

## Chapter 4

# Managing Demand for Water

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### Introduction

Climate change is already having an impact on the limited freshwater resources of the United States. The patterns and intensity of precipitation are shifting.<sup>1</sup> The nature of drought is changing.<sup>2</sup> There is widespread melting of the snowpack that many areas of the country rely on for water supply.<sup>3</sup> The temperature is increasing and so is the rate of evaporation.<sup>4</sup> Soil moisture and runoff are different than they once were.<sup>5</sup>

Moreover, there is growing competition for this evolving, finite resource among farms, municipalities, and industries, which are all vying for the same prize in the arena of our nation's aging water supply infrastructure.<sup>6</sup> This competition will grow more intense and water will become more scarce as the temperature rises—and this rising temperature will exacerbate the already considerable strain on fresh water. Growing seasons will become longer and farms will require more water for irrigation. Higher ambient temperatures will force power plants and industry to extract more water for cooling.<sup>7</sup>

In addition to the direct effects of a changing water cycle, a growing population will place greater strain on this resource.<sup>8</sup> More people will require more electricity and more food, contributing further to the expanding water requirements of the agricultural and energy sectors. Climate change is fundamentally altering the natural processes that govern the United States' freshwater resources as the country's population continues to increase.<sup>9</sup> Furthermore, the most dramatic population growth is occurring in arid areas of the country that are already water stressed, primarily in the Southwest.<sup>10</sup>

These parallel stresses will increase demand for water across multiple sectors, but the expected changes in the timing and intensity of the water cycle and the increased pressure on water supplies across the country can be offset by managing demand through a variety of efficient water use practices, improvements to infrastructure, and legal and policy reforms.

The second section of this chapter provides an overview of the stresses that climate change will place on existing demand for water in the coming years, as well as tools various sectors might utilize in order to cope with these stresses. The third section will discuss challenges that the United States will face in meeting water demand

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and opportunities for conservation and extending our existing water supplies. The fourth section will discuss current and potential water management tools available to policymakers. The important topic of managing *supplies of water* (as opposed to *demand for water*) is the subject of chapter 3. International issues in climate change adaptation and water supply and demand are the subject of chapter 22.

## **Climate Change and Managing Demand through Efficiency and Conservation**

### **Thermoelectric Power Generation**

Thermoelectric power generation accounts for approximately 50 percent of water withdrawals in the United States, 41 percent of total freshwater withdrawals, and 53 percent of fresh surface water withdrawals.<sup>11</sup> California withdraws more water for thermoelectric use than any other state.<sup>12</sup> Illinois, Texas, Michigan, and Tennessee account for 28 percent of thermoelectric withdrawals of fresh water.<sup>13</sup> Thermoelectric water withdrawals are less significant in western states (aside from California), which rely more on hydroelectric plants for power generation.<sup>14</sup>

The power sector withdraws more water than any other category of water user, but it is important to note that these withdrawals are not highly consumptive.<sup>15</sup> Simply put, power plants remove a high volume of water from the source, but most of what is taken out is returned. However, despite this relative efficiency, thermoelectric power plants still require a large amount of water to function: shortages can result in irregularities in plant operation and unreliable service to customers.<sup>16</sup> Therefore the volume of water necessary for thermoelectric power generation is not available to other users and power plant operations, which affects supply and demand despite the low level of water consumption.<sup>17</sup>

There are three types of water-based cooling systems used by thermoelectric power plants: once through, wet recirculating (or closed loop) and dry.<sup>18</sup> These systems can use either fresh or saline water.<sup>19</sup> Once-through systems withdraw water from a lake or river, then that water passes through a surface condenser before being discharged back into the source.<sup>20</sup> Once-through systems are characterized by high levels of water withdrawal but low levels of water consumption.<sup>21</sup> Wet recirculating systems use cooling towers to dissipate heat from the cooling water into the atmosphere.<sup>22</sup> Wet recirculating systems withdraw less water than once-through systems but consume more of it, losing a higher percentage of the withdrawal to evaporation.<sup>23</sup> Indirect dry cooling is the most efficient method in terms of both withdrawals and consumption: these systems utilize a water-cooled surface condenser, but a dry cooling tower transfers heat from the water into the air, resulting in no evaporative loss.<sup>24</sup>

Thermoelectric generation is going to increase over the course of the next several years, paralleling worsening effects of climate change. The Energy Information Administration projects that thermoelectric generating capacity will increase by 11 percent by 2030.<sup>25</sup> This will result in an increased demand for cooling water. Moreover, the U.S. Department of Energy predicts that power plants will implement wet recirculating systems in greater numbers over the next 20 years, thereby placing additional strain on water resources already burdened by the necessity of increased power demands.<sup>26</sup>

The direct effects of global warming will also result in increased demand on power plants for cooling water: higher ambient temperatures mean that more coolant

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is needed to keep plants operational.<sup>27</sup> This is in addition to the public's increased use of electricity for air conditioning and other refrigeration as the climate warms, as discussed in chapter 5, "Energy System Impacts."<sup>28</sup> Furthermore, many power plants across the country pump their cooling water from underground aquifers—and these aquifers are becoming depleted.<sup>29</sup> High temperatures will force power producers to consume more water to cool their facilities at the same time that more electricity will be required to access increasingly elusive supplies of water. To produce the electricity necessary to pump cooling water, power plants will require more cooling water, creating a vicious cycle of rapidly accelerating and often inefficient water use.

Finally, certain regulatory efforts to combat climate change could actually have the perverse result of increasing thermoelectric power plant demand for cooling water. Carbon capture and storage technology may increase water consumption in power plants.<sup>30</sup> To mitigate their contribution to anthropogenic climate change, power generators will be forced to consume more of the nation's limited freshwater resources.

However, the outlook is not entirely bleak in the context of water consumption in power generation. Thermoelectric power-generating facilities have several options available to them to decrease the amount of limited fresh water required for their operations. Efficiency measures and alternative water supplies offer coping mechanisms for power plants confronting climate change.

A number of power plants across the country are already using reclaimed wastewater instead of clean fresh water that might be better used for other purposes. This is especially common in dry, western states.<sup>31</sup> Water reuse also has applications in other sectors of water use as well, including both irrigation and domestic uses.<sup>32</sup> As of 2007, approximately 50 power plants across the United States were using reclaimed wastewater for cooling.<sup>33</sup>

However, there is some resistance to this practice because of health concerns, primarily regarding controlling the level of bacteria and other disease-causing organisms.<sup>34</sup> These can be controlled through filtration or disinfectants such as chlorine, but chemical treatments come with their own environmental ramifications.<sup>35</sup> In some places, state regulations specify requirements for disinfection procedures, or they place limits on the total number of such organisms that can be present in returned cooling water.<sup>36</sup> In addition to health concerns, reclaimed water also presents a number of operational problems that may limit the viability of its widespread adoption as an alternative to cleaner cooling water: the chemicals and waste in reclaimed water can corrode and otherwise stress some of the metal surfaces within a power plant.<sup>37</sup>

Nontraditional sources of water might also provide some relief to overtaxed freshwater resources as climate change increases demand for electricity and makes power plant cooling more expensive. Some of these sources include water from deep saline aquifers; coal bed fractures and pores, which can contain large volumes of water; accumulated water in abandoned mines; and water that is returned after the extraction of shale gas.<sup>38</sup>

In addition to turning to alternative sources of cooling water, thermoelectric power plants might also adopt more efficient operational systems and practices, although some of these come with a number of drawbacks. Some examples of more efficient plant configurations and cooling methods include dry cooling, hybrid cooling, and synergistic energy and water production.<sup>39</sup> In dry cooling systems, towers that use only air for cooling replace the evaporative towers of wet recirculation systems.<sup>40</sup> No

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water is lost to evaporation during this process, but it negatively affects the efficiency of power generation.<sup>41</sup>

Hybrid cooling systems employ a combination of wet recirculation and dry cooling to strike a balance between efficiency of water use and efficiency of plant operation.<sup>42</sup> This compromise decreases the amount of water that must be withdrawn but maintains higher performance in areas with warmer climates where air cooling is not as effective.<sup>43</sup>

## **Agriculture**

After thermoelectric power generation, agricultural irrigation is the second most significant use of water in the United States, accounting for 31 percent of withdrawals.<sup>44</sup> Water is used in numerous aspects of the agricultural process: frost protection, application of chemicals, weed control, field preparation, crop cooling, harvesting, dust suppression, leaching salts from the root zone, and water lost in conveyance.<sup>45</sup> California, Nebraska, Texas, Arkansas, and Idaho withdrew 52 percent of the nation's irrigation water in 2005.<sup>46</sup> More water is used in arid western states, which primarily draw their water from surface sources.<sup>47</sup> Despite the significant role that agriculture plays in total U.S. water consumption, irrigation has gotten more efficient since the 1950s: the total irrigated acreage in the United States has increased and withdrawals have remained static or decreased.<sup>48</sup> Between 1950 and 2005, the application rate of water used in irrigation has declined from 2.55 acre-feet per acre to 2.35 acre-feet per acre.<sup>49</sup>

Climate change will have a variety of effects on the demand for water in agriculture, as detailed in chapter 11, "Agriculture and Forestry." A longer growing season and increased rates of evaporation due to higher temperatures will increase demand in some regions. Moreover, as accumulated snowpack becomes less viable as a water source due to rising temperatures, demand for water from surface bodies of water and aquifers will increase.<sup>50</sup> Drought has become more common in the United States during the past several decades, and these extended dry spells will seriously complicate issues of water supply and demand for agricultural users.<sup>51</sup> On the other hand, some areas of the country might receive more precipitation as a result of climate change, which could decrease demand in those regions.<sup>52</sup> However, increases in precipitation come with their own potentially deleterious effects on agriculture: too much water could damage seedlings, reduce growth, and foster an environment conducive to pests and disease.<sup>53</sup>

The climate is changing and the population is growing simultaneously. In 1950 the population of the United States was just over 150 million—approximately half the current number.<sup>54</sup> Even if population growth slows, climate change may make agriculture more difficult in broad swaths of the country either because there is too much water (flooding) or too little (droughts). It may not always be feasible or legal to transport water from places where it is overabundant to places experiencing drought. In addition to the question of their cost and practicability, transbasin water diversions are also often fraught with numerous other complexities and hurdles.<sup>55</sup>

Absent a coordinated approach to efficient water management in agriculture, farming could become significantly less viable in various regions across the United States. However, there are a number of tools available to farmers and policymakers that will be invaluable in addressing the effects of climate change on water supply.

