled water if elected not to use a higher efficiency).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$145(water)+$57 (sewer)+$4(elec)+$174(gas)=$380	

Table A11. Model inputs/potential savings, CII PRSV.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
28,285*	10%**	0	50%	10	0

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)

* Estimated use of 6hrs of per day, 260 days/yr
**"Worst-Case" reduction of 0.3 gpm, more efficient models are available

Table A12. Additional savings, CII PRSV.

Utility Saving (KwH/yr)*	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
51 kWh/yr	10%**	28 therms/yr	10%	0.61 tons***	10%	22,628	10

*Data source: AWE Tool
** Utility savings scale with water use
*** Based on EPA estimation of tons CO_2/therm

Table A12. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
Unknown	Unknown	N/A	N/A	N/A

Table A12. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>80% sewer + 20% evaporation)	100% (potable=>80% sewer + 20% evaporation)	N/A	N/A	Unknown	Unknown

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

EPA. 2007. *Calculations and References*. Accessed 18 July 2012, from Clean Energy: http://www.epa.gov/cleanenergy/energy-resources/refs.html

SBW Consulting, Inc. 2005. *Pre-Rinse spray valve installation program (Phase 2).* Sacramento, CA: California Public Utilities Commission.

Laundry: ENERGY STAR washers (multi-family/barracks)

Activity description

ENERGY STAR clothes washers use 14 gal/load or less, compared with 27 for a standard model. Modified energy factor (MEF) and water factor (WF) describe the energy and water efficiency of clothes washers. The MEF is equal to the ratio of the capacity of the clothes container to the sum of the energy required for heating the water, the energy required for removing the remaining moisture, and the electrical energy consumed by the machine. The WF is the ratio of the per cycle water consumption to the capacity. This measure considers installing high-efficiency (HE) washers in common areas of multi-family residential buildings, according to AWE. The models are H-axis.

Old/existing standards

None.

Efficiency standards

ENERGY STAR: MEF>2, WF<6, starting 1 January 2011.

Tables A13-A16 summarize costs and savings.

Table A13. Costs, laundry.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$790		$3973	7.5	8		

Table A14. Avoided costs, laundry (cost of water and recycled water if elected not to use a higher efficiency).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			8	$130(water)+$51(sewer)+ $7(elec)+ $550(gas)=$738	

Table A15. Model inputs/potential savings, laundry.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
25,310	37%	0%	50%	8	0%

Table A16. Additional savings, laundry.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
91 kWh/yr*	50%	89 therms/yr	50%	1.07	Unknown	20,248	11
* Energy savings from AWE Water Conservation Tracking Tool User Guide.							

Table A16. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
Unknown	Unknown	N/A	N/A	N/A

Table A16. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>80% sewer, 20% evaporation)	100% (potable=>80% sewer, 20% evaporation)	Unknown	Unknown	Unknown	Unknown

Plumbing code

N/A.

Constraints

None.

References

USEPA. 2012. *Appliance Savings Calculator*.

USEPA. 2007. *Calculations and References*. Accessed 18 July 2012, from Clean Energy, http://www.epa.gov/cleanenergy/energy-resources/refs.html

USEPA. 2012. *Clothes Washers Key Product Criteria*. Accessed 18 July 2012, from ENERGY STAR, http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers

EPA. 2012. *Clothes Washers Key Product Criteria*. Accessed 18 July 2012, from Energy Star: http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers

Nextag. 2012. Accessed 18 July 2012, http://www.nextag.com/energy-star-washer/stores-html

Commercial ENERGY STAR dishwasher (high temp, multi-tank conveyor)

Activity description

ENERGY STAR commercial dishwashers, on average, use 25% less energy and water than standard models. This measure considers replacing a standard multi-tank conveyor high temperature commercial dishwasher with an ENERGY STAR version of the same type.

Old/existing standards

None.

Efficiency standards

ENERGY STAR: multi-tank conveyor, high temp, <2.6 kW (idle energy rate), <0.54 gal/rack, effective October 2007.

Tables A17–A19 summarize costs and savings.

Table A17. Costs, commercial ENERGY STAR dishwasher.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$24,000	$75,682	6.67				

Table A18. Avoided costs: Cost of water and recycled water if elected to use a higher efficiency unit than commercial ENERGY STAR.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008		0	20	$7,999	

Table A19. Model inputs/potential savings, commercial ENERGY STAR.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)		Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)	
120,960*	50%**	0%	50%		20***	0%	
Utility Saving (KwH/yr)	% Savings KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
12, 249 kWh/yr	32%	993 therms/year	51%			96,768†	20

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)

* Multi-tank conveyor model, high temp. from Waste Reduction Partners, http://wastereductionpartners.org/phocadownload/Energy/Commercial%20Dishwashers%20Fact%20Sheet.pdf

** Estimate from Waste Reduction partners: http://wastereductionpartners.org/phocadownload/Energy/Commercial%20Dishwashers%20Fact%20Sheet.pdf

*** AWE estimates lifetime of HE dishwasher at 20-25 years, http://www.allianceforwaterefficiency.org/commercial_dishwash_intro.aspx

† Assuming 20% lost to evaporation, etc.

Table A19. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
26,029 kWh/yr*	38,278 kWh/yr*	N/A	N/A	N/A

* Extrapolated from % savings.

Table A19. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>80% sewer, 20% evaporation) <0.54 gal/rack*	100% (potable water=>80% sewer, 20% evaporation)	high temp, <2.6 kW (idle energy rate),	Unknown	450 racks/hr**	450 racks/hr

* http://www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers

** http://rc.etundra.com/commercial_dishwasher/capacity.aspx

Constraints

None.

References

How to Size a Commercial Dishwasher. Undated. Accessed 18 July 2012, from eTundra Restaurant Supply, http://rc.etundra.com/commercial_dishwasher/capacity.aspx

Commercial Dishwashers Key Product Criteria. Undated. Accessed 18 July 2012, from Energy Star, http://www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers

Commercial Dishwashing. Undated. Accessed 18 July 2012, from Alliance for Water Efficiency, http://www.allianceforwaterefficiency.org/commercial_dishwash_intro.aspx

Energy- and Water-Saving Fact Sheet: Commercial Dishwashers. 2011. Accessed 18 July 2012, from Waste Reducton Partners, http://wastereductionpartners.org/phocadownload/Energy/Commercial%20Dishwashers%20Fact%20Sheet.pdf

Fixtures

Plumbing and building codes influence the adoption of water-efficient products and processes. DoD adopts the ICC IPC as the primary standard for DoD facility plumbing systems. The code has a 3-year development cycle for updates. The process of amending codes is long and labor intensive and requires the support of water stakeholders. Any additions, deletions, and revisions to the IPC are listed in Appendix A “Supplemental Technical Criteria” of UFC 3-420-01, 25 October 2004.

WaterSense® is a USEPA partnership program that certifies water fixtures that meet rigorous criteria in both performance and efficiency. Specifications and criteria are available for bathroom sink faucets, shower heads, toilets, and urinals.

Commercial tank-type HE toilet

Activity description

This measure considers replacing a toilet using 3.5 gpf with one using 1.28 gpf.

Old/existing standards

Energy Policy Act of 1994 (EPAct 1994) requires all toilets sold to use 1.6 gpf or less.

Efficiency standards

1.28 gpf

Tables A20–A23 summarize costs and savings.

Table A20. Costs, commercial tank-type HE toilet.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$300/unit	$303*	4.35				

* Using 10 yr time period.

Table A21. Avoided costs, commercial tank-type HE toilet.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			15	$87	

Table A22. Other costs: Maintenance (recurring, periodic), life cycle of commercial tank-type HE toilet.

Savings, Per Unit (gpy)	Unit Savings % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
11,413.8	63%	0	50.14%	15	0

Table A23. Additional savings, commercial tank-type HE toilet.

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	11,413.8	15

Table A23. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	7.2 tons/yr	7.2 tons/yr	N/A

Table A23. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>sewer)	100% (potable=>sewer)	N/A	N/A	5,200 flushes/yr	5,200 flushes/yr

Plumbing code

Current Uniform Plumbing Code (UPC) plumbing codes place no limitations on horizontal run distances within a building.

Requirements examples

State Legislation introduced in California would require all toilets sold or installed in the state to be high efficiency by 2014.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Commercial HE valve type toilet

Activity description

This measure considers replacing a commercial valve type toilet using 3.5 gpf with one using 1.28 gpf.

Old/existing standards

EPAct 1994 requires all new toilets sold to use 1.6 gpf or less.

Efficiency standards

Tables A24–A27 summarize costs and savings.

Table A24. Costs, commercial HE valve type toilet.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$400	$539	3.4				

Table A25. Avoided costs, commercial HE valve type toilet.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			15	$87	

Table A26. Savings, commercial HE valve type toilet.

Savings, Per Unit (gpy)	Unit Savings % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
11,413.8	63%	0	50%	15	0

Table A27. Additional savings, commercial HE valve type toilet.

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	11,413.8	15

Table A27. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	7.2 tons	7.2 tons	N/A

Table A27. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>sewer)	100% (potable=>sewer)	N/A	N/A	5,200 flushes/yr	5,200 flushes/yr

Plumbing code

N/A.

Constraints

The minimum amount of water required for effective flushing is often considered to be 0.8 gpf.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Commercial tank-type HE toilet

Activity description

Uses 1.28 gpf or less.

Old/existing standards

EPAct 1992 requires all toilets sold after 1994 to use 1.6 gpf or less.

Tables A28–A31 summarize costs and savings.

Table A28. Costs, commercial tank-type HE toilet.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$300/unit	$603	4.35				

Table A29. Avoided costs, commercial tank-type HE toilet.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			15	$87	

Table A30. Savings, commercial tank-type HE toilet.

Savings, Per Unit (gpy)	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
11,413.8	0	50%	15	0

Table A31. Additional savings, commercial tank-type HE toilet.

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	11,413.8	15

Table A31. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	7.2 tons/yr	7.2 tons/yr	N/A

Table A31. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>sewer)	100% (potable=>sewer)	N/A	N/A	5,200 flushes/yr	5,200 flushes/yr

Plumbing code

Legislation introduced in California would require all toilets sold or installed in the state to be high efficiency by 2014.

Constraints

The minimum amount of water required for effective flushing is often considered to be 0.8 gpf.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Residential ultra low-flow toilet, single-family

Activity description

Ultra-low-flow toilets use 1.6 gpf or less. This measure considers replacing toilets using 3.5 gpf with ultra-low-flow toilets. Existing toilets using more than 1.6 gpf must have been sold before 1994.

Old/existing standards

EPAct 1992 requires all toilets sold after 1994 to use 1.6 gpf or less.

Tables A32–A35 summarize costs and savings.

Table A32. Costs, residential ultra low-flow toilet, single-family.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$250	$350	3.5				

Table A33. Avoided costs, residential ultra low-flow toilet, single-family.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			15	$55.6	

Table A34. Savings, residential ultra low-flow toilet, single-family.

Savings, Per Unit (gpy)	Unit Savings % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
7,296	20%	0	50%	15	23%*
* Reported by AWE as average for typical toilet programs.					

Table A35. Additional savings, residential ultra low-flow toilet, single-family.

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	7,296	15

Table A35. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	7.2 tons/yr	7.2 tons/yr	N/A

Table A35. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>sewer)	100% (potable=>sewer)	N/A	N/A	5,200 flushes/yr	5,200 flushes/yr

Plumbing code

Legislation introduced in California would require all toilets sold or installed in the state to be high efficiency by 2014.

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Toilet displacement device retrofit

Activity description

Toilets can be retrofitted to reduce flush volume through the use of displacement devices in the tank (bags and bottles), toilet dams, early closure devices, dual-flush adapters, and flush valve adjustments for valve toilets. This measure considers distribution of bags for retrofit of residential toilets, reducing volume from 3.5 to 2.5 gpf. The savings are weighted by a response rate of 50%, based on the 68% reported by Vickers. Flush valve urinals can also be retrofitted with diaphragm kits.

Old/existing standards

EPAct 1992 requires all toilets sold after 1994 to use 1.6 gpf or less.

Efficiency standards

N/A.

Tables A36–A39 summarize costs and savings.

Table A36. Costs, toilet displacement device retrofit.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2001	$1.05*		$86	95.2			

* Based on average reported by Vickers.

Table A37. Avoided costs: Cost of water and recycled water if elected to use a higher efficiency unit than toilet displacement device retrofit.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			5	$20	

Table A38. Savings, toilet displacement device retrofit.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
2,600*	29%**	0	50	5	0

* Assuming bag reduces flush volume by 1 gpf as reported by Vickers, and residential toilet flushed 5,200 times per year, weighted by 50% installation rate.

** Not weighted by response rate. Weighted by response rate, overall savings for the program would be estimated around 14%.

Table A39. Additional savings, toilet displacement device retrofit.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	2,600	5

Table A39. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	7.2*	7.2	N/A (fits in toilet tank)

* Assuming a family of 4

Table A39. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>sewer)	100% (potable=>sewer)	N/A	N/A	5,200 flushes/yr	5,200 flushes/yr

Plumbing code

N/A.

Constraints

Low-flow (1.6 gpf or less) toilets can generally not be retrofitted in this manner and care must be taken to ensure that retrofits do not disrupt the flushing mechanism. Bricks are not recommended as displacement devices in tanks, since they can cause damage to toilet parts.

References

Vickers, A. 2001. *Water Use and Conservation*. Amherst, MA: Waterplow Press.

Toilet valve replacement (3.5 to 1.28gpf)

Activity description

This measure considers replacement of a toilet valve to reduce flush volume from 3.5 to 1.28 gpf. The specific costs refer to a manual flushometer valve from Kohler.

Old/existing standards

EPAct 1992 sets a maximum of 1.6 gpf for new toilets, starting in 1994. Before that, toilets used as much as 3.5 gpf.

Efficiency standards

N/A.

Tables A40–A43 summarize costs and savings.

Table A40. Costs, toilet valve replacement (3.5 to 1.28gpf).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$337*	$567	3.9				

* Cost of individual piston valve from Kohler ($164) + 173 for labor, assuming productivity of two valves/hr http://www.grainger.com/Grainger/ZURN-INDUSTRIES-Toilet-Flush-Valve-3KLF4; RSMeans 2012 ($345/hr)

Table A41. Avoided costs: Cost of water and recycled water if elected to use a higher efficiency method than toilet valve replacement (3.5 to 1.28gpf).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$87	

Table A42. Model inputs/potential savings, toilet valve replacement (3.5 to 1.28gpf).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
11,414*	63%**	0	50%	10	0

* From savings for HE commercial valve type toilet

**Assuming reducing volume from 3.5 to 1.28 gpf

Table A43. Additional savings, toilet valve replacement (3.5 to 1.28 gpf).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
0	0	0	0	0	0	13,019.6	10

Table A43. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A43. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100%	100%	N/A	N/A	4,770* flushes/year	4,770 flushes/year
*					

Table A43. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100%	100%	N/A	N/A	2,200	2,200

Plumbing code

EPAct 1992 may apply.

Constraints

Piston valves are considered preferable because they fail in the closed position, as opposed to the open position for diaphragm valves.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

RS Means Construction Cost Data. 2012. Hoboken, NJ: Wiley.

Zurn Industries Flush Valve, Toilet, 1.6 GPF . Undated. Accessed 18 July 2012, from Grainger, http://www.grainger.com/Grainger/ZURN-INDUSTRIES-Toilet-Flush-Valve-3KLF4

Toilet valve replacement (1.6 to 1.28gpf)

Activity description

Assuming that valve reduces volume from 1.6 to 1.28 gpf

Old/existing standards

N/A.

Efficiency standards

EPAct 1992 sets a maximum of 1.6 gpf for new toilets, starting in 1994. Before that, toilets used as much as 3.5 gpf.

Tables A44–A47 summarize costs and savings.

Table A44. Costs, toilet valve replacement (1.6 to 1.28 gpf).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$323*	-$239	0.4				

* Cost of individual valve from Grainger Supply ($150) + 173 for labor, assuming productivity of two valves/hr http://www.grainger.com/Grainger/ZURN-INDUSTRIES-Toilet-Flush-Valve-3KLF4;; RSMeans 2012 ($345/hr)

Table A45. Avoided costs: Cost of water and recycled water if elected to use a higher efficiency method than toilet valve replacement (1.6 to 1.28 gpf).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$87	

Table A46. Generic input data, toilet valve replacement (1.6 to 1.28 gpf).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
11,414	20%*	0	50%	10	0

* Assuming reduction from 1.6 gpf toilet

Table A47. Additional savings, toilet valve replacement (1.6 to 1.28 gpf), energy, waste, GHG, chemicals.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
0	0	0	0	0	0	13,019.6	10

Table A47. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A47. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100%	100%	N/A	N/A	4,770*flushes/year	4,770 flushes/year
* Based on savings in AWE model, flushes per year of a toilet in a commercial building (AWE Conservation Tracking Guide, p 188)					

Table A47. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100%	100%	N/A	N/A	2,200*	2,200*
* Based on assumption in AWE Tracking Tool Guide of 8.5 flushes/day per urinal in commercial building, 260 days/yr.					

Plumbing code

EPAct 1992 may apply.

