8

Water management strategies

Quick facts

Approximately 5,500 recommended water management strategies, including conservation, would provide approximately 8.5 million acre-feet per year in additional water supplies to water user groups in 2070.

The cost of implementing the approximately 2,500 recommended water management strategy projects by 2070 is $63 billion.

Conservation strategies were recommended for over 1,300 of the approximately 2,600 water user groups and compose approximately 28 percent, or 2.3 million acre-feet per year, of all the recommended water management strategy volumes serving water user groups in 2070.

The planning groups recommended 26 new major reservoirs that, if implemented, would provide approximately 1.1 million acre-feet per year in additional supplies to water user groups by 2070.

Approximately 45 percent of all recommended water management strategy supplies in 2070 are based on surface water resources, and just under 10 percent of new supplies will rely on groundwater resources.

After identifying water surpluses and potential water shortages in their regions, regional water planning groups identify, evaluate, and recommend water management strategies to avoid potential water shortages during a repeat of the drought of record over the next 50 years. A water management strategy is a plan to meet a water need (potential shortage) of a water user group.

Water management strategies allocate water to specific water user groups, often through an intermediate regional or wholesale water provider. In the same manner that projected water demands, existing water supplies, and water needs in this plan are associated with water user groups, recommended water management strategy water volumes are also associated directly with water user groups.

Strategies may or may not require new water infrastructure—referred to as water management strategy projects—to be developed. Construction of most new water infrastructure projects requires financing through long-term borrowing.

The TWDB may provide financial assistance to support the implementation of water supply projects only if the needs to be addressed by the project will be addressed in a manner consistent with the regional water plans and the state water plan. This same provision applies to the granting of water right permits by the Texas Commission on Environmental Quality, although the governing bodies of these agencies may grant waivers to the consistency requirement. Also, the TWDB funding programs that target the implementation of state water plan projects, such as the State Water Implementation Fund for Texas (SWIFT) program, further require that projects, including their capital costs, must be recommended water management strategy projects in the state water plan to be eligible for financial assistance.

8.1 Selecting water management strategies

Each planning group identified and evaluated feasible water management strategies and recommended a final set of strategies. The range

of strategies that were considered feasible and were actually recommended varied from region to region, but, overall, the planning groups were required to consider certain factors when evaluating strategies, including

- quantity of supply provided by a strategy;
- reliability of the supply under drought of record conditions;
- cost of the supply (including borrowing costs and mitigation); and
- impacts of the strategy on water quality and on water, agricultural, and natural resources.

Water management strategy evaluations were based on drought of record conditions and honored all existing water rights, which are the same benchmark conditions used for water demand and water supply evaluations. Planning groups were also required to consider conservation and drought management strategies for all water user groups that have identified water needs.

If all the approximately 5,500 recommended strategies were implemented, they would provide approximately 3.4 million acre-feet per year, including in the form of conservation savings, to water user groups in 2020, and 8.5 million acre-feet per year in 2070 (Table 8.1). The total capital costs of all the recommended water management strategy projects is $63 billion and is associated with approximately 2,500 projects (Table 8.2). Detailed lists of the recommended water management strategies and the recommended water management strategy projects may be found on the 2017 State Water Plan website at www.twdb.texas.gov/waterplanning/swp/2017 and the interactive state water plan website at texasstatewaterplan.org.

Table 8.1 - Annual volume of recommended water management strategies by region (acre-feet)

Region	2020	2030	2040	2050	2060	2070	Number of strategies
A	178,000	310,000	490,000	554,000	595,000	637,000	140
B	53,000	53,000	71,000	72,000	72,000	73,000	128
C	192,000	427,000	670,000	900,000	1,147,000	1,436,000	2,341
D	176,000	205,000	269,000	294,000	335,000	369,000	137
E	143,000	158,000	186,000	212,000	241,000	268,000	64
F	126,000	160,000	185,000	196,000	202,000	212,000	291
G	384,000	436,000	479,000	542,000	589,000	648,000	429
H	716,000	904,000	1,468,000	1,572,000	1,648,000	1,791,000	621
I	269,000	433,000	488,000	530,000	575,000	594,000	86
J	21,000	22,000	22,000	22,000	22,000	22,000	64
K	436,000	498,000	547,000	619,000	678,000	745,000	264
L	180,000	268,000	331,000	419,000	519,000	610,000	260
M	282,000	351,000	418,000	498,000	599,000	669,000	478
N	51,000	109,000	103,000	97,000	98,000	98,000	54
O	139,000	177,000	224,000	228,000	251,000	253,000	124
P	62,000	62,000	63,000	63,000	63,000	63,000	14
Texas[a]	**3,408,000**	**4,573,000**	**6,014,000**	**6,818,000**	**7,634,000**	**8,488,000**	**5,495**

[a] *Statewide totals may vary between tables due to rounding.*

Table 8.2 - Capital costs, by required online decade, of all recommended water management strategy projects by region (in millions)

Region	2020	2030	2040	2050	2060	2070	Total capital cost	Number of projects[a]
A	$270	$348	$60	$18	$0	$170	$866	81
B	$291	$0	$339	$0	$0	$0	$630	21
C	$3,730	$5,457	$3,304	$6,728	$3,119	$1,296	$23,635	557
D	$697	$11	$17	$413	$22	$80	$1,241	120
E	$843	$42	$514	$274	$258	$0	$1,930	45
F	$917	$190	$35	$58	$0	$0	$1,201	145
G	$3,604	$579	$69	$42	$21	$6	$4,321	215
H	$2,946	$4,853	$1,612	$836	$578	$54	$10,879	717
I	$1,362	$737	$562	$77	$0	$16	$2,754	58
J	$115	$0	$29	$0	$0	$0	$144	55
K	$3,069	$506	$142	$42	$12	$3	$3,773	123
L	$5,594	$201	$7	$2,253	$2	$19	$8,076	61
M	$1,202	$123	$81	$41	$386	$33	$1,866	195
N	$178	$331	$0	$1	$0	$0	$510	18
O	$452	$192	$87	$2	$80	$1	$814	112
P	$332	$0	$0	$0	$0	$0	$332	11
Texas	**$25,601**	**$13,570**	**$6,857**	**$10,787**	**$4,478**	**$1,678**	**$62,971**	**2,534**

[a] *Some projects are associated with multiple sponsors.*

8.2 Summary of recommended strategies

Recommended water management strategies may be considered from different perspectives, including

- by the water resources on which they rely; or
- by the configurations required to implement them based on the combination of specific water source(s), projects, and/or technology.