Improving irrigation practices is the best way to increase the efficiency of water use in the agricultural sector. Recent years have seen a trend toward increasing the

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efficiency of irrigation, which is likely to continue into the future.<sup>56</sup> Drip irrigation and sprinkler systems have gradually replaced flood irrigation as water has grown scarcer and it has gotten more expensive to pump water from place to place.<sup>57</sup> Some of this transition has been motivated by public subsidies for the installation of new irrigation systems. However, these incentives are not without drawbacks. Some studies have shown that subsidies can have the perverse result of adding to strain on water resources because drip irrigation increases crop yields by increasing water consumption.<sup>58</sup>

Optimally scheduling irrigation is another way to increase the efficiency of water use in agriculture. Irrigation scheduling takes a number of different factors into account—evaporation rates, soil moisture, and climate conditions—to calculate the exact amount of water that crops need on a daily basis.<sup>59</sup> Delaying irrigation for as long as possible can also increase efficiency, although this has the potential to affect crop yield.<sup>60</sup> Some conservation districts even require measurement and scheduling of water used in irrigation to obtain information to project future water supply needs.<sup>61</sup>

Irrigation audits are another way to calculate the amount of water used on a farm-by-farm basis. Audits monitor the trends of use and can help irrigators locate leaks and other problem areas in the water supply system before they become widespread.<sup>62</sup> In addition to providing information on water use itself, irrigation audits can assist farmers in resizing, reshaping, or leveling their fields to allow the most efficient delivery of water.<sup>63</sup> Additionally, at the time of writing, a new satellite technology was in development to help farmers optimize the use of water by identifying the areas on a farm where water is used least and most efficiently.<sup>64</sup>

In addition to studying and developing irrigation practices, a number of other agricultural techniques can increase the efficiency of water use on farms. Planting drought-resistant crops or plants that use less water can increase efficiency.<sup>65</sup> Additionally, selecting plants that are better adapted to the ambient level of soil moisture can decrease the amount of water required to cultivate these crops.<sup>66</sup>

Crop residue management can also increase the efficiency of water use for agricultural producers. This practice leaves a portion of the previous crop on the field, which helps reduce erosion, captures precipitation, and reduces runoff.<sup>67</sup> Another similar, nonirrigation practice that can increase water use efficiency is conservation tillage, reducing or eliminating field tilling.<sup>68</sup> A reduction of field tillage leaves root development and soil structure intact, which in turn facilitates the efficient uptake of nutrients and water by plants.<sup>69</sup> Furthermore, it reduces air pollution, preserves habitats for beneficial organisms, lowers fuel consumption and labor costs, improves weed suppression, and decreases evaporation of water from the soil.<sup>70</sup>

## **Nonagricultural Irrigation, and Commercial and Residential Uses**

Domestic and commercial water use accounts for a much smaller percentage of water withdrawals than does agriculture or energy. Public supply, domestic use, and water used in industrial processes comprise approximately 16 percent of total use.<sup>71</sup> For the purposes of the United States Geological Survey that documented water use as of 2005, public supply can include domestic use but is specifically defined as “water withdrawn by public and private water suppliers that provide water to at least 25 people or have a minimum of 15 connections.”<sup>72</sup> Domestic use is both indoor and outdoor and can be self-supplied or provided by public suppliers.<sup>73</sup> Landscape irrigation makes up nearly

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a third of residential use, the single largest category.<sup>74</sup> Industrial water use is made up of “fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product; or for sanitation needs within the manufacturing facility.”<sup>75</sup>

Climate change will have fewer direct effects on commercial and domestic uses of water than it will on agriculture and thermoelectric power generation, although in some ways the effects of climate change on those sectors will trickle down to the commercial and residential spheres. Industrial production and fabrication is not very sensitive to climate change effects, although more water will be needed for cooling processes, as is the case for power plants.<sup>76</sup> As previously mentioned, with higher temperatures comes an increased demand for electricity to power air conditioners, refrigerators, and other cooling devices.<sup>77</sup> These appliances will not only become more costly to power but will likely be used at an increased rate. Additionally, domestic water use might increase in order to continue to irrigate lawns and landscapes, which will require more water as aridity increases.<sup>78</sup>

On average, Americans use more water domestically than do the citizens of any other country in the world, withdrawing more than 90 gallons of water per person each day.<sup>79</sup> More than half of these withdrawals go toward lawn and landscape irrigation.<sup>80</sup> The remainder satisfies indoor household needs: toilet use accounts for 26.7 percent; clothes washing, 21.7 percent; showers, 16.8 percent; faucets, 15.7 percent; leaks, 13.7 percent; and the remainder is used for smaller, miscellaneous purposes. Even though domestic use represents a relatively small percentage of overall use in the United States, the withdrawals in this sector are still significant, and the effects of climate change will inevitably affect the patterns of American water use.

As will be the case for commercial agriculture, increased aridity, longer warm seasons, inconsistent precipitation, and heightened risk of drought will increase the demand for water for domestic landscape irrigation. Consumers will have to implement efficiency and conservation methods if they wish to maintain their historical levels of use, if this is even possible in the face of worsening global climate change.

Major gains could be made in domestic water use efficiency if consumers adopted saner landscape irrigation practices, as this application accounts for the majority of domestic water withdrawals.<sup>81</sup> The easiest method for domestic consumers to implement is simply to stop oversaturating their lawns and landscapes; this can be accomplished by testing to see whether the grass actually needs to be watered.<sup>82</sup> Additionally, incorporating water-efficient plants can significantly decrease the amount of water necessary to irrigate a landscape.<sup>83</sup> Water-efficient landscaping design such as micro-irrigation, which involves the frequent application of small quantities of water as drops, tiny streams, or miniature spray through emitters or applicators placed along a water delivery line, can also be employed.<sup>84</sup> Finally, the installation of efficient watering systems, which can include drip irrigation lines and soil moisture sensors, can reduce water use.<sup>85</sup>

Using rainbarrels to capture and store precipitation for later use in the landscape can also reduce the need of domestic users to withdraw water from their municipal supply.<sup>86</sup> Cisterns can also be used to store rainwater for landscape and irrigation purposes. Cisterns are encouraged at the state level, such as by California’s Green Building Code,<sup>87</sup> and at the local level by cities such as Santa Fe, New Mexico, which encourages collecting, storing, and using rainwater for landscape irrigation and for use in toilets.<sup>88</sup> A number of states and municipalities also encourage rainwater harvesting.

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For example, Texas has enacted a law that reduces property taxes for commercial and industrial facilities that use rainwater harvesting and pollution control and provides a sales tax exemption for rainwater harvesting equipment.<sup>89</sup>

Internal home-efficiency measures can also be used to reduce domestic use. The most obvious examples of these include buying high-efficiency washing machines and low-flow toilets.<sup>90</sup> Keeping pitchers of water in the fridge means that users do not need to run the tap until the water turns cold.<sup>91</sup> Also, not rinsing dishes before putting them in the dishwasher can save up to 10 gallons of water per load.<sup>92</sup> Utilities can encourage such conservation efforts by implementing conservation-oriented rate reform, such as increasing block or tiered rate structures. For example, utilities in California encourage water conservation by billing higher per-gallon rates for water above set thresholds.<sup>93</sup>

Local governments across the country have begun instituting programs to motivate and compel homeowners and municipal water suppliers to adopt water-saving practices. Payson, Arizona, requires homeowners to replace old fixtures with modern, more efficient appliances when remodeling.<sup>94</sup> San Francisco has adopted similar conservation measures, including encouraging the use of water-efficient plumbing, awareness-raising programs, and water surveys and audits.<sup>95</sup> This program provides specific standards that must be met, but some programs give more leeway to consumers and water suppliers to decide how efficiency benchmarks are met. For instance, Alpharetta, Georgia, has simply required a 10 percent reduction in water use but provided no criteria on how to meet this goal.<sup>96</sup>

In addition to local ordinance programs, there are voluntary certification programs that include water efficiency, such as the United States Green Building Council's Leadership in Energy and Environmental Design (LEED) system. LEED is a point-based system that rates new construction and major renovations on their incorporation of environmentally sound development practices.<sup>97</sup> To be LEED certified, a building must reduce aggregate water use by 20 percent.<sup>98</sup> Once this requirement has been met, the construction project can earn additional points that go toward the building's ultimate score and level of LEED certification.<sup>99</sup> A higher number of points means a more illustrious environmental certification. These points can be earned by incorporating water-efficient landscaping, rainwater capture, and innovative wastewater technologies.<sup>100</sup>

The methods for reducing domestic water use can range from the simple, such as taking shorter showers, to the complex, such as citywide incentive- or command-and-control-based ordinance programs with highly specified efficiency standards and guidelines. However, even the widespread adoption of home-efficiency measures will be literally only a drop in the bucket if municipalities cannot learn to control the single-most significant source of inefficiency and waste in the domestic use sector: losses due to leakage in municipal water distribution systems. This problem will be discussed in detail in the following section.

## **Water Demand Challenges and Water Conservation Opportunities**

### **Leakage in Municipal Water Distribution Systems**

As previously mentioned, the primary source of waste in the residential and municipal sector stems from defects and losses in water distribution systems. There is a wide

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range in the estimated quantity of water lost due to system leakages and other inefficiencies. These losses can range from 14 to 60 percent of the water treated by water systems in some areas.<sup>101</sup> Across the country, this amounts to over *six billion gallons of water lost each day*.<sup>102</sup> This is a staggering amount of water that is simply wasted and not delivered to its intended recipients for its intended purposes.