Constraints

California Assembly bill 715 requires all toilets sold or installed be HE toilets as of 1 January 2014.

Dual-flush toilet retrofit

Activity description

Dual-flush toilets have an option for flushing liquids and paper, which uses less water than a full flush. This measure considers retrofitting existing single-flush toilets to make them dual-flush, instead of replacing them completely. This measure considered is MJSI's HydroRight valve installed in a 1.6 gpf toilet (left) or MJSI's HydroClean valve installed in a 3.5 gpf toilet (right), each flushed 5,200 times a year.

Old/existing standards

EPAct 1992 requires all toilets sold after 1994 to use 1.6 gpf or less.

Efficiency standards

N/A.

Tables A48–A51 summarize costs and savings.

Table A48. Costs, dual-flush toilet retrofit.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$193*		-$111/23	0.5/1.3			

* Based on costs found online from Wal-Mart ((http://www.walmart.com/ip/Dual-Flush-Toilet-Converter/12537085?&wmlspartner=NTWp0rpInQ8&sourceid=04918824592626263554&veh=aff)) and Home Depot ((http://www.homedepot.com/Bath-Toilets-Toilet-Parts-Repair/BlueSource/h_d1/N-5yc1vZas0eZ6wg/R-202267979/h_d2/ProductDisplay?langId=-1&storeId=10051&catalogId=10053).), plus $173 for installation

Table A49. Avoided costs: Cost of water and recycled water if elected to use a higher efficiency technology than dual-flush toilet retrofit.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			5*	$19/$50	

* Conservative estimate since product is new.

Table A50. Model inputs/potential savings, dual-flush toilet retrofit.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
2,496*/6,552	30%/36%	0	50%	5	0

* Based on assumption of 5,200 flushes per year of 1.6 gpf toilet, and estimate of 30% savings. ((http://www.gomjsi.com/uploads/water_conservation/veritec270-660_03-10.pdf))

Table A51. Additional savings, dual-flush toilet retrofit.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	2,496	5

Table A51. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	7.2 tons/yr	7.2 tons/yr	Installed directly in tank

Table A51. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>sewer)	100% (potable water=>sewer)	N/A	N/A	5,200 flushes/yr	5,200 flushes/yr

Plumbing code

N/A.

Constraints

Care must be taken to ensure that retrofit does not interfere with proper functioning of the toilet. Aesthetic concerns may apply, since there may be "streaking" of waste in the bowl.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

RS Means Construction Cost Data. 2012. Hoboken, NJ: Wiley.

Zurn Industries Flush Valve, Toilet, 1.6 GPF . Undated. Accessed 18 July 2012, from Grainger, http://www.grainger.com/Grainger/ZURN-INDUSTRIES-Toilet-Flush-Valve-3KLF4

Residential HE toilets, single-family

Activity description

Use 1.28 gpf or less.

Old/existing standards

EPAct 1994 requires all toilets sold to use 1.6 gpf or less.

Efficiency standards

WaterSense

Tables A52–A55 summarize costs and savings.

Table A52. Costs, residential HE toilets, single-family.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$300		$4523	4.0			

Table A53. Avoided costs, residential HE toilets, single-family.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			15	$79.28	

Table A54. Savings, residential HE toilets, single-family.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
10,391	37%	0	50%	15	0%

Table A55. Additional savings, residential HE toilets, single-family.

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	10,391	15

Table A55. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	7.2 tons/yr	7.2 tons/yr	N/A

Table A55. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>sewer)	100% (potable=>sewer)	N/A	N/A	5,200 flushes/yr	5,200 flushes/yr

Plumbing code

EPAct 1992 requires all toilets sold to use 1.6 gpf or less.

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool.*

AWE. 2011. *Water Conservation Tracking Tool User Guide*.

Residential ultra low-flow toilet, multi-family

Activity description

This measure considers replacing a residential toilet using 3.5 gpf with a ultra-low-flow toilet using 1.6 gpf.

Old/existing standards

EPAct 1994 requires all toilets sold after 1994 to use 1.6 gpf or less.

Tables A56–A59 summarize costs and savings.

Table A56. Costs, residential ultra low-flow toilet, multi-family.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$250	$362	3.5				

Table A57. Avoided costs, residential ultra low-flow toilet, multi-family.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$250		15	$56.7	

Table A58. Model input/ potential savings, residential ultra low-flow toilet, multi-family.

Savings, Per Unit (gpy)	Unit Savings % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
7,438	54%	0	50%	15	23%*

* Reported by AWE as average for typical toilet programs.

Table A59. Additional savings, residential ultra low-flow toilet, multi-family.

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	7,438	15

Table A59. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	7.2 tons/yr	7.2 tons/yr	N/A

Table A59. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>sewer)	100% (potable=>sewer)	N/A	N/A	5,200 flushes/yr	5,200 flushes/yr

Plumbing code

Legislation introduced in California would require all toilets sold or installed in the state to be high efficiency by 2014.

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Commercial 0.5 gpf urinals

Activity description

This measure considers replacing an existing urinals using 2.5 gpf with a models using ½ gpf.

Old/existing standards

EPAct 1992 sets the maximum water use for urinals at 1 gpf.

Efficiency standards

Tables A60–A63 summarize costs and savings.

Table A60. Costs, commercial 0.5 gpf urinals.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$450	$42	1.6	0	0	0	0

Table A61. Avoided costs: Cost of water and recycled water if elected to use a higher efficiency technology than commercial 0.5 gpf urinals.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008		0	25	$47.3	0

Table A62. Model inputs/potential savings, commercial 0.5 gpf urinals.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
6,206	80%	0%	50%	25 years*	0%
* AWE estimates 25 -30 yr lifetime for urinals					

Table A63. Additional savings, commercial 0.5 gpf urinals.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
0	0	0	0	0	0	6,206	25 yrs

Table A63. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A63. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>blackwater)	100% (potable water=>blackwater)	N/A	N/A	2,200 flushes/yr	2,200flushes/yr

Plumbing code

N/A.

Constraints

Legislation introduced in California would require all urinals sold or installed starting in 2014 to be high efficiency, using no more than 0.5 gpf.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

One (1) pint (0.125 gpf) urinals

Activity description

This measure considers replacing existing urinals (using 2.5 gpf) with ones using 1 pint (or 1/8 gal) per flush or less.

Old/existing standards

EPAct 1992 set maximum water use for urinals of 1 gpf.

Tables A64–A67 summarize costs and savings.

Table A64. Costs, 1-pint (0.125 gpf) urinals.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$450	-$158	1.2	0	0	0	0

Table A65. Avoided costs: Cost of water and recycled water if elected to use a higher efficiency technology than 1-pint (0.125 gpf) urinals.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008		0	25	$20.72	0

Table A66. Model inputs/potential savings, 1-pint (0.125 gpf) urinals.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
2715*	95%	0%	50%	25 years**	0%
* Average 8.5 flushes per urinal, per day. ** From Koeller & Company estimate for urinals using ½ gpf or less					

Table A67. Additional savings, 1-pint (0.125 gpf) urinals.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
0	0	0	0	0	0	2715	25 yrs

Table A67. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A67. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>blackwater)	100% (potable water=>blackwater)	N/A	N/A	2,200 flushes/yr*	2,200flushes/yr*
* Assuming 8.5 flushes/day per urinal in commercial building, 260 days/yr.					

Plumbing code

For example, legislation introduced in California would require all urinals sold or installed starting in 2014 to be high efficiency, using no more than 0.5 gpf.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Replacing urinal valve

Activity description

This measure considers replacing a urinal valve to reduce flush volume from 1.5 to 0.5 gpf.

Old/existing standards

Current standards set 1 gpf as the maximum flush volume for a urinal. Old urinals often use 1.5 gpf.

Efficiency standards

WaterSense urinals use 0.5 gpf or less.

Tables A68–A71 summarize costs and savings.

Table A68. Costs, replacing urinal valve.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$350*	-$175	0.73				
* From $177 valve cost found online (Toto TMU1LN-CP 0.5gpf flushometer valve chrome), + $173 for installation, assuming productivity of 2 valves/hr							

Table A69. Avoided costs: Cost of water and recycled water if elected to use a higher efficiency method than replacing urinal valve.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			15	$17	

Table A70. Model inputs/potential savings, replacing urinal valve.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
2,210	67%	0%	50%	15	0%

Table A71. Additional savings, replacing urinal valve.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
0	0	0	0	0	0	2,210	15

Table A71. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A71. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>sewer)	100% (potable=>sewer)	N/A	N/A	2,200 flushes/yr	2,200 flushes/yr

Plumbing code

California requires all urinals sold after 2014 to be high efficiency, using no more than 0.5 gpf.

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

WaterSense showerheads

Activity description

This measure considers replacing a standard showerhead (using 2.5 gpm) with a WaterSense model using 2.0 gpm.

Old/existing standards

EPAct 1992 required new showerheads after 1994 to use 2.5 gpm or less. Popular models in use now typically use from 2.5 to 5.0 gpm.

Efficiency standards

WaterSense aims to improve efficiency standards by 20% to require 2.0 gpm showerheads. There is a growing market that provides as low as 1.5 gpm showerheads with increasing quality of showers.

Tables A72–A75 summarize costs and savings.

Table A72. Costs, WaterSense showerheads.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$116/unit*	$423	6.0	0	0	0	0

* Based on estimate for Fort Carson's zip code from: http://www.homewyse.com/services/cost_to_install_shower_head.html

Table A73. Avoided costs: Cost of water and recycled water if elected to use a more efficient technology than WaterSense showerheads.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	0	0	10	$70	0

Table A74. Model input/potential savings, WaterSense showerheads.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
1,898	20%	0	50%*	10**	0%

* Conservative assumption since showers tend to be taken during the daily peak water times between 6-9 a.m., but are taken at the same rate throughout the year.

** EPA assumes 10 yr lifespan: http://epa.gov/watersense/pubs/faq_showerheads.html

Table A75. Additional savings, WaterSense showerheads (energy, waste, GHG, chemicals).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
0*	0	9.11 therms/yr**	13.4%	0.05 tons CO_2	13.4	1,708***	10

* Assuming minimal pumping energy
** Assuming 0.0048 therms/gal as estimated by AWE (based on 0.0072 therms/gal to heat hot water, and 67% of water is hot)
*** Assuming 10% lost to evaporation, etc

Table A75. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
59 therms/yr	68 therms/yr	N/A	N/A	N/A

Table A75. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>10% evap, 90% sewer)	100% (potable=>10% evap, 90% sewer)	N/A	N/A		

Constraints

In locations where hard water persists, shower heads may clog from calcification. Water softeners may be considered as a means to reduce weekly or monthly maintenance to clear clogged showerheads. The use of softeners also requires water.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Cost to Install Showerhead. 2012. Accessed 18 July 2012, from Homewyse, http://www.homewyse.com/services/cost_to_install_shower_head.html

Energy Cost Calculator for Faucets and Showerheads. 2010. Accessed 18 July 2012, from US DOE--Energy Efficiency & Renewable Energy, http://www1.eere.energy.gov/femp/technologies/eep_faucets_showerheads_calc.html

EPA. 2007. *Calculations and References*. Accessed 18 July 2012, from Clean Energy, http://www.epa.gov/cleanenergy/energy-resources/refs.html

Showerheads. Undated. Accessed 18 July 2012, from WaterSense, http://www.epa.gov/WaterSense/products/showerheads.html

WaterSense faucets

Activity description

Installation of faucets that use 0.5 gpm. This measure considers a 100-occupant facility, and assumes 10 lavatory faucets, per Occupational Safety and Health Administration (OSHA) regulations, replacing 2.2 gpm faucets with 0.5 gpm faucets.

Old/existing standards

EPAct 1992 set 2.2 gpm as maximum water use for faucets.

Efficiency standards

Tables A76–A79 summarize costs and savings.

Table A76. Costs, WaterSense faucets.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net present value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$2116*	$4380	4.0	0	0	0	0
* Average cost for 10 faucets with installation							

Table A77. Avoided costs: Cost of water and recycled water if elected to use a more efficient technology than WaterSense faucets.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	0	0	10	$145 (water) +64(sewer)+$82(gas) =$291(tot)	0

Table A78. Model inputs/potential savings, WaterSense faucets.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
28,300*	77%	0	50%	10	0
*EPA assumes each person washes hands for 10 seconds, 4 times per day, 250 days per year, for a 100-occupant facility.					

Table A79. Additional savings, WaterSense faucets.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings(Therms /gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	102 therms/yr*	77% therms/yr	0.51 tons/yr	9%	25,470**	10
* Assuming 50% of water used is hot, and 0.0072 therms/gal used to heat water (AWE) ** Assuming 10% lost to evaporation, etc.							

Table A79. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
132 therms/yr	30 therms/yr	N/A	N/A	N/A

Table A79. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>90% sewer, 10% evap)	100% (potable=>90% sewer, 10% evap)	N/A	N/A	10,000 uses/faucet/yr	10,000 uses/faucet/yr

Plumbing code

EPAct 1992 may apply.

Constraints

None.

References

Cost to Install a Bathroom Faucet. 2012. Accessed 19 July 2012, from Homewyse, http://www.homewyse.com/services/cost_to_install_bathroom_faucet.html

Energy Cost Calculator for Faucets and Showerheads. (2010, November 3). Accessed 18 July 2012, from US DOE--Energy Efficiency & Renewable Energy, http://www1.eere.energy.gov/femp/technologies/eep_faucets_showerheads_calc.html

EPA. 2007. *Calculations and References*. Accessed 18 July 2012, from Clean Energy, http://www.epa.gov/cleanenergy/energy-resources/refs.html

Greening EPA--Lavatory Faucet Retrofits. (2011, August 16). Accessed 19 July 2012, from EPA, http://www.epa.gov/oaintrnt/water/faucets.htm

HE toilets, barracks

Activity description

Toilets using 1.28 gpf or less.

Old/existing standards

EPAct 1994 requires all toilets sold to use 1.6 gpf or less.

Efficiency standards

WaterSense.

Tables A80–A83 summarize costs and savings.

Table A80. Costs, barracks.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$300	$949	6.0				

Table A81. Avoided Costs, barracks.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			15	$120.38	

Table A82. Savings, barracks.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
15,777	37%	0	50%	15	0

Table A83. Additional savings, barracks.

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
			15,777	15

Table A83. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	7.2 tons/yr	7.2 tons/yr	N/A

Table A83. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>sewer)	100% (potable=>sewer)	N/A	N/A	5,200 flushes/yr	5,200 flushes/yr

Plumbing code

Legislation introduced in California would require all toilets sold or installed in the state to be high efficiency by 2014.

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Industrial

Alternate water for cooling towers (condensate)

Activity description

Condensate collection for cooling tower water. Condensate is very pure and requires almost no treatment. This measure considers condensate collection at Fort Carson, based on weather data from Denver, for a building with 20,000 CFM outside air.

Old/existing standards

None.

Tables A84–A87 summarize costs and savings.

Table A84. Costs, alternate water for condensate cooling towers.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$3500*		$15,043	6.9			

* From system at University of Georgia.

Table A85. Avoided costs: Cost of water and recycled water if elected to use a more efficient technology than condensate cooling towers.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$2,401	

Table A86. Model inputs/potential savings, condensate cooling towers.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
320,000*	0.2%**	0%	75%	10	0%

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)

* Based on actual data from Denver, CO
** 6750 gpd, 120 days/yr=>810kgal/yr

Table A87. Additional savings, condensate cooling towers.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	304,000*	10

* Assuming 5% lost to evaporation.

Table A87. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	Space for collection lines

Table A87. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (95% potable, 5% gray=>95% sewer, 5% evap)	100% (potable=>95% sewer, 5% evap)	N/A	N/A	100 tons	100 tons

Plumbing code

N/A.

Constraints

The cost effectiveness of this measure depends on the amount of condensate generated, and thus, is highly dependent on climate. In more humid climates, and places with higher water rates, this measure is more likely to pay back. Installation of condensate collection systems is much more cost effective in new buildings than in existing buildings.

References

Air-Conditioning Condensate Calculator. Undated. Accessed 19 July 2012, from Building Green, http://www.buildinggreen.com/calc/calc_condensate.cfm

Lawrence, T. 2010. Capturing Condensate by Retrofitting AHUs. *ASHRAE* , 48-54.

Alternate water for cooling towers (rainwater)

Activity description

This measure considers harvesting of rainwater for makeup water for a cooling tower. This measure assumes that the cooling season lasts from May through August, and that only rainwater collected then will be used. Assuming 60,078 gal of rainwater captured per cooling season) 7.6 in. of rain from May-Aug, 15,000 sq ft roof => 0.62 gal/sq ft captured per inch of rain*85% collection efficiency,). The volume of the tanks was selected to hold runoff resulting from half of highest average rainfall (1.97 in., April=>8,274 gal [WRCC 2012]) with some margin of error, resulting in the selection of two 10,000-gal underground storage tanks. Underground tanks were chosen because of the risk of water freezing in winter. In a warmer climate, tanks could be above ground or partially above ground, lowering the cost. Considered over the expected 10-year lifetime of the pump. It was assumed that the pump was ¾ HP and ran 4 hrs per week during the cooling season, based on assumption of a low 30 gpm flow to the cooling tower.