Some water management strategies do not require projects with capital costs to implement. For example, certain types of conservation may be supported by annual program budgets, and many water purchase strategies will rely on existing infrastructure capacity to increase water supply deliveries. Many other strategies, such as new reservoirs and seawater desalination plants, will require significant investment in infrastructure with an associated capital cost. The significance of these investments is relative; for example, installation of a single new well may represent a major investment for many small communities.

The complexity of recommended strategies and projects varies greatly. Some strategies, such as a new groundwater well, may serve and be implemented by a single water provider from a single water source. Other large regional projects, such as conveyances from reservoirs, may encompass a mixture of water sources assigned to numerous water user groups, require several major pipelines, pump stations, and serve multiple water providers.

8.2.1 Water resources for recommended strategies

Recommended water management strategies serving water user groups will rely on both future demand management (reducing the requirement for additional water) and a variety of Texas' water

resources (Figures 8.1 and 8.2). If implemented, all the recommended water management strategies would provide approximately 8.5 million acre-feet per year in additional water supplies to water user groups in 2070.

Demand management, mostly in the form of conservation savings, provides approximately 2.6 million acre-feet per year to water user groups, which is approximately 30 percent of the recommended strategy supplies in 2070.

Reuse provides 1.2 million acre-feet per year to water user groups, which is approximately 14 percent of the total recommended strategy supplies in 2070.

Surface water is the most significant water resource on which strategies are based, providing approximately 3.8 million acre-feet per year to water user groups, which is approximately 45 percent of the total recommended strategy supplies in 2070.

Groundwater resources provide approximately 810,000 acre-feet per year to water user groups, which is approximately 10 percent of the total recommended strategy supplies in 2070.

Seawater provides approximately 120,000 acre-feet per year to water user groups, which is approximately 1 percent of the total recommended strategy supplies in 2070.

8.2.2 Strategy types

Planning groups recommended a wide variety of water management strategies that will serve water user groups, each of which relies on a specific combination of water source(s), infrastructure, and technology (Figure 8.3, Table 8.3). The types of recommended strategies depended on the water needs, location, available water resources, impacts, and costs. Some recommended strategies require no new infrastructure, while others may require significant capital investments including various combinations of pipelines, wells, pump stations, river diversion facilities, or water treatment plants.

Figure 8.1 - Share of recommended water management strategies by water resource in 2070

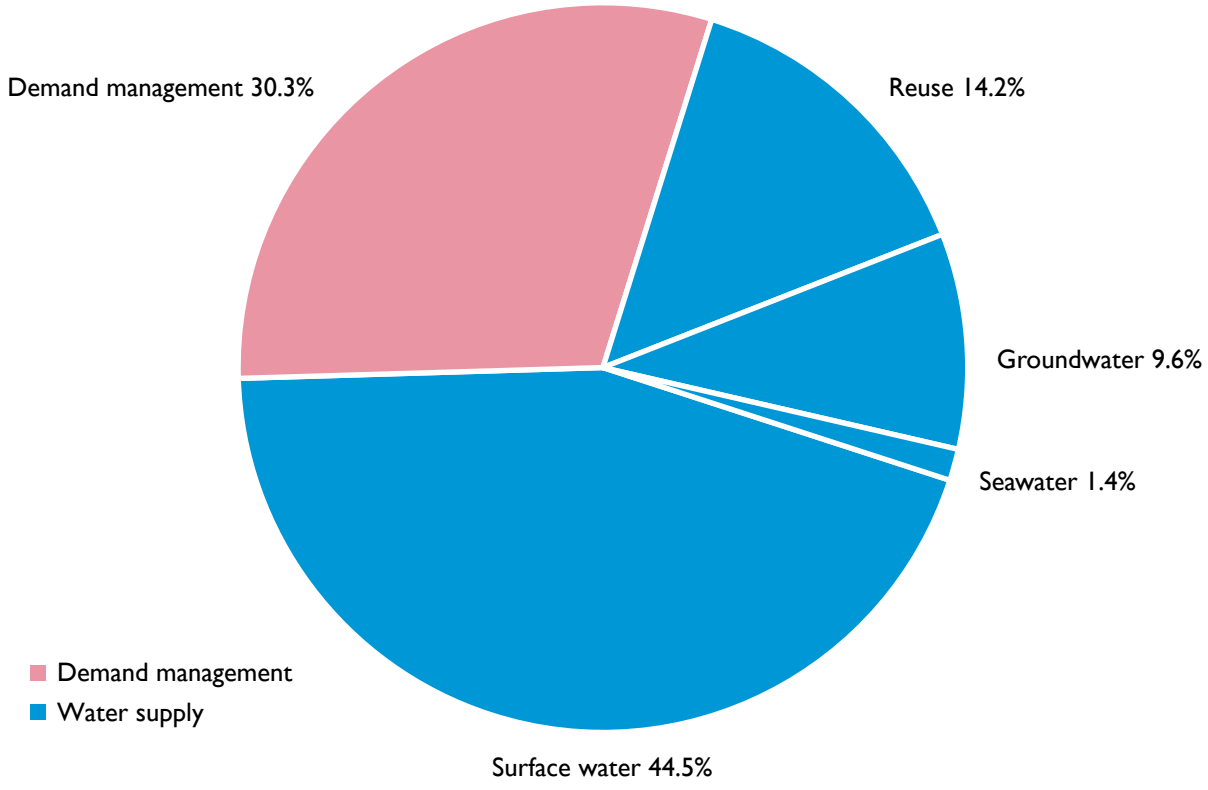


Figure 8.2 - Annual volume of recommended water management strategies by region and water resource in 2070 (thousands of acre-feet)

