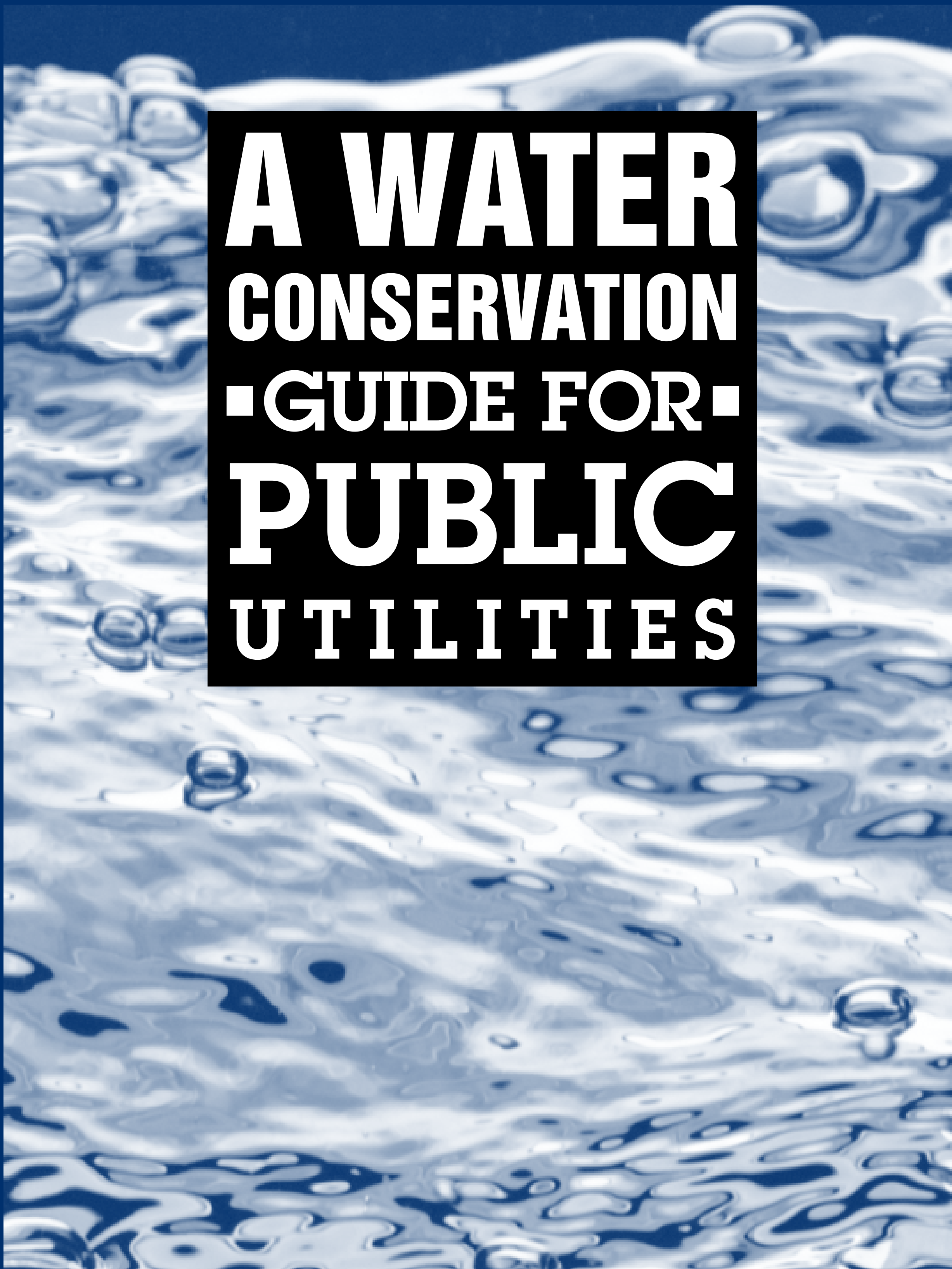

A WATER CONSERVATION GUIDE FOR PUBLIC UTILITIES

NEW MEXICO OFFICE OF THE STATE ENGINEER

A WATER CONSERVATION GUIDE FOR PUBLIC UTILITIES

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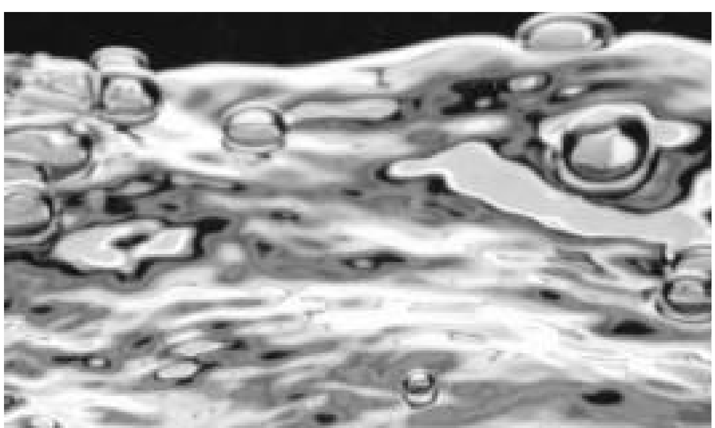
MARCH 2001



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SECTION 1

INTRODUCTION

INTRODUCTION

WHY WATER CONSERVATION IS IMPORTANT IN NEW MEXICO

Even in the best of years, water is a limited resource in New Mexico. Local rainfall varies throughout the state, but the statewide average throughout New Mexico is less than 13 inches of annual precipitation. In Albuquerque, the state's largest metropolitan area, annual precipitation is only nine inches. Because of the arid climate, water conservation is vital to the health and welfare of every community in New Mexico.

Unfortunately, competition for the state's limited water resources is growing. New Mexico's population growth is increasing the demands on the state's already-scarce water supplies. For the first time, water demands in some of the state's urban areas are approaching available supplies. The state's agricultural users want to retain their water resources in order to protect their livelihoods. Recreational users need adequate streamflows to meet their needs and protect the interests of the recreational industry.

Environmental factors and concerns also have an impact upon municipal water supplies. Citizens are concerned about protecting riparian areas and the aquatic habitats of rivers and streams. The Endangered Species Act requires that adequate water supply must remain in rivers to protect endangered fish. Another concern is water pollution, which has contaminated water wells in several municipalities in New Mexico. The water in these polluted wells is not available for drinking purposes, which further reduces the available water supply.

The state also appears to be in a long-term drought cycle that began in 1996, making statewide water supplies even more precious than ever before. As a result, some municipalities have enacted mandatory water-use restrictions. Other communities have ventured into the water rights marketplace to purchase water from agricultural users in order to meet urban water demands.

Because the costs of water development and treatment continue to rise, many communities are faced with expensive water and wastewater treatment facility expansions to meet growing water demands. Fortunately, water conservation can delay, and in some cases actually eliminate, the need for these costly infrastructure expansions. The simple fact is this: ***conservation is almost always the least-costly water supply alternative.***

This guide was developed to help municipalities and community water systems conserve New Mexico's most precious natural resource. Working now to take drought-preparedness actions such as water conservation and drought contingency planning can help to "drought-proof" our communities. By following the step-by-step procedures for developing and implementing a local water conservation plan as outlined in this guide, water planners and administrators can effectively reduce water demand and potentially postpone or even eliminate the need for the expansion of water distribution and wastewater treatment systems.

The goal of this manual is to present virtually everything a municipality or water utility might conceivably consider when dealing with water conservation issues. However, each local situation is different, and each local community must choose the elements necessary for its own water conservation program.

In presenting this very detailed guidebook, the Office of the State Engineer is not mandating that each form must be filled out and every item must be enacted. In some communities, for example, detailed historical water-use information may simply not be available. Other communities may find it advantageous to start a small-scale water conservation program, adding more-detailed elements later as resources become available.

WATER USE IN NEW MEXICO

While municipalities do not account for the largest amount of water used in the state, meeting future water demands and ensuring the long-term viability of public water systems is absolutely essential to the welfare of New Mexico's citizens. Reducing water demand may add years to the life of aquifers that are being mined, reduce the cost of water and wastewater treatment, save energy, postpone or eliminate the expansion of water treatment and distribution systems, and decrease the volume of wastewater discharged into rivers and streams.

Every five years the New Mexico Office of the State Engineer (OSE) conducts a comprehensive inventory of water uses in the state and publishes the results. Water withdrawals and depletions for the inventory year are tabulated by county and river basin for nine water-use categories. These categories include:

- Public Water Supply (Municipal water uses)
- Self-Supplied Domestic Water
- Irrigated Agriculture
- Water Use in Livestock Production
- Self-Supplied Commercial
- Industrial
- Mining
- Power Generation
- Reservoir Evaporation.

A *withdrawal* is the quantity of water taken from a ground or surface water source; *depletion* is that part of a withdrawal that has been evaporated, transpired, incorporated into crops or products, consumed by man or livestock, or otherwise removed from the water environment.

In 1995, Public Water Supply (municipal water uses) accounted for 349,042 acre-feet or 7.84% of the total water withdrawals in the state. Surface water accounted for 38,172 acre-feet or 10.94% of the municipal withdrawals, and groundwater for 310,870 acre-feet or 89.06% of municipal withdrawals.

Figure 1-1 Withdrawals

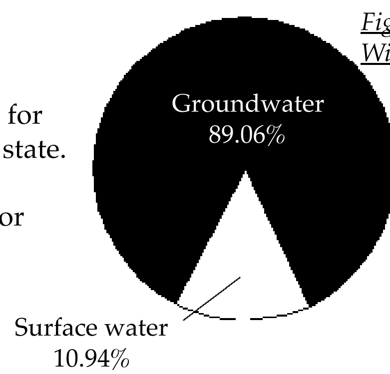
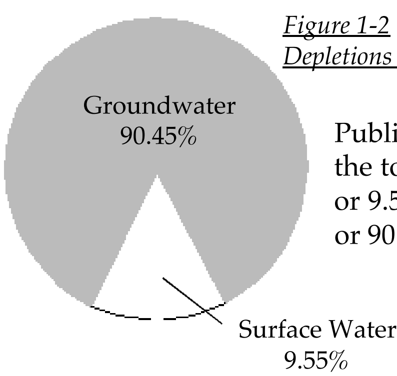


Figure 1-2 Depletions



Public Water Supply accounted for 198,369 acre-feet or 7.18% of the total depletions. Surface water accounted for 18,947 acre-feet or 9.55% of the depletions, and groundwater for 179,422 acre-feet or 90.45%.

SECTION 2

BUILDING THE FOUNDATION OF A WATER CONSERVATION PROGRAM

BUILDING THE FOUNDATION

GETTING STARTED

Water utilities throughout the United States have found that conservation is an important component of an overall water supply plan. In New Mexico, many water utilities have proven that reducing water requirements by decreasing demand and increasing operating efficiencies is a cost-effective way to delay capital facilities, reduce operation and maintenance costs, reduce the need for development of costly new water sources, and demonstrate responsible water-use efficiency to regulatory agencies.

This section of the manual gives an overview of the recommended steps that should be undertaken in launching a successful water conservation program. Included in this section are the following steps:

- evaluating the existing water system, which includes quantifying water production and water demand
- specifying water conservation goals
- describing water conservation measures that have already been implemented
- creating a detailed description of new water conservation measures scheduled for implementation.

Throughout this manual, we will use the following definitions of "water conservation" and "public water supply":

Water Conservation is defined as any action or technology that reduces the amount of water withdrawn from water supply sources, reduces consumptive use, reduces the loss or waste of water, improves the efficiency of water use, increases recycling and reuse of water, or prevents the pollution of water.

Public Water Supply is defined by the U.S. Safe Drinking Water Act as any water utility, publicly or privately owned, that has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year.

The New Mexico Office of the State Engineer defines a "public water supply" as any community water system and/or water utility, publicly or privately owned, incorporated or unincorporated, that relies upon surface and/or groundwater diversions other than wells permitted by the Office of the State Engineer under Section 72-12-1 NMSA 1978 which allows individual domestic wells, and that consists of common collection, treatment, storage, and distribution facilities operated for the delivery of water to multiple service connections.

Examples of such systems include municipalities that serve residential, commercial, and industrial water users; prisons; residential and mixed-use subdivisions; and mobile home parks. Water use for the irrigation of golf courses, athletic fields, parks, cemeteries, and greenbelts—or to maintain the water level in ponds and lakes owned and operated by a municipality or water utility—is also included in this category.

BUILDING THE FOUNDATION

STEP 1: EVALUATE YOUR SYSTEM.

The first step in any successful conservation program is a detailed assessment of the existing water supply system. The profile of your water supply system should include but not be limited to:

- **Water Rights**—A description of existing water rights and/or lease agreements including surface and groundwater diversion points, transfer points for water imports and/or exports to or from other water suppliers, and any return flow credits claimed.

- **Treatment Systems**—A description of the location and type of treatment systems used to produce water of drinking water quality. Describe the capacity of these systems, including their ability to meet average and peak day demands and water quality standards.

- **Wastewater Treatment Systems—**A description of the location and type of wastewater treatment systems used and the method of effluent disposal. Describe the capacity of these systems and their ability to meet average demands, peak-day demands, and water quality standards.

- **Water Production—**A detailed history of water production (in one-year intervals for the last five years or more) and transfers by source of supply (surface water or groundwater) plus wastewater discharges, wastewater reuse, and return flow. This history should include the items that are shown in Table 6-1 in the section on Recordkeeping and Water Audits.

  (a) **Monthly and annual surface and groundwater production.** Note whether or not withdrawals are metered.
  (b) **Water transfers.** These include: (1) Monthly and annual water imports from other water suppliers and/or organizations, and (2) Monthly and annual water exports to other water suppliers and/or customers outside of the city, village, or subdivision in which the water supplier is based.
  (c) **Monthly and annual discharges from wastewater treatment facilities and wastewater reuse.** These data may be used to calculate depletions (consumptive use) and justify return flow credits. Return flows may require adjustment to account for wastewater received from self-supplied entities that do not purchase potable water from the water supplier.

- **Water Demand**—A detailed history of water demand (one-year intervals for the past five years or more) and baseline projections of demand that would exist without new conservation measures (in five-year intervals for the next 40 years), categorized by customer class. This history and projection may serve as the basis for selecting and evaluating potential water conservation measures, and it should include the following items shown in Table 6-2 in the section on Recordkeeping and Water Audits.

  (a) ***Monthly and annual population (or accounts) served*** including customers who are located outside of the city, village, or subdivision in which the water supplier is based.
  (b) ***Monthly and annual water deliveries or sales*** to each of the customer classes shown in Table 6-2; residential per capita water use; and the aggregate per capita water use for the water system.

(c) ***Monthly and annual unaccounted-for-water losses*** based on the difference between total withdrawals (net supply) and total metered deliveries.
(d) ***Monthly and annual population living in multi-family residential complexes plus the population living in single-family residences.*** See Table 6-3 in the Section on Recordkeeping and Water Audits.
(e) ***Monthly single-family residential water deliveries separated into indoor and outdoor uses*** to facilitate the determination of potential water savings from plumbing fixture retrofits or limits on irrigated turf area. See Table 6-4 in the section on Recordkeeping and Water Audits.

- **Large Users—**Connections/sites that use 50,000 gallons per day (gpd) or more, and their actual use in gpd and gallons per year. This information may be presented in the format shown in Table 6-8 in the section on Recordkeeping and Water Audits. The largest commercial water users typically include restaurants, hotels and motels, hospitals and health care facilities, nursing and personal care facilities, public administration offices, schools, universities, recreational facilities, car washes, and commercial laundries. The largest industrial water users typically include producers of chemical and allied products, food and kindred products, electric and electronic equipment, and transportation equipment.

- **Historical Records—**History of annual water levels and yields of wells that reflects the impact of withdrawals on the water supply and the sustainability of the water source. This information may be presented in the format shown in Table 6-9 in the section on Recordkeeping and Water Audits.

STEP 2: STATE YOUR CONSERVATION PROGRAM GOALS.

The next step in laying the foundation for a water conservation program is to specify the goals of the program. Specific goals will help to determine the elements of your conservation program and can also be used to define the ultimate success of the program. The list of conservation goals should include, but be not limited to:

- **Reduction in Per Capita Water Use—**Stated in gallons of per capita consumption per day (gpcd) based upon total annual water deliveries to service connections. In areas where a significant portion of the population lives in multi-family dwelling units, it may be prudent to separate single-family and multi-family residential water deliveries.

- **Reduction in Total Annual Withdrawals—**Percent reduction in total annual withdrawals and depletions (consumptive use) including self-supplied facilities. Include targeted limits in acre-feet. While end-use water conservation measures may reduce the amount of water used at an individual service connection, the number of connections and population served may continue to rise, increasing the aggregate demand on the water supply and the rate at which nonrenewable sources are depleted. Ideally, the annual water demand should be balanced with the sustainable yield of the water supply.

[NOTE: *The sustainable yield of groundwater supplies may be defined as the average annual recharge from snowmelt and rainfall, seepage from watercourses, and return flow from surface and groundwater withdrawals for water use activities. Sustainable yield may also be described as the annual withdrawal that does not result in a long-term decline in the water table. The sustainable yield of surface water supplies may be defined as the yield available from streams and reservoirs during one or more years of drought (also referred to as the firm yield).*]

- **Reduction in Water Losses—**Unaccounted-for-water losses expressed as a percent of total annual withdrawals. Losses of 10% or below are considered reasonable.

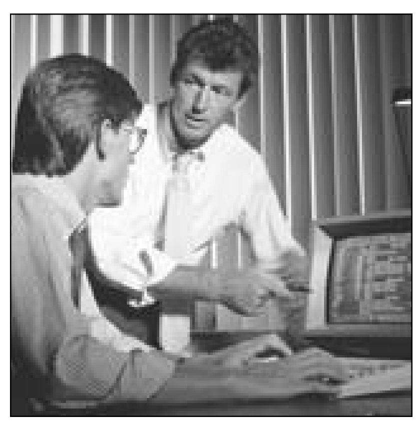
- **Basis for Goals and Time Frame for Achievement—**Goals for per capita water use at residential service connections may be determined using the procedure described in Office of the State Engineer Technical Report 48 entitled Water Conservation and Quantification of Water Demands in Subdivisions. This procedure includes a basic water requirement for indoor domestic use (which may be adjusted to reflect improvements in the water use efficiency of plumbing fixtures and appliances) plus water requirements for evaporative cooling, water softening, and landscape irrigation, based upon local climatic conditions and water quality. An abbreviated version of this procedure is included in Section 6: Recordkeeping and Water Audits.

STEP 3: DESCRIBE EXISTING CONSERVATION MEASURES.

Next, describe in detail the water conservation measures that have already been implemented. Include how and when each conservation measure was implemented. Note the methods used to evaluate the effectiveness of each conservation measure and estimate existing water-use savings and the effect of such savings on your utility's ability to further reduce demands.

Such estimates should separate water saved into two components-withdrawals and depletions (consumptive use). Existing conservation measures that are meeting the goals identified in Step Two (above) may partially or completely preempt the need for new conservation measures.

STEP 4: OUTLINE NEW CONSERVATION MEASURES.



With the conservation goals and existing water conservation efforts in mind, it is now time to specify the new water conservation measures that will be scheduled for implementation. Include in this information how each conservation measure will be implemented, the methods that will be used to evaluate the effectiveness of each measure, and the estimated water-use savings. Also include the marketing and communications efforts that will be used to provide information to your water customers and encourage conservation.

As in Step 3 (above), such estimates should separate water saved into two components—withdrawals and depletions (consumptive use). Recommended conservation measures, include, but are not limited to, the following:

- **Public Education/Information**—Educational and informational materials directed to the water-using public for the purposes of explaining the need for the conservation program and how to conserve water.
- **In-School Education**—Specific information-based programs directed to schools to promote conservation among school-age children.
- **Metering**—Metering for the purposes of water conservation should include installation of meters at all water sources, import or export points, customer service connections, and public landscape irrigation sites (one acre or larger) including self-supplied golf courses, athletic fields, parks, cemeteries, and greenbelts. A program for meter testing, repair, and replacement should also be included. Customers using more than 50,000 gpd should be a high priority for meter calibration.
- **Conservation Rate Structuring**—New conservation-based rate structuring (water pricing) and a water bill that shows rates for each block of water and historical water use information so customers can monitor effects of conservation measures. Water bills should also separate water and sewer charges.
- **Recordkeeping/Water Audits**—Recordkeeping and water audits to quantify and control unaccounted-for-water. The difference between a water supplier's monthly and annual withdrawals and its water deliveries/sales may be interpreted as a measure of unaccounted-for-water. Water audits should separate the total water demand by customer class, as shown in Table 6-2 in the section on Recordkeeping and Water Audits.
- **Leak Detection and Repair**—Leak detection and repair can dramatically reduce distribution system losses revealed by water audits.
- **Pressure Reduction**—Aprogram to reduce water pressure in the distribution system and at service connections to reduce waste.
- **Indoor Audits and Incentives**—Indoor plumbing fixture and appliance audits, retrofits, and incentive programs for residential, commercial/institutional, and industrial sites designed to eliminate leaks/losses and provide an opportunity to install water-saving devices.
- **Landscape Ordinances, Audits, and Incentives**—Landscape design ordinances, audits, retrofits, and incentive programs for residential, commercial/institutional, and industrial sites to encourage low-water-use landscapes and efficient irrigation.
- **Training of Landscape Maintenance Personnel**—Training of professional landscape personnel to encourage efficient irrigation. Well-trained landscape personnel can serve as an effective and ongoing "front line" for irrigation conservation.
- **Irrigation Management Information System (IMIS)**—Determines when to irrigate and how much water to apply at public landscape irrigation sites such as golf courses, athletic fields, parks, cemeteries, greenbelts, schools, and civic centers.

- **Irrigation with Reclaimed Wastewater—**Use of reclaimed and treated wastewater for nonpotable water uses such as landscape irrigation can be an effective way to conserve water at large facilities such as parks and golf courses.

- **Hotels/Motels—**Encourage hotels and motels to launder linens less often. Guests staying longer than one night should be given the option of reusing towels and linens.

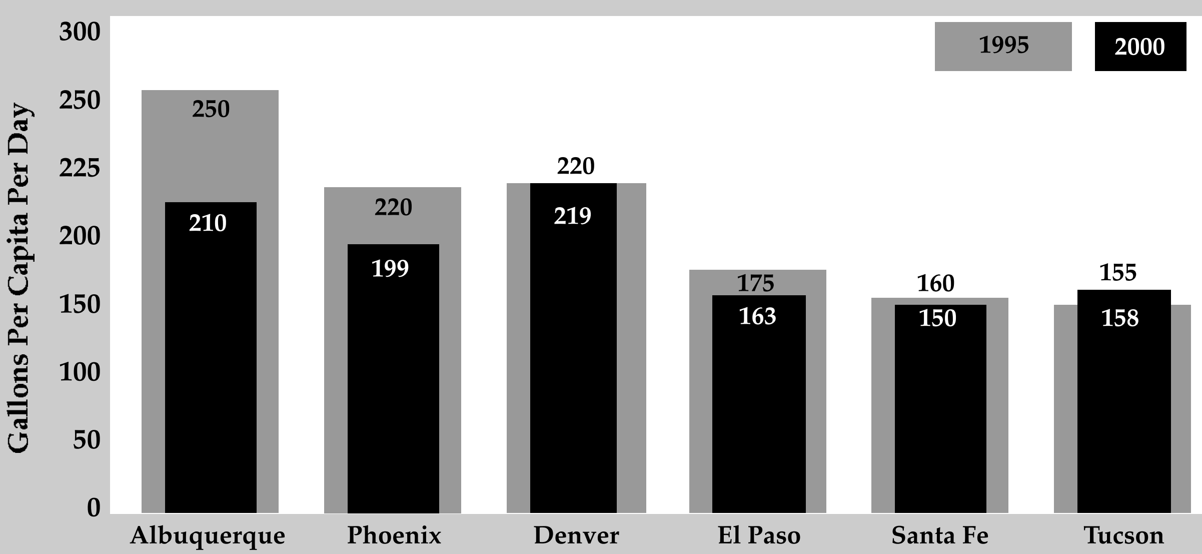
- **Water Waste Ordinances—**Water waste ordinances typically list specific uses of water that are deemed wasteful. These can include landscape irrigation during the hottest daytime hours (when the evaporation rate is at its highest) and excessive water runoff from irrigation or other water uses.

- **Emergency Action Plan for Drought Management—**Outlines the steps the utility takes in the event of a drought. Recommended elements also include the applicable definitions of what constitutes various "drought" levels and the mechanisms by which drought measures are enacted.

Implementation of all these measures may not be necessary. However, your water utility should take sufficient action to reduce water use and losses to meet the goals specified in Step Two.

THE EFFECTS OF CONSERVATION ON WATER USE

Albuquerque's gallons per capita per day (gpcd) water usage did not compare favorably to other southwestern U.S. when its water conservation program was initiated in 1995. Five years later, however, the effects of a major water conservation initiative are apparent. Albuquerque's ultimate water conservation goal is to reach 175 gpcd by 2005.



NOTE: Albuquerque had reached 204 gpcd in 1999, but a drier-than-usual summer in 2000 boosted water use.

SECTION 3

PUBLIC INFORMATION

PUBLIC INFORMATION

PUBLIC INFORMATION: THE LINK TO COMMUNITY PARTICIPATION

A public information program is essential to the success of any comprehensive water conservation effort. If the public is being asked to conserve water, citizens need to know what the water supply situation is in the community, why they need to save water, and how to do so. Even the best conservation program will not achieve the desired goal unless both the intent and content of the program are communicated effectively.

A public information campaign plays an important role whether the conservation measures being requested are voluntary or mandatory. A well-planned public information program will not only increase the public's awareness about the need to conserve water and tell customers how to conserve it, but it will also provide a positive public relations benefit for the water utility.

HOW TO DEVELOP A PUBLIC INFORMATION PROGRAM

A successful public information program takes thoughtful planning and conscious implementation. Public information programs are sometimes seen as not being important, or they are added to a water conservation plan at the last minute. Hurriedly implemented, an information program is almost certain to be less than optimally effective.

Before beginning a public information program, your water utility should assess the conservation information needs of the community and identify the types of communication methods that work most effectively in your local service area. Creating a program that addresses the specific characteristics of the community is very important to its success; what may be appropriate for one community may not work in another.

The costs will depend upon the type and scope of program chosen. Most costs will come from staffing the program and developing public information materials.

STEP 1: IDENTIFY TARGET AUDIENCES.

Identify the audiences and the types of water use that the information program is to target. Ideally, a program will provide general information to the total community and more specific information to targeted customer classes. For example, if institutional water use accounts for a large percentage of total community use, specific conservation information programs could be designed for conserving water in hospitals, schools, universities, prisons and other public facilities. If outdoor water use accounts for a significant portion of community use, public information materials and events should address water-efficient landscaping and irrigation.

PUBLIC INFORMATION

STEP 2: DETERMINE PROGRAM ACTIVITIES.

Select the type of program activities to be included in the public information program. There are four basic categories of activities that have been used by communities to effect water savings, each of which can be used alone or combined with the others for greater impact.

Print, Radio, and Television News Media. There are many options available through these media, including news releases for newspaper articles and news programs, radio and television public service announcements, paid advertisements, talk shows, and special documentaries. The advantage of using these media is that they reach a wide audience, as a large percentage of the population either read the newspaper, listen to the radio, see billboards, or watch TV. The disadvantage is that these media are expensive if paid advertisements are used or special documentaries are developed.

- **News releases.** A news release is a document issued to the news media to alert them to news from a company, government department, or other news-making group. News releases are a common, inexpensive way to get information to the public. However, in order for news releases to be used by the media, they need to be prepared properly. Some tips for preparing successful news releases are:

  ' Write only about items in which the media might be interested. The subject of the stories should be timely, relate to the locale, be of some consequence, or contain a human-interest angle.

  ' Write in newspaper style placing the most important information (who, what, where, when, why, and how) in the first two paragraphs.

  ' Do not editorialize. Statements of opinion should be enclosed in quotation marks and attributed to a person.

  ' Identify the earliest date that the information in the news release can be used, or indicate that the information is “For Immediate Release.” Send the release early enough to meet media deadlines. Call local newspapers, radio stations, and TV stations to find out what these deadlines are.

- **News conferences, public service announcements, and talk shows.** News conferences should be reserved for very important announcements, such as launching a water conservation program. Public service announcements, if well written and/or produced, are often used by local media. These announcements should be written for the exact time length preferred by the media, normally 30 seconds. Having utility staff or other conservation experts appear on radio or television talk shows is yet another way to provide conservation information to the public through the news media.

Public Information Materials. A direct way to reach the public is through the development and distribution of conservation materials such as brochures, bill stuffers and messages, bumper stickers, signs, guidebooks, films, and slide shows. The advantage of using these materials is that the message is available to the targeted audience to use again and again. The disadvantage is that some of these materials can be costly to produce and distribute.

Conservation brochures on efficient landscaping, residential conservation tips, and indoor water use are commonly used. The Office of the State Engineer offers a number of brochures and guidebooks on conservation topics (see notes at the end of this chapter), or your water utility can develop its own locally oriented materials. Many municipalities use small brochures sent with water bills, commonly referred to as bill stuffers. Conservation messages printed on the bills themselves are another option. A common practice for this type of message is to compare the billed monthly water use with water use the previous month and with water use the same month during the prior year. This comparison lets water users easily see how they are doing in their water conservation efforts.

Exhibits, Tours, and Presentations at Water Events. An excellent way to get informational materials to the public and talk directly to customers is through appearances at workshops, conferences, fairs, garden shows, and other community events. Sponsors of these events usually welcome exhibits from municipal water suppliers or offers to make presentations about the municipality's water conservation program. Although professional "trade show" exhibits can be expensive, an attractive, informal exhibit can be created without much expense. Your utility can also sponsor tours of water-efficient gardens, residences or commercial facilities; create water-efficient demonstration gardens open to the public; or sponsor conservation classes or workshops.

Web Site Information. With the increasing use of computers in homes as well as businesses, the Internet offers another medium in which to provide water conservation information to water users. The development of a web site allows information to be transferred directly to any person who accesses the site. Although the initial costs for setting up a web site can be expensive, the posting and transfer of information can be made fairly inexpensively—without having to print large numbers of materials, create mailing labels, or incur postage costs. The disadvantage is that a person has to take the initiative to access the web site and find the information housed there, so all of a targeted audience may not be reached in this manner.

STEP 3: OBTAIN PROGRAM SUPPORT.

Obtain support of management and integrate the program with the other activities of your water agency. Meeting with management before launching a public information program can help clarify and reach agreement on program goals and determine the role of management in participating in the program. Meeting with financial and field staff also helps to ensure a successful program launch by alerting them ahead of time to the activities that are planned, identifying any potential conflicts with other agency programs, and providing a forum for additional public information ideas.

PUBLIC INFORMATION

STEP 4: IDENTIFY STAFF AND FUNDING RESOURCES.

Designate one person to coordinate all public information activities and contacts. Other staff members and volunteers can certainly contribute to the effort, but one person should oversee the program to avoid duplication and ensure maximum productivity. A volunteer group of interested citizens (usually persons who are highly committed and energetic) can help expand the reach of a public information effort by providing additional staffing resources and program design ideas.

Funds for supporting the public information program should be identified early in the process so that their availability and dependability can be assessed and program adjustments can be made accordingly. If additional funds are needed, possible cost-sharing sources include local energy, gas, or sewer utilities (as they would typically benefit from reduced water use). Other sources of funds might be state or federal water agencies, private foundations, schools, and nonprofit organizations.

STEP 5: TRACK PROGRAM EFFORTS AND EVALUATE RESULTS.

Upon the implementation of a public information program, staff should track program efforts to make sure the targeted audiences were reached, identify the materials and activities that were distributed or used, and determine the results which were achieved. It is sometimes difficult to quantify water savings directly attributable to public information programs, but good estimates can be made. Public information methods that are successful should be retained and emphasized, and unsuccessful components should be dropped or adjusted. Remember: your water utility should widely publicize the amount of water conservation achieved in your community! Also, make sure your public information campaign includes a message emphasizing the continued need for conservation.

SOURCES OF PUBLIC INFORMATION MATERIALS

Contact the following municipalities, government departments, and organizations to receive more information on creating public information materials for water conservation programs and to obtain copies of previously produced water conservation materials.

- City of Albuquerque, Water Conservation Office, www.cabq.gov
- City of Santa Fe, Sangre de Cristo Water Company, (505) 954-7199
- Office of the State Engineer, Water Use and Conservation Bureau, 1-800-WATER-NM (1-800-928-3766), www.seo.state.nm.us
- WaterWiser National Water Conservation Clearinghouse, www.waterwiser.org

SECTION 4

IN-SCHOOL EDUCATION

IN-SCHOOL EDUCATION

INSTILLING THE CONSERVATION ETHIC IN YOUNG MINDS

To encourage long-term water conservation, it is important to educate children and help them develop water-saving habits. Teaching children to respect the value of water will help them grow into environmentally responsible adults who possess a conservation ethic. An educational program for children has long-lasting effects because today's water-aware children become tomorrow's water-wise adults.

That's why educating school children about the value of water resources and the need to use them wisely should be part of your municipal conservation program. Children can initiate conservation activities in their schools, homes, and in the community at large. School-age children can also teach others (including their parents) about the importance of efficient water use. In some communities, students distribute plumbing retrofit kits to homes and even help conduct water audits. There are many excellent water conservation educational materials, complete classroom programs, and web sites available. In addition, local educators and students can design their own water conservation materials. Students can also help carry out some of the public education activities described in the preceding chapter.

A good conservation curriculum can:

- increase a student's awareness of the environment and the importance of water in sustaining our society
- enhance knowledge of where water comes from and how the water utility ensures it is safe for drinking
- educate students on how we use water and in what quantities
- provide information on water pollution and how to prevent it
- encourage students to adopt attitudes and behaviors that will avoid wasteful practices and conserve our water resources
- help children develop analytical skills so they can make environmentally responsible choices about water and other natural resources
- encourage participation in decisions and activities affecting water use in students' schools, neighborhoods, and communities.

When considering conservation education, it is also important to keep in mind that not everyone learns in the same way. All educational activities should be geared to auditory, visual, and/or kinesthetic learning styles. Ideally, a school program should have something for each type of student learner:

- those who learn by hearing ("audio learners")
- those who understand best when they see something ("visual learners")
- those who comprehend an idea better when they have touched something, done the lab experiment, etc. ("kinesthetic learners")

An educator who presents material in only one of these learning domains potentially loses two-thirds of the intended audience no matter what their age. In addition, children need the opportunity not only to experiment and explore, but also to apply what they learn to everyday situations where they can see the results of their actions, and know that they can make a difference.

IN-SCHOOL EDUCATION

BRINGING CONSERVATION EDUCATION INTO THE CLASSROOM

Teachers who are thinking about using conservation topics and activities in their classrooms for the first time typically have many questions. These include:

- Where do I start?
- Where can I find appropriate educational materials?
- How do I integrate conservation into the curriculum?
- How do I get the financial resources needed to get my program started?
- How can I get in-service training to learn more about conservation education?

Unfortunately, teachers seldom have time to initiate and implement water conservation education programs on their own. Your water utility can make life a lot easier for teachers by providing assistance that helps answer all of the above questions. The following procedure may be used to develop an in-school water conservation program sponsored by your water utility.

Step 1: Prepare an "Introduction to Water" Report. Create a briefing paper for educators that describes the current and projected status of the local water supply and demand in your utility's service area. An important element of this paper is an overview of the utility's conservation plan. Explain the value to the community of an in-school conservation program and describe the support the utility can provide to the educational system. Your water utility must show determination, enthusiasm, and commitment to gain support for the conservation initiative.

Step 2: Contact the School System. Contact the school board and the superintendent of education to schedule a meeting to solicit their support in establishing an in-school water conservation program. Obtain approval to establish a steering committee to direct the development and implementation of the program. This steering committee can be comprised of utility staff, educators, parents, and other interested parties (which may include high school students). Define the responsibilities of the steering committee and its overall role in the conservation program.

Step 3: Announce the Water Conservation Initiative. Using various public media and school communication networks, announce the cooperative educational initiative. Solicit participation on the steering committee from interested parties. Subsequent steps in this procedure will require the assistance of the steering committee.

Step 4: Assign Utility Personnel to the Program. Determine the utility personnel who will develop and run the program. Provide the office space and equipment needed to conduct the program. Arrange transportation for the program coordinator to visit schools during the formative and implementation phases of the project.

Step 5: Contact Schools to Determine Existing Conservation Activities. Contact schools and other agencies that work with children to determine what conservation activities, if any, are already underway. In some schools there may be one or two teachers who have introduced conservation education into their classroom activities. If so, ask them to share what they have learned about teaching conservation. Soil and Water Conservation Districts and County Extension 4-H groups may also be involved in providing group learning activities on water conservation.

Step 6: Review Conservation Materials. Review existing conservation materials and select the most appropriate items for each grade level, or develop new materials as needed. Conservation materials can include:

- exercise books for students
- computer games and exercises
- slides
- videos
- models
- experiments
- guest presentations
- other materials for field and classroom projects
- teacher's guides

Estimate the quantity of selected items that will be required for the school system and calculate the annual cost.

The following educational materials are offered by the Office of the State Engineer, Water Use and Conservation Bureau. These materials may be ordered by calling 1-800-WATER-NM (1-800-928-3766) or by emailing the bureau at waternm@seo.state.nm.us. For more information on the materials, visit the OSE web site at www.seo.state.nm.us/water-info/conservation/h20-products.html.

Agua Action (All grades). This brochure was developed for community education, but may also be used in schools. Folding out into a poster, it gives tips for indoor and outdoor water conservation and sets the stage for good discussion on what individuals and families can do to save water. Available in Spanish.

Conserve Water (Grades 4-7). This is a cartoon magazine with stories and games about water conservation. An accompanying educator's guide is available directly from the publisher: The Watercourse, P.O. Box 170575, Bozeman, MT 59717-0575.

Coyote Tales (Preschool-Grade 1). Includes two separate stories: (1) "How Coyote Brought Us Water," and (2) "Coyote Wanders Up River." These stories introduce children to water through Coyote and his friends, Turtle and Rabbit. Available in English and Spanish. A teacher's guide accompanies the tales.

Water Detective (Grades 2-3). Introduces students to all the places in their homes where water is used and can be wasted through leaks or wasteful practices. Students take the brochure home and look for ways to save water indoors and outdoors. A teacher's guide accompanies the brochure.

Water: A Never Ending Story (Grades 4-7). A curriculum and video which include hands-on, interdisciplinary activities to help students cultivate a water conservation attitude. Specific activities are designed for use with segments from the video.

Also of interest:

> ***Learning to be WaterWise.*** This school-based program empowers students and their parents through the integration of instructional materials and hands-on devices while teaching them the importance of using water wisely. The "student kit" portion of the program contains water-saving devices that students install in their homes. This program requires a financial commitment on the part of the community. However, the results (lower overall community water use) may allow a payback within a few years as water use declines through education, behavior change, and use of the devices. For information on the WaterWise program, contact the Program Center, 2351 Tenaya Drive, Modesto, CA, 95354. Call 1-888-GETWISE (1-888-438-9473) or visit the website at www.getwise.org.
>
> ***The Watercourse.*** This not-for-profit water science and education program is based at Montana State University, Bozeman, which specializes in the development of educational materials on water and water-related management issues. The materials include teacher guides and resources, activity-filled student booklets, and children's books. The Watercourse also manages the Project WET (Water Education for Teachers) teacher-training program. The scope of The Watercourse is international, its delivery unbiased, and its mission is to build informal leadership in resource decision-making. The Watercourse is located at 201 Culberson Hall, Montana State University, Bozeman, Montana 59717-0570; phone (406) 994-5392; email watercourse@montana.edu; website www.montana.edu/wwwwater/index.html.

NOTE: Utilities have been known to combine some of the more attractive elements of individual programs to create unique programs specific to their communities. For example, an older, non-affluent community might benefit the most from the water-saving devices in the "student kits" that are provided with the Learning to be WaterWise program, but it may not be able to afford the program. A combination of a strong curriculum with a specific item from the "student kit" (such as a low-flow showerhead) might obtain some of the same results at a lower cost. In addition, holding a student assembly and having program sponsors hand out "Certificates of Achievement" at the completion of the education program is a good way to recognize students and sponsors alike.

Step 7: Establish Evaluation Methods. Create a means of evaluating the students' understanding of the subject matter before and after the conservation lessons have been completed. Tests for this purpose are often included with the available instructional materials. Results from student tests may be used to measure the effectiveness of the program and to identify deficiencies in the teaching materials and techniques that need to be corrected.

Step 8: Establish In-Service Training. Determine a means of providing in-service conservation training for teachers and estimate the annual cost of providing such training.

Here's one option:

- ***Project WET Teacher Training.*** Project WET (Water Education for Teachers) is a nationally developed K-12 environmental education program that utilizes water as its theme. Designed for delivery by formal or non-formal teachers, it contains lab exercises and activities designed for small or large classes. Trained facilitators present the curricula to teachers in a six-hour workshop, after which teachers receive their own copy of the Project WET book—a collection of 80 water related lessons. For information on Project WET in New Mexico, contact New Mexico State

University, Waste Management Education Resource Consortium (WERC), Box 30001, Las Cruces, NM 99003. Call 1-800-523-5996 or visit the website at www.werc.net.

Step 9: Determine Annual Budget. Compile the costs of educational materials and teacher training to arrive at the total annual cost. The purchase of educational materials and teacher training can be subsidized not only by your water utility but also by various state agencies, federal agencies, and private institutions. If financial resources fall short of the required funding, prepare proposals to obtain grants from institutions such as community-minded businesses, federal and/or state government agencies, or private foundations. Grant writing can be an intimidating and time-consuming process, but it can also lead to solid financial support for your conservation program.

CASE STUDY: THE WATERWISE PROGRAM IN LEAGUE CITY, TEXAS

The students in Jennifer Cook's fifth grade class at Hyde Elementary School knew little about water conservation, but they were eager to begin the award-winning, technology-based "Learning to be WaterWise" educational program. Cook, a 23-year teaching veteran, had been heightening their anticipation for months.

"The kids can't wait to get the water and energy-saving kits in their hands" she said. Cook and her students are a one-classroom representation of the approximately 250,000 fourth- through eighth-grade teachers and students in 15 states who have taken part in the nonprofit National Energy Foundation conservation program since its inception in 1992.

The rapid expansion of "Learning to be WaterWise" has generated impressive results: an estimated annual savings of 1.2 billion gallons of potable water, 1.2 billion gallons of wastewater, 70 million kWh of electricity, 2.5 million therms of natural gas, and 11 million dollars in utility bills as a result of the program's ability to introduce water-saving devices into students' homes and encourage water- and energy-conserving behaviors in students' families.

These accomplishments do not come cheap. Program costs average $31.50 per student and are paid for by sponsors that include local utilities, government agencies such as the U.S. Environmental Protection Agency and the U.S. Bureau of Reclamation, and private companies such as Texas Instruments and CH2M Hill. Sponsors benefit from increased recognition, free publicity in the form of student- and teacher-generated press releases, the ability to meet environmental and low-income regulatory requirements, and increased conservation of resources. According to Learning to be WaterWise Program Director Christian Scheder, more sponsors are needed to reach the goal of one million users, "but it's going gangbusters, it's going great."

Students participating in the program receive an activity booklet, a CD-ROM conservation game, a resource action kit containing water-and energy-saving devices, unlimited access to the web site at www.getwise.org, and a number of additional items.