A large portion of the cost of a rainwater harvesting system is made up of the tank or tanks, and the cost of a tank is heavily dependent on the type of material. Plastic tanks are cheaper than concrete or metal cisterns, but may sometimes need to be partially or completely underground for stability. Excavating for placement of a tank can increase the cost of the system significantly.

Old/existing standards

None.

Efficiency standards

N/A.

Tables A88–A91 summarize costs and savings.

Table A88. Costs, alternate water for cooling towers (rainwater).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$48,244 (tanks)+$6,756(main pumps) +$2,956(booster pumps)=$57,956		-$59,129	-0.03	Every 5 years	$3000*	
* Mucking tanks and minor fittings replacement.							

Table A89. Avoided costs: Cost of water and recycled water if elected to use a more efficient technology than alternate water (rainwater) for cooling towers.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$448	

Table A90. Model inputs/potential savings, alternate water (rainwater) for cooling towers.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
60,078	7.4%*	0%	75%	10	0%
* Assuming total annual water use of 810 kgal for cooling (6750 gpd for 100 ton chiller, for 120 days/yr)					

Table A91. Additional savings, alternate water (rainwater) for cooling towers.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	57,074*	10
* Assuming 5% lost to evaporation, etc.							

Table A91. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	Unobstructed roof space for collection(assumed 15,000 sf) and space for underground storage tanks

Table A91. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (87.2% potable, 12.8% gray=>95% sewer, 5% evap)	100% (potable=>95% sewer, 5% evap)	N/A	N/A	100 tons	100 tons

Constraints

Rainwater harvesting systems require at least annual maintenance to clean pre-cistern filters and the cisterns themselves. Cleaning of the rooftop before heavy storms is recommended to avoid having debris swept into the cistern. For the first 5–10 minutes of a rain storm, the valve should be opened to dispose of the “first flush,” which is likely to be polluted. If harvested rainwater is to be used indoors, additional treatment and biannual testing is required.

States have varying laws and regulations regarding rainwater harvesting and reuse. Colorado law prohibits most reuse of rainwater in residential applications. Regulations vary from county to county.

References

Air-Conditioning Condensate Calculator. Undated. Accessed 19 July 2012, from Building Green, http://www.buildinggreen.com/calc/calc_condensate.cfm

Lawrence, T. 2010. Capturing Condensate by Retrofitting AHUs. *ASHRAE* , 48-54.

Reducing cooling tower blowdown with ozone treatment system

Activity description

Blowdown is the use of water flushed through the tower to lower concentration levels of contaminants, which increase as pure water is lost to evaporation. This measure considers increasing concentration ratio from 2 to 4 using ozone treatment instead of conventional chemical treatment for chiller water. A report by the New Mexico State Engineer notes that “conserving water in cooling towers is largely a function of water quality,” since water with higher concentrations of dissolved solids requires more frequent blowdown. Scale and corrosion associated with low quality water also reduce the cooling tower efficiency. Ozone treatment can also control corrosion and scale and increase efficiency “by oxidizing inorganics and soluble ions.” Ozone dissipates quickly and will not be found in the blowdown water, “reducing the overall chemical load within the discharged water, and making it easier to comply with regulations,” notes a Federal technology alert. “Ozone is typically applied to cooling water through a side stream of the circulating tower water.”

Old/existing standards

None.

FEMP guidelines: (N/A for chillers <150 tons),

Tables A92–A95 summarize costs and savings.

Table A92. Costs, ozone treatment system to reduce cooling tower blowdown.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$3,600*	$18,600	8.0**		As long as desired	$200***	

* Based on estimate of ozone system cost of $36/ton, from Federal technology alert.

** Assuming 10-year horizon for NPV

*** Assuming 10-year horizon for SIR; based on estimate of operating energy cost of ozone system to be $2/ton, from Federal technology alert

Table A93. Avoided costs: Cost of water and recycled water if elect to use a more efficient technology than an ozone treatment system to reduce cooling tower blowdown.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			As long as desired	$2,927 water+ $1,018 chemicals-$200 (elec)=$2875 total*	

* Assuming same cost of chemicals as in NASA case study, $10.18/ton/yr, from Federal technology alert.

Table A94. Model inputs/potential savings, ozone treatment system to reduce cooling tower blowdown.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
390,000*	33%	0%	75%	As long as desired	0%

* Assuming 100 ton cooling tower, increasing concentration from 2 to 4, decreasing water use from 6750 gpd to 3500 gpd, assuming operated 120 days per year(based on graph from New Mexico report)

Table A95. Additional savings.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
-2500*		0	0	-1.73		370,500**	As long as desired

* Electricity use of ozone system.

** Assuming 5% lost to evaporation

Table A95. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
2,500 kWh/yr*	N/A(water treatment), efficiency of chiller unknown	N/A	N/A	Indoor space needed for ozone generator, 5X5X10(height)ft needed
* Extrapolating from energy cost estimate of $200/yr, assuming $0.08/kWh				

Table A95. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water in=>evaporation(5%), reduced blowdown, sewer)	100% (potable water in=>evaporation(5%), blowdown, sewer)	Can vary, see FEMP standards	Can vary, see FEMP standards*	100 tons	100 tons
* FEMP standards for water-cooled chillers,					

Constraints

Ozone can also be a corrosive agent, due its high chemical oxidation potential. Typically it is used in quantities too small to promote corrosion. However, care must be taken to ensure that ozone use is appropriate for materials in the cooling tower.

References

New Mexico Office of the State Engineer. 1999. *A Water Conservation Guide for Commercial, Institutional, and Industrial Users.*

Pacific Northwest National Laboratory. 1995. *Ozone Treatment for Cooling Towers.*

Water-Cooled Electric Chillers. 2010. Accessed 19 July 2012, from US DOE--Energy Efficiency & Renewable Energy, http://www1.eere.energy.gov/femp/pdfs/spec_watercooledchiller.pdf

Atmospheric water generator

Activity description

An AWG "extracts water from humid ambient air." An AWG condenses water below its dew point. This measure considers an AWG, EcoloBlue 30 model from EcoloBlue. AWGs work most efficiently when temperature is above 65 °F and relative humidity is above 30%. The model is rated at 8 gal/day, but produces 5-7 gal/day at 30-35% humidity, so the savings are based on a production rate of 7 gal/day to be conservative. This measure assumes that the system runs 24 hrs a day, 260 days per year, at 280W, as specified.

Old/existing standards

None.

Tables A96–A99 summarize costs and savings.

Table A96. Costs, AWG.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$1200.00	-$1,061*	0.15*	0	0	0	0
* Assuming 10 yr time period.							

Table A97. Avoided costs, AWG.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	0	0	0	$5.4(sewer)+$12.3(water)=$18	0

Table A98. Savings, AWG.

Savings, Per Unit (gpy)	Unit % Savings from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
2400	Unknown*	0	100 %	1**	0
* Percent of conventionally derived potable water it replaces depends on the use. ** EcoloBlue model comes with only 1 yr warranty.					

Table A99. Additional savings, AWG.

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
-1,971	N/A	N/A	2,160*	N/A
* Assuming 10% lost to evaporation, etc.				

Table A99. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
1,971 kWh/yr*	0	N/A	N/A	5X5X10 space need for equipment
* 450 W model, assuming runs 50% of the time (4,380 hrs/yr)				

Table A99. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (humidity=>potable water)	N/A	450W model(efficiency not known)	N/A	N/A	2400 gal

Plumbing code

N/A.

Constraints

This measure is practical only in areas with sufficiently high humidity. Performance curves for an individual water generator indicate its production at different humidity levels. For example, the Ecolo Blue 30 produces 10 gal/day at 35% relative humidity, 18.5 gal/day at 50% relative humidity, and 33 gal/day at 90% relative humidity.

References

Atmospheric Water Generator--How it Works. Undated. Accessed 19 July 2012, from Atmospheric Water Supply, http://www.atmosphericwatersupply.com/index.php/component/content/article?id=26

EcoloBlue 26. 2012. Accessed 19 July 2012, from EcoloBlue, http://www.ecoloblue.com/ecoloblue26.html

Home & Office Products. 2012. Accessed 19 July 2012, from EcoloBlue, http://www.ecoloblue.com/home-office.html

Corrosion control

Activity description

Failure of water pipes can be classified as corrosion failures or mechanical failures. Mechanical failures occur when the pipe is "no longer able to resist applied forces," while corrosion failures occur as a result of "holes or thinning of the pipe due to corrosion to the point where normal water pressure will blow out the thin skin of metal that remains." This measure considers cathodic protection, or an impressed current system, which "use an active direct current that is impressed into the pipeline making it catholic, thereby protecting if from corroding … the anode of this system is a buried probe that will corrode overtime," according to the USEPA.

Old/existing standards

None.

Tables A100–A103 summarize costs and savings.

Table A100. Costs, corrosion control.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2005	$12,681,160*		-$3,745, 416	1.25			

* Assuming same cost per foot of main as cathodic protection for 13,800 ft section of main in Des Moines.

Table A101. Avoided costs: Cost o-f water and recycled water if elected use a more efficient method than corrosion control.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			25*	$634,013**	

* Based on 25% of total cost of water main breaks at Fort Carson($157,410 for small pipes+$2,378,640)=$2,536,050 total)

** Estimated 25% of pipe failures caused by corrosion (Folkman 2012) and total water lost in pipe failures per year at Fort Carson is 23,013,153 gal (1,428,403 from small diam pipes, 21,584,750 from large diam pipes)

Table A102. Model inputs/potential savings, corrosion control.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
5,753,289	Unknown	0	50%	25	0

Table A103. Additional savings, corrosion control.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	4,588,231*	25

* Assuming 20% lost to evaporation, etc.

Table A103. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	

Table A103. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>80% sewer, 20% evap)	100% (potable=>80% sewer, 20% evap)	N/A	N/A	796,308 kgal/yr	796,308 kgal/yr

Constraints

None.

References

USEPA. 2010. Control and Mitigation of Drinking Water Losses.

Schramuk, J. 2005. Cathodic protection for a new ductile iron water transmission main. *Materials Performance*.

Leak detection for chilled-water lines

Activity description

This measure considers performing preventative leak detection for chilled-water lines and assumes that leak detection results in avoiding breaks and major repairs. Based on reports from operations personnel, Fort Carson has approximately 15 miles of chilled-water lines. Assuming most chilled-water lines are steel, according to data from Utah State University (2007), the average rate of breaks is 13.5/100 miles per year, resulting in an estimated two breaks per year at Fort Carson. Since most chilled-water lines have diameters less than 8 in., the cost for a break was assumed to be same as for a small water main, around $6,000. Water savings was calculated based on assuming that water costs, at Fort Carson rates, made up 5% of the total direct cost of repairs, $12,000 per year, a conclusion made in Peter Gaewski's "Analysis of the Cost of Large Diameter Pipe Failures" (2007). Water savings is positive for this measure because leak detection avoids chilled-water line breaks.

Leak detection was assumed to have the same cost as for regular water mains, with a net present value of -$304,310 over the next 20 years for leak detection using noise correlators. The net present value of repairing chiller lines as they break was found to be -$156,792, so leak detection is not economical for chilled-water lines.

Old/existing standards

None.

Efficiency standards

Tables A104–A107 summarize costs and savings.

Table A104. Costs, leak detection for chilled-water lines.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2010		-$304,310	0.02		As long as desired	25,000	

Table A105. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than leak detection for chilled-water lines.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			As long as desired	$581*	

* Assuming that water costs are 5% of the total direct costs of repairs, included in the $12,000 total.

Table A106. Model inputs/potential savings, leak detection for chilled-water lines.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
108,893	Unknown	0	50%	As long as desired	0%

Table A107. Additional savings, leak detection for chilled-water lines.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
298	Unknown	N/A	N/A	0.2	Unknown	0*	As long as desired

* Assuming water from break flows to storm sewer or is absorbed by ground.

Table A107. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A107. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100%	100%	N/A	N/A	200-500 GPH*	200-500 GPH**

* As reported by operations staff at Fort Carson.

** As reported by operations staff at Fort Carson, assuming no change in capacity.

Plumbing code

N/A.

Constraints

None.

References

EPA. 2010. *Control and Mitigation of Drinking Water Losses in Distribution Systems.* Washington, DC: USEPA, http://water.epa.gov/type/drink/pws/smallsystems/upload/Water_Loss_Control_508_FINALDEc.pdf

Folkman, S. 2012. *Water Main Break Rates in the USA and Canada: A Comprehensive Study*. Utah State University.

Gaewski, P. 2007. *Analysis of Total Cost of Large Diameter Pipe Failures*. Denver, CO: AWWA Research Foundation, http://www.infra-tect.com/pdffiles/Analysis%20of%20Total%20Cost%20of%20Large%20Diameter%20Pipe%20Failures

Repair for chilled-water lines

Activity description

This measure considers waiting for chilled-water lines to break and repairing them then, as opposed to performing preventative leak detection**.** Based on reports from operations personnel, Fort Carson has approximately 15 miles of chilled-water lines. Assuming most chilled-water lines are steel, according to data from Utah State (2007), the average rate of breaks is 13.5/100 miles per year, resulting in an estimated two breaks per year at Fort Carson. Since most chilled-water lines have diameters less than 8 in., the cost for a break was assumed to be the same as for a small water main, around $6,000. Water savings was calculated based on assuming that water costs, at Fort Carson rates, made up 5% of the total direct cost of repairs, $12,000 per year Gaewski'2007). Water savings is negative for this measure because broken chilled-water lines result in water loss.

Leak detection was assumed to have the same cost as for regular water mains, with a net present value of -$304,310 over the next 20 years for leak detection using noise correlators. The net present value of repairing chiller lines as they break was found to be -$156,792, so leak detection is not economical for chilled-water lines.

Old/existing standards

None.

Tables A108–A111 summarize costs and savings.

Table A108. Costs to repair chilled-water lines.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012		-$156,792	-0.05		As long as desired	$12,000	

Table A109. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than to repair chilled-water lines.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			As long as desired	-$581*	

* Assuming that water costs are 5% of the total direct costs of repairs, included in the $12,000 total.

Table A110. Model inputs/potential saving for repair of chilled-water lines.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
-108,893	Unknown			As long as desired	

Table A111. Additional savings for repair of chilled-water lines.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
-298	Unknown	N/A	N/A	-0.2	Unknown	0*	As long as desired

* Assuming water lost goes to storm sewers or is absorbed by the ground and assuming 20% lost to evaporation, etc.

Table A111. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A111. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100%	100%	N/A	N/A	200-500 GPH*	200-500 GPH**

* Based on information from operations staff at Fort Carson.

** Based on information from operations staff at Fort Carson, assuming no change in capacity.

References

EPA. 2010. *Control and Mitigation of Drinking Water Losses in Distribution Systems.* Washington, DC: USEPA, http://water.epa.gov/type/drink/pws/smallsystems/upload/Water_Loss_Control_508_FINALDEc.pdf

Folkman, S. 2012. *Water Main Break Rates in the USA and Canada: A Comprehensive Study*. Utah State University.

Gaewski, P. 2007. *Analysis of Total Cost of Large Diameter Pipe Failures*. Denver, CO: AWWA Research Foundation, http://www.infra-tect.com/pdffiles/Analysis%20of%20Total%20Cost%20of%20Large%20Diameter%20Pipe%20Failures

Eliminate single-pass cooling

Activity description

This measure considers eliminating a 10-ton single-pass cooling system by connecting it to an existing cooling tower, operating at two cycles of concentration, using 6,750 gal/100 tons.

Old/existing standards

None.

Tables A112–A115 summarize costs and savings.

Table A112. Costs to eliminate single-pass cooling.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$10, 000*	$18,600**	4.29**				

* Based on assumption of $1,000/ton to "replace" single-pass cooling system, possibly an overestimate for connecting it to an existing chiller.

** Assuming 10 yr time period.

Table A113. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than eliminating single-pass cooling.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$753(sewer)+$1,617(water)+$1916(elec)=$4,286		20		

Table A114. Model inputs/potential savings for eliminating single-pass cooling.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
315,900*	97.5%**	0%	50%	20***	0%

* Assuming replacing by connecting a 10-ton load with cooling tower operating at two cycles of concentration, using 67.5 gal of water/day (6750 gal/100 tons), from New Mexico Water report, assuming single-pass system used 40 times as much water, assuming operates 120 days/yr,

** Single-pass cooling system uses 40 times as much water

*** Lifetime of existing chiller, based on Facilities Net estimations for different types of chillers,

Table A115. Additional savings for eliminating single-pass cooling.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
23,952*	Depends on type of single-pass chiller being replaced	N/A	N/A	16.5	Depends on type of single-pass chiller being replaced	300,105**	20

* Assuming chilled-water temp of 40 °F and average outdoor temperature of 66.4 °F, 220 BTU/gal to chill water, based on average temps May-Sept (and formula (assuming replaced with 85% efficient chiller

** Assuming 5% lost to evaporation, etc.

Table A115. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
5,760 kWh/yr*	Depends on type of single-pass chiller being replaced	N/A	N/A	N/A

* Annual energy use of cooling tower for that a 10-ton system's load, assuming 0.2 kW/ton per day, operating 120 days/yr, including pumps, off-peak

Table A115. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
90%(assuming 5% lost to evaporation, and 5% to blowdown)	0%(all water dumped after each cycle)	85%	Depends on type of system being replaced	Connected to larger system	10 tons

Constraints

None.