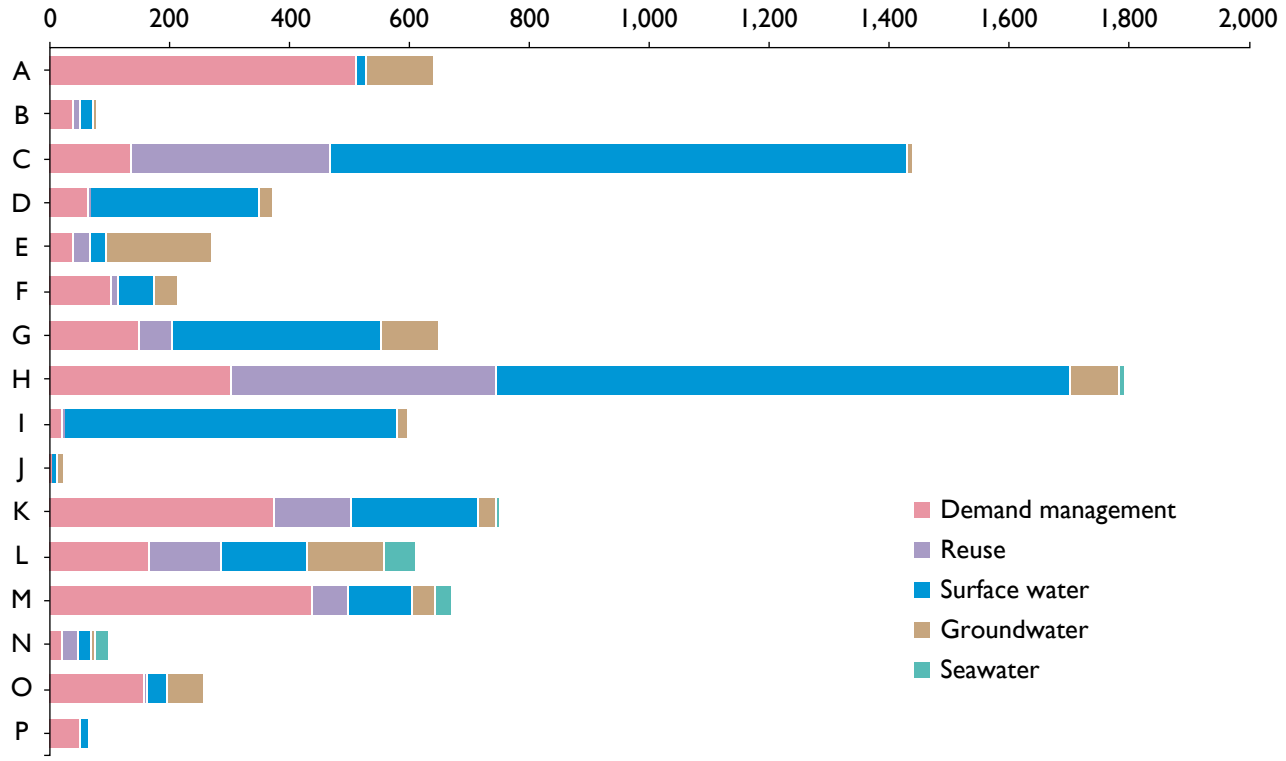


Figure 8.3 - Share of recommended water management strategies by strategy type in 2070

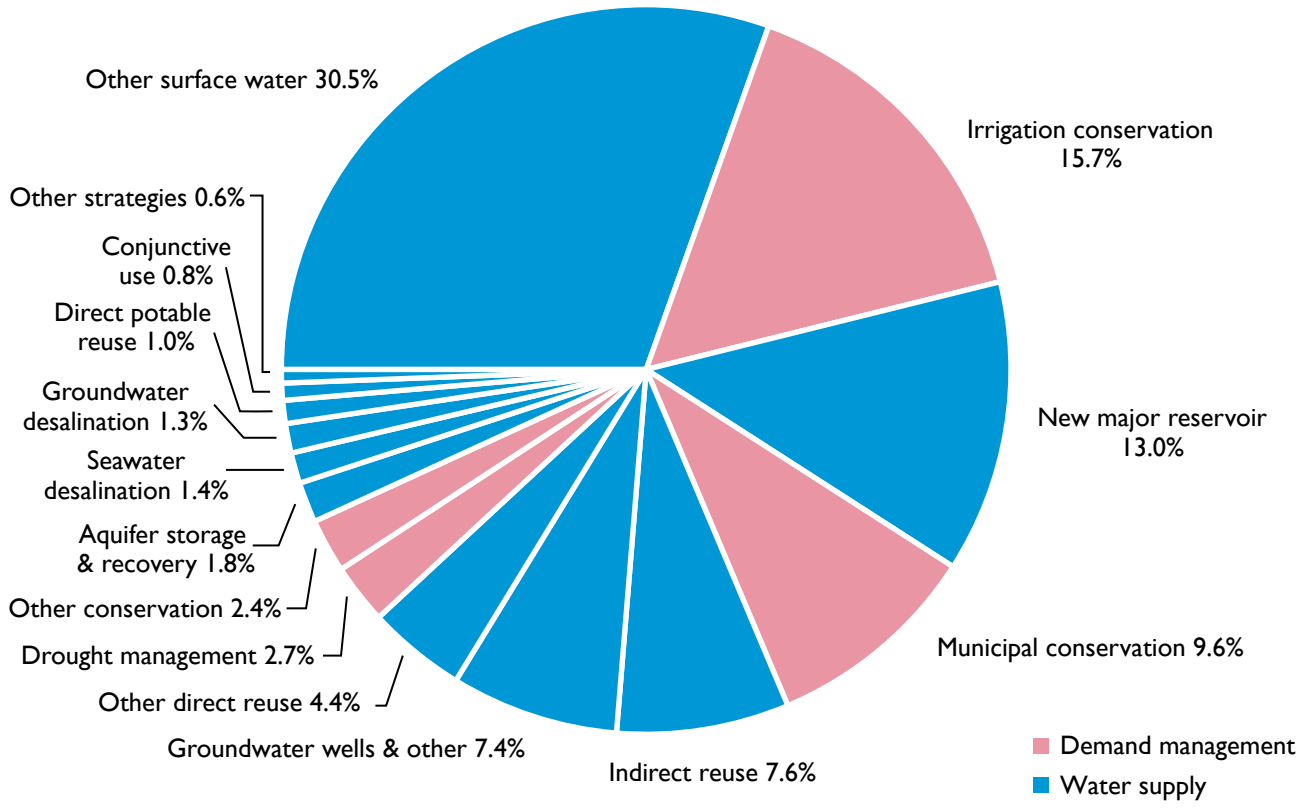


Table 8.3 - Annual volume of recommended water management strategies by strategy type (acre-feet)

Water management strategy type	2020	2030	2040	2050	2060	2070
Aquifer storage & recovery	53,000	91,000	105,000	124,000	135,000	152,000
Conjunctive use	40,000	60,000	65,000	65,000	65,000	64,000
Direct potable reuse	33,000	45,000	54,000	66,000	76,000	87,000
Drought management	152,000	178,000	199,000	208,000	217,000	226,000
Groundwater desalination	70,000	73,000	86,000	92,000	100,000	111,000
Groundwater wells & other	305,000	426,000	471,000	540,000	582,000	631,000
Indirect reuse	230,000	288,000	516,000	569,000	577,000	649,000
Irrigation conservation	639,000	809,000	1,084,000	1,175,000	1,267,000	1,330,000
Municipal conservation	204,000	333,000	435,000	562,000	686,000	811,000
New major reservoir	220,000	406,000	525,000	679,000	786,000	1,100,000
Other conservation	76,000	98,000	126,000	145,000	168,000	203,000
Other direct reuse	163,000	222,000	257,000	297,000	331,000	371,000
Other strategies	30,000	31,000	37,000	41,000	46,000	51,000
Other surface water	1,192,000	1,488,000	2,000,000	2,188,000	2,494,000	2,584,000
Seawater desalination	3,000	25,000	54,000	65,000	105,000	116,000
Texas[a]	**3,410,000**	**4,573,000**	**6,014,000**	**6,816,000**	**7,635,000**	**8,486,000**

[a] *Statewide totals may vary between tables due to rounding.*

Conservation

Conservation includes a variety of activities that either reduce everyday water consumption or increase water use efficiency, allowing more to be done with the same amount of water. Conservation occurs throughout both wet and dry weather and maintains all normal economic and domestic activities. Conservation was a recommended strategy in all regional water plans and is associated with over 1,300 water user groups (Table 8.4).

