Ipswich River Targeted Watershed Grant Fact Sheet:

Water Conservation Case Studies

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Massachusetts Department of Conservation and Recreation and The Ipswich River Watershed Association

Water conservation in the Ipswich River Watershed

The Ipswich River Watershed, located in Northeastern Massachusetts, refers to the 155-square-mile-area that drains into the Ipswich River. This watershed is the source of drinking water for approximately 330,000 people and businesses. Over the years, a variety of human activities, including pumping of water from the river and its shallow groundwater reserves, has contributed to extremely low flows in the river and, during some summers, sections of the river have completely dried up. These problems were so severe that, in 2003, American Rivers, a national river conservation group, designated the Ipswich as the third most endangered river in the nation.

In 2004, the Massachusetts Department of Conservation and Recreation (DCR), under a cooperative agreement with the U.S. Environmental Protection Agency, implemented five water conservation projects in the Ipswich River watershed and collaborated with researchers at Tufts University to evaluate their effectiveness at reducing water demand:

- Installation of rainwater harvesting systems that collect rain running off rooftops and store it to use for irrigation or other outdoor purposes
- Installation of weather-based irrigation controller switches (WICs), which track and use weather information to ensure that automatic sprinkler systems only deliver water when it is needed
- Incorporation of mineral amendments into the soil at a municipal athletic field to improve soil moisture retention and reduce water demand
- Free indoor water-use audits and water-saving retrofit kits
- Rebates for the replacement of conventional toilets and washing machines with water-efficient alternatives.

The irrigation controllers and soil amendment projects were designed to reduce the amount of water needed for lawn and landscape irrigation, while the rainwater harvesting systems were designed to replace a portion of the drinking water used for outdoor irrigation with rainwater. The homeowner rebate and water audit programs were focused on reducing indoor water consumption, year round.

DCR acknowledges the cooperation and contributions of the following entities in completing these demonstration projects:

- Ipswich River Watershed Association
- City of Peabody, Massachusetts
- Town of Hamilton, Massachusetts
- Town of Middleton, Massachusetts
- Town of North Reading, Massachusetts
- Town of Reading, Massachusetts
- Town of Wilmington, Massachusetts
- AquaSave, LLC
- Rainwater Recovery, Inc.
- Tufts University
- U.S. Environmental Protection Agency

Rainwater harvesting

Rainwater harvesting systems capture runoff from rooftops and store the water in barrels, tanks, or underground cisterns, to be used for purposes that do not require the same high level of treatment as drinking water. Substituting captured rainwater for activities such as lawn watering or car washing saves money and energy needed to treat and transport public water and helps reduce the use of water from the river and groundwater.

To measure the effectiveness of rainwater harvesting as a water conservation tool, DCR cooperated with homeowners at 39 residences in Wilmington, outfitting each house with a rainwater harvesting system during the spring of 2006. These residential systems consisted of a 200-gallon or 800-gallon above-ground storage tank, a pressure pump to help deliver water through a hose or sprinkler, and a water meter, which homeowners used to measure the amount of rainwater used during the 2006 and 2007 growing seasons. The rainwater was used for a variety of outdoor purposes, but primarily lawn and landscape irrigation. Participating homeowners were surveyed to evaluate how often, and for what purposes, they used the rainwater harvesting systems.

DCR also cooperated with the Wilmington Water Department to install a large underground rainwater storage vault at the Boutwell School in the spring of 2007. The underground system consisted of an 8,000-gallon storage vault, a pressure pump, a water meter, and a mechanism to switch to public water as a backup. The school system was used to irrigate an adjacent ball field.

Key Findings

Was there a difference in how homeowners used the 200-gallon and 800-gallon systems?

- **Yes:** In both 2006 and 2007, homeowners with the 800-gallon systems used more rainwater, on average, than those with the 200-gallon systems. Even though houses with 800-gallon systems did not necessarily have larger contributing roof areas, the larger storage size enabled homeowners to capture more rain from each storm for use during dry periods. This suggests that the 800-gallon system was more appropriately sized for the frequency and volume of outdoor water used by the average participating homeowner in the study.