Replacing steam system with hot water system

Activity description

Hot water systems are much more energy and water efficient than steam for distributing heat from a central plant. The conversion is more cost effective in two-pipe steam systems, as opposed to single pipe systems. Fort Carson already has a hot water system in place, with two 40 MMBtu and one 25 MMBtu generators. Water savings were calculated based on 18% water savings found in conversion of steam system on Stanford's campus. Water use of boilers was calculated based on the size of the boilers at Fort Carson and on water's specific heat.

Old/existing standards

None.

Tables A116–A119 summarize costs and savings.

Table A116. Costs, replacing steam system with hot water system.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2010	$14,490, 564*		-$3,826,204	1.18			
* Scaled from costs at Savannah Hospital (based on feet of pipe), and increased by 20% for inflation since 1992							

Table A117. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than replacing steam system with hot water system.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
			20	$855,736	

Table A118. Model inputs/potential savings, replacing steam system with hot water system.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
46,800	18%	0	50%	20	0

Table A119. Additional savings, replacing steam system with hot water system.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	137,970 therms/yr	60%	690	50%	33,800*	20
* Assuming 30% lost to evaporation							

Table A119. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A119. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
			63%		

Constraints

Certain process applications (i.e., sterilization) that are connected to the heating loop may require steam or hot water of a certain temperature.

References

Residual stream reduction: Membrane filtration

Activity description

Measures taken to reduce the amount of water pumped that does not leave the treatment plant as treated effluent. Concentrate that is not pushed through a primary membrane filtration system can be run through a secondary system, thereby reducing the residual stream. Water pushed through the second membrane is routed back to the main treatment process.

Old/existing standards

None.

Tables A120–A122 summarize costs and savings.

Table A120. Costs, residual stream reduction (membrane filtration).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$187,878		$2,892,574	26.3	20	$1189*	
* Membrane replacement every 7 years							

Table A121. Savings, residual stream reduction (membrane filtration).

Savings, Per Unit (gpy)	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
32,900,000*	0%	50%	20	0%
* Assume 1 MGD Treatment Plant, 90% stream reduction after secondary membrane treatment				

Table A122. Additional savings, residual stream reduction (membrane filtration).

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
-33,182			32,900,000	20

References

Christianson, B., and Fiorante, R. 24 July 2012. *Saving Water, Seeing Green: Water Treatment Plant Strives for Sustainability*. Accessed 24 July 2012, from Water World: http://www.waterworld.com/articles/print/volume-23/issue-3/editorial-feature/saving-water-seeing-green-water-treatment-plant-strives-for-sustainability.html

McAdam, E. J., and Judd, S. J. 2008. Immersed membrane bioreactors for nitrate removal from drinking water: Cost and feasibility. *Desalination*, 52-60.

Tech Brief: Water Treatment Plant Residuals Management. March 1998. Accessed 23 July 2012, from National Drinking Water Clearinghouse: http://www.nesc.wvu.edu/pdf/dw/publications/ontap/2009_tb/water_treatment_DWFSOM49.pd

Residual stream reduction: Ion exchange

Activity description

Reduce brine stream associated with the ion exchange resin by installing a membrane bioreactor to regenerate brine. Example assumes ion exchange is used for nitrate removal.

Old/existing standards

None.

Tables A123–A125 summarize costs and savings.

Table A123. Costs, residual stream reduction (ion exchange).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2007	$24,261	$24,261	$145,553	11.2	20	160.17*	160.17
* Includes membrane replacement every 7 years							

Table A124. Avoided costs, residual stream reduction (ion exchange).

Savings, Per Unit (gpy)	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
1,825,000*	0%	50%	20	0%
* 90% brine recovery, assume brine makes up 5% of influent				

Table A125. Additional savings, residual stream reduction (ion exchange).

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
-1728.22	0	0	1,825,000	20

References

Steam trap replacement

Activity description

Steam traps are valves intended to remove condensate and air from the system. Air can reduce heat transfer capability, and cause corrosion. Failed (leaking) traps allow steam to escape, wasting water and energy. Steam traps can be mechanical using difference in density between steam and condensate, thermostatic (detect difference in temperature), or thermodynamic (using volumetrics and pressure differences between condensate and gas). EERE recommends that high-pressure steam traps (150 psig) be inspected weekly to monthly to check for leaks, medium pressure (30-150 psig) be inspected monthly to quarterly, and low-pressure traps (below 30 psig), annually. They estimate that in systems that have not been inspected in 3-5 years, 15-30% of traps may have failed. These costs are based on a steam trap maintenance program that looks for and repairs failed traps.

Old/existing standards

None.

Efficiency standards

N/A.

Tables A126–A129 summarize costs and savings.

Table A126. Costs, steam trap replacement.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$4000+ $55/trap[*]	$67,761,604[**]- $1,355,527,208[***] $122,334,108[†]– $244,672,216[‡] (total)	53.4-84.6[§], 304.4 -482[f]			$5000+$29/trap	

[*] Based on EERE estimate, including training, equipment, and labor costs

[**] Assuming 50 traps at high pressure

[***] Assuming 100 traps at high pressure

[‡] Assuming 50 traps at low pressure,

[§] Assuming 100 traps at low pressure

[f] For 50 traps, 100 traps, respectively, at low pressure; for 50 traps, 100 traps, respectively, at high pressure

Table A127. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than steam trap replacement.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$3, 130,948/$565,153* per trap				

* High-pressure case/low-pressure case

Table A128. Model inputs/potential savings, steam trap replacement.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
5.54 mil/1 mil gal/trap*	20%*	0	50%	5**	0%

* High-pressure case, savings per trap, assuming 150 psig steam, leaking from completely failed 1/8” diameter trap=>75.8 lb steam lost/hr, =>664,008 lb steam lost year (24/7 operation), 1 lb=>8.35 gal =>5.54 mil gal;
Low-pressure case, savings per trap, assuming 15 psig steam, leaking from completely failed 1/8” diameter trap=>13.7 lb steam lost/hr=>120,000 lb steam lost year (24/7 operation), 1 lb=>8.35 gal =>1 mil gal

** Recommended by steam trap manufacturer (Spirax-Sarco)

Table A129. Additional savings, steam trap replacement.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
		0.09*		0.00045 tons CO_2/gal		4.49 million/ 0.73million/gal /fixture**	5

* High-pressure case, 150 psig, assuming 150 °F feedwater temp, 0.01 therms/lb of steam=> 0.09 therms/gal, assuming low-pressure case is similar

** Assuming 10% lost to evaporation, and 90% of remaining condensate returned

Table A129. Cont’d.

Energy use/yr(new equipment)	Energy use/yr(old equipment)	Waste produced (new) (tons)	Waste produced (old) tons	Space impacts
N/A	N/A	N/A	N/A	N/A

Table A129. Cont’d.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>evaporation (10%) + leaks (9%) sewer (81%))	100% (potable water=> evaporation (10%) + leaks (9%) sewer (81%))	80%*	80%	15 or 150 psig	15 or 150 psig

* Assuming same boiler, 80% efficient.

Constraints

None.

References

Benchmark the Fuel Cost of Steam Generation. 2000. Accessed 19 July 2012, from Energy Star, http://www.energystar.gov/ia/business/industry/bnch_cost.pdf

EPA. 2007. *Calculations and References*. Accessed 18 July 2012, from Clean Energy, http://www.epa.gov/cleanenergy/energy-resources/refs.html

State Supply. 2014. *Float and Thermostatic Traps*. Web page. Accessed 19 July 2012, from Spirax-Sarco: http://www.statesupply.com/steam-traps/spirax-sarco

Sustainable Stanford. 2011. *Stanford Energy Systems Innovations*. Accessed 19 July 2012, http://sustainable.stanford.edu/sesi

FEMP. 1999. *Steam Trap Performance Assessment*. DOE/EE-0193. Accessed 19 July 2012, http://www1.eere.energy.gov/femp/pdfs/FTA_SteamTrap.pdf

Natural Gas Boiler Burner Consortium. 2007. *Steam Traps*. Accessed 20 July 2012, http://cleanboiler.org/Eff_Improve/Steam_Distribution/Steam_Traps.asp

Direct reuse

Activity description

Direct potable reuse, i.e., the introduction of recycled water directly into a potable water distribution system, could provide further flexibility than indirect potable reuse to augment potable water supplies.

Direct potable reuse is technically demanding because wastewater requires more extensive treatment before re-introduction in the drinking water plant. Direct potable reuse does suffer some serious questions regarding health and hygiene. The dilution of pollutants by receiving bodies of water in traditional water treatment plays a significant role in cleaning the water. A system that loops back a large quantity of its water volume has the risk of concentrating pollutants over time. While USEPA-limited pollutants and pathogens are closely monitored, there are other potential problem chemicals whose effects are unknown. Measure information based on 17-year wastewater pilot study using the city of Denver, CO. In Denver, wastewater is treated at the main wastewater plant and pumped to an advanced water treatment plant specifically built for direct reuse. The measure does not assume savings in wastewater treatment costs. A user is not charged for water that is produced by direct reuse water treatment plant. Costs incurred are considered to be capital and operational costs of a direct reuse plant.

Old/existing standards

None.

Efficiency standards

Direct potable reuse requires a careful examination of issues regarding public acceptance, public health, regulatory requirements, and project management and operation. A significant public outreach campaign is required prior to any actual direct use project to be potentially successful.

Tables A130–A133 summarize costs and savings.

Table A130. Costs, direct reuse.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012*	$8,511,000	0	$4,633,000	2.3	17**	$921,400	0
* Costs Adjusted from 1998 dollars using a 3% inflation rate ** Length of Denver, CO case study							

Table A131. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than direct reuse.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
1998	N/A	N/A	17	$2,086,912	0

Table A132. Model inputs/potential savings, direct reuse.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
407,600,000	48%	0	50%	17	0

Table A133. Additional savings, direct reuse.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	0	N/A	0	17

Table A133. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	0	0	40,000

Table A133. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
0%	100%	N/A	N/A	Same	Same

Constraints

Currently, no plumbing codes allow direct reuse. Water rights may present additional challenges for implementation of this type of project.

References

Direct Potable Reuse Workshop. 2010. *Workshop Report*. Sacramento, CA: California Urban Water Agencies, National Water Research Institute, and WateReuse California, http://www.nwri-usa.org/pdfs/DirectPotableWorkshopSummaryFINAL091010.pdf

Wingo, Andy. 2001. *Direct potable reuse*, http://wingolog.org/writings/water/html/node55.html

Indirect reuse tertiary treated effluent

Activity description

Reclaimed water is urban wastewater that has undergone additional treatment following secondary treatment to be reused rather than discharged into the environment. Treatment for indirect reuse often consists of a period of natural attenuation, either in surface or groundwater forms.

A reclaimed water system consists of a water reclamation facility that provides treatment in addition to secondary treatment. It also contains a distribution system that includes pipelines, storage facilities and pumping facilities. Benefits may include that:

- Reclaimed water can contain high concentrations of nutrients, which effectively adds an additional "soil treatment" that may eliminate the need for fertilizer and provide long-term soil enrichment.
- The use of reclaimed water decreases demand on the potable water supply.
- The use of reclaimed water may also prevent water not in compliance with clean water act requirements being discharged to receiving waters.

Direct groundwater injection will be considered for this measure because surface discharge is already the standard for wastewater, leading to de-facto indirect reuse. Aquifer Recharge and Recovery (ARR) systems use direct groundwater injection up-gradient from drinking water wells to recharge the aquifer. Aquifers must be sufficiently thick and allow for enough lateral distance between the wells to allow for some natural attenuation of treated wastewater.

Area water laws will dictate the practicality of using indirect water reuse. Because of the interconnected nature of indirect reuse, analysis of the current area water balance must also be conducted to accurately predict how indirect reuse will affect the watershed.

Old/existing standards

Standards that concern wastewater drained into local surface water may apply.

Tables A134–A137 summarize costs and savings.

Table A134. Costs, indirect reuse of tertiary treated effluent.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$3,750,000	N/A	$6,411,650	3.5	10	$180,000+$277,895(reuse fee)*=$ 457,895	0

* Based on Fort. Carson reuse rate fee of $0.8021/kgal

Table A135. Avoided costs, indirect reuse of tertiary treated effluent.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2009	$10,905,000*	N/A	10	$177,875	0

* Based on average cost per acre ft of water rights sold in the state of Colorado during 2009

Table A136. Model inputs/potential savings, indirect reuse of tertiary treated effluent.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
346,460,000*	N/A	0	50%	10	0

* Assuming 15% loss due to evapotranspiration via soil

Table A137. Additional savings, indirect reuse of tertiary treated effluent.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	0	N/A	0	10

Table A137. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	0	0	40,000

Table A137. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
85%	0%	N/A	N/A	400,000*gal	N/A
* Assume designed for 1.5% per year					

Plumbing code

Local and state regulations that govern treated wastewater transport may apply.

Constraints

State and local regulation son wastewater injection and stream flow to drinking water wells

Social barriers still exist for graywater reuse. Consider a significant public outreach as part of the implementation plan along with signage to protect from misuse.

References

Stoughton, K. M. 2012. *Fort Carson Net Zero Water Balance Report*. US Department of Energy.

USEPA. 2013. Water Recycling and Reuse: The Environmental Benefits. Web page, http://www.epa.gov/region9/water/recycling/

Gaesser, Lindsay. 2011. San Diego Showdown: IPR vs. Purple Pipes. Web page, http://www.sdcoastkeeper.org/blog/san-diego-water-supply/item/148-san-diego-showdown-ipr-vs-purple-pipes.html

Repair of water mains

This measure considers using leak detection vs. replacing lines as they break for both small and large diameter lines. A 20-year time horizon was considered for the LCCA. Based on statistics found for the number of water main breaks per mile of iron pipe per year, it was estimated that Fort

Carson would experience 8.25 breaks per year. It was assumed that leak detection would need to be done every year.

LCCA comparing detection for small diameter pipes concluded that the net present value, over the next 10 years, was -\$132,273. The costs of detection annually exceed the savings from averted water loss. For large diameter pipes, due to the larger loss averted, the net present value over the next 10 years was \$1,042,913. It was assumed for the purposes of comparison that detection would prevent 90% of all bursts. Accounting for the costs of repair as well as water lost, it was found that the net present value of waiting until small diameter pipes broke to repair them, over the next 10 years, was -\$1,215,478. It was assumed that 10% of breaks were in small diameter pipes and 90% in large diameter, consistent with the ratio between mains of those size in use. Utah State (2012) reports that 66% of mains are 8-in. or less in diameter, and that 18% vary from 10-14 in. It was inferred that roughly 10% have diameters greater than 20 in. For large diameter pipes, this cost was found to be –\$18,367,228 due to the higher costs of repair and the greater amounts of water lost. Based on these calculations, it appears worthwhile to perform leak detection for large diameter pipes, diameters greater than 20 in., but not small diameter ones.

Large diameter vs. short diameter pipes

Repair (small diameter pipe, diameter <20 in.)

Tables A138–A141 summarize costs and savings.

Table A138. Costs, repair of water mains.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed (\$)	Utility Costs, Initial Variable (\$/unit)	Net Present Value(\$)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed (\$/yr)	Utility Costs, Follow-up Variable (\$/unit/yr)
2010	129,266		-\$1,215,478*	As long as desired	\$157,410**	

* Based on 10-year time period.

** Based on average cost of water main break in Kansas City (http://www.kctv5.com/story/16903123/kctv5-investigates-water-main-woe?clienttype=printable) and assuming 8.25 breaks per year

Table A139. Avoided costs: Cost of water and recycled water if elected to use a more efficiency method than repair of water mains.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			As long as desired	-$7,870*	

* Based on estimate that water losses are 5% of the total cost of repair, and included in the repair cost.

Table A140. Model inputs/potential savings, repair of water mains.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
-1,428,403*		0%	50%	1	0%

* Based on estimate that water losses are 5% of the total cost of repair.

Table A141. Additional savings, repair of water mains.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
						-1,142,722*	1

* Assuming 20% lost to evaporation

Table A141. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)

Repair (large diameter pipe, diameter>20 in.)

Tables A142–A145 summarize costs and savings.

Table A142. Costs, repair (large diameter pipe, diameter>20 in.).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value($)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2010			$18,367,228*	As long as desired	$2,378,640**	

* Based on 10-year time period.

** Based on cost of average "large diameter pipe failure" ($1.7 mil, per Gaelewski [2007], p 19), and assuming 8.25 breaks per year and that 50% are large diameter pipes

Table A143. Avoided costs: Cost of water and recycled water if elected to use a more efficient alternative than repair (large diameter pipe, diameter>20 in.).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			As long as desired	-$118,932*	

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
* Included in the $1.7 mil total cost. Based on the conclusion in Analysis of Total Cost of Large Diameter Pipe Failures (Gaewski 2007, p 21), that water loss makes up 5% of total direct cost.					

Table A144. Model inputs/potential savings, repair (large diameter pipe, diameter>20 in.).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
-21,584,750*		0%	50%	As long as desired	0%
* Based on estimate that water losses make up 5% of repair cost.					