During the first cycle of regional water planning, a portion of water savings generated through non-passive conservation strategies, beyond those anticipated to be achieved due to existing state and federal plumbing standards (Section 5.6), was incorporated directly into the water demand projections developed by the TWDB. That approach could be interpreted to suggest that an additional lowering of per capita water use, for example, was inevitable. In response to subsequent criticisms of that approach, estimates of future non-passive water savings have since been shifted from the demand side of the planning equation to the supply side. This current approach better reflects the fact that a significant portion of future water savings will only be realized through the proactive implementation of conservation strategies by sponsors.

Municipal conservation includes a variety of activities such as installation of low flow plumbing fixtures, water conservation pricing structures, water system audits, or landscape irrigation restrictions. About 204,000 acre-feet per year in municipal conservation strategies is recommended in 2020, and 811,000 acre-feet per year is recommended in 2070. This is in addition to the estimated share of future passive conservation savings from plumbing codes and water efficiency standards (295,000 acre-feet per year in 2020 and 887,000 acre-feet per year in 2070), which are embedded in municipal water demand projections (Chapter 5).

The near-term conditions of no water management strategies in 2020 were compared to 2070 conditions assuming full implementation of the

state water plan using a calculation method equivalent to that used by the Water Conservation Implementation Task Force for calculating gallons per capita per day, which includes

- using the baseline projected municipal gallons per capita per day projections,
- the addition of supply volumes that are provided by municipalities to manufacturing, and
- exclusion of existing municipal reuse supply volumes.

If all the recommended municipal conservation and reuse strategies were implemented in 2070, the projected statewide municipal average gallons per capita per day would decline from the currently projected 163 gallons per capita per day in 2020 (without recommended conservation or reuse strategies) to approximately 124 gallons per capita per day in 2070 (with recommended conservation and reuse strategies). This calculated 2070 water use is well below the comparable statewide municipal total water use goal of 140 gallons per capita per day recommended by the Water Conservation Implementation Task Force created by the 78th Texas Legislature through Senate Bill 1094 (TWDB, 2004). This is the first state water plan to report meeting the Task Force's recommended statewide water conservation goal within the planning horizon.

Table 8.4 - Number of water user groups relying on different types of water management strategies by region

Water management strategy type	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Texas
Aquifer storage & recovery	0	0	0	0	1	9	9	0	0	2	7	14	0	0	1	0	43
Conjunctive use	3	0	0	1	1	0	2	59	0	0	0	0	0	0	8	0	74
Direct potable reuse	0	1	0	0	1	5	1	0	0	0	0	2	28	0	2	0	40
Drought management	0	0	0	0	0	1	5	0	0	1	81	31	0	0	0	7	126
Groundwater desalination	0	0	0	0	8	4	0	6	0	1	0	9	24	1	3	0	56
Groundwater wells & other	31	25	27	32	17	42	71	34	9	20	35	54	25	5	32	0	459
Indirect reuse	0	17	220	5	1	0	5	29	3	0	5	0	0	0	0	0	285
Irrigation conservation	20	10	10	0	2	30	18	8	0	0	3	7	8	2	21	0	139
Municipal conservation	36	22	268	9	12	57	96	244	11	11	51	104	67	22	40	5	1,055
New major reservoir	0	17	247	4	1	4	31	26	15	0	27	3	0	4	1	0	380
Other conservation	0	11	11	6	0	36	53	13	0	0	0	3	20	4	0	0	157
Other direct reuse	0	0	10	0	0	10	16	14	0	1	10	7	3	3	0	0	74
Other strategies	8	1	0	0	0	22	1	0	0	6	9	0	7	0	0	0	54
Other surface water	0	17	283	38	2	35	59	53	32	3	7	4	44	5	2	0	584
Seawater desalination	0	0	0	0	0	0	0	1	0	0	0	2	4	3	0	0	10

Irrigation conservation includes water savings associated with changes to irrigation methods and equipment. It includes, for example, conversion to Low Energy Precision Application (LEPA) systems as well as other activities associated with irrigation best management practices. About 639,000 acre-feet per year in irrigation conservation strategies is recommended in 2020, and 1.3 million acre-feet per year is recommended in 2070.

Other conservation includes water savings associated with steam-electric, manufacturing, and mining conservation activities based on best management practices appropriate for each facility, which may include evaluating cooling and process water practices, water audits, or submetering. About 76,000 acre-feet per year in other conservation strategies is recommended in 2020, and 203,000 acre-feet per year is recommended in 2070.

Drought management

Drought management reduces water use during times of drought by temporarily restricting certain economic and domestic activities such as car washing and lawn watering. Drought measures vary and are generally implemented by local water providers. Planning groups recommended drought management strategies for certain water user groups and in limited instances, for example, to address near-term shortages that will eventually be met in future decades from other water supply strategies. About 152,000 acre-feet per year in drought management strategies is recommended in 2020, and 226,000 acre-feet per year is recommended in 2070.

Reuse

Reuse takes many forms and is broadly categorized as either direct or indirect. Either type of reuse may be used for potable or non-potable purposes.

Direct potable reuse is relatively new to Texas and involves taking treated wastewater effluent, further treating it at an advanced water treatment plant, and then either introducing it upfront of the water treatment plant or directly into the potable water distribution system. About 33,000 acre-feet per year in direct potable reuse strategies is recommended in 2020, and 87,000 acre-feet per year is recommended in 2070.

Other direct reuse strategies generally convey treated wastewater directly from a treatment plant to non-potable uses such as landscaping or industrial processes. About 163,000 acre-feet per year in direct reuse (other than direct potable reuse) strategies is recommended in 2020, and 371,000 acre-feet per year is recommended in 2070.

Indirect reuse generally involves discharging wastewater into a natural water body and diverting that water for subsequent use. About 230,000 acre-feet per year in other reuse strategies is recommended in 2020, and 649,000 acre-feet per year is recommended in 2070.