200-gallon (top) and 800-gallon (bottom) rainwater harvesting systems were installed at 39 residences.

Did use of rainwater decrease reliance on public water?

- **Yes:** Surveys administered to the participating homeowners suggested that most of the rainwater used during the study period was a direct replacement of public water. Meters measured the amount of stored rainwater used for outdoor purposes. Homeowners with 800-gallon systems used an average of 2,600 gallons of rainwater per year; those with the 200-gallon systems used an average of 1,100 gallons per year. However, the reduction in domestic water consumption was hard to determine directly from customer water bills. Since each household used significantly more public water than rainwater, determining the actual amount of public water replaced by rainwater (a much smaller number), was very difficult to do.

Was the large underground system at the school able to reduce reliance on public water for irrigation?

- **Yes:** To answer this question, researchers used a computer model to estimate the percentage of irrigation demand at the adjacent ball field that could be met by the rainwater system. The model used daily rainfall patterns from a seven-year period of record, the size of the building's roof, the storage capacity of the vault, and watering demands of the field. According to the model, the rainwater system should be able to provide 79% of the water needed to irrigate the adjacent athletic field .

8000-gallon vault system at the Boutwell School that captures rainwater for irrigating athletic fields.

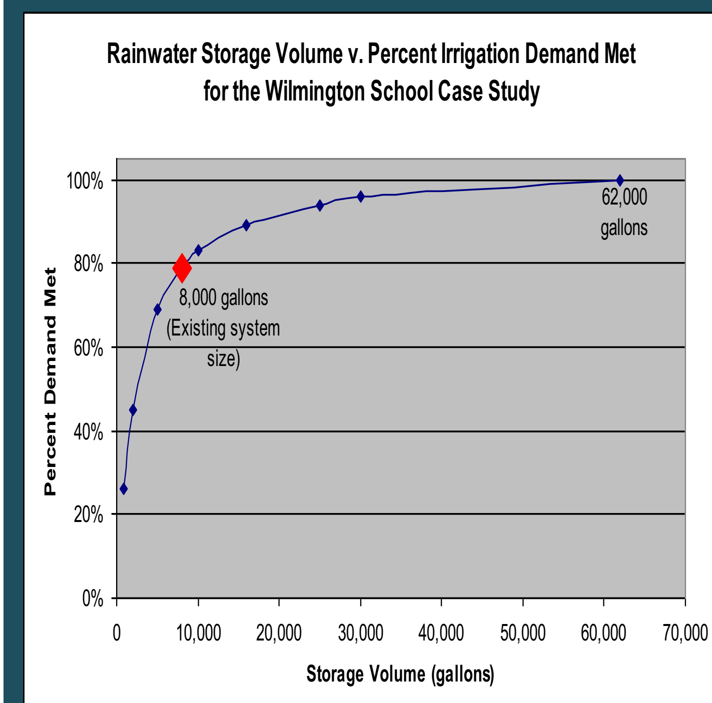
Things to keep in mind

Generally speaking, the larger the storage capacity of a rainwater harvesting system, the more the system will cost to install. However, if a system has too little storage capacity, it may frequently overflow, and sufficient water may not be available during dry periods. To design a cost-effective rainwater harvesting system, it is useful to consider the following three factors and the relationships among them:

- **Contributing roof area:** This determines the volume of runoff generated for each storm. A large roof area will produce a lot of runoff even during a small storm.

- **Tank size:** This sets the limit of how much runoff can be captured during a storm, regardless of the size of the storm. Once a system is full, any additional runoff will be lost to overflow.

- **Watering needs and frequency of use:** These determine how quickly the stored water is used and how much room the tank will have for incoming rainwater from the next storm. If the water in the tank is not used up quickly enough, there will be less room left in the tank for additional rainwater, and the newer rainwater will be lost to overflow.