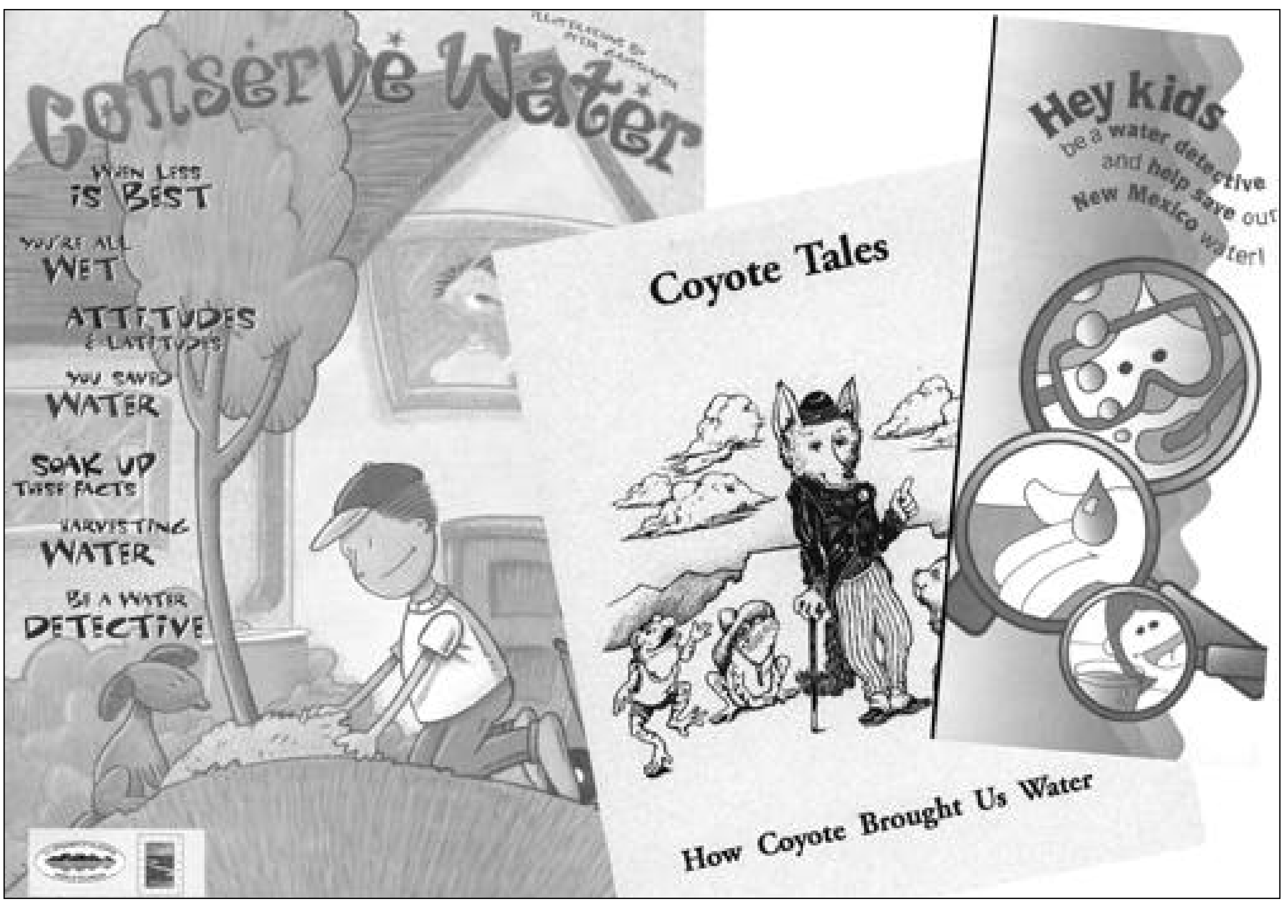
Excitement is delivered to program students through the LivingWise educational CD-ROM, a Nintendo-like game of energy conservation in which students enter a virtual three-dimensional house to lower their energy consumption rate from 100 to 1 while the clock is ticking.

At home, students work with their parents to install two-gallons-per-minute high-efficiency showerheads and two-gallons-per-minute kitchen and bathroom faucet aerators. They measure flow rates and test for toilet water leakage with devices provided. The families develop an awareness of the importance of water-conserving behaviors and technologies after completing the activities.

"I'll never forget that one girl wrote, 'My mother got into the shower in her business suit, and we got wet trying to measure the flow rate,'" Cook said. "She had a great time with her mother." Another girl in Cook's class wrote "I've never done anything with my dad before. We did something with tools."

Some parents have used the money saved on utility bills to increase their child's allowance. In another family, a student followed his parents around the house, turning off lights behind them.

Learning to be WaterWise takes advantage of the inclination of the younger generation to embrace a change in personal habits for the greater good of water and energy conservation. As Scheder pointed out, "The kids are a source of learning for their parents."
—U.S. Water News, July 1999, p. 21



SECTION 5

METERING

METERING

WHY METERING IS ESSENTIAL

Metering is an essential element of any water conservation initiative. Without water meters, individual users cannot tell how much water they are using—or how much they are saving. By installing water meters and basing water bills on actual water use, a utility can create a strong "dollars and cents" incentive for consumers to use less water. According to a 1984 study prepared by Brown and Caldwell for U.S. Housing and Urban Development, when residential customers were billed for their actual usage, as compared to a flat rate for unlimited usage, customers used an average of 13% to 45% less water than nonmetered customers.

Water metering offers the following benefits to municipalities and water utilities:

- By using meters, water utilities can track water production and deliveries, and pinpoint any leakage in the distribution system.
- Metering is a more equitable means of billing for water use, and water-conserving customers will benefit directly.
- Metering provides utilities with the opportunity to manage demand through pricing.

All residential, commercial/institutional, and industrial service connections and/or self-supplied public buildings, golf courses, athletic fields, parks, cemeteries, and construction projects should be metered.

Most utilities require meters for new services. It is less expensive to install water meters at the time of construction than to retrofit a customer connection with a meter later. Meter installation cost for a new service may be less than $200, while retrofitting can cost $400 or more per meter. Labor costs are the biggest factor in meter retrofit programs, and account for much of the difference in cost. Other factors include manual versus machine excavation and the cost of landscape and driveway replacement.

DEVELOPING A METERING PROGRAM

The following steps will help your utility establish a water metering program:

Step 1: Develop a Water Metering Regulation. Develop and adopt a regulation, resolution, or ordinance that requires the installation and reading at regular intervals of meters at all water sources. Meters should be installed at import or export points, customer service connections, and public landscape sites (one acre or larger) including self-supplied golf courses, athletic fields, parks, cemeteries, and greenbelts. All water provided free of charge for public use should be metered and read at regular intervals to allow the utility to more accurately account for water use. Lack of metering undermines control of water losses, costing and pricing, and other conservation measures.

Step 2: Document Water Sources. To the extent possible, document the geographic location of all water sources including import and export points, the type of metering device if any at each site, manufacturer and model number of device, inlet/outlet size in inches, capacity in cubic feet per second (cfs) or gallons per minute (gpm), date of installation, the condition of the metering device, frequency of meter calibration, and last date of calibration. For sites that are metered, indicate whether meter repair or replacement is required, and estimate service and installation costs (metering device, building materials, construction equipment, and labor). For sites that are not metered, specify meter requirements, and estimate installation costs. Prioritize servicing and installation of meters at each site based on the daily water production. Those sites with the largest daily production should be given highest priority.

Step 3: Classify Customers. Separate customers into customer classes:

(1) single-family residential
(2) multi-family residential
(3) commercial/institutional
(4) industrial
(5) public landscape irrigation, and
(6) other

Service-line sizes will generally vary with the customer class. If your water utility serves customers in a wide geographic area, you may also need to break down the customers in each customer class by geographic area within the utility service area to facilitate the orderly implementation of the metering program. In each customer class, enumerate service connections that require meter replacement, specify line and meter size needed at each connection, and estimate installation costs. Also enumerate service connections that are not metered and specify line size, meter size, and installation costs.

It may be prudent to have a crew do one or more test runs to arrive at some reasonable figures for time, labor, and materials required to replace an old meter with a new one. The same also applies to the installation of a meter at a nonmetered site. Time, labor, and material requirements may be much greater than would be required for a simple retrofit.

Finally, prioritize installation of meters by area and customer class, and assign meter routes to new meters. A representative sample of new meters should be tested before they are installed to ensure that they are accurate.

NOTE: If water use at multi-family residential complexes and mobile home parks is recorded by one master meter, consider installing a submeter for each individual dwelling. (See following section on submetering for more information.)

Step 4: Establish Meter-Testing and Repair Unit. Establish an organizational unit within the water utility that will provide a continuous program for meter testing, repair, and replacement. Water meters can be damaged and deteriorate with age, thus producing inaccurate readings which give misleading information regarding water usage, make leak detection difficult, and result in lost revenue for the water system. Meters, especially those that have been in service for more than 10 years, should be tested on a regular basis to ensure accurate water accounting and billing.

The system should also determine that meters are appropriately sized. Meters that are too large for a customer's level of use will tend to under-register water use. Because there are so many customer meters, it is not practical to inspect and test every one each year. Instead, annual inspections and testing should include all meters greater than two inches in diameter, along with a random sample of smaller meters. In large municipalities, commercial and industrial meters typically produce a much greater share of revenue per account than do residential meters. Revenues that can be recovered by recalibrating and repairing meters for customers with large volumes of water use may pay for a substantial portion of the meter testing and repair program.

Determining the Meter Replacement Cycle. An estimated meter replacement cost for materials and labor can be used to determine the age at which a meter can be replaced with the least average annual cost. To calculate this, the cost of meter replacement and cumulative revenue lost (unrecorded water) over a specific number of years are added, and the sum is divided by the number of years that the meter has been in the system. The optimal economic replacement age is when the average annual cost is at a minimum (Yee, 1999, p. 76) as illustrated in the sample calculation in **Table 5.1.**

All-brass meters, which typically have a 30-year replacement cycle, are no longer manufactured. The market is now dominated by less expensive plastic meters that typically have a replacement cycle of about 15 years. When selecting new replacement meters, compare the reliability and maintenance requirements of the new meters to the existing meters. Check with other water utilities to find out what their experience has been with different brands. Remember, the most reliable and longest-lasting brand may not be the least expensive initially, but it may be the most economical choice in the long-term.

Step 5: Establish a Fixed-Interval Meter Reading Program. Determine the number of people needed to read meters, the type and number of recording devices, the number of vehicles required, the meter reading routes, and the monthly schedules for reading meters in all of the designated sectors within the service area. Source meters and service connection meters should be read at the same relative time in order to facilitate accurate comparisons and analysis. Meters can be read visually by a reader who records data manually or electronically, or the reader can employ a hand-held scanner, which sends electronic data immediately back to the office. Meters can also be read remotely by shortwave or telephone connection, which completely eliminates the need for a reader. (Remote meter-reading technology not only produces accurate and immediate readings but also overcomes problems such as an inadequate number of readers, transposing numbers, difficulty in accessing meters located in residences and other buildings, and difficulties lifting meter pit lids.)

Step 6: Establish Transportation Program. Establish a motor pool and vehicle maintenance program to keep the meter servicing, installation, and reading program going.

Step 7: Establish Annual Budget. Once all of the areas of the metering program have been outlined and the necessary staffing and resources have been detailed, your utility can develop a comprehensive annual budget needed to implement the full metering program. After the budget amount has been determined, establish a means of funding all facets of the metering program.

Table 5-1

Table 5-1. Sample Calculation of Plastic Meter Replacement Age Based on Lost Revenues Due to Meter Accuracy Degradation.

1	2	3	4	5	6	7	8	9
Year Meters Installed	Number of Years Old	Accuracy Degradation Profile (%)	Annual Unrecorded Water (gal)	Annual Lost Revenue ($)	Cumulative Annual Lost Revenue ($)	Meter Replacement Cost ($)	Accumulated Cost ($) (Col 6+Col 7)	Average Cost Per Year ($) (Col 8/Col 2)
1997	0	100.00	0	0.00	0.00	0.00	0.00	0.00
1996	1	99.66	427	0.79	0.79	55.72	56.51	56.51
1995	2	99.32	854	1.59	2.38	55.72	58.10	29.05
1994	3	98.98	1282	2.38	4.76	55.72	60.48	20.16
1993	4	98.64	1709	3.17	7.93	55.72	63.65	15.91
1992	5	98.30	2136	3.96	11.89	55.72	67.61	13.52
1991	6	98.00	2513	4.66	16.55	55.72	72.28	12.05
1990	7	97.70	2890	5.36	21.91	55.72	77.64	11.09
1989	8	97.40	3267	6.06	27.97	55.72	83.70	10.46
1988	9	97.10	3644	6.76	34.73	55.72	90.47	10.05
1987	10	96.80	4021	7.46	42.19	55.72	97.93	9.79
1986	11	96.45	4461	8.28	50.47	55.72	106.21	9.66
1985	12	96.10	4901	9.09	59.56	55.72	115.20	9.61
1984	13	95.75	5341	9.91	69.47	55.72	125.21	9.63
1983	14	95.40	5780	10.73	80.20	55.72	135.84	9.71
1982	15	95.12	6128	11.37	91.57	55.72	147.31	9.82
1981	16	94.80	6533	12.12	103.69	55.72	159.43	9.96
1980	17	94.48	6939	12.88	116.57	55.72	172.31	10.14
1979	18	94.16	7345	13.63	130.20	55.72	185.94	10.33
1978	19	93.83	7750	14.38	144.38	55.72	200.32	10.54
1977	20	93.51	8156	15.13	159.71	55.72	215.45	10.77

Notes: In this example, the lowest average annual cost for meter replacement would occur when the meter has been in service for 12 years. (Source: Economic analysis for replacing residential meters by Michael D. Yee, in "Journal of the AWWA," 91(7), July 1999, p. 75)

METERING

SUBMETERING

Water deliveries to multi-family residential complexes and mobile home parks are often recorded by one master meter, while individual dwelling units are not metered. Submetering is the use of separate meters in the individual supply lines to apartments, condominiums, mobile homes, stores, or offices where the main facility or building is still billed by the water utility from a master meter.

Why is Submetering Needed?
Submetering ensures equitable billing for water used, and it provides occupants in multi-family residential units with an incentive to conserve water. Traditionally, residents in these units are billed for water at a flat rate, which is incorporated into the rent, condo fee, or management fee. Submetering also provides landlords, building managers, and others with an opportunity to manage what is often an uncontrollable cost—their monthly water bill. Submetering is advantageous to everyone except the residents who are using water inefficiently. If offers a fair way to cover the costs of providing clean water and treating wastewater.

Potential Water Savings with Submetering
A study of submetering of water customers in apartment buildings, condominiums, and mobile home parks suggested that, although additional costs are incurred by utilities to meter each dwelling unit, water savings can range from 10% to 30%. In addition, submetering can also assist in a utility's leak detection program (Beecher, 1994, p. 70). A high percentage of unaccounted-for water (UAW) is assumed to be low-flow slippage that is not recorded on the large master meters sized to handle the peak demands of the facility. A leaky toilet or a dripping faucet would not normally be recorded by a facility's master meter, but the more sensitive smaller meters used in submetering could record these flows. Residents would have a reason to report such problems to the landlord—to avoid higher water bills. Early reporting of such problems would mean lower repair bills for the landlord. Ultimately, the goal is to eliminate as many instances of UAW as possible.

Technology Options for Submetering
Submetering is basically a refinement of technologically similar systems used in the traditionally more expensive gas and electric utilities that were developed in the early 1970s as a result of the oil embargo. A submetering system can be as simple as individual mechanical water meters used as part of a mobile home park hookup. Or, it can be as complicated as flow sensors hardwired via a two-way telemetry system to a computer control station miles away, where load-shedding control monitors are programmed to shut down non-critical loads to achieve peak shaving of the utility's demand.

In some areas of the country, a third party (not the landlord or the water utility) called a "submetering supplier" installs encoded remote water meters. These meters are read by franchisees on a regular basis via hand-held data collection devices. The data are then transferred to the submetering vendor's office, where computer software systems subsequently generate and mail bills to the individual tenants. On receipt of payment, the submetering vendor reimburses the landlord, minus an operating fee, who then pays the master bills for water and sewage.

Interfacing Submetering with Existing Metering Practices
As described above, submetering is completely separate yet entirely compatible with the traditional water metering system, which is generally regarded as ending at the outlet of the master meter. If, in the future, a water utility were to replace the master meter with individual water meters at each unit, the submetering vendor would have to be reimbursed for the cost of the meters, installation, and opportunity costs.

Cost of Submetering
The actual cost of submetering varies depending upon the installation geography and the submetering technology employed. Prices range from about $200 per connection for the installation of a simple mechanical water meter to more than $600 per connection for a completely remote electronic water meter with some control functions. The real question is: who pays for the cost of submetering? With some submetering vendors, the landlord or facility manager purchases the meter and pays for the installation. Other submetering vendors pay for the meters and their installation as part of their service. In most cases, neither the individual tenants nor the water utilities experience any additional equipment costs.

EVALUATING CONSERVATION PROGRAMS AFTER A METER RETROFIT: A NOTE OF CAUTION

Evaluations of conservation programs based upon metered water use must take into account any changes made to water meters during the evaluation time period. Due to normal wear and tear, water meters become less sensitive to water flow over time. As a result, the typical water meter under-registers water use. The older a meter is, the less accurately it measures water flow, thus under-reporting actual water use.

The measured increase in metered water use after a meter retrofit could decrease the apparent effect of a water conservation program unless the retrofit is explicitly accounted for in a water demand analysis (Chesnutt, 1995, p. 38).

FOUR WAYS TO USE METERS TO TRACK WATER CONSERVATION PROGRESS

One of the ultimate goals of metering, of course, is to be able to accurately quantify and track water use throughout the water utility. Four different methodologies exist to track water conservation progress, each of which has strengths and weaknesses:

- **Per Capita Usage—**To use per capita methodology, divide the total water production by the estimated service population. Per capita usage enables your water utility to gauge the success of water conservation efforts based upon the water used by the average water customer. Per capita figures factor out growth in your customer base (which is beneficial when you want an “apples to apples” comparison of water use), but it can be difficult to accurately estimate served population.
- **Per Account Usage—**The per account methodology offers the ability to track changes in overall water use as well as changes by billing class (residential, commercial, industrial, and institutional). Per account usage is derived by dividing total billed sales by number of accounts, thereby factoring out growth.
- **Regression Model—**The regression model factors out growth and forecasts per account usage given weather conditions. This is probably the most accurate methodology since weather is a significant determinant of water use in the Southwest, but it requires additional weather information which must be obtained from outside sources.
- **Peak Day Production—**Peak day production has the greatest effect on the need for new major facilities such as wells and reservoirs, and it plays an important part in overall system planning. However, because production peaks in the summer, peak day production figures are not typically relevant during other months of the year.

Source: City of Albuquerque

SECTION 6

RECORDKEEPING & WATER AUDITS (WATER DEMAND ANALYSIS)

RECORDKEEPING AND WATER AUDITS

WHAT IS A WATER AUDIT OR WATER DEMAND ANALYSIS?

For any water conservation program to succeed, it is imperative that a recordkeeping system be established to monitor operation and maintenance costs, revenues, and the use of water. The foundation of any recordkeeping system is the water audit.

A water audit is a detailed examination of where and how much water enters the system, and where and how much leaves it. At minimum, water audits should separate the total water demand into the following categories:

(1) single-family residential
(2) multi-family residential
(3) commercial/institutional
(4) industrial
(5) public landscape irrigation, and
(6) other water demand

Water system audits help identify and assess current water uses and provide data needed to reduce water losses, reduce revenue losses, and forecast future demand. With this information, your water utility is better equipped to target conservation efforts and system improvements where they are most needed.

Estimating and reducing unaccounted-for water is a major objective of a water system audit. Unaccounted-for water includes distribution-system losses through leaks, unmetered water delivered through fire hydrants, water taken illegally from the distribution system, inoperative system controls (for example, blowoff valves and altitude-control valves), water used in flushing water mains or sewers, and meters out of calibration. (Center for the Study of Law and Politics, 1990, p. 35). Unauthorized use of hydrants can include theft by building contractors, water haulers, and others who have the tools needed to open hydrants without permission.

DEVELOPING A WATER DEMAND ANALYSIS

The following tables and procedures may be used to record annual water audits and to develop a history of water demand. (Each table is followed by a set of instructions.) This data will provide the foundation for water demand projections with and without new conservation measures. This data should be compiled for each month of each year inventoried, in the format illustrated.

Table 6-1. Monthly and Annual Water Supply and Potential Return Flow Data.

Table 6-1. Monthly and Annual Water Supply and Potential Return Flow Data.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Production (1,000 gals)			Change in Storage (+/-)		Gross Supply (4+5+6)		Net Supply (7-8)	Native Wastwtr Inflow	Imported Wastwtr Inflow	Wastwtr Reuse & Evap	Return Flow (10-12)		Depletion Ratio (14/9)
Mon & Yr	Surface	Ground	Total		Imported		Exported						Depletion (9-13)	
Jan														
Feb														
Mar														
Apr														
May														
Jun														
Jul														
Aug														
Sep														
Oct														
Nov														
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Total														
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May														
Jun														
Jul														
Aug														
Sep														
Oct														
Nov														
Dec														
Total														

Notes: If water is exported and the population is enumerated, the net supply is the same as the gross supply; if water is exported and the population served is not enumerated (e.g. commercial or industrial deliveries), the net supply is the gross supply less water exported. Decreases in storage (-) are added to the supply, storage increases (+) are subtracted from the supply. Form created by B. C. Wilson, P.E., New Mexico Office of the State Engineer, 02/16/2000.

Instructions for filling in Table 6-1: Monthly and Annual Water Supply and Potential Return Flow Data.

Column 1: Enter the month and year in each row, and after the month of December, enter "Total" in the next row.

Columns 2-4: Enter the total water production (gallons or thousands of gallons) from all raw water sources. Surface water sources include rivers, streams, lakes, and reservoirs; groundwater sources include springs and wells. Readings from source meters and measuring devices should be adjusted to correct for meter inaccuracies, if appropriate.

Column 5: Enter change in reservoir and tank storage. If source meters are located upstream of reservoirs and storage tanks, then the stored water must be accounted for in the water audit. Generally, water flowing out of storage is replaced; as the "replacement" water flows from the source into storage, it is measured as supply into the system. If the reservoirs have more water at the end of the study period than at the beginning, then the increased storage was measured by the source meters but not delivered to customers. Such increases in storage should be subtracted from the metered supply. Conversely, if there is a net reduction in storage, then the decreased amount of stored water should be added to the metered supply. In short, decreases in storage are added to the supply, storage increases are subtracted from the supply.

Column 6: Enter water imported from other water suppliers.

Column 7: The gross supply is the sum of water production, change in storage, and water imported.

Column 8: Enter water exports to areas outside the boundaries of the municipality and water exports to other water suppliers.

Column 9: If water is exported to customers outside the boundaries of a municipality and the population served is enumerated, the net supply is equal to the gross supply. If water is exported to other water suppliers and the population served is not enumerated, the net supply is the gross supply less the water exported.

Column 10: Enter native wastewater (sewage) inflows collected from the water supplier's service area.

Column 11: Enter wastewater (sewage) inflows collected from other communities outside of the water supplier's service area. In some areas, several different communities, each of which may have their own water supply facilities, may share a common wastewater treatment facility.

Column 12: Enter any wastewater that is reused and evaporation from sewage lagoons if applicable. For example, treated wastewater may be used for irrigation of golf courses, athletic fields, parks, cemeteries, and greenbelts, and for the production of agricultural forage crops. Some industrial facilities may purchase reclaimed wastewater.

Column 13: The potential return flow is calculated by adding the entries in Column 10 and 11, and subtracting the wastewater reuse from this sum. Actual return flow may be less than the potential return flow due to the nature of geologic conditions which affect the movement of water in the soil and the ability to recover this water; also evapotranspiration losses from vegetation that can access the discharge water, and evaporation losses from a receiving surface water body (lake, pond, river, stream).

Column 14: The total amount of water depleted is calculated by subtracting the return flow (Column 13) from the net supply (Column 9).

Column 15: The depletion ratio is calculated by dividing the depletion (Column 14) by the net supply (Column 9).

Table 6-2. History of Water Demand by Customer Class.

Table 6-2. History of Water Demand by Customer Class.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
			Residential (1,000 gals)				Non-Residential (1,000 gals)									
Mon & Yr	Days	Pop Served	Single Family	Multi Family	Res Total	Res GPCD	Com/Inst	Industrial	Public Landscap Irrigation	Other	Non-Res Total	Total Deliveries (6+12)	Net Supply from Table 1	Net GPCD	UAW (14-13)	UAW Ratio (16/14)
Jan	31															
Feb	28															
Mar	31															
Apr	30															
May	31															
Jun	30															
Jul	31															
Aug	31															
Sep	30															
Oct	31															
Nov	30															
Dec	31															
Total	365															

Notes: Com/Inst is Commercial/Institutional. Public landscape irrigation includes authorized water deliveries (estimated or metered) to athletic fields, golf courses, parks, cemeteries, and greenbelts. Other includes authorized water deliveries (estimated or metered) for firefighting training, main flushing, storm drain flushing, sewer cleaning, street cleaning, schools, decorative water facilities, swimming pools, construction projects, water quality and other testing, and process water at treatment plants. The net supply should reflect the same values entered in Table 6-1. Residential gpcd is calculated as (1000)(Res Total)/(Pop)(Days). Net gpcd is calculated as (1000)(Net Supply)/(Pop)(Days). UAW is unaccounted-for-water. Form created by B. C. Wilson, P.E., New Mexico Office of the State Engineer, 02/16/2000.

Instructions for filling in Table 6-2: History of Water Demand by Customer Class.

This data should be compiled for each month of each year inventoried to record water demand and distribution system losses information. In this table, water deliveries or sales are separated into customer classes: (1) single-family residential, (2) multi-family residential, (3) commercial/institutional, (4) industrial, (5) public landscape irrigation, and (6) other. Wastewater inflows, wastewater reuse, and unaccounted-for-water losses are also entered. This analysis may reveal a potential for reducing residential water use and unaccounted-for-water losses.

Column 1: Enter the month and year in each row, and after the month of December, enter "Total" in the next row.

Column 2: Enter the number of days in the month.

Column 3: Enter the population served.

Column 4: Enter the amount of water delivered (gallons or thousands of gallons) to single-family residential units.

Column 5: Enter the amount of water delivered to multi-family residential units.

Column 6: The residential total is the sum of the entries in Columns 4 and 5.

Column 7: The residential water use in gallons per capita per day (gpcd) is calculated by dividing the residential total (Column 6) expressed in gallons per month by the product of the population served (Column 3) and the number of days in the month (Column 2). If the residential total was entered in thousands of gallons, this needs to be taken into consideration when calculating the gpcd. If gpcd's are unusually high, there may be an opportunity to reduce residential water use.

Column 8: Enter the amount of water delivered to commercial and institutional customers.

Column 9: Enter the amount of water delivered to industrial customers.

Column 10: Enter the amount of water delivered to public landscape irrigation sites, i.e., golf courses, athletic fields, parks, cemeteries, and greenbelts. If possible, estimate the amount of authorized unmetered water delivered for these uses. Water used for many of these uses may be estimated by multiplying the rate of discharge (e.g. gallons per minute) by the total time during which it flows.

Column 11: Enter the amount of water delivered to any other water users not covered by the customer classes above. This may include firefighting and firefighting training, main flushing, storm drain flushing, sewer cleaning, street cleaning, decorative water facilities, swimming pools, water quality and other testing, and process water at treatment plants. If possible, estimate the amount of authorized unmetered water delivered for these uses.

Column 12: The non-residential total is the sum of the entries in Columns 8-11.

Column 13: The total deliveries are the sum of Columns 6 and 12.

Column 14: The net supply is obtained from the monthly entries tabulated in Table 6-1.

Column 15: The net gpcd is calculated by dividing the net supply (Column 14) expressed in gallons per month by the product of the population served and the number of days in the month (Column 2).

Column 16: The amount of unaccounted-for-water (UAW) is calculated by subtracting the net supply (Column 14) from the total deliveries (Column 13). All water that is not identified as authorized unmetered water is considered to be water lost from the distribution system.

Column 17: Dividing the unaccounted-for water (Column 16) by the net supply (Column 14) yields the unaccounted-for-water ratio. UAW losses should be 10% or less. If losses exceed this value, a leak detection and repair program should be considered.

Table 6-3. Multi-Family Housing Complexes and Annual Water Deliveries.

Table 6-3. Multi-Family Housing Complexes and Annual Water Deliveries (thousands of gallons).

1	2	3	4	5	6	7	8	9	10	11
Year	Property Name	Address	Phone	No. of Dwelling Units	No. of Units Occupied	Total Pop in Complex	Capita per Dwelling Unit (7/6)	Dwelling Units are Metered (Y/N)	Total Water Deliveries	MF GPCD

Notes: GPCD is (1000)(Total Water Deliveries)/(Total Population)(365 days). Form created by B. C. Wilson, P.E., New Mexico Office of the State Engineer, 02/16/2000.

Instructions for filling in Table 6-3: Multi-Family Housing Complexes and Annual Water Deliveries.

In some communities, a significant portion of the population may live in multi-family complexes. The purpose of this table is to enumerate the population living in these multi-family residences so that an accurate estimate of the population living in single-family residences can be determined. This information is needed in order to develop Table 6-4, which looks at the seasonal breakdown of single-family residential water use to identify opportunities to reduce indoor and outdoor water use.

Column 1: Enter the calendar year.

Column 2: Enter the property name. City planning offices, local housing authorities, and other entities may maintain an inventory of multi-family complexes. This information may also be available from publishers of local apartment guides.

Column 3: Enter the address of the property.

Column 4: Enter the phone number of the property manager's office.

Column 5: Enter the number of dwelling units in the complex.

Column 6: Enter the number of dwelling units that are normally occupied throughout the calendar year.

Column 7: Enter the average population in the complex throughout the calendar year. Sum the population entries in the column to get the total population served in multi-family complexes.

Column 8: Calculate the capita per unit (i.e., the number of occupants per unit) by dividing the total population (Column 7) by the number of occupied units (Column 6).

Column 9: Are individual dwelling units metered? (yes/no). In many apartment complexes, there may only be one main meter connection to the complex-individual buildings and dwelling units may not be metered (no submetering).

Column 10: Enter the total annual water deliveries to the complex.

Column 11: Calculate the per capita water use (gallons per capita per day) by dividing the total annual water deliveries (Column 10) by the product of the average population in the complex (Column 7) and the number of days in a calendar year (365).

Table 6-4. Breakdown of Seasonal Single-Family Residential Water Use

Table 6-4. Breakdown of Seasonal Single-Family Residential Water Use.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Mon & Yr	Days	No. of SF Res Connect	Capita per SF Res	SF Res Deliveries (gal/mon)	SF Res Deliveries (gal/res-mon) (5/3)	SF Res Deliveries (gal/res-day) (6/2)	SF Res GPCD (7/4)	Baseline Indoor Dom Use (gal/res-mon)	Water Used for Cooling & Irrigation (gal/res-mon) (6-9)	Irrigation Req for 800 sf of Bluegrass (gal/res-mon)	Ratio of Monthly Irrigation Req to Annual Total	Ratio of Monthly Cooling Req to Annual Total	Evap Cooling Req (gal/res-mon)	Potential Reduction in SF Res Water Use (gal/res-mon) (10-11-14)	Potential Reduction in SF Res Water Use (gal/mon) (3x15)
Jan	31														
Feb	28														
Mar	31														
Apr	30														
May	31														
Jun	30														
Jul	31														
Aug	31														
Sep	30														
Oct	31														
Nov	30														
Dec	31														
Total/Avg	365														

Notes: This table separates single-family residential water use into indoor and outdoor and estimates the potential water savings by limiting irrigated turf area to 800 square feet per lot. In Column 4 the number of capita per single-family residence is calculated by dividing the single-family population by the number of connections in Column 3. The single-family population is calculated by subtracting the total multi-family population in Table 6-3 from the total population served in Table 6-2. In Column 9 the baseline indoor domestic use is determined by examining Column 6 for the months of December, January, February, and March, when water use is lowest. Select the lowest value, or average the lowest values for two or more months. Form created by B. C. Wilson, P.E., New Mexico Office of the State Engineer, 02/16/2000.

Instructions for filling in Table 6-4: Breakdown of Seasonal Single-Family Residential Water Use.

The breakdown of seasonal single-family residential water use is necessary in order to separate indoor domestic use from water used for evaporative cooling and landscape irrigation. This analysis may reveal the potential for reducing indoor domestic water use by retrofitting residences with low-flow plumbing fixtures and to reduce outdoor water use by limiting irrigated turf area.

Column 1: Enter the month and year in each row, and after the month of December, enter “Total” in the next row.

Column 2: Enter the number of days in the month.

Column 3: Enter the number of single-family residential connections served.

Column 4: The number of capita (occupants) per residence is calculated by dividing the population served by the number of connections. The single-family population is calculated by subtracting the total multi-family population in Table 6-3 from the total population in Table 6-2. The population and number of connections used in this calculation should reflect the average for the calendar year.

Column 5: Enter the amount of water delivered (gallons or thousands of gallons) to single-family residences.

Column 6: The residential deliveries expressed in gallons per residence per month are calculated by dividing the residential deliveries (Column 5) by the number of the single-family connections (Columns 3).

Column 7: The residential deliveries expressed in gallons per residence per day are calculated by dividing the residential deliveries per month (Column 5) by the number of days in the month (Column 2).

Column 8: The residential water use expressed in gallons per capita per day (gpcd) is calculated by dividing the residential deliveries expressed in gallons per residence per day (Column 7) by the capita per residence (Column 4). If the gpcd is more than 55, there is a potential for reducing indoor domestic water use by retrofitting the residences with low-flow plumbing fixtures. If the gpcd is 55 or less, a plumbing fixture retrofit may not have a significant impact on reducing indoor water use. (NOTE: In a 1984 study of residential water use in the United States, Brown and Caldwell found that indoor water use exclusive of evaporative cooling and water softening requirements in a home without water-conserving plumbing fixtures and appliances averaged 77 gpcd, while indoor water use in a home with water-conserving plumbing fixtures averaged 55.8 gpcd. See Table 6-5 on the next page.)

Table 6-5. Indoor Water Use in Single and Multi-Family Dwellings with Water-Conserving Plumbing Fixtures.

[Measured in gallons per capita per day (gpcd)]. The prototype for this table is based on data published in a report prepared by Brown and Caldwell (1984) for the U.S. Department of Housing and Urban Development, Washington, DC.

Item and Assumptions	GPCD
Toilets (1.6 gal/flush x 6 flush/capita day)	9.6
Toilet leakage (0.17 x 24 gal/capita day)	4.1
Showers (2.5 gpm x 4.8 minute)	12.0
Baths (50 gal/bath x .14 bath/capita day)	7.0
Faucets (Estimated)	9.0
Dishwasher (7 gal/load x .17 load/capita day)	1.2
Washing machine (43gal/load x .30 load/capita day	12.9
Subtotal	**55.8**
Evaporative cooling (0-25 gpcd depending on location)	
Water softening (2-5 gpcd)	
Total	

Column 9: The baseline indoor domestic use expressed in gallons per residence per month is determined by examining Column 6 for the months, of December, January, February, and sometimes March, when water use in lowest. Select the lowest value, or average the lowest values for two or more months. Note that the coldest months may not have the lowest water use in some communities where residences let indoor taps run to prevent pipes from freezing.

Column 10: The water used for evaporative cooling and landscape irrigation is calculated by subtracting the baseline indoor water use expressed in gallons per residence per month (Column 9) from the deliveries per residence per month (Column 5). If the result is a negative number, the value entered in Column 10 should be zero.

Column 11: To explore the potential for reducing landscape irrigation water use, assume that the area that can be irrigated is limited to a specific number, say 800 square feet. Using the SCS Modified Blaney-Criddle Method or alternative ET formula, calculate the monthly consumptive irrigation requirements (CIR) for the type of turfrass grown in the study area ("cool season" e.g. Tall Fescue, or "warm season" e.g. Bermuda grass) using long-term weather data from a local weather station and crop coefficients that have been calibrated to reflect the species of turfgrass grown. Dividing the CIR expressed in inches by 12 inches per foot and multiplying the result by 7.48 gallons per cubic foot will yield the CIR expressed in gallons per square foot. Dividing this CIR by the application efficiency (Ef) will yield the amount of water that needs to be applied in gallons per square foot or what is referred to as the farm/field delivery requirement (FDR).

An application efficiency of 50% is reasonable for residential landscape irrigation. Sprinkler systems that are well designed and carefully managed to apply the right amount of water at the right time may achieve application efficiencies of 70% or more. Multiplying the FDR by the total square feet irrigated yields the FDR expressed in gallons per month. Monthly irrigation requirements for Tall Fescue at selected locations in New Mexico are presented in Appendix A.

Column 12: Divide the monthly irrigation water requirement by the annual total.

Columns 13 and 14: To understand the calculation of evaporative cooling water requirements, a basic overview of how these coolers work is in order. In a drip type evaporative cooler, also known as a swamp cooler, water trickles down pads made of very wettable porous material and a fan which is generally a centrifugal or "squirrel cage" type of blower, draws outside air through the pads, and this cools and humidifies the air. Evaporative coolers are designed for 100% outside air intake, and therefore provision must be made for exhausting this same quantity of air from the conditioned spaces. Unevaporated water trickles down through the pads and collects in the sump (bottom pan) for discharge or recirculation.

RECORDKEEPING AND WATER AUDITS

Every gallon of water evaporated from a cooler leaves behind its entire content of dissolved minerals. The accumulation of scale on the pads reduces the quantity of air flowing through them and the performance of the cooler decreases. Water used to flush the pads is called "bleed-off." Bleed-off water reduces the build-up of lime scale and dirt on the pads, dilutes the mineral concentration of the sump water, and prevents pump malfunctions due to blockages.

There are two types of bleed-off systems: the once-through or pumpless type and the recirculating or pump type that lifts water from the sump and delivers it to perforated troughs at the top of the unit. The pumpless type is simpler and cheaper but it consumes significantly more water and needs constant drainage. The recirculating pump type cools better, saves water, and can operate with intermittent draining but, for pad life, should be flushed periodically or have a small constant drain flow. The necessary bleed-off rate varies with the entering water mineral content and its scaling tendency. Owners of recirculating coolers often drain the sump only once a year. This saves water but may require that the pads be changed more frequently.

The total annual water requirement (W) in gallons for an evaporative cooler includes water lost to evaporation, and the bleed-off drained from the sump. It may be calculated using the following expression:

$$W=(V/T1)(0.001)(DB-WB/10)(K)(T2)(F)$$

where V is the volume in cubic feet of the interior space that will be cooled (i.e., floor area multiplied by ceiling height); T1 is the time in minutes required for a 100% air change (4 minutes is the normal design criteria); 0.001 gallons of water are required per cubic foot per minute (cfm) of airflow for each 10 degrees Fahrenheit of wet bulb depression; DB is the design dry bulb temperature in degrees Fahrenheit and WB is the mean coincident wet bulb temperature in degrees Fahrenheit for the area under study; K is a coefficient (0.80 is reasonable) to reflect the fact that the cooling unit may operate at less than maximum capacity part of the time (e.g. nighttime operation;) T2 is the number of cooling hours in a calendar year; F is the bleed-off water multiplier to account for water requirements in addition to evaporative losses, and may range from 1.15 to 1.67 for a recirculating cooling unit (but could be as low as 1.00 if the sump is only drained once a year). Ultimately, the value of F is dependent upon water quality and how frequently the owner of the cooling unit is willing to change the pads. Dry and wet bulb design temperatures and annual cooling hours are published by air conditioning manufacturers and the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). Annual cooling hours and design temperatures for dry and wet bulb temperatures for selected locations in New Mexico are shown in Table 6-6.

In the following example, annual water requirements (gallons per year) for a recirculating cooling unit are calculated for a 1,700 square foot home with 8-foot-high ceilings, in Grants, New Mexico. From tables, the design dry bulb and wet bulb temperatures are 89 and 59 degrees Fahrenheit respectively, and the annual number of cooling hours is estimated by interpolation to be 847 hours.
W=(1,700 sf)(8 ft)/4 min)(0.001 gph/cfm)(89-59)/10)(0.80)(847 hrs)(1.15)=7948 gpy

In lieu of published information giving the number of cooling hours per month, the total annual water requirement can be broken down into monthly requirements as follows: First, for the warmest months of the year, say June through September, multiply the number of days in each month by the average monthly temperature based on the 30-year normal if available. Average monthly temperatures at selected locations in New Mexico are presented in Appendix B.

Dividing the product of each month by the sum of products for all months yields the monthly distribution ratio (MDR). Multiplying the total annual cooling water requirement (W) by the MDR calculated for each month yields the monthly cooling water requirements. The derivation of monthly cooling water requirements for Grants, New Mexico, is illustrated in Table 6-7.

In communities where a significant number of residences do not have evaporative coolers, the total evaporative cooling requirement should be reduced to reflect this. So, for example, the entries in Column 14 would be multiplied by a factor of 50% if only half of the residences have coolers. If a reduction factor is applied, this should be annotated in a footnote in the table.

Table 6-6. Annual Water Requirements for Recirculating Evaporative Cooler for Selected Locales in New Mexico.

Table 6-6. Annual Water Requirements for Recirculating Evaporative Cooler for Selected Locales in New Mexico.						
			Design Temperatures in Degrees Fahrenheit for 99% Confidence Level		Cooling Water Req. (gal/yr) for 1700 Square-foot Home	
Locale	Elevation (feet)	Annual Cooling Hours	Dry Bulb	Wet Bulb	K=0.80; F=1.15	K=0.80; F=1.67
Alamogordo	4350	1718	98	64	18271	26519
Albuquerque	5311	1130	96	61	12399	17956
Artesia	3320	1779	103	67	20033	29076
Carlsbad	3232	1779	103	67	20033	29076
Clayton	4970	See Distrib.	91	61		
Clovis	4280	1199	95	65	11252	16330
Deming	4300	1718	99	64	18808	27299
Farmington	5395	See Distrib.	95	63		
Gallup	6473	See Distrib.	90	59		
Grants	6520	See Distrib.	89	59		
Hobbs	3615	See Distrib.	101	66		
Las Cruces	3881	1718	99	64	18808	27299
Las Vegas	6857	See Distrib.	91	64		
Los Alamos	7357	See Distrib.	89	60		
Raton	6920	See Distrib.	91	60		
Roswell	3669	1617	100	66	17198	24960
Santa Fe	6720	686	90	61	6223	9032
Silver City	5920	See Distrib.	95	61		
Socorro	4585	See Distrib.	97	62		
Truth or Consequences	4820	See Distrib.	99	66		
Notes: K reflects the percentage of time cooler operates at maximum capacity; F is the bleed-off water multiplier. (Source of cooling hours and temperature data: Ecodyne, 1980; Watt, 1986). Prepared by B. C. Wilson, P.E., New Mexico Office of the State Engineer, 04/05/2000.						

Table 6-7. Monthly distribution ratios (MDR) for evaporative cooling water requirements for a 1,700 square foot home in Grants, New Mexico, based on a total annual water requirement of 7,948 gallons.

Month	Days	Avg Temp	Col 2 x Col 3	MDR	Gallons
June	30	66.1	1983	0.244	1939
July	31	70.9	2198	0.270	2146
August	31	68.1	2111	0.260	2067
September	30	61.4	1842	0.226	1796
Totals	**122**		**8134**	**1.000**	**7948**

Column 15: The potential reduction in residential water use in gallons per residence per month is calculated by subtracting the projected irrigation (Column 11) and evaporative cooling water requirements (Column 14) from the existing water use for those purposes (Column 10).

Column 16: The potential reduction for all single-family residential water is calculated by multiplying the number of residential connections (Column 3) by the potential reduction per residence (Column 15).

Table 6-8. Identification of Large Water Users.

Table 6-8. Identification of Large Water Users (e.g. 50,000 gallons per day).

1	2	3	4	5	6	7	8	9
Year	Customer Class	SIC	Meter Size (Inches)	User Identification	Address	Total Gal/Year	Average Gal/Day	Maximum Gal/Day

Notes: SIC is the Standard Industrial Classification Code published by the U.S. Government. Water use may be expressed in gallons or thousands of gallons per unit of time. Form created by B. C. Wilson, P.E., New Mexico Office of the State Engineer, 02/16/2000.

Instructions for filling in Table 6-8: Identification of Large Water Users.

Large meters are major revenue producers and represent a major source of potential loss for all utilities, regardless of size. It is not uncommon to see a small percentage of customers use a high percentage of a utility's total water volume. This table identifies large water users (e.g. 50,000 gallons per day) and their total annual water use, average daily water use, and maximum daily use. These customers should be targeted for water audits to determine what opportunities may exist for conserving water. Each customer may conduct its own water audit, or this service can be provided by the water utility. However, it is important to find out first what conservation measures have already been implemented, how each conservation measure was implemented, the methods used to evaluate the effectiveness of each measure, and an estimate of existing water use savings.

Column 1: Enter the calendar year.

Column 2: Enter the water utility's customer classification code.

Column 3: Enter the standard industrial classification code (See references). The application of these codes facilitates the grouping and sorting of data by specific types of water users and comparative analysis within a customer class.

Column 4: Enter meter size in inches (5/8″, 3/4″, 1″, 1-1/2″, 2″, 3″, 4″, 6″, 8″, 10″).

Column 5: Enter name of customer.

Column 6: Enter address of customer.

Column 7: Enter the customer's total metered water deliveries for the calendar year.

Column 8: The number of gallons used per day is calculated by dividing the total annual water delivery in gallons by the number of days the facility is operational (This may be less than 365 days for some facilities).

Column 9: Enter the maximum number of gallons used per day based on meter records.