Conjunctive use

Conjunctive strategies combine multiple water sources, usually surface water and groundwater, to optimize the beneficial characteristics of each source, yielding additional firm water supplies. For example, a strategy may rely intermittently on groundwater to supplement surface water supplies that may not be fully available under drought of record conditions. About 40,000 acre-feet per year in conjunctive use strategies is recommended in 2020, and 64,000 acre-feet per year is recommended in 2070.

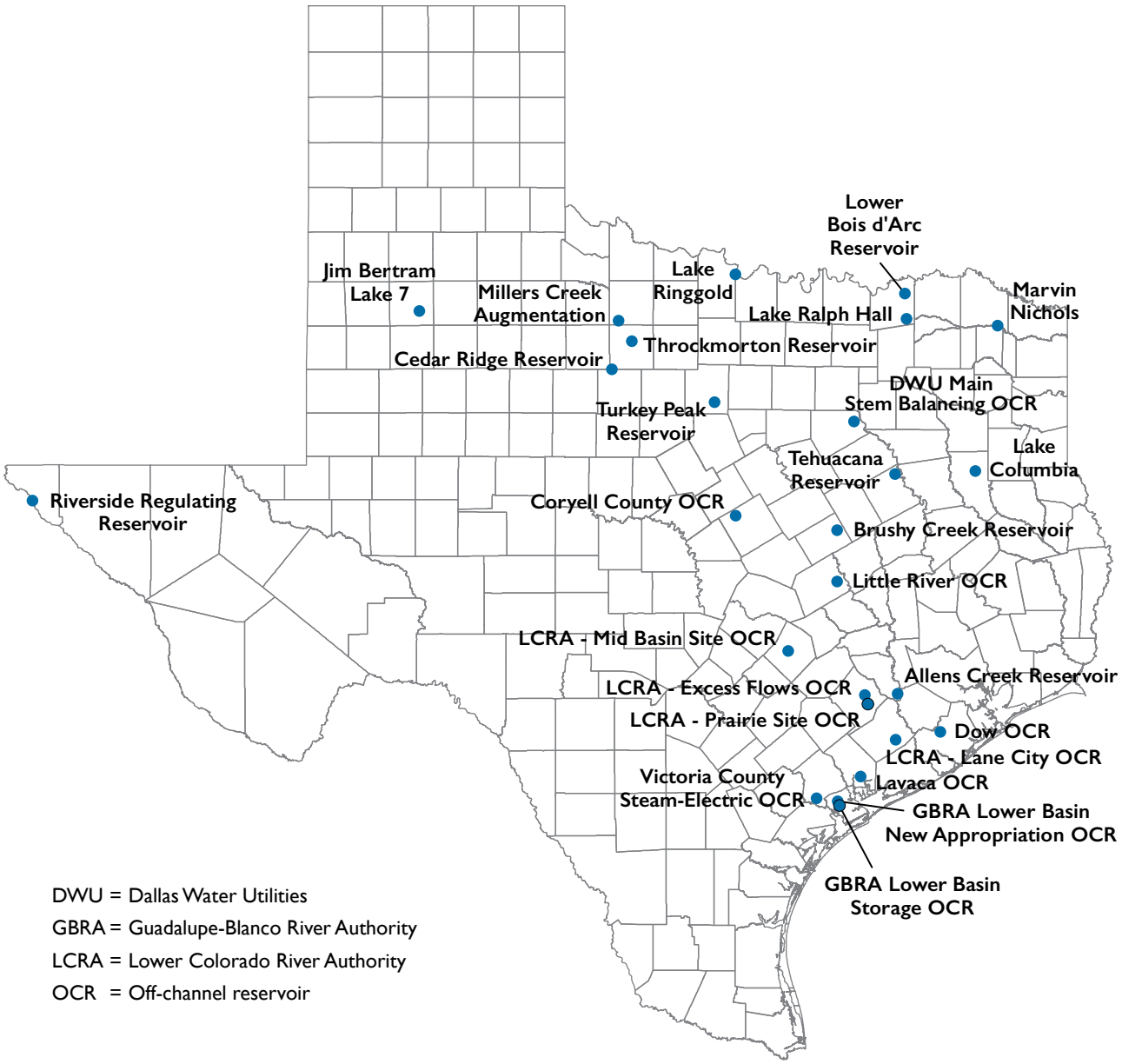
Aquifer storage and recovery

Aquifer storage and recovery refers to the practice of injecting water, when available, into an aquifer where it is stored for later use. This strategy is feasible only in certain geologic formations and in areas where only the project sponsor may retrieve the stored water. About 53,000 acre-feet per year in aquifer storage and recovery strategies is recommended in 2020, and 152,000 acre-feet per year is recommended in 2070.

New surface water reservoirs

Planning groups recommended 26 new major reservoirs (a reservoir with more than 5,000 acre-feet of storage) (Figure 8.4). About 220,000

Figure 8.4 - Recommended new major reservoirs



acre-feet per year from new major reservoir strategies, including some that rely on indirect reuse, is recommended in 2020 and 1.1 million acre-feet per year is recommended in 2070. Many of these reservoir sites are off-channel, meaning that they would not be built on the main stem of the river, although they may rely on the main stem flows.

Other surface water

Other surface water supplies include strategies relying on surface water that is not associated with new major reservoirs, surface water desalination, conjunctive use, or aquifer storage and recovery. Other surface water includes minor reservoirs (less than 5,000 acre-feet of storage) and subordination as well as a wide variety of other strategies that convey, treat, reassign, or otherwise make accessible additional surface water supplies to users with or without additional infrastructure.

Some of these strategies are based on building pipelines to convey previously developed surface water supplies over long distances to either wholesale or retail water providers, for example from an existing reservoir. These strategies generally

do not require further development of surface water resources, but simply convey previously developed surface water to users. In addition to pipelines, the types of projects associated with these strategies may include, but are not limited to, constructing pump stations, adding water treatment capacity, or lowering a reservoir intake to allow a water provider to continue to draw water when lake levels are low.

Another portion of these strategies is based on reassigning existing surplus water supplies or more fully utilizing the capacity of existing infrastructure to deliver surface water to wholesale and/or retail water providers. Many of these strategies are based on transactions (such as sales, contracts, or purchases) between wholesale and/or retail water providers involving previously developed supplies. These transactions may include voluntary reallocations of existing supplies, for example, to support an emergency connection between water providers. Delivery and treatment of these additional water supplies may or may not require new or expanded water infrastructure.

The remaining other surface water strategies increase supplies simply by removing infrastructure "bottlenecks," which limit the volume of supplies that can be delivered. Expanding the capacity of a water treatment plant to better align with the larger capacity of the pipeline that already delivers water to the plant is an example of this type of infrastructure.