The simulation model developed for the Wilmington School harvesting system predicted that approximately 79% of the irrigation demand at the ball field could be met by rainwater. The above graph shows how this percentage would change with different storage sizes. Beyond a certain tank size, the benefit of increased storage begins to diminish quickly.

Weather-based irrigation controllers (WIC)

Weather-based irrigation controllers automatically control irrigation systems in response to rainfall so water is not wasted.

Watering lawns and gardens when there is sufficient rainfall or moisture in the soil only wastes water, energy, and money. Weather-based irrigation controllers (WIC) automatically control irrigation systems so they do not turn on if enough natural water is available. The WIC used in this study includes an on-site rain guage and a control unit that receives a continuous wireless data signal from a regional weather station that reports on solar radiation, temperature, relative humidity, and wind speed. The WIC device uses the regional weather data and the on-site rain guage to continually estimate moisture in the soil. When the moisture level drops below a certain threshold, the WIC device allows the automatic irrigation system to come on and deliver enough water to replenish the lost moisture. The threshold that triggers an irrigation cycle can be set individually for each system, based on type of plants, soil composition, and other factors. Until the threshold is reached, the WIC device prevents the automatic irrigation cycle from coming on, reducing unnecessary watering, such as during rain storms.

As a part of this study, DCR coordinated with homeowners to install WIC devices at thirteen residences in the town of Reading during the summer of 2005. DCR also partnered with municipal officials in Hamilton, Middleton, North Reading, Reading, and Peabody to install the devices at ten municipal athletic fields during the same summer.

DCR and Tufts University researchers compared the outdoor water use from the five-year period prior to WIC installation to the two-year period after installation for households that received WIC devices, and for a group of similar households with automatic sprinkler systems that did not receive the WIC devices. The latter group was used as a "control" to account for any weather differences between the two time periods that might have affected water use. The researchers also used historic weather records to simulate how much water the WIC devices would have applied at the thirteen residences and the five ball fields that had the necessary data records for analysis, during the summers of 2003 and 2004. They then compared these volumes to the water that was actually applied during this period by the conventional automatic sprinkler systems that were in place at that time.

Key Findings

Did households reduce water use after WIC devices were installed?

- On average, households using the WIC devices did reduce water use after the devices were installed, compared to households that continued to use conventional timer-based systems (the control group). However, there was so much variability in how the WIC units were operated by the different households that researchers could not conclude that the WIC units would reduce water use in all cases. For example, households that tended to have very low water demands prior to installing the WIC device actually saw an increase in demand after the WIC unit was installed. Researchers suspect that this was because the WIC devices were calibrated to keep lawns green, whereas homeowners with very low historic water demands might not have previously watered their lawns during dry periods, and instead allowed their grass to brown up.

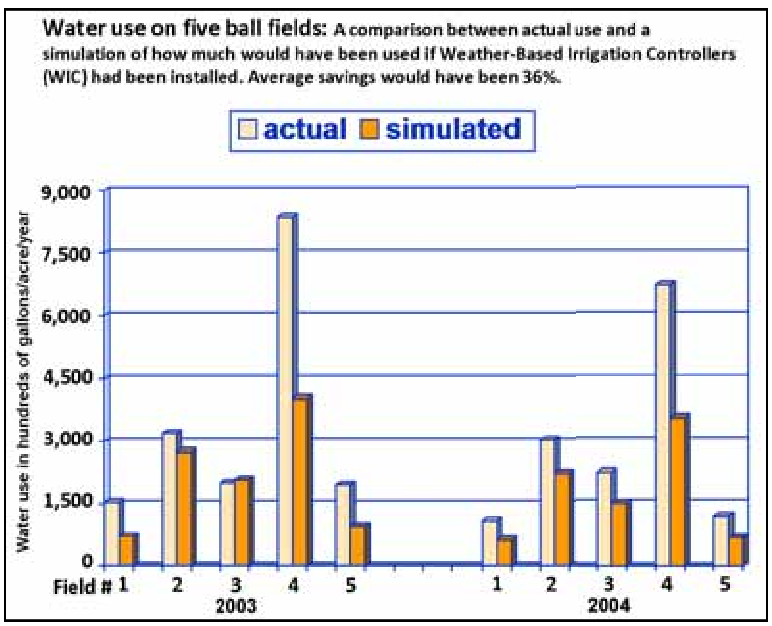
- The households with the highest water demands prior to installing the WIC device, on the other hand, showed a consistently sharp decline in water use after installation. This suggests that WIC devices are more likely to be beneficial in residences that use a lot of water for irrigation.