Column 10: Sort on the average or maximum day usage to prioritize the largest users that should be targeted for water audits to identify opportunities for water conservation.

Table 6-9. History of Water Levels (feet) and Yield (gallons per minute) of Wells.

Table 6-9. History of Water Levels (feet) and Yields (gallons per minute) of Wells.

Well ID:			Well ID:			Well ID:		
Date Measured	Water Level (ft)	Yield (gpm)	Date Measured	Water Level (ft)	Yield (gpm)	Date Measured	Water Level (ft)	Yield (gpm)

Form created by B. C. Wilson, P.E., New Mexico Office of the State Engineer, 02/16/2000.

Table 6-9. History of Water Levels (feet) and Yield (gallons per minute) of Wells.

The purpose of this table is to monitor the impact of withdrawals on the water supply and the sustainability of the water source. Monitoring well water levels and yields at regular intervals can provide important signals about approaching water supply and production problems. Failure to maintain such a monitoring program could result in unexpected problems and the sudden inability of the water supplier to meet demand. At regular intervals, for each well, enter into the table the date measured, the water level, and the yield.

SECTION 7

LEAK DETECTION AND REPAIR

LEAK DETECTION AND REPAIR

LEAKAGE IS LOST REVENUE

Whenever a water leak occurs in a utility's system, it's more than just water that is being wasted. Because the utility has already paid to obtain, treat, and distribute the water, any water lost to leakage represents a significant loss in revenue. Not only does the utility not get paid for the water, the water is not available for alternative uses. That's why a systematic leak detection and repair program can greatly reduce distribution costs and wastewater treatment expenses.

A leak reduction program begins with a water audit (see previous chapter), which enables utilities to decide if a leak detection and repair program is justified. If so, the leak detection and repair program should be followed by improved system maintenance and rehabilitation designed to prevent future leaks and the resulting lost water.

Leak detection is a systematic method of using listening equipment to survey the water distribution system, identify leak sounds, and pinpoint the exact locations of hidden underground leaks. Trained personnel are needed to effectively conduct a leak detection survey. Some leaks are easy to find because water is visible at the ground surface. However, many leaks do not surface and go unreported indefinitely. Nonvisible leaks include leaks that percolate into the surrounding ground and leaks that enter other conveyance facilities such as storm drains, sewers, stream channels, or old abandoned pipes. Most nonvisible underground leaks go undetected for an average period of two years. Although the repair procedures may be the same for both visible and nonvisible leak conditions, the method of detection and the sense of urgency involved are quite different.

DEVELOPING A LEAK DETECTION PROGRAM

Step 1: Determine Unaccounted-for Water. Before surveying a water distribution system to find leaks, unaccounted-for-water (UAW)-including losses caused by inaccurate metering and unmetered water use-should be determined as described in the preceding chapter. The amount of water lost is more meaningful than the percentage of UAW. When the total volume of unsold water is known, the utility can place a value on that water and determine the cost effectiveness of implementing corrective measures.

Step 2: Determine the Total Dollars Lost Due to Leaks. The cost of underground leakage is tied to variable costs, which are the volume-dependent production costs that include purchased water from other sources, energy for pumping, and chemicals to treat the water. The total volume of lost water is multiplied by the production costs (excluding labor) to determine the minimum lost revenue for the utility. The most expensive water loss in the distribution system is associated with under-registration of water meters or theft of water, since that loss reflects the retail rate. The total volume of water loss should be multiplied by the retail rate to determine maximum lost revenue.

Step 3: Compare Revenue Lost from UAW to Cost of Implementing Corrective Measures. Determine how much money your water utility is willing to spend to recover the revenue lost to UAW. After the utility has determined the annual cost of UAW, management can make a more informed decision concerning the cost-effectiveness of corrective measures.

For example, if a utility is losing $100,000 per year because of UAW and it has an aggressive meter accuracy testing and repair program, it can be reasonably sure most of the loss is attributable to leakage. If a leak detection and pinpointing survey of the distribution system will cost about $10,000, it is likely that such a survey will be cost effective. Likewise, if a utility is losing $100,000 per year in UAW and it has recently conducted a comprehensive leakage detection and pinpointing survey, it can reasonably conclude that most of the loss is attributable to meter inaccuracies or under-registration. If a testing and repair program to determine meter accuracy will cost about $20,000, it would be cost effective.

As indicated by some studies (Schultz, 1986, p. 9), it is possible that 50% of UAW is due to leaks, and 50% is due to meters that are the wrong size or type, have not been accurately calibrated, or have not been properly maintained (parts wear out and need to be replaced). This suggests that, before your utility sets up a costly leak detection program, the most cost-effective measure may be a thorough check of all metering equipment.

Step 4: Examine Programs from Other Utilities. Check with other utilities that have had leak detection programs to determine what worked and what did not.

Step 5: Prepare a Preliminary Leak Detection and Repair Plan. Your plan should specify the method that will be used to survey and pinpoint leaks, the equipment and personnel requirements, and estimated costs. Experience has shown that a two-person leak detection team can survey about 800 miles of distribution system lines per year for nonvisible leaks. Interruption for pinpointing visible leaks will reduce this rate of productivity by 50% or more (Schultz, 1986, p. 8). However, experience indicates that the pinpointing function is very cost effective because of the reduced amount of pavement replacement.

Step 6: Decide Who Should Perform the Leak Survey. Determine whether the problem will be better solved by an in-house effort or by outside contract services. The size of the leakage problem, as well as the availability of utility personnel and financing, are the primary factors in deciding whether to use in-house or contract services. ***If your utility decides to perform the leak survey with in-house personnel, go to Step 11.***

Step 7: Request Information from Outside Vendors. If your utility decides to use contract services, ask several consultants or contractors to prepare a proposal describing the scope of service and associated costs. Request proposals for a number of different types of leak detection programs, from a cursory listening-type survey (listening for leak sounds at each fire hydrant) to a more extensive sound survey or a full water audit using flow measurements, meter testing and analysis, meter reading, and billing analysis.

Step 8: Select the Scope of Service. From the information provided by outside contractors, decide what service plan best suits the utility's needs and budget. Determine the method of payment—lump sum, a set amount per day, or cost per mile.

Step 9: Request Final Bids from Selected Consultants or Contractors. Be specific in describing the precise work to be performed and how it is to be done. All of the companies should clearly understand the job requirements and procedures so they can provide accurate bids.

Step 10: Make Final Selection. If the bids are within the utility's budget, select the consultant or contractor that can provide the best services at the lowest cost.

Step 11: Inventory Equipment. If your utility has decided to perform the leak survey with in-house personnel at Step 6, inventory equipment to make sure all items that will be needed are available. Obtain new equipment as required and train leak detection team members before conducting the survey. Members of the leak detection team should have a keen sense of hearing and ability to discern different sounds. Their familiarity with water meters and the distribution system will also be important. Manufacturers of leak detection equipment typically offer training seminars for using their equipment; on-the-job training may also be included as part of the equipment purchase. Training may also be available from consultants and utilities with existing leak detection programs.

Step 12: Check Nighttime Flowrates. Check the nighttime distribution system flowrate in selected zones within the service area to determine if it is unreasonably higher than anticipated. Isolate a zone or district from the rest of the water system by closing valves and measuring the flow into the zone with either a meter, or by volumetrically recording decreases in reservoir storage levels. Subtract all nighttime commercial and industrial use, reservoir filling, and an assumed volume for normal nighttime use for residences from the total metered water use or change in reservoir storage to yield an estimate of the UAW that is being lost through line breaks and leakage. The winter months are the best time for zone measurements as they are less affected by landscape irrigation. However, nights that are subject to extreme freezing temperature should be avoided because customers may leave water running (indoor faucet) to prevent their water line from freezing up.

Step 13: Check Customer Meters. Check the suitability of customer meters to ensure meters are accurate, properly sized, and are the best type of meter for the customer's use. Maintain a database to record all instances of inaccurate meters, stoppages, and over and under-sized meters.

Step 14: Use the Leak Detection Checklist. (See below)

CHECKLIST FOR LEAK DETECTION

(1) Complete a pre-survey review of the water distribution system, including the types, sizes, brands, age, leak history, and preventive maintenance records for mains, services, valves, meters, hydrants, blowoffs, and control systems. Also review distribution system maps to know what is shown on the maps, how current the information is, and how often the information is updated. Identify those areas on the map that have the highest potential for recoverable leakage that should be surveyed.

(2) Use sound-intensifying instruments to listen on (a) fire hydrants, (b) valves, (c) meters, (d) mains, and (e) services. If your utility prefers to minimize the number of falsely detected leaks (false positives) in order to minimize unnecessary excavations, instruct operators to set the threshold levels in their devices relatively high. This will, however, increase the possibility of missing real leaks with weak noise signals. NOTE: A substantial amount of lost revenues may be recovered during the repair of visible leaks by using noise correlation equipment to pinpoint the exact location of the leak. Savings result from reduced size of excavation, labor and materials for replacement of backfill and paved surface. Recovery of revenue and reduction in excavation and labor cost result in significant cost savings as well as water savings.

(3) **If leak sounds are heard, conduct a detailed investigation** by listening on each meter in the area of the leak sound. Meters are convenient points for making contact with the underground piping system. Listening on the meter also allows you to check the meter coupling and curb stop for leakage. The sound heard at a meter may be a leak on the service or on the street main. Determine if the sound is louder on the customer side or the utility side of the meter. The water utility is typically only responsible for repairing leaks up to the residential meter. All leaks that occur from that point on are normally the responsibility of the customer.

(4) **If meters are widely spaced, listen over the main** at closely spaced intervals with sound-intensifying instruments to locate leaks in the main.

(5) **Have meter readers listen on services.** Develop incentive programs to encourage meter readers to report leaks.

(6) **Inspect sewer manholes and catch basins** for unusual amounts of clear water running in the sewer or coming through joints in the manhole.

(7) **Check all stream crossings** for water bubbling up through the streambed or for the stream to be carrying a much larger volume of water than normal.

(8) **Check all sudden increases in metered use.** Sudden increases in UAW can indicate a problem such as a major leak or break in the distribution system. Sudden increases at customer connections could indicate a service line leak.

(9) **Investigate complaints from customers who report hearing water running** in their house piping. This may be caused by a service leak, by a leak on the neighbor's service, or by a leak on the main.

(10) **Investigate complaints of low pressure in the distribution system.** This could indicate that a large leak has occurred. This condition may be reported by customers or by the fire department.

(11) **Maintain a database** to which all leaks and breaks can be recorded.

(12) **Check for unmetered** use by commercial, industrial, and residential customers.

(13) **Check for unmetered use from fire services** and private yard hydrants.

(14) **Review policy on unmetered use.** Is public use (for parks, street cleaning, etc.) unmetered? Review the policy on allowing contractors and others to fill tank trucks from hydrants without the water being metered.

(15) **Install meters** in public buildings, churches, hospitals, schools, parks, municipal golf courses, pollution control plants, fire services, or anywhere unmetered water is used.

(16) **Meter all blowoffs** of water from the distribution system.

(17) **Monitor UAW** to measure the effectiveness of the leak detection and repair program.

LEAK DETECTION AND REPAIR

CASE STUDY: LEAK DETECTION SURVEYS CONDUCTED BY THE MASSACHUSETTS WATER RESOURCES AUTHORITY

The Massachusetts Water Resources Authority (MWRA) delivers water to 44 communities through 157 metered connections. In June of 1987, the MWRA launched a leak detection survey to find and repair leaks in 260 miles of MWRA-owned water mains. The first leak detection survey exposed 87 leaks wasting 3.8 million gallons per day (mgpd). A second survey exposed 27 more leaks wasting 1.28 mgpd. MWRA also tested 139 of the 157 community master meters and found that 6.6 mgpd that was delivered to the communities was not accounted for due to faulty meters. An additional 5.7 mgpd were measured when four faulty meters in the city of Boston were replaced. As a result of these efforts, MWRA's unaccounted-for-water (UAW) was reduced from a high of 30 mgpd in 1980 or about 9% of water production, to 14 mgpd in 1989, or about 5% of water production.

In 1989-90, a leak detection survey covering approximately 6,000 miles of water lines in 43 out of the 44 communities supplied by MWRA exposed 1,947 leaks wasting an estimated 25.1 mgpd. These leaks consisted of the following: 247 main leaks, 908 service leaks, and 792 valve and hydrant leaks. Leaks accounting for about 85% of the waste were repaired, and as a result, UAW was reduced from about 28% of water delivered to these communities, to 20%.

LEAK DETECTION PROGRAM FORMS

THE FOLLOWING FORMS ARE INCLUDED IN THIS CHAPTER:

(1) LEAK DETECTION AND REPAIR PLAN
(2) LEAK DETECTION SURVEY DAILY LOG
(3) LEAK DETECTION REPORT
(4) LEAK REPAIR REPORT
(5) LEAK DETECTION AND REPAIR PROJECT SUMMARY

LEAK DETECTION AND REPAIR PLAN

Author(s) of plan:____ Date:__________

(A) Area to be Surveyed

(1) Using the results of the water audit, show on a map which areas in the distribution system will be surveyed. Indicate which areas have the highest potential for recoverable leakage and explain why. Consider records of previous leaks, type of pipe, age of pipe, soil conditions, high pressures, ground settlement, and improper installation procedures.________________________

(2) Total miles of main to be surveyed (excluding service lines). __________ The average crew can survey about two miles of main per day. Items to be considered include distances between services, traffic and safety conditions, and number of listening contact points.

(3) Number of working days needed to complete survey.__________

(B) Procedures and Equipment

(1) Describe the procedures and equipment you will use to detect leaks. Experience indicates that the best results are obtained by listening for leaks at all system contact points such as water meters, valves, hydrants, and blowoffs. ____________________________________

(2) If you will be listening for leaks at all system contact points, describe your plan for effectively detecting leaks. ____

(3) Describe the procedures and equipment you will use to pinpoint the exact location of the detected leaks. Minimizing excavations is an important consideration. ______________________

(4) Describe how the leak detection team and the repair crew will work together. A leak is normally reported by a citizen or utility employee who sees the water leaking out of the ground or a building. The leak detection crew should be called in first (or at the same time as the repair crew) to pinpoint the leak. In other cases, the leak detection crew might discover a leak, pinpoint it, and initiate the work order.____________________________________

(5) Describe the methods that will be used to determine the flow rates for excavated leaks of various sizes. ____

(C) Leak Detection Survey Budget

Item	No. of Days	Dollars/Day	Cost
Utility crew costs			
Consultant crew costs			
Vehicle costs			
Leak detection equipment			
Leak detection crew training			
Supervision and administration			
Other costs			
Total estimated survey costs			

(D) Leak Detection Survey and Repair Schedule

(1) For each area, indicate when the leak detection survey will begin and end.

(2) For each area, indicate when repairs will begin and end.

LEAK DETECTION SURVEY DAILY LOG

Date: __________ Sheet ____ of ____

Crew: ____

Area: ____

Starting address: ____

Ending address: ____

Route: ____

Miles surveyed: __________ Survey time in hours and minutes: ____________________

Describe each leak suspected or discovered, including: (a) location; (b) is the rate of water loss high or low (estimate in gpm if possible); (c) observed effect on pavement or property; (d) was the leak pinpointed, if not, what are the dimensions of the suspected target area, and what additional action will be required to zero in on the leak; (e) listening points used; and (f) pinpointing time in hours.

(1) ____

____

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________________________________ Pinpointing time in hours: ________

(2) ____

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________________________________ Pinpointing time in hours: ________

(3) ____

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________________________________ Pinpointing time in hours: ________

LEAK DETECTION SURVEY DAILY LOG

Date: __________ Sheet ____ of ____

(4) ____

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______________________________________ Pinpointing time in hours: ________

(5) ____

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______________________________________ Pinpointing time in hours: ________

(6) ____

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______________________________________ Pinpointing time in hours: ________

(7) ____

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______________________________________ Pinpointing time in hours: ________

(8) ____

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______________________________________ Pinpointing time in hours: ________

LEAK DETECTION REPORT

Confirmed for Work Order

Date: ________________ By: ____

Crew: ____ Scheduled date for repair: ____________

Area: ____

Location (street address/map reference): _______________________________________
____
____

In the space below, draw a sketch showing the location of the leak, including intersections and street names, building addresses, property lines, electric and gas lines, water and sewer lines, hydrants, valves, and distances from specific features.

LEAK REPAIR REPORT

Sheet ____ of ____

Work order number: ____________________ Foreman: ____

Leak Identification (Refer to Leak Detection Report)

Leak number: _______________ Discovery date: __________________ Leak pinpointed (y/n): ________

Location (street address/map reference): ____
____
____

Refer to sketch in leak detection report; enhance if need be; and include photographs.

Type and Size of Leak

Meter leak: ____ Meter spud leak: ____ Meter yoke leak: ____ Curb stop leak: ____
Meter line leak: ____ Service lateral leak: ____ Fire hydrant leak: ____ Valve leak: ____
Joint leak: ____ Other leak (describe): ____

Size of leak. Measured gpm:______________ Estimated gpm: _______________

Description of Repair

Damaged part was: ______ repaired or ______ replaced

If repaired, what repairs were made?
Leak clamp: ____ Welded: ____ Repacked valve: ____ Recaulked joint: ____
Other (describe):____

If replaced, what material was used? ____

Repair costs:

Materials: __________
Labor: __________
Equipment: __________
Other: __________
Total: __________

LEAK REPAIR REPORT

Sheet ____ of ____

Description of Damage for Mains and Services

What part was damaged?
Pipe barrel: ____ Joint: ____ Valve: ____ Flange nuts, bolts, tie rods: ____
Other (describe): ____

Type of break.
Split: ____ Hole: ____ Circumferential split: ____ Broken coupling: ____ Service pulled: ____
Cracked at corporation stop: ____ Gasket blown: ____ Crushed pipe: ____ Cracked bell: ____
Other (describe): ____

In your opinion, what caused the damage? ____
____

Age of leak in months and how it was determined: ____
____

Diameter of main or lateral in inches: __________

Depth to top of pipe in inches: __________

Type of pipe material.
Galvanized iron: ____ Black iron: ____ Cast iron: ____ Ductile iron: ____ Steel: ____ Copper: ____
ACP: ____ PVC: ____ Polybutylene: ____

System pressure (psi) and how it was determined: ____
____

Examine broken edge of cast- or ductile pipe.
Original thickness (inches): _____
Minimum thickness of good grey metal remaining: _____
Deterioration is on ____ outside or ____ inside

Is there evidence of previous leak or repairs in same general area (y/n)? ______

Number of previous leak repair clamps present: ______

Last repair date (if known): ______________ Cause of leak: ____
____

In your opinion should pipe be replaced (y/n)? ______

If yes, describe extent: ____
____

For Excavations, Indicate Ground Conditions
Type of soil.
Rocky: ____ Clay: ____ Loam: ____ Sandy: ____ Other: ____

Existing bedding.
Gravel/sand: ____ Native soil: ____ Pea gravel: ____ Other: ____

Type of cover.
Concrete: ____ Asphalt: ____ Soil: ____ Other: ____

LEAK DETECTION AND REPAIR PROJECT SUMMARY

Sheet ____ of ____

Author(s) of report: ____ Date: ________________

Leak Detection Survey

Date of first survey: ______________Date of last survey: ______________

Total number of days leak surveys were conducted: __________

Number of listening points.
Meters: ____ Hydrants: ____ Valves: ____ Test rods: ____ Other: ____

Miles of main surveyed: ____
Number of suspected leaks: ____ Number of pinpointed leaks: ____
Total survey time in hours: ____ Total pinpointing time in hours: ____

Average number of miles surveyed per day (AMPD).
AMPD=(miles of main surveyed)(8 hrs/day)/total survey time in hours)

Total number of visible leaks reported from other sources since survey started (Leaks not discovered during the leak detection survey): ____

Leak Repair Summary

Date first leak repair was made: __________ Date last leak repair was made: _________

Number of repairs requiring excavation: ________
Number of repairs not requiring excavation: ________
Total number of repaired leaks: ________

Total water losses in gallons, from excavated leaks: ________
Total water losses in gallons, from non-excavated leaks: ________

LEAK DETECTION AND REPAIR PROJECT SUMMARY

Sheet ____ of ____

Repair Costs in Dollars		
Excavated Leaks	Non-Excavated Leaks	Total
Materials:	Materials:	Materials:
Labor:	Labor:	Labor:
Equipment:	Equipment:	Equipment:
Other:	Other:	Other:
Subtotal:	Subtotal:	Total:

Leak Detection Project Cost Effectiveness

Step 1: Calculate the value of water losses from all leaks. The minimum value is computed by multiplying the volume of water lost by the variable costs, i.e., purchased water, energy, treatment chemicals. The maximum value is computed by multiplying the volume of water lost by the retail rate customers would be billed.

Step 2: Calculate the total cost of the leak detection survey. Do not include the cost of repairs.

Item	No. of Days	Dollars/Day	Cost
Utility crew costs			
Consultant crew costs			
Vehicle costs			
Leak detection equipment			
Leak detection crew training			
Supervision and administration			
Other costs			
Total survey costs			

Step 3: Calculate the benefit to cost ratio by dividing the value of the water saved (minimum and maximum as above) by the total cost of the leak detection survey.

Step 4: Calculate the average survey costs per mile of main surveyed by dividing the total survey costs by the miles of main surveyed.

SECTION 8

PRESSURE REDUCTION

PRESSURE REDUCTION

HOW MUCH PRESSURE IS ENOUGH?

Over-pressurized water systems can result in inefficient water use. High water pressure at the outlets will generally result in higher water use because the flow rate is higher than under low-pressure conditions. Pressure will also have an effect on leakage because the rate of flow from a leak is proportional to the square root of the water pressure. Pressure-reducing valves should be installed when static pressure exceeds 80 pounds per square inch (psi) at customer meters. (Center for the Study of Law and Politics, 1990, p. 43; Great Lakes Upper Mississippi Board, 1987, p. 108; Rocky Mountain Institute, 1991, p. 26; International Association of Plumbing and Mechanical Officials, 1997, p. 52).

Section 608.2 of the Uniform Plumbing Code (1997), which applies throughout New Mexico, specifically requires that where local static water pressure is in excess of eighty (80) pounds per square inch (552 kPa), an approved type of pressure regulator, preceded by an adequate strainer, must be installed and the static pressure reduced to eighty (80) pounds per square inch (552 kPa) or less. For potable water services up to and including one and one-half inch (1-1/2) inch (38 mm) regulators, provision must be made to prevent pressure on the building side of the regulator from exceeding main supply pressure. Approved regulators with integral bypasses are acceptable. Each such regulator and strainer should be accessibly located, and the strainer must be readily accessible for cleaning without (1) removing the regulator, (2) removing the strainer body, or (3) disconnecting the supply piping.

The static pressure at a residential service connection where a pressure-reducing valve is installed will generally be maintained at 45-55 psi. Note that in some areas, particularly where dwellings are built on slopes, differences in elevation and friction losses in the piping system may require working pressures at the street of up to 80 psi to ensure that automatic indoor fire sprinkler systems and landscape irrigation sprinklers function properly (American Water Works Association, 1989, p. 41).

In new housing developments where water pressure is maintained at 50 psi instead of 80 psi, a 3% to 6% savings in water use may be expected.

PRESSURE REDUCTION

CONDUCTING A RESIDENTIAL PRESSURE SURVEY

Because water pressure can have a significant impact on water use, a formal residential water pressure survey is a recommended part of any municipal water conservation program. To conduct a residential water pressure survey, follow the steps listed below.

Step 1: Review distribution system maps. Identify those areas on the maps that have the highest probability of excessive pressure due to the location of storage tanks, pumping plants, and changes in elevation.

Step 2: Target residential subdivisions. Based upon the above information, select residential subdivisions within the service area for a random sampling of pressure checks. Review available construction records to make sure the subdivisions selected don't already have pressure-reducing valves installed at customer service connections.

Step 3: Determine locations of water mains. In the subdivisions selected, determine where the water mains are located. Relative to the location of these water mains, identify high, low, and average elevation zones. Check the water pressure at various customer sites within each elevation zone by attaching a pressure gauge to the outdoor hose bibs or other easily accessible water connections to obtain instantaneous readings. Record the address of each test site, the date, time of day, and the pressure reading.

Step 4: Determine where pressure-reducing valves are needed. Review the recorded data to determine in what areas pressure-reducing valves should be installed. Schedule installations.

SECTION 9

INDOOR PLUMBING FIXTURE AND APPLIANCE AUDITS & RETROFITS

INDOOR PLUMBING FIXTURE AND APPLIANCE AUDITS AND RETROFITS

EFFICIENT PLUMBING FIXTURES AND APPLIANCES

The installation of water-saving plumbing fixtures (toilets, showerheads and faucets) and appliances (dishwashers, washing machines, evaporative coolers, and water softeners) is a very effective method to reduce water usage in both residential and commercial settings. The National Energy Policy Act of 1992 requires that all toilets manufactured in the United States use no more than 1.6 gallons per flush, that the maximum flow rate for showerheads not exceed 2.5 gallons per minute, and that the maximum flow rate of kitchen and bathroom faucets not exceed 2.5 gallons per minute. While new residential and commercial construction must incorporate low-flow toilets and faucets, older homes and workplaces that still use older water fixtures are a potential target for major water savings.

Many communities have had significant success in reducing indoor water use through toilet rebate programs and other rebate and audit programs. Retrofit devices for toilets, such as early-closing flapper valves and toilet dams, can also reduce water use.

Manufacturers have also made significant improvements in the efficiency of water-using appliances. Replacement of once-through evaporative coolers with coolers that recirculate bleed-off water, and replacement of old water softeners with new models equipped with controls to minimize the amount of water used for regeneration, can also save significant amounts of water.

Before examining the specific steps needed to develop a successful audit and retrofit program, a review of the most common water-using fixtures and appliances will provide important background information. Your utility can also direct customers to Consumer Reports magazine for the most current evaluations on the water-use efficiency of household appliances produced by various manufacturers.

Toilets

In the United States, most toilets used 7 to 8 gallons per flush (gpf) until the 1950s, when the 5.5 gpf toilet entered the market. By the early 1980s, the 3.5 gpf toilet became the standard. The 1992 National Energy Policy Act has made the installation of 1.6 gpf toilets a universal standard in new homes and most commercial establishments. NOTE: These figures do not include toilet leakage, which is estimated to be as high as 20%.

The average family of four flushes approximately 24 times per day; hence six flushes per capita per day is a reasonable assumption for estimating water use in single and multi-family residences.

Showerheads

The maximum flow rate of pre-1980 showerheads in the United States is 5 to 8 gallons per minute (gpm). However, studies indicate (Brown and Caldwell, 1984), that the average measured flow rate of pre-1980 showerheads is more often about 3.4 gpm because people run these showers at about two-thirds of maximum capacity. In the 1980s, 3 gpm showerheads became the industry standard. Today, 2.5 gpm is the standard.

INDOOR PLUMBING FIXTURE AND APPLIANCE AUDITS AND RETROFITS

Faucets
Prior to the National Energy Policy Act, kitchen and bathroom faucets had a maximum flowrate of 3 to 7 gpm; today the standard is 2.5 gpm. But, no matter how thrifty a faucet's flow rate, leaving the tap running constantly is really the most wasteful practice. There are faucets available, however, which shut off automatically, including some that use infrared sensors to detect any object that enters the beam's range. There are also kitchen faucet aerators that have handy on-off switches.

Dishwashers
To meet U.S. energy-efficiency standards, dishwashers manufactured since mid-1994 save energy by reducing the number of hot water wash and rinse cycles, which decreases the total water use. Today's newest dishwashers generally use 6 to 8 gallons per load compared to dishwashers manufactured in the mid-1990s that use 13 gallons. (The reduction of water use does not affect how clean the dishes get, and low-water-use machines are just as effective in removing bacteria and germs.) Note that a study conducted by Ohio State University showed that 16 gallons of water are typically used to hand wash 8 place settings and serving pieces (Buzzelli, 1991, p. 57).

Washing Machines
To meet U.S. energy-efficiency standards, washing machines manufactured since mid-1994 save energy by eliminating hot water rinses and using fewer rinse cycles, which also reduces the total water use without affecting how clean the clothes get. In the regular cycle, some newer top-loaders use 40 to 45 gallons per load compared to older machines that use 50 to 55 gallons. The newest front-loading washers (and some top-loaders as well) use 20 to 30 gallons per load. In the permanent press cycle, water use generally increases slightly for top loaders, but is about the same for the front loaders. Suds-saver washing machines, which spew wash water into a tub or sink next to the machine and then suck it up again to be reused for one or more additional wash, can save laundry detergent and up to 17 gallons of water for each reuse. Water level adjustments for small loads can also reduce the amount of water used.

Air Conditioners
An evaporative cooler (also known as a "swamp cooler") installed in a 1,700 square foot single-family residence may consumptively use (evaporate) 10,758 gallons of water during a 1,130 hour cooling season in Albuquerque. In Las Cruces, an evaporative cooler would consume 16,355 gallons in a 1,718 hour cooling season. Bleed-off water that is used to reduce mineral build-up on the pads inside the cooler may increase the total water use by 67% in coolers without pumped bleed-off recirculation (Watt, 1986, pp. 105, 110).

Hot Water Heaters
There are no noteworthy ways to save water in the selection of a typical hot water heater. However, installing a point-of-use water heater that produces hot water instantaneously can reduce water waste. This can be especially important in homes or apartments where the hot water tank is a long way from the bathroom, and occupants have to run the water a long time before it gets hot enough for a bath or a shower. Adding insulation to exposed pipes running from the water heater may also help deliver hot water more quickly, thus saving both water and energy.

Water Softeners
A water softener is designed to remove hardness, i.e., calcium and magnesium, the minerals that lead to soap-curd deposits in the bathtub and sinks, dull-looking laundry, spots on dishes, scaly deposits on faucets and showerheads, and scale inside the water heater and pipes. A water softener is not

intended to make water any safer to drink. Water requirements for regeneration vary from 15 to 120 gallons per 1,000 gallons of water softened (Consumer Reports, 1990). The Environmental Protection Agency (1980) has reported that water softener regeneration typically occurs once or twice a week, discharging 30 to 88 gallons per regeneration; and that water requirements for this purpose range from 2.3 to 15.7 gallons per capita per day (gpcd), but average about 5 gpcd. A softener controlled only by a timer regenerates at regular intervals and may use more salt and water than necessary because it regenerates whether or not the resin needs it. On the other hand, demand-control softeners monitor water flow or changes in hardness to adjust regeneration more precisely to the actual demand for water. There are also softeners that have electronic controls that can calculate the average number of gallons of water used in the previous seven days, or track abnormal variations in average water use, and call for regeneration accordingly.

DEVELOPING AN AUDIT AND RETROFIT PROGRAM

Successful audit and retrofit programs take careful planning and thoughtful implementation. These programs can range from the simple distribution of plumbing devices and complimentary audits of residences and businesses to cash rebate programs for toilet and clothes washer replacements.

Before beginning an audit and retrofit program, your utility should evaluate the need for, and the possible effect of, such an effort. Potential benefits include delaying future water resource acquisitions, eliminating some water and wastewater treatment construction costs, and reducing water demands during a drought. These programs can also create a positive public perception of community conservation efforts and augment the results of voluntary conservation requests by your utility. Costs depend upon the type of retrofit equipment selected and the possible revenue loss resulting from reduced water sales due to conservation.

Step 1: Identify Program Targets. Most new building construction after 1994 incorporates water-efficient plumbing fixtures, including 1.6 gallon-per-flush toilets and 2.5 gallon-per-minute showerheads and faucets. Therefore, audit and retrofit programs should target older houses and businesses as a first priority.

Determining the percentage of water use by customer class (single family residential, multi-family residential, commercial, institutional, and industrial) will also help direct the program to the sector identified as most important for conservation benefits, particularly if resources are limited. In Albuquerque, single-family residential use accounts for the highest percentage of total water use, so the city's program was directed at residences first and businesses later. In Santa Fe—where commercial, institutional, and industrial water use equals roughly half of the total use—audits were offered first to apartment complexes and then to residences.

Another consideration involves property owners versus renters. Experience shows that those who own their home or business are much more likely to participate in a voluntary water conservation program than those who are renting. Therefore, owner and renter data is important in targeting audit and retrofit programs.

Step 2: Select the Type of Program to be Implemented. There are three basic types of programs that have been used by communities to reduce indoor water use:

INDOOR PLUMBING FIXTURE AND APPLIANCE AUDITS AND RETROFITS

- Toilet and Clothes Washer Rebates
- Water Audits with Retrofit Devices
- Distribution of Retrofit Devices

Each of these programs can be used alone, or they can be combined with the others for greater impact. A major decision that must be made when designing any rebate/audit/retrofit program is whether to use utility staff or contract with a consultant to provide needed services. Contracting with a consultant can be more expensive initially, but it may provide better results in the long run. Experienced contractors are able to perform the work with less lead time and training. Contractors can also save your water utility the costs of employee recruitment, wages, taxes, insurance, and benefits. Retrofit staff should also be bonded to protect the water utility from liability for possible damage.

- **Toilet and Clothes Washer Rebates.** In these programs, water utilities offer rebates in the form of cash, water bill credits, or manufacturer rebates to residents or businesses that replace high-water-use toilets and clothes washers with more efficient models. Typically, a homeowner may receive a $100 rebate on the purchase of the first low-flow toilet, and lesser amounts on additional toilets. Toilet rebate programs have been used by many communities, including Albuquerque. Clothes washer rebates are less common but increasing. Of the audit and retrofit program options described, toilet and clothes washer rebate programs provide the most certain and most significant water savings.

- **Water Audits with Retrofit Devices.** Some communities choose to offer water audits for homes and businesses upon request and to supply water-saving devices during those audits. These devices can include efficient showerheads, toilet dams or bags (which reduce the amount of water a toilet tank holds), early-closing toilet flapper valves, and soil moisture sensors for scheduling landscape irrigation. The audit usually includes testing of flow rates from showers, installation of retrofit devices as agreed to by the customer, a review of outdoor watering techniques, and educational tips offered by the auditors.

  The success of an audit program relies on a well designed and continual marketing effort to urge customers to take advantage of the service, an organized and responsive audit schedule, knowledgeable and congenial staff to work with homeowners and facility managers, and the use of high-quality retrofit products. Success is directly tied to the willingness of residents and business managers to use the service and to install the retrofit devices. Both Albuquerque and Santa Fe offer water conservation audit services.

- **Distribution of Retrofit Devices.** Communities with restricted financial or staff resources may choose to make retrofit devices available to customers who voluntarily choose to pick up and install the devices. This program option is the least costly, does not demand as much staff time to implement as do the other two options, and still has the potential for achieving measurable water savings. However, it does not reach the water consumer as directly as audits, nor does it usually provide as high a level of water savings as the other two options. The success of this approach depends upon the ease of obtaining the retrofit devices, the quality of the devices, and inclusion of educational materials to encourage additional water conservation measures.

Step 3: Choose Appropriate Retrofit Hardware Products. The importance of choosing high-quality retrofit devices cannot be overstated. The quality of the product relates directly to its performance, and customers judge performance when they decide whether or not to continue using a plumbing product. Since community water savings depend upon the retention of retrofit devices after installation, quality becomes an important consideration in their purchase. Higher quality usually means a higher price must be paid for these products. Quality is also important in the purchase of efficient toilets and appliances and will affect customer satisfaction with these products. Typical retrofit devices include toilet dams and bags, early closing toilet flapper valves, and efficient showerheads and faucets.

Step 4: Choose Appropriate Distribution Methods. Consideration should be given to the method of distributing retrofit devices. Customers can obtain them through mass mailings, door-to-door canvassing, kit requests, depot pickups, and direct installation. A short description of each method follows.

- **Mass Mailings.** Mass mailings can be used to send retrofit kits containing water conservation information and retrofit devices to each customer in the targeted area. This method can reach the maximum number of customers in the least amount of time at a fairly low cost. Unfortunately, there is no assurance that the retrofit products will be installed. Many kits may be wasted due to non-installation, driving up the cost and lowering the effectiveness of the program.

- **Door-to-Door Canvassing.** This method delivers retrofit kits directly to the customer's residence or business. If no one is present, the kit is left on the doorknob in a plastic hanging bag. Sometimes the delivery is followed up by a door-to-door or telephone survey to determine installation and encourage participation. Door-to-door canvassing generally has the same advantages and disadvantages of mass mailings, although the direct contact with persons who are present at the location encourages a higher rate of participation. Staff time adds to the cost of the program, however, volunteer organizations (e.g. Boy Scouts) can to be used to reduce costs and encourage community participation.

- **Kit Requests.** Water utilities may provide retrofit kits upon receiving customer requests in response to an advertisement or mailer. This method results in less waste of retrofit kits. However, it requires an action by the customer to receive the kit, and there is no verification that the retrofit product has been installed.

- **Depot Pickup.** In this program, the water utility designates locations where retrofit products can be picked up by customers. Usual locations are shopping malls, libraries, water customer payment offices, fire stations, or parks. Only customers who are motivated pick up kits, thus resulting in less waste of materials but also in reduced customer participation. Staffing is required to operate the depot centers, and staff must be available to work weekends and evenings to make it convenient for customers to pick up the retrofit kits. Volunteer organizations can be used to assist at pickup centers, thus reducing staffing costs.

- **Direct Installation.** The water utility, through staff or contractor, actually installs the retrofit products in a home or business. This method ensures that the materials are installed correctly and are not wasted. Water savings are predictable. The cost per household can increase significantly for low-volume installations; therefore, this type of program is most cost effective in high-density areas. Liability issues need to be considered when an installation crew enters a home or business, although historically such damages are minimal. Properly trained staff is necessary.

Step 5: Analyze the Costs and Benefits of the Program. Costs include initiating the program, public education efforts, and possible reductions in utility revenues resulting from reduced water use. Benefits may include reductions in purchased water, energy, water, and wastewater treatment chemicals; deferred costs of new or expanded water supply and distribution facilities; and reduced energy bills for customers.

Step 6: Involve Decision Makers. Experience shows that the support of water agency managers, mayors, city managers, local elected officials, and others affected by audits and retrofits is needed to ensure program success. It is also important to gain the support of the plumbing industry, plumbing and appliance retailers, landscape professionals, and others whose businesses might be affected by water conservation audits and retrofits. The water agency should also brief key members of the residential, industrial, commercial, and institutional sectors and request their support of the program.

Step 7: Provide Adequate Funding for a Successful Program. Cost-sharing approaches can be useful in distributing costs among those who benefit from the program to avoid a cost burden on one entity. Local gas utilities, electric utilities, and sewage treatment plants that stand to benefit from energy savings derived from hot-water savings or reduced sewage flows might be willing to share the costs of an audit and retrofit program. In some communities, the customer picks up part of the cost of the retrofit items.

Step 8: Track Program Efforts and Evaluate Results. During the implementation of a program, staff should carefully track audit efforts to make sure schedules are followed and that audits are conducted according to procedures. Staff should keep records on the number of locations covered and audits completed to avoid duplication or lack of coverage in some areas. Adequate data should be gathered to properly assess program participation levels and effectiveness. Program effectiveness should be tracked throughout implementation; and, if reductions do not meet expectations, staff should make operational adjustments in order to meet program goals.

Step 9: Publicize Results. The public needs to be kept informed about the progress on all water conservation programs. Not only does this publicity entice new participants to join the program, but it reinforces the need for continued water conservation among those who are already participating in the program. Your water utility should widely publicize the amount of water reductions achieved—thanking the people in community for their efforts and challenging them to reduce water use even further.

SOURCES OF INFORMATION ON AUDIT AND RETROFIT PROGRAMS

City of Albuquerque, Water Conservation Office, www.cabq.gov

New Mexico Office of the State Engineer, Water Use and Conservation Bureau 1-800-WATER-NM (1-800-928-3766), www.seo.state.nm.us

City of Santa Fe, Sangre de Cristo Water Company, 505-954-7120

WaterWiser National Water Conservation Clearinghouse, www.waterwiser.org

SECTION 10

XERISCAPE AND LANDSCAPE DESIGN ORDINANCES

XERISCAPE AND LANDSCAPE DESIGN ORDINANCES

WHAT IS XERISCAPE?

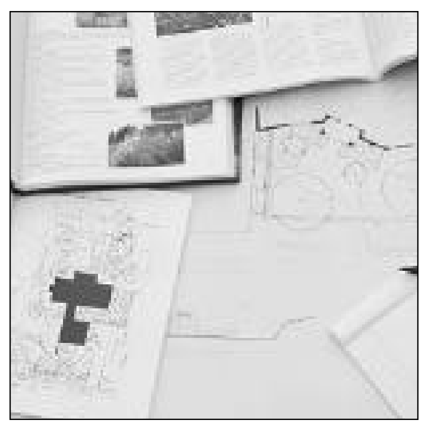
In 1980, the Denver Water Department coined the term *xeriscape* for a systematic approach to landscaping that uses plants selected for their water efficiency. The term *xeriscape* is derived from the Greek word *xeros*, which means dry. The goal in xeriscaping is to create a beautiful, water-wise landscape.

A well-designed xeriscape minimizes the area of irrigated turf-largely because traditional turfgrasses such as Kentucky bluegrass and tall fescue require a tremendous amount of additional irrigation to survive in the desert Southwest. Instead of large expanses of turfgrass, low-water-use trees, shrubs, flowers, and groundcovers are planted. Plants are zoned (i.e., grouped in the landscape according to their different water needs) so they can be irrigated separately and efficiently.

Xeriscapes have been proven to reduce outdoor water use by 50% or more without sacrificing the quality and beauty of a landscape environment. Furthermore, by using native and other plants well adapted for the local climate, xeriscapes require far less maintenance than lawn-dominated landscapes. They are also environmentally sound, requiring less fertilizer and chemicals.

The following seven steps serve as a basic introduction to the principles of xeriscaping.

Step 1: Planning and Design

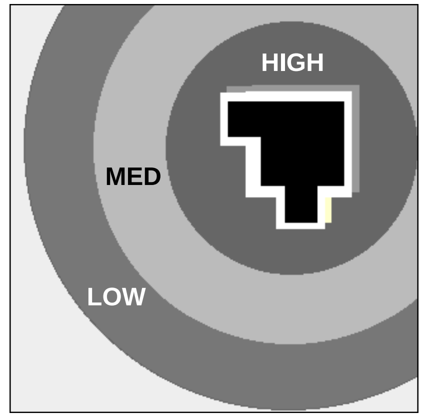


A healthy and beautiful xeriscape begins with a good design. The landscape design should reflect the property owner's needs— as well as personal aesthetic preferences. Ultimately, a well-planned xeriscape can increase the owner's satisfaction with the property, increase the value of property, and reduce water use.

Prepare a site plan drawn to scale showing the location of building structures, orientation to the sun, utilities, and existing vegetation. Delineate those areas that will be developed for specific uses, such as playing areas for children or outdoor patio areas. Limit the disturbance of native vegetation on slopes and the perimeter of lots to eliminate the need for planting vegetation that must be watered.

Divide the landscape into water-use zones:

- **The high-water-use zone** (also known as the oasis zone) is a small, highly visible area that receives the most care and requires frequent watering. High-water-use zones are normally nearest to buildings and are typically where most activity occurs. This zone typically includes the lawn area (cool season turfgrass is a high-water-use plant) and other "oasis" plants, thus creating the lushest area of the landscape. The best areas for oasis zones are the shady north and east sides of a building and anywhere that water collects naturally (such as off a roof or at the base of a slope).



- **The moderate-water-use zone** blends the lush, verdant area with the more arid parts of the landscape. Plants in this zone are watered only occasionally.

- **The low-water-use zone** requires the least care. Plants are irrigated only during establishment (typically the first 12-18 months after planting). Thereafter, they survive on rainfall only.

NOTE: It is important to avoid abrupt changes from low- to high-water-use zones because this results in overwatering along the edge of the low-water-use zone.

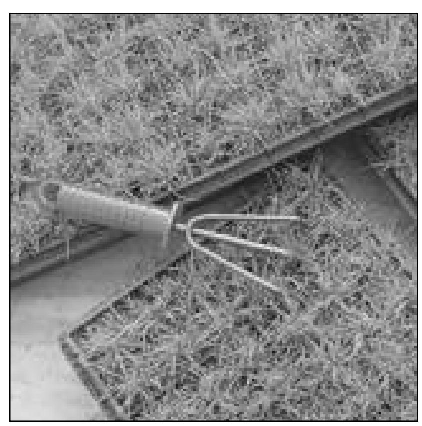
Step 2: Soil Analysis and Improvement

Evaluate the soil, including its structure, texture, water-holding capacity, and drainage. The physical and chemical characteristics of the existing soil will determine the type of soil improvement needed.