About 1.2 million acre-feet per year from other surface water is recommended in 2020, and 2.6 million acre-feet per year is recommended in 2070.

Groundwater wells and other

Most planning groups recommended the development of at least some additional groundwater. This includes single wells or multiple wells, which may be part of the development of new well fields or expansions of existing well fields. New wells were often the only feasible strategy to meet the water needs of rural municipal water users.

Other groundwater strategies do not involve installation of new wells but instead convey, reassign, or otherwise make accessible previously developed groundwater supplies to users with or without additional conveyance and/or treatment infrastructure. These strategies may include, for example, maximizing the use of existing facilities by increasing production from existing groundwater wells and conveying groundwater supplies from one provider to another through a purchase.

About 305,000 acre-feet per year of supply from groundwater development strategies (not associated with groundwater desalination, conjunctive use, or aquifer storage and recovery strategies) is recommended in 2020, and 631,000 acre-feet per year is recommended in 2070.

Desalination of groundwater and seawater

Desalination is the process of removing dissolved solids from seawater or brackish groundwater, often by forcing the source water through membranes under high pressure. The specific process used to desalinate water varies depending upon the total dissolved solids, the temperature, and other physical characteristics of the source water but always requires disposal of concentrate that has a higher total dissolved content than the source water. Disposal may take the form of an injection well, evaporation beds, discharge to surface water, or an ocean outfall diffuser.

About 70,000 acre-feet per year of supply from groundwater desalination strategies is recommended in 2020, and 111,000 acre-feet per year is recommended in 2070. About 3,000 acre-feet per year of supply from seawater desalination strategies is recommended in 2020, and 116,000 acre-feet per year is recommended in 2070.

Other strategies

These include strategy types that, individually, provide less than 0.5 percent of the total recommended strategy supplies in 2070.

Rainwater harvesting

Surface water desalination is the process of removing dissolved solids from brackish surface water, often by forcing the source water through membranes under high pressure. About 3,000 acre-feet per year of supply from surface water desalination strategies is recommended in 2070.

Other less common strategies that are recommended include weather modification and brush control. These strategies share a common trait: it is difficult to quantify the reliable supplies that they are capable of providing under drought of record conditions when there is less cloud cover, precipitation, runoff, and infiltration of precipitation into the soil.

Weather modification, sometimes referred to as cloud seeding, is the application of technology to enhance precipitation from clouds. About 22,000 acre-feet per year of supply from weather modification strategies is recommended in 2070.

Brush control is a land stewardship technique that involves removal of species, such as ashe juniper, that may reduce runoff to streams and rivers and recharge to aquifers. However, since it is difficult to quantify reliable water volumes that can be produced and permitted for use under drought conditions, it was not often recommended as a strategy to meet needs (Research & Planning Consultants and Espey, Padden Consultants, Inc, 2000). About 10,000 acre-feet per year of supply from brush control strategies is recommended in 2070.

Rainwater harvesting is an ancient practice involving the capture, diversion, and storage of rainwater for landscape irrigation, drinking and domestic use, aquifer recharge, and, in modern times, stormwater abatement. Rainwater harvesting can reduce municipal outdoor irrigation demand on potable systems. Building-scale type rainwater harvesting that can meet planning rules, as was generally considered by regional water planning groups, requires active management by each system owner and a way to economically develop to a scale that will ensure a significant drought of record firm yield. About 17,000 acre-feet per year of supply from rainwater harvesting strategies is recommended in 2070.

8.3 Assignment of strategy and project supply volumes

The volume of water associated with all recommended water management strategy projects may, in some cases, be greater than an identified need or what was actually assigned to specific water user groups. Differences in water volumes may occur between the yield developed by certain projects at the source and the volume that would actually be conveyed to wholesalers or water user groups, the volume assigned to wholesale water providers and retail water providers, and/or the identified water user needs and strategy volume assigned to a specific water user. Depending on the project and provider, these differences in water volumes generally represent

- anticipated water losses in conveyance and/or treatment;
- a management supply or safety factor to address uncertainties such as whether recommended projects will be implemented, unanticipated water supply reductions, or greater than anticipated water demand for wholesale and retail water system operations;
- a planning buffer against a future drought worse than the drought of record;
- water supply available to a wholesale provider that could eventually be distributed to meet the needs of its customer water user groups; and/or
- a portion of the capacity of larger, optimally sized regional projects, such as major reservoirs, that come online later in the planning decades and that may not be fully connected to or utilized by water user groups until after 2070.

In some cases, additional water may be developed at the source only, while in other instances the water may be delivered to a wholesale provider but may not have been assigned to any specific water user group in a particular decade. Future delivery of these unassigned water volumes may require additional water infrastructure that may not be included in the plan.

The full capacities of all recommended projects and strategies that are included in the approved regional water plans, including any of their associated capacities or volumes of water that may not be assigned to specific water user groups, are also considered to be part of the state water plan.

8.4 Costs of recommended strategies

Planning groups estimated the costs of their recommended water management strategy projects using common cost elements and methodologies. This is the first cycle of regional plans in which planning groups utilized a cost estimation tool that was developed under a TWDB-funded research study. Extensive use of the spreadsheet-based tool introduced greater consistency in the cost estimates and helped planning groups ensure that all required cost considerations were included in the estimates.

In accordance with planning rules and guidance, this state water plan is intended to include only those recommended projects and costs necessary to conserve, develop, deliver, or treat additional water supply volumes; it specifically excludes the cost for maintenance or replacement of existing infrastructure as well as retail distribution projects, such as an expansion of internal distribution infrastructure to serve a new subdivision, other than those directly associated with recommended conservation strategies.

The total capital cost required to implement all recommended water management strategy projects is $63 billion. This includes approximately 2,500 projects that would be built and completed during different planning decades.