Moreover, the consequences of this waste are not limited to the revenue of water suppliers.<sup>103</sup> Lost water means that more water needs to be withdrawn and treated to meet demand.<sup>104</sup> Additional treatment requires more energy to power processing plants.<sup>105</sup> The need for more energy to treat water means that more water must be withdrawn elsewhere to cool the plants that create that energy. Frequently, power plants contribute to the exacerbation of climate change, which is having a negative impact on water supply in many places. Thus, in a multitude of ways, municipal distribution system losses are unnecessarily contributing to the strain on water resources in a warming world.

In large part, leakages are caused by the aging delivery systems of municipal water suppliers.<sup>106</sup> There are over 880,000 miles of drinking water infrastructure in the United States and much of it is gradually decaying.<sup>107</sup> Poorly constructed pipelines, inadequate corrosion protection, poorly maintained valves, and mechanical damage all contribute to losses.<sup>108</sup> Structural weaknesses in the distribution system frequently lead to lower water pressures. This causes suppliers to increase pressure in the system, which accelerates loss and increases energy consumption.<sup>109</sup>

Losses in municipal water supplies occur in two distinct ways. First, there are apparent losses, which are attributable to customer meter inaccuracies, billing system data errors, and unauthorized consumption.<sup>110</sup> Second, real losses are water that is extracted but never reaches its destination or intended purpose because it escapes the system altogether.<sup>111</sup> Both of these deficiencies in delivery can be resolved through better water management practices and a comprehensive water conservation program.

Once primarily associated with arid western states, such management programs are becoming more common throughout the United States.<sup>112</sup> Additionally, the scope of these programs is growing to include residential, commercial, institutional, and industrial customers.<sup>113</sup> The implementation of better management practices has to overcome the historical lack of detailed knowledge about the nature of losses in distribution systems: in previous eras suppliers knew that water was being lost but they were ignorant as to the precise causes of that loss.<sup>114</sup>

Water loss control programs apply techniques to recover as much water and prevent as much loss as is economically justifiable.<sup>115</sup> Frequently, the determined balance between water loss reduction and cost reduction results in some water still being lost.<sup>116</sup> Achieving zero loss could potentially cost more than the savings attained by conservation.<sup>117</sup>

As previously discussed, a well-designed water loss control program can improve the fiscal performance of water suppliers by reducing the expenditures necessary to extract, treat, and distribute water.<sup>118</sup> However, these programs have a number of other benefits as well.

First, sound conservation practices can reduce the severity of the effects of drought.<sup>119</sup> More water retained in the system means that more water is reaching customers in need and less water must be withdrawn from the source.

Second, such practices increase the utility's knowledge of its own distribution system and allow the supplier to respond to emergencies more quickly.<sup>120</sup> This knowledge

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has additional ancillary benefits, which include improved relations with the public and employees and increased firefighting capacity due to reliance on water pressure and availability.<sup>121</sup>

Third, fuller knowledge of water distribution systems improves the environment beyond the direct benefits of water conservation. Fewer leaks in the system mean fewer avenues for possible contamination.<sup>122</sup>

Different parts of the country have different types of hydrological systems and therefore no water loss control program can be designed for the entire country. Each water supplier must tailor its program to its region.<sup>123</sup> However, three primary components are crucial to a successful conservation program regardless of location: the water audit, intervention, and evaluation.

During a water audit, the supplier determines how much water is being lost and where it is being lost.<sup>124</sup> This is accomplished by examining the utility's distribution, metering, and accounting practices.<sup>125</sup> Ideally, water audits are conducted on an annual basis so that the supplier can measure its performance and its improvements (or lack thereof) and compare itself to other water utilities.<sup>126</sup>

There are two types of water audits: top down and bottom up. A top-down audit is performed by examining existing information and records; no fieldwork is necessary.<sup>127</sup> A bottom-up audit involves inspecting individual components of the distribution system.<sup>128</sup> Bottom-up audits are usually performed only after several top-down audits have determined that a more specific examination of the system is required.<sup>129</sup>

Auditing is highly dependent on water meters, which measure withdrawals. Frequently, bottom-up audits include installing additional meters to improve the accuracy of data collection.<sup>130</sup> Simply put, meters allow water suppliers to charge their customers for the water they use.<sup>131</sup> When water users are aware of how much water they are using—and how much that use is costing them—demand tends to decrease.<sup>132</sup> Also, meters can help reduce unauthorized consumption—when unscrupulous individuals steal water from the supplier and contribute to the strain on supply.<sup>133</sup> Installing meters can raise complex and sometimes contentious issues of cost, landlord-tenant leasing, and difficulties with existing water infrastructure.<sup>134</sup> However, the presence of functioning meters works toward the goal of water use reduction in an age of strained freshwater supply.

But to serve their intended purpose, meters must be accurate. Frequently, meters lose a measure of accuracy when water use reaches a threshold of high consumption.<sup>135</sup> Water audits are vital to maintaining the accuracy of meters over time.

Water audits also provide suppliers with the information necessary to successfully complete step two of a water loss control program: physically repairing each weakness in the distribution system. The technology for locating leaks is evolving rapidly from a “find and fix” approach to a more comprehensive “predict and prevent” strategy.<sup>136</sup> Some of the methods for adopting this new strategy and adapting to the increasingly pressing need for water loss control include sonically canvassing the system for leaks and using automated leak noise monitoring or minimum flow analysis to detect leaks as they occur.<sup>137</sup> Additionally, reducing pressure within the system during low demand hours can reduce strain on aging infrastructure.<sup>138</sup>

The final step of a water loss control program is evaluation. After the utility completes the water audit and repairs any found flaws in the system, the water supplier must evaluate its data and its performance and progress to look for ways to improve water loss control in the future.<sup>139</sup> Sometimes success is immediately

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apparent, such as when a leak has been fixed, but in other cases the outcome of the water auditing and intervention processes are less clear.<sup>140</sup> Repeated audits, intervention, and evaluation are necessary to refine the loss control program over time and clarify the steps necessary to improve the efficiency of these complex and vital distribution systems.

Historically, water loss control programs have been used inconsistently and ineffectively. However, in recent years, states and utilities across the country have implemented better water management practices.<sup>141</sup>

Texas was the first state to require water utilities to submit water audits to the Texas Water Development Board. Over 2,000 water audits were submitted to the board in 2005.<sup>142</sup>

The State of Washington passed comprehensive legislation promoting loss control programs and water use efficiency.<sup>143</sup> As a result of this legislation, suppliers must “[p]ublicly establish water savings goals for their customers,” “[e]valuate or implement specific water saving measures to achieve customer-based goals,” “[d]evelop a WUE planning program to support the established goals,” “[i]nstall meters on all customer connections by January 22, 2017,” “[a]chieve a standard of no more than 10% water loss,” and “[r]eport annually on progress towards achieving these goals.”<sup>144</sup>

The Delaware River Basin Commission oversees water use in its titular watershed, which was experiencing losses of over 150 million gallons a day.<sup>145</sup> As a result the commission amended its water code to promote efficiency among suppliers. Effective in 2012, the code requires mandatory annual water audits. Tennessee has enacted legislation with similar requirements.<sup>146</sup>

Leakages in municipal water distribution systems number among the most common and pervasive forms of water demand challenges: this is water that simply disappears. Although solutions to such a pervasive problem must necessarily be complex and rigorous, significant gains can be made in the realm of water conservation—gains that boil down to fixing the leaks.

## **Shale Gas Extraction**

Shale gas is a form of natural gas that is extracted from hydrocarbon-rich shale formations, and it is quickly becoming one of the most important new trends in onshore domestic fuel production in the United States.<sup>147</sup> In the past, petroleum and natural gas wells had to be drilled vertically, and the resource either flowed to the surface naturally or was pumped.<sup>148</sup> Advances in drilling technology have made directional, nearly horizontal wells possible.<sup>149</sup> After a directional well is drilled, hydraulic fluids are injected into the wellbore to crack the surrounding rock so that the well can produce significant amounts of gas; this process is called hydraulic fracturing or “fracking.” These technological developments have made unconventional sources of natural gas, like shales, accessible for exploitation.<sup>150</sup> (See chapter 5 of this volume for more about the water demands of fracking and the relationship between energy, water, and climate adaptation.)

A great deal of water is necessary to extract the gas within these shale formations. The amount of water needed to drill and fracture a horizontal gas well ranges from two to nearly eight million gallons, depending upon the individual characteristics of the shale formation.<sup>151</sup> The water used in hydraulic fracturing comes from a variety of sources: surface water, like lakes and rivers; groundwater; private sources; municipal water; and reused water.<sup>152</sup> Sometimes it can be difficult to meet the needs of

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companies drilling for shale gas due to growing populations, industrial requirements, seasonal variations in precipitation, and other sources of demand.<sup>153</sup> In some cases, operators are capturing seasonal overflows of rivers and then using the stored water to extract the shale gas later in the year.<sup>154</sup>

Although shale gas is controversial and the future of the practice is uncertain, if demand for natural gas continues to grow and water continues to be used in its extraction, there are potential avenues for water conservation in the recovery of water used during mining. The water used in shale gas development represents only a small fraction of use in most basins, between 0.1 percent and 0.8 percent.<sup>155</sup> Nearly all of the water used to fracture the rock surrounding the wellbore is recovered; this is simply a necessity because the gas cannot be retrieved while the water is still in the well and in the way.<sup>156</sup> Although this water is recovered, it might be treated and discharged in a different watershed than that from which it was withdrawn.