Understanding how to amend soils to provide optimum conditions for root development, water retention, and drainage is extremely important. Heavy clay soils can restrict root development and stunt plant growth. Although clay soils retain water and nutrients well because they have a low infiltration rate, they can be difficult to irrigate efficiently. Very sandy soils have a high infiltration rate and do not retain water and nutrients well. Sandy soils typically require frequent irrigation to provide adequate soil moisture for plants. Alkaline soils will require very different soil amendments than acid soils to provide a proper nutrient balance for plants.

On some sites the best solution to providing good soil for plantings may be to remove the existing soil and replace it with bulk-mixed garden soil that is available locally. Before purchasing bulk-mixed soils, test the soil or arrange for a landscape professional or county extension agent to test the soil. And finally, be aware that, when most structures are built, the soil around them is usually altered. The area against building foundations is especially likely to be filled with poor soil and debris, and it may be far from ideal for growing turf, perennials, and other plants.

Step 3: Appropriate Plant Selection



Select plants that are well-suited to the site and local growing conditions. Soil type and exposure to direct sunlight are important considerations. Match the water-use zones with the specific conditions of the planting site. Place high-water-use plants in areas of the landscape that stay moist, and low-water-use plants in areas that naturally tend to stay drier. In order to avoid water waste, plants with similar light and water requirements should be grouped together. The irrigation system should then be designed to deliver the amount of water that each grouping needs to be healthy.

Step 4: Practical Turf Areas

Use turf for a specific function or aesthetic benefit. A small "oasis" of turf near the entrance to a building or a playing surface of durable turf in a recreational area are examples of practical turf areas.

These tips will help create a water-wise and practical turf area:

- Where possible, use low-water-use varieties of grasses that are well adapted to the climate, soil, exposure, intended use, and expected level of care they will receive.
- Minimize the area of irrigated turf.
- Avoid planting a steep slope with turf because it will be difficult to water and maintain sufficient soil moisture to keep the turf green (Christopher, 1994, p. 63).
- Design turf areas in practical shapes that can be efficiently irrigated and maintained. Avoid sharp angles and long narrow strips that are difficult to mow and water (Christopher, 1994, p. 63; University of Georgia, 1992, p. 10).
- Consider the solar exposure (i.e., full sun, partial shade, etc.), heat, frost and drought tolerance, resiliency under wear, aesthetic appeal, and maintenance requirements (mowing, watering, fertilizing, and weeding) when selecting a turfgrass.

Step 5: Efficient Irrigation

A water-wise landscape requires a minimal amount of irrigation water. To make every drop count, water should be applied efficiently and effectively. Just as plants are zoned in the landscape according to their different water needs, zone the irrigation system so that plants with different water needs are irrigated separately. For example, turfgrass should be watered separately from shrubs and flowers.

Using irrigation water efficiently also requires the selection of an appropriate type of irrigation system for the plants and for each area of the landscape. Trees and shrubs in the low-water-use zone need supplemental water only during establishment, while plants in moderate-water-use zones may require additional supplemental water. For these plants, a temporary system such as a soaker hose or watering by hand may be all that is required. However, high-water-use zones require frequent watering and may warrant a permanent irrigation system with automatic controls.

Considerable water savings can be realized by studying the water needs of plants, breaking wasteful watering habits, and learning how to water, when to water, and the most efficient ways to water. Drip irrigation, which delivers small amounts of water directly to the root zones of plants, is considered the most efficient method of irrigation for perennials, shrubs, and trees. Irrigation controllers may be used to water plants for a specific length of time and in sequence, but they must be properly programmed to reflect seasonal changes in plant water requirements, otherwise water may be wasted. Adding a sensor, which automatically turns the irrigation system off if rain falls or if the soil is too wet to need watering, can improve irrigation efficiency and reduce waste. In addition, devices such as Bermadon valves can also help to reduce irrigation water use. (A Bermadon valve must be turned on manually, but it turns itself off after a set amount of water passes through it [Christopher, 1994, p. 38]).

Use the following guidelines for lawn watering:

- Water only when the grass really needs it.
- Water deeply and less frequently. Daily sprinkling may result in a shallow root system that weakens the grass, making it more susceptible to disease and more fragile in dry conditions and during winter.
- Water during the cool, early morning hours to minimize evaporation.
- Avoid watering on windy days to minimize wind drift and evaporation.
- Aim sprinklers so they water plants. Don't waste precious water on open dirt, sidewalks, or driveways.
- Adjust sprinklers to throw a low pattern of water to help minimize evaporation.
- Monitor the amount of water applied. (Buzzelli, 1991, p. 89)

Field tests conducted by Sternberg (1967) suggest that evaporation and drift losses may range from 17% to 22% of sprinkler discharge in the daytime and 11% to 16% at night.

Research conducted by the Rodale Institute indicates that—for uniformity, efficiency, and range (distance) of coverage—the impulse-type or impact-type sprinklers are the best (Ellefson, 1992, p. 107). Inexpensive revolving sprinklers (with revolving arms that move by water pressure), as well as fixed sprinklers that shoot water through a pattern of holes in their tops, give the least uniform coverage, often leaking and/or distributing most of the water near the sprinkler. Oscillating sprinklers cover a square area, but often deposit too much water at the ends of their oscillations where they pause to reverse direction. In addition, though oscillating sprinklers may be great for children to play in, throwing water high in the air increases evaporation and wind drift losses. Traveling sprinklers (the ones that look like little tractors) have revolving arms and move across the lawn for better distribution and efficiency.

Step 6: Use of Mulches

Mulching is a very beneficial landscape practice. Mulches conserve moisture by preventing evaporative water loss from the soil surface and reducing the need for irrigation during periods of limited rainfall. By maintaining an even moisture supply in the soil, mulches prevent fluctuations in soil moisture that can damage roots. Mulches also prevent crusting of the soil surface and allow water to penetrate readily to plant roots. They insulate the roots of plants from summer heat and winter cold and help control weeds that compete with plants for moisture.

By serving as a barrier between the plant and the soil, mulches help discourage soil-borne diseases that stress plants and cause them to use more water. A three- to four-inch depth of mulch is typically recommended. Depending on the mulch and growing conditions, a depth greater than five inches will discourage plants from growing and retard the percolation of water down to the soil.

Use fine-textured, organic non-matting mulches when possible. Fall leaves, pine straw, pine bark nuggets, and shredded hardwood bark are excellent choices. Mulch as large an area as possible under trees and shrubs. Islands of unplanted mulch require no water and little routine maintenance.

Step 7: Appropriate Maintenance

Keep plants healthy, but do not encourage water-demanding new growth. Once plants are established, reduce the amount of nitrogen fertilizer applied, the application rate, and the frequency of application. Avoid plant stress by mowing lawns properly, by thinning shrubs instead of shearing, and by controlling weeds and pests before they affect plant health.

Table 10-1.

LANDSCAPE IRRIGATION WATER REQUIREMENTS FOR TALL FESCUE

Selected locations in New Mexico in a normal weather year, in inches and gallons per square foot (assuming an irrigation efficiency of 50%).

City	*Inches*	*Gallons/Sq. Ft.*
Albuquerque	74.82	46.64
Carlsbad	94.18	58.70
Clayton	52.14	32.50
Farmington	61.34	38.24
Grants	48.32	30.12
Las Cruces	88.04	54.88
Las Vegas	38.16	23.79
Roswell	89.18	55.59
Ruidoso	29.56	18.42
Santa Fe	44.18	27.54
Socorro	74.40	46.38
Taos	41.92	26.13
Tucumcari	72.28	45.05

XERISCAPE AND LANDSCAPE DESIGN ORDINANCES

CONSERVATION GUIDE FOR LARGE TURF AREAS

Even though the principles of xeriscaping recommend reduced turf areas, municipalities must still maintain some large turf areas. These large turf areas include golf courses, athletic fields, parks, cemeteries, and greenbelts that have an irrigated area of one or more acres. The recommendations below are based on the premise that the efficient use of water requires that a large turf area irrigation system be properly designed using established engineering practices, that best management practices should be adopted to efficiently use the limited available water, and finally, that the irrigation system must be properly maintained.

- Design the landscape layout to minimize the irrigated turf area and the areas where sprinkler over-throw will result in wasted water. (Rectangular turf areas are easiest to water efficiently.)
- Grade the topography to avoid steep slopes that are difficult to irrigate efficiently.
- Use swales (land contouring) to intercept surface runoff for the establishment of drought-tolerant plants, shrubs, and trees, or to encourage groundwater recharge.
- Except where they provide erosion control and stormwater management (detention ponds), minimize the number and size of water features and line them with an impermeable membrane to minimize seepage losses and make-up water requirements.
- Select turfgrass species to match local climatic conditions and soil properties and minimize irrigation water requirements. Important factors to be considered include drought tolerance, hardiness against unusually late spring frosts or early fall frosts, salt tolerance, durability under foot traffic, and susceptibility to disease and insect problems.
- Use reclaimed wastewater as the source of supply if available.
- Design the irrigation system according to established engineering practices. Pressure, spacing, nozzle size, discharge rate, and angle of trajectory of sprinkler heads should be designed to match soil intake rate and wind conditions and to obtain good distribution uniformity. An irrigation efficiency of at least 70% should be achieved. A back-flow prevention device should be used to prevent contamination of the water supply.
- Install flow measurement devices at the ultimate source of supply, and, if the source is off-site, at the head of the distribution main on the irrigated landscape. Metering at the source and point of delivery facilitates monitoring and control of leakage from the conveyance system.
- Establish a recordkeeping system to track water diversions and field applications.
- Establish a water budget (irrigation system run schedule) using historical monthly evapotranspiration (ET) and weather data. Modify the run schedule based upon daily ET and daily weather data.
- Use soil moisture sensors or other devices to ensure that the right amount of water is applied at the right time.
- Install rain sensors to turn the irrigation system off when rainfall occurs.
- Install wind sensors to turn the irrigation system off when the wind velocity exceeds 10 miles per hour.
- Train landscape maintenance personnel to manage the irrigation system efficiently.
- Install excess flow sensors in the distribution system to signal abnormally high flows due to broken lines or a missing sprinkler.

PROCEDURE FOR ENACTING AN ORDINANCE GOVERNING LANDSCAPE DESIGN

Step 1: Prepare an ordinance for adoption and use it as a part of city or county building permit approval process. The ordinance may include:

(1) Limits on turf area size by percentage of landscapable area (typically 20-50%). The landscapable area is the total lot or project area less the footprint of all buildings; driveways; non-irrigated portions of parking lots; hardscape such as decks, patios, walkways, and other non-porous paved areas; and utility easements. Water features are included in the calculation of landscapable area, but areas dedicated to the production of food crops such as vegetable gardens and orchards are not. (California Department of Water Resources, 1992, p. 8)
(2) The prohibition of turf and high-water-use plants in areas next to buildings, along narrow pathways or median islands, in the drip line area of native trees, or in sloping locations. (Solar radiation reflected off south- and west-facing walls increases evapotranspiration, plant stress, and irrigation water requirements. Sprinkler irrigation of turf planted next to walls is inefficient because, in order to achieve full coverage on the turf area, a significant amount of water will get sprayed on the walls.)

Step 2: Prepare landscaping design guidelines, which are a detailed explanation of how landscapers can comply with the ordinance. Include:

(1) A suggested list of plants with low water requirements.
(2) Descriptions of the recommended types of irrigation control systems, methods of irrigation, soil preparation methods, lower water-use varieties of turf, a maintenance and watering schedule, and proper placement of plants in the landscape. Remember that plants with similar light and water needs should be grouped together.

Step 3: Present the ordinance and guidelines to city and county governments for review and comment. Solicit comments from landscape architects, planners, developers, and water purveyors and incorporate comments received into the proposed ordinance and guidelines.

Step 4: Adopt the ordinance and guidelines. Incorporate them into the building permit approval process and apply them to all new construction.

Step 5: Enforce the ordinance and guidelines. Landscape design requirements are most effective when accompanied by a design review service offered through the city or county planning office, or local water utility. Such services can help subdividers and homeowners develop landscaping plans that are consistent with community water conservation goals. Some communities designate review boards, usually consisting of landscape architects or planners, to evaluate and approve landscape designs for certain types of new development. For example, a city or county may use a review board to ensure that new landscaping and irrigation systems comply with its xeriscape requirements. After the landscape project has been completed, the site is visited and a certificate of compliance is issued if all landscape design requirements are met. To provide an incentive for low-water-use landscaping, a credit or rebate may be offered toward the connection fee if homeowners comply with landscaping guidelines. (Center for the Study of Law and Politics, 1990, p. 61.)

XERISCAPE AND LANDSCAPE DESIGN ORDINANCES

PROTOTYPE FOR LANDSCAPE REBATE PROGRAM

A landscape rebate program provides an incentive to homeowners to convert high-water- use landscapes to low-water-use landscapes by providing compensation in the form of a one-time payment to the homeowner. Such compensation may only account for a small portion of the total cost of the landscape conversion. However, a rebate provides your water utility with a means of expressing its appreciation for the public's cooperation in working toward water conservation goals. A prototype for landscaping guidelines that must be met to qualify for a rebate is presented in the text that follows.

(1) There is 20% less turf area than traditional landscapes and not more than:
  - 800 square feet of irrigated turf per single-family detached dwelling,
  - 500 square feet of irrigated turf per condominium or townhouse, or
  - 300 square feet of irrigated area per apartment or mobile home dwelling

(2) Not more than 40% of the total irrigated landscaped area is turf.

(3) In planned unit developments, turf areas are consolidated into large, relatively flat areas creating "oases of green" surrounded by dwelling unit clusters, thereby producing the greatest visual impact and optimizing irrigation efficiency. Turf is not used adjacent to building foundations, along narrow paths or median strips, or within the drip line of native trees.

(4) Low water-use shrubs and groundcovers are used in landscaped areas where turf is not used.

(5) Water-loving plants generally are confined to drainage areas and patios or other intensively used or highly lighted areas.

(6) Rock-garden plants and other colorful low-water-use plants are used to add seasonal color, visual interest, and balance.

(7) Prior to landscaping, soil tests are conducted, and the ground is carefully prepared. At a minimum, ground beneath planting is scarified and covered with a mixture of not less than four-to-six inches of topsoil amended with a least four cubic yards of organic material per 1,000 square feet and other soil amendments in a quantity and type approved by a landscape architect.

(8) Well-designed underground sprinkler systems are installed in landscaped areas. Turf heads are on a system that is separately controlled from shrub and other non-turf areas. Design of the turf-area system provides uniform water application. Low-discharge heads are used in non-turf areas or where slopes present a runoff problem. Automatic water timers and rain sensing shut-off devices are used at all stations. (Center for the Study of Law and Politics, 1990, p. 69)

(9) Drip irrigation systems are recommended (or should be considered) for xeriscaped (or non-turf) areas.

CASE STUDY: LANDSCAPE WATER BUDGET ORDINANCE ADOPTED BY OTAY WATER DISTRICT, CALIFORNIA

In the fifth year of a five-year drought (1991), the Otay Water District in California developed a water budget-based ordinance to assist commercial irrigation customers with dedicated irrigation meters to reduce water use. Dedicated landscape accounts represented just 3% of Otay's customers but 17% of its water use, and these customers were faced with elimination of all landscape water use.

The ordinance was adopted in part to provide for the economic survival of commercial landscape firms and to avoid regulations that might restrict the type and amounts of specific landscape plant materials such as turfgrass. The industry said: "Tell us how much water we can have and let us make the decisions." The ordinance was enacted after a one-year study by a 24-member task force drawn from the landscape industry, the Otay Water District, and local government.

The ordinance that resulted from this process provides dedicated meters for commercial irrigation accounts, with water allocations determined on the basis of the reported square footage of irrigated landscape. The annual allocation is spread out over the year and unused water is banked to avoid incurring overuse penalties during brief hot spells, establishment of new plantings, or irrigation system failures resulting in unanticipated usage. Specifically:

- The customer measures and reports square footage of irrigated landscape (usually equal to all non-hardscape area).
- When a meter is activated, the billing computer automatically checks for the square footage data. Failure to report square footage causes a flat seven units of water to be allocated to the account until the correct amount is reported.
- An annual irrigation allocation is assigned to accounts based on reported square footage and the applied water requirement for landscape as if planted completely with tall fescue grass. This requirement was estimated to be equal to 100% of local reference evapotranspiration (ET).
- The customer is allowed to bank up to 12 inches to avoid incurring overuse penalties during scheduled or emergency pipeline shutdowns, plant establishment or rehabilitation, fertilization procedures, or exceptionally hot weather.
- Actual monthly irrigation water use is monitored by computer, which tracks water use over the last three years. Over-use penalties are automatically calculated and compliance is enforced through the billing system.

Using this approach, Otay's dedicated irrigation meter water demand was reduced by 23% in the first year. The ordinance has been in effect since June 1992 and has met with overwhelming support from the landscape industry, which now endorses the fairness and workability of the program.

CASE STUDY: WATER CONSERVATION ORDINANCE ADOPTED BY THE MARIN MUNICIPAL WATER DISTRICT, CALIFORNIA

Marin Municipal Water District
Water Conservation Requirements
Ordinance 326

BE IT ORDAINED by the Board of Directors of the Marin Municipal Water District as follows:

All applicants for new, increased, or modified service shall comply with the requirements set forth herein.

(A) Definitions

(1) **Developed landscape area.** All outdoor areas under irrigation, surrounding hardscape areas, swimming pools, and decorative pools and fountains.

(2) **Hardscape.** Patios, decks and paths. Does not include driveways and sidewalks.

(3) **High-water-use plants.** Annuals, plants in containers, and plants not on MMWD's list of low-water-use plants.

(4) **Landscape plans.** This includes a planting plan, an irrigation plan, and a grading plan. All plans must be drawn at a scale that clearly and accurately identifies plants, irrigation layout, equipment, and finish grades. Landscape plans shall include the following:

(a) **Planting plan.** Planting plans must accurately identify and locate, but are not limited to the following:

(i) New and existing trees, shrubs, groundcovers and turf areas within the developed landscape area.
(ii) Plants by botanical name, common name, container size, spacing and quantities.
(iii) Property lines, streets and street names.
(iv) Driveway(s), sidewalk(s) and other hardscape features as necessary.
(v) Pool(s), fountain(s), fence(s) and retaining wall(s).
(vi) Existing and proposed buildings.
(vii) The square footage(s) of the various landscape hydrozones on the plan. Hydrozones are separate portions of the landscape area having plants with similar water needs that are served by a valve or set of valves with the same setting. These hydrozones include, but are not limited to, turf, high-water-use plants with overhead irrigation, low-water-use plants with overhead irrigation, drip irrigation and fountain and pool areas. If more than one water meter serves the site, the individual hydrozones must be identified with the meter providing water service.

(b) **Irrigation plan.** The irrigation plan shall be drawn at the same scale as the planting plan. The irrigation plan will be separate from but in the same format as the planting plan. The irrigation plan shall show but not be limited to the following:

(i) Irrigation system point of connection.
(ii) Water service pressure at point of irrigation system connection.
(iii) Water meter size.
(iv) Backflow prevention devices.
(v) Major components of the irrigation system.
(vi) Total precipitation rate in inches per hour for each overhead irrigation circuit.
(vii) Total flow rate (gph) and operating pressure (psi) for each irrigation circuit.

(viii) Irrigation legend will have the following elements: Symbols for various irrigation equipment, general description of equipment, manufacture name and model number, operating pressure, manufacturer's irrigation nozzle rating in gallons per minute (gpm) or gallons per hour (gph) as necessary, minimum and maximum spray radius, manufacturer's rated precipitation rate per nozzle.

(ix) Reclaimed water piping and guidelines as required.

(c) **Grading plan.** The grading plan shall be drawn at the same scale as the planting and irrigation plan. The grading plan must show all finish grades, spot elevations as necessary and existing, and new contours within the developed landscape area.

(5) **Landscape architect.** A person who holds a certificate to practice landscape architecture in the state of California under the authority of the California State Board of Landscape Architects.

(6) **Low-water-use plants.** Plants on MMWD low-water-use plant list, or any other plant approved by MMWD. (Generally, once a plant is established, it can survive on two irrigations per month during summer months.)

(7) **Overhead irrigation.** An irrigation method that delivers water to the landscape in a spray or stream-like manner from above-ground spray heads (includes micro-misters; does not include bubblers).

(8) **Overspray.** Water is delivered beyond the targeted landscape area during windless hours onto adjacent pavements, walks, structures, or other non-landscaped areas during an irrigation cycle.

(9) **Runoff.** Irrigation water that is not absorbed by the soil or landscape area to which it is applied and which flows onto other areas.

(B) Requirements for all services.

(1) **Pressure regulation.** A pressure-regulating valve shall be installed and maintained by the consumer if static service pressure exceeds 80 pounds per square inch. The pressure-regulating valve shall be located between the meter and the first point of water use, or first point of division in the pipe, and set at not more than 50 pounds per square inch when measured at the most elevated fixture in the structure served. This requirement may be waived if the consumer presents evidence satisfactory to the District that excessive pressure has been considered in the design of water-using devices and that no water will be wasted as a result of high pressure operation.

(2) **Interior plumbing fixtures.** All plumbing installed, replaced or moved in any new or existing service must meet the following requirements:

(a) Toilets shall use 1.6 gallons or less, of water per flush.

(b) Showerheads shall use 2.5 gallons or less, of water per minute.

(c) Kitchen and lavatory faucets shall use 2.5 gallons or less, of water per minute.

(d) Non-residential services with more than one showerhead or one sink (lavatory) per bathroom facility shall equip these fixtures with self-closing valves.

(3) **Pool covers.** Pool covers are required for all new outdoor swimming pools.

(C) Landscape requirements for single-family residences (new and modified landscapes).

(1) The combined size of turf areas and swimming pools for new single family residences shall be limited to not more than 25% of the total developed landscape area. When existing landscape areas are modified by the addition of turf and/or a pool, the total combined area of the turf and pool shall be no more than 25% of the total developed landscape area.

(D) Landscape requirements for all services other than single-family residences (new and modified landscapes).

(1) **Turf and swimming pools.** The combined size of turf areas and swimming pools shall be limited to no more than 25% of the total developed landscape area in services irrigated with potable water. In landscapes irrigated with reclaimed water, the combined size of turf areas and swimming pools shall be limited to not more than 40% of the total developed landscape area. In areas designated for future reclaimed water service, the 40% turf/pool limit will be allowed only if the service will have reclaimed water available within one year of the service agreement date.

(2) **High-water-use plants and features.** High-water-use plants, decorative pools (non-swimming), fountains, and water features shall be limited to not more than 10% of the total developed landscape area.

(3) **Other plants.** All other plantings shall be composed of low-water-use plant materials. The District may waive this requirement if sufficient evidence is presented that the site is not suitable for such plants.

(4) **Irrigation systems.** All irrigated landscaped areas will be irrigated by an automatic irrigation system which meets these requirements.

(a) Electric controller with repeat start time and multiple program potential, set for irrigation between the hours of 6 p.m. and 11 a.m. for potable water and 10 p.m. and 7 a.m. for reclaimed water.

(b) Automatic rain shut-off unit for each controller.

(c) In areas with slopes exceeding 15%, the precipitation rate shall not exceed 0.85 inches per hour.

(d) Under-the-head check valves, built-in spray head check valves, or in-line check valves must be installed as needed to prevent low head drainage and puddling.

(e) Separate irrigation circuit(s) must be provided for each of the following: turf, high-water-use plants, low-water-use plants, plants on drip irrigation, planting areas with different exposures, slopes and soils with different infiltration rates.

(f) Use as point application (drip, bubbler, etc.) or subsurface irrigation where overspray, angle of slope, soil texture, or widely spaced plants make overhead irrigation impractical due to overspray, runoff, or inefficiency. (Overhead irrigation is inefficient when less than 50% of spray pattern of any head will hit mature plants.)

(g) Overhead irrigation must meet the following additional requirements:

(i) Distance between spray heads on turf shall not exceed 55% of the spray diameter.

(ii) Distance between spray heads elsewhere shall not exceed 70% of the spray diameter.

(iii) Spray heads must be adjusted so spray radius or special pattern is within 25% of the manufacturer's rating.

(iv) Spray heads must be located so that overspray will not accumulate and flow off adjacent pavements, walkways, structures, and other non-landscaped areas during an irrigation cycle.

(v) Overhead irrigation is prohibited in median strips and parking islands less than eight feet wide.

(vi) Planted areas which are acutely angled or irregulary shaped and which are adjacent to hardscape surfaces shall not be irrigated by an overhead system unless they are at least 120% of the spray diameter of the irrigation head being used.

(vii) Precipitation rates for heads within each valve circuit must be matched to within 20% of one another.

(5) **Soil preparation.** For overhead irrigation, soil preparation must meet the recommendations of a soils laboratory report or otherwise meet the following minimum requirements:
  (a) Areas with slope area ratios greater than 3:1 must be amended as recommended by a landscape architect.
  (b) Areas with slope ratios of 3:1 or less must meet the following soil preparation requirements.
    (i) Rip or rotary cultivate existing soil to a depth of six inches.
    (ii) Incorporate an organic amendment at the rate of five cubic yards per 1,000 square feet into the top six inches of soil.

(6) **Mulching.** All exposed soil surfaces of non-turf areas within the developed landscape area must be mulched with a minimum two inch deep layer of organic material.

(7) **Plan review, certification, and site inspections.**
  (a) Plan review and certification.
    (i) For all services other than single-family residences, applicants shall obtain approval for landscape plans for new or modified landscapes from MMWD before construction begins.
    (ii) All landscape plans submitted must be certified by a landscape architect that they are in compliance. The landscape architect must also sign and return a District checklist indicating compliance with District requirements. Each page of plans must also be stamped to certify compliance.
  (b) It shall be the responsibility of the owner or the owner's agent to:
    (i) Schedule a site inspection with a landscape architect prior to installation of the irrigation system. The inspection is to verify that the installing contractor is using District approved plans for the site and that the soil preparation requirements of this section have been met. The landscape architect must complete and submit to the District a District verification form within 10 days of this inspection.
    (ii) Schedule an inspection with a landscape architect within 10 days of completion of work to verify compliance with the approved landscape plans. The landscape architect must complete and submit to the District a District verification form within 10 days of this inspection.
  (c) The District reserves the right to perform site inspections at any time before, during, or after irrigation system and landscape installation and to require corrective measures if requirements of this ordinance are not satisfied.

(E) The District will consider and may allow the substitution of well-designed conservation alternatives or innovations which may equally reduce water consumption for any of the foregoing requirements of this chapter.

Adopted by the following role call vote:

AYE:

NAY:

ABSTAIN:

ABSENT:

DATED:

SECTION 11

LANDSCAPE IRRIGATION AUDITS

LANDSCAPE IRRIGATION AUDITS

WHAT IS A LANDSCAPE IRRIGATION AUDIT?

The purpose of a landscape irrigation audit is to evaluate the performance of sprinkler irrigation systems and improve the irrigation system efficiency. Improved irrigation efficiencies can reduce water and energy use and costs, reduce fertilizer applications and costs, and improve the appearance of the landscape.

A landscape irrigation audit consists of three parts:

(1) a sprinkler efficiency evaluation
(2) the development of an appropriate irrigation schedule
(3) an analysis to determine how much water and money can be saved annually.

To evaluate sprinkler efficiency, "catch" cans are set out in a turf area in a grid pattern and the sprinkler system is run for about 15 minutes. The water collected in each catch can is measured and the precipitation rate and distribution uniformity are calculated. This data is then used to establish monthly irrigation schedules based on local weather conditions and the evapotranspiration rate for turfgrass. Irrigation water requirements based on the proposed schedule are compared with monthly water bills to determine how much water and money can be saved. Upon completion of an audit, a report is prepared which includes the results of the evaluations and recommendations for improving the performance of the irrigation system.

CONDUCTING AN IRRIGATION AUDIT

The step-by-step audit that follows was originally developed for large turf areas such as golf courses, athletic fields, parks, and greenbelts. However, the same concepts also apply to residential landscapes.

A simplified landscape irrigation audit (LIA) can be conducted by performing the tasks listed under Steps 3 through 5 in the itemized list. This simplified audit will determine the distribution uniformity (DU) and provide sufficient information to set up irrigation schedules. However, the simplified LIA will not provide enough information to determine the causes of low distribution uniformity (i.e., DU values less than 70%), nor will it provide enough information to prepare a cost/benefit analysis that would enable a water utility to prioritize sites for irrigation scheduling based on potential water savings.

The full version of the LIA includes the tasks listed under Steps 1 and 2, which include diagnostic procedures to identify problems in the design of the irrigation system that should be corrected to improve the performance of the irrigation system to an acceptable level. If significant design problems are not corrected and the value of the DU remains low, large volumes of water will continue to be wasted even if a new irrigation schedule is established based on the results of a LIA.

Step 1: Select Sites

Task 1.1. Obtain the name and phone number of the facility manager and the principle individual responsible for the operation and maintenance of the irrigation system.

Task 1.2. Obtain a site plan (plat) that shows the boundaries of the property and distinctive features such as location of buildings, parking lots, and irrigated areas. Irrigated areas should be clearly delineated on the site plan so that the irrigated square footage can be accurately calculated. Features in the site plan that may affect irrigation requirements due to reflected solar heat or shading should be noted.

Task 1.3. Obtain and analyze drawings of the landscape irrigation system that show location of irrigation wells, water meters, controller stations, water lines, valves, and sprinkler heads. (This information may be included on the site plan).

NOTE: If the drawings cannot be provided, the sprinkler efficiency and irrigation schedule can still be determined, however, other facets of the landscape irrigation audit may be compromised.

- **Subtask 1.3a.** On the drawing, specify the following:
  (i) manufacturer and model number of irrigation system components
  (ii) type of sprinkler heads (fixed spray head, gear-driven rotary, impact-driven rotary, single stream, or double stream)
  (iii) discharge capacity in gallons per minute (gpm) of sprinkler heads
  (iv) pipe sizes (inside diameter in inches) and material
  (v) discharge capacity of well in gpm or flowrate into inlet of irrigation system.

- **Subtask 1.3b.** Specify the species of turf grass (this may be a mix) and identify problem areas (wet and dry spots).

- **Subtask 1.3c.** Review the drawings and determine if the precipitation rates of full, half, and quarter-circle sprinklers are correctly matched.

- **Subtask 1.3d.** Review the drawings and determine if the spacing of sprinkler heads is correct. Typically, the uniformity of water distribution is the weakest part of sprinkler irrigation. Even without considering the effects from pressure variations, wind speed, and land slopes, the depth of application from the sprinkler heads varies from a maximum near the sprinkler to zero at the outer edge of the wetted circle (Jarrett, 1985, p. 9-10). Uneven distribution results in brown or uneven turf. Good coverage is achieved by overlapping sprinkler distribution areas. Spacing, expressed as a percent, is calculated by dividing the distance between sprinklers by the wetted diameter. The recommended spacing between sprinklers is generally 50-60% of the wetted diameter. Spacings of less than 50% may result in overwatering (Jarrett, 1985, p. 13).

  The spacing percentage may be calculated from drawings of the irrigation system and manufacturer's specifications for the wetted diameter at given pressures. Both the spacing between sprinkler heads on a single water line and the spacing between separate sprinkler water lines should be calculated. This analysis may reveal deficiencies in design or equipment selection. Manufacturer's specifications for wetted diameter should be compared with the wetted diameter measured in the field when the sprinklers are running (See Subtask 3.6b regarding measurement of wetted diameter in the field). This comparison may reveal operational problems and needed repairs.

NOTE: *Wind speed will influence a sprinkler's distribution by causing the precipitation rate to increase when the sprinkler sprays against the wind and to decrease when it sprays downwind. Instead of having circles of application, an egg-shaped pattern results. To compensate for the effect of wind, most sprinkler manufacturers recommend closer spacings for higher wind speeds. If this is done, the precipitation rate increases during irrigation with no wind.*

- **Subtask 1.3e.** Review the drawings and determine if the effective coverage is reasonable. Effective coverage (EC) is the percentage of a sprinkler's radius that will reach a specific target such as the edge of a turf area. It is calculated by dividing the radial distance from the sprinkler head to the target by the radius (maximum trajectory) of the sprinkler (Jarrett, 1985, p. 10). The percentage-of-radius can then be equated to the precipitation rate (depth of water being applied) in the target area, expressed as a percentage of the precipitation rate at the sprinkler head which is taken as 100%.

  So, for example, at 25% of the radius of the sprinkler stream trajectory, the precipitation rate might be 100%; but at 50% of the radius, the precipitation rate might only be 75%. The distance the water over-shoots the edge of the turf area to provide effective coverage is an important consideration. An effective coverage of 70% of the sprinkler radius is recommended. This means that 30% of the sprinkler stream trajectory would over-shoot the edge of the turf area. Thus, if the half-width (W) of a turf area is 60 feet and the desired EC=70%, the required sprinkler radius (R) would be 85 feet (i.e., R=W/EC=60 ft/0.70). Lower EC values such as 60% may be used, but this may result in a substantial waste of water on areas beyond the edge of the turf area; on the other hand, higher EC values such as 80% may result in inadequate irrigation of the turf area (Jarrett, 1985, p. 12).

- **Subtask 1.3f.** Review the system hydraulics to determine if pipes have been correctly sized and the flow rate into the inlet of the irrigation system is adequate. Use the procedure presented in the Hunter design education manual entitled *Irrigation Hydraulics* (See References).

Task 1.4. Obtain and analyze the monthly water bills for the last three years which show the amount of water used and the cost. If necessary, request permission from the facility manager to obtain these records from the local water utility.

- **Subtask 1.4a.** Where indoor and outdoor water use is not separated in the billing records, use the reported water use in the winter months (December, January, February) to determine the normal indoor water use. Subtract this indoor-use figure from the water use reported in the monthly water bills in the summer to estimate the amount of water used for irrigation and evaporative cooling. Estimate evaporative cooling requirements if sufficient information is available and subtract from the residual computed in the previous step.

Task 1.5. Determine the square footage irrigated from the site plan or drawings of the irrigation system. The square footage irrigated may also be determined from field measurements if the areas are not too irregular in shape.

Task 1.6. Obtain monthly temperature and precipitation data for the study area for each of the years for which water billing records are provided. It is also recommended to obtain 30-year normal weather data.

Task 1.7. Compute the monthly evapotranspiration rate (ET) for turfgrass using the SCS Modified Blaney-Criddle Method and/or obtain evapotranspiration data from other sources if reliable data is available. Monthly consumptive use coefficients (Kc) should be calibrated to reflect local conditions and the species of turfgrass. (For modified Blaney-Criddle Method, see Irrigation Water Requirements, Technical Release #21, September 1970, by U.S. Department of Agriculture, Soil Conservation Service.)

Task 1.8. Compute the monthly irrigation requirements based on the ET and a reasonable irrigation efficiency (Ef). An efficiency of 70% is reasonable.

Task 1.9. Compare estimated irrigation water requirements and costs with metered water use and/or billing records to rank sites in terms of potential water savings.

Task 1.10. Select sites for irrigation efficiency evaluation.

Step 2: Schedule Field Tests

Task 2.1. Make an appointment with the facility manager and establish a method of reimbursement for travel costs and the landscape irrigation audit if recovery of costs is required. Personnel who can operate the irrigation system must be available throughout the field test.

Task 2.2. Make arrangements for travel to site.

Step 3: Perform Site Inspection and System Tune-up

Task 3.1. Before actually conducting the field test, collect all of the equipment for field test including:

- soil sampler
- catch cans and wire stands
- pressure gage
- measuring tape
- watch or timer
- tools for minor repairs
- drawings
- raincoat
- extra footwear to keep feet dry during or after the test.

Task 3.2. Observe and record weather conditions, including temperature, relative humidity, wind speed, and wind direction. If the wind speed exceeds five miles per hour, reschedule the test. In lieu of getting the weather data onsite, local information may be obtained from the weather service, radio and television stations, or newspapers (daily forecasts or day-after records).

Task 3.3. Locate the water meter, irrigation controller, and all other irrigation components delineated in the drawings provided. It is important to determine the location of the first and last sprinkler head on each water line for the pressure test.

Task 3.4. Take soil samples to determine soil types and root depths. Record this information. Also make notes about compaction and thatch.

Task 3.5. Set out wire stands if sprinkler heads can be easily located. If they are hard to find, go to next task.

Task 3.6. Turn sprinkler system on briefly to locate sprinkler heads and set out wire stands.

- **Subtask 3.6a.** Measure and record water pressure at sprinkler heads. The difference in pressure between the first and last sprinkler head on each water line should not exceed 20%. Also note any activities at the facility (clothes washing, dishwashing, showering, evaporative cooling, other irrigation) that may cause a significant fluctuation in water pressure in a normal day.

  Pressure testing is an important diagnostic tool for troubleshooting irrigation systems. Low operating pressure might indicate a leak, worn pump impellers, or a partially closed control valve; high pressure might indicate a plugged nozzle or pipe, a defective pressure reducing valve, or increased pressure from the water utility (Keesen, 1995, p. 122). Pressure that is too high or too low ultimately results in poor uniformity of coverage.

- **Subtask 3.6b.** Measure and record the wetted diameter of several sprinklers, taking into consideration the difference in pressures observed in the previous task. Compare these measurements with the manufacturer's specifications discussed in Subtask 1.3d. and note where performance does not meet design specifications.

- **Subtask 3.6c.** Record the number of minutes required for a complete sprinkler rotation (typically about three minutes). A minimum of five rotations is required for the field test.

- **Subtask 3.6d.** Observe any problems. Look for the following:
  - missing or broken sprinkler heads
  - heads that don't pop up
  - sunken sprinklers
  - tilted sprinklers
  - plugged sprinklers
  - leaky seals and fittings
  - low pressure (short trajectory)
  - high pressure (long trajectory)
  - trajectory angle (too high/too low)
  - arc misalignment or rotation malfunction
  - too much over-throw beyond edge of turf
  - spray deflection
  - water ponding
  - runoff

Task 3.7. Prepare a drawing showing the location of the sprinkler heads and catch cans. Identify steep slopes and obstructions on drawing. Steep slopes may be difficult to irrigate efficiently, and they may skew the results of a test.

Task 3.8. Measure the distance between sprinkler heads and record this information on the drawing.

Step 4: Perform Irrigation Efficiency Test

Use the procedure presented in the Irrigation Association publication entitled *Landscape Irrigation Auditor Training Manual* (See References).

Task 4.1. Set out the catch cans.

Task 4.2. Record controller settings before starting test.

Task 4.3. Turn sprinklers on and run for 10 or 15 minutes.

Task 4.4. Measure the depth of the water collected in the catch cans and record this information.

Task 4.5. Compute the precipitation rate in inches per hour (PR1=CVA x 3.66/RT x CDA) where CDA is the catch device throat area in square inches. CVA is computed by dividing the total catch volume by the number of catch cans.

- **Subtask 4.5a.** Check to make sure that the precipitation rate does not exceed the infiltration rate of the soil. If it does, the sprinkler spacing may be to close or the discharge rate of the sprinklers and/or the water pressure may be too high.

Task 4.6. Compute the distribution uniformity (DU=LQCV/CVA) where LQCV is the average of the low quarter of catch volumes, i.e., the lowest 25% of the sample.

Step 5: Prepare Base Irrigation Schedule

Use the procedure described in *Landscape Irrigation Auditor Training Manual.*

Task 5.1. Compute the monthly irrigation water requirement (MIWR=ET/DU) in inches where ET is the monthly evapotranspiration in inches and DU is the distribution uniformity determined in the field test.

Task 5.2. Compute the minutes of runtime required each month (MRT=60 x MIWR/PR1) where PR1 is the precipitation rate in inches per hour determined in the field test.

Task 5.3. Determine the available water-holding capacity of the soil (AWHC) in inches per hour based on the soil type. See table in *Landscape Irrigation Auditor Training Manual.*

Task 5.4. Compute the inches of available water in the root zone (RZAW=AWHC x RZ) where RZ is the root depth in inches.

Task 5.5. Compute the inches of working storage in the root zone (WS=RZAW x MAD) where MAD is the management allowed deficit.

Task 5.6. Compute the number of irrigation days in each month (NID=ET/WS).

Task 5.7. Compute the minutes of runtime required per day (DRT=MRT/NDM) where NDM is the number of days in the month.

Task 5.8. Compute the minutes of runtime per cycle (CRT) and the number of cycles required per day so that the runtime does not exceed the infiltration rate of the soil.

- **Subtask 5.8.1.** Obtain the final infiltration rate of the soil (I) in inches per hour from tables in *Landscape Irrigation Auditor Training Manual.*
- **Subtask 5.8.2.** Convert the precipitation rate from inches per hour to inches per minute (PR2=PR1/60).
- **Subtask 5.8.3.** Compute the allowable minutes of runtime per cycle (CRT=I/PR2) that will not exceed the infiltration rate of the soil.
- **Subtask 5.8.4.** Compute the number of cycles required per day (NC=DRT/CRT).

Task 5.9. Adjust the cycles and runtimes to match programming options on the irrigation controller. The controller may not provide sufficient options to implement the ideal irrigation schedule. If a reasonable irrigation schedule cannot be programmed on the existing controller, consider purchasing a model that has the required features.

Step 6: Prepare Final Cost-Benefit Analysis

Based upon the proposed schedule, prepare a final cost-benefit analysis.

Task 6.1. Compare the estimated irrigation water requirements and costs based on the proposed schedule with actual metered water use and/or billing records.

Step 7: Report Audit Results

Prepare a report that includes the results of the evaluations and recommendations for improving the performance of the irrigation system.

Step 8: Monitor Results of Irrigation Scheduling Program

Track monthly and annual water use and costs after the proposed schedule has been implemented to determine how effective the program is in conserving water. Make additional recommendations for adjustments as needed.

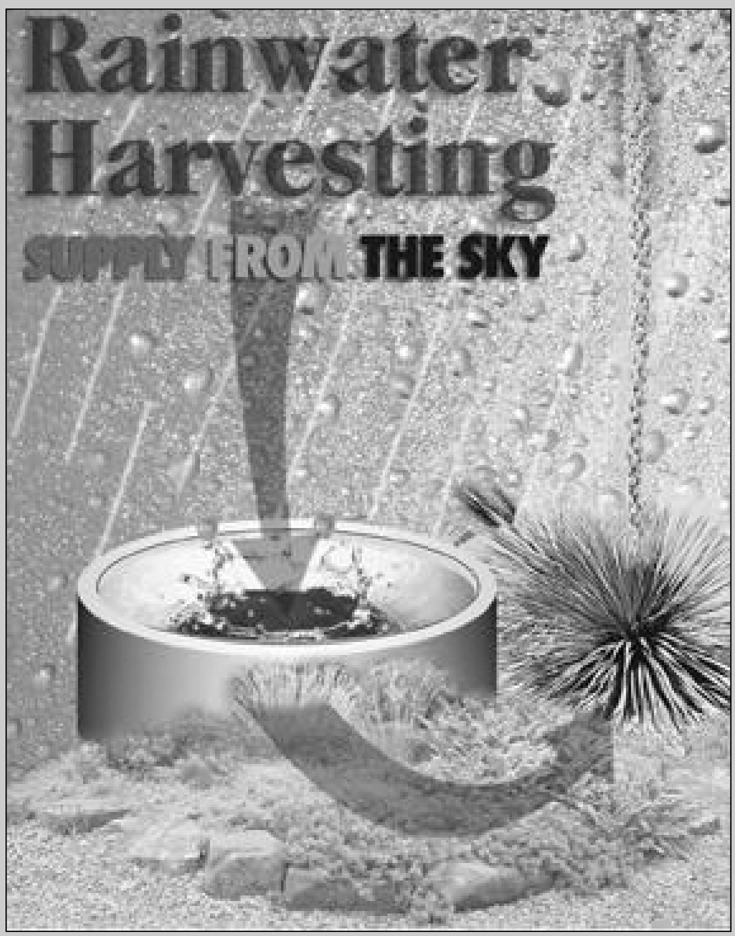
Using Rainwater Harvesting to Reduce Landscape Irrigation

Rainwater harvesting refers to the capture, diversion, and storage of rainwater for landscape irrigation (and sometimes for other uses), and it can be an effective water conservation tool. Rainwater harvesting can be incorporated into large-scale landscapes—such as parks, schools, commercial sites, parking lots, and apartment complexes—as well as small-scale residential landscapes.

Some harvesting systems can be very simple, consisting of a roof catchment area, 55-gallon rain barrels, and garden hoses. Other systems are more complex and include large cisterns and piped distribution systems. Costs vary greatly also, depending upon the type of system chosen.

Most homeowners can install and use a rainwater harvesting system for landscape irrigation without public health and water rights concerns. For larger-scale commercial projects, check with the local OSE Water Rights Division to make sure the project does not inappropriately affect rainwater runoff into a stream system, therefore impacting a public water supply. Also, contact the local New Mexico Environment Department regarding any potential public health concerns.