The estimated unit cost of water delivered to water user groups varies greatly depending on the type of strategy, location, water source, and infrastructure required to convey and treat the water. Weight-averaged[4] on a statewide basis, the least expensive recommended water management strategy type in the year 2070 is irrigation

[4] *The weighted average is the average of values scaled by the relative volume of each strategy.*

Table 8.5 - Weight-averaged unit costs (dollars per acre-foot)* of strategy water supplies by region and strategy type in 2070

Water management strategy type	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Texas
Aquifer storage & recovery	na	na	na	na	$296	$480	$252	na	na	$205	$645	$442	na	na	$243	na	$450
Conjunctive use	$106	na	na	na	$361	na	$1,031	$928	na	na	na	na	na	na	$106	na	$753
Direct potable reuse	na	$950	na	na	$1,212	$1,041	$740	na	na	na	na	$743	$1,137	na	$2,065	na	$1,134
Groundwater desalination	na	na	na	na	$415	$718	na	$850	na	na	na	$698	$1,146	$646	$1,713	na	$713
Groundwater wells & other	$314	$635	$350	$522	$756	$226	$360	$582	$303	$236	$774	$667	$66	$120	$256	na	$493
Indirect reuse	na	$360	$111	$288	$563	na	$125	$398	na	na	$46	na	na	na	na	na	$283
Irrigation conservation	$17	$53	$310	na	$55	na	$230	$112	na	na	$163	na	$531	$230	$42	$134	$147
Municipal conservation	$446	$254	$154	$591	$226	$437	$460	$257	$182	$381	$311	$652	$464	$483	$599	$345	$373
New major reservoir	na	$482	$563	$95	$267	$710	$450	$72	$270	na	$585	$596	na	$595	$179	$33	$470
Other conservation	na	$573	$310	na	na	$794	na	na	na	na	na	na	$1,899	na	na	na	$190
Other direct reuse	na	na	$285	na	na	$267	$290	$210	na	$58	$1,157	$356	$505	$341	na	na	$423
Other strategies	$8	$280	na	na	na	$308	na	na	na	na	$2,978	na	$10	na	na	na	$1,249
Other surface water	na	$361	$571	$490	$356	$83	$320	$245	$437	$99	$176	$606	$222	$508	$427	na	$380
Seawater desalination	na	na	na	na	na	na	na	$1,461	na	na	na	$611	$3,708	$550	na	na	$1,431

** Unit costs include a mixture of projects, some of which will be beyond their debt service period by 2070.*

na = not applicable or not available.

conservation. The most expensive is seawater desalination (Table 8.5), although this can vary greatly by individual project and depends on whether the unit costs still include debt service in any given decade. There can be a substantial range in unit costs even within a single type of strategy and also between regions (Table 8.5). For example, if a seawater desalination strategy requires a 100-mile pipeline inland, the costs of that strategy will likely be substantially greater than a seawater desalination plant built to serve an entity located on the coast.

8.5 Comparison to the 2012 State Water Plan

The annual volumes and relative mix of recommended water management strategy types will change between each state water plan for a variety of reasons. Some strategies recommended in the previous plan will have been implemented by the adoption of the next water plan, at which time the new supplies are accounted for as existing water supplies (Chapter 6) and thereby reduce the estimated water needs.

Recommended water management strategy water volumes in this plan are directly associated with water user groups in the same way that the projected water demands, existing supplies, and water needs are associated with water user groups. In addition to strategy supplies that were associated with those groups, the 2012 State Water Plan also included a varying mixture of other volumes. For example, volumes associated with project facility capacities at water sources but not delivered to or otherwise directly associated with water user groups are included. This difference makes some plan comparisons difficult. The recommended water management supplies, as presented here, are those supply volumes that planning groups

associated with specific water user groups. Notable changes from the 2012 State Water Plan include the following:

- The anticipated total strategy supplies directly associated with water user groups in the 2060 decade increased from 7.4 million acre-feet per year in the 2012 plan to 7.6 million acre-feet per year in this plan.
- The total capital costs of all the recommended strategies increased significantly, from $55.7 billion in the previous plan to $63 billion due to many factors, including inflation, increased engagement of water suppliers in the planning process, and a more comprehensive effort to include all projects that will conserve water or increase treated water supply volumes.
- The inclusion of many more capital-intensive conservation strategies resulted in an increase of over $3 billion in plan costs associated with conservation projects to a total of over $4 billion.
- The volume of recommended municipal conservation savings of 686,000 acre-feet per year in 2060 is greater than the 627,000 acre-feet per year recommended in the 2012 plan.
- The volume of recommended direct potable reuse strategies in 2060 increased approximately six-fold, from approximately 12,000 acre-feet per year in the 2012 plan to 76,000 acre-feet per year.
- The volume of recommended aquifer storage and recovery strategies increased more than four-fold, from approximately 30,000 acre-feet per year in the 2012 plan to 135,000 acre-feet per year in 2060.

8.6 Uncertainty of future strategies

Implementation of each particular recommended water management strategy project is not a certainty. Many of the more significant projects will require obtaining a water right permit from a regulatory entity. Some projects, such as large reservoirs, will require extensive and time-intensive studies, including additional environmental permitting from the U.S. Army Corps of Engineers and the National Environmental Policy Act process, which involves wide-ranging information collection, study, and public input.

Implementation of all water supply projects remains subject to political and financial processes associated with project sponsors and communities. Eventually, some recommended projects may become politically or financially infeasible and therefore will not provide any supply.

To account for uncertainties, including the possibility of projects being downsized or not being implemented at all, planning groups sometimes recommended a combination of water management strategies that, if implemented, would provide more water supplies than are required to meet needs. Planning groups also included alternative water management strategies, which are fully evaluated strategies that can be substituted at a future date in the event that a recommended strategy becomes infeasible. The farther we look into the 50-year planning period, the greater the uncertainty of implementing any given strategy. Regulations may change or technological advances may make a certain type of strategy more affordable. Water planning in Texas is an adaptive process in which regional and state water plans are developed every five years to reflect these and many other changes.

8.7 Impacts of recommended strategies

The process of developing regional water plans requires that planning groups describe the major impacts on key water quality parameters and how the plans are consistent with the long-term protection of water, agricultural, and natural resources.

8.7.1 Potential impacts on water quality

To assess how water management strategies could potentially affect water quality, planning groups identified key water quality parameters within their regions. These parameters were generally based on surface and groundwater quality standards, the

list of impaired waters developed by the Texas Commission on Environmental Quality, and input from local and regional water management entities and the public.

Planning groups presented high-level assessments on how the implementation of strategies could potentially affect the water quality of surface water and groundwater sources. Regions used different approaches, including categorical assessments (such as low, moderate, high) or numerical impact classifications (such as 1, 2, 3, 4, 5).

To evaluate the potential impacts of the recommended water management strategies on surface water quality, the planning groups most commonly used the Texas Surface Water Quality Standards, which include these considerations:

- **Total dissolved solids (salinity):** For most purposes, total dissolved solids is a direct measure of salinity. Salinity concentration determines whether water is acceptable for drinking water, livestock, or irrigation.
- **Nutrients:** A nutrient is classified as a chemical constituent, most commonly a form of nitrogen or phosphorus, that can contribute to the overgrowth of aquatic vegetation and impact water uses in high concentrations.
- **Dissolved oxygen:** Dissolved oxygen concentrations must be sufficient to support existing, designated, presumed, and attainable aquatic life uses in classified water body segments.
- **Bacteria:** Some bacteria, although not generally harmful themselves, are indicative of potential contamination by feces of warm-blooded animals.
- **Toxicity:** Toxicity is the occurrence of adverse effects to living organisms due to exposure to a wide range of toxic materials.