Table A145. Additional savings, repair (large diameter pipe, diameter>20 in.).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
						-17,267,800*	As long as desired
* Assuming 20% lost to evaporation							

Table A145. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

References

Blaha, F. B., and Gaewski, P. 2007. Analysis of Total Cost of Large Diameter Pipe. In *AWWA 2007 Research Symposium on Distribution Systems: The Next Frontier.*

Water mains: Leak detection

This measure considers using leak detection vs. replacing lines as they break for both small and large diameter lines. A 20-year time horizon was considered for the LCCA. Based on statistics found for the number of water main breaks per mile of iron pipe per year, it was estimated that Fort Carson would experience 8.25 breaks per year. It was assumed that leak detection would need to be done every year.

LCCA comparing detection for small diameter pipes concluded that the net present value, over the next 10 years, was -$132,273. The costs of detection annually exceed the savings form averted water loss. For large diameter pipes, due to the larger loss averted, the net present value over the next 10 years was $1,042,913. It was assumed for the purposes of comparison that detection would prevent 90% of all bursts. Accounting for the costs of repair as well as water lost, it was found that the net present value of waiting until small diameter pipes broke to repair them, over the next 10 years, was -$1,215,478. It was assumed that 10% of breaks were in small diameter pipes, and 90% in large diameter, consistent with the ratio between mains of those size in use. (Utah State [2012] reports that 66% of mains have diameters 8-in. or less, and 18% have diameters that vary from 10-14 in. It was inferred that roughly 10% have diameters greater than 20 in.) For large diameter pipes, this cost was found to be -$18,367,228 due to the higher costs of repair and the greater amounts of water lost. Based on these calculations, it appears worthwhile to perform leak detection for large diameter pipes, diameters greater than 20 in., but not small diameter ones.

Large diameter vs. short diameter pipes

Leak detection (small diameter pipe)

Tables A146–A149 summarize costs and savings.

Table A146. Costs, leak detection (small diameter pipe).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2010		-$132,273*		As long as desired	$25,000**	

* Considering 10-year time period.
** Based on estimations in Leak Mitigation and Control

Table A147. Avoided costs: Cost of water and recycled water if elected to use a more efficient alternative than leak detection (of small diameter pipe).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			20	$7,870*	

* Included in the $6,000 total cost. Based on the conclusion in Analysis of Total Cost of Large Diameter Pipe Failures (Gaewski 2007, p 21), that water loss makes up 5% of total direct cost

Table A148. Model inputs/potential savings, leak detection (small diameter pipe).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
1,428,403		0%	50%	2	0%

Table A149. Additional savings, leak detection (small diameter pipe).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
						1,142,722*	2
* Assuming 20% lost to evaporation							

Table A149. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)

Table A149. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100%	100%	N/A	N/A	796,308 kgal/yr	796,308 kgal/yr

Leak detection—large diameter pipes

Tables A150–A153 summarize costs and savings.

Table A150. Costs, leak detection (large diameter pipes).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2010		$1,042,913*		As long as desired	$25,000**	
* Considering a 10 yr time period. ** Based on estimations in Leak Mitigation and Control						

Table A151. Avoided costs: Cost of water and recycled water if elected to use a more efficient alternative than leak detection (large diameter pipes).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			As long as desired	$118,932*	
* Included in the $6,000 total cost. Based on the conclusion in Analysis of Total Cost of Large Diameter Pipe Failures (Gaewski 2007, p 21), that water loss makes up 5% of total direct cost.					

Table A152. Model inputs/potential savings, leak detection (large diameter pipes).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
21,584,750		0%	50%	As long as desired	0%

Table A153. Additional savings, leak detection (large diameter pipes).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
						-17,267,800*	As long as desired
* Assuming 20% lost to evaporation.							

Table A153. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)

Table A153. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100%	100%	N/A	N/A	796,308 kgal/yr	796,308 kgal/yr

References

Blaha, F. B., and Gaewski, P. 2007. Analysis of Total Cost of Large Diameter Pipe. In AWWA 2007 Research Symposium on Distribution Systems: The Next Frontier.

Replacement of sewer lines

Activity description

This measure considers "upgrading" storm sewers to prevent them from backing up during large rainfalls by replacing 12-in. diameter mains with 30-in. diameter mains. Thus, there is no direct water or sewer savings. Costs are based on the cost of the John St. watershed sewer line replacement project in Champaign, IL, and assume an area with 400 households (scaled to one-fourth the size of the sewer main replaced the John St. watershed. Avoided costs are the annual costs associated from homes damaged to during a flood. It is assumed the utility would reimburse that cost. This was estimated by an online calculator from Federal Emergency Management Agency (FEMA), plus the cost of rebates to area residents for purchasing sewage ejectors for their basements, as Champaign did. Sewage ejectors pump material below the sewer lines back up to them and are typically used in basement bathrooms. In this case, residents needed them to remove backed up sewage from their basements after rainfall events.

This measure assumes a scale of 1,320 linear feet (1/4 mile) of 12-in. lines being replaced with 30-in. lines.

Old/existing standards

None.

Tables A154–A157 summarize costs and savings.

Table A154. Costs, replacement of sewer lines.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2009	$1, 183,592*		$324,335	2.0			

* Estimated cost of enlarged sewer for John St. watershed project per: http://ci.champaign.il.us/cms/wp-content/uploads/2008/09/John_St._Watershed_Draft_Report.pdf, p 58
Given 400 households in the area (http://linc.illinois.edu/john-street-watershed), assuming 10% use sewage ejector rebate (75% rebate, noted here: http://www.news-gazette.com/news/agriculture-and-environment/2010-01-03/complaints-push-champaign-toward-fixing-flooding-problem)) and assuming $600 cost ((http://www.bobvila.com/articles/429-adding-a-basement-bathroom/pages/1).),

Table A155. Avoided costs: Cost of water and recycled water if elected to use a more efficient alternative than replacement of sewer lines.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012			20	$18,000 (rebates) + $103,000 (flood damage)* =$121,000	

* Assuming ¼ of the 400 households experience damage reimbursed, and assuming it is $180 (HVAC repairs) +$850(cleaning, half of that for whole house 1" flooding), http://www.floodsmart.gov/floodsmart/pages/flooding_flood_risks/the_cost_of_flooding.jsp

Table A156. Model inputs/potential savings, replacement of sewer lines.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
N/A	N/A	0	50%	20	0

Table A157. Additional savings, replacement of sewer lines.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	0	20

Table A157. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	

Table A157. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
Unknown	Unknown	N/A	N/A	1,320 ft	

Constraints

None.

References

Clark Dietz Engineers. 2009. *John Street Watershed Master Plan--Draft Report*. Champaign,IL: City of Champaign.

Hardy, Benjamin. 2014. *Adding a basement bathroom*. Web page. Accessed 19 July 2012, from Bob Vila.com: http://www.bobvila.com/articles/429-adding-a-basement-bathroom/pages/1

John Street Watershed. Undated. Web page. Accessed 19 July 2012, from Learning in Community: http://linc.illinois.edu/john-street-watershed

Wade, P. 2010. *Complaints push Champaign toward fixing flooding problems*. Accessed 19 July 2012, from Champaign News Gazette: http://www.news-gazette.com/news/agriculture-and-environment/2010-01-03/complaints-push-champaign-toward-fixing-flooding-problem

Sewer line rehabilitation

Activity description

This measure considers a sewer line ¼ mile in length in need of repairs ever 100 ft, for a total of 13 repairs. The repairs are made by wrapping. It was assumed that wrapping would avert 5% of the flooding damage considered by the sewer line repair measure.

Old/existing standards

None.

Tables A158–A61 summarize costs and savings.

Table A158. Costs, sewer line rehabilitation.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2010	$585 (repair kits) + $4,200 (excavation) + $1,560 (labor)* = $6,345		$82,842	16.2			
* Assuming each kit costs $45, the middle of the range estimated by the EPA, that 3 hrs of labor required to install each one, at $40/hr, and that 210 CY(13 locations, and assuming each is 12 ft deep and requires a 6ft X 6ft area) excavation is needed at $20/CY							

Table A159. Avoided costs: Cost of water and recycled water if elected to use a more efficient alternative than sewer line rehabilitation.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			5*	$20,600	
* Chosen to be conservative.					

Table A160. Model inputs/potential savings, sewer line rehabilitation.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
N/A	N/A	0	50%	5	0

Table A161. Additional savings, sewer line rehabilitation.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A*	N/A	N/A	N/A	N/A	N/A	N/A	5
* Not considered.							

Table A161. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	

Table A161. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
N/A	N/A	N/A	N/A	1,320 ft	

Constraints

Gunnite or steel jackets may provide a more affordable option, but are considered less durable than CFRPs.

References

Pressure management

Activity description

PRVs reduce water lost through leaks by lowering pressure in water mains. This assumes that PRVs lower pressure from 140 to 80 psi, and a total of 29 PRVs in Fort Carson's water distribution system, as reported by their operations personnel. This analysis assumes no excavation is required to install the PRVs.

Old/existing standards

None.

Tables A162–A165 summarize costs and savings.

Table A162. Costs, pressure management.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$6,900*	$97,324	19.6		10	$5000	

* Assuming installation and maintenance done by plumbers, at $345/hour, and maintaining two valves per hour, 29 PRVs at Fort Carson, and inspected once a year (Labor from RSMeans 2012) and assuming initial cost of $67/valve from Grainger.

Table A163. Avoided costs: Cost of water and recycled water if elected to use a more alternative than pressure management.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10*	$13,498	

* Estimated lifetime of PRV

Table A164. Model inputs/potential savings, pressure management.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
1,947, 104*		0%	50%	10	0%

* Assuming pressure increase from 80 to 140 psi, and 3-⅛-in. diameter leaks downstream=>(1/3 of the total pipe length of 75 miles from the end)

Table A165. Additional savings, pressure management.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
57,732*	10%**	N/A	N/A	N/A	N/A	1,849, 749***	10

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years

* Assuming average of 725 kWh/MG for distribution, and assuming that 10% of distribution energy is saved by use of pressure management(low end of range estimated)=>57,732 kWh saved/yr

** Assuming 10% of distribution energy saved, conservative end of estimated 10-30% range.

*** Assuming pressure increase from 80 to 140 psi, and 3-⅛-in. diameter leaks downstream=>(1/3 of the total pipe length of 75 miles from the end)

Table A165. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A165. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>evaporation+leaks+graywater)	100% (potable water=>evaporation+leaks+graywater)	N/A	N/A	N/A	N/A

Plumbing code

Most fixtures gpf and gpm ratings are based on psi rating between 60-80 psi.

Constraints

Sufficient pressure must be maintained at fire hydrants, often in the range of 50-80 psi.

References

Gronczniak, B. 2012. Mechanical Engineering Technician, Fort Carson. Interviewed by A. Allen.

Rego Products. 2012. *Pressure Relief Valves and Relief Valve Manifolds*. Accessed 19 July 2012, from: http://www.regoproducts.com/PDFs/L-500_Section-D.pdf

RS Means Construction Cost Data. 2012. Hoboken, NJ: Wiley.

Expansion of purple pipe infrastructure for reclaimed water

Activity description

Purple pipe infrastructure allows the replacement of potable water used for toilets or landscaping with reclaimed water. Purple colored pipes are used to feed this water to an alternative distribution system to avoid contamination of potable water and indicate the water in them is non-potable.

This measure is based on the city of El Paso's Northwest Reclaimed Water Project. An example includes 26 miles of pipeline and a fully automated pumping station, connecting treated wastewater to irrigation and other non-potable uses. Implementation of purple pipe infrastructure within existing buildings was not considered in this case, because it was not considered to be cost effective.

Old/existing standards

None.

Efficiency standards

Every gallon of recycled water used results in a gallon of drinking water that can be saved for potable uses.

Tables A166–A169 summarize costs and savings.

Table A166. Costs, expansion of purple pipe infrastructure for reclaimed water.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2005	$23,000,000		$11,515,887	2.9	N/A	$417,092*	N/A
* Fort. Carson is charged $0.8021/1000 gal for reuse, other locations may not have reuse charge							

Table A167. Avoided costs, expansion of purple pipe infrastructure for reclaimed water.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012			30	$2,662,400	N/A

Table A168. Model inputs/potential savings, expansion of purple pipe infrastructure for reclaimed water.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
520,000,000	100%	0	50%	30	0

Table A169. Additional savings, expansion of purple pipe infrastructure for reclaimed water.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	0	N/A

Table A169. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	0	0	40,000 sq ft (Pumping Station) + Pipeline

Table A169. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100%	0%	N/A	N/A	Same	Same

Plumbing code

Local and state regulations that govern treated wastewater transport may apply.

Constraints

Social barriers still exist for reclaimed water use. Consider a significant public outreach as part of the implementation plan along with signage to protect from misuse.

References

iDUS Controls, Ltd. 2013. *Purple Pipes – Driving the Next Wave of Water Conservation*. Web page, http://www.iduscontrols.com/blog/?p=48

Stoughton, K. M. 2012. *Fort Carson Net Zero Water Balance Report*. US Department of Energy.

USEPA. 2013. Water Recycling and Reuse: The Environmental Benefits. Web page, http://www.epa.gov/region9/water/recycling/

Gaesser, Lindsay. 2011. San Diego Showdown: IPR vs. Purple Pipes. Web page, http://www.sdcoastkeeper.org/blog/san-diego-water-supply/item/148-san-diego-showdown-ipr-vs-purple-pipes.html

Sub-metering of high use buildings or activities

Activity description

Sub-metering allows buildings to install meters to keep track of water use by the buildings' occupants. Under this measure, a separate meter is installed in each unit, which will read and measure actual consumption.

Old/existing standards

None.

Tables A170–A173 summarize costs and savings.

Table A170. Costs, sub-metering of high use buildings or activities.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$761.00/participant	$2,546	6.29		0	0	0

Table A171. Avoided costs: Cost of water and recycled water if elected not to use a higher efficiency

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
N/A		N/A	15	$319	N/A

Table A172. Savings, sub-metering of high use buildings or activities.

Savings, Per Unit (gpy)	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
37,850	0	68%	15	0

Table A173. Additional savings, sub-metering of high use buildings or activities.

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG tons/yr	Utility Savings Sewer (GPY)	Effective Years
N/A	14 therms/yr*	N/A	15136	15
* Assuming 5% of water saved is hot (1,893 gal), and 0.0072 therms/gal to heat.				

Table A173. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip)
N/A	N/A	N/A	N/A	Increase*

Table A173. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>sewer)	100% (potable water=>sewer)	N/A	N/A		

Plumbing code

N/A.

Constraints

Extra space requirements for sub-metering units can reduce rental space available in commercial buildings and can increase the cost of rental space in expensive urban areas.

References

Plotner, Stephen et al. RSMeans facilities maintenance and repair cost data. 2011 Reed Construction Data. Construction Publishers & Consultants. Kingson MA. 2010.

Low impact development/landscaping

Non-potable well for landscape irrigation

Activity description

Considers drilling of a 100-ft well, providing 15 GPM flow rate. Assuming the well can offset 1% of Fort Carson's annual irrigation.

Old/existing standards

Existing non-potable wells are available on Fort Carson. However, water rights associated with the well's use are not known.

Tables A174–A177 summarize costs and savings.

Table A174. Costs, LID/landscaping.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$11,000*		$141,381	17.9	10	$150**	

* Estimate from Pearson Drillers for 100 ft deep well, delivering 15 GPM

** For maintenance, assuming 3 hrs required per year, at $50/hr

Table A175. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than LID/landscaping.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$19,735	

Table A176. Model inputs/potential savings, LID/landscaping.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
2,949,930*	1%	0	75%	10**	0
* Assuming non-potable well replaces 1% of irrigation ** Based on lifetime of pump.					

Table A177. Additional savings, LID/landscaping.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
-405 kWh/yr	N/A	N/A	N/A	0.08 tons	N/A	1,947,455*	20
* Assuming 35% evapotranspiration							

Table A177. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A*	N/A	57.5**	57.5	
* Assuming negligible pumping energy. ** Assuming 1 40-lb bag of yard waste produced each time 1,000 sq ft area is mowed, and mowing is done once a week, 20 weeks a year.				

Table A177. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (non-potable->65% sewer, 35% evapotranspiration)	100% (potable=>65% sewer, 35% evapotranspiration)	N/A	N/A	3.3 acres*	330 acres
* 1% of Fort Carson's landscaped area, assuming irrigation water use scales with area.					

Constraints

Drilling a well in Colorado and other states requires obtaining a permit. If wells are considered "non-exempt," meaning that they draw more than 15 gpm, among several other conditions, the owner must provide water to replace groundwater used. Other western states have similar rules for use of wells. The limit on drilling wells is determined by the system of water rights.

References

Colorado Division of Water Resources. Undated. *Ground Water Administration and Well Permitting*. Web page. Accessed 20 July 2012, http://water.state.co.us/groundwater/groundwater.asp

Pearson, K. 2012. Pearson Drilling & Pump Service. Interviewed by A. Allen.