For more information on determining the amount of water you can collect, the types of systems to consider, and how to build, install and maintain a rainwater harvesting system, consult *Rainwater Harvesting, Supply from the Sky*, a publication of the City of Albuquerque. For a copy, call 1-800-WATERNM or email waternm@seo.state.nm.us.



SECTION 12

TRAINING LANDSCAPE MAINTENANCE PERSONNEL

TRAINING LANDSCAPE MAINTENANCE PERSONNEL

TRAINING FOR WATER EFFICIENCY

A water utility's landscape and maintenance staff need to understand:

- The utility's water conservation goals
- The opportunities for conserving water in landscape irrigation, and
- How to implement conservation measures effectively.

To achieve these objectives, the utility must provide its staff with an overview of the conservation plan (a step-by-step work breakdown structure is preferable) and explain the changes that will be made to landscape designs, plant materials, irrigation system infrastructure, and management practices. The utility needs to enlist staff support in making the conservation plan a quantifiable success. Thus, it is important that landscape maintenance personnel be provided with adequate training to achieve the utility's objectives. This will require some classroom instruction as well as hands-on training in the field. A good training program for landscape maintenance personnel will not only make them much more effective water conservers, it can make their work more interesting.

CONTENT OF TRAINING PROGRAM

The following outline highlights what should be included in a training program for landscape maintenance personnel.

Step 1: Introduce Personnel to the Basic Concepts of Xeriscape

(See Section 10: Xeriscape and Landscape Design Ordinances.) Landscape maintenance personnel should be instructed to read selected publications on the subject, view slides and videos, attend conferences and seminars, and visit xeriscaped sites. It is important that they see a variety of xeriscapes to develop an understanding of how the concept can be creatively applied to landscape design under many different conditions.

Step 2: Provide Materials That Describe Suitable Xeric Plants

Publications that separate turf, trees, shrubs, and groundcovers into high- and low-water-use may be available from local sources. Personnel should also be instructed in appropriate planting techniques including:

- proper sizing of holes for new plants to ensure adequate root development for healthy plant growth and drought tolerance
- presoaking bare-root trees and shrubs before planting
- use of root stimulators and fertilizers at the time of planting
- mulching to keep soil moist and optimize survival rates after planting.

Local nurseries may offer seminars on planting and maintenance of plants. Information on this subject may also be obtained from local county agricultural extension agents.

Step 3: Introduce Personnel to the Basic Techniques of Water Harvesting

Water harvesting makes maximum use of natural precipitation. The principles of water harvesting include:

Grading. Design paved surfaces to slope into turfgrass areas, planting beds, holding ponds, or cisterns. On steeply sloping sites, use terraces to slow down and collect the runoff. Create small depressions or swales at the bottom of slopes to catch runoff (Ellefson, 1992, p. 104).

Swales. These are long, level excavations which can vary greatly in width and construction from small ridges in gardens, rock piles placed across slope, or deliberately excavated hollows at the base of slopes or in flatlands (Mollison, 1992, p. 167). The purpose of a swale is to intercept overland flow, to hold it for a few hours or days, so that it can be absorbed by soil and recharge the groundwater. Swales are built on contour or on dead level survey lines, and it is important to emphasize that they are not designed to be a watercourse. The base is ripped, graveled, sanded, loosened, or dressed with gypsum to increase infiltration. Runoff from slopes, roofs, roads and other paved areas, and flows in diversion drains may be directed into the swale. The interswale may be left bare, however, it is generally seeded with cereal grasses and covered with a mulch to increase infiltration, reduce evaporation, and prevent soil erosion. Trees are normally planted on the outer banks, and will shed about 25% of their root system each year, and this, together with leaf litter and soil micro-organisms, become organic matter (humus), which increases water retention in the soil (Morrow, 1993, p. 42).

Collection Basins, Ponds, and Cisterns. These may be used to store runoff and should be lined with either hard-packed clay, concrete, or nonporous vinyl liners to prevent the water from percolating into the soil. A pump with a filtration system or gravity flow siphons can be used to withdraw water for landscape irrigation. Small cisterns, adequately elevated, work well with drip-irrigated planting beds. Ponds and cisterns may also be a source of water for fire fighting, provided that sufficient storage can be maintained. However, in regions that experience cold winters, ice cover may preclude the use of ponds and cisterns for this purpose.

Downspout Collection. A 1,000-square-foot roof will yield 150 gallons of water during a 0.25-inch rain. By extending downspouts from gutters into the ground and adding on a section of solid pipe followed by a perforated pipe, water can be directed into planting beds.

Step 4: Introduce Personnel to Irrigation Water Requirements

Landscape maintenance staff should be introduced to the basic parameters that are used to quantify landscape irrigation water requirements, including how each is derived. These parameters include:

- evapotranspiration (ET)
- effective rainfall (Re)
- consumptive irrigation requirement (CIR, which equals ET-Re)
- system irrigation efficiency (Ef)
- field delivery requirement (FDR, which equals CIR/Ef).

Using the same CIR, compare field delivery requirements (FDR) for a sprinkler irrigation system with an irrigation efficiency of 50% and 70% to illustrate the potential water savings that can be achieved from systems that are properly designed and managed. For example, if the ET is 42 inches/year, and

Re is 5 inches/year, the CIR would be 37 inches/year (42-5). If Ef is 0.50 the FDR is 74.0 inches/year (37/0.5) and if Ef is 0.70 the FDR is 52.8 inches/year (37/0.70). The amount of water saved is 21.2 inches/year (74.0-52.8) or 28.6% (100 x 21.2/74.0). Note however, that the CIR does not change even though Ef does.

Step 5: Train Personnel to Perform Landscape Irrigation Audits

By performing a landscape irrigation audit, the staff can:

- determine the water application rate and distribution uniformity of an irrigation system
- set up an irrigation schedule which establishes the number of irrigation days in each month, the runtime per day, the runtime per cycle, and the number of cycles per day
- analyze monthly water use records and determine which sites are using more water than is really necessary and would benefit the most from improved water management.

Personnel should also be instructed in how to perform irrigation system tune-ups, which include adjusting station pressures, aligning and straightening sprinkler heads, reducing the blocking of sprinkler spray by plant materials and other objects, and repairing hardware as necessary to improve performance of irrigation systems. Training to perform landscape irrigation audits is available locally through the Irrigation Association. For more information on courses offered and schedules, contact the Irrigation Association at 6540 Arlington Blvd., Falls Church, Virginia, 22042-6638, (703) 536-7080; www.irrigation.org.

Step 6: Provide Instruction on Maintenance Practices

Personnel should be provided instruction on maintenance practices that reduce the need for irrigation water, including proper height for turf mowing, proper frequency of turf aeration and dethatching to increase water retention, proper fertilization scheduling to maintain plant health and drought tolerance, and mulching practices to increase water retention.

CHECKLIST FOR IRRIGATON SYSTEM MAINTENANCE

Monthly

(1) Check for leaks. Inspect water lines, sprinklers, emitters, and other components. Look for wet spots in the landscape to help locate broken pipes, leaky sprinkler heads, etc.
(2) Replace broken sprinkler heads, bubblers, micro-sprayers, and drip emitters immediately with identical or equivalent parts to ensure even water delivery throughout the irrigation zone.
(3) Locate and clean any dirty sprinkler heads, drip emitters, clogged tubing, etc.
(4) Use water meter and water bills to help reveal the presence of hidden leaks.

Spring

(1) Set controller for watering times and durations. Remember to adjust the timer clock for the beginning of Daylight Savings Time.
(2) Replace back-up battery in controller.
(3) Test the manual shut-off/isolation valve.
(4) Check the water pressure in each irrigation zone. Adjust as necessary to match the manufacturer's recommendations for the water-delivery devices in the irrigation system.
(5) Check and clean filters.
(6) Check and clean screen in sprinkler heads. Adjust pattern to eliminate water waste due to overspray.
(7) Test sprinkler heads to make sure they are delivering consistent amounts of water over the entire area.
(8) Inspect all drip emitters. Make sure emitters are applying water to the entire root zone of each plant.

Early Summer

(1) Adjust controller for watering times and durations during the hottest months.
(2) Check and clean filters.
(3) Inspect all drip emitters and clean if clogged.
(4) As plants grow bigger, move drip emitters to the edge of each plant's root ball to encourage additional root development.

Late Summer

(1) Adjust controller to shorten watering times and durations during New Mexico's rainy season.

Fall

(1) Adjust controller to further shorten watering times and durations as the weather cools.
(2) Adjust controller clock for the end of Daylight Savings Time.
(3) Test manual shutoff/isolation valve.
(4) Check and clean filters.
(5) Inspect all drip emitters and clean or replace if necessary.

Winter

(1) Adjust controller to further shorten watering times and durations.
(2) When daytime temperatures are below 40 degrees Fahrenheit, discontinue automatic watering and turn on irrigation system manually as needed.

DEFINITIONS OF IMPORTANT IRRIGATION TERMS

Consumptive Use or Evapotranspiration (ET): The amount of water consumed in a given area in the transpiration, building of plant tissue, and evaporation from adjacent soil, water surface, snow or intercepted rainfall in any specified time. The term includes effective rainfall. Evapotranspiration may be expressed either in volume per unit area such as acre-inches or acre-feet per acre, or depth, such as in inches or feet. Note, however, that the evapotranspiration of water by a crop does not include incidental depletions such as evaporation from sprinkler spray and drift losses, and evaporation of runoff and seepage from irrigated fields.

Effective Rainfall (Re): Rainfall occurring during the growing period of a crop that becomes available to help meet the evapotranspiration requirements of the crop. It does not include rain which is intercepted by the plant canopy and evaporates, surface runoff, or deep percolation below the root zone.

Consumptive Irrigation Requirement (CIR): The quantity of irrigation water, expressed as a depth or volume, exclusive of effective rainfall, that is consumptively used by plants or is evaporated from the soil surface during any specified time. It does not include incidental depletions nor does it include water requirements for leaching, frost protection, wind erosion protection or plant cooling. The consumptive irrigation requirement is computed by subtracting effective rainfall (Re) from the evapotranspiration (ET).

Irrigation Efficiency (Ef): The irrigation efficiency is the product of the distribution uniformity (DU) and the application efficiency (AE), i.e., Ef=(DU)(AE). The distribution uniformity reflects how evenly water is applied to a field and it is defined as the ratio, expressed as a percentage, of the average low-quarter depth or volume of irrigation water infiltrated and stored in the root zone to the average depth or volume of water stored in the root zone.

The application efficiency indicates what portion of the total diversion from the water source is stored in the root zone recognizing that some water evaporates before it is absorbed by the soil and that some water will percolate below the root zone in order to obtain good distribution uniformity. AE is defined as the ratio of the average depth or volume of water stored in the root zone to the volume of water diverted from the water source.

For the purpose of simplifying this concept, if deep percolation losses could be kept close to zero, AE can be approximated by subtracting the evaporation losses (EVL) expressed as a percent, from 100%, i.e., AE=100%-%EVL. Field tests conducted by Sternberg (1967) suggest that evaporation and drift losses may range from 17% to 22% of sprinkler discharge in the daytime and 11% to 16% at night. Thus, if the minimum evaporation loss is 11%, the potential AE=100%-11%=89%. So if, the DU is 70% and AE is 89%, Ef=(0.70)(0.89)=0.623 or 62.3%.

Field Delivery Requirement (FDR): The quantity of water, exclusive of effective rainfall, that is delivered to the field. The field delivery requirement is computed by dividing the consumptive irrigation requirement (CIR), expressed as a depth or volume, by the system irrigation efficiency (Ef), expressed as a decimal.

Monthly Water Budgets

Regardless of the types of plants in a landscape—xeric or high-water-use—the monthly water demands are fairly predictable. This table, based upon average monthly evaporation and plant transpiration, is a handy guide to setting irrigation timers to provide adequate water throughout the year.

Month	**Water Budget**
January	5%
February	9%
March	20%
April	38%
May	64%
June	89%
July	100%
August	90%
September	62%
October	35%
November	13%
December	6%

Source: City of Albuquerque

SECTION 13

IRRIGATION MANAGEMENT INFORMATION SYSTEM (IMIS)

IRRIGATION MANAGEMENT INFORMATION SYSTEM (IMIS)

WHAT IS AN IMIS?

An irrigation management information system (IMIS) can improve irrigation efficiency and reduce waste caused by over-irrigation. An IMIS is used to determine when to irrigate and how much water to apply at public landscape irrigation sites such as golf courses, athletic fields, parks, cemeteries, greenbelts, schools, and civic centers.

One or more weather stations are equipped with instrumentation to measure temperature, rainfall, relative humidity, solar radiation, wind speed, and direction. Each weather station records hourly weather data and transmits it to a central computer where it is checked for accuracy and the reference evapotranspiration rate (ETr) is calculated. Using appropriate crop coefficients, the ETc for landscape plants and turfgrass is calculated with an ET formula such as the modified Penman-Monteith formula. Readings from electronically controlled soil moisture sensors may also be used to verify the results from the ET program. Satellite irrigation controllers located at the landscape sites are then programmed with the appropriate irrigation cycles.

HOW TO DEVELOP AN IMIS

Step 1: List Sites and Information

Prepare a table listing the name, location, total acres irrigated, and monthly and/or annual water deliveries in a normal weather year of all public landscape irrigation sites. If possible, estimate the amount of authorized unmetered water delivered to these areas by multiplying the rate of discharge by the total time during which water flows.

Step 2: Calculate Irrigation Requirements

To explore the potential for reducing landscape irrigation water use, use the SCS Modified Blaney-Criddle Method or alternative ET formula to calculate the monthly and annual consumptive irrigation requirements (CIR) for the type of turfgrass grown in the study area. (Typical cool season turfgrasses include tall fescue and Kentucky bluegrass; typical warm season grasses include Bermuda grass and blue gramma.) Use long-term weather data from a local weather station and crop coefficients that have been calibrated to reflect the species of turfgrass grown. (See Appendix A for monthly irrigation requirements for tall fescue at selected locations in New Mexico).

Multiplying the total annual CIR expressed in acre-feet by the acreage irrigated at each site yields the total annual CIR in acre-feet. Sprinkler systems that are well designed and carefully managed to apply the right amount of water at the right time may achieve application efficiencies (Ef) of 70% or more. Assuming an efficiency of 70%, divide the CIR expressed in acre-feet per year by the efficiency (Ef) expressed as a decimal to get the total annual amount of water that should be delivered to the site (Field Delivery Requirement). Subtracting this number (FDR) from the metered deliveries in a normal weather year yields an estimate of the amount of water that could be saved. Multiplying the amount of water that could be saved by the dollar value of the water will yield an estimate of cost savings.

Step 3: Perform an Irrigation Audit

In some cases, it may be prudent to perform an irrigation audit to determine the actual irrigation efficiency based on the configuration of the existing irrigation system. If the measured efficiency is significantly less than the assumed efficiency used in the previous calculation, the system may need to be redesigned or rehabilitated to bring its performance up to a level that will ensure that an irrigation scheduling program will be effective in reducing the amount of water used for irrigation.

Step 4: Establish an Irrigation Management Information System

If the above analysis indicates that the sites are being over-irrigated, the establishment of an irrigation management information system should be considered. Rank the sites according to the potential reduction in water use, and locate them on a map. If a full weather station that measures temperature, rainfall, humidity, solar radiation, and wind is not located within close proximity to the targeted sites, select one or more locations that would be appropriate for the establishment of weather stations.

Step 5: Prepare a Preliminary Plan
Prepare a preliminary plan that specifies requirements for an ET-based monitoring system for scheduling irrigation runs. Specifications should include:

- type and number of weather stations
- irrigation controllers
- communication system components
- computers
- software
- office space
- personnel
- training

Step 6: Obtain Proposals
Contact consultants or manufacturers to obtain proposals including cost specifications for the installation of an ET-based monitoring system.

Step 7: Evalute the Proposals
Evaluate the technical and financial merits of each proposal. Determine whether the proposed costs for purchase and installation of equipment and annual operating expenses can be justified by the annual savings in water.

Step 8: Select the Vendor
If costs are justified and within the utility's budget, select the consultant or manufacturer that can provide the best product and services at the lowest cost.

Step 9: Monitor the Effectiveness
After the IMIS system has been established, monitor the effectiveness of the program by comparing current monthly and annual water use data and operation costs with historical data.

WATER-SAVING DEVICES FOR IRRIGATION SYSTEMS

Even a properly designed, efficiently operating irrigation system can be improved upon. If the irrigation controller turns the system on during or immediately following rainfall, then precious irrigation water is being wasted. The solution is to make the irrigation system "smarter."

Soil moisture sensors and rain meters can be used to override the controller's programmed run times. Soil moisture sensors test the available moisture in the root zone and tell the irrigation controller not to run if the soil is already sufficiently moist. Rain gauges that measure precipitation override the controller if the preset amount of rainfall has fallen.

The newest controller override device goes a step farther. It reacts to the increase in relative humidity that typically precedes rain. When relative humidity rises above the level set by the operator (based upon historical weather data), it overrides the irrigation timer, eliminating an unnecessary watering cycle. For more information, visit the manufacturer's website at www.weathermiser.com.

SECTION 14

IRRIGATION WITH RECLAIMED WASTEWATER

IRRIGATION WITH RECLAIMED WASTEWATER

TO REUSE OR NOT TO REUSE

In an effort to conserve supplies of potable water, some communities have considered using reclaimed wastewater for irrigation or other nonpotable purposes. Whether reusing water is right for your utility and the communities it serves can be determined only after a thorough evaluation of all the factors involved.

The reuse of reclaimed wastewater offers many conservation benefits—yet it also presents many unique challenges. A complete feasibility study must be performed to determine if it is possible and practical to use reclaimed wastewater for landscape irrigation or other purposes in each community. The results of the feasibility study should be meticulously documented.

A general overview of this subject is provided in the following text. More detailed information may be obtained from federal guidelines, state regulations, municipal ordinances, engineering texts, and journal articles.

Regulations Governing Water Reuse

There are no federal standards governing water reuse in the United States. However, the U.S. Environmental Protection Agency has published guidelines for water reuse (USEPA, 1992) that address all important aspects of water reuse, including:

- recommended wastewater treatment processes
- treatment reliability provisions
- reclaimed water quality limits
- monitoring frequencies
- setback distances
- other controls for various water reuse applications.

The regulations that do exist have been developed at the state level. These regulations normally define the acceptable levels of constituents of reclaimed water and prescribe means for assurance or reliability in the production of reclaimed water to ensure that the use of reclaimed water for the specified purposes does not impose undue risks to health (Crook, 1994, p. 67).

Higher treatment standards are usually specified for the irrigation of crops, golf courses, parks, and playgrounds than for forage produced for non-milk-producing cattle and roadway landscaping. Where the risk of human exposure is high, regulations may specify treatment and water quality requirements that will produce an effluent that is essentially free of measurable levels of pathogens, including viruses. General guidelines for the reuse of domestic wastewater in New Mexico have been prepared by the New Mexico Environment Department, and these may be obtained by contacting that agency.

Water Quality

The presence of toxic chemicals and pathogenic microorganisms in untreated wastewater creates the potential for adverse health effects where there is contact, inhalation, or ingestion of chemical or microbiological constituents. Thus, acceptability of reclaimed water for landscape irrigation depends on its physical, chemical and microbiological quality.

The quality of reclaimed water depends upon:

- the quality of the water source
- wastewater treatment processes and treatment effectiveness
- treatment reliability
- distribution system design and operation

Factors that affect the source water quality include use of water softeners (which increase sodium) and detergents (which increase boron) in dwelling units, presence of industrial waste, infiltration into the sewage collection system, and seasonal variations in flow caused by stormwater.

Treatment Reliability

In order for reclamation facilities to reliably and consistently produce and distribute reclaimed water of adequate quality and quantity, careful attention must be given to reliability features during the design, construction, and operation of the facilities.

Reliability requirements include:

- standby power supplies
- alarm system
- multiple or standby treatment process units
- equipment to prevent treatment upsets during power and equipment failures, flooding, peak loads, and maintenance shutdowns
- emergency storage or disposal of inadequately treated wastewater
- elimination of treatment process bypassing
- design flexibility of piping and pumping to permit rerouting of flows under emergency conditions
- monitoring devices and automatic controllers
- provisions for uninterrupted chlorine feed

Reliability features that are not design-related include:

- qualified personnel
- an effective monitoring program
- a quality assurance program
- an effective maintenance and process control program (Crook, 1994, pp. 60-61, 70)

In addition, an industrial pretreatment program and enforcement of a sewer-use ordinance to prevent illicit dumping of hazardous materials into the collection system are generally required to ensure treatment reliability.

Conveyance and Distribution Facilities

The primary concern that guides design, construction, and operation of a reclaimed water distribution system is the prevention of cross-connections. A cross-connection is a physical connection between a potable water system and any source containing nonpotable water, through which potable water could be contaminated. Another major concern of regulatory agencies is improper or inadvertent use of reclaimed water.

Typical regulatory controls designed to prevent cross-connections and intentional or unintentional misuse of reclaimed water include the following:

- color-coding of pipes and appurtenances (pumps, outlets, and valve boxes)
- horizontal and vertical separation of potable and reclaimed water lines
- preventing ties into reclaimed water line
- backflow protection devices on potable water lines
- pipeline design and construction criteria (Crook, 1994, p. 61-62)

The color purple is generally used to identify reclaimed water lines and appurtenances. Additional design, operation, and safety requirements include:

- a certified operator on duty at reclamation plant 24 hours per day
- adequate storage or rerouting of excess flows during rainy periods and winter months
- lining of detention ponds
- key-operated valves and outlets
- use of area controls including groundwater monitoring, surface runoff control, and prohibition of irrigation when the ground is saturated or frozen
- fencing and signage
- setback distances (from dwellings, public roads, wells, and reservoirs)
- control of windblown spray
- provisions for worker protection (Crook, 1994, p. 70-71)

It is important to emphasize that, in locales where groundwater is the source of potable water for residents, the installation of groundwater monitoring wells will be necessary to determine the impact, if any, of the application of reclaimed water on water quality and water levels.

Water Rights to Reclaimed Water

It is important to establish who has the legal right to the water—the supplier of the water entering the wastewater treatment plant, the treatment plant owner, or the public. The reuse of wastewater is subject to the administrative requirements that normally apply to changes in freshwater diversions, and the impact on return flow and downstream users must be taken into consideration.

Depending upon the situation, it may be necessary to file an application with the Office of the State Engineer for a new appropriation of water, or to change the place and purpose of use.

Feasibility Studies

Before a plan for the reuse of reclaimed water is adopted, a feasibility study should be prepared that would include:

- an evaluation of environmental regulations
- ownership and appropriation of water rights
- impact on return flow
- legal liability
- quality of water required for the proposed use
- contractual provisions which set forth the responsibilities and liabilities of the provider and users
- public acceptance
- past reuse experience
- environmental conditions (climate, soil, topography, groundwater levels and quality) at the point of use
- economics
- technical feasibility

Conditions that must be met before reclaimed water is a viable option generally require that:

- the reclaimed water is of adequate quality for the use, considering all relevant factors
- the reclaimed water is provided at a reasonable cost to the user (comparable to or less than the cost of potable domestic water)
- the use will not be detrimental to public health
- the use will not adversely affect downstream water rights, will not degrade water quality, and is determined not to be injurious to plants, fish and wildlife (Thomas, 1994, p. 94-95)

IRRIGATION WITH RECLAIMED WASTEWATER

USING RECLAIMED WATER IN NEW MEXICO

Several New Mexican municipalities are already using reclaimed water or have a recycling project in the works. New Mexico communities have filed between 75 and 100 discharge plans that include the release of treated water for irrigation, according to Fred Kalish, Water Resource Engineering Specialist at the Ground Water Quality Bureau of the New Mexico Environment Department.

In July 1999, Albuquerque began construction of its North I-25 recycling project, which blends recycled wastewater from Philips Semiconductors (1.2 million gallons per day), Sumitomo, and Silmax with reclaimed surface water from the Rio Grande. This project is expected to provide 3,900 acre-feet/year of irrigation and industrial water to nearby parks, schools, golf courses, and factories.

Since a major expense of providing recycled water is the cost of transporting it to customers, the city is also working on a recycling project in the south part of Albuquerque. More than 3,000 acre-feet of reclaimed water from a southside reclamation plant will be further treated and sent through a new system of recycled water pipelines to possibly irrigate a championship golf course and city parks.

Communities interested in a reclamation program should consult the nearest Office of the State Engineer Water Rights Division office regarding the effect of the program on the municipality's water rights. Municipalities should also contact the Ground Water Quality Bureau of the New Mexico Environment Department for the latest water quality and health guidelines regarding the discharge of treated effluent. A community must show that its reclamation program protects groundwater and fulfills the requirements of the federal Clean Water Act, the federal Safe Drinking Water Act, the Interstate Stream Commission, and regulations of the New Mexico Water Quality Control Commission.

Since safety is of prime importance, domestic wastewater used for irrigation of playgrounds, schoolyards, golf courses, cemeteries, and other places in which the public has access must be treated and disinfected. Greywater (reclaimed wastewater) used to irrigate freeway and other landscapes with much less public access also must be treated and disinfected, but the standards for fecal coliform bacteria and other pollutants are less stringent. Kalish notes that water used for subsurface irrigation (a buried drip system or leach field) does not have to be disinfected.

Irrigation systems using reclaimed water are required to:

- water when the chances of public contact are minimal
- be designed so that there is no pooling of the effluent
- include a system for uniformly marking all components as nonpotable. Warning signs are also recommended.
- include backflow devices and be designed so that the wastewater has no direct or indirect cross connections with potable water. *(Once reclaimed water flows through a system, that system can never be used for potable water.)*

Reclaimed water provides additional nutrients for some kinds of vegetation, but not all plants do well with treated water. Some plants, such as certain types of evergreen trees, cannot handle the additional salt and mineral levels. The county extension service may be able to help identify salt-intolerant plants.

NOTE: Information About Using Reclaimed Water

There are existing water quality and health regulations regarding the use of greywater. To obtain more information, call the New Mexico Environment Department at (505) 827-2855.

Before your utility decides to initiate a water reclamation project, consult with the nearest Office of the State Engineer Water Rights Division office. (Offices are located in Santa Fe, Albuquerque, Roswell, Deming, Las Cruces, and Aztec.)

SECTION 15

WATER WASTE ORDINANCES

WATER WASTE ORDINANCES

WHEN DOES WATER USE BECOME WATER WASTE?

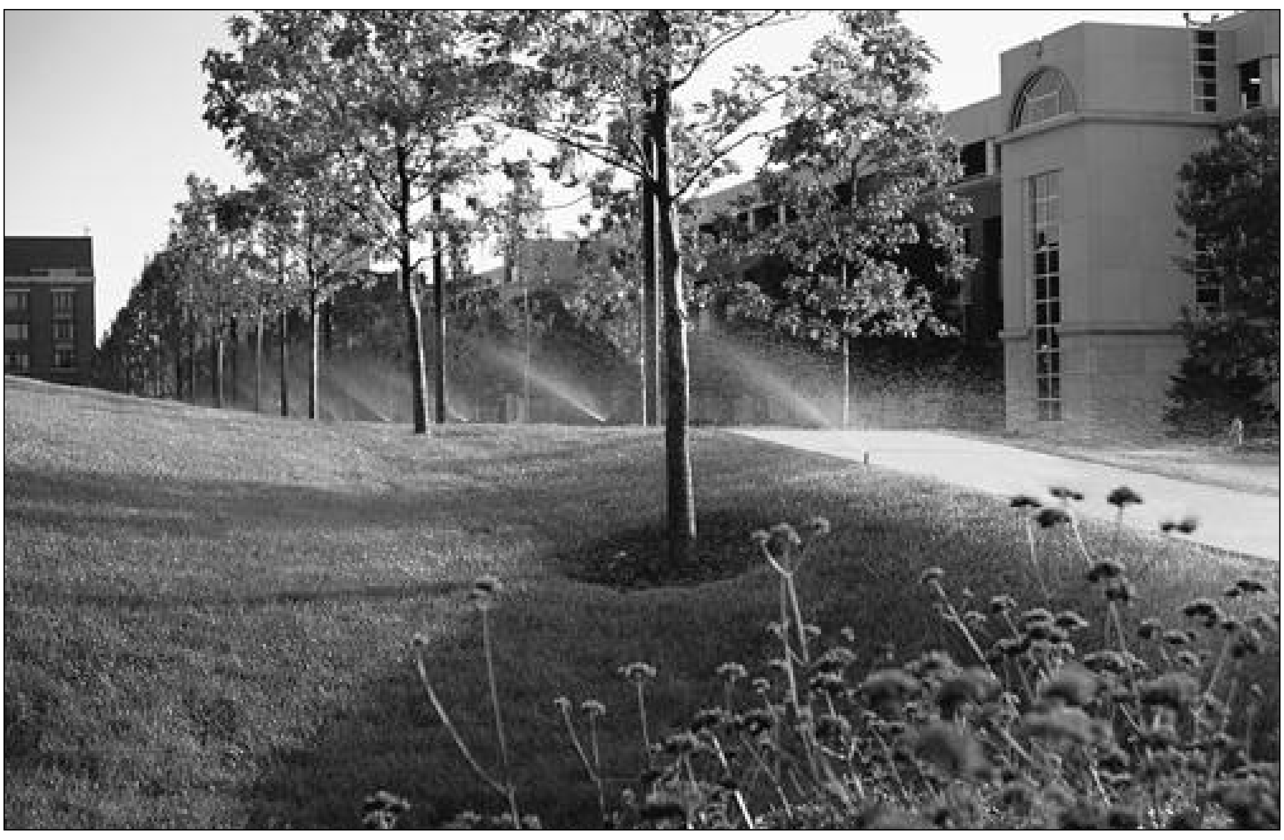
Water waste is usually defined in local government ordinances as water that flows or is discharged from a residence or place of business onto an adjacent property. Such discharges occur most often from landscape irrigation or leaking water pipes. In addition to loss of potable water, these events have safety and maintenance impacts. Water running onto streets can cause vehicle accidents, and it is damaging to road surfaces, particularly when it freezes.

The enforcement of waste ordinances can include warning citations, and restriction or shutoff of water flow. Exemptions to compliance with water waste ordinances are typically made for:

- water lost from storm runoff
- breaks in distribution water lines
- fire hydrant testing
- other temporary or emergency uses related to the protection of public health and safety.

Mandatory compliance measures are more effective than voluntary measures. The principal drawback to these measures is the resentment they may cause if customers perceive them to be excessively restrictive. For this reason, a mandatory water waste ordinance should be accompanied by a good public relations campaign emphasizing that the guidelines are based on common sense.

A water waste ordinance should also be responsive to varying water-supply circumstances. During a drought, the list of water-use practices that are considered wasteful should be expanded.



WATER WASTE ORDINANCES

PROTOTYPE FOR WATER WASTE ORDINANCE

Prohibitions on Water Waste and Restrictions on Water Use During Drought or Emergencies

BE IT ORDAINED by the Board of directors of the American Water Utility as follows:

Section 1: Prohibition on Waste

No customer shall waste any water supplied through the distribution system of the water utility. The following uses of water constitute "waste" as used in this Ordinance.

(A) The watering of grass, lawns, groundcover, shrubbery, trees, and open ground, in a manner or to an extent which allows substantial amounts of water to run off the area being watered.
(B) The washing of sidewalks, walkways, driveways, parking lots and all other hard-surfaced areas by direct hosing, except such as may be necessary to dispose of flammable or otherwise dangerous liquids or substances or otherwise necessary to prevent or eliminate matters dangerous to the public health and safety.
(C) The escape of water through breaks or leaks within the customer's plumbing or distribution system for any substantial period of time within which the break or leak should reasonably have been discovered and corrected. It shall be presumed that a period of eight hours after the customer discovers the break or leak is a reasonable time within which to correct the break or leak.
(D) The watering of grass, lawns, groundcover, shrubbery, trees, and open ground within any portion of the water utility's service area between the hours of 10 a.m. and 6 p.m. daily, except where a water conserving irrigation practice such as drip irrigation is used to minimize evaporation losses and no amount of water is permitted to run off the area of application. Irrigation by commercial nurseries, on their own sites, are exempt from the hours restrictions.

Section 2: Restrictions on Use During Droughts or Emergencies

(A) Every customer shall restrict their use of water supplied through the water utility's distribution system to the amount of the allotment established from time to time by resolution of the Board of Directors and specified in Section 3 below.
(B) Priority, by customer class, for continued water service during times of shortage is established as follows:
  (1) Residential indoor (domestic use only) and fire protection have the highest priority.
  (2) Commercial/Institutional/Industrial uses have the second highest priority.
  (3) Public and private landscape irrigation sites including golf courses, athletic fields, parks, cemeteries, and greenbelts have the third highest priority.
  (4) Other uses-including firefighting training, main flushing, storm drain flushing, sewer cleaning, street cleaning, decorative water facilities, and swimming pools-have the lowest priority.
(C) From time to time the water utility's Board of Directors may, based upon the existing and projected water supply and demand, establish allotments for each customer account within each of the above classifications, based upon the following criteria:
  (1) For the residential class, a quantity of water for indoor domestic use shall be allotted for each inhabitant served by each service account based on reasonable conservative water use. Such per capita water use allocation shall be determined by the Board of Directors in their sole discretion. In so doing, the Board of Directors is not required to review and analyze each and

every particular customer account, but may, where it deems appropriate, use samples, averages and projections, and any other factors it deems material. It shall be presumed that any customer exceeding the water allotment for indoor domestic use is using water for some other purpose, and shall have the burden of proof to show actual indoor domestic use in any proceeding or controversy involving that issue.

(2) For commercial, institutional, industrial, public and private landscape irrigation sites, and other, for each water service account within these customer classes, the Board of Directors shall from time to time, after first allotting water to the residential class, apportion and allot the projected remaining available water among each of the remaining customer classes, and amongst each customer account within such customer class as it determines in its sole discretion to be reasonable and in the best interests of the water utility, based upon all facts and circumstances it deems material to the issue. In so doing, the Board of Directors may make a greater apportionment of the available water supply to one customer class than another, and may from time to time alter such priority of apportionment.

Section 3: Allotment Schedule

(A) The allotments referred to shall be as specified in Exhibit A to this Ordinance, which shall be adopted separately by the Board of Directors and shall be attached hereto and incorporated herein by reference.

(B) From time to time said allotments may be modified by the Board of Directors by amending Exhibit A to this Ordinance.

(C) During any period in which no current Exhibit A allotment schedule is in effect, all customer classes and customer accounts shall be deemed to have an allotment of 100% of actual water use during such period.

Section 4: Manner or Use of Allotment Water

It shall be the sole responsibility of each customer to use and manage their allotted water in such manner as not to exceed such allotment.

Section 5: Place of Use of Allotment Water

Water allotments for each customer account shall be used only on and for the premises for which such customer account is designated or intended, and no other premises.

Section 6: Notice of Customer Class and Allotment

On the next water billing statement following the determination of water allotments, each affected account customer will be notified in writing of the applicable customer class and water allotment for such account for the next following monthly billing period, or such other period specified therein.

Section 7: Violations and Surcharges

(A) Use of the amount of water by a water customer during a given monthly billing period in excess of the water allotment for that period, or during a period of months in excess of the cumulative total of the monthly water allotments for said months, shall constitute a violation of this

Ordinance, and the water utility shall, by writing, notify the account customer by name and at the address shown on water utility records of such violation. Such notification may be stated upon the normal water billing statement.

(B) For the first and second violation of a water allotment under this Ordinance within any calendar year, an excess water use rate shall be charged for the amount of such excessive use for each such violation at four times the highest water rate for the customer class.

(C) For the third and all subsequent violations of a water allotment under this Ordinance within any calendar year, an excess water use rate shall be charged for the amount of such excessive use for each such violation at ten times the highest water rate for the customer class.

(D) All excess water use charges shall appear on the account statement for the monthly billing period immediately following the monthly period for which the excess use occurred, and shall be due and payable at the time the basic bill is due and payable. Failure to make payment of the entire amount due (basic amount plus the surcharge) shall subject the customer to the same penalties as imposed in the water utility's rules and regulations, or by law, for failure to pay the basic water rate bill.

Section 8: Cure of Violations and Refunds for Water Conservation

Any violation of a water allotment may be cured and any surcharge paid pursuant to Section 7 of this Ordinance shall be refunded to the customer, upon application in writing, provided that water use through the customer account for which the violation occurred has, during two monthly allotment periods following the period of violation, been reduced to an extent below the allotments equal to the amount of the prior excess use. In such event, the violation shall be deemed cured for all purposes, including purposes of calculating the number of violations under Section 7, B and C.

Section 9: Additional Penalties

(A) **Civil Remedies.** In the event any person, firm, partnership, association, corporation or political entity is found by the Board of Directors to be in violation of any restriction or prohibition of this Ordinance, the Board of Directors may impose a special water waste surcharge against such person's account and may temporarily or permanently discontinue or restrict with a flow regulating device, water service to the affected property. Before taking such action, the Board of Directors shall give any such person reasonable notice and an opportunity to be heard to protest against the finding of such violation and the imposition of such measures. The Board may determine the terms and conditions of the discontinuance or restriction of service and may establish by Resolution, a schedule or the amounts or such surcharges as in its sole discretion will fully compensate the water utility and it customers for all loss or water and other damages incurred and as will foster water conservation within the water utility's service area.

(B) **Emergency Staff Action.** In unusual emergency circumstances where members of the water utility staff observe substantial amounts or water being wasted in violation of this Ordinance and where after reasonable efforts have been made to persuade the water service account registrant to terminate such waste, but have failed, the General Manager may authorize the immediate temporary discontinuance or restriction with a flow regulating device of service to the expected property. A written notice of such action and the reasons therefore shall be delivered to any adult person present at the premises, or if none can be found, left in a conspicuous place on the property within twenty-four hours of the discontinuance or restriction of service. Any such person may have water service promptly reinstated by applying therefore at the water utility, upon payment of the utility's standard connection fee. Notwithstanding such reinstatement, such person may still be cited for and subject to all other penalties for water wastage provided elsewhere in this Ordinance.

Section 10: Appeals and Exceptions

(A) **Appeals.** Any customer may appeal any decision or application of the provisions of this Ordinance by the water utility's General Manager, to the Board of Directors by filing a written appeal with the utility's secretary within ten days from the date of the decision or application appealed from, and the Board of Directors shall set the matter for a hearing de novo at a regular or special meeting within thirty days from the date the appeal is filed, and may in its discretion thereafter affirm, reverse, or modify the General Manager's decision, and impose any conditions it deems just and proper.

(B) **Exception.** The Board of Directors may, in its discretion, grant exceptions to the terms of this Ordinance, including exceptions to any water allotment, if it finds and determines that (1) restrictions herein would cause an undue hardship or emergency conditions, or (2) that the granting of the exception will not adversely affect the water supply or service to other existing customers, or (3) that due to peculiar facts and circumstances, the Board of Directors at its discretion finds that the Applicant is entitled to substantially similar treatment as set forth in some provision of this Ordinance not otherwise specifically applicable to the circumstances. Such exceptions may be granted only upon application in writing therefore and review of the matter at a regular or special meeting of the Board of Directors, except that the Board may in its discretion, dispense with the writing and meeting requirements if it finds that an emergency condition requiring immediate action exists. Upon granting any such exception, the Board of Directors may impose any conditions it determines to be just and proper. The terms of any exception shall be set forth in writing, the original to be kept on file with the water utility, and a copy to be furnished to the Applicant.

Section 11: Definitions

The terms customer, customer account, service account, and applicant used herein shall apply to every person, firm, partnership, association, corporation, city, county, state, or local agency, political subdivision, district, or entity of every kind receiving water service from the water utility. All water customers whose names are shown on utility account records shall be equally responsible and liable for water use by tenants, lessees, co-owners, and all other persons utilizing water on the premises through the account.

Section 12: Severability

If any section, subsection, sentence, clause or phrase of this Ordinance is for any reason held to be unconstitutional or invalid, such decision shall not affect the validity or the remaining portions of this Ordinance. The utility hereby declares that it would have passed this Ordinance and each section, subsection, sentence, clause, or phrase thereof irrespective of the fact that any one or more sections, subsections, sentences, clauses, or phrases be unconstitutional or invalid.

Section 13: Effective Date

This Ordinance shall become effective on the date of its adoption.

Section 14: Board Findings

The Board of Directors of the American Water Utility finds and determines that the provisions hereof will conserve the water supply for the greatest public benefit, that all uses of water prohibited hereby are nonessential, and that the restrictions on use are reasonable and necessary.

Adopted by the following role call vote:

AYE: ______________________

NAY: _____________________

ABSTAIN: _________________

ABSENT: __________________

DATED: ___________________

SECTION 16

EMERGENCY ACTION PLAN FOR DROUGHT MANAGEMENT

EMERGENCY ACTION PLAN FOR DROUGHT MANAGEMENT

PLANNING AHEAD TO AVOID CONFUSION

Recurring drought is a natural part of New Mexico's arid climate. Drought, which is defined as a prolonged period of below-normal rainfall, can have a widespread impact on communities—especially if those communities have not prepared for periods of drought or water shortages.

Drought contingency plans improve a water utility's efficiency and response time during a drought or water emergency. Planning ahead will enable the water utility to avoid confusion during a crisis when immediate action is required and ensure better results from water use reduction programs. The following procedure may be used to develop an emergency action plan for drought management.

DEVELOPING AN EMERGENCY ACTION PLAN

Water shortages may not be predictable, but preparations can be made so that the effect of water shortages—whether caused by drought, natural disaster, or other emergency—can be minimized.

Step 1: Form a Drought Task Force and Define its Structure and Membership

The responsibilities of the Drought Task Force must be clearly defined, and will typically include:

(1) supervising and coordinating the development of the plan
(2) public education
(3) monitoring reservoir levels, groundwater levels, and precipitation to estimate water shortages
(4) assessing the impact of shortages on each customer class and the economic livelihood of the community
(5) coordinating the implementation of drought mitigation actions
(6) monitoring compliance

Step 2: Prepare a History of Droughts in the Area

Prepare a chronological history of droughts in the study area and describe the effects on the community based upon articles published in newspapers, journals, professional papers, public records, and interviews with the public. Determine the reductions in demand that were necessary to provide adequate amounts of water to customers. Based on this information, what will be the impacts on the community with reduced allocations of water in the next drought? This information will play an important role in educating the public and gaining their support for the emergency action plan.

Step 3: Identify Supply Constraints

Identify constraints affecting the water utility's ability to meet water demand. These will include limits on supply and limits on system capacity.

- **Limits on Supply.** What are the limits on the utility's sources of water such as stream diversions, reservoir levels, aquifer yield, and water supply contracts? The firm yield of surface water and groundwater supplies should be established. The firm or sustainable yield of a stream or reservoir may be defined as the maximum quantity of water that can be withdrawn on a dependable basis, during a repetition of the most critical drought on record. The firm or sustainable yield of an aquifer may be defined as the average annual recharge from snowmelt and precipitation, seepage from watercourses, and return flow from surface and groundwater withdrawals for water-use activities. Sustainable aquifer yield may also be defined as the annual withdrawal that does not result in a long-term decline in the water table.

- **Limits on System Capacity.** What are the limits on production, treatment, storage, and distribution capacity? During droughts, customer demand typically increases. However, older systems or systems serving rapidly growing areas may not have the infrastructure capacity to meet above-average demands.

Step 4: Examine Additional Supply Options

If the available supply is the limiting factor in meeting demand, evaluate supply augmentation options. The following questions must be asked:

- Are there existing wells or reservoirs that can be used?
- Can water be purchased from another water utility?
- Can unaccounted-for-water losses be reduced?
- Can wastewater be reused for non-potable water requirements?

In the event that a community is close to exhausting its water supplies entirely, additional options must be considered. These can include actions such as setting up agreements with neighboring communities to lease or share supplies and laying emergency pipelines to supply water on a temporary basis.

Step 5: Identify Necessary Infrastructure Improvements

If system capacity is the limiting factor in meeting demand, identify the critical system components that are vulnerable to failure or need to be upgraded and enlarged to meet the projected peak demand. Evaluate the feasibility of making infrastructure improvements and rank each option based on (1) feasibility of implementation and (2) effectiveness in increasing capacity.

When evaluating the effectiveness of a proposed change, the relationships between system components must be considered. For example, increasing pumping capacity at the source of supply will not increase the amount of water that can be delivered to customers if the treatment plant or distribution mains cannot handle the increased flow rate.