In addition to the water retrieved from the drilling process, natural water occasionally accompanies fracking fluid to the surface. Some industry groups have suggested that this water be viewed as a resource in its own right.<sup>157</sup> Currently a number of regimes and practices are used to manage this water. The Clean Water Act regulates surface discharges of water associated with shale gas drilling and production, as well as storm water runoff from production sites.<sup>158</sup> The Safe Drinking Water Act regulates the underground injection of fluids from shale gas activities.<sup>159</sup> Physical management includes injecting the water underground, treating it, discharging it, and recycling it.<sup>160</sup>

However, a number of environmental concerns have accompanied the growing attractiveness of shale gas.<sup>161</sup> During fracking, additives, called proppants, are injected into the water that is pumped into the wellbore.<sup>162</sup> Although the percentage of chemicals in fracking water is relatively low—less than 0.5 percent by volume—the massive amount of water used in shale gas extraction means that even this small percentage can translate into tens of thousands of gallons of chemical waste.<sup>163</sup> Additionally, gas wells that are not constructed properly might allow contaminated water to flow to the surface or into potable groundwater and wreak environmental havoc.<sup>164</sup>

Currently there is an exemption to the Safe Drinking Water Act, commonly referred to in environmental circles as the “Halliburton Loophole,” that excludes hydraulic fracturing from regulation.<sup>165</sup> The exemption was originally created by the Energy and Policy Act of 2005.<sup>166</sup> Consequently, fracking has become a thorny environmental issue because of its potential to contaminate water supplies and its lack of coverage under existing legislation. As the extraction process has grown more prevalent, there has been a commensurate increase in public concern that this method of shale gas extraction will lead to contamination of the groundwater drinking supply.

Environmental opposition to hydraulic fracturing during shale gas mining has already reached Congress in the form of a proposed amendment to the Safe Drinking Water Act. The Fracturing Responsibility and Awareness of Chemicals (FRAC) Act, introduced into both the 111th and 112th Congresses, would repeal the Halliburton Loophole exemption.<sup>167</sup> Disputes over this exemption remain unresolved as of this publication.

Shale gas extraction is also accompanied by a number of serious environmental hurdles. The question then becomes, “How do we make this water safe for use?” The most obvious answer is to circumvent the problem of contamination and keep the water on site, simply reusing hydraulic fracturing water for hydraulic fracturing.<sup>168</sup> The water would not have to be treated to a high standard of purity, and there would

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be no transport costs.<sup>169</sup> When a shale gas well is situated near an urban center, it might also be possible for the water to be treated in municipal facilities.<sup>170</sup> New technologies are currently being developed to treat hydraulic fracturing water to the point where it might be used in other applications such as irrigation or even drinking water; however, these treatment systems might not be feasibly implemented into currently existing gas plans.<sup>171</sup>

Thus the water byproduct of shale gas extraction might help alleviate strain on freshwater resources in the future, but there are a number of prerequisites to the viability of this option. The water used in shale gas extraction presents a possibility for water conservation, but it also presents a water-quality challenge for meeting growing demand in a warming world.

## **Ethanol and Biofuel Production**

Biofuels have emerged as an alternative to petroleum-based fuel in recent years, and the cultivation of crops for their production is rapidly increasing in the United States.<sup>172</sup> Ethanol, a biofuel derived from corn, is the most common biofuel produced in the United States, and it will become more prevalent in the coming years. In 2007, President George W. Bush called for the annual production of 35 billion gallons of ethanol by 2017, or nearly 15 percent of U.S. liquid transportation fuels.<sup>173</sup> Currently, the United States is the world's largest producer of ethanol, accounting for about 36 percent of global output.<sup>174</sup>

A number of factors are contributing to the booming ethanol/biofuel industries in the United States. Biofuel production reduces U.S. dependency on foreign fossil fuels, which has potential environmental and national security benefits.<sup>175</sup> Additionally, farmer income benefits from the cultivation of biomass as a result of increased demand and government subsidies.<sup>176</sup> Biofuel policy is a complex area with many tradeoffs beyond water use: food security, food cost, fossil fuel reduction, farmland preservation, photosynthetic ceiling concerns, and so on.

Increased biofuel production will dramatically shift the nature of agricultural production in the United States and will have significant impacts on the quantity and quality of freshwater resources that are already strained by growth in other sectors and by climate change. Although biofuels have the potential to reduce the use of fossil fuels—which is a direct cause of anthropogenic climate change—we must also take care to not exacerbate the effects of global warming in our attempts to mitigate them.

Biofuel production will negatively impact water availability.<sup>177</sup> Although the net negative effects of increased production will probably not radically alter national aggregate water use, there will likely be significant regional and local impacts.<sup>178</sup> Large quantities of water are critical at multiple points of the production process.<sup>179</sup> Water is necessary for agricultural irrigation, and it is integral to the conversion of those crops into the fuel itself, primarily for the heating and cooling of the biorefinery.<sup>180</sup>

The amount of water necessary for biofuel production will vary by region and by the type of crop being grown.<sup>181</sup> For instance, in many parts of the country corn will replace soybeans as the demand for biofuels grows.<sup>182</sup> The effects of increased corn production on the water supply depend on the region in which the shift in crop cultivation occurs.<sup>183</sup> “Corn generally uses less water than soybeans and cotton in the Pacific and Mountain regions, but the reverse is true in the Northern and Southern Plains. . . .”<sup>184</sup> The largest increases in corn production are expected to take place in the Northern Plains region, which is already water scarce.<sup>185</sup>

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Growing demand for biofuels and government subsidy of the industry will also place additional strain on water resources as farmers place marginal lands back into production.<sup>186</sup> Marginal lands have less productive soil and thus require more water for irrigation.<sup>187</sup>

In addition to negatively affecting water quantity, increased biofuel crop cultivation has the potential to harm water quality. As more fertilizer is applied to improve yields, nutrient water pollution and marine dead zones caused by hypoxia become more pronounced.<sup>188</sup> Excess nitrogen in the Mississippi River has led to the formation of an enormous dead zone in the Gulf of Mexico, an oxygen-depleted area with almost no marine life.<sup>189</sup> The Chesapeake Bay and other coastal water bodies across the country are experiencing the same problems.<sup>190</sup> Additionally, if more fertilizers are used to grow more and more biofuel-producing crops, groundwater will be negatively affected as well.<sup>191</sup> Moreover, increased agricultural production comes with increased pesticide usage, which may also contribute to water pollution.<sup>192</sup>

Soil erosion caused by crop tillage will also decrease water quality.<sup>193</sup> There are methods to offset the negative effects of erosion in agricultural areas, but if biofuel production increases on marginal fields or other lands that are especially prone to erosion, water-quality problems might increase.<sup>194</sup>

The booming biofuels industry has the potential to negatively affect water quality and quantity beyond the confines of its agricultural production component. Biofuel refinery operations and biofuel use also have a number of implications in a water-strained world.

All biofuel production facilities require water.<sup>195</sup> The amount used during the conversion of crops into fuel is relatively small when compared to other forms of water use.<sup>196</sup> However, because refinery withdrawals are concentrated in a small area, the effects can still be extremely detrimental to the locality in which the refinery is sited.<sup>197</sup> A biorefinery that produces 100 million gallons of ethanol each year uses about the equivalent of the water supply for a town of 5,000 people.<sup>198</sup> Moreover, these plants are frequently built in areas that are already water stressed, which exacerbates existing water supply problems.<sup>199</sup> Although the additional burden these plants place on the water resources of arid regions is somewhat modest, it is one more strain on a finite, disappearing resource.

The consumptive use of biorefineries is relatively low in the overall context of consumptive water use in the United States. With current technologies, the consumptive water use of biorefineries amounts to about four gallons of water for every gallon of ethanol, but this figure is expected to drop as refinement technology improves.<sup>200</sup>

Biofuel processing and biofuel use can also harm water quality. Biorefineries generally require water from high-quality sources to prevent corrosion and damage to their facilities.<sup>201</sup> Thus some kinds of water reuse might not be available alternatives for biofuel facilities in water-scarce regions. Additionally, biofuel plants discharge salts, wastewater, and other contaminants (although discharges are relatively well regulated through the Clean Water Act and through National Pollutant Discharge Elimination System (NPDES) permitting systems).<sup>202</sup>

The actual consumer end use of biofuels may also create new water-quality challenges. Currently, most ethanol-enhanced fuel is 90 percent gasoline and 10 percent ethanol. However, new mixtures containing more ethanol might become more common.<sup>203</sup> Although a great deal is known about the behavior of gasoline in water, much less is known concerning the effects of these chemicals once larger quantities of ethanol

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have been added to the fuel.<sup>204</sup> Ethanol is highly soluble and its presence enhances the solubility of more toxic gasoline compounds.<sup>205</sup> Additionally, ethanol increases the durability and facilitates the migration of carcinogens in gasoline throughout the water supply.<sup>206</sup>

Thus the growing production of biofuels presents a number of challenges for future water availability. The strain on water resources created by shifting agricultural practices throughout the country might be mitigated by efficiency measures and better management practices like those discussed in earlier sections. However, the fact remains that the demands for biofuels and for water are increasing synergistically and simultaneously. These related, parallel forces cannot be maintained without intelligent management and sound conservation practices.

## **Water Reuse and Storage**

The challenges of decreased water supply might be met by diversifying that supply. Water reuse and water storage could both play important roles in such a strategy.<sup>207</sup>

Discussed elsewhere in this chapter, governmental agencies and utility companies have explored the possible reuse of water as an alternative supply in thermoelectric power generation. However, the reuse and reappropriation of water has potential conservation applications in other sectors. Many communities across the country are already reusing water, and this is occurring in both arid and wetter states.<sup>208</sup> The practice has numerous benefits. In addition to conservation in supply-strained areas, reuse diverts discharges of pollutants away from ecologically sensitive waters and acts as an alternative wastewater treatment method.<sup>209</sup> Simply put, it protects the environment and cuts costs.