Would households have saved water in 2003 and 2004 if they had used WIC devices?

- On average, simulations indicated that households would have used less water in 2003 and 2004 if they had been using WIC devices instead of conventional timer-based controllers. However, these results were not statistically significant, due to highly variable results among the households in the study.
- Among the highest water users, the simulation found that using the WIC units would have saved a statistically significant amount of water in 2003 and 2004. These results again suggest that WIC devices are more likely to save water for households with patterns of high water use.
- The simulation also showed that the WIC devices were most likely to save water during rainy months. This is not surprising, because the devices are designed to eliminate unnecessary irrigation, which most often occurs during wet weather.

Would ball fields have saved water in 2003 and 2004 if they had used WIC devices?

- **Yes.** For all five ball fields analyzed, the simulation described above showed that significant water savings would have occurred if the WIC devices had been installed in 2003 and 2004. For these years, the WIC units would have reduced ball field irrigation by approximately 120,000 gallons/acre/year, compared to the irrigation volumes that were applied by the conventional irrigation systems at these fields. **This represents a water savings of approximately 36%.**



Things to Keep in Mind

Weather-based irrigation control devices are designed to eliminate unnecessary irrigation. As a result, they provide the greatest water savings when installed in systems that have been watering unnecessarily. Water users that already use other mechanisms to irrigate efficiently are presumably less likely to realize savings if they convert to WIC devices.

Moisture-retaining soil amendments

Plants draw the water they need out of the soil that surrounds their roots. Soils can be made to hold water longer with the addition of organic or mineral soil amendments. If soil can hold water for longer periods of time, the need for irrigation will be reduced, saving water that would otherwise have to be pumped out of the river or groundwater.

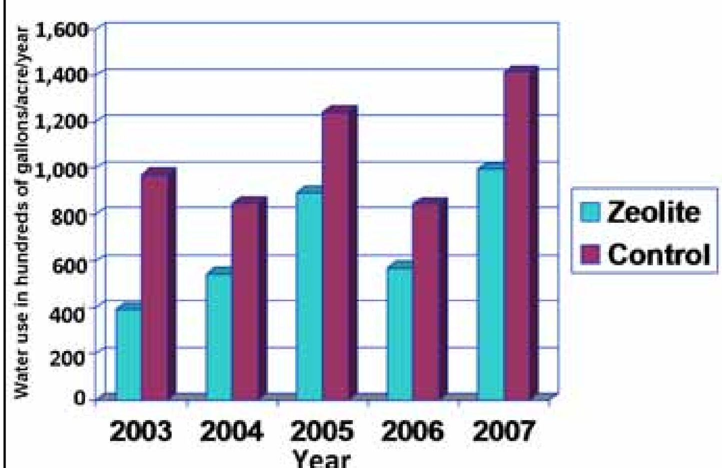
DCR partnered with the town of North Reading to study whether adding zeolite, a soil mineral additive that retains water, at a town athletic field would reduce the field's need for irrigation. The study compared water use at two adjacent fields. Both fields were planted with hardy, drought-resistant turf and irrigated with the weather-sensitive irrigation controllers described above. Both fields had the same original soil characteristics and were exposed to virtually the same amount of sun, wind, rain, and temperatures. One of the fields was enhanced with a zeolite additive. Because the town did not want to close the field to recreation for the season, the zeolite was applied in two doses over two summers, without removing any of the turf. A third of the zeolite was mixed with sand and introduced into the deeper layers of soil through 2½ -inch and 7-inch aeration holes. The rest was applied directly to the surface and worked itself into the soil, so that by the end of the second year of application, 4% of the top inch of soil was composed of zeolite. The town progressively adjusted the settings on the weather-sensitive irrigation controller (WIC) devices for each field, and monitored the field conditions to determine the most conservative watering schedule that could be tolerated by each field, while maintaining healthy turf.