Step 6: Define Criteria That Will Trigger Drought Responses

Define trigger criteria that will determine the level of response required based upon the severity of drought. Acceptable triggers include the Palmer Index, precipitation, reservoir/lake storage, streamflow, groundwater levels, soil moisture, or any combination of these parameters. Criteria for the phaseout or a downgrade of the condition's severity should also be considered. The following are examples of trigger conditions that might be used for various levels of severity.

Phase 1 Trigger: Water Shortage Advisory

Snowpack, precipitation, streamflows, and reservoir levels are only 70% of normal.

Phase 2 Trigger: Water Shortage Watch

(1) Water demand has reached or exceeded a specific percentage of the firm capacity of the system.
(2) Reservoir or well levels are still high enough to provide an adequate supply, but the levels (specify level) are low enough to disrupt some other beneficial activity, such as recreation.
(3) The water supply is still adequate, but the reservoir or well levels are low enough that there is a possibility that the supply situation may become critical if the drought or emergency continues. An example is a reservoir that has a 4-month supply in storage, if no more rain occurs, or a well that has dropped to a specified level.

Phase 3 Trigger: Water Shortage Warning

(1) Water demand has reached the predetermined limit of the system, beyond which the failure of a pump or some other piece of equipment could cause a serious disruption of service to part or all of the system. An example might be that daily demand has exceeded 90% of the capacity of the system for three consecutive days.
(2) Reservoir levels, well levels, or streamflows have reached the second impact level, beyond which operational problems will occur.
(3) Water supply storage levels have declined to the second impact level.

Phase 4 Trigger: Water Shortage Emergency

(1) The imminent or actual failure of a major component of the system has occurred which will cause an immediate health or safety hazard.
(2) Water demand has reached or exceeded the third impact level. An example might be that demand exceeds the system's capacity on a regular basis, thereby presenting the imminent danger of a major system failure.
(3) Reservoir levels, well levels, or streamflows have declined to the third impact level. An example might be that reservoir levels (specify a level in feet above mean sea level) are so low that diversion or pumping equipment will not function properly.
(4) Water levels in the distribution storage reservoirs are too low to provide adequate fire protection.

Step 7: Specify Actions To Be Taken

Define the level of response and actions that will be taken in each phase. The following are examples of actions that might be taken for various levels of severity.

Phase 1 Response: Voluntary Conservation

(1) Provide the public with information on current storage levels in reservoirs and streamflows and the long-range forecasts for precipitation. Alert water customers to the possibility of implementing mandatory conservation measures if drought conditions persist.
(2) Inform the public by mail and through the news media that they should try to reduce their water use.
(3) Inform the public daily whether they should water or not water their lawns.

Phase 2 Response: Mandatory Conservation—Level 1

It is important that the water utility take a lead role in setting an example on efficient water use. Before the utility can expect cooperation from its customers, it must put its own house in order. The utility can demonstrate its intent to improve the efficiency of operations and minimize waste by pursuing any or all of the first three actions listed in this section.

(1) Implement leak detection and repair program.
(2) Reduce flushing of water mains, sewers, storm drains, and streets to the minimum necessary to maintain sanitary conditions.
(3) Reduce frequency and duration of irrigation at public landscape sites such as golf courses, athletic fields, parks, cemeteries, and greenbelts. Adopt irrigation schedules based on the results of water audits if available.
(4) Impose a mandatory lawn watering schedule such as alternate day sprinkling and restrictions on time of day for watering.
(5) Prohibit nonessential water uses such as ornamental fountains; pool filling; car, bus, and heavy equipment washing; washing and steam cleaning of building exteriors.

Phase 3 Response: Mandatory Conservation-Level—2

In addition to the above:
(1) Implement a special pricing structure.
(2) Distribute water-saving plumbing fixture kits.
(3) Curtail irrigation at athletic fields, parks, cemeteries, and greenbelts.
(4) Curtail fairway irrigation at all public and private golf courses using public water supplies, and reduce watering of tees and greens to a minimum.
(5) Prohibit all outdoor water use.

Phase 4 Response: Rationing

In addition to the above:
Limit the amount of water each customer can use and take legal action as needed to achieve compliance. For example, restrict residential water users to 45 gallons per capita per day and require a percentage reduction by commercial, institutional, and industrial users.

Step 8: Establish a Public Education Program

No drought plan will be successful without a comprehensive public education program. Customers must understand why their cooperation is needed before they will sacrifice water uses.

Customers must also be instructed in how to conserve. Often they are willing to cooperate but do not know how. The utility's credibility is crucial to the success of any drought program. Customers must believe that the utility is an authority on the drought situation and that the emergency action programs are necessary and effective. To maintain credibility, the utility must be consistent:

- each spokesperson must report the same data or advice
- each education effort must be coordinated
- programs should proceed without major changes.

Step 9: Establish Implementation Procedures

Procedures for the implementation of the emergency action plan should define when and how customers, other utilities, and government agencies are informed that the emergency action plan is going into effect. Procedures may include:

(1) automatic regulatory implementation provisions
(2) prearranged media notification or press release procedures
(3) direct notification procedures including mail, or, if needed, telephone notification systems
(4) prearranged contract procedures to obtain emergency water supplies from other sources if needed
(5) checklists or operating procedures as necessary.

Step 10: Establish Procedures for Termination Notification

The termination of water restrictions procedure should define when and how customers and others are informed that the emergency has passed and the program is being shut down. The establishment of termination triggers and the decision to terminate must be based on sound judgment by appropriate city or utility authorities.

Step 11: Obtain Legal Authority

Obtain the required legal authority and regulatory permits for implementing the individual measures in the emergency action plan. It is generally advantageous to adopt an ordinance or regulation providing authorization to a designated official to begin immediate implementation of contingency measures when a trigger condition is reached.

Prepare memorandums of agreement (MOA), and contracts as needed, with all agencies that will be players in the implementation of the drought action plan so that the role of all participants is clearly understood. Because verbal agreements are easily forgotten or compromised by changes in priorities or personnel within an agency, agreements must be documented in writing to ensure that they will be honored in time of need.

EMERGENCY ACTION PLAN FOR DROUGHT MANAGEMENT

SANTA FE WATER ORDINANCE RESTRICTIONS CHART

This table highlights the four stages of water restrictions outlined in the water conservation ordinance adopted by the Santa Fe City Council on June 25, 1997. Each of the stages is tied to projected shortages of water. This drought management plan was instrumental in the summer of 2000 when water shortages prompted Santa Fe to declare its first Stage 2 Water Alert and Stage 3 Water Warning. (For more information, see the Santa Fe case study on page 157.)

	Stage 1 **Water Watch**	**Stage 2** **Water Alert** **(City Manager)**	**Stage 3** **Water Warning** **(City Council)**	**Stage 4** **Water** **Emergency**
Voluntary (V) or Mandatory (M)	V	M	M	M
Demand deficiency*	15%	16% - 35%	36% - 50%	> 50%
Residential				
Outdoor landscape watering	All elements of Stage 2 apply on voluntary basis from 10 a.m. to 4 p.m.	All elements of Stage 2 apply on voluntary basis from 10 a.m. to 4 p.m. No watering on Mondays, then every other day depending on address; No watering between 10 a.m. and 4 p.m. Handheld buckets, shut-off hoses can be used anytime. Reclaimed and greywater may be used anytime.	Permitted only on Tuesdays and Fridays, even for hose with shut-off. May water anytime if by hand-held container or drip irrigation, or if using reclaimed or greywater.	Prohibited except for plants that are rare, exceptionally valuable or essential to well being of public or rare animals. Trees and shrubs only with shut-off hose, hand-held container or drip. Greywater okay on fruit trees, ornamental trees and shrubs.
Car washing		Anytime if bucket or shut-off hose is used.	All vehicle washing at a residence is prohibited.	Prohibited
Spas and Swimming Pools		One initial filling for recirculating pools only, no draining and refilling.	Filling and refilling prohibited except when used for water storage. Pool must be covered when not in use.	Prohibited except as water storage
Water runoff from property; washing down pavement, sidewalk		Prohibited	Prohibited	Prohibited
Ornamental Fountains		Allowed only if water is recirculated	Prohibited	Prohibited

EMERGENCY ACTION PLAN FOR DROUGHT MANAGEMENT

SANTA FE WATER ORDINANCE RESTRICTIONS CHART (cont.)

	Stage 1 Water Watch	**Stage 2 Water Alert (City Manager)**	**Stage 3 Water Warning (City Council)**	**Stage 4 Water Emergency**
Voluntary (V) or Mandatory (M)	V	M	M	M
Demand deficiency*	15%	16% - 35%	36% - 50%	> 50%
Commercial				
Car washing	All elements of Stage 2 apply on voluntary basis from 10 a.m. to 4 p.m.	Anytime on immediate premises	Anytime on premises, but if business does not use reclaimed or recycled water, volume will have to be reduced.	All car washes must reduce usage.
Nurseries		Must curtail all non-essential watering and encouraged to use conservation practices, but exempt from irrigation restrictions.	Reduce use.	Reduce use; may use greywater to irrigate fruit trees, groundcovers and ornamental trees and shrubs.
Restaurants		Only serve water on request	Only serve water on request	Only serve water on request
Construction Projects		Limited to water use required by regulatory agencies (e.g. dust control). Must use reclaimed water if reasonably available.	Limit to new construction meters; water used only for purposes required by regulatory agencies. Effluent water used for dust control only.	No new construction meters will be issued. Construction water not used for earth work or road construction. Effluent water used for dust control only.
Golf courses		Only during designated hours/days	Only during designated hours/days	Prohibited

*Applies during periods when the possibility exists that the utility will not be able to meet all of the water demands of its customers by up to X% of the annual demand projection.

SECTION 17

CASE STUDIES OF WATER UTILITY CONSERVATION PROGRAMS IN NEW MEXICO

CASE STUDIES OF WATER UTILITY CONSERVATION PROGRAMS IN NEW MEXICO

RIO RANCHO

Population: 54,000
Water source: Groundwater

As one of the fastest-growing cities in New Mexico, Rio Rancho is keenly aware of the need for water conservation. From 1990 to 1999, the city's population increased 54% and the number of utility accounts rose by over 4,000. Currently, the city pumps more than 10,000 acre-feet/year (af/y) of its allotted 14,419 af/y. To meet the anticipated increase in demand, the city has applied for an additional 12,000 af/y and, in 1998, launched a water conservation program.

Because Rio Rancho is a fairly new community (incorporated in 1981), about 25 percent of residences are new homes that conform to federal standards for low-flow toilets, showerheads, and faucets. Rio Rancho also charges higher water rates than neighboring Albuquerque, which serves to promote water conservation. As a result, current water consumption is 185 gallons per capita per day (GPCD). (This figure includes the water consumed by the large Intel manufacturing plant. Without Intel's consumption, Rio Rancho's GPCD is 165.) By contrast, the goal of Albuquerque's ambitious water conservation program is 175 GPCD.

The budget for the city's Water Conservation Program is approximately $100,000, which is funded by a 1/16 cent Environmental Gross Receipts Tax.

Landscape Conservation

"A lot of people move here from other places where there's a lot of water," said Colleen Logan, Water Conservation Officer at Rio Rancho's Department of Utilities. "People are used to green lawns, and they expect them to be part of their lives here, too."

Consequently, promoting efficient irrigation and xeriscaping is Logan's highest priority.

One successful program is the annual Water Wise Landscaping Contest. Eligible yards must have plants in at least 50 percent of the yard area, with lawns accounting for less than 40 percent of the total area. The judges look for native, drought, and semi-drought tolerant plants, as well as efficient irrigation (proper zoning according to water needs plus use of drip, microspray, and efficient overhead spray). The brochure/entry form offers landscaping tips, from grouping plants according to water use to avoiding large areas covered in rocks and no plants.

The contest is conducted in conjunction with the local newspaper, a garden nursery and the contractor that runs the day-to-day utility operations. The newspaper prints ads and articles that promote the contest and publishes pictures of the winners as a public service. The nursery offers gift certificates to the winners and displays the contest brochure in its stores. The contractor contributes cash prizes and includes promotional brochures in the utility bills. Representatives from the three partner-companies also judge the contest. According to Logan, the total cost to the Water Conservation Program for printing flyers and utility-bill inserts is about $1,800.

To further promote water-efficient landscaping, the program recently began a demonstration garden exhibiting irrigation systems, mulches and drought-tolerant plants. The cost for the 15,000-square-foot garden is approximately $65,000. Gardening groups will hold workshops to train master gardeners and Parks Department personnel for maintaining the garden and giving tours. In addition, Logan has arranged for maps of the demonstration garden and additional books on xeriscaping to be available at the public library.

To spread the word about water conservation, an independent contractor was hired to help develop a marketing/education campaign. The campaign will include a logo and slogan for the program, developing conservation advertisements (e.g., newspaper inserts, rack pamphlets and targeted mailings) and conducting a survey to evaluate the public's knowledge, conservation efforts, willingness to pay for conservation and the effectiveness of the program's various advertising efforts.

Toilet Rebate Program

Rio Rancho's toilet rebate program began in April 2000 with an annual budget of $25,000. Water customers can receive $100 by replacing a high-flow toilet with a 1.6-gallon-per flush toilet. Each new toilet must have a glazed trap and not rely on early-closing or specialized flappers, which are often eventually replaced with generic flappers that permit much more than 1.6 gallons per flush. The application form also warns customers to avoid chlorine-based bowl cleaners as they tend to break down the flapper material.

The program's advertising and overhead cost less than $1,200. One local business recycles the old toilets into roadfill for free and another business offers a 10 percent discount for the new toilets. Rebate customers are asked to provide statistical information (e.g., number of people in the household, number of showers, baths, flushes per day) and Logan plans to look for the effects of low-flush toilet installation by tracking water use in each household.

Other Conservation Efforts

Logan looks for opportunities to inexpensively promote conservation by plugging into pre-existing events or organizations. For example, when the Rio Rancho Chamber of Commerce has its Springfest, Logan sets up a booth promoting Drinking Water Week and distributes conservation information. Together with Albuquerque and Los Lunas, Rio Rancho also helps fund and organize the fall Middle Rio Grande Water Festival, which teaches fourth graders and their teachers about water resources.

In early 2000, Rio Rancho bought "Every Drop Counts" water education kits for the 860 seventh-grade students in its three middle schools at a cost of about $15,000. The kits teach students how the aquifer works, how to read a water meter, and how to conduct water use surveys at home and school. Rio Rancho's in-school education programs will be expanded to include the high school level as well.

On the legislative side, Logan is working to develop a water conservation ordinance. The recently hired contractor will help organize an advisory group comprised of representatives from industry, local landscaping companies, developers, community leaders and other stakeholders concerned about water use. The results from a series of meetings and community-wide forums will go to the utilities commission, which will then pass on its recommendations to the city council. The results may also be used to modify existing landscaping requirements for new building permits.

Advice from Rio Rancho:

Join professional groups such as the AWWA. Conferences are good places to learn and network—and sometimes find funding.

Get support of the city administration and government and work with local media. This not only helps promote the idea of water conservation, but it engenders financial support. Budget is a key tool.

Lead by example. Make sure the city, which in Rio Rancho's case is the second biggest water consumer, is saving as much water as possible in every one of its operations.

CASE STUDIES OF WATER UTILITY CONSERVATION PROGRAMS IN NEW MEXICO

LAS VEGAS

Population: 18,000
Water source: Gallinas River
(also leases water storage from Storrie Lake)

Las Vegas, a town of charming Victorian houses and gardens, is situated at the headwaters of the Pecos River in a high mountain meadow next to the Rocky Mountains. This pastoral setting, however, belies a serious water problem.

In six of the nine years from 1992 to 2000, the city imposed restrictions on water use. The drain on the water supply during the 1999-2000 fiscal year was due to a combination of factors including drought, competition with upstream irrigators, a population growing at about 2% a year and a forest fire which burned 2% of Las Vegas's watershed. Starting in November 1999 (the earliest month in the fiscal year that restrictions have ever begun), the city began restricting water use at either serious (Stage I) or severe (Stage II) drought condition levels.

The good news is that the emergency situation helped to mobilize the community. "People are getting aware," said Veronica Flores, Water Conservation Specialist at the City of Las Vegas Utility Center. "We get a lot of calls for information on how to change out bluegrass or if they can wash their car today. That alone tells me our conservation program is working. Before, people would do what they wanted and then say they didn't know they were wasting water."

Before the restrictions went into effect, water production levels peaked at 6 million gallons a day, according to Flores. Now production is down to about 2.5 million gallons a day. Flores credits the water conservation ordinance, an educational campaign, and a more aggressive stance towards finding and fixing leaks. And all this on little to no water conservation budget.

"Running a water conservation program is hard work, especially if there's only one staff person," notes Flores. Without much money or staff, she advises utilities to do little things. Instead of printing its own pamphlets, Las Vegas uses those available from the Office of the State Engineer. Flores has relied on bigger cities such as Albuquerque and Santa Fe for information, and she's applied for grants to help fund some programs. Most importantly, she emphasizes education, which she believes has helped the most in saving Las Vegas water.

Schools

"If you educate the kids, they're the first ones to tell Mom and Dad," said Flores. When she visits elementary schools, she shows videos, talks about water conservation and gives out a water conservation booklet to children in preschool through fifth grade. She also works with a seventh-grade teacher using a curriculum and activity guide from Project WET, sponsored by the Tierra y Montes Soil and Water Conservation District, which holds free training workshops. In the summer, Flores works with children in the National Youth Sports Program.

Public Education

Flores gets the word out about conservation by talking with community groups such as the Elks club and Kiwanis club, putting conservation messages on utility bills, and answering questions on two call-in radio shows (one weekly, the other once a month). She provides packets of information for realtors to give to prospective buyers and for people who want to build. The local newspaper, *The Daily Optic*, prints a weekly "Las Vegas Water Watch" column, which lists river flow and consumption levels for the week as well as a conservation tip. The newspaper also prints many stories generated by the utility, ranging from explanations of how the watershed works to changes in restriction stages.

With a $15,000 grant from the U.S. Bureau of Reclamation, Flores held the first Water Conservation Solutions Expo in Las Vegas in the fall of 2000. Exhibitors at the Expo demonstrated irrigation and rain harvesting systems, native grasses, xeriscaping and low-flow fixtures. More than 2,000 water conservation kits were distributed, which included low-flow showerheads and toilet displacement bags that the utility installs at no charge.

Retrofitting

A town that has 900 buildings on the National Register of Historic Places is bound to have a lot of old, high-flow toilets and other fixtures. Indeed, 55% of Las Vegas' residential water consumption is for indoor use. Flores is hoping to get another grant from the Bureau of Reclamation so the city can offer a toilet rebate program for many of the 7,000 residential and commercial customers on the city water system. She's investigating whether a toilet exchange program, in which the city buys low-flow toilets outright and offers them as trade-ins, would be more economical for the city than a rebate program.

Enforcement

Time permitting, Flores patrols the town looking for water violations for an hour in the morning and an hour in the afternoon. The police department enforces the ordinance after hours and on weekends.

If the volume of water used by a customer increases suddenly, Flores sends out letters asking people to check for and fix leaks in 30 days (or else their water will be turned off). She does the same for high-consumption customers (top 25 residential users) or people reported by neighbors. "This doesn't usually solve the problem entirely," said Flores, "but it does make people more aware."

Hopefully these efforts will significantly reduce water use in Las Vegas. Yet, writes Richard R. Trujillo, Water and Gas Director for the city, in the August 7, 2000 *Daily Optic,* "in an arid climate such as New Mexico's it is foolish to expect a magical point will be reached where final solutions to water issues will occur." The Las Vegas Water Resource Committee is currently investigating additional sources of water.

Advice from Las Vegas:

A 1996 drought precipitated the passage of the Las Vegas Water Conservation Ordinance. (The ordinance was based largely on Santa Fe's ordinance.) Based upon the utility's experience in 2000 with restrictions, several items in the ordinance will be modified. At the time of printing, Flores anticipated the following changes:

- Expand water-use restrictions to all year instead of April 1 through September 30.
- Extend ordinance to entire service area instead of only within city limits.
- Relax watering restrictions by allowing two days of watering per week during Stage I restrictions and one day a week during Stage II.
- Exempt commercial car washes from restrictions if they use a recycling system.
- Close various loopholes. For example, the ordinance had said that in Stage II car washes cannot use treated water for washing cars on Mondays, Wednesdays and Fridays between the hours of 8:00 a.m. and 5:00 p.m. The intent had been that they would not operate on those days, but instead the businesses did conduct business before 8:00 a.m. and after 5:00 p.m.
- Doubling surcharges during an emergency stage.

CASE STUDIES OF WATER UTILITY CONSERVATION PROGRAMS IN NEW MEXICO

ROSWELL

Population: 50,000
Water Source: Artesian Basin

Roswell draws its drinking water from a self-recharging aquifer, which means the city is not as dependent on the whims of rainfall as are some municipalities. In fact the city's water table has been rising in recent years—so much so that a downtown bank periodically has water seepage in its basement, and springs and wells that were dry for decades are now flowing. Moreover, Roswell only requires between 9,000 and 12,000 acre-feet of water per year of the 35,000 acre-feet the city is allowed to pump. Total water pumped in 1999 was just over 4 billion gallons, and the daily per capita usage was 221.7 gallons.

Larry Loy, Special Services Administrator, believes the main reason the water table is rising is that local farmers and ranchers, who use between 90% and 95% of county water, have taken a proactive stance to conserve water. Specifically, they have destroyed water-guzzling salt cedars, cottonwoods and Tree of Heavens. (In fact there is now an ordinance prohibiting the planting of these trees.)

This enviable position, however, makes it hard to argue the case for water conservation. In 1997, the city council voted down a proposed water conservation ordinance after some citizens complained about the penalties for violating the ordinance. "Most councilors don't want to send the message that we have a water shortage. They didn't want to alarm people," noted Loy, who researched and wrote the draft ordinance. "Roswell is a fairly conservative place."

The council did approve a water rationing ordinance tied to levels in storage tanks in the event of a serious shortage, although the city has yet to need it. The council also endorsed a Water Conservation Program Guide, which details a "wish list" of water conservation projects including installing moisture sensors and drip systems in city parks, testing meters, and making informational presentations to civic organizations. The Water Conservation Program Guide sets a goal of reducing consumption by 5-15% over the next 20 years.

However, Loy noted that the guide doesn't have legislative teeth, so he can only encourage people to conserve through public education. And without a direct budget or staff, this encouragement consists mostly of issuing public service announcements every other month to the media and sending out letters to people reported to be wasting water. He doesn't have the staff to send to schools or to effectively audit and track usage.

Still, Loy, whose job entails far more than water conservation, has found ways to pitch the conservation message without a specific program. He's directed building and plumbing inspectors to suggest the use of water efficient landscape plants during the permit process, and he's requested the use of low-flow devices when fixtures in city-owned property have to be replaced.

Through personal contacts, he's asked local nurseries to encourage customers to buy drought-tolerant trees and shrubs, and he's worked with the nearby New Mexico Military Institute and other large users to promote conservation. Loy hopes his involvement with a committee working to strengthen an existing landscape ordinance will lead to the inclusion of some water conservation provisions.

Loy is also working with a Roswell citizen interested in Groundwater Guardian, a network of communities concerned with groundwater protection. This organization offers community conferences, a hot-line, and how-to information on defining goals, community action, fundraising, organizing events and working with the media. More information about the group is available at www.groundwater.org/gardian/ggindex.htm.

Advice from Roswell:

- Research and modify what other cities have done (often available on the internet) and contact groups such as the American Water Works Association (AWWA) www.awwa.org/ and the Office of the State Engineer (1-800-WATER-NM).
- Loy recommends the AWWA's August 1993 "The Water Conservation Guidebook for Small and Medium-Sized Utilities" as the best single resource, especially for smaller utilities. Other helpful publications include: "Water Less Water Better" (Albuquerque Citizens guide to Albuquerque landscaping requirements); "Water Audit and Leak Detection Guidebook" (AWWA); "Evaluating Urban Water Conservation Programs: A Procedures Manual" (California Urban Water Agencies and AWWA); and "Achieving Efficient Water Management: A Guidebook for Preparing Agricultural Water Conservation Plans" (December 1996, U.S. Department of Interior, Bureau of Reclamation; available on the web at: www.usbr.gov/wrrl/rwc/guide/).
- Get input from the public about water conservation perceptions so you'll know what issues to address and how to best address them.

CASE STUDIES OF WATER UTILITY CONSERVATION PROGRAMS IN NEW MEXICO

ALBUQUERQUE

Service Population: 480,000
Water Source: Middle Rio Grande Aquifer

As the largest city in New Mexico and the one with the largest water conservation budget, Albuquerque has engineered a conservation success story that's still unfolding. In 1995, the city council set the goal of reducing Albuquerque's water consumption by 30% in 10 years. By the end of 1999, the city had already achieved almost two-thirds of this goal, pumping 2.25 billion gallons less water than it had 10 years earlier—despite below average rainfall and a 17% increase in customer accounts. Since the water conservation program began, Albuquerque has saved an estimated 35 billion gallons of water.

"The key to success is marketing," said Jean Witherspoon, Water Conservation Officer at the Public Works Department. "Communication is the primary issue because you have to change the way people think and live. People in Albuquerque have been receptive to conservation because it's the right thing to do."

LEGISLATION

Albuquerque's water conservation program has its roots in the early 1990s when a city council task force began to study the issue. In August 1993, the United States Geological Survey (USGS) released findings that gave water conservation a scientific foundation and political impetus. The USGS discovered the city was consuming groundwater faster than it could be replenished. In fact, water levels had dropped by up to 160 feet since 1960. The bottom line: there was not as much groundwater as the city thought, and drilling deeper would probably produce poorer quality water.

After public input, in March 1995 the city council passed a conservation resolution and the Water Conservation Landscaping and Water Waste Ordinance. The most important provisions in the Ordinance were a limit on high-water-use turf in all new construction to 20% of the landscaped area, a new process for enforcing water waste, and water budgets for parks and golf course.

In April 2000, the city started prohibiting all landscape watering between 10:00 a.m. and 6:00 p.m. in April through October for all customers. The city council also approved a water rate increase of 8.8 cents per unit (a portion of which funds the Water Conservation Program's budget of just over $2 million a year) and a modest summer rate surcharge.

PUBLIC EDUCATION

When the conservation program began, Witherspoon made a point of involving the community. She spoke to the League of Women Voters, the Sierra Club, neighborhood and professional associations and business groups.

"We made ourselves available to anyone who wanted to know what we were doing," she said. "This helped get the word out and gave us feedback. Talking face to face is far more effective than getting materials in the mail. It's important to put a human face on the program."

Witherspoon estimates that 20% of the conservation budget is spent on marketing and public information. Under Witherspoon's direction, a local public relations and marketing firm has produced a multitude of videos, brochures, television and radio ads, public service announcements, bill stuffers, and newspaper inserts. One measure of the campaign's success is that the office receives about 350 calls during a typical week—and double that amount when a new video or manual is released.

Because Albuquerque residents use two to three times as much water in the summer than in the winter, primarily due to landscape irrigation, a major thrust of the campaign has been to reduce the amount of water people use in their yards. To encourage xeriscaping, the city has published a wide variety of free brochures, manuals and videos that cover everything from xeric plants and drip irrigation to rainwater harvesting. The city has helped build five xeriscaping demonstration gardens, and it regularly offers free three-hour seminars on xeriscaping with city staff and/or landscape professionals. The seminars cover design strategies, drip irrigation, how to pick city-approved plants, and how to apply for the city rebate (see below). The city also recently sponsored a seminar for nearly 100 do-it-yourself homeowners and landscape professionals on harvesting rainwater.

To help water customers adjust their watering according to weather conditions, the city launched the Water Watch program in April 1999. It uses green, yellow and red drops to indicate whether it's okay to water. The drops appear daily from April to September in The Albuquerque Journal and on local television and radio stations. Witherspoon said the city buys time for other water-related public service announcements, while the media include water watch as part of normal weather reports at no charge.

The Water Conservation Office maintains an easy-to-navigate website (www.cabq.gov) containing the text of the water resolution and ordinance as well as numerous pages on how to read a meter and a water bill, conservation tips, rebate programs, an explanation of how the aquifer works, a breakdown of water use, news on what the city has done, and how to report water waste. Internet users may also directly email Witherspoon and other Water Conservation Office staff.

The utility changed its bill format in January 1995 to show residential customers how their water use compares to the average residential consumption—a move that greatly personalizes the conservation campaign. There are also two places on the bill for the conservation tips or announcements.

Schools

An educational planner in the Water Conservation Office makes conservation presentations in schools and works with teachers to continue the program on their own. The city provides coloring books, posters, and videos, as well as "Every Drop Counts," a hands-on water education kit that teachers may borrow.

In the fall of 1999, nearly 800 students and 100 teachers from 17 area schools attended the first annual Children's Water Festival, sponsored in part by the city. Children created a mini-river, purified water from the Rio Grande and built aquifers, among other activities. More than 50 volunteers developed the curriculum based on materials from the National Groundwater Foundation. The city also sponsors live performances by National Theatre, which promote water conservation at local elementary schools each spring.

CASE STUDIES OF WATER UTILITY CONSERVATION PROGRAMS IN NEW MEXICO

INCENTIVE PROGRAMS

About $1.2 million of the Water Conservation Office annual budget is allocated to fund Albuquerque's toilet, xeriscaping, and clothes washer rebate, and audit/retrofit incentive programs.

Toilets

"We tend to focus on outdoor use in the summer," notes Witherspoon. "But indoor use is important and low-flow toilets and fixtures can make a big difference."

Overall, indoor use accounts for 60% of Albuquerque's water consumption and, of that, toilets consume up to 40%. Albuquerque's first rebate program, initiated in 1995, offers single family customers water bill credits of $100 for one toilet, $75 for a second, and $50 for a third. Customers of the rebate program may also replace their showerheads, with an $8 credit applied to their water bill. Owners of multi-family residential units receive a $75 rebate per toilet. Non-residential customers can receive a $75 rebate per toilet, up to 100 toilets per calendar year.

Homeowners are responsible for getting the toilets installed either by themselves or a plumber, but the change-out must be verified by a licensed plumbing contractor. As of June 30, 2000, the conservation program had given rebates for 32,447 toilets at a cost of $2.8 million.

Audits

In conjunction with the toilet rebate, the city also offers free residential audits and retrofitting of homes and apartment complexes. The audit includes a review of water use patterns and billing, leak checks, outdoor landscape and sprinkler assessment, plus installation of 2.5 gallons-per-minute showerheads, high-efficiency faucet aerators, auto-shutoff hose nozzles, and a toilet fill tube diverter or displacement device if needed. In the last four years, the city has conducted 5,500 audits of single-family homes and 10,000 audits of multi-family residences.

Clothes Washers

In September 1999, the city began offering rebates for high-efficiency clothes washers, which use half the water and energy of traditional top-loading washers. As of July 2000, 697 washing machines were rebated at a cost of $100 each. The average age of the replaced machine is 5.3 years, indicating that people are electing to buy new machines even though their old ones are still working.

Xeriscaping

To encourage the conversion of high-water-use turf and plants to water-conserving xeriscapes, the city now offers a water bill credit of $0.25 for every square foot of qualifying landscape—to a maximum rebate of $500 for a single family dwelling and $700 for an apartment building or non-residential customer. Fifty percent of the rebate project area must be covered by low- and medium-water-use plants at maturity, and an inspector must approve the application prior to the commencement of work. By the middle of 2000, the program had fielded 6,200 calls about xeriscaping and had approved 611 plans at a cost of $101,000.

Commercial, Institutional, and Industrial Customers

The conservation office initially focused on residential water use since it accounted for 71% of total water consumption. In the last couple of years, said Witherspoon, the program has shifted more attention to nonresidential customers, since the commercial reductions were lagging behind (an 18%

drop since the program began versus 24% and 28% for residential and institutional customers, respectively).

Nonresidential customers have been targeted with newsletters, mailings, a How to Save Water at Work booklet, and seminars. The city also extended toilet rebates to nonresidential users and began providing free water use audits for businesses, which include calculated payback periods for upgrades in water-use technology. More than 60 companies requested audits following one promotional effort.

The city adopted a Large Users Policy in 1998, and it offers collaborative assistance to Kirtland Air Force Base and the Albuquerque Public Schools. Large users (customers who use an average of over 50,000 gallons per day) must develop and implement a water conservation plan. Approximately half of these customers are apartment complexes.

At a recent water management seminar, national irrigation experts talked with 200 turf managers from golf courses and institutions around the state. The seminar was sponsored by the city in conjunction with the Rio Grande Golf Course Superintendents Association, the New Mexico Irrigation Association and numerous local green industry companies.

CITY INVOLVEMENT

One of the reasons that institutional water use has dropped significantly is that the city has aggressively cut its own water waste. The Water Conservation Office budget contains about $100,000 to match with other city departments' funds to implement conservation measures. Actions taken to date include installing low-flow toilets and fixtures in all senior centers and in nearly 300 public housing units, metering older parks to improve irrigation management, requiring the use of low- and medium-water-use plants in all new city-owned landscapes, converting the Rio Grande Zoo's exhibits to recycled water, and installing a weather sensor that will turn off the Civic Plaza fountain during heavy winds.

Enforcement

The city employs three Water Use Compliance Inspectors who investigate water waste and help customers find ways to water without producing excessive runoff. During 1999, they made 4,801 inspections and issued 462 violations, assessing $23,810 to violators' water bills.

GOOD NEWS, BAD NEWS

In spite of all these conservation efforts, Albuquerque's water use during the first half of 2000 rose to about 210 gallons per capita per day (gpcd) from 204 gpcd in 1999, due largely to unusually hot, dry weather. But that's much better than the almost 40 gpcd increase experienced in 1989, a very dry year that preceded the adoption of the conservation program. Moreover, Witherspoon thinks the overall downward trend will continue to the 175 gpcd goal as increased xeriscaping diminishes exterior water demand during the summer months.

In addition to the ongoing conservation efforts, there are several projects underway to increase the water supply through recycling and other means:

- Collect wastewater from industry to supply process water to neighboring industries and irrigation water for the Balloon Fiesta Field and city parks.

- Treat municipal wastewater effluent and pipe it to the golf course at the University of New Mexico and Public Service Company of New Mexico generation facility for irrigation.

- Inject excess treated water into the aquifer and then pump out the same amount at a later time when the water is needed—during droughts for example, or to meet peak demand in summer. (As allowed by the Groundwater Storage and Recovery Act, passed by the State Legislature in 1999.)

- Construction of the San Juan-Chama River Project. In the 1960s, the city purchased 48,200 acre-feet of San Juan-Chama water, which comes from southwestern Colorado to the Rio Grande Basin through 26 miles of tunnels. When completed in 2004, this project will allow the city to divert 94,000 acre-feet/year, half of which will be treated and returned to the river after use.

Even then, the conservation job will not be over. "We have to keep the water conservation issue in front of people," said Witherspoon. "We're never going to be able to go back to the higher usage levels where we started. This is not a short-term program. It's not going to go away, and I'm not sure everyone understands this is a permanent problem."

TIPS FROM ALBUQUERQUE

Even without Albuquerque's resources, Jean Witherspoon, Water Conservation Officer, said there's much that other municipalities can do:

- **Water bill inserts** are an inexpensive way to get the conservation word out. Print black ink on colored paper to get their attention. Keep the message simple.
- **Work with kids.** Talk to kids in their school classrooms. Kids are more receptive to new ideas about water conservation than adults. They're the future, and this is a long- term issue.
- **Give awards and incentives** for those who conserve water, which encourages other people to conserve too.
- **Get media attention** by informing them of conservation programs and awards.
- **Adjust rates to discourage water waste.** This is a tool available to everyone. (Having just a feel-good program will result in some conservation progress, but not enough.)
- **Learn what worked for other cities with similar climates.** Much of Albuquerque's success is due to learning what worked for Tucson and El Paso.
- **Use materials from other cities and sources**, including the Office of the State Engineer. The conservation community is open to using materials developed by other groups. For example, anyone may modify or reproduce Albuquerque's material as long as credit is given to the city.
- **Be fair.** Make sure you spread the program over the whole customer base (not just residential or large users), and understand who is using the water.
- **Get information about your water source.** Ask the U.S. Bureau of Reclamation, the U.S. Corps of Engineers, USGS or local university for help in understanding the water source. This is not necessarily inexpensive. Albuquerque paid for part of the USGS effort to better understand its aquifer.
- **Reduce water use by city facilities.** There has to be an internal effort as well as an external one.
- **Realize this is a long-term issue.** Don't get too excited by early success. Keep spreading the conservation message.

CASE STUDIES OF WATER UTILITY CONSERVATION PROGRAMS IN NEW MEXICO

LAS CRUCES

Population: 83,000
Water Source: Mesilla Bolson Aquifer

Las Cruces, the second largest city in New Mexico, is located in the south-central part of the state in the foothills of the Organ Mountains. Like many municipalities, Las Cruces passed a water conservation ordinance in 1996 in part to satisfy the requirements for applying for new water rights. The mandatory ordinance requires customers to water according to an odd/even address schedule and, from April 1 to September 30, to water before 10:00 a.m. or after 6:00 p.m. Cars must be washed with a bucket or shut-off hose, or in a commercial facility. Water waste is prohibited.

Since the ordinance went into effect, water use has decreased by 3%, according to Gilbert Morales, Director of Water Resources. Morales also notes that, during the peak days in the summer months, the utility now relies less on the more costly and poorer quality wells. He believes that the city's inclining block rate structure is the strongest deterrent to water waste.

Dan Santantonio, Regulatory Compliance Officer, equates changing perceptions about water conservation to changing attitudes towards litter in the past. "It takes a while to sensitize the public to the need," he said.

Another difficulty that Las Cruces faces is that the city doesn't have one person whose sole job is to coordinate the city's water conservation program (the city's Water Resources Director is also the water conservation officer). "In a municipal government, having a sole focus is what it takes to get things to happen at an operational level," said Santantonio. "When people are doing a little here and there in their spare time, nothing significant happens."

Public Information and Education

On the public education front, the city sends out public service announcements (PSAs) and news releases in the spring and summer months reminding people that the conservation ordinance is in effect. Catherine Lazorko, public information officer, also writes newspaper columns and produces radio and TV spots encouraging conservation. She produces three radio segments on water conservation which air about three to four times a week during June and July on four stations, at a total cost of $1,600 (including production). The TV PSAs air on the public television station at no charge. Lazorko is currently approaching the commercial TV market as well.

"I've seen four-color glossy calendars talking about water conservation," she notes. "Not every city has that kind of money, and distribution is key. A lot of the things we're doing don't cost that much." For example, she appears on a local talk radio show to discuss water conservation and other city issues. And for about $600 she prints one-sided, one-color utility stuffer flyers, which go out to 40,000 households. The flyers invite residents to pick up additional information on xeriscaping and other issues at the city's public information office. Lazorko usually orders a print overrun of the flyers, so she can give the extra flyers to the commercial service that welcomes new residents to Las Cruces.

In 1999, the utility developed a trade show display on water, which it exhibits with pamphlets and flyers at the county fair, the National Water Festival, and economic development fairs.

The city has offered free water audit survey kits and water conservation information to water customers. Many city buildings have been xeriscaped, and the city maintains a xeriscape demonstration garden at City Hall and has developed xeriscaping brochures. Through its Keep Las Cruces Beautiful program, the city and the Mesilla Valley Landscape Association have sponsored quarterly xeriscape awards.

Schools

The city received a grant from the U.S. Bureau of Reclamation for a pilot program introducing the National Energy Foundation's "Learning to be Water Wise" curriculum to nearly 300 fourth graders. As part of this program, the children measured water flow in their own homes and, with the help of their parents, installed low-flow devices. According to Santantonio, this is precisely the kind of activity that kids will remember. "You need to connect water conservation information to an activity, something tangible, if the message is going to be reinforced."

Unfortunately, the city did not receive a grant to continue the program. Given the funds, however, Santantonio ranks education first in conservation priorities. He envisions a program in which water conservation is integrated into the fourth- and fifth-grade science, history, social studies, and math curriculum, and students visit water facilities to understand the city system as a whole. "You'll end up with a better educated public who can soundly address water problems in the future," he said.

> ***"If people had to pay what water is really worth, or if they had to carry their water from a truck, water conservation would be a whole lot easier."***
>
> *—Dan Santantonio,*
> *Regulatory Compliance Officer*

CASE STUDIES OF WATER UTILITY CONSERVATION PROGRAMS IN NEW MEXICO

SANTA FE

Population: 70,000
Water Source: Santa Fe River (40%) and wells (60%)

When it came to water, 2000 was a tough year for New Mexico's capital and tourist hot spot. With its reservoirs down to as low as 19%, Santa Fe declared its first Stage 2 drought emergency in June and its first Stage 3 drought emergency in August. The State 3 alert limited landscape watering to once a week.

Fortunately, even before the drought, the city of Santa Fe was actively working to reduce water demand. From 1995 to 1999, consumption dropped 21% (on a population-adjusted basis) to 143 gallons per capita per day. Still, city planners know that increasing demand caused by population increases will require the development of new sources of water in addition to continued conservation measures, which is why the city has published a comprehensive 40-year water plan.

Legislation

Four stages of water restrictions are outlined in a water conservation ordinance adopted by the Santa Fe City Council on June 25, 1997. Each of the stages is tied to projected shortages of water. Besides containing indoor and outdoor water use provisions, the ordinance authorizes conservation rebates and water surcharges from May through October.

"Consumption normally drops 25% when the ordinance and surcharges kick in," noted Edwin Lovato, Ordinance Enforcement Specialist at Sangre De Cristo Water Division, the city's water company. "Most of the reduction has come from less watering of landscapes by all customers and all kinds of water use reductions by residential customers." Residential use accounts for about 50% of total consumption and landscaping consumes about 50-60% of the residential total.

During its normal, voluntary Stage 1 period in the summer of 2000, Santa Fe used about 13 million gallons per day on average. With the mandatory restrictions of Stage 2 and 3, the city's use fell to about 10 million gallons per day on average (down about 23%), with a low of 8 million gallons per day (a 38% decrease). Lovato attributes the steep drops in use during Stages 2 and 3 to a cooperative public that takes conservation seriously.

Public and School Education

On a recent visit to another city, Lovato noticed a considerable amount of wasted water. "It is so sad to see people watering the street," he said. "It's very crucial to have people out in the field educating the public." In fact, Lovato estimates that education accounts for about 80% of his job.

The water utility offers water conservation tips and ordinance information through its website and in billing inserts. It also produces and runs weekly conservation advertisements in the newspaper, and during the drought made daily radio announcements. Twelve different conservation pamphlets are distributed from racks in government buildings throughout the city and at local plant nurseries.

There are several public xeriscape demonstration gardens and the utility provides a list of nurseries, landscapers, and non-profit organizations that offer free xeriscape advice. The city also offers xeriscape/irrigation efficiency training workshops. Local nurseries and landscape contractors are required to provide low-water-use landscape and irrigation literature to all customers purchasing perennial plants. Water conservation literature is also given to real estate buyers, to new water customers and to building permit applicants.

The city offers presentations to businesses and other groups such as hotel/motel associations and the Chamber of Commerce. It hosts field trips to the watershed, which, from 1932 until last year, was closed to public visits. Lovato said the city, worried about fire, has opened the watershed to guided tours in order to educate and elicit support from people—especially environmental groups—about the need to thin the forest.

Stage 2 restrictions require hotels and other lodging facilities to mention conservation at the time of check-in and to display a sign offering the option of not having towels and linens changed for multiple-night stays. It also calls for the posting of city water shortage announcements in all public restrooms and showers and in all commercial establishments. Restaurants may serve water only upon request and many establishments provide table tents explaining the restrictions.

"Public outreach really helped a lot," notes Lovato. "It gets everybody on the same program." When Stage 2 was implemented, the water waste hotline received about 20 to 30 calls a day, up from the typical 10 calls per day.

Santa Fe doesn't have any rebate programs, but it does offer free audits for residential customers, providing leak checks, conservation kits, showerheads, aerators and toilet dams for high-volume tanks, as well as an analysis of outdoor irrigation systems at no charge. The utility also conducts free audits for commercial facilities including apartment houses, but no longer provides fixtures.

According to the Winter 1998 *Conservation Current,* a newsletter published by the New Mexico Water Conservation Alliance:

> "...the city initiated a water conservation survey and retrofit program focusing on multi-family housing units such as apartments and condominiums. The utility staff discusses each apartment complex's historic water use and provides retrofit hardware and a sample letter to notify residents about the retrofit. Previously the materials were offered at cost, but this proved to be a barrier to proactive participation, so now they are now distributed at no charge, causing a substantial increase in participation. One of the byproducts of this program is that conservation staff were able to help update utility billing information."

Lovato stresses the importance of getting the conservation message to young people, especially in elementary schools. "It's up to them to educate their parents," he said. "Many parents both work. They're tired. They don't have the time or energy to think about conservation. The kids are a way to reach them. So public education is a big effort for us."