Opportunities for water reuse are numerous. In an urban setting, water may be reused for a wide variety of applications including irrigation of public parks, playing fields, golf courses, highway medians and shoulders, and landscaped areas surrounding public facilities; commercial uses such as vehicle-washing facilities, laundry facilities, window washing, and mixing water for pesticides, herbicides, and liquid fertilizers; ornamental landscape uses and decorative water features, such as fountains, reflecting pools, and waterfalls; dust control and concrete production for construction projects; fire protection through reclaimed-water fire hydrants; and numerous other potential applications.<sup>210</sup> Reused water presents similar opportunities in industrial settings as treatment technologies improve, reducing the chance of corrosion and fouling of equipment.<sup>211</sup>

Water reuse might also have a role to play in environmental protection and restoration: wetlands might be created and enhanced with reused water.<sup>212</sup> Additionally, reused water might be used to recharge underground aquifers and groundwater supplies.<sup>213</sup> In coastal areas, injecting reclaimed water directly into aquifers could reduce the risk of saltwater intrusion that arises when groundwater sources are heavily pumped.<sup>214</sup> Moreover, underground injection provides a manner of treatment (through filtration) for reclaimed water, provides storage of water for later use, and prevents subsidence.<sup>215</sup>

In addition to municipal and public utility reuse of water, individuals can also conserve by adopting their own reuse systems. The water reused in this context is referred to as graywater: nontilet household water that comes from showers, baths, washing machines, laundry troughs, spas, sinks, hand basins, dishwashers, and kitchen sinks.<sup>216</sup>

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Graywater is most commonly used for household landscape irrigation, car washing, and toilet flushing.<sup>217</sup>

However, water reuse does not come without risks, and there remains public opposition to the practice.<sup>218</sup> To be sure, there are serious health concerns associated with reclaimed water. It can contain pathogenic bacteria, parasites, and/or dangerous chemicals.<sup>219</sup> Environmental protection, avoiding public nuisance, and meeting user requirements for water quality are all considerations, but the foremost objective of any water reuse standard is the protection of the public health.<sup>220</sup> However, there are treatment options for every health risk associated with water reuse.<sup>221</sup>

Most states have enacted safety and treatment standards for water reuse. Some of these regulations require specific treatment processes, others impose effluent quality criteria, and some require both.<sup>222</sup> Arizona, California, Colorado, Florida, Georgia, Hawaii, Massachusetts, Nevada, New Jersey, New Mexico, North Carolina, Ohio, Oregon, Texas, Utah, Washington, and Wyoming have all developed regulations simultaneously encouraging the conservation and reuse of water while protecting the environment and public health.<sup>223</sup>

Water storage also presents an opportunity for the conservation and more efficient management of strained water resources and is a necessary complement for large-scale water reuse. Unlike traditional sources of underground or surface water supply, reused water is continuously generated as a byproduct of everyday life, so it must be stored until it is needed.<sup>224</sup> Improving storage capacity is an important component of any attempts to improve water supply infrastructure in a world experiencing worsening global climate change.<sup>225</sup>

Reclaimed water can be stored in a number of different ways. Dams and reservoirs are one method, and, as previously discussed, injecting reclaimed water into aquifers is another way of banking water for later use. Aquifer recharge has some advantages over storing water in open-air reservoirs. For one thing, this method is cheaper than building new dams, which might be necessary to accommodate the volumes of water storage needed to ensure a consistent water supply throughout the warm season in arid parts of the country.<sup>226</sup> Additionally, reservoirs experience significant evaporative losses, a problem that is avoided by injecting and storing water in underground aquifers.<sup>227</sup> Management of aquifer recharge with reclaimed water also intrinsically treats the water, a benefit not provided by storage in surface reservoirs.<sup>228</sup>

The use of reclaimed water is an obvious step in efforts to improve and expand water supplies as climate change places more pressure on limited freshwater resources. There are a number of prerequisites to the widespread implementation of this method of conservation: expanding storage capacity, developing intelligent safety standards, and improving treatment technology. However, water remains valuable even after it has been gently—or not so gently—used.

### **Disappearing Snowpack: Coping with Snow Shortages in the West**

Increased average temperatures attributable to global climate change are leading to significant reductions in the volume of snowpack in the western United States.<sup>229</sup> Some studies predict that snowpack will disappear by 2100 from some western mountain ranges, such as California's Sierra Nevada.<sup>230</sup> This trend could have dire consequences for water management because, in the arid West, mountain snowpack contributes up to 75 percent of the year-round water supply.<sup>231</sup> As spring runoff increases and the storage capacity of mountain snow decreases, there may be more water available

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earlier in the spring, but this supply could become nearly exhausted by summer or autumn due to heightened irrigation demand created by a longer growing season and increased evaporative losses.<sup>232</sup> Historically, western water management has depended on the gradual melting of mountain reserves of frozen water.<sup>233</sup> (See chapter 22 of this volume for further discussion of the implications of disappearing snowpack on international water management.)

In addition to creating supply shortages, decreased snowpack volume has a number of other serious implications for western states. Mountain snowpack plays an important role in flood control because it allows for the gradual release of accumulated precipitation and therefore reduces the risk of flooding.<sup>234</sup> Intelligent reservoir management can mitigate the threat of flooding, but if western reservoirs are filled to capacity early in the warm season due to heightened spring runoff, they will be unable to accommodate a sudden influx of water from storms later in the year.<sup>235</sup>

Additionally, the early melting of snowpack in the West is leading to rashes of dust storms across the region.<sup>236</sup> These storms in turn deposit dust and other detritus on top of mountain snowpacks, which increases the rate of melt even more, creating a positive feedback cycle in which snow is melting faster and faster.<sup>237</sup> This is a problem that starkly illustrates the inextricable linkages between the causes and consequences of climate change. Emissions from motor vehicles are a component in the coating that is accelerating early snowpack melt, which is also being accelerated by increased temperatures caused by global warming—a phenomenon that is caused in part by greenhouse gas automobile emissions. Moreover, the development of solar, wind, and geothermal projects frequently disturbs parched land in the West and creates ideal conditions for more dust storms.<sup>238</sup> Certain attempts to mitigate the causes of climate change are exacerbating its effects.

Some water managers have viewed the problem of melting snowpack as inexorable and inevitable. Scott Brinton, assistant division engineer in the Colorado Division of Water Resources' Southwest regional office, described the response to early snowpack melt thusly, "There's not a whole lot we can do about it. We're telling people, 'You'll be getting your water early this year, so use it while it lasts.'"<sup>239</sup>

However, there are various possibilities for coping with snow shortages. First, more dams and reservoirs could increase storage capacity for early spring runoff. However, such projects might be cost prohibitive in some places. Also, dams are always accompanied by irreparable environmental consequences: downstream riparian ecosystems and upland habitats are wiped out.<sup>240</sup>

Some land managers have begun restoring wild watersheds to store water and reduce the risk of flooding.<sup>241</sup> Mountain meadows and wetlands act as natural water reservoirs and allow the more gradual release of water during the dry summer months.<sup>242</sup> This strategy has fewer adverse environmental consequences than dam building and actually restores habitat for wildlife.<sup>243</sup> The results of such projects have been largely positive thus far: post-restoration monitoring indicates that water is being released for a longer portion of the warm season, water temperatures have decreased despite elevated ambient temperatures, turbidity has decreased, and groundwater is once again reaching the surface.<sup>244</sup>

Local governments and power companies have also attempted weather modification, or cloud seeding, as a way to increase snow levels.<sup>245</sup> During this process, silver iodide is spread by aircraft or ground-based generators to facilitate the development of ice crystals and catalyze snowfall.<sup>246</sup> This technique traces its origins as far back as

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the first half of the 20th century, and industry and government groups claim that it is well understood.<sup>247</sup> However, its efficacy and unintended side effects in the face of worsening global climate change effects are less certain. Western water managers have found that the deposition of dust atop snowpack increases the rate of melt regardless of the depth or volume of snow.<sup>248</sup>

None of these options is a magic bullet to solve the problem of decreased water supply caused by early snowpack melt. Frequently, mitigation measures have adverse environmental consequences. The only lasting solution is to develop smarter water management programs and educate consumers in conservation. The preparedness of water suppliers in this sphere has been woefully inadequate. A 2007 study conducted by the University of Oregon found that only a small number of water suppliers in snow-dependent basins had investigated the potential risks of reduced snowmelt.<sup>249</sup> Moreover, more than a quarter of these suppliers expressed doubt that climate change would affect their water sources.<sup>250</sup>

It is uncertain whether the accelerating reduction in western mountain snowpack has a solution, but if one is to be found, water providers and their customers must be more conscious of the changing nature of water supply in a warming world.

## **Policy and Legal Tools**

### **The Common Law: Riparianism and Prior Appropriation**

The law governing water in the United States is composed of two different systems—riparianism and prior appropriation. Riparianism reigns in the more water-rich states in the East and prior appropriation reigns in the arid West, with the Mississippi roughly acting as the dividing line between the geographic spread of the two regimes. Riparian law grants rights to water to those living adjacent to the water body. Prior appropriation confers usage rights on a first-come, first-served basis to those who have diverted water and put it to a beneficial use.<sup>251</sup> The rights obtained under both of these systems are not complete property rights but are grounded in the use of water rather than ownership over it.<sup>252</sup>

Both riparianism and prior appropriation offer opportunities for conservation and maintenance of dwindling water supplies as the effects of climate change worsen. However, these systems were developed when supplies were relatively more plentiful than expected demand and when water managers mistakenly assumed that water supplies would remain unchanged.<sup>253</sup> Water-quality and pollution problems, rapid urban growth, and the looming threat of global climate change will continue to put the lie to this assumption.<sup>254</sup> Thus, like so many aspects of current water usage and governance, these common law systems will be forced to adapt to the changing climate.

#### **Riparianism and Reasonable Use**

Riparian law offers a number of opportunities for conservation as climate change continues to negatively affect water supply. The adjacency requirement of riparianism—that one must own physical property abutting the water body in order to have rights to the water—encourages conservation and responsible environmental stewardship. There are ways to get around this restriction, such as through easements, but on balance, requiring adjacency limits the number of people who can withdraw water and potentially harm a threatened supply. Furthermore, the fact that users in a riparian system own riverfront or lakefront property also provides some incentive

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to take care of that water body since it enhances the aesthetic and material value of their land.

Additionally, a reasonable use inquiry is central to any dispute between water users in a riparian district. In the early days of riparian law, riparians (property owners who own land adjacent to a freshwater body) were prohibited from diminishing the quantity and quality of the water flowing naturally to other riparians.<sup>255</sup> However, in response to commercial development during the industrial revolution, courts gradually adopted the reasonable use doctrine, which provides that all riparians have a correlative right to the shared reasonable use of the water body, with consideration of the water needs of other riparians. This doctrine provided more flexibility as large commercial users, such as mills, became more common.<sup>256</sup> Enumerated in § 850A of the *Restatement (Second) of Torts*, a reasonable use inquiry considers a variety of factors, including “the suitability of the use to the watercourse or lake, the economic value of the use, the social value of the use,” and “the extent and amount of the harm it causes.”<sup>257</sup> This inquiry is expansive enough to encompass some of the adaptations necessary to adjust to the impacts of climate change on water supply. The harm and social value factors enumerated in the *Restatement* and in state cases adopting similar tests could very easily contemplate the conservation of water so that some water remains available to users.<sup>258</sup> An explicit legislative enactment of these factors in riparian states could expand the potential of this component of the common law to address the effects of climate change on the freshwater supply.