Key Findings

Did the zeolite additive reduce the watering requirements of the field?

- **Yes:** The field with the zeolite was watered less and appeared visibly healthier than the control field.
- Using historic weather records and settings on the WIC system, irrigation volumes over a 5-year period were simulated for each field; the zeolite field would have required 38,000 gallons/acre less water, per year, than the control field during the years 2003 - 2007. **This represents a savings of 37%.**
- These results imply that soil amendments can have a dramatic impact on moisture retention, and can in turn significantly reduce water demand of athletic fields and lawns.

Comparison of simulated water use for fields treated with zeolite vs. untreated fields. The average savings would have been 37%



Things to Keep in Mind

The amount of water needed to maintain healthy turf without over-watering depends on many factors, including type of turf, root depth, soil characteristics, and climate. While this study suggests that zeolite can significantly reduce irrigation demands, further studies are needed to determine the optimal amount and method of application of zeolite.

Water conservation programs for homeowners: water-use audits and appliance rebates

As part of a town-wide water conservation program beginning in 2003, the town of Reading began offering water customers two opportunities to reduce their indoor water use:

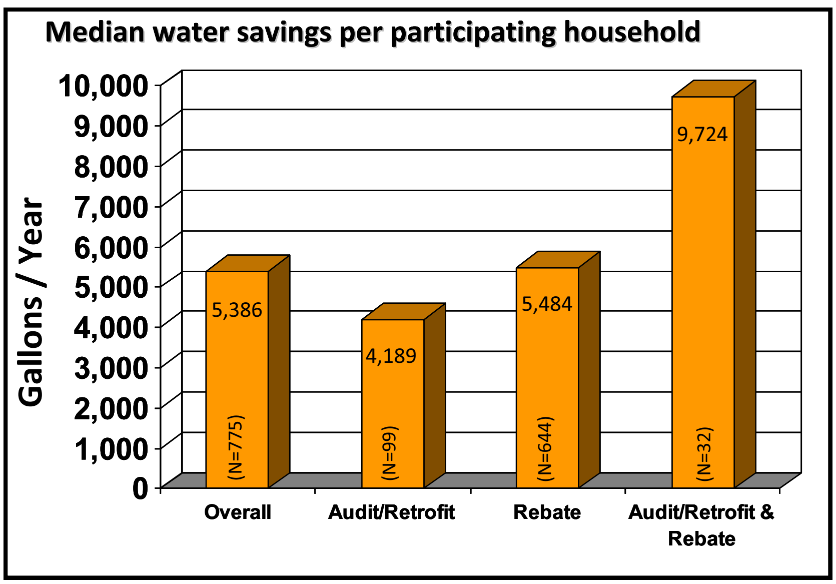
- Free indoor water-use audits and water-saving retrofit devices tailored to the results of the audits
- Rebates for eligible water-efficient washing machines and toilets.

Between 2003 and 2006, 775 households (approximately 9% of the town) participated in one or both of these voluntary programs. DCR evaluated the effectiveness of the programs on household and town-wide water use by examining customer water records from the winters of 2002 through 2007. Water records from the summer growing seasons were not examined because outdoor water uses, such as lawn irrigation, could mask the results of changes in indoor water use. For each participating household, DCR compared winter water use before and after the audit took place or before and after the installation of one or more water-saving appliance was installed.

Key Findings

Did the two water-conservation programs lead to savings in the households who chose to participate?