LID—Capture for reuse

Activity description

Rainwater harvesting is a means of capturing rain and putting it to beneficial use before it reaches the ground. Buildings and landscapes can be designed to collect or harvest rainwater from rooftops, concrete patios, driveways and other impervious surfaces. This water can be used for various non-potable uses, such as in evaporative coolers, toilet flushing, pet and car washing, indoor plant watering, pet and livestock watering, and for lawn and garden irrigation. Rainwater harvesting systems mainly consist of gutters, downspouts, and storage containers. Any container capable of holding rain dripping from roof or patio can be used as a rainwater harvesting system to capture water for reuse.

Before implementing rainwater harvesting systems in Colorado, it is advisable to check with the Colorado Division for Water Resources for special plumbing requirements, local restrictions, neighborhood covenants, and other regulations and guidelines that may apply. Currently, graywater is regulated under the State of Colorado Guidelines on Individual Sewage Disposal Systems and applicable county Individual Sewage Disposal System regulations. The Colorado Department of Public Health and Environment does not separate graywater from blackwater and hence both surface and subsurface applications require permitting and may trigger monitoring requirements.

Old/existing standards

None.

Efficiency standards

None.

The following cost-benefit analysis is representative based on a case study of rainwater harvesting in the Navy League Building in Arlington, VA (Hicks 2008). The case study assumes 90% of the rainwater will be collected. The total floor area under consideration in this study is 212,947 sq ft while the site area is 1.13 acres.

Tables A178–A181 summarize costs and savings.

Table A178. Costs, LID (capture for reuse).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$179,424*	-$153,357	0.19	0	0	0	0
* This includes first-flush filters, underground storage tank, plumb tank, pump, floating intake, distribution piping and rooftop material.							

Table A179. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than LID (capture for reuse).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$3376 (water+sewer)+$50,000(flood control)=$53,815	0

Table A180. Savings, LID (capture for reuse).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
500,000	10%	0	10%	10	0

Table A181. Additional savings, LID (capture for reuse).*

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
0	0	0	0	N/A	N/A	325,000	10
*Assuming 35% evapotranspiration							

Table A181. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip)
N/A	N/A	0	0	No change

Table A181. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (stormwater=>35% evapotranspiration, 65% sewer)	100% (potable water=>35% evapotranspiration, 65% sewer)	N/A	N/A	1,000 cf	N/A

Plumbing code

State and local laws also have differing requirements on the exact standards for water quality. New International Association of Plumbing and Mechanical Official (IAMPO) and UPC editions are beginning to address a standard water quality depending on the use.

Constraints

Many municipalities have restrictions on graywater capture and reuse, and Colorado generally does not allow it for residential applications. Colorado regulations vary by county. States restrict rainwater harvesting or stormwater retention.

References

Hicks, B. 2008. *A Cost-Benefit Analysis of Rainwater Harvesting at Commercial Facilities in Arlington County, VA*. Durham, NC: Duke University.

LID—Retrofit projects

Activity description

LID retrofits include a variety of site design approaches and small-scale stormwater management practices that are designed to reduce runoff and associated pollutants from the site at which they are generated. LID techniques manage stormwater by means of infiltration, evapotranspiration, and reuse of rainwater. Such techniques help prevent or reduce the effect of development on rivers, streams, lakes, coastal waters, and groundwater. LID also aims to reuse the collected stormwater runoff for non-potable use, thus reducing the use of potable water for non-potable needs. While LID retrofits are expensive, they are relatively cheaper than conventional stormwater management costs. USEPA (2007) summarizes 17 different projects that were implemented in various cities across the United States that resulted in a total capital cost savings ranging from 15 to 80% when LID methods were used.

Advantages of LID projects are that they:

- Reduce flooding and protection of property
- They reduce pollutant loadings discharged into receiving waters. This in turn decreases stormwater and drinking water treatment costs by decreasing the need for regional stormwater management systems and expansions in drinking water treatment systems.
- Are cost effective compared to other stormwater management programs.

Old/existing standards

Conventional stormwater management that concerns curb and gutter and piping systems may apply.

Efficiency standards

None.

Tables A182–A185 summarize costs and savings.

Table A182. Costs, LID (retrofit projects).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2010	260,700*	0	0	0	$600**

* These costs are based on a case study of a 9.7-acre site in Pierre County, Washington where a combination of LID retrofits were put in place,

** Annual maintenance costs were expected to be $600 more than under conventional stormwater management techniques.

Table A183. Avoided costs: Cost of water and recycled water if elected to use more efficient method than LID (retrofit projects).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	0	0	0	$3,000	0

Table A184. Savings, LID (retrofit projects).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
Undetermined*	25%**	0			0

* It is difficult to assign a fixed amount of annual water savings due to the LID projects.

** LID retrofits are expected to capture and reuse about 25% of the stormwater that would otherwise act as “runoff” under conventional stormwater management techniques.

Table A185. Additional savings, LID (retrofit projects).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
0	0	0	0			Undetermined, assume 90% of water savings	

Table A185. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip)
N/A	N/A	N/A	N/A	

Table A185. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (stormwater=>sewer+evaporation)	100% (potable water=>sewer+evaporation)	N/A	N/A	9.7 acres	9.7 acres

Constraints

The site design and surrounding area can influence whether or not a LID retrofit is possible, and levels and frequency of rainfall affect how much water can be captured. State laws may also prevent its capture.

References

USEPA. 2013. *Fact Sheet: Reducing Stormwater Costs through Low Impact Development Strategies & Practices*. EPA 841-F-07-006 (December 2007), http://water.epa.gov/polwaste/green/costs07_index.cfm

Large landscape irrigation controls

Activity description

This measure considers technologies such as "centralized computer control, moisture sensors, rain shutoff switches, telephone connections to California Irrigation Management Information System (CIMIS) information," and others.

Old/existing standards

None.

Tables A186–A189 summarize costs and savings.

Table A186. Costs, large landscape irrigation controls.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$3,571		$7,583	4.0			

Table A187. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than large landscape irrigation controls.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$1445	

Table A188. Model inputs/potential savings, large landscape irrigation controls.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
282,139	10%*		70%	10	

* Total water use for irrigation at Fort Carson is 294,993 kgal/yr. Water use for 3-acre area scaled from that, and % savings calculated from that baseline. Economies of scale are anticipated.

Table A189. Additional savings, large landscape irrigation controls.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	183,390*	10

* Assuming 35% lost to evapotranspiration.

Table A189. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A189. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>35% evapotranspiration, 65% soil)	100% (potable=>35% evapotranspiration, 65% soil)	N/A	N/A	Unknown	Unknown

Constraints

Savings may be dependent on local climate.

References

Rain Bird. 2014. *ESP SMT Series Smart Timer*. Undated. Accessed 15 April 2014, http://store.rainbird.com/product/detail/F39000-M.aspx

Stoughton, K. M. 2012. *Fort Carson Net Zero Water Balance Report*. US Department of Energy.

Smart irrigation controls

Activity description

Smart irrigation controls stop irrigation when it rains and can measure the amount of rainfall to adjust watering afterwards based on rainfall. The technologies considered in this measure adjust (irrigation) schedules according to real-time measures of evapotranspiration by sending a signal by satellite pager technology or telephone line. This measure considers one RainBird ESP-LXME modular timer with smart controller, with three expansion modules, covering 3 acres, and assuming the water use in irrigation for that area scales proportionately to the total for Fort Carson. The system is equipped to handle 8-48 station timers. The measure uses 12 station timers.

Old/existing standards

None.

Efficiency standards

Tables A190–A193 summarize costs and savings.

Table A190. Costs, smart irrigation controls.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$1185*		$35,660	20.8		$140**	

* $600 system cost + $585 installation

** Annual subscription fee and maintenance.

Table A191. Avoided costs: Cost of water and recycled water if elected to use a more efficient technology than smart irrigation controls.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2009			10	$5065	

Table A192. Model inputs/potential savings, smart irrigation controls.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
989,277*	40%**	0%	70%	10	0
* Fort. Carson Water Balance- assumes even watering of acreage at Fort. Carson, 40% savings of average watering for 3-acre area. ** Average reported water savings.					

Table A193. Additional savings, smart irrigation controls.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
						0	10

Table A193. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	

Table A193. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>82.5% soil, 17.5% evapotranspiration)	100% (potable=>65%soil, 35% evapotranspiration)	N/A	N/A	Variable	Variable

Constraints

Customizing and programming the irrigation controls for climate unique locations will require some trial and error to adjust irrigation system and realize water savings.

References

Rain Bird. Undated. *ESP SMT Series Smart Timer*. Accessed 19 July 2012, http://store.rainbird.com/product/detail/F39000-M.aspx

Stoughton, K. M. 2012. Fort Carson Net Zero Water Balance Report. US Department of Energy.

Large landscape efficient nozzles (multi-stream rotational heads)

Activity description

Multi-stream rotational spray heads (MSRSHs) have multiple trajectories of water application and are intended to have higher distribution uniformity and lower evaporation rates. One study reported that, on average, MSRSHs reduced the overall mean evaporation rate from 2.07 in./hr to 1.00 in./hr, and improved distribution uniformity by over 25% (Sococool et al.).

Old/existing standards

None.

Tables A194–A197 summarize costs and savings.

Table A194. Costs, large landscape efficient nozzles (multi-stream rotational heads).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008		$50*	$645	21.4	0	0	0

* Conservative including delivery and installation. Individual heads cost $5-$10.

Table A195. Avoided costs: Cost of water and recycled water if elected to use a more efficient technology than, large landscape efficient nozzles (multi-stream rotational heads).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			15	$18 sewer+ $49 water =$67 tot	0

Table A196. Model inputs/potential savings, large landscape efficient nozzles (multi-stream rotational heads).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
9, 636*	22%	0		15	0

* Assuming landscape water use is 45 gal/1000 sq ft/day, watered 195 days/yr, and a 5000 sq ft area to water, baseline is 43,800 gal/yr

Table A197. Additional savings, large landscape efficient nozzles (multi-stream rotational heads).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
0	0	0	0	0	0	7,227*	15

* Assuming 35% lost to evapotranspiration

Table A197. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>65% sewer, 35% evapotranspiration)	100% (potable water=>65% sewer, 35% evapotranspiration)	N/A	N/A		

Plumbing code

Beginning in January 2010, California law has required cities and counties to prevent runoff, low head drainage, and overspray.

References

Colorado Division of Water Resources Undated. *Commercial Small Capacity Well Water Use Breakdown Sheet*. Accessed 19 July 2012, http://water.state.co.us/DWRIPub/Documents/gws-61.pdf

Rain Bird. Undated. *Rotary Nozzles*. Accessed 19 July 2012, http://store.rainbird.com/custom/product_catalog.aspx?category_guid=415b87d6-ce74-4a4e-86be-a752f2190981

Seymour, R. M. Undated. *Best Management Practices for Landscape Irrigation System Water Conservation*. Accessed 19 July 2012, http://apps.caes.uga.edu/urbanag/BookBMPS/Chapter4IrrigationSys.pdf

Sovocool, K. *Field Study of Uniformity Improvements from Multi-Stream Rotational Spray Heads and Associated Products*. Las Vegas, NV: Southern Nevada Water Authority.

Sovocool, K., M. Morgan, and M. Drinkwine. *Observed Long-Term Results of Multi-Stream Rotational Spray Heads and Associated Product Retrofits*. Las Vegas, NV: Southern Nevada Water Authority.

Large landscape turf replacement

Activity description

Turf replacement involves replacing existing turf grass with landscape material that requires little or no irrigation. Artificial turf replaces grass and eliminates the need for mowing and watering. For calculation purposes, large landscapes are assumed to be an area of three acres or more (130,680 sq ft). Measure considers cost and installation of an inexpensive turf used for cosmetic purposes.

Old/existing standards

None.

Tables A198–A201 summarize costs and savings.

Table A198. Costs, large landscape turf replacement.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$130,680*	$1/sq ft	$99,672	1.9	10	$720**	0

* Turf Area of 130,680 sq ft; Cost of $1/sq ft, includes installation.

** Assume 3 hr/mo of maintenance (weeding, patching, cleaning, etc) at rate of $20/hr.

Table A199. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than, large landscape turf replacement.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012			10	$25,375*	

* Water + Mowing costs. Assuming 12,00 sq ft mowed in an hour, and assuming mowing costs $50/hr and is done once per peek, 20 wks/yr

Table A200. Model inputs/potential savings, large landscape turf replacement.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
2,829,041*	100%	0%	80%	10	0%

* Average yearly watering for 3-acre area (Fort Carson, CO)

Table A201. Additional savings, large landscape turf replacement.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	0	10

Table A201. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	0		N/A

Table A201. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
N/A (eliminates water use)	100% (potable=>35% evapotranspiration, 65% soil)	N/A	N/A	Unknown	330 acres available total

Constraints

Aesthetic concerns may be a constraint for some areas. Local climate will dictate the xeriscape options that are most efficient.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Residential turf replacement

Activity description

Artificial turf replaces grass and eliminates the need for mowing and watering. For calculation purposes, large landscapes assumed to be an area of 2160 sq ft. Measure considers cost and installation of an inexpensive turf used for cosmetic purposes. Replacement material may include xeriscape and hardscape for residential applications.

Old/existing standards

None.

Tables A202–A205 summarize costs and savings.

Table A202. Costs, residential turf replacement.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$2160*	$1/sq ft	-$464	1.0	10	$240**	

* Turf Area of 2160 sq ft; cost of $1/sq ft, includes installation.

** Assume 1hr/mo of maintenance (weeding, patching, cleaning, etc) at rate of $20/hr.

Table A203. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than residential turf replacement.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012			10	$420*	

* Water + Mowing costs. Assuming 12,000 sq ft mowed per hr, and assuming mowing costs of $50/hr, and that mowing is done once a week for 20 wks/yr. Artificial turf will eliminate this need. Mowing cost does not apply if residents maintain the lawn by themselves.

Table A204. Model inputs/potential savings, residential turf replacement.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
46,761*	100%**	0	80%	10	0

* Average yearly watering for 2160 sq ft residential area (Fort Carson, CO).

** Assume no watering necessary for turf

Table A205. Additional savings, residential turf replacement.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	0	10

Table A205. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	0	

Table A205. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
N/A(eliminates water use)	100% (potable=>65% soil, 35% evapotranspiration)	N/A	N/A	Unknown, 3,368 family housing units at Fort Carson*	N/A
*Fort Carson NZ Water Balance Report, p 52					

Constraints

Aesthetic concerns may affect replacement of turf in some areas. Local climate will dictate the xeriscape options that are most efficient.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Stoughton, K. M. 2012. *Fort Carson Net Zero Water Balance Report*. US Department of Energy.

Large landscape turf replacement-high quality

Activity description

Considers artificial turf replacement for high activity areas. The measures considers a high quality lawn turf that provides additional padding for playgrounds, sports, or training grounds. Artificial turf replaces grass and eliminates the need for mowing at watering. For calculation purposes, large landscapes assumed to be an area of 3 acres or more (130,680 sq ft).

Old/existing standards

None.

Tables A205–A209 summarize costs and savings.

Table A206. Costs, large landscape turf replacement-high quality.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$1,372,140*	-1,170,333	0.2		10	$720**	

* Assuming artificial turf grass costs $10.5/sq ft installed.

** Assume 3hr/mo of maintenance (weeding, patching, cleaning, etc) at rate of $20/hr.

Table A207. Avoided costs: Cost of water and recycled water if elected to use a more efficient technology than large landscape turf replacement-high quality.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012			10	$25,375*	

* Water+ Mowing costs. Assuming 12,000 sq ft mowed in an hour, and assuming mowing costs $50/hr and is done once a week for 20 wks/yr. Artificial turf eliminates this need.

Table A208. Model inputs/potential savings, large landscape turf replacement-high quality.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
2,829,041*	100%	0%	80%	10	0%

* Average yearly watering for 3-acre area (Fort Carson, CO).

Table A209. Additional savings, large landscape turf replacement-high quality.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	0	10

Table A209. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	0	0	N/A

Table A209. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
N/A(water use eliminated)	100% (potable water in=>35% evapotranspirated, 65% to soil)	N/A	N/A	130,680 sq ft	130,680 sq ft

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Retention ponds

Retention ponds capture runoff and rain water. This measure considers use of water from a ¼ acre (11,000 sq ft) retention pond with an average depth of 3 ft for landscape irrigation, which can store 246,000 gal. Retention ponds can also provide a habitat for wildlife. The volume is 1,222 cy.

Activity description

None.

Old/existing standards

None.

Tables A210–A213 summarize costs and savings.

Table A210. Costs, retention ponds.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$3,000(excavation)*	$81,145	45.0				

* Assuming an excavation cost of $2.50/cy.

Table A211. Avoided costs: Cost of water and recycled water if elected to use a more efficient technology than retention ponds.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			20	$5,120(water)+$1,632(sewer)=$6,752	

Table A212. Model inputs/potential savings, retention ponds.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
1,000,000*	.3%	0%	75%	20	

* Assuming 10 kgal taken from retention pond each day during watering season, using 1,000,000 gal from it a year during watering season (assuming 100 days).

Table A213. Additional savings, retention ponds.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)		Effective Years
0	0	0	0	0	0	650,000*		20

*Assuming 35% lost to evapotranspiration.

Table A213. Cont'd.