Regulated riparianism, or an administrative form of the common law system based on permits, is another potential avenue for modifying the existing system to confront climate change.<sup>259</sup> A permit system might be more adaptive to the rigors of climate change because permits could consider *ex ante* the types of reasonableness factors contained in the reasonable use doctrine and *Restatement*, thereby preventing conflicts. However, it seems uncertain that an administrative agency could make an entirely accurate usage prediction given the enormity of the problems posed by climate change. Additionally, once a permit has been issued it may prove difficult to revoke or amend, thus exacerbating a strain on the supply that might have been resolved equitably in court absent the permit.<sup>260</sup>

However, despite the capaciousness of the reasonable use doctrine and the potential of regulated riparianism, riparian water law is not without its flaws as a method for adapting to climate change. Some commentators have noted that the basic remedy in times of shortage in riparian jurisdictions is to require all users to cut back equitably, which could potentially have the perverse effect of reducing all users below the level of water usage they need to remain economically viable.<sup>261</sup> If climate change affects water supplies to an extreme degree, the normal equitable remedy inherent in riparianism could lead to perverse and inefficient results.

Additionally, the adjacency requirement cuts two ways in terms of conservation. The requirement gives riparians a reason to care about their water, but it also forces industries that require water to locate their facilities on the water itself. This leads to pollution and damage to the aesthetic value of the water body. Requiring adjacency also limits the ability of the public to access water for recreational use, which in turn reduces public awareness of waters that need protection. State and municipal parks grant public access to water in riparian states, but public access and the awareness that comes with it are not ensured in riparian jurisdictions.

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Riparian water law offers a number of possibilities for adapting to climate change, and, as a common law system, it is capable of adapting to changes in the future. Some reforms are necessary, such as legislative recognition of environmental factors in a reasonableness inquiry or added flexibility to permitting systems. However, as an existing body of law, riparianism is not wholly unprepared to address climate change.

### **Prior Appropriation**

Prior appropriation was born of the United States' efforts to develop the West. Consequently, its emphasis is not on conservation but on consumption. The reasonable use requirements of riparianism were ill-suited for the needs of the burgeoning industries of emerging western states, such as mining, irrigation, and other uses on nonriparian lands.<sup>262</sup> By simple virtue of the differences in the geography between the arid West and the East, riparian law was not feasible west of the Mississippi River: far less land abuts bodies of water in the West, and the adjacency requirements of riparianism would have stymied growth.

The first-come, first-served principle determines who can use water in prior appropriation states, so there is a strong incentive to get to the water, to divert it, and to start using it as quickly as possible. The date of priority is determined by the time at which the water was first put to a "beneficial use."<sup>263</sup> The system also contains "use it or lose it" provisions. Water users can have their appropriative rights reduced or lose them altogether if water does not continue to be put to beneficial use.<sup>264</sup> Most uses, within reason, will be deemed beneficial.<sup>265</sup> Moreover, although there are some provisions within appropriative systems prohibiting waste, generally practices will have to be extremely wasteful for courts to step in.<sup>266</sup> Thus there is a significant incentive for appropriators to use as much of their permitted appropriation as possible; appropriative systems reward the rapid development and consumption of water resources and, by extension, discourage conservation. Consequently, states operating under this regime will likely encounter supply problems as the effects of climate change grow more pronounced.<sup>267</sup>

Because of the use-it-or-lose-it nature of appropriative systems, there is almost no incentive for users to conserve.<sup>268</sup> If an appropriator does not use all of the water he is legally entitled to, that water must go back into the system. In most prior appropriation states, conserved water—called salvage—cannot be sold by the environmentally conscious appropriator; there is no potential to profit from improved efficiency measures and therefore no reason to expend money on conservation efforts.<sup>269</sup> Some states are beginning to adopt salvage legislation that would create a transferable property right in salvaged water, but this has not yet become the norm.<sup>270</sup> As climate change adds additional stresses to already strained water resources, adoption of laws authorizing the transferability of salvaged water will become increasingly necessary.

Some characteristics of appropriative systems might constitute a silver lining from an environmentalist's perspective. First, junior appropriators have a right to quality in their water; senior appropriators are not permitted to dramatically pollute the water that must flow to users with lower priority.<sup>271</sup>

Second, prior appropriation states have largely switched from the Wild West approach to allocating water to more scientifically oriented permitting systems. Moreover, states have entered into compacts with one another to preemptively deal with

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possible interstate water disputes. The Colorado River Compact of 1922 is foremost among interstate prior appropriation agreements.<sup>272</sup> However, these agreements—and many of the appropriations permits issued by state agencies—were drawn up during years of relative abundance *before* climate change became known as a pressing issue for water management. It is unlikely that these agreements and administrative permits will continue to be viable as water grows scarcer.

Third, in some prior appropriation states, legislatures have begun to take steps to protect instream flows, or water that is simply left in the system and not appropriated.<sup>273</sup> Although the conservation motivations behind these efforts have frequently been the protection of wildlife and habitat, instream flows could conceivably be used to maintain flow in systems hit particularly hard by climate change. However, recognition of instream flows as a qualifying beneficial use in appropriative systems is not yet widespread, and, even where adopted, the priority of instream appropriations remains secondary to most other uses.<sup>274</sup>

Finally, some commentators have noted that the risk allocation inherent in prior appropriation makes it a better adaptation candidate than riparian law.<sup>275</sup> This is because “it clearly assigns all risks of climate variability to junior users and eliminates the inchoate and inefficient features of the common law of riparian rights.”<sup>276</sup> However, others have noted that appropriative systems’ theoretical advantages over riparianism survive only because “the harsh implications of prior appropriation have yet to be tested in a significant way.”<sup>277</sup> The West’s extensive system of dams and canals has generally provided enough water to accommodate even the most junior users and “there have been few losers throughout most of the history of prior appropriation.”<sup>278</sup> As water becomes less plentiful and the rights of seniors actually begin to interfere with the rights of those with lower priority, the system will become less politically viable.

## **Economic Incentives and Water Marketing**

Markets in water have played a role in the efficient allocation of the resource in the past and they will likely become a more important component of water management as climate change increasingly affects the United States’ supply.<sup>279</sup> The Intergovernmental Panel on Climate Change has noted that water transfers could play an important role in climate change adaptation in the context of maintaining water supplies: “Where feasible, short-term transfers can provide flexibility and increased security for highly valued water uses such as urban supply, and in some circumstances may prove more beneficial than constructing additional storage reservoirs.”<sup>280</sup> For purposes of this discussion, water markets are mechanisms to allow the sale or transfer of recognized water use rights.

Although water markets have developed primarily in prior appropriation states where usage rights are more easily severable from land, there is also some support in existing riparian law for the adoption of marketing. Conceivably, riparian rights could be severed if there is no injury to other riparians, and some states with regulated riparianism have eliminated per se rules against interbasin transfers.<sup>281</sup> Regardless of whether and where water marketing is developed, the inefficiencies of riparian and appropriative systems as they currently exist are no longer tolerable.

Historically, water transfers have involved individual stakeholders and relatively small quantities of water, but the nature of this process is changing. Larger stakeholders, such as cities, are purchasing larger blocks of water from areas distantly removed from the actual location of use.<sup>282</sup> These purchases can be permanent or temporary;

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for example, usage rights can be severed from the land to which they were originally assigned, or the water that a farmer might have used to irrigate a fallow field might be reallocated for a single season.<sup>283</sup>

This evolution in water markets has not been without controversy. In the eyes of many, water is no mere fungible commodity: it has higher, transcendental values and no one can truly own water; it plays a central role in almost all ecosystems; and it is necessary for the maintenance of life itself.<sup>284</sup> There are also more practical objections to the commoditization of water, such as that food production might be threatened because farmers might make more money selling their water rights than irrigating crops.<sup>285</sup>

Also, in many places the quality of the water to be transferred cannot be unequivocally ensured; variations in governing environmental regimes could create uncertainty regarding what exactly is being purchased and therefore impede transfers.<sup>286</sup> Additionally, imposing a functional market in water will likely take time; efficiency cannot be imposed by governmental fiat.<sup>287</sup> Finally, existing state laws and administrative regulations represent a wide variety of obstacles to the adoption of water marketing.<sup>288</sup>

Another potential roadblock to the widespread adoption of water markets lies in the nature of water rights themselves. Appropriative and riparian rights are usufructuary rights; the rights lie in the usage—as opposed to the ownership—of water.<sup>289</sup> Therefore there might be some uncertainty as to what exactly is being transferred in an exchange on a water market. Creating further confusion and expense, in prior appropriation systems, a water right cannot be transferred unless there is no injury to junior users.<sup>290</sup> Discovering all the junior appropriators that might be affected by a transfer and determining how much water might be transferred without injuring those users could drastically increase transaction costs and impede sales of water rights.<sup>291</sup>

In riparian states, uncertainty could arise out of the reasonable use doctrine. Riparians' uses are measured equitably against the uses of other riparians. A riparian property owner might want to sell the entirety of her usage rights, but the full extent of those rights is uncertain, a problem that will be compounded if every other riparian seeks to make the same kind of sale. A court would be forced to determine how much of the water body is allocated to each riparian.<sup>292</sup> This would essentially require the conversion of riparian water law to prior appropriation.