- **Yes:** Both programs resulted in water savings for participating households:
  - Median household reduction in water use after receiving an audit/retrofit kit was 11.5 gal/day (4,189 gal/yr)
  - Median household reduction in water use after installing one or more water-efficient appliances was 15 gal/day (5,484 gal/yr)
  - Households participating in both programs saw the highest median savings (27 gal/day; 9,724 gal/yr).



Water conservation programs for homeowners: water-use audits and appliance rebates (continued)

What were the overall water savings realized by the town from the two programs?

- As a result of the 775 households that had participated in one or both of the programs by 2006, the town-wide water savings was approximately 11,600 gal/day or 4.2 million gal/yr. This is equivalent to about two full days of water supply in Reading. Households have continued to join both programs since 2006, and the town-wide savings is presumably continuing to rise.

Things to Keep in Mind

This study evaluated the effectiveness of two water conservation programs for the average participating household and for the town, overall. The water savings varied greatly among households; some in the appliance rebate program replaced a single toilet, while others replaced three toilets and a washing machine. Similarly, an indoor water use audit in one household may have resulted in the installation of a single low-flow faucet device, while in another, several such devices may have been installed and a leaking toilet may have been identified and fixed. The findings are, therefore, most appropriate for town-wide planning; any individual households that install water-efficient appliances or retrofit devices could see water savings higher or lower than the averages reported here, depending on the number of appliances or devices they install.

Additionally, over the five-year period of the study, the town saw waves of new participation in response to various outreach efforts, including a significant spike in participation after implementation of a water conservation curriculum in third-grade classes in all of Reading's schools. It should be expected that participation in this type of water conservation program is closely related to the frequency and type of outreach.

The case studies described in this report illustrate many ways to reduce water demand in areas with critical water resources. The studies also suggest that conservation practices must be carefully planned and designed in order to achieve optimal results.

The Ipswich River Targeted Watershed Grant

In 2004, through its Targeted Watersheds Grant Program, the United States Environmental Protection Agency (EPA) provided $1 million through a cooperative agreement to the Massachusetts Department of Conservation and Recreation (DCR) to demonstrate and study practices to help conserve water, reduce storm water pollution, and increase groundwater recharge throughout the Ipswich River watershed, in northeastern Massachusetts. Under this cooperative agreement, four low impact development (LID) and five water conservation projects were undertaken by DCR in cooperation with EPA, the United States Geological Survey (USGS), eight municipalities, the Ipswich River Watershed Association, and other cooperating partners. The projects were designed to (1) implement and quantify the benefits of LID and water-conservation techniques and (2) evaluate the impact of wide-spread application of these techniques throughout the watershed, using computer modeling simulations. Additional funding for this work was provided by DCR; USGS; the Ipswich River Watershed Association; and the towns of North Reading, Reading, Topsfield, and Wilmington. In-kind support was provided by DCR; the towns of Hamilton, Ipswich, Middleton, North Reading, Reading, Topsfield, Wilmington, and the city of Peabody; AquaSave LLC; the Martins Companies; the North Shore Housing Trust (since merged with Harborlight Community Partners); and Rainwater Recovery.

This is one in a series of three fact sheets that describes the work conducted under the cooperative agreement. The complete series includes:

- **Ipswich River Targeted Watershed Grant Fact Sheet: Green Roof Case Study**
- **Ipswich River Targeted Watershed Grant Fact Sheet: Water Conservation Case Studies**
- **Ipswich River Targeted Watershed Grant Fact Sheet: Three Low-Impact Development Case Studies**

For more information on the Ipswich River Targeted Watershed Grant, including links to study results and other publications, please visit:

http://www.mass.gov/dcr/watersupply/ipswichriver/index.htm.

The Massachusetts Department of Conservation and Recreation (DCR), an agency of the Executive Office of Energy and Environmental Affairs, oversees 450,000 acres of parks and forests, beaches, bike trails, watersheds, and dams, whose mission is to protect, promote, and enhance our common wealth of natural, cultural, and recreational resources. To learn more about DCR, our facilities, and our programs, please visit www.mass.gov/dcr. Contact us at mass.parks@state.ma.us.

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