Energy use (new equipment) (kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	Requires a circular area of 11,000 total sq ft

Table A213. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (stormwater=>35% evapotranspirated, 65% to sewer)	100% (potable water=>35% evapotranspirated, 65% to sewer)	N/A	N/A	1,222 cy	N/A

Constraints

A large area may be required for the pond. State law may prevent the creation of retention ponds.

References

RS Means. 2012. *RS Means Construction Cost Data*. Hoboken, NJ: Wiley.

New –LID- bioretention

Activity description

This measure considers 3-acre bioretention systems. Bioretention is used to reduce combined sewer overflows after storms. Bioretention also treats return flows in arid climates. Bioretention can be accomplished through infiltration planters or rain gardens, among other measures.

Old/existing standards

None.

Tables A214–A217 summarize costs and savings.

Table A214. Costs, LID – bioretention.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2011	$60,000		-$41,236	0.41	10	$3,100	

Table A215. Avoided costs: Cost of water and recycled water if elected to use a more efficient technology than LID – bioretention.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$2,430 (sewer)	

Table A216. Model inputs/potential savings, LID – bioretention.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
N/A		0	50%	10	0

Table A217. Additional savings, LID – bioretention.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	968,200	10

Table A217. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	3 acres

Table A217. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
N/A	N/A	N/A	N/A	3 acres	300 acres*

* Irrigated area at Fort Carson.

Constraints

Rainfall frequency and amount affects the amount of water captured. Site conditions and surrounding area may restrict LID options. State law may prevent retention.

References

Save the Rain. 2012. *Onondaga County Executive Announces First Projects to Receive Funding Through $3 Million Expansion of Save the Rain*. Accessed 19 July 2012, http://savetherain.us/suburban-green-infrastructure-program-recipients/

Walker, J. 2012. *Engineered Rain Gardens & Bioretention for Sustainable Stormwater Management*. Reston, VA: American Society of Civil Engineers.

Xeriscaping

Activity description

For Use landscapes that require less water, savings are based on landscapes converted from turf grass to xeriscape. Xeriscapes take several years to establish. The measure estimates the replacement of a 3-acre area of low visibility, non-drought resistant landscape. Irrigation figures estimated from Fort Carson's water balance report.

Old/existing standards

None.

Tables A218–A221 summarize costs and savings.

Table A218. Costs, xeriscaping.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$252,212*	-$6866	1.6		20	$1000**	

* Cost estimate of $1.93/sq ft installed.

** Assuming 5 person hrs of maintenance a month, 4 months of the year, at $50/hr, plus 30% less mowing.

Table A219. Avoided costs: Cost of water and recycled water if elected to use a more efficient technology than xeriscaping.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			20	$4098 (water) + $1600 (maintenance)+) $10,890* (mowing) = $16,588	

* Assuming mowing is not needed for xeriscape, and that mowing costs $50/hr and 12,000 sq ft can be done in an hour, and that mowing is done every week for 20 weeks of the year

Table A220. Model inputs/potential savings, xeriscaping.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
800,340*	30%	0%	75%	20	0%

* Assuming 294,993 kgal of water used annually for landscaping at Fort Carson, and pro rating that to replacing 20% of the low visibility, non-drought resistant landscape(1,609,978 sq ft out of 8,049,888 sq ft low vis non-drought resistant, which is 56% of total), assuming that area uses 11.2% of the total landscaping water, or 33,039,216 gal/year. Average xeriscape reduces water use by 30%.

Table A221. Additional savings, xeriscaping.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A*	N/A	N/A	N/A	1.99**	100%**	0	20

* Xeriscapes immediately around buildings can reduce cooling demand. Not quantified.

** Assuming 218 hrs spent mowing per year now eliminated, and that 1 hr in lawnmower = CO_2 emissions of 20 miles in car, and car emits 0.916 lb of CO_2/mile, http://epa.gov/otaq/consumer/f00013.htm

** Assuming mowing eliminated by xeriscape, and only GHG emissions from mowing.

Table A221. Cont'd.

Energy use/yr(new equipment)	Energy use/yr(old equipment)	Waste produced (new) (tons)	Waste produced (old) tons	Space impacts
N/A	N/A	0*	621**	N/A

* Assuming that mowing is eliminated.

** Assuming 1,552,478 sq ft area replaced, and 1, 40-lb bag of yard waste generated per 1,000 sq ft mowed, and that when covered with grass the area is mowed once a week, 20 weeks a year.

Table A221. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (35% to evapo-transpiration, 65% to sewer)	100% (35% to evapo-transpiration, 65% to sewer)	N/A	N/A	1,305 sq ft	1,305 sq ft

Plumbing code

N/A

Constraints

Plants suitable for a xeriscape depend on the climate. Aesthetic concerns may constrain choices and may present possible restrictions on landscapes in high visibility areas.

References

Mesa, AZ (website). 2014. *10 Reasons to Convert to Xeriscape*. Undated. Accessed 19 July 2012, http://www.mesaaz.gov/conservation/convert.aspx

USEPA. 2008. *Emissions Facts: Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks*. EPA420-F-08-024. Accessed 16 April 2014, http://www.epa.gov/otaq/consumer/420f08024.pdf

Sovocool, Kent A. 2005. *Xeriscape Conversion Study*. Southern Nevada Water Authority, Accessed 16 April 2014, https://www.snwa.com/assets/pdf/about_reports_xeriscape.pdf

Stoughton, K. M. 2012. *Fort Carson Net Zero Water Balance Report*. US Department of Energy.

Sutherland, Steve. 2010. *How to Price a Lawn Mowing Job--Two Common Methods*. Accessed 19 July 2012, from EZ Articles: http://ezinearticles.com/?How-to-Price-a-Lawn-Mowing-Job---Two-Common-Methods&id=4155404

Strategies

Large landscape surveys

Activity description

Landscape surveys, or audits, address causes of excess irrigation. Past studies have indicated that contract landscapers are less efficient in water consumption and irrigation practices; smaller sites (<2 acres) have potential for greater percentage water savings because they are not as well managed … and savings from water audits decline rapidly over time. In a study done by the Contra Costa Water District (1994), "water savings were estimated to be 20.6% in first year, 7.7% in the second year, and 6.5% in the third year."

Old/existing standards

None.

Tables A222–A224 summarize costs and savings.

Table A222. Costs, large landscape surveys.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$2,071		$2793	0.4			

Table A223. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than large landscape surveys.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			5	$1123	

Table A224. Model inputs/potential savings, large landscape surveys.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
219,436	7%*	0	70%	5	0

* Total water use for irrigation at Fort Carson is 294,993 kgal/yr. Water use for 3-acre area scaled from that, and % savings calculated from that baseline.

Table A225. Additional savings, large landscape surveys.

Additional Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	142,633*	5

* Assuming 35% evapotranspiration.

Table A224. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A224. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>65% soil, 35% evapotranspiration)	100% (potable=>65% soil, 35% evapotranspiration)	N/A	N/A	330 acres available	N/A

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool.*

———. 2011. *Water Conservation Tracking Tool User Guide.*

Contra Costa Water District. 2014.Large Landscape Water Survey. *Water Conservation*. Web site. Accessed 17 April 2014, http://www.ccwater.com/conserve/comm_landscape_lg.asp

Stoughton, K. M. 2012. *Fort Carson Net Zero Water Balance Report*. US Department of Energy.

Landscape plan

Activity description

Creating and implementing a sustainable landscape plan alters landscape from turf grass to groundcover that does not require mowing.

Old/existing standards

None.

Tables A226–A229 summarize costs and savings.

Table A226. Costs, landscape plan.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$1,115* for initial plan + $1,500 for landscaping** = $2,615 total	-$2,202	0.25		10		

* Based on 10 hrs of work at $115/hr by landscape architect.

** Assuming $1.50 sq ft for landscaping(adjusted from Sovocool 2005, which noted $1.93/sq ft for xeriscaping).

Table A227. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than landscape plan.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$33*	

* Assuming past and current maintenance costs are roughly the same, replacing some mowing with pruning, etc.

Table A228. Model inputs/potential savings.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
6,156*	30%**	0%	75%	10 years***	80%†

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)

* Assuming 1,000 sq ft out of 14,374,800 sq ft total are replaced, and that it reduces water use on that area by 30% (294,993 k gal/yr used total => 20,522 gal/yr used on this area as is=>savings of 6,156 gal/yr.

** 30% estimated savings for landscape audit.

** Assuming landscape designed to last for 10 yrs.

† Potentially 80% if domestic restrictions imposed, which are estimated to save 25%.

Table A229. Additional savings, landscape plan.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	38.8 lb*	100%**	4,001***	10 yrs

* Assuming 2.1 hrs spent mowing per year now eliminated, and that 1 hr in lawnmower = CO_2 emissions of 20 miles in car, and car emits 0.916 lb of CO_2/mile,

** On area applied to, assuming that the sustainable landscape eliminates need for mowing.

*** Assuming 35% evapotranspiration.

Table A229. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	0	0.499 tons/yr*	N/A

* Assuming 1 40-lb bag of waste per 1,000 ft each time mowed, and assume the area is mowed once a week, 20 weeks a year.

Table A229. Cont'd.*

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (35% evapotranspiration, 65% to sewer)	100% (35% evapotranspiration, 65% to sewer)	N/A	N/A	1,257 sq ft out of 12, 569 sq ft total, 10 areas	12,569

* Assuming 310,000 kgal of water used annually for landscaping at Fort Carson.

Constraints

While there are no specific constraints, note that the challenge for any plan is the sustainably and dynamic implementation of that plan. The surveys and ideas can be done and a paper copy created that lays out the strategies, but the implementation and continued collaboration of all stakeholders is often the biggest challenge.

References

Owen Dell and Associates. 2013. *Design Fee Schedule*. Undated. Accessed 17 April 2014, http://www.owendell.com/Design/designfees.html

USEPA. 2008. *Emissions Facts: Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks*. EPA420-F-08-024. Accessed 16 April 2014, http://www.epa.gov/otaq/consumer/420f08024.pdf

Smith, C. Undated. *ICI Water Conservation Program Analysis--Savings in the Landscape*. Accessed from American Water Works Association: http://www.awwa.org/waterwiser/references/pdfs/CII_LSCAPE_Smith_C_ICI_Water_Conservation_Program_Analys.pdf

Sovocool, Kent A. 2005. *Xeriscape Conversion Study*. Southern Nevada Water Authority, Accessed 16 April 2014, https://www.snwa.com/assets/pdf/about_reports_xeriscape.pdf

Large landscape water budget

Activity description

A landscape water budget is an annual plan that sets a monthly maximum volume of water to be allocated to different parts of the landscape. The allocated volume is calculated based on evapotranspiration and coefficients for the type of plant and irrigation system, and accounts for the effective rainfall. The term “large landscape” refers to area occupying more than 2-3 acres of irrigated area.

Old/existing standards

None.

Tables A230–A233 summarize costs and savings.

Table A230. Costs, large landscape water budget.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$5,952		-$$5952	0.3	10		

Table A231. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than a large landscape water budget.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$5952		10	$270.14	

Table A232. Model inputs/potential savings, large landscape water budget.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
52,762	20%*	0	70%	10	0

* Total water use for irrigation at Fort Carson is 294,993 kgal/yr, water use for 3-acre area scaled from that, and % savings calculated from that baseline.

Table A233. Additional savings, large landscape water budget.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	0	10

Table A233. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A233. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>65% soil, 35% evapotranspiration)	100% (potable=>65% soil, 35% evapotranspiration)	N/A	N/A	330 acres available	330 acres available

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool.*

California Landscape Contractors Association. 2010. Accessed 19 July 2012, http://www.clca.us/water-pro/assets/downloads/LandscapeWaterBudget.pdf

Stoughton, K. M. 2012. *Fort Carson Net Zero Water Balance Report*. US Department of Energy.

Conservation education—advertising

Activity description

This measure considers the impact of an advertising campaign to encourage conservation, including radio, television, and online ads. Denver Water ran a successful advertising campaign around conservation, and over the course of the campaign local household water use declined by 20%.

Old/existing standards

None.

Tables A234–A237 summarize costs and savings.

Table A234. Costs, conservation education (advertising).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2010	$33,333*		$1,094,934**	4.5			

* Based on 20,000 population at Fort Carson of residents of family housing + contractors, and scaled from $1 million annual cost for Denver Water conservation campaign.

** Based on a 10-yr time period.

Table A235. Avoided costs: Cost of water and recycled water if elected to use a more efficient, method than conservation education (advertising).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			1	$146,116	

Table A236. Model inputs/potential savings, conservation education (advertising).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
8,739,550*	5%**			1	

* Based on Fort Carson's avg family housing indoor water use, 174, 791 kgal/yr.

** As reported in results from advertising in Israel.

Table A237. Additional savings, conservation education (advertising).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	13,843 therms/yr*	5%	69	5%	7,541,595**	1

* Assuming 22% of water used in home is hot (Vickers 2001), thus 1,992,701 gal of hot water saved, and that 0.0072 therms/gal is used to heat hot water (AWE).

** Assuming 10% lost to evaporation, etc.

Table A237. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A237. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
		N/A	N/A		

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool User Guide.*

USEPA. 2007. Calculations and References. Clean energy. Web site. Accessed 18 July 2012, http://www.epa.gov/cleanenergy/energy-resources/refs.html

Heiman, A. 2002. The Use of Advertising to Encourage Water Conservation: Theory and Empirical Evidence. *Journal of Contemporary Water Research and Education.* Accessed 17 April 2014, http://opensiuc.lib.siu.edu/cgi/viewcontent.cgi?article=1151&context=jcwre

Stoughton, K. M. 2012. *Fort Carson Net Zero Water Balance Report.* US Department of Energy.

Water conservation education

Activity description

Human behavior is one of the hardest things to change, but can be the most cost-effective way to conserve water. Targeted education strategies to both residential and military personnel should relate how their behavior affects not only the environment, but also their fellow Soldiers. The conservation education should not emphasize sacrifice. Soldiers are already doing that. Rather, it should emphasize responsibility and social impacts without judging. Education is a program that needs to be dynamic and long term. The effects of the education are, however, very brief and need constant reinforcement. Thus, education programs should be designed to be several years before a cultural shift can be expected.

Old/existing standards

None.

Tables A238–A241 summarize costs and savings.

Table A238. Costs, water conservation education.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Net Present Value ($)	Savings/Investment Ratio	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2010	33,333*		$812,065**	33.2			

* Based on 20,000 population at Fort Carson of residents of family housing + contractors, and scaled from $1 million annual cost for Denver Water conservation campaign.

** Considering a 10 yr time period.

Table A239. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than water conservation education.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			1	$109,440	

Table A240. Model inputs/potential saving, water conservation education.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
6,338,275*	2.5%	0	50%	1	0

* Based on % savings from Fort Carson family housing indoor and outdoor water use combined, average.

Table A241. Additional savings, water conservation education.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	10,108 therms/yr*	2.5%	50.5	2.5%	5,704,448**	1

* Assuming 22.15% of household water use is hot (based on breakdown of household water use in Vickers 2001, p 15) meaning 1, 403, 921 gal of hot water saved per year, and assuming all heated to shower type temperature,

** Assuming 10% lost to evaporation etc.

Table A241. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (status quo) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (status quo) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A241. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>90% sewer, 10%evap)	100% (potable=>90% sewer, 10%evap	N/A	N/A	20,000 people living on base	N/A

Constraints

None.

References

AWE. 2011. *Water Conservation Tracking Tool User Guide.*

USEPA. 2007. Calculations and References. Clean energy. Web site. Accessed 18 July 2012, http://www.epa.gov/cleanenergy/energy-resources/refs.html

Mabel, Ira. 2012. *Sustainable Soldiers: Water Usage and Conservation Techniques on US Army Training Bases*. Poster. Champaign, IL: ERDC-CERL, http://www.urban.uiuc.edu/academic-programs/mup/capstones/2012/Mabel_Poster.pdf

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Domestic water use restrictions

Activity description

Restrictions on domestic water use are usually imposed temporarily by water utilities in times of drought. They can apply different proportionate reductions to different uses. This considers mandatory domestic water use restrictions, e.g., reducing lawn watering to 2 days a week. Estimates are based on savings during a 4-month period of drought. Restrictions imposed for longer periods of time will decline in efficacy. There are several strategies that could be used for water restrictions. The case studies applied toward a military installation should still be comparable in cost and efficiencies.

Old/existing standards

None.

Tables A242–A245 summarize costs and savings.

Table A242. Costs, domestic water use restrictions.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$1,991	$1,278,074*	675*				
* Assuming a 1-year horizon.							

Table A243. Avoided costs: Cost of water and recycled water if elected to use a more efficient method than domestic water use restrictions.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			4 months	$324,795(sewer)+$1,019,275(water)=$1,344,069	

Table A244. Model inputs/potential savings, domestic water use restrictions.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
199, 077,000*	25%**	Unknown***	75%	4 month time period considered	0

* Based on Fort Carson's annual demand of 796, 398 kgal.

** Based on per-capita reductions in Boulder, CO.

*** A rate of decay is not known, however it is expected that savings from drought controls would decrease significantly if extended permanently.

Table A245. Additional savings, domestic water use restrictions.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	129, 400,050*	4 months

* Assuming 35% is lost to evapotranspiration.