The water quality indicators that planning groups most commonly used to evaluate groundwater quality impacts of the recommended water management strategies include these considerations:

- **Total dissolved solids (salinity):** As was noted with surface water, total dissolved solids is a measure of the salinity of water and represents the amount of minerals dissolved in water.
- **Nitrates:** Although nitrates exist naturally in groundwater, elevated levels generally result from human activities, such as overuse of fertilizer and improper disposal of human and animal waste.
- **Arsenic:** Although arsenic can occur both naturally and through human contamination, most of the arsenic in Texas groundwater is naturally occurring.
- **Radionuclides:** A radionuclide is an atom with an unstable nucleus that emits radiation (this occurs naturally in several Texas aquifers).

Water management strategies for water supply are subject to the Texas Commission on Environmental Quality's Public Drinking Water and Water Quality standards, permitting, monitoring, assessment, treatment, sampling, and other requirements or methods used by that agency to address water quality problems related to water supply.

8.7.2 Protecting the state's water, agricultural, and natural resources

In developing their plans, the planning groups honored all existing water rights and contracts, adhered to the Texas Commission on Environmental Quality's existing and pass-through requirements for instream flows and estuaries, and considered conservation strategies for all water user groups with a water supply need. The regional water plans are based on environmental flow standards adopted by the Texas Commission on Environmental Quality, Consensus Criteria for Environmental Flow Needs, or when available, site-specific studies. The plans do not include any recommended strategies that are incompatible with the desired future conditions of aquifers or that divert greater-than-permitted surface water volumes.

Planning groups quantified and took into consideration the impacts of water management strategies to agricultural resources. In developing their plans, planning groups were required to consider and, when feasible, recommend water management

strategies to meet the water supply needs of irrigated agriculture and livestock production. Recommended strategies that would involve conversion or transfer of water associated with existing water right permits either being used for agricultural purposes or from rural areas were based on future voluntary transactions between willing buyers and willing sellers.

Planning groups included estimated costs of mitigation and quantified the potential impacts of water management strategies related to environmental factors such as bay and estuary inflows and habitat. Some categorized assessments as "high," "moderate," and "low," based on underlying quantified impacts or quantified ranges of impacts.

Environmental factors were quantified and summarized primarily based on existing data and the potential to avoid or mitigate impacts. For example, a quantification associated with a "low" impact rating indicated that impacts could generally be avoided or mitigated relatively easily. In contrast, an impact quantified and rated as "high" generally indicated that impacts would be significant and that there would likely be substantial mitigation requirements.

Planning groups considered a variety of factors including the volume of discharges a strategy would produce, the number of acres of habitat potentially impacted, changes to streamflows, and changes to bay and estuary inflow patterns. Approaches also relied on identifying the number of endangered or threatened species or cultural sites occurring within the vicinity of the recommended projects.

The emphasis of these evaluations varied by region based on the type of project under consideration and the relevant resources impacted. Evaluations included project-by-project evaluations as well as cumulative, region-wide impact analyses. In general, most planning groups relied on existing information and data generated as part of the technical

Figure 8.5 - Annual water supply needs and needs met by the plan by region in 2070 (acre-feet)

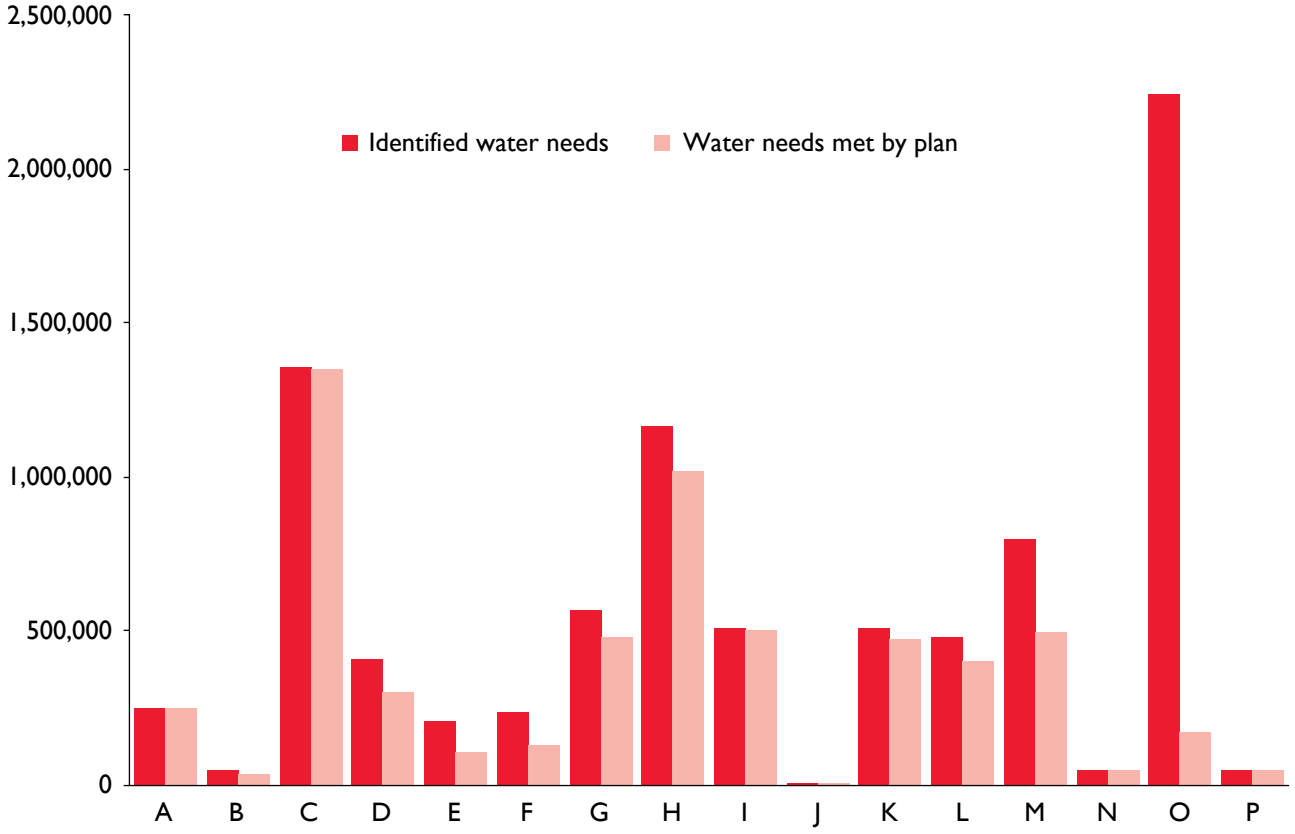