However, despite some potential difficulties, water markets are widely favored among water law scholars as an efficient method of adapting to climate change within existing water management frameworks. Some commentators have noted that the government is not necessarily the best decision maker when it comes to the allocation of resources and private individuals might allocate water more efficiently by means of a market in the resource.<sup>293</sup>

Water markets are flexible and decentralized, and they harness economic incentives.<sup>294</sup> These characteristics will be particularly advantageous in responding to the dire uncertainties of climate change. The costs of a purely command-and-control regulatory response to climate change would be extremely high. The water management agency would have to continually measure and monitor existing water supplies as it went about ensuring that water was allocated in the most efficient and “appropriate” fashion.<sup>295</sup> Such a system would certainly benefit from the experience of scientific experts, but a market system would be more adaptive, less resource intensive, and allow users and market participants to allocate water to those who want it most.<sup>296</sup>

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This kind of transferability implicates a possible criticism of water marketing: that only those with deep pockets will have access to water. Some market proponents have countered this with the argument that markets are capable of considering moral decisions: “[T]he various ‘green’ marketing and certification schemes depend on the influence of moral considerations on market choices. Unless society is willing to mandate particular resource allocations on the basis of moral considerations, and thus constrain human freedom, markets are social institutions in which moral factors can influence allocative results.”<sup>297</sup> Additionally, advocates for water marketing point out that, unlike administrative allocation methods, markets provide compensation for those who “lose” from water transfers by reallocating risk to those who are best able to bear it.<sup>298</sup> Other favorable arguments point out that “by some estimates, the net welfare gains from water markets exceed the value of the water rights themselves.”<sup>299</sup>

Water marketing also has the potential for environmental conservation. If water rights are fully transferable, environmental groups can purchase appropriative quantities for instream flows and habitat preservation.<sup>300</sup> Numerous nonprofit “water trusts” have emerged to pursue this opportunity.<sup>301</sup> One example of this potential policy tool in action is the ongoing work of The Freshwater Trust.<sup>302</sup> The Freshwater Trust strategically identifies water conservation and habitat protection opportunities in the Pacific Northwest, through purchasing, trading, leasing, or otherwise transferring water rights from historic consumptive uses to instream flow protections.<sup>303</sup> Similarly, the not-for-profit Colorado Water Trust “acquires decreed water rights through voluntary transactions to provide instream flows that benefit aquatic ecosystems.”<sup>304</sup>

In addition to purchases for environmental purposes, marketing would also encourage water users to be more efficient. As water becomes more valuable and more expensive, consumers will try to cut back and conserve.<sup>305</sup> Currently, public water authorities resist raising prices, even when water is scarce.<sup>306</sup> A water market would circumvent this reluctance by sparing administrators from the political fallout that would ensue if the cost of water were increased; the market would take care of this. It should be noted that most proposals to increase the role of the market in managing water demand would take into account the hardships of low-income water users and provide either a subsidy or a reduced-cost water supply for basic needs.

Finally, critics of water markets point out that water transfers could ignore the potential harms that will be visited upon innocent third parties that are not in a position to approve or disapprove the transfer. There are a few ways such third-party effects might be mitigated. Some states require that the public interest be considered in the context of any water transfer.<sup>307</sup> Other states subject transfers to searching administrative review.<sup>308</sup> Yet other states have adopted protections for the original water delivery system.<sup>309</sup> Legal and regulatory oversight of water transfers is still developing in most Western states, and the regulatory approval of the state water agency is typically required for any transfer of water rights.

These kinds of protections could prevent the possible detrimental effects of water marketing, while still allowing the market itself to increase efficiency and protect the public from the negative outcomes derived from the inefficient allocation of water. Regardless of what kind of response is adopted to adapt to climate change, inefficiency can no longer be tolerated in a warming world with dwindling water supplies.

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## Urban Planning and Climate Change

Simply put, there is not enough water to indefinitely sustain the expansion of American cities using water within their watershed. Planning for urban growth and allocating water supplies for that growth have not historically been married in any meaningful way, especially in the West. Currently, the water budgets of many cities are fixed, and growth is maintained by reallocating existing water supplies rather than managing demand or implementing efficiency measures.<sup>310</sup> Some of these possible alternatives were discussed earlier in this chapter. (See chapters 6 and 7 of this volume for further discussion on the implications of climate change on urban planning and infrastructure.)

Urban growth in the United States stresses existing water supplies in four ways. First, it increases demand for water for purely industrial and municipal uses.<sup>311</sup> Second, it increases the risk of water pollution, especially in groundwater.<sup>312</sup> Once a groundwater source is polluted, it can no longer be used as easily, and supply is thereby further diminished. Third, it creates pressure to tap unallocated water supplies and therefore places greater strain on the environment.<sup>313</sup> Fourth, it creates pressure to transfer water rights from existing agricultural users.<sup>314</sup> Further, while population growth may generally stress water supplies, urban growth puts disproportionate stress on regional water supplies, especially because many cities are located on the ocean coasts and lack a nearby freshwater supply adequate for significant population growth.

As the effects of climate change continue to negatively affect water supplies, the traditional water management toolkits of many cities—new diversions, high-capacity wells, and the construction of large storage reservoirs—will no longer be feasible in sustaining expansion.<sup>315</sup> Cities must coordinate water policies and urban growth policies.<sup>316</sup> If expanding urban centers continue their current trajectory, they will be forced to deal with water shortages, environmental crises, increased numbers of water conflicts, and growing strain on the water infrastructure.<sup>317</sup> Cities will have to look beyond their own watersheds to meet growing demand.

The water management problems currently facing American cities developed largely because municipalities have historically been given a “super-preference” in the context of water supply priority.<sup>318</sup> Urban planners were under the obligation to anticipate future growth and anticipate necessary allocations of water supplies to meet those projections.<sup>319</sup> Thus there was little pressure to integrate available water supplies into land use planning. Prior appropriation law facilitated these patterns of growth and exacerbated land use problems in the West. Under prior appropriation, water can be used in any place to which it can be transported.<sup>320</sup> Moreover, consonant with the cities’ super-preference, a water right could be perfected upon a demonstration of anticipated growth.<sup>321</sup> Cities have been permitted to gobble up water resources, frequently with little regard for scarcity or sustainability.

Water management and land use planning are frequently handled by separate entities and different levels of government, which generates confusion and a wide variety of disconnects that have, in turn, led to unrealistic water management in the context of urban growth. For instance, federal and state governments have historically been primarily concerned with economic efficiency, while local governments have focused on preventing nuisances.<sup>322</sup> Water management plans are frequently drawn up by individuals without the power to implement these plans.<sup>323</sup> Moreover, the ways in which water allocations are implemented—by elected officials and budget expenditures or

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through zoning ordinances or other laws—are frequently unconnected to the agencies and individuals responsible for water management.<sup>324</sup> Finally, there have been conflicting management plans within the same jurisdiction in many instances.<sup>325</sup>

The problem of unsustainable urban growth and disconnected water management has a great deal of historical inertia behind it. However, American cities, propelled by that inertia, are careening toward the implacable realities of climate change and all that it portends for the availability of water. Professor Tarlock has outlined five ways that this challenge might be met:

- (1) continuing unlimited growth accommodation;
- (2) capping growth;
- (3) shifting the burden of supply acquisition to local governments and developers;
- (4) adopting aggressive, technological, and managerial water conservation initiatives such as information provision, xeriscaping requirements, marginal cost pricing, desalinization and the use of greywater; and
- (5) constraining growth to match available and projected supplies.<sup>326</sup>

The first option is the current status quo, but it will not be sustainable for much longer in a post-climate change world. The second seems both infeasible and unrealistic. The remaining three options are being tried out by urban planners in various places across the country.<sup>327</sup>

Water rights transfers are another way in which growing urban demand might be met without engaging in new large diversion projects or tapping unallocated or environmentally delicate water supplies.<sup>328</sup> As discussed in the water marketing section, transfers can be economically advantageous to the parties directly involved.<sup>329</sup> Moreover, the transaction costs of transfers will almost always be less than the cost of developing new supplies in many areas.<sup>330</sup> Negative effects on third parties or the environment could be prevented through considerations of potential harms, public interest considerations, or comprehensive administrative review.<sup>331</sup>

Regardless of whether one agrees with the wisdom of transfers and water marketing, land use planning and water supplies must be more intelligently linked. Coordinating the parties involved in urban planning and water management in areas such as land use, transportation, water and natural resources, and economic development could resolve current inefficiencies and set urban growth on a more sustainable path.<sup>332</sup> Making the water management process less opaque and incorporating greater public involvement could ensure that a wider variety of interests, such as the sustainability of growth in the face of climate change, are considered.<sup>333</sup> Additionally, requiring strict adherence to water management and growth plans—and an informed amendment process when changes are necessary—could prevent the decay of intelligent land use plans.<sup>334</sup> Continuously measuring progress could also prevent water management plan decay.<sup>335</sup>

Some steps are already being taken by courts and legislatures to resolve the historical problems associated with water management in urban expansion. In *Pagosa Area Water and Sanitation District v. Trout Unlimited*, the Colorado Supreme Court held that the District had not carried its “burden of proving a non-speculative intent to put the water amounts contained in the remand decree to beneficial use.”<sup>336</sup> As Professor Tarlock notes, this case might be limited to smaller cities with unrealistic growth predictions. However, it still stands as a warning that there must be *some* justification for the water that expanding cities would like to claim.<sup>337</sup>

Legislatively, some states have begun to implement stricter requirements concerning water supply availability. California has passed two bills requiring cities to

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consider the availability of water supplies when making certain land use decisions.<sup>338</sup> Arizona passed the Groundwater Management Act in 1980 and agreed to stop mining its aquifers to support urban growth.<sup>339</sup> Colorado requires developers to acquire adequate water supplies before their projects are approved.<sup>340</sup>

Steps are being taken to link water management and urban planning, but the status quo remains strongly in favor of no limitations on growth. As climate change affects water supplies more significantly, greater steps will have to be taken to intelligently connect the availability of water to the growth of American cities.

## **Additional Recommendations and Adaptation Tools**

### **Unifying Groundwater Law**

In most states, groundwater and surface water are governed under separate regimes. This separation developed because of the historical lack of understanding of groundwater: its origins and systems were unknown and unknowable.<sup>341</sup> Modern hydrological science recognizes the close interconnection between underground and surface waters, and the continued separation of water law into above- and below-ground governance hampers the intelligent administration of dwindling water supplies.<sup>342</sup> Conjunctive management of groundwater and surface water supplies is necessary to ensure their maximum sustainability as climate change diminishes freshwater resources in the United States.