Table A245. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Waste produced (new) (tons)	Waste produced (old) tons	Space impacts
N/A	N/A	N/A	N/A	N/A

Table A245. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>sewer)	100% (potable water=>sewer)	N/A	N/A	Municipalities w populations from 20,000-300,000 considered in study	Any size area

Constraints

Some cities in Colorado, such as Denver, have extensive water rights to the South Platte. Access to greater supplies of water will make utilities less likely to implement drought controls. The extent and severity of drought controls may be limited by the scale of coordination and the severity of the restrictions. As droughts persist and supplies become more stressed the coordination of restrictions does not necessarily get easier. Early and prepared scenario planning for every agency is often the best practice for handling drought conditions.

References

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Building water monitoring program (with real-time data)

Activity description

Building water monitoring systems offer real-time data, on intervals as small as 1 minute, on water use and cost, often with graphs showing water consumption over time. These systems can help maintenance personnel identify leaks, and also educate building users on water use. These systems also usually have web-based data storage.

Old/existing standards

None.

Efficiency standards

Tables A246–A249 summarize costs and savings.

Table A246. Costs, building water monitoring program (with real-time data).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008	$12,500*	-$20,100	-0.78		10	$4,200	

* Based on initial and maintenance costs for an Energy Dashboard system from Instep averaged for academic buildings

Table A247. Avoided costs: Cost of water and recycled water if elected to use a more efficient, method than building a water monitoring program (with real-time data).

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			10	$3,126	

Table A248. Model inputs/potential savings, building water monitoring program (with real-time data).

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
330,200*	10%**	0%	50%	10	0%

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)

* Based on avg of 127/gal/employee per day, assuming 260 days/yr and 100 employees=>3.3 mil gal yr
** Based on Noveda's estimate for their iQuatic system, avg of 5-15% savings,

Table A249. Additional savings, building water monitoring program (with real-time data).

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
0	0	119 therms/yr*	N/A	3.3**		313,690***	10

* Assuming 0.0072 therms/gal, and 5% of water savings is hot water (16,510 gal).
** From 3.3 ton reduction in CO_2/yr from decreased gas use.
*** Assuming 5% lost to evaporation, etc.

Table A249. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	Small amount of space required for monitoring system

Table A249. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable water=>5% evap, 95% sewer)	100% (potable water=>5% evap, 95% sewer)	N/A	N/A	N/A	N/A

Constraints

Buildings may require metering upgrades for a digital monitoring program to be feasible. No meters may currently be installed.

References

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Efficient irrigation practices

Activity description

Losses from evaporation can be 60% higher during mid-day than during the cool early morning hours. This measure considers savings from a shift of 50% of watering from mid-day to early morning.

Old/existing standards

None.

Tables A250–A253 summarize costs and savings.

Table A250. Costs, efficient irrigation practices.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	$3000*	$141,472	54		10	$3000**	

* Assume $1000 for management set up costs.

** Assuming that watering occurs 100 days out of the year, and that early morning watering requires three additional person hours per day at 50% overtime, out of a $20/hr rate, only includes net cost increase.

Table A251. Avoided costs, efficient irrigation practices.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012			As long as desired	$165,196	

Table A252. Model inputs/potential savings, efficient irrigation practices.

Savings, Per Unit (gpy)	Unit Saving % from Retrofit	Savings, Annual Rate of Decay (%)	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
32,264,859	11%*	0%	60%	As long as desired	0%

* Assume that 50% of mowing is shifted to the early morning hours; 35% of water lost to evaporation in daytime and early morning watering reduces this to only 14% (60% reduction of evaporation). Because only 50% of the watering is shifted to early morning, 50% of watering benefits from the reduced evaporation rate.

Table A253. Additional savings, efficient irrigation practices.

Utility Saving (KwH/yr)	% Saving KwH/yr	Utility Savings (Therms/gal)	% Saving Therm/gal	GHG reduction Tons/yr	% Reduction GHG	Utility Savings Sewer (GPY)	Effective Years
N/A	N/A	N/A	N/A	N/A	N/A	0	As long as desired

Table A253. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A253. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (25% to evapotranspiration, 75% soil)*	100% (35% to evapotranspiration, 65% to soil)	N/A	N/A	310 kgal/day	310 kgal/day

* Assume that 50% of mowing is shifted to the early morning hours; 35% of water lost to evaporation in daytime and early morning watering reduces this to only 14% (60% reduction of evaporation). Because only 50% of the watering is shifted to early morning, 50% of watering benefits from the reduced evaporation rate; therefore, average evapotranspiration rate will be 24.5%.

Constraints

None.

References

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Building water audit

Activity description

A building water audit, conducted by maintenance personnel, can identify areas of water waste and, where and how water use can be reduced. In an office building, the largest sources of water use are likely mechanical systems, domestic water use, such as hand washing and toilets), and cleaning. Outdoor irrigation and kitchens, if applicable, are also sources of water use. Mechanical systems can account for 25% of total building water use. Water audits may not save water directly. However, they do create the baseline and also inform operators on usage, which can then drive planning for future conservation projects.

Old/existing standards

None.

New Standards: New EISA requirements include wall to wall audits covering 25% of an installation annually.

Tables A254–A257 summarize costs and savings.

Table A254. Costs, building water audit.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Net Present Value($)	Savings/Investment Ratio	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2012	Conducting audit: $120*+improvements: $35,000**	-$19,947	.48				

* Assuming audit conducted by maintenance staff over 6 person hrs, and paid $20/hr

** Assuming measures are chosen having an average of 5 yrs simple payback.

Table A255. Avoided costs, building water audit.

Utility Costs, Year Denominated	Utility Costs, Initial Fixed ($)	Utility Costs, Initial Variable ($/unit)	Utility Costs, Years of Follow-up (yrs)	Utility Costs, Follow-up Fixed ($/yr)	Utility Costs, Follow-up Variable ($/unit/yr)
2008			5	$9,772	

Table A256. Savings, building water audit.

Savings, Per Unit (gpy)	Savings, Annual Rate of Decay (%)	Percent Savings	Savings, Peak Period (% of Annual Savings)	Savings, Useful Life (yrs)	Savings, Participant Free Riders (% of Participants)
990, 600*	0%	30%**	50%	5	0%

*Based on avg of 127/gal/employee per day, assuming 260 days/yr and 100 employees=>3. mil gal yr

** Assuming measures are chosen having an average of 5 yrs simple payback; from low range of estimated savings, Pacific Institute.

Table A257. Additional savings, building water audit.

Utility Saving (KwH/yr)	Utility (Therms/gal)	GHG Tons/yr	Utility Savings Sewer (GPY)	Effective Years
	357 therms/yr*	1.78	941,070**	5

* Assuming 5% of water use in office building is hot, meaning 49,530 gal of hot water saved per year, and assumed heated to same temperature as a shower, 0.0072 therms/gal (per AWE).

** Assuming 5% lost to evaporation etc.

Table A257. Cont'd.

Energy use (new equipment)(kWh/yr or therms/yr)	Energy use (old equipment) (kWh/yr or therms/yr)	Solid waste produced (new equipment) (tons)	Solid waste produced (old equipment) tons	Spatial considerations (increase/decrease in space req'd for new equip) (sq ft)
N/A	N/A	N/A	N/A	N/A

Table A257. Cont'd.

Water efficiency (new equipment)	Water efficiency (old equipment)	Energy efficiency (new equipment)	Energy efficiency (old equipment)	Capacity (new equipment)	Capacity (old equipment)
100% (potable=>sewer, 5%evap)	100% (potable=>sewer, 5%evap)	N/A	N/A	N/A	N/A

Constraints

While there are no specific constraints, some states require utilities to perform periodic audits.

References

Pacific Institute. 2003. *Details of Commercial Water Use and Potential Savings By Sector*. Accessed 17 April 2014, http://pacinst.org/reports/urban_usage/appendix_e.pdf

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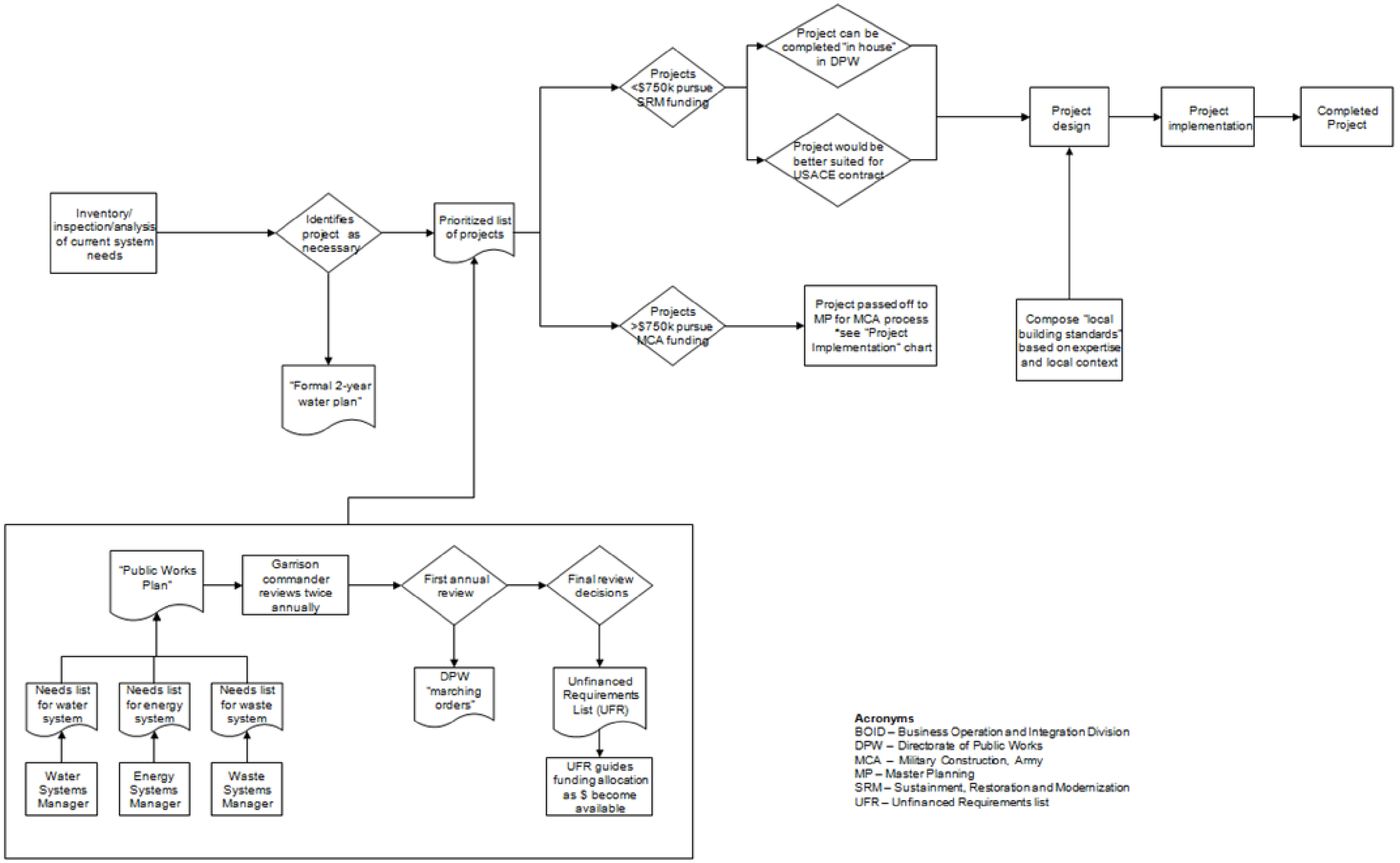
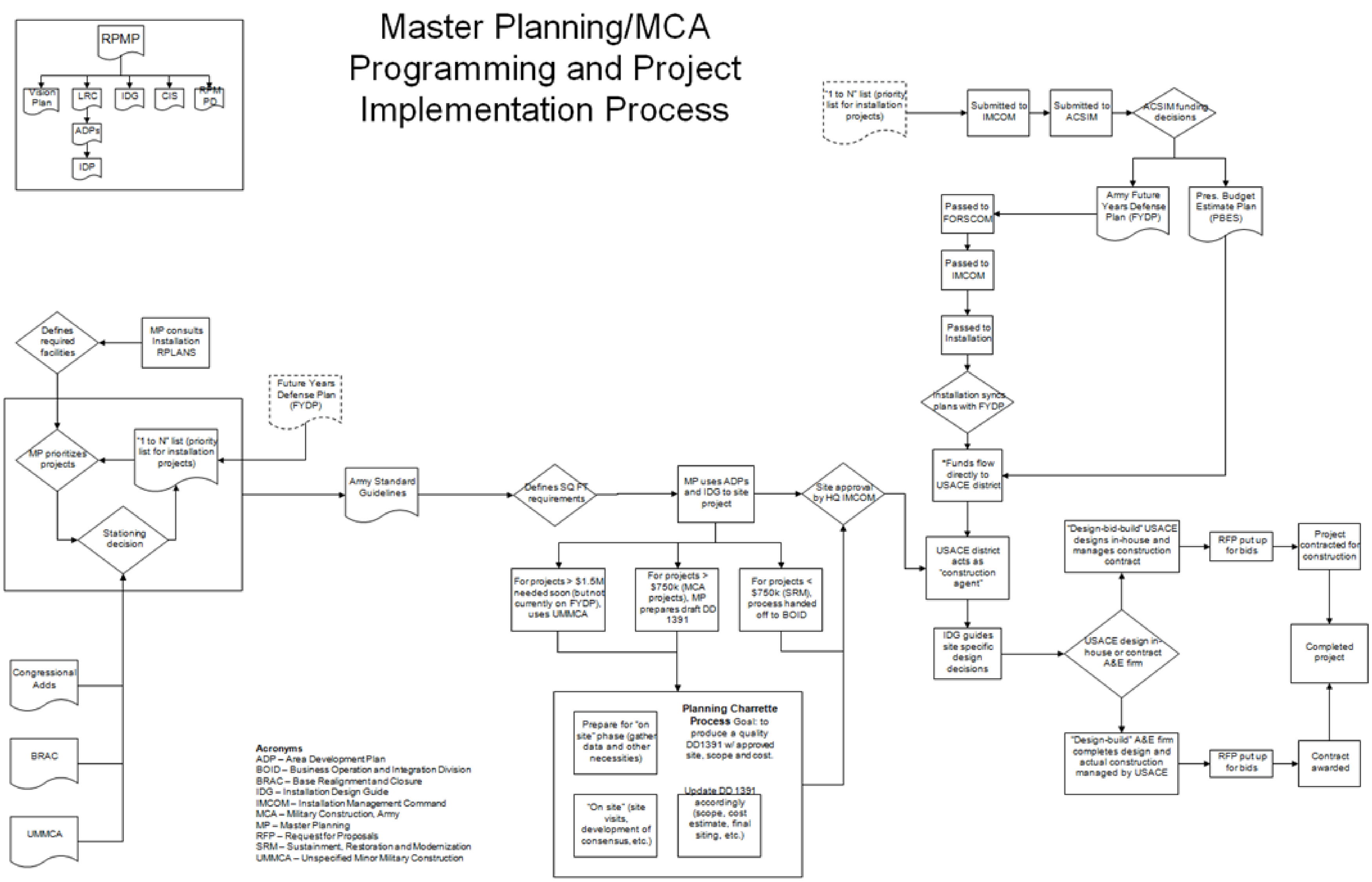
Appendix B: BOID Process

Operational Planning (BOID)/SRM Programming and Project Implementation Process



Acronyms
BOID – Business Operation and Integration Division
DPW – Directorate of Public Works
MCA – Military Construction, Army
MP – Master Planning
SRM – Sustainment, Restoration and Modernization
UFR – Unfinanced Requirements list

Appendix C: MCA Process



Master Planning/MCA Programming and Project Implementation Process

Acronyms
ADP – Area Development Plan
BOID – Business Operation and Integration Division
BRAC – Base Realignment and Closure
IDG – Installation Design Guide
IMCOM – Installation Management Command
MCA – Military Construction, Army
MP – Master Planning
RFP – Request for Proposals
SRM – Sustainment, Restoration and Modernization
UMMCA – Unspecified Minor Military Construction

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14. ABSTRACT

Over the past decade, Federal legislation and executive orders that stipulate increasingly rigorous water conservation requirements have emerged. The Army has adopted these requirements through policy and regulation, and has advanced the concept even further by establishing challenging targets for installations to achieve “net zero water,” an emerging sustainable buildings concept in which an installation limits its consumption of freshwater resources and returns water to the same watershed from which it is drawn so as to not deplete the groundwater and surface water resources of that region in quantity or quality. This work was undertaken to select and/or develop tools to support integrated modeling of energy, water, and waste for Army installations. The first year’s water effort involved reviewing, demonstrating, and developing water models and tools at a variety of spatial scales. Water conservation and efficiency measures were evaluated and documented to enable life cycle costing. The tools and models described in this work were documented for Fort Carson, CO, but the concepts developed here will benefit all Army installations which are working to achieve mandated water conservation targets, to minimize utility costs, and to preserve finite natural resources.

15. SUBJECT TERMS
net zero water, sustainability, water conservation, Army facilities

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