Lovato gives presentations on Santa Fe's water system in both public and private schools. For children in elementary school through junior high, he provides Hands on Learning's water education kits that have been customized to reflect Santa Fe's population and water sources. The city also offers a one-day training program for teachers who want to use the water kits. Lovato sends out a press release each conservation season alerting teachers to the availability of the kits and his presentations.

In 1993, a volunteer conservation group received funding from the U.S. Bureau of Reclamation and the Office of the State Engineer to develop a children's booklet explaining aquifers and water use. The group distributed the booklet and visited elementary schools and the Santa Fe Children's Museum.

Enforcement

Before the water emergency of 2000, Lovato was the only enforcement officer, issuing perhaps 200 to 300 citations in an entire year. With the drought, the city put together an eight-person enforcement team which included some employees from other city departments. In the month after Stage 2 was declared, the team issued up to 400 citations. For the first week and a half, violators received only warnings. Thereafter, citations and fines were issued.

The division sent out letters about Stage 2 and Stage 3 water restrictions and made follow-up calls to motels and hotels in the tourist-centered city. Most were already in a conservation mode from the surcharges levied in Stage 1. "They had already cut down on towel and linen washing and already had low-flow fixtures," he said. "There's not much more they can do."

Moving from Stage 2 to Stage 3 was more difficult at first, especially for nurseries and landscaping businesses—particularly since new landscaping was prohibited. After a few weeks, Lovato said most water customers were complying with the ordinance. "I could finally sleep at night and not dream about giving out citations," he said.

Long-Term Strategies

The drought years of 1996 and 2000 have been wake-up calls for city planners. In order to meet ever-growing demand, Santa Fe is developing a 40-year water management plan designed to ensure a sustainable supply of water. The city is working on a number of strategies including:

- Diverting 5,605 acre-feet of water from the San Juan-Chama Project through horizontal collector wells near the Rio Grande. A $8-15 million test gallery completed in the fall of 2000 will provide information about water quality;
- Returning treated effluent to the Rio Grande, enabling the city to fully utilize its existing San Juan-Chama contract water. Adding reclaimed water to the Santa Fe River will help recharge the aquifer. About 60% of water used by the city reaches the treatment plant;
- Continuing (and possibly expanding) the reclaimed water program to include irrigating landscaping with treated effluent;
- Combining surface water and groundwater rights so that surface water can be maximized during wet years, preserving groundwater for meeting peak-season demands and supplying a larger portion of Santa Fe's needs during periods of drought;
- Continuing rehabilitation of groundwater wells to increase their capacity;
- Restricting new domestic wells in the vicinity of the service area and connecting up to 50% of the population now serviced by domestic wells in a proposed urban area.

CASE STUDIES OF WATER UTILITY CONSERVATION PROGRAMS IN NEW MEXICO

ALAMOGORDO

Population: 30,000
Water Source: 74% surface, 26% wells

Unlike most other New Mexico cities, Alamogordo harvests the majority of its water from an extensive and far-flung network of springs. This not only leaves the city vulnerable to changes in rainfall and snowfall, but it also requires substantial investments in its water collection system.

In the past few years, the Department of Public Works has revitalized the aging system, replacing corroded spring boxes with plastic devices and improving the efficiency of French drains, among other things, according to director Jose Miramontes.

The department is also working to minimize losses. In 1999, the city covered and lined two of its three raw storage reservoirs with plastic to prevent evaporation and percolation. After work on the third reservoir is completed, Miramontes expects to save about 100 million gallons a year. "Where we live, that's very significant," he said. These improvements are financed by the gross receipt tax. The city also saves water by irrigating city parks and baseball fields with effluent water.

On the legislative side, Alamogordo passed a mandatory water conservation ordinance in 1995. When daylight savings time is in effect, landscape watering is restricted to three days a week before 10 a.m. and after 6 p.m. Wasting water, prolonged leaks, and washing cars with a free-flowing hose is prohibited, as are evaporative cooler bleeder lines that are routed to the sewer system when they could be used to water plants. The ordinance also contains stages of water rationing that are triggered by low reservoir levels.

"Most people follow the ordinance," said Susan Flores, Executive Assistant to the City Manager. "It's not too much of a problem." When violations do occur, they're usually for watering in the middle of the day or on Monday, which is prohibited. The second most frequent area requiring enforcement, said Flores, is repair of evaporative cooler systems when runoff is occurring. Enforcement is handled by the Code Administration Division during regular working hours and by the Department of Public Safety during non-regular business hours. Enforcement can include citations or court summons. Penalties are up to $500 and 90 days in jail.

While Alamogordo doesn't have a stand-alone conservation program, Flores is able to promote water conservation through the "Keep Alamogordo Beautiful" campaign, funded by the State of New Mexico Highway and Transportation Department. The city hands out conservation literature at Earth Day and Arbor Day celebrations and offers a free xeriscape seminar. Using Keep Alamogordo Beautiful volunteers, the city built an 18,000-square-foot xeriscaping demonstration garden in August 1999.

The city runs free public service announcements on radio and on a weekly community page in the newspaper during the conservation season. It also puts water conservation messages in two issues of the quarterly city newspaper. Flores noted that they no longer send flyers out with utility bills because she says most people just throw them out without reading them. She said that the city spends about $500 for printing restaurant table tents and $100 for Earth Day flyers.

Miramontes underscored the importance of public education, especially xeriscaping. “Like most communities we struggle with the need to conserve resources while maintaining enough revenues to operate,” he said. “If you make big dents in water conservation then you have to increase rates, and there’s a lot of resistance to that. It’s going to take a lot of public education to change attitudes and that takes political will.”

Alamogordo’s Water Use (gallons per capita per day)

	Includes loss	Loss taken out	Loss after treatment*
1999	219	182	16.6%
1998	216	183.6	15%
1997	194	171	11.7%
1996	201	180	10.4%

** Losses due to water breaks, fire fighting, flushing hydrants*

NOTE: Total water treated in 1999: 2.4 billion gallons. Summer water use is 1.6 times that of winter use.

CASE STUDIES OF WATER UTILITY CONSERVATION PROGRAMS IN NEW MEXICO

GALLUP

Population: 21,000
Water source: Gallup Sandstone and Dakota West Water Formation Aquifers

Made famous by Nat King Cole's Route 66, Gallup's number one industry is tourism. Each year, thousands of visitors come to the city to buy original Native American arts, crafts, and silver jewelry from people living on the surrounding reservations. Gallup's portion of the world's trade in these goods is a staggering 75 percent.

A less publicized but equally admirable feature of Gallup was its 154 gallons per capita per day (gpcd) water consumption in 1998. Even though the city has a high percentage of old homes, its residential indoor consumption is a lower-than-average 64.5 gpcd—an amount approaching the OSE benchmark of 55.8 gpcd for highly efficient households. While residential customers account for 50 to 60% of water use in most communities, Gallup residents consume only 35% of municipal water even though they represent 79% of all water customers.

"Gallup's climate is the single largest reason for our low residential use," noted Lance Allgood, Water Systems Superintendent at Gallup Joint Utilities. Gallup sits on a high desert plateau. The city's low rainfall and temperature extremes make growing grass very difficult. As a result many people don't even try to grow lawns and are more receptive to native landscaping, said Allgood. This may also account for Gallup's relatively low seasonal peaking factor of 1.38 (as compared to 2.5 for Albuquerque, for example).

Ordinances

Many of Gallup's conservation efforts, including its water ordinance, were precipitated by a series of water shortages. From 1950 to 1980, Gallup's population doubled in size and its water consumption increased almost sixfold. In the 1970s, the shortages were so severe the city drilled emergency wells and nearly ran out of water during the peak summer months. Gallup passed conservation and water waste ordinances in 1983. The mandatory year-round ordinance prohibits watering that results in ponding or wasted flow; washing of hard-surfaced areas; the use of non-recirculating water in fountains and ponds, new car wash systems, and industrial laundry systems; and the use of water for construction activities. Under emergency conditions, the City Manager may limit irrigation times, prohibit irrigation, impose a water rate surcharge, and declare a temporary moratorium on any new development including lawn installations.

Rates

Conservation has also been abetted by the utility's inclining rate structure, in effect since the early 1990s. Allgood thinks this is the most effective means of conserving. He notes that water production fell 8.6 percent to 1.2 billion gallons in 1999 when a significant rate increase was instituted mid-year. Rate increases are most effective, he says, if they are coupled with public education. To that end, the utility sends out conservation information to its customers in April and May just before the peak usage season. Throughout the year, the city provides pamphlets on xeriscaping, irrigation, and indoor conservation developed by the American Water Works Association and the Office of the State Engineer. The water department also makes informational presentations at public schools upon request.

In 1983, Gallup was one of several New Mexican communities that participated in a public education program funded by ACTION, the federal volunteer service agency and the U.S. Department of Energy. Thousands of water conservation kits containing brochures and water-saving devices were distributed. The Gallup project, which cost an estimated $1.00 per 1,000 gallons of water saved per person per year, helped drop water consumption from 160 gpcd to 150 gpcd, according to the Environmental Protection Agency's Office of Water.

Commercial Users

Of the utility's 5,746 accounts in 1998, 20 percent were commercial customers who were responsible for about 62 percent of demand. Allgood said the utility has made some attempt at reducing commercial use through its rate structure and ordinance. In 2000, Gallup revised its conservation ordinance to ban single-pass cooling systems in new or retrofitted establishments. At one time the city offered conservation signs for hotels, but there is no mandate on linen and towel washing. Even if there were, Allgood thinks enforcement would be nearly impossible. "We do not have the staff to institute a real intensive program in the commercial sector," he said.

Allgood also said that water concerns have limited growth in the city. "High-water-use industries haven't located here because of the limited water supply and the expense of treating water to their standards," he said.

Recycling

Gallup reuses sewage effluent to irrigate a golf course and two sports facilities, saving an estimated 264 million gallons over three years (1998-2000). It also delivers an estimated 1.7 million gallons of nonpotable water per year to irrigation systems on medians and landscapes in 25 locations.

Goals for the future

"Reuse is the strategy of the future," said Allgood, who is investigating aquifer storage and recovery in the city's wastewater treatment plan. The technology is available, but there are regulatory and, more significantly, public education hurdles to overcome. "It's hard to get people to realize that the water is okay to drink—whether the treatment is done by us or by nature," he said. Funding is also a concern. Most conservation grants are geared towards developing conservation plans instead of offering implementation money.

Other goals include the following items:

- Improve the municipal wastewater system by increasing treatment and hydraulic capacity. (A $30 million project is now being considered.)
- Improve residential irrigation conservation. "We believe we can further reduce our seasonal as well as average residential use through a combination of a seasonal rate increase and increased enforcement of existing conservation ordinances," said Allgood.
- Promote conservation by emphasizing that it reduces the money required for wastewater treatment, and implement a more formal and comprehensive program.

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SCS Modified Blaney-Cridde Crop Coefficients (Kc) for Tall Fescue in New Mexico.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
0.50	0.67	1.02	1.35	1.30	1.26	0.99	0.80	0.77	1.03	0.90	0.77	0.50

Based on 1998-99 ET data from the Farmington Ag Science Center. No data was recorded for November, December, January. Thus the Kc values shown for these months are speculative but reflect seasonal patterns observed in other states such as *Blaney-Criddle Coefficients for Western Turfgrasses by Borelli, ASCE, 1981.* Prepared by B. C. Wilson, P.E., New Mexico, Office of the State Engineer, 05/23/2000.

APPENDIX A

Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Abiquiu	ET				2.68	4.97	7.01	6.70	4.67	3.11	2.47	0.05		31.66
Abiquiu	Re				0.28	0.56	0.54	1.41	1.43	0.80	0.62	0.02		5.66
Abiquiu	CIR				2.41	4.40	6.47	5.29	3.25	2.31	1.85	0.04		26.02
Abiquiu	FDR				4.82	8.8	12.94	10.58	6.5	4.62	3.7	0.08		52.04
Alamogordo	ET		0.91	2.65	5.35	7.75	10.03	8.38	6.04	4.42	3.85	1.75	0.20	51.33
Alamogordo	Re		0.28	0.35	0.14	0.35	0.78	1.97	1.71	1.21	0.83	0.26	0.07	7.95
Alamogordo	CIR		0.63	2.30	5.21	7.40	9.25	6.41	4.34	3.21	3.02	1.49	0.14	43.40
Alamogordo	FDR		1.26	4.60	10.42	14.80	18.50	12.82	8.68	6.42	6.04	2.98	0.28	86.80
Albuquerque	ET			1.34	4.18	6.54	8.97	8.11	5.74	3.93	3.17	0.53		42.51
Albuquerque	Re			0.23	0.28	0.37	0.48	1.20	1.21	0.63	0.61	0.09		5.10
Albuquerque	CIR			1.12	3.91	6.17	8.49	6.90	4.52	3.30	2.56	0.44		37.41
Albuquerque	FDR			2.24	7.82	12.34	16.98	13.80	9.04	6.60	5.12	0.88		74.82
Acalde	ET			0.19	3.24	5.09	7.02	6.76	4.72	3.11	2.49	0.06		32.68
Acalde	Re			0.03	0.26	0.55	0.62	1.14	1.36	0.79	0.62	0.03		5.40
Acalde	CIR			0.16	2.98	4.54	6.40	5.61	3.36	2.32	1.87	0.04		27.28
Acalde	FDR			0.32	5.96	9.08	12.80	11.22	6.72	4.64	3.74	0.08		54.56
Animas	ET		0.73	2.55	4.93	7.12	9.28	8.13	5.78	4.25	3.83	1.71	0.14	48.45
Animas	Re		0.23	0.35	0.11	0.06	0.43	1.78	1.78	1.06	0.66	0.31	0.07	6.84
Animas	CIR		0.50	2.19	4.82	7.06	8.85	6.35	4.00	3.18	3.17	1.39	0.07	41.58
Animas	FDR		1.00	4.38	9.64	14.12	17.70	12.70	8.00	6.36	6.34	2.78	0.14	83.16
Artesia	ET		0.45	2.53	5.31	7.66	9.74	8.38	6.10	4.28	3.72	1.65	0.03	49.85
Artesia	Re		0.11	0.24	0.26	0.84	1.18	1.43	1.44	1.32	0.91	0.23	0.01	7.97
Artesia	CIR		0.34	2.30	5.05	6.82	8.56	6.94	4.66	2.97	2.81	1.42	0.03	41.90
Artesia	FDR		0.68	4.60	10.10	13.64	17.12	13.88	9.32	5.94	5.62	2.84	0.06	83.80

ET is evapotranspiration; Re is effective rainfall; CIR is the consumptive irrigation requirement (ET-Re); and FDR is the field delivery requirement assuming an irrigation efficiency of 50%. Prepared by B. C. Wilson, P.E. New Mexico Office of the State Engineer, 05/25/2000.

Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Aztec Ruins	ET			0.10	3.20	5.22	7.33	7.30	5.08	3.36	2.62	0.09		34.30
Aztec Ruins	Re			0.03	0.45	0.38	0.21	0.80	0.87	0.60	0.87	0.04		4.25
Aztec Ruins	CIR			0.07	2.75	4.84	7.12	6.49	4.20	2.76	1.75	0.05		30.03
Aztec Ruins	FDR			0.14	5.50	9.68	14.24	12.98	8.40	5.52	3.50	0.10		60.06
Bell Ranch	ET			1.40	4.30	6.66	8.88	8.01	5.74	3.91	3.24	0.70		42.84
Bell Ranch	Re			0.21	0.53	1.12	1.32	2.48	1.98	0.97	0.72	0.16		9.49
Bell Ranch	CIR			1.19	3.77	5.54	7.56	5.52	3.76	2.94	2.52	0.54		33.34
Bell Ranch	FDR			2.38	7.54	11.08	15.12	11.04	7.52	5.88	5.04	1.08		66.68
Bernalillo	ET			1.05	3.89	5.99	8.10	7.66	5.38	3.61	2.92	0.36		38.96
Bernalillo	Re			0.21	0.30	0.49	0.53	1.36	1.30	0.60	0.70	0.09		5.58
Bernalillo	CIR			0.84	3.59	5.50	7.57	6.30	4.08	3.01	2.22	0.27		33.38
Bernalillo	FDR			1.68	7.18	11.00	15.14	12.60	8.16	6.02	4.44	0.54		66.76
Bloomfield	ET			0.36	3.49	5.72	8.07	7.67	5.34	3.60	2.78	0.18		37.21
Bloomfield	Re			0.09	0.39	0.31	0.21	0.89	1.01	0.60	0.80	0.07		4.37
Bloomfield	CIR			0.27	3.10	5.41	7.86	6.78	4.33	3.00	1.98	0.11		32.84
Bloomfield	FDR			0.54	6.20	10.82	15.72	13.56	8.66	6.00	3.96	0.22		65.68
Bosque del Apache	ET		0.09	2.23	4.55	6.72	8.77	7.97	5.64	3.91	3.30	0.81		43.99
Bosque del Apache	Re		0.01	0.20	0.17	0.38	0.62	1.20	1.30	0.97	0.71	0.10		5.66
Bosque del Apache	CIR		0.07	2.03	4.38	6.34	8.15	6.76	4.35	2.95	2.59	0.71		38.33
Bosque del Apache	FDR		0.14	4.06	8.76	12.68	16.30	13.52	8.70	5.90	5.18	1.42		76.66
Caballo Dam	ET		0.57	2.50	5.02	7.23	9.51	8.47	6.06	4.33	3.71	1.71	0.05	49.16
Caballo Dam	Re		0.09	0.14	0.08	0.20	0.50	1.64	1.56	1.07	0.65	0.19	0.02	6.14
Caballo Dam	CIR		0.48	2.36	4.94	7.03	9.01	6.83	4.51	3.26	3.06	1.52	0.04	43.04
Caballo Dam	FDR		0.96	4.72	9.88	14.06	18.02	13.66	9.02	6.52	6.12	3.04	0.08	86.08

ET is evapotranspiration; Re is effective rainfall; CIR is the consumptive irrigation requirement (ET-Re); and FDR is the field delivery requirement assuming an irrigation efficiency of 50%. Prepared by B. C. Wilson, P.E. New Mexico Office of the State Engineer, 05/25/2000.

APPENDIX A

Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Carlsbad	ET	0.08	1.12	2.91	5.96	8.46	10.53	8.91	6.48	4.58	4.04	1.83	0.43	55.33
Carlsbad	Re	0.02	0.19	0.20	0.30	0.89	0.71	1.62	1.55	1.58	0.86	0.27	0.05	8.24
Carlsbad	CIR	0.06	0.92	2.71	5.66	7.58	9.82	7.29	4.93	3.00	3.18	1.56	0.38	47.09
Carlsbad	FDR	0.12	1.84	5.42	11.32	15.16	19.64	14.58	9.86	6.00	6.36	3.12	0.76	94.18
Carrizozo	ET			1.44	4.13	6.26	8.44	7.43	5.22	3.69	3.06	0.57		40.24
Carrizozo	Re			0.30	0.25	0.52	0.79	1.93	1.91	1.31	0.73	0.17		7.91
Carrizozo	CIR			1.14	3.88	5.73	7.65	5.50	3.31	2.38	2.34	0.41		32.34
Carrizozo	FDR			2.28	7.66	11.46	15.30	11.00	6.62	4.76	4.68	0.82		64.58
Cerro	ET				0.72	3.84	5.68	5.49	3.80	2.58	1.34			23.45
Cerro	Re				0.13	0.71	0.69	1.49	1.35	0.74	0.47			5.58
Cerro	CIR				0.59	3.13	4.98	4.00	2.46	1.84	0.87			17.87
Cerro	FDR				1.18	6.26	9.96	8.00	4.92	3.68	1.74			35.74
Chaco Canyon	ET				2.18	4.71	6.82	6.79	4.75	3.08	2.12			30.45
Chaco Canyon	Re				0.17	0.43	0.31	0.95	1.03	0.74	0.69			4.32
Chaco Canyon	CIR				2.01	4.28	6.51	5.84	3.72	2.34	1.43			26.13
Chaco Canyon	FDR				4.02	8.56	13.02	11.68	7.44	4.68	2.86			52.26
Chama	ET					3.18	5.00	5.07	3.50	2.30	1.01			20.06
Chama	Re					0.75	0.62	1.53	1.77	1.12	0.58			6.37
Chama	CIR					2.43	4.38	3.54	1.73	1.18	0.43			13.69
Chama	FDR					4.86	8.76	7.08	3.46	2.36	0.86			27.38
Cimarron	ET				2.52	4.73	6.59	6.02	4.23	2.92	2.46	0.06		29.53
Cimarron	Re				0.57	1.52	1.36	2.22	1.88	1.02	0.73	0.03		9.33
Cimarron	CIR				1.95	3.21	5.23	3.80	2.35	1.91	1.73	0.04		20.22
Cimarron	FDR				3.90	6.42	10.46	7.60	4.70	3.82	3.46	0.08		40.44

ET is evapotranspiration; Re is effective rainfall; CIR is the consumptive irrigation requirement (ET-Re); and FDR is the field delivery requirement assuming an irrigation efficiency of 50%. Prepared by B. C. Wilson, P.E. New Mexico Office of the State Engineer, 05/25/2000.

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Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Clayton	ET			0.23	3.46	5.56	7.76	7.15	5.09	3.38	2.80	0.26		35.69
Clayton	Re			0.06	0.76	1.72	1.55	2.10	1.81	1.04	0.52	0.07		9.63
Clayton	CIR			0.17	2.70	3.84	6.21	5.05	3.29	2.34	2.28	0.19		26.07
Clayton	FDR			0.34	5.40	7.68	12.42	10.10	6.58	4.68	4.56	0.38		52.14
Cliff	ET			1.69	3.96	5.92	8.11	7.56	5.35	3.83	3.20	0.89		40.51
Cliff	Re			0.48	0.20	0.09	0.45	2.26	2.18	1.08	0.85	0.22		7.81
Cliff	CIR			1.21	3.76	5.83	7.66	5.30	3.17	2.75	2.35	0.67		32.70
Cliff	FDR			2.42	7.52	11.66	15.32	10.60	6.34	5.50	4.70	1.34		65.40
Cloudcroft	ET				0.78	3.67	5.09	4.27	3.10	2.28	1.39			20.58
Cloudcroft	Re				0.16	0.70	1.42	3.53	2.94	1.78	0.70			11.23
Cloudcroft	CIR				0.62	2.97	3.67	0.74	0.16	0.50	0.68			9.34
Cloudcroft	FDR				1.24	5.94	7.34	1.48	0.32	1.00	1.36			18.68
Clovis	ET			1.65	4.41	6.68	8.77	7.73	5.56	3.85	3.28	0.93		42.86
Clovis	Re			0.31	0.63	1.51	2.25	2.37	2.03	1.33	1.02	0.24		11.69
Clovis	CIR			1.34	3.78	5.17	6.51	5.36	3.53	2.52	2.26	0.70		31.17
Clovis	FDR			2.68	7.56	10.34	13.02	10.72	7.06	5.04	4.52	1.40		62.34
Cuba	ET				0.89	4.03	5.95	5.97	4.14	2.73	1.58			25.29
Cuba	Re				0.16	0.59	0.51	1.73	1.64	0.90	0.59			6.12
Cuba	CIR				0.74	3.44	5.43	4.24	2.49	1.83	0.99			19.16
Cuba	FDR				1.48	6.88	10.86	8.48	4.98	3.66	1.98			38.32
Deming	ET		0.67	2.50	4.79	7.03	9.40	8.28	5.99	4.33	3.76	1.70	0.08	48.53
Deming	Re		0.20	0.27	0.14	0.13	0.40	1.70	1.37	1.01	0.56	0.25	0.03	6.06
Deming	CIR		0.46	2.23	4.65	6.90	8.99	6.59	4.62	3.32	3.20	1.44	0.05	42.45
Deming	FDR		0.92	4.46	9.30	13.80	17.98	13.18	9.24	6.64	6.40	2.88	0.10	84.90

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Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Des Moines	ET				2.14	4.71	6.77	6.33	4.46	3.02	2.36			29.79
Des Moines	Re				0.53	1.75	1.42	2.70	1.97	1.25	0.68			10.30
Des Moines	CIR				1.62	2.96	5.35	3.63	2.49	1.77	1.68			19.50
Des Moines	FDR				3.24	5.92	10.70	7.26	4.92	3.54	3.36			38.94
Dilia	ET			0.79	3.65	5.76	8.04	7.15	5.09	3.52	2.92	0.52		37.44
Dilia	Re			0.19	0.54	0.82	0.99	2.08	1.94	1.20	0.80	0.11		8.67
Dilia	CIR			0.60	3.12	4.94	7.05	5.07	3.15	2.32	2.12	0.42		28.79
Dilia	FDR			1.20	6.24	9.88	14.10	10.14	6.30	4.64	4.24	0.84		57.58
Dulce	ET				0.37	3.49	5.09	5.46	3.89	2.49	1.05			21.84
Dulce	Re				0.11	0.81	0.57	1.36	1.69	1.02	0.50			6.06
Dulce	CIR				0.26	2.69	4.52	4.10	2.20	1.46	0.55			15.78
Dulce	FDR				0.52	5.38	9.04	8.20	4.40	2.92	1.10			
Eagle Nest	ET					1.99	4.28	4.20	2.96	1.87	0.21			15.51
Eagle Nest	Re					0.60	0.82	2.01	1.80	0.72	0.07			6.02
Eagle Nest	CIR					1.39	3.45	2.19	1.15	1.15	0.13			9.46
Eagle Nest	FDR					2.78	6.90	4.38	2.30	2.30	0.26			18.92
El Rito	ET				2.16	4.73	5.99	6.07	4.14	2.94	2.56	0.15		28.74
El Rito	Re				0.36	0.79	0.63	1.27	1.42	0.96	0.74	0.05		6.22
El Rito	CIR				1.80	3.94	5.36	4.80	2.72	1.98	1.83	0.10		22.53
El Rito	FDR				3.60	7.88	10.72	9.60	5.44	3.96	3.66	0.20		45.06
El Vado Dam	ET				0.75	3.86	5.48	5.66	3.99	2.55	1.27			23.56
El Vado Dam	Re				0.18	0.72	0.64	1.41	1.55	1.03	0.50			6.03
El Vado Dam	CIR				0.57	3.15	4.85	4.24	2.44	1.52	0.77			17.54
El Vado Dam	FDR				1.14	6.30	9.70	8.48	4.88	3.04	1.54			35.08

ET is evapotranspiration; Re is effective rainfall; CIR is the consumptive irrigation requirement (ET-Re); and FDR is the field delivery requirement assuming an irrigation efficiency of 50%. Prepared by B. C. Wilson, P.E. New Mexico Office of the State Engineer, 05/25/2000.

Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Elk	ET			1.12	3.72	5.52	7.12	6.13	4.44	3.16	2.80	0.62		34.63
Elk	Re			0.15	0.41	0.77	1.15	2.08	2.42	1.72	0.91	0.16		9.77
Elk	CIR			0.97	3.32	4.75	5.97	4.05	2.02	1.44	1.90	0.45		24.87
Elk	FDR			1.94	6.64	9.50	11.94	8.10	4.04	2.88	3.80	0.90		49.74
Espanola	ET			0.28	3.48	5.40	7.37	6.77	4.83	3.31	2.44			33.88
Espanola	Re			0.06	0.46	0.76	0.50	1.19	1.23	0.59	0.71			5.50
Espanola	CIR			0.22	3.02	4.64	6.87	5.58	3.60	2.72	1.73			28.38
Espanola	FDR			0.44	6.04	9.28	13.74	11.16	7.20	5.44	3.46			56.76
Estancia	ET			0.09	3.11	5.02	6.95	6.47	4.52	3.04	2.43	0.04		31.67
Estancia	Re			0.02	0.35	0.66	0.63	1.6	1.73	0.89	0.79	0.01		6.68
Estancia	CIR			0.07	2.75	4.36	6.32	4.87	2.79	2.15	1.64	0.03		24.98
Estancia	FDR			0.14	5.5	8.72	12.64	9.74	5.58	4.3	3.28	0.06		49.96
Farmington	ET			0.13	3.20	5.33	7.45	7.45	5.14	3.35	2.54	0.07		34.66
Farmington	Re			0.03	0.37	0.38	0.30	0.67	0.84	0.67	0.70	0.02		3.98
Farmington	CIR			0.10	2.83	4.96	7.15	6.78	4.30	2.67	1.83	0.05		30.67
Farmington	FDR			0.20	5.66	9.92	14.30	13.56	8.60	5.34	3.66	0.10		61.34
Fort Sumner	ET		0.06	2.18	4.67	6.97	9.14	7.99	5.72	3.94	3.31	1.10		45.08
Fort Sumner	Re		0.01	0.30	0.38	0.88	1.37	2.22	1.86	1.23	0.92	0.21		9.38
Fort Sumner	CIR		0.05	1.88	4.29	6.10	7.78	5.76	3.86	2.71	2.39	0.88		35.70
Fort Sumner	FDR		0.10	3.76	8.58	12.20	15.56	11.52	7.72	5.42	4.78	1.76		71.40
Glenwood	ET		0.37	2.22	4.32	6.02	7.96	7.43	5.34	3.94	3.42	1.57		42.59
Glenwood	Re		0.22	0.69	0.30	0.37	0.57	2.21	1.72	1.13	1.05	0.47		8.73
Glenwood	CIR		0.14	1.53	4.01	5.65	7.39	5.22	3.62	2.81	2.37	1.11		33.85
Glenwood	FDR		0.28	3.06	8.02	11.30	14.78	10.44	7.24	5.62	4.74	2.22		67.70

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Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Grants Airport	ET				2.43	4.69	6.77	6.35	4.43	2.97	2.14			29.78
Grants Airport	Re				0.17	0.34	0.45	1.50	1.53	0.93	0.68			5.60
Grants Airport	CIR				2.26	4.35	6.32	4.85	2.89	2.04	1.45			24.16
Grants Airport	FDR				4.52	8.70	12.64	9.70	5.78	4.08	2.90			48.32
Hatch	ET		0.50	2.51	5.04	7.14	9.26	8.19	5.82	4.14	3.56	1.58		47.74
Hatch	Re		0.10	0.14	0.09	0.19	0.48	1.75	1.74	1.03	0.79	0.22		6.53
Hatch	CIR		0.40	2.36	4.95	6.95	8.78	6.43	4.07	3.11	2.78	1.36		41.19
Hatch	FDR		0.80	4.72	9.90	13.90	17.56	12.86	8.14	6.22	5.56	2.72		82.38
Hillsboro	ET		0.26	2.28	4.51	6.52	8.54	7.47	5.29	3.80	3.26	1.22		43.15
Hillsboro	Re		0.10	0.26	0.20	0.34	0.56	2.02	1.71	1.51	0.76	0.25		7.71
Hillsboro	CIR		0.16	2.02	4.31	6.17	7.98	5.45	3.57	2.29	2.50	0.97		35.42
Hillsboro	FDR		0.32	4.04	8.62	12.34	15.96	10.90	7.14	4.58	5.00	1.94		70.84
Hobbs	ET		1.06	2.78	5.70	7.97	9.83	8.33	6.15	4.44	4.02	1.86	0.54	52.68
Hobbs	Re		0.24	0.34	0.52	1.80	1.50	1.84	1.89	1.70	1.23	0.35	0.08	11.49
Hobbs	CIR		0.82	2.44	5.18	6.18	8.33	6.49	4.26	2.73	2.79	1.52	0.46	41.20
Hobbs	FDR		1.64	4.88	10.36	12.36	16.66	12.98	8.52	5.46	5.58	3.04	0.92	82.40
Jemez Springs	ET			0.24	3.24	5.18	7.19	6.67	4.67	3.28	2.76	0.29		33.52
Jemez Springs	Re			0.09	0.55	0.77	0.79	2.07	2.23	0.85	1.06	0.15		8.56
Jemez Springs	CIR			0.15	2.69	4.41	6.40	4.60	2.45	2.43	1.70	0.14		24.97
Jemez Springs	FDR			0.30	5.38	8.82	12.80	9.20	4.90	4.86	3.40	0.28		49.94
Laguna	ET			0.48	3.48	5.60	7.86	7.16	5.06	3.45	2.80	0.29		36.18
Laguna	Re			0.07	0.18	0.46	0.40	1.42	1.44	0.78	0.78	0.04		5.57
Laguna	CIR			0.41	3.30	5.14	7.46	5.75	3.62	2.67	2.02	0.25		30.62
Laguna	FDR			0.82	6.60	10.28	14.92	11.50	7.24	5.34	4.04	0.50		61.24

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Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Las Vegas Airport	ET				2.01	4.59	6.51	5.89	4.17	2.86	2.32			28.35
Las Vegas Airport	Re				0.34	1.18	1.14	2.42	2.37	1.05	0.74			9.24
Las Vegas Airport	CIR				1.67	3.41	5.36	3.46	1.80	1.81	1.57			19.08
Las Vegas Airport	FDR				3.34	6.82	10.72	6.92	3.60	3.62	3.14			38.16
Lordsburg	ET		0.75	2.53	4.99	7.19	9.63	8.59	6.10	4.44	3.86	1.71	0.10	49.89
Lordsburg	Re		0.25	0.43	0.11	0.10	0.41	1.78	1.74	0.96	0.66	0.25	0.05	6.74
Lordsburg	CIR		0.50	2.11	4.89	7.09	9.22	6.81	4.36	3.48	3.20	1.45	0.05	43.16
Lordsburg	FDR		1.00	4.22	9.78	14.18	18.44	13.62	8.72	6.96	6.40	2.90	0.10	86.32
Los Lunas	ET			1.28	3.92	5.95	8.02	7.48	5.35	3.61	2.90	0.41		38.92
Los Lunas	Re			0.16	0.19	0.32	0.49	0.96	1.36	0.76	0.73	0.06		5.03
Los Lunas	CIR			1.12	3.73	5.63	7.54	6.51	3.99	2.85	2.18	0.35		33.90
Los Lunas	FDR			2.24	7.46	11.26	15.08	13.02	7.98	5.70	4.36	0.70		67.80
Magdalena	ET			0.50	3.48	5.42	7.48	6.55	4.61	3.30	2.71	0.27		34.32
Magdalena	Re			0.09	0.27	0.42	0.52	1.78	1.91	1.22	0.62	0.04		6.87
Magdalena	CIR			0.41	3.20	5.00	6.96	4.77	2.71	2.08	2.10	0.24		27.47
Magdalena	FDR			0.82	6.40	10.00	13.92	9.54	5.42	4.16	4.20	0.48		54.94
Maxwell	ET				2.09	4.63	6.54	6.19	4.36	2.94	2.13			28.88
Maxwell	Re				0.38	1.22	1.29	2.08	2.21	1.02	0.58			8.78
Maxwell	CIR				1.71	3.41	5.25	4.11	2.16	1.92	1.55			20.11
Maxwell	FDR				3.42	6.82	10.50	8.22	4.32	3.84	3.10			40.22
Mimbres Ranger Station	ET			0.17	3.07	4.70	6.61	6.09	4.27	3.05	2.54	0.26		30.76
Mimbres Ranger Station	Re			0.06	0.29	0.31	0.75	2.43	2.44	1.53	0.94	0.11		8.86
Mimbres Ranger Station	CIR			0.12	2.78	4.39	5.86	3.66	1.84	1.52	1.60	0.15		21.92
Mimbres Ranger Station	FDR			0.24	5.56	8.78	11.72	7.32	3.68	3.04	3.20	0.30		43.84

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Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Navajo Dam	ET			0.10	3.20	5.25	7.48	7.38	5.16	3.36	2.61	0.12		34.66
Navajo Dam	Re			0.05	0.68	0.65	0.46	1.04	1.33	0.84	0.92	0.09		6.06
Navajo Dam	CIR			0.04	2.53	4.59	7.02	6.35	3.83	2.52	1.69	0.04		28.61
Navajo Dam	FDR			0.08	5.06	9.18	14.04	12.70	7.66	5.04	3.38	0.08		57.22
Pecos Ranger Station	ET				1.79	4.49	6.32	5.98	4.21	2.89	2.17			27.85
Pecos Ranger Station	Re				0.34	0.85	0.94	2.22	2.22	1.25	0.67			8.49
Pecos Ranger Station	CIR				1.46	3.64	5.38	3.76	1.99	1.64	1.50			19.37
Pecos Ranger Station	FDR				2.92	7.28	10.76	7.52	3.98	3.28	3.00			38.74
Picacho	ET		0.31	2.3	4.61	6.5	8.28	7.12	5.2	3.73	3.32	1.6	0.08	43.05
Picacho	Re		0.08	0.22	0.34	0.59	1.2	2.02	1.92	1.49	0.84	0.26	0.03	8.99
Picacho	CIR		0.23	2.08	4.27	5.91	7.08	5.09	3.29	2.23	2.48	1.34	0.06	34.06
Picacho	FDR		0.46	4.16	8.54	11.82	14.16	10.18	6.58	4.46	4.96	2.68	0.12	68.12
Portales	ET		0.10	2.25	4.73	7.15	9.12	7.94	5.72	4.03	3.39	1.12		45.55
Portales	Re		0.03	0.31	0.49	1.46	2.09	2.34	2.02	1.32	0.90	0.27		11.23
Portales	CIR		0.07	1.94	4.24	5.70	7.02	5.60	3.70	2.71	2.49	0.85		34.32
Portales	FDR		0.14	3.88	8.48	11.40	14.04	11.20	7.40	5.42	4.98	1.70		68.64
Quemado Ranger Station	ET				1.65	4.20	5.95	5.83	4.09	2.81	2.00			26.53
Quemado Ranger Station	Re				0.11	0.22	0.34	1.46	1.74	0.74	0.55			5.16
Quemado Ranger Station	CIR				1.54	3.98	5.61	4.36	2.35	2.07	1.46			21.37
Quemado Ranger Station	FDR				3.08	7.96	11.22	8.72	4.70	4.14	2.92			42.74
Raton Filter Plant	ET				2.02	4.47	6.35	6.02	4.21	2.82	2.34	0.05		28.28
Raton Filter Plant	Re				0.52	1.64	1.62	2.06	2.20	1.09	0.66	0.02		9.81
Raton Filter Plant	CIR				1.50	2.83	4.73	3.96	2.01	1.73	1.69	0.03		18.48
Raton Filter Plant	FDR				3.00	5.66	9.46	7.92	4.02	3.46	3.38	0.06		36.96

ET is evapotranspiration; Re is effective rainfall; CIR is the consumptive irrigation requirement (ET-Re); and FDR is the field delivery requirement assuming an irrigation efficiency of 50%. Prepared by B. C. Wilson, P.E. New Mexico Office of the State Engineer, 05/25/2000.

APPENDIX A

Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red River	ET					1.50	4.07	4.05	2.83	1.86	0.20			14.51
Red River	Re					0.59	0.93	1.93	1.93	0.92	0.13			6.43
Red River	CIR					0.91	3.14	2.13	0.90	0.94	0.07			8.09
Red River	FDR					1.82	6.28	4.26	1.80	1.88	0.14			16.18
Red Rock	ET		0.37	2.34	4.51	6.45	8.57	8.12	5.83	4.20	3.53	1.63		45.55
Red Rock	Re		0.20	0.45	0.19	0.14	0.45	2.09	1.71	1.34	0.70	0.36		7.63
Red Rock	CIR		0.18	1.89	4.32	6.32	8.12	6.02	4.12	2.86	2.84	1.27		37.94
Red Rock	FDR		0.36	3.78	8.64	12.64	16.24	12.04	8.24	5.72	5.68	2.54		75.88
Reserve Ranger Station	ET				3.01	4.58	6.42	6.39	4.49	3.14	2.55	0.17		30.75
Reserve Ranger Station	Re				0.36	0.31	0.56	1.81	1.91	1.30	0.98	0.08		7.31
Reserve Ranger Station	CIR				2.65	4.28	5.86	4.57	2.58	1.83	1.57	0.09		23.43
Reserve Ranger Station	FDR				5.30	8.56	11.72	9.14	5.16	3.66	3.14	0.18		46.86
Roswell Airport	ET		0.76	2.71	5.57	8.00	10.09	8.67	6.22	4.38	3.78	1.67	0.12	51.97
Roswell Airport	Re		0.10	0.15	0.27	0.71	0.91	1.31	1.74	1.27	0.73	0.19	0.02	7.40
Roswell Airport	CIR		0.66	2.57	5.30	7.28	9.18	7.35	4.48	3.11	3.06	1.49	0.11	44.59
Roswell Airport	FDR		1.32	5.14	10.60	14.56	18.36	14.70	8.96	6.22	6.12	2.98	0.22	89.18
Ruidoso	ET				2.01	4.11	5.64	5.06	3.65	2.58	1.98			25.03
Ruidoso	Re				0.31	0.65	1.46	2.81	2.61	1.61	0.80			10.25
Ruidoso	CIR				1.70	3.46	4.18	2.25	1.04	0.97	1.18			14.78
Ruidoso	FDR				3.40	6.92	8.36	4.50	2.08	1.94	2.36			29.56
Santa Fe	ET				2.35	4.69	6.65	6.05	4.36	2.98	2.33			29.41
Santa Fe	Re				0.48	0.91	0.86	1.82	1.56	1.01	0.69			7.33
Santa Fe	CIR				1.87	3.79	5.79	4.23	2.80	1.97	1.64			22.09
Santa Fe	FDR				3.74	7.58	11.58	8.46	5.60	3.94	3.28			44.18

ET is evapotranspiration; Re is effective rainfall; CIR is the consumptive irrigation requirement (ET-Re); and FDR is the field delivery requirement assuming an irrigation efficiency of 50%. Prepared by B. C. Wilson, P.E. New Mexico Office of the State Engineer, 05/25/2000.

Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Santa Rosa	ET		0.12	2.18	4.53	6.88	9.05	7.96	5.72	3.97	3.39	1.30		45.10
Santa Rosa	Re		0.03	0.37	0.44	0.97	1.33	2.22	2.22	1.09	0.82	0.27		9.76
Santa Rosa	CIR		0.09	1.81	4.09	5.91	7.71	5.74	3.49	2.88	2.58	1.04		35.34
Santa Rosa	FDR		0.18	3.62	8.18	11.82	15.42	11.48	6.98	5.76	5.16	2.08		70.68
Shiprock	ET			0.53	3.67	5.81	7.84	7.73	5.43	3.57	2.74	0.16		37.48
Shiprock	Re			0.10	0.24	0.40	0.23	0.49	0.73	0.59	0.57	0.05		3.40
Shiprock	CIR			0.43	3.43	5.40	7.61	7.24	4.69	2.98	2.16	0.11		34.05
Shiprock	FDR			0.86	6.86	10.80	15.22	14.48	9.38	5.96	4.32	0.22		68.10
Socorro	ET		0.03	2.19	4.51	6.58	8.64	7.78	5.49	3.85	3.21	0.63		42.91
Socorro	Re		0.01	0.20	0.26	0.27	0.56	1.32	1.30	0.93	0.77	0.08		5.70
Socorro	CIR		0.02	1.99	4.25	6.30	8.08	6.46	4.19	2.92	2.44	0.55		37.20
Socorro	FDR		0.04	3.98	8.50	12.60	16.16	12.92	8.38	5.84	4.88	1.10		74.40
Springer	ET			0.09	3.17	5.22	7.27	6.71	4.74	3.17	2.54	0.05		32.96
Springer	Re			0.02	0.64	1.51	1.27	2.29	2.31	0.81	0.82	0.02		9.69
Springer	CIR			0.07	2.53	3.72	6.00	4.42	2.43	2.36	1.72	0.03		23.28
Springer	FDR			0.14	5.06	7.44	12.00	8.84	4.86	4.72	3.44	0.06		46.56
Stanely	ET				2.26	4.73	6.75	6.29	4.43	2.97	2.18			29.61
Stanely	Re				0.21	0.63	0.74	1.69	1.68	0.96	0.73			6.64
Stanely	CIR				2.06	4.10	6.01	4.59	2.74	2.02	1.46			22.98
Stanely	FDR				4.12	8.20	12.02	9.18	5.48	4.04	2.92			45.96
State University	ET		0.92	2.62	5.16	7.31	9.57	8.40	5.99	4.27	3.76	1.71	0.16	49.87
State University	Re		0.23	0.18	0.03	0.16	0.63	1.40	1.48	0.86	0.61	0.23	0.04	5.85
State University	CIR		0.69	2.44	5.13	7.16	8.94	7.00	4.51	3.41	3.15	1.47	0.12	44.02
State University	FDR		1.38	4.88	10.26	14.32	17.88	14.00	9.02	6.82	6.30	2.94	0.24	88.04

ET is evapotranspiration; Re is effective rainfall; CIR is the consumptive irrigation requirement (ET-Re); and FDR is the field delivery requirement assuming an irrigation efficiency of 50%. Prepared by B. C. Wilson, P.E. New Mexico Office of the State Engineer, 05/25/2000.

Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Taos	ET				1.68	4.39	6.20	5.91	4.23	2.79	1.68			26.88
Taos	Re				0.33	0.81	0.72	1.29	1.36	0.85	0.54			5.90
Taos	CIR				1.35	3.58	5.48	4.61	2.87	1.93	1.14			20.96
Taos	FDR				2.70	7.16	10.96	9.22	5.74	3.86	2.28			41.92
Tatum	ET		0.23	2.30	4.75	6.96	8.95	7.60	5.61	3.95	3.46	1.24		45.05
Tatum	Re		0.08	0.34	0.51	1.66	1.87	2.12	1.88	1.66	1.12	0.29		11.53
Tatum	CIR		0.15	1.96	4.24	5.30	7.08	5.48	3.73	2.29	2.35	0.95		33.53
Tatum	FDR		0.30	3.92	8.48	10.60	14.16	10.96	7.46	4.58	4.70	1.90		67.06
Thoreau	ET				2.43	4.71	6.82	6.39	4.43	3.07	2.47	0.09		30.41
Thoreau	Re				0.23	0.40	0.49	1.34	1.59	0.83	0.68	0.03		5.59
Thoreau	CIR				2.20	4.32	6.33	5.05	2.83	2.24	1.78	0.06		24.81
Thoreau	FDR				4.40	8.64	12.66	10.10	5.66	4.48	3.56	0.12		49.62
Tierra Amarilla	ET				0.41	3.71	5.38	5.41	3.80	2.45	1.21			22.37
Tierra Amarilla	Re				0.11	0.67	0.51	1.56	1.75	1.03	0.50			6.13
Tierra Amarilla	CIR				0.30	3.04	4.88	3.85	2.05	1.41	0.71			16.24
Tierra Amarilla	FDR				0.60	6.08	9.76	7.70	4.10	2.82	1.42			32.48
Tohatchi	ET				3.11	5.20	7.60	7.40	5.01	3.47	2.85	0.25		34.89
Tohatchi	Re				0.28	0.36	0.27	1.25	1.23	0.72	0.68	0.09		4.88
Tohatchi	CIR				2.83	4.84	7.33	6.16	3.78	2.75	2.18	0.16		30.03
Tohatchi	FDR				5.66	9.68	14.66	12.32	7.56	5.50	4.36	0.32		60.06
Torreon	ET				2.75	4.97	7.04	6.74	4.71	3.10	2.41			31.72
Torreon	Re				0.34	0.53	0.49	1.24	1.31	0.89	0.71			5.51
Torreon	CIR				2.41	4.44	6.55	5.50	3.39	2.21	1.70			26.20
Torreon	FDR				4.82	8.88	13.10	11.00	6.78	4.42	3.40			52.40

ET is evapotranspiration; Re is effective rainfall; CIR is the consumptive irrigation requirement (ET-Re); and FDR is the field delivery requirement assuming an irrigation efficiency of 50%. Prepared by B. C. Wilson, P.E. New Mexico Office of the State Engineer, 05/25/2000.

Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Tres Piedras	ET				0.14	3.38	5.10	4.93	3.51	2.31	1.41			20.78
Tres Piedras	Re				0.03	0.70	0.62	1.50	1.60	0.92	0.49			5.86
Tres Piedras	CIR				0.11	2.68	4.47	3.43	1.91	1.39	0.92			14.91
Tres Piedras	FDR				0.22	5.36	8.94	6.86	3.82	2.78	1.84			29.82
Truth or Consequences	ET		0.48	2.45	4.95	7.27	9.53	8.16	5.82	4.21	3.66	1.57		48.10
Truth or Consequences	Re		0.07	0.14	0.11	0.34	0.77	1.36	1.33	1.17	0.72	0.21		6.22
Truth or Consequences	CIR		0.41	2.31	4.85	6.93	8.76	6.80	4.48	3.04	2.94	1.36		41.88
Truth or Consequences	FDR		0.82	4.62	9.70	13.86	17.52	13.60	8.96	6.08	5.88	2.72		83.76
Truchas	ET				0.30	3.80	5.15	5.12	3.80	2.67	1.73			22.57
Truchas	Re				0.09	0.74	0.63	1.32	1.53	1.07	0.68			6.06
Truchas	CIR				0.21	3.06	4.52	3.81	2.27	1.60	1.06			16.53
Truchas	FDR				0.42	6.12	9.04	7.62	4.54	3.20	2.12			33.06
Tucumcari	ET		0.14	2.24	4.77	7.14	9.39	8.17	5.90	4.12	3.59	1.41		46.87
Tucumcari	Re		0.04	0.40	0.67	1.29	1.57	2.66	2.01	0.99	0.75	0.33		10.71
Tucumcari	CIR		0.10	1.84	4.10	5.85	7.82	5.51	3.88	3.12	2.84	1.08		36.14
Tucumcari	FDR		0.20	3.68	8.20	11.70	15.64	11.02	7.76	6.24	5.68	2.16		72.28
Tularosa	ET		1.06	2.62	5.14	7.39	9.52	8.17	5.96	4.38	3.81	1.75	0.25	50.05
Tularosa	Re		0.29	0.32	0.27	0.41	0.68	1.45	1.31	1.10	0.62	0.29	0.08	6.82
Tularosa	CIR		0.77	2.30	4.87	6.98	8.84	6.72	4.64	3.28	3.19	1.46	0.17	43.22
Tularosa	FDR		1.54	4.60	9.74	13.96	17.68	13.44	9.28	6.56	6.38	2.92	0.34	86.44
Valmora	ET				1.99	4.53	6.29	5.98	4.20	2.84	2.28			28.11
Valmora	Re				0.37	1.26	1.43	2.31	2.13	1.23	0.68			9.41
Valmora	CIR				1.62	3.27	4.86	3.67	2.06	1.61	1.60			18.69
Valmora	FDR				3.24	6.54	9.72	7.34	4.12	3.22	3.20			37.38

ET is evapotranspiration; Re is effective rainfall; CIR is the consumptive irrigation requirement (ET-Re); and FDR is the field delivery requirement assuming an irrigation efficiency of 50%. Prepared by B. C. Wilson, P.E. New Mexico Office of the State Engineer, 05/25/2000.

APPENDIX A

Monthly Irrigation Requirements in Inches for Tall Fescue at Selected Locations in New Mexico.

Weather Station	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Zuni	ET				2.63	4.69	6.67	6.45	4.58	3.17	2.56	0.12		30.87
Zuni	Re				0.31	0.28	0.27	1.61	1.52	0.83	0.81	0.05		5.68
Zuni	CIR				2.32	4.41	6.41	4.84	3.06	2.34	1.76	0.07		25.21
Zuni	FDR				4.64	8.82	12.82	9.68	6.12	4.68	3.52	0.14		50.42

ET is evapotranspiration; Re is effective rainfall; CIR is the consumptive irrigation requirement (ET-Re); and FDR is the field delivery requirement assuming an irrigation efficiency of 50%. Prepared by B. C. Wilson, P.E. New Mexico Office of the State Engineer, 05/25/2000.

APPENDIX B

Average Monthly Temperature in Degrees Fahrenheit and Total Precipitation in Inches at Weather Stations in New Mexico.

Station/Record/Source	T/P	ID No	Lat	Elev	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Abiquiu Dam/1957-83/Kun	T	41	36.14	6380	27.60	33.40	39.60	48.10	57.40	67.00	72.20	69.70	62.60	52.00	39.60	30.90	50.00
Abiquiu Dam/1957-83/Kun	P	41	36.14	6380	0.39	0.26	0.57	0.47	0.72	0.62	1.68	1.92	1.14	0.91	0.50	0.36	9.53
Alamogordo/1951-80/NOA	T	199	32.53	4350	42.50	46.20	52.30	60.90	69.40	78.90	80.30	78.20	72.60	62.10	49.90	42.90	61.40
Alamogordo/1951-80/NOA	P	199	32.56	4350	0.62	0.53	0.52	0.24	0.41	0.78	2.18	2.15	1.63	1.13	0.43	0.56	11.18
Albuquerque/1951-80/NOA	T	234	35.03	5311	34.80	39.40	46.20	55.10	64.30	74.50	78.80	76.10	69.00	57.40	44.00	35.60	56.20
Albuquerque/1951-80/NOA	P	234	35.03	5311	0.41	0.40	0.52	0.40	0.46	0.51	1.30	1.51	0.85	0.86	0.38	0.52	8.12
Alcalde/1953-83/Kunkel	T	245	36.06	5680	29.80	35.40	41.70	49.80	58.00	67.10	72.50	70.00	62.60	52.10	39.80	31.60	50.90
Alcalde/1953-83/Kunkel	P	245	36.06	5680	0.34	0.29	0.37	0.40	0.70	0.71	1.33	1.82	1.12	0.91	0.62	0.33	8.95
Animas/1931-83/Kunkel	T	417	31.57	4415	41.50	45.70	51.50	58.90	67.20	76.30	79.30	76.70	71.70	61.70	49.40	42.50	60.20
Animas/1931-83/Kunkel	P	417	31.57	4415	0.61	0.54	0.53	0.21	0.16	0.46	1.98	2.29	1.43	0.90	0.50	0.78	10.40
Artesia/1951-80/NOA	T	600	32.46	3320	40.40	44.60	51.40	60.70	69.10	77.90	80.30	78.50	71.70	61.20	48.80	41.60	60.50
Artesia/1951-80/NOA	P	600	32.46	3320	0.34	0.40	0.38	0.36	0.92	1.18	1.54	1.78	1.80	1.26	0.39	0.32	10.67
Aspen Grove/1948/NOA	P	606	36.39	9700	1.89	2.46	0.95	0.52	1.65	1.45	1.88	1.01	1.98	1.58	0.52	1.48	17.37
Aztec Ruins/1951-80/NOA	T	692	36.50	5644	28.50	34.80	41.10	49.40	58.60	68.10	74.70	72.20	64.60	53.40	39.60	29.70	51.20
Aztec Ruins/1951-80/NOA	P	692	36.50	5644	0.95	0.63	0.69	0.64	0.50	0.29	0.90	1.11	0.84	1.28	0.65	0.83	9.31
Bell Ranch/1951-80/NOA	T	858	35.32	4500	35.70	40.40	46.20	55.70	64.80	74.20	78.20	76.10	68.90	57.90	45.20	37.50	56.70
Bell Ranch/1951-80/NOA	P	858	35.32	4500	0.29	0.21	0.48	0.70	1.31	1.37	2.89	2.58	1.33	1.01	0.51	0.40	13.08
Bernalillo/1951-82/Kunkel	T	903	35.19	5045	34.00	38.70	45.30	53.50	62.00	71.30	76.80	74.00	66.60	55.50	42.70	34.50	54.60
Bernalillo/1951-82/Kunkel	P	903	35.19	5045	0.47	0.46	0.59	0.43	0.60	0.58	1.52	1.66	0.82	1.00	0.50	0.57	9.20
Bloomfield/1951-80/NOA	T	1063	36.40	5806	29.30	35.60	42.40	51.10	60.80	71.00	76.40	73.80	66.50	54.60	40.70	30.80	52.80
Bloomfield/1951-80/NOA	P	1063	36.40	5806	0.59	0.44	0.66	0.55	0.41	0.28	0.93	1.27	0.83	1.16	0.64	0.61	8.37

APPENDIX B

Average Monthly Temperature in Degrees Fahrenheit and Total Precipitation in Inches at Weather Stations in New Mexico.

Station/Record/Source	T/P	ID No	Lat	Elev	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bosque del Ap/1951-80/N	T	1138	33.46	4520	37.60	42.30	48.90	57.00	65.30	74.20	78.30	75.90	68.90	58.30	45.70	37.60	57.50
Bosque del Ap/1951-80/N	P	1138	33.46	4520	0.25	0.28	0.34	0.28	0.46	0.65	1.31	1.63	1.32	0.99	0.32	0.45	8.28
Caballo Dam/1951-80/NO	T	1286	32.54	4190	41.10	45.20	51.10	59.30	67.40	77.10	80.70	78.30	72.00	61.20	49.40	41.40	60.40
Caballo Dam/1951-80/NO	P	1286	32.54	4190	0.30	0.31	0.26	0.18	0.28	0.51	1.77	1.94	1.44	0.89	0.33	0.50	8.71
Carlsbad/1951-80/NOA	T	1469	32.20	3232	43.20	47.40	54.30	63.70	72.20	80.60	82.50	80.60	73.90	63.20	50.80	44.30	63.10
Carlsbad/1951-80/NOA	P	1469	32.20	3232	0.34	0.35	0.33	0.40	0.93	0.71	1.70	1.88	2.16	1.16	0.44	0.26	10.66
Carrizozo/1951-80/NOA	T	1515	33.39	5438	36.60	40.00	46.40	54.80	63.40	73.00	76.00	73.40	67.20	56.60	44.40	37.20	55.80
Carrizozo/1951-80/NOA	P	1515	33.39	5438	0.60	0.53	0.64	0.37	0.63	0.83	2.26	2.57	1.86	1.03	0.62	0.67	12.67
Cerro/1951-80/NOA	T	1630	36.49	7685	22.20	27.00	34.70	43.20	51.80	61.20	66.20	63.90	57.90	47.60	34.00	24.30	44.50
Cerro/1951-80/NOA	P	1630	36.49	7685	0.62	0.41	0.59	0.68	0.96	0.85	1.92	1.90	1.08	1.07	0.75	0.61	11.44
Chaco Cany/1951-80/NOA	T	1647	36.02	6175	27.40	32.70	38.80	47.00	56.20	66.30	72.70	70.20	62.30	50.60	37.40	27.80	49.10
Chaco Cany/1951-80/NOA	P	1647	36.02	6175	0.42	0.43	0.48	0.36	0.57	0.39	1.10	1.35	1.05	1.12	0.58	0.58	8.43
Chama/1951-80/NOA	T	1664	36.55	7850	21.90	25.30	30.90	39.90	48.90	58.10	64.00	61.70	55.30	45.90	32.80	24.40	42.40
Chama/1951-80/NOA	P	1664	36.55	7850	1.98	1.34	1.59	1.24	1.10	0.79	2.02	2.62	1.70	1.66	1.37	1.60	19.01
Cimarron/1951-80/NOA	T	1813	36.31	6427	32.00	35.00	39.70	47.60	56.30	65.20	68.90	66.80	61.00	52.00	39.80	34.00	49.90
Cimarron/1951-80/NOA	P	1813	36.31	3427	0.33	0.40	0.69	0.96	2.05	1.62	2.89	2.68	1.48	1.07	0.67	0.42	15.26
Clayton AP/1951-80/NOA	T	1887	36.27	4970	33.00	36.40	41.40	51.00	60.10	69.90	74.20	72.30	64.80	54.70	41.70	35.50	52.90
Clayton AP/1951-80/NOA	P	1887	36.27	4970	0.27	0.28	0.59	1.05	2.23	1.74	2.53	2.43	1.48	0.75	0.48	0.29	14.12
Cliff/1951-80/NOA	T	1910	32.52	4800	38.40	41.70	46.70	53.90	62.00	72.00	76.80	74.20	68.30	57.60	45.90	38.90	56.40
Cliff/1951-80/NOA	P	1910	32.52	4800	0.98	0.76	0.86	0.32	0.19	0.50	2.67	2.95	1.49	1.21	0.56	1.00	13.49
Cloudcroft/1931-83/Kunkel	T	1927	32.58	8801	30.40	31.90	36.10	43.60	51.10	59.20	60.30	59.00	55.10	47.10	37.80	32.60	45.40
Cloudcroft/1931-83/Kunkel	P	1927	32.58	8801	1.84	1.63	1.64	0.76	0.96	1.86	5.51	4.81	2.85	1.55	0.98	1.78	26.16

Average Monthly Temperature in Degrees Fahrenheit and Total Precipitation in Inches at Weather Stations in New Mexico.

Station/Record/Source	T/P	ID No	Lat	Elev	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Clovis/1951-80/NOA	T	1939	34.36	4280	37.00	40.70	46.90	56.30	65.00	73.90	77.20	75.20	68.40	58.20	46.10	39.30	57.00
Clovis/1951-80/NOA	P	1939	34.36	4280	0.44	0.49	0.59	0.83	1.81	2.47	2.79	2.69	1.87	1.45	0.58	0.47	16.48
Cuba/1951-80/NOA	T	2241	36.02	7045	25.50	29.20	35.40	43.70	52.80	62.60	68.80	66.20	59.30	48.40	35.80	27.10	46.20
Cuba/1951-80/NOA	P	2241	36.02	7045	0.91	0.69	0.87	0.65	0.80	0.63	2.19	2.32	1.32	1.19	0.75	0.74	13.06
Deming/1899-1983/Kunkel	T	2436	32.15	4300	41.30	45.50	51.10	58.20	66.80	76.70	79.90	77.90	72.20	61.30	49.30	41.90	60.20
Deming/1899-1983/Kunkel	P	2436	32.15	4300	0.41	0.52	0.42	0.25	0.22	0.43	1.86	1.69	1.35	0.76	0.42	0.61	8.91
Des Moines/1951-80/NOA	T	2453	36.45	6632	30.60	33.40	38.10	47.00	56.20	65.90	70.30	68.30	61.80	51.30	38.80	32.70	49.50
Des Moines/1951-80/NOA	P	2453	36.45	6632	0.35	0.44	0.79	1.03	2.40	1.68	3.54	2.78	1.83	1.01	0.59	0.39	16.83
Dilia/1941-83/Kunkel	T	2510	35.11	5200	35.70	39.40	44.40	52.20	61.00	71.10	74.60	72.30	65.90	55.50	44.10	36.90	54.40
Dilia/1941-83/Kunkel	P	2510	35.11	5200	0.46	0.44	0.67	0.74	1.00	1.07	2.50	2.63	1.71	1.15	0.44	0.58	13.40
Dulce/1931-83/Kunkel	T	2608	36.57	6950	20.20	26.00	34.00	42.30	49.90	58.50	66.00	64.50	57.10	46.10	33.30	23.70	43.50
Dulce/1931-83/Kunkel	P	2608	36.57	6950	1.51	1.37	1.41	1.01	1.12	0.73	1.74	2.43	1.53	1.37	1.19	1.39	16.82
Eagle Nest/1951-80/NOA	T	2700	36.33	8275	19.70	23.50	30.00	38.30	46.30	54.60	59.30	57.60	51.00	41.70	30.00	21.50	39.50
Eagle Nest/1951-80/NOA	P	2700	36.33	8275	0.72	0.50	0.77	0.75	1.31	1.09	2.90	2.77	1.10	0.80	0.77	0.68	14.16
El Rito/1931-66/OSE	T	2820	36.20	6870	25.00	29.00	36.40	47.40	56.30	62.70	69.20	66.20	61.10	52.80	40.90	31.00	48.20
El Rito/1931-66/OSE	P	2820	36.20	6870	0.71	0.67	0.75	0.71	1.02	0.76	1.56	1.97	1.39	1.08	0.56	0.64	11.82
El Vado Dam/1936-83/Kun	T	2837	36.36	6740	21.20	26.70	34.50	43.30	51.90	60.40	67.10	65.20	57.70	47.10	34.70	25.80	44.60
El Vado Dam/1936-83/Kun	P	2837	36.36	6740	1.14	0.86	1.13	0.88	0.97	0.79	1.79	2.19	1.54	1.18	0.80	1.03	14.29
Elk/1951-80/NOA	T	2865	32.56	5700	38.40	40.40	45.40	52.60	60.20	68.10	70.20	68.50	63.00	54.60	44.70	39.70	53.80
Elk/1951-80/NOA	P	2865	32.56	5700	0.50	0.55	0.41	0.57	0.95	1.31	2.67	3.53	2.60	1.32	0.57	0.60	15.58
Espanola/1931-60/NOA	T	3031	36.00	5643	29.10	35.00	41.70	51.20	59.40	68.50	72.60	70.70	64.20	51.70	39.00	32.00	51.30
Espanola/1931-60/NOA	P	3031	36.00	5643	0.53	0.40	0.50	0.64	0.95	0.57	1.39	1.62	0.82	1.05	0.53	0.42	9.42

APPENDIX B

Average Monthly Temperature in Degrees Fahrenheit and Total Precipitation in Inches at Weather Stations in New Mexico.

Station/Record/Source	T/P	ID No	Lat	Elev	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Estancia/1951-80/NOA	T	3060	34.45	6107	31.70	35.50	41.40	49.00	57.70	66.90	71.50	68.80	62.00	51.60	39.70	32.20	50.70
Estancia/1951-80/NOA	P	3060	34.45	6107	0.46	0.51	0.56	0.52	0.84	0.72	1.95	2.40	1.27	1.16	0.50	0.65	11.54
Farmington/1931-78/Kunk	T	3134	36.45	5395	27.90	34.60	41.40	49.40	59.10	68.60	75.40	72.60	64.50	52.70	39.50	29.70	51.30
Farmington/1931-78/Kunk	P	3134	36.45	5395	0.56	0.58	0.55	0.54	0.49	0.37	0.75	1.06	0.94	1.03	0.44	0.66	7.99
Fort Sumner/1951-80/NOA	T	3294	34.28	4030	38.20	42.30	48.50	57.60	66.20	75.30	78.30	76.20	69.10	58.40	46.70	39.90	38.10
Fort Sumner/1951-80/NOA	P	3294	34.28	4030	0.31	0.33	0.47	0.51	1.00	1.40	2.56	2.41	1.70	1.30	0.47	0.33	12.79
Glenwood/1943-83/Kunkel	T	3577	33.19	4752	40.90	44.40	48.80	55.80	62.40	71.30	76.10	74.10	69.10	59.20	48.10	41.70	57.70
Glenwood/1943-83/Kunkel	P	3577	33.19	4752	1.30	0.94	1.02	0.43	0.47	0.62	2.63	2.26	1.56	1.49	0.73	1.34	14.80
Grants AP/1953-83/Kunkel	T	3682	35.10	6520	29.10	33.70	39.40	47.50	56.10	66.10	70.90	68.10	61.40	50.30	38.40	30.30	49.30
Grants AP/1953-83/Kunkel	P	3682	35.10	6520	0.43	0.45	0.48	0.34	0.47	0.54	1.83	2.11	1.34	1.09	0.45	0.56	10.11
Hatch/1951-80/NOA	T	3855	32.40	4052	40.80	44.90	51.20	59.40	67.10	76.20	79.50	76.90	70.70	60.10	48.50	40.90	59.70
Hatch/1951-80/NOA	P	3855	32.40	4052	0.43	0.35	0.27	0.19	0.27	0.50	1.94	2.23	1.39	1.09	0.38	0.54	9.58
Hillsboro/1889-1983/Kunk	T	4009	32.56	5270	39.50	43.70	49.30	56.80	64.50	73.60	76.40	73.80	68.10	58.00	47.10	40.20	57.60
Hillsboro/1889-1983/Kunk	P	4009	32.56	5270	0.57	0.58	0.41	0.31	0.43	0.60	2.37	2.26	2.16	1.07	0.51	0.73	11.99
Hobbs/1951-80/NOA	T	4026	32.42	3615	42.90	46.60	53.30	62.50	70.30	78.20	80.10	78.80	72.80	63.20	51.10	44.90	62.10
Hobbs/1951-80/NOA	P	4026	32.42	3615	0.33	0.41	0.51	0.64	2.02	1.50	2.03	2.39	2.37	1.70	0.54	0.33	14.77
Jemez Sprs/1951-80/NOA	T	4369	35.47	6250	32.90	36.60	42.10	49.80	58.40	67.80	72.20	69.70	64.00	54.30	42.20	34.30	52.00
Jemez Sprs/1951-80/NOA	P	4369	35.47	6250	0.95	0.86	0.90	0.77	0.97	0.89	2.56	3.16	1.20	1.56	0.96	0.89	15.67
Laguna/1951-80/NOA	T	4719	35.02	5800	33.40	37.40	43.10	51.20	60.30	70.40	74.70	72.10	65.30	54.60	42.10	34.00	53.20
Laguna/1951-80/NOA	P	4719	35.02	5800	0.33	0.42	0.40	0.30	0.58	0.46	1.64	1.90	1.08	1.13	0.30	0.48	9.02
Las Vegas AP/1951-80/N	T	4856	35.39	6857	31.20	34.00	38.60	46.60	55.60	65.00	68.50	66.40	60.40	50.80	39.20	32.90	49.10
Las Vegas AP/1951-80/N	P	4856	35.39	6857	0.27	0.26	0.46	0.70	1.57	1.35	3.22	3.50	1.53	1.11	0.60	0.42	14.99

APPENDIX B

Average Monthly Temperature in Degrees Fahrenheit and Total Precipitation in Inches at Weather Stations in New Mexico.

Station/Record/Source	T/P	ID No	Lat	Elev	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Lordsburg/1951-80/NOA	T	5079	32.18	4250	42.00	45.70	51.40	59.20	67.40	77.50	81.20	78.50	73.00	62.00	49.40	42.10	60.80
Lordsburg/1951-80/NOA	P	5079	32.18	4250	0.84	0.56	0.63	0.21	0.19	0.43	1.93	2.19	1.27	0.89	0.42	0.84	10.40
Los Lunas/1957-83/Kunk	T	5150	34.46	4840	33.70	39.30	46.00	53.70	61.90	71.10	76.10	73.90	66.60	55.40	43.20	35.20	54.70
Los Lunas/1957-83/Kunk	P	5150	34.46	4840	0.31	0.43	0.41	0.31	0.42	0.54	1.07	1.75	1.05	1.04	0.33	0.45	8.10
Magdalena/1931-83/Kunk	T	5353	34.07	6540	33.30	38.00	43.20	51.20	59.70	69.20	71.90	69.60	64.10	53.90	42.10	35.80	52.70
Magdalena/1931-83/Kunk	P	5353	34.07	6540	0.47	0.44	0.51	0.41	0.54	0.59	2.18	2.66	1.76	0.89	0.30	0.49	11.24
Maxwell/1931-83/Kunkel	T	5490	36.34	6017	28.20	32.20	37.90	46.90	55.80	65.00	69.70	67.70	61.10	50.70	37.40	30.00	48.50
Maxwell/1931-83/Kunkel	P	5490	36.34	6017	0.25	0.23	0.42	0.76	1.62	1.54	2.66	3.19	1.48	0.94	0.45	0.30	13.84
Mimbres RS/1931-83/Kunk	T	5754	32.56	6238	35.80	38.30	42.20	48.80	56.40	66.00	70.00	67.40	62.10	52.50	42.30	36.70	51.50
Mimbres RS/1931-83/Kunk	P	5754	32.56	6238	1.10	0.93	0.83	0.44	0.43	0.87	3.19	3.59	2.30	1.39	0.78	1.19	17.04
Navajo Dam/1961-90/NOA	T	6061	36.49	5770	27.40	33.80	41.10	49.40	58.70	68.70	75.10	72.70	64.60	53.30	40.20	29.90	51.20
Navajo Dam/1961-90/NOA	P	6061	36.49	5770	1.01	0.96	1.29	0.95	0.82	0.53	1.16	1.72	1.18	1.35	1.13	1.19	13.29
Pecos RS/1931-83/Kunkel	T	6676	35.35	6900	29.90	33.10	38.30	46.10	55.10	64.20	69.00	66.70	60.70	50.60	38.10	32.20	48.70
Pecos RS/1931-83/Kunkel	P	6676	35.35	6900	0.70	0.72	0.91	0.76	1.11	1.11	2.90	3.24	1.85	1.07	0.73	0.65	15.75
Picacho/1951-78/Kunkel	T	6804	33.21	4965	41.80	44.00	49.50	57.30	64.40	72.50	74.70	73.30	67.50	58.50	48.30	42.60	57.90
Picacho/1951-78/Kunkel	P	6804	33.21	4965	0.32	0.43	0.37	0.47	0.69	1.28	2.43	2.58	2.14	1.18	0.43	0.55	12.86
Portales/1951-80/NOA	T	7008	34.11	4010	38.40	42.40	49.10	57.90	67.00	75.30	78.10	76.30	69.80	59.00	46.80	39.90	58.30
Portales/1951-80/NOA	P	7008	34.11	4010	0.37	0.42	0.48	0.64	1.69	2.23	2.72	2.65	1.84	1.27	0.57	0.46	15.34
Quemado RS/1951-80/NO	T	7180	34.21	6879	30.20	33.90	38.90	45.70	53.80	62.80	68.40	66.10	60.00	49.80	38.10	31.20	48.20
Quemado RS/1951-80/NO	P	7180	34.21	6879	0.45	0.51	0.62	0.31	0.34	0.44	1.84	2.48	1.07	0.91	0.43	0.49	9.89
Raton FP/1953-83/Kunkel	T	7279	36.55	6920	31.60	33.90	38.00	46.40	55.10	64.40	69.00	67.20	61.20	51.80	40.20	33.70	49.40
Raton FP/1953-83/Kunkel	P	7279	36.55	6920	0.39	0.45	0.87	0.97	2.32	1.75	2.93	2.96	1.26	1.03	0.70	0.52	16.15

Average Monthly Temperature in Degrees Fahrenheit and Total Precipitation in Inches at Weather Stations in New Mexico.

Station/Record/Source	T/P	ID No	Lat	Elev	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red River/1951-80/NOA	T	7323	36.42	8676	19.80	22.00	28.40	36.70	45.20	53.50	58.40	56.60	50.80	41.70	29.10	21.50	38.60
Red River/1951-80/NOA	P	7323	36.42	8676	1.08	0.92	1.51	1.38	1.68	1.25	2.79	3.02	1.41	1.48	1.26	1.17	18.95
Red Rock/1931-83/Kunkel	T	7340	32.42	4150	41.20	44.30	49.80	56.80	64.30	73.70	79.20	77.00	71.10	59.90	48.50	41.60	58.90
Red Rock/1931-83/Kunkel	P	7340	32.42	4150	0.85	0.81	0.67	0.30	0.23	0.49	2.37	2.18	1.84	0.96	0.56	0.97	12.23
Reserve RS/1931-83/Kunk	T	7386	33.43	5847	33.60	36.80	41.40	48.40	55.80	65.00	71.20	68.80	62.80	52.60	41.20	34.40	51.00
Reserve RS/1931-83/Kunk	P	7386	33.43	5847	1.04	0.86	1.09	0.53	0.43	0.66	2.25	2.68	1.91	1.46	0.82	1.21	14.92
Roswell AP/1951-80/NOA	T	7610	33.18	3669	41.40	45.90	52.80	61.90	70.30	79.00	81.40	79.20	72.30	61.70	49.10	42.50	61.40
Roswell AP/1951-80/NOA	P	7610	33.18	3669	0.24	0.28	0.27	0.37	0.77	0.91	1.38	2.17	1.72	0.99	0.33	0.27	9.70
Ruidoso/1951-80/NOA	T	7649	33.22	6838	33.40	35.10	39.70	46.40	53.40	61.70	64.60	63.10	57.90	49.10	39.60	34.20	48.20
Ruidoso/1951-80/NOA	P	7649	33.22	6838	1.12	1.16	1.33	0.63	0.87	1.86	4.02	4.04	2.50	1.31	0.88	1.63	21.35
Santa Fe/1867-1972/Kunk	T	8085	35.39	6720	29.50	33.20	39.40	47.30	56.10	65.60	69.30	67.70	61.50	50.90	39.10	30.90	49.20
Santa Fe/1867-1972/Kunk	P	8085	35.39	6720	0.62	0.70	0.74	0.86	1.18	1.00	2.31	2.16	1.46	1.03	0.66	0.71	13.41
Santa Rosa/1951-80/NOA	T	8107	34.57	4620	39.40	42.90	48.50	56.90	65.70	74.80	78.20	76.00	69.30	59.00	47.30	40.90	58.20
Santa Rosa/1951-80/NOA	P	8107	34.57	4620	0.33	0.39	0.57	0.59	1.12	1.37	2.56	2.95	1.49	1.14	0.50	0.55	13.56
Shiprock/1931-83/Kunkel	T	8284	36.47	4870	28.90	35.50	43.20	52.10	61.20	70.10	76.60	74.30	66.30	54.30	40.40	30.50	52.80
Shiprock/1931-83/Kunkel	P	8284	36.47	4870	0.49	0.39	0.52	0.37	0.51	0.30	0.55	0.91	0.82	0.83	0.49	0.53	6.72
Socorro/1951-80/NOA	T	8387	34.05	4585	37.00	41.80	48.60	56.80	64.70	73.60	77.40	75.00	68.40	57.70	44.80	37.00	56.90
Socorro/1951-80/NOA	P	8387	34.05	4585	0.27	0.35	0.34	0.38	0.36	0.59	1.46	1.65	1.27	1.09	0.32	0.55	8.63
Springer/1951-80/NOA	T	8501	36.23	5857	29.60	34.90	41.10	49.30	58.60	68.00	72.20	70.10	63.10	52.60	39.20	31.10	50.80
Springer/1951-80/NOA	P	8501	36.23	5857	0.31	0.28	0.56	0.90	1.97	1.45	2.86	3.28	1.15	1.20	0.56	0.36	14.88
Stanley/1954-83/Kunkel	T	8518	35.10	6382	28.60	33.20	39.30	47.10	56.30	66.00	70.60	68.10	61.40	50.40	38.70	30.80	49.20
Stanley/1954-83/Kunkel	P	8518	35.10	6382	0.38	0.40	0.44	0.41	0.82	0.85	2.10	2.34	1.38	1.14	0.48	0.43	11.14

Average Monthly Temperature in Degrees Fahrenheit and Total Precipitation in Inches at Weather Stations in New Mexico.

Station/Record/Source	T/P	ID No	Lat	Elev	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
State Univ/1951-80/NOA	T	8535	32.17	3881	42.50	46.20	52.10	60.00	67.90	77.30	80.40	77.90	71.80	61.30	49.40	42.70	60.80
State Univ/1951-80/NOA	P	8535	32.17	3881	0.39	0.45	0.31	0.14	0.24	0.63	1.50	1.84	1.15	0.83	0.39	0.43	8.30
Taos/1931-83/Kunkel	T	8668	36.22	6945	24.40	30.20	37.40	45.90	54.60	63.60	68.40	66.80	59.80	48.90	35.90	27.00	46.90
Taos/1931-83/Kunkel	P	8668	36.22	6945	0.75	0.61	0.78	0.80	1.07	0.86	1.60	1.87	1.24	1.04	0.77	0.63	12.02
Tatum/1931-83/Kunkel	T	8713	33.16	4100	39.20	43.40	49.50	58.00	66.30	75.00	76.90	75.70	69.20	59.50	47.10	40.50	58.40
Tatum/1931-83/Kunkel	P	8713	33.16	4100	0.46	0.53	0.52	0.66	1.97	1.99	2.49	2.46	2.37	1.58	0.56	0.44	16.03
Thoreau/1953-83/Kunkel	T	8830	35.26	7100	31.00	34.60	40.10	47.30	56.20	66.30	71.00	68.10	62.20	51.90	40.40	32.60	50.10
Thoreau/1953-83/Kunkel	P	8830	35.26	7100	0.65	0.58	0.71	0.43	0.53	0.58	1.61	2.20	1.18	1.00	0.52	0.62	10.61
Tierra Amarilla/1951-80/N	T	8845	36.45	7425	21.00	25.50	32.90	42.60	51.20	59.60	65.50	63.70	56.70	46.40	33.30	23.90	43.50
Tierra Amarilla/1951-80/N	P	8845	36.45	7425	1.27	1.01	1.04	0.97	0.99	0.85	1.98	2.48	1.78	1.26	0.98	1.13	15.73
Tohatchi/1951-80/NOA	T	8919	35.51	6420	31.40	35.90	40.70	49.00	58.50	69.40	75.50	71.80	65.50	55.00	41.50	32.70	52.20
Tohatchi/1951-80/NOA	P	8919	35.51	6420	0.81	0.49	0.64	0.42	0.48	0.34	1.41	1.60	1.00	0.97	0.63	0.64	9.43
Torreon1961-90/NOA	T	9031	35.48	6700	27.30	33.10	40.10	48.10	57.40	67.20	72.50	69.90	62.50	51.40	38.80	29.40	49.80
Torreon1961-90/NOA	P	9031	35.48	6700	0.55	0.46	0.60	0.54	0.68	0.57	1.45	1.75	1.27	1.04	0.66	0.53	10.10
Tres Piedras/1931-58/OSE	T	9085	36.40	8110	18.90	24.40	31.40	41.40	49.30	58.60	63.30	61.80	55.40	48.30	31.40	24.40	42.40
Tres Piedras/1931-58/OSE	P	9085	36.40	8110	0.67	0.82	0.76	0.81	0.98	0.79	2.00	2.34	1.38	1.10	0.63	0.78	13.06
Truth or Con/1951-80/NOA	T	9129	33.14	4820	40.60	44.80	50.70	59.00	67.50	77.10	79.30	76.90	71.10	60.90	48.60	40.70	59.80
Truth or Con/1951-80/NOA	P	9129	33.14	4820	0.30	0.28	0.26	0.21	0.41	0.77	1.47	1.66	1.59	0.99	0.37	0.47	8.78
Truchas/1931-60/NOA	T		36.02	8025	27.60	28.60	32.20	41.10	51.60	59.00	64.50	63.90	58.80	48.90	36.90	29.90	45.25
Truchas/1931-60/NOA	P		36.02	8025	0.99	1.14	0.94	0.96	1.01	0.80	1.71	2.19	1.59	1.27	0.82	0.82	14.24
Tucumcari/1951-80/NOA	T	9156	35.12	4096	38.90	42.80	49.00	58.10	66.70	76.00	79.00	77.00	70.40	60.40	47.80	40.90	58.90
Tucumcari/1951-80/NOA	P	9156	35.12	4096	0.37	0.42	0.60	0.87	1.48	1.60	3.09	2.61	1.34	1.04	0.57	0.50	14.49

APPENDIX B

Average Monthly Temperature in Degrees Fahrenheit and Total Precipitation in Inches at Weather Stations in New Mexico.

Station/Record/Source	T/P	ID No	Lat	Elev	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Tularosa/1908-83/Kunkel	T	9165	33.05	4535	42.80	46.70	52.10	59.90	68.00	77.10	79.40	77.70	72.30	61.90	49.90	43.30	60.90
Tularosa/1908-83/Kunkel	P	9165	33.05	4535	0.51	0.48	0.49	0.38	0.48	0.68	1.58	1.62	1.47	0.85	0.47	0.57	9.59
Valmora/1951-80/NOA	T	9330	35.49	6300	30.90	34.10	38.90	46.50	55.30	64.10	68.90	66.60	60.30	50.60	39.30	32.90	49.00
Valmora/1951-80/NOA	P	9330	35.49	6300	0.32	0.37	0.57	0.76	1.69	1.74	3.03	3.10	1.83	1.02	0.63	0.47	15.53
Zuni/1949-83/Kunkel	T	9897	35.06	6440	30.80	34.70	40.10	47.80	56.10	65.70	71.40	69.10	63.10	52.70	40.50	32.80	50.40
Zuni/1949-83/Kunkel	P	9897	35.06	6440	0.87	0.73	0.91	0.52	0.40	0.35	1.97	2.07	1.18	1.18	0.67	0.85	11.70
Duncan, AZ	T																
Duncan, AZ	P																
Dell City, TX	T																
Dell City, TX	P																
Station Combinations																	
Abiquiu/Espanola	T		36.07		28.20	34.20	40.80	49.30	58.40	67.80	72.80	70.40	63.40	52.20	39.50	31.10	50.70
Abiquiu/Espanola	P		36.07		0.43	0.32	0.55	0.52	0.76	0.62	1.58	1.84	1.04	0.90	0.51	0.41	9.48
Artesia/Roswell	T		32.82		40.90	45.20	52.10	61.30	69.70	78.40	80.80	78.80	72.00	61.40	49.00	42.00	61.00
Artesia/Roswell	P		32.82		0.29	0.34	0.32	0.36	0.84	1.04	1.46	1.98	1.76	1.12	0.36	0.30	10.17
Aspen Grove/Tres Piedras	T		36.40		18.90	24.40	31.40	41.40	49.30	58.60	63.30	61.80	55.40	48.30	31.40	24.40	42.40
Aspen Grove/Tres Piedras	P		36.40		1.29	1.64	0.86	0.66	1.32	1.12	1.94	1.68	1.68	1.34	0.58	1.09	15.20
Bernalillo/Los Lunas	T		34.82		33.80	39.00	45.60	53.60	62.00	71.20	76.40	74.00	66.60	55.40	43.00	34.80	54.60
Bernalillo/Los Lunas	P		34.82		0.39	0.44	0.50	0.37	0.51	0.56	1.30	1.70	1.34	1.02	0.42	0.51	9.06
Bloomfield/Shiprock	T		36.44		29.10	35.60	42.80	51.60	61.00	70.60	76.50	74.00	66.40	54.40	40.60	30.60	52.80
Bloomfield/Shiprock	P		36.44		0.54	0.42	0.59	0.46	0.46	0.29	0.74	1.09	0.82	1.00	0.56	0.57	7.54
Cerro/Taos	T		36.36		23.30	28.60	36.00	44.60	53.20	62.40	67.30	65.40	58.80	48.20	35.00	25.60	45.70
Cerro/Taos	P		36.36		0.68	0.51	0.68	0.74	1.02	0.86	1.76	1.88	1.16	1.06	0.76	0.62	11.73

APPENDIX B

Average Monthly Temperature in Degrees Fahrenheit and Total Precipitation in Inches at Weather Stations in New Mexico.																	
Station/Record/Source	T/P	ID No	Lat	Elev	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
El Vado/Abiquiu	T		36.25		24.40	30.00	37.00	45.70	54.60	63.70	69.60	67.40	60.20	49.60	37.20	28.40	47.30
El Vado/Abiquiu	P		36.25		0.76	0.56	0.85	0.68	0.84	0.70	1.74	2.06	1.34	1.04	0.65	0.70	11.92
Grants/Laguna	T		35.06		27.20	35.60	41.20	49.40	58.20	68.20	72.80	70.10	63.40	52.40	40.20	32.20	50.90
Grants/Laguna	P		35.06		0.38	0.44	0.44	0.32	0.52	0.50	1.74	2.00	1.21	1.11	0.38	0.52	9.56
Lower Vallecitos & Tusas	T		37.17		27.30	31.60	38.90	49.10	58.00	65.40	71.10	68.70	62.60	52.40	40.20	31.40	49.70
Lower Vallecitos & Tusas	P		37.17		0.55	0.39	0.58	0.38	0.77	0.37	1.24	1.86	0.96	0.95	0.64	0.48	9.17
Middle Tusas	T		36.30		23.10	28.00	35.20	45.20	53.60	62.00	67.20	65.20	59.00	50.40	35.80	27.90	46.00
Middle Tusas	P		36.30		0.92	1.02	0.50	0.36	1.04	0.74	1.59	1.77	1.30	1.14	0.61	0.78	11.77
Middle Vallecitos	T		36.35		23.10	28.00	35.20	45.20	53.60	62.00	67.20	65.20	59.00	50.40	35.80	27.90	46.00
Middle Vallecitos	P		36.35		1.22	1.42	0.76	0.45	1.21	0.91	1.56	1.44	1.47	1.26	0.58	0.98	13.26
Pecos/Santa Rosa	T		34.96		34.60	38.00	43.40	51.50	60.40	69.50	73.60	71.40	65.00	54.80	42.70	36.60	53.40
Pecos/Santa Rosa	P		34.96		0.52	1.11	0.74	0.68	1.11	1.24	2.09	3.10	1.67	1.10	1.23	0.60	15.19
Picacho/Roswell	T		33.89		41.60	45.00	51.20	59.60	67.40	75.80	78.00	76.20	69.90	60.10	48.70	42.50	59.70
Picacho/Roswell	P		33.89		0.28	0.36	0.32	0.42	0.73	1.10	1.90	2.38	1.93	1.08	0.38	0.41	11.29
Upper Tusas	T		36.40		18.90	24.40	31.40	41.40	49.30	58.60	63.30	61.80	55.40	48.30	31.40	24.40	42.40
Upper Tusas	P		36.40		1.29	1.64	0.86	0.66	1.32	1.12	1.94	1.68	1.68	1.34	0.58	1.09	15.20
Upper Vallecitos	T		36.35		18.90	24.40	31.40	41.40	49.30	58.60	63.30	61.80	55.40	48.30	31.40	24.40	42.40
Upper Vallecitos	P		36.35		1.89	2.46	0.95	0.52	1.65	1.45	1.88	1.01	1.98	1.58	0.52	1.48	17.37

APPENDIX B

Average Monthly Temperature in Degrees Fahrenheit and Total Precipitation in Inches at Weather Stations in New Mexico.

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