A number of different doctrines govern groundwater in the United States. Under the rule of capture, “absent malice or willful waste, landowners have the right to take all the water they can capture under their land and do with it what they please, and they will not be liable to neighbors even if in so doing they deprive their neighbors of the water’s use.”<sup>343</sup> This rule is particularly ill-suited as a means of water supply management when adaptations to climate change become increasingly necessary. The rule of capture creates a race to the bottom and will inevitably result in users exhausting groundwater supplies. A second groundwater doctrine, the American reasonable use rule, is essentially analogous to the rule of capture, with the additional limitation that the use be on tract.<sup>344</sup>

The surface water legal systems of riparianism and prior appropriation have groundwater analogs. Correlative groundwater rights are very similar to riparian surface rights in that usage disputes are resolved by applying equitable considerations. Section 858 of the *Restatement (Second) of Torts* lays out some reasonableness factors that a court might consider in a groundwater dispute including “harm to a proprietor of neighboring land,” whether “the withdrawal of ground water exceeds the proprietor’s reasonable share of the annual supply or total store of ground water,” and whether the withdrawal “has a direct and substantial effect” on the water body that “unreasonably causes harm to a person entitled to the use of its water.”<sup>345</sup> The scope of these factors is expansive and gives courts a great deal of leeway in determining the reasonableness of groundwater use.

Some western states apply prior appropriation to their groundwater as well as surface water.<sup>346</sup> However, the problems that prior appropriation creates for dwindling water supplies are even more pronounced in the context of groundwater, as many critical groundwater resources (notably the Ogallala Aquifer) are largely nonrenewable.<sup>347</sup> Even if a river or lake is fully appropriated, it will be largely replenished the following year. Many underground water sources are slow to recharge—if they recharge at all—so, technically, after the first priority user, no one else should get

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access to a nonrenewable water supply. Courts are forced to decide how much depletion of a nonrenewable resource is acceptable per year when prior appropriation is applied to groundwater.

In addition to the individual problems posed by these disparate groundwater doctrines, there are no clear rules for how groundwater use is treated when it significantly affects a hydrologically connected surface water body.<sup>348</sup> Conjunctive management, which acknowledges that surface water and underground water are inextricably linked, is necessary to properly manage water supplies as they diminish due to climate change.

A case from Michigan, *Michigan Citizens for Water Conservation v. Nestlé Waters North America Inc.*, combines groundwater and surface water management with a single test and acknowledges the close hydrological connections between these two sources of water supply.<sup>349</sup> Nestlé, a water-bottling company, was drawing on groundwater and reducing the flow of a nearby stream by almost 24 percent. The Michigan Court of Appeals laid out three overarching principles to be considered in a groundwater conflict and detailed a number of reasonableness factors that were essentially analogous to those detailed in Section 850 of the *Restatement (Second) of Torts*, which governs riparian surface water disputes.<sup>350</sup> The three underlying principles were: (1) ensuring fair participation by the greatest number of users, (2) protecting only reasonable uses, and (3) protecting only against actual harms.<sup>351</sup> Considering these principles and its own similar versions of the *Restatement's* reasonableness factors, the appellate court ultimately held that the extent of Nestlé's use was unreasonable.<sup>352</sup> The court acknowledged that Nestlé was entitled to fair participation in the resource, but because of the magnitude of the harms and because Nestlé was in the best position to bear the costs, the use was enjoined.<sup>353</sup>

Thus, the *Nestlé* case represents a possible avenue for conjunctively managing groundwater and surface water as climate change diminishes the supply in both of those sources. Modern science is explicit in its recognition that hydrological systems are not bifurcated above and below the ground. Unifying groundwater and surface water law into a more cohesive whole will help ensure the most intelligent management of freshwater supplies as the effects of global climate change grow more pronounced.

## Water Banks

Water banks are related to water markets—they facilitate transfers between those with water rights and those who need water.<sup>354</sup> Exchanges through water banks are not permanent; instead, water rights are rented or leased for a specific period of time.<sup>355</sup> Banks streamline the transfer process, substantially reducing the transaction costs that might arise if two parties tried to deal with each other independently.<sup>356</sup> Furthermore, water banks provide water rights holders with a method for protecting their rights from forfeiture or abandonment if the full appropriation is not needed during a particular year.<sup>357</sup> Finally, in some ways, water banks are easier to implement than a pure water market because they clash less with existing regulatory structures and institutions.<sup>358</sup>

A few states have benefited from water banks. Over the past 20 years, California has developed a statewide water market that functions without active state participation.<sup>359</sup> In 1992, the Central Valley Improvement Act permitted the transfer of CVP water to buyers outside of the Central Valley Project for the first time.<sup>360</sup> In 2000, the Environmental Water Account was founded to use state and federal funds to purchase water rights for conservation purposes.<sup>361</sup> Idaho has also found some success with water banks.<sup>362</sup>

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Water banks face some of the same obstacles that confront water markets. Foremost among these is the requirement that a transfer, whether to a bank or on a market, cannot harm other existing uses.<sup>363</sup>

### **Dam Building: Reclamation for the 21st Century?**

Another option for maintaining water supplies affected by climate change would be to continue the primary water management strategy of the past hundred years: building dams and other large diversion projects. The Hoover Dam was one of the most notable and first dam-building projects embarked upon by the United States in the early 20th century. Dam building helped lift the United States out of the Great Depression and aided the rise of some of America's most successful companies.<sup>364</sup>

Historically, dams have functioned to smooth the delivery of water supplies, especially in the western prior appropriation states.<sup>365</sup> Some more arid states rely on melted snowpack for a large portion of their water supplies. Dams create reservoirs by blocking rivers, which also collects this snowmelt, ensuring that water supplies remain more or less constant throughout the year.<sup>366</sup> Increasing the number of dams and reservoirs would be a very mechanically straightforward way of increasing water supply.

However, as some commentators have noted, the adoption of this kind of policy would require a “political and legal reversal of the past fifty years; a possible but not yet probable scenario.”<sup>367</sup> There are numerous environmental obstacles and objections to the construction of yet more dams. Dams dramatically harm ecosystems: they prevent the flow of nutrients, block the migration of fish, slow rivers, and decrease aquatic oxygen levels, among other things.<sup>368</sup> Consequently, there is significant opposition to new diversion projects among environmentalists.<sup>369</sup>

Furthermore, there simply are not many good potential sites left for new dams, and communities have begun to see the benefits in decommissioning and removing dams that provide little in the way of hydropower or the other supposed benefits of dams.<sup>370</sup> Around 140 dams across the country have been removed since 1999, starting with Edwards Dam in Maine.<sup>371</sup> Larger dams are also being targeted by advocates of dam deconstruction: four dams on the Snake River, the O’Shaughnessy Dam in California, and the Glen Canyon Dam on the Colorado River.<sup>372</sup> On the other hand, dams are an important source of low-carbon electricity, and there remains significant potential for expanding the electricity-generating capability of existing hydropower dams in the United States.<sup>373</sup>

Finally, the two agencies responsible for the construction of most of America’s major dams—the Bureau of Reclamation and the Army Corps of Engineers—are in the process of changing their missions from water development to water management.<sup>374</sup> Thus, in addition to modern criticisms of dams, the institutions that would oversee the construction of new dams are evolving beyond their early 20th-century dam-building personas.

Building new dams is a familiar and easily understood potential avenue for securing water resources in a warming world, but for the reasons described above, it is not politically and practically viable.

### **Federal Preemption of State Water Law**

The possibility of the federal government preempting the patchwork of state laws regulating water to ensure more uniformity and sustainability in water management is necessarily accompanied by the obvious caveat that it is completely infeasible

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politically and would raise numerous legal issues regarding taking of protected property rights. That said, there would be some advantages to a unified national law responsible for water management.

The traditional arguments for state control have less salience than when they were originally formulated. The principal arguments against federal preemption are that state and local governments have more access to the regional knowledge necessary to make informed policy choices on water management and that state and local politicians are more politically accountable than are federal regulatory agencies.<sup>375</sup>

However, the challenges that climate change will likely create for water managers, as well as the far-flung consequences of failing to fully meet those challenges, militate in favor of federal control according to some commentators. Justifications for federal intervention include that the federal government is better suited to address nationwide problems and some water policy decisions have national economic implications.<sup>376</sup>

The effects of climate change on the nation's limited freshwater resources could very easily raise issues requiring a concerted federal response. As noted earlier in this chapter and in chapter 11, water policy has major implications for the national food supply.<sup>377</sup> In fact, impacts on agriculture could potentially have economic effects on an international scale, adding even more support to the argument for federal preemption.<sup>378</sup> Beyond the realm of agriculture, major disruptions in water supply—in part fueled by inconsistent state management—could affect the location, productivity, and profitability of many major U.S. industries, which certainly implicates a national interest.<sup>379</sup>

The federal government could protect these national interests through a variety of means, most notably through its spending power authority and/or its power to regulate interstate commerce. For instance, Congress could end subsidies on water that distort individual economic decisions concerning consumption.<sup>380</sup> Alternatively (or additionally), Congress could regulate water as an article of interstate commerce. This status of water was recognized in the Supreme Court's ruling in *Sporhase v. Nebraska*.<sup>381</sup>

As noted above, although it is not likely that the federal government is going to preempt state water law, there are many opportunities for the federal government to require or encourage more efficient water use.

## Conclusion

The future of water management in the United States and across the world will be fraught with challenges. The twin stresses of climate change and population growth will place a strain on water resources unlike anything experienced in the past. Several possible solutions to this problem are available to consumers and policymakers: conservation practices, marketing and economic tools, scientific advancements, and educational campaigns. No single potential avenue toward sustainable use will likely be sufficient on its own, however, and intelligent, regionally contextual programs will have to be developed across the country to meet the challenges that will arise in a warming world.

Regardless of the water management measures that are eventually adopted, there is one inescapable truth underlying any discussion about water demand management. Someday everyone will have to make do with less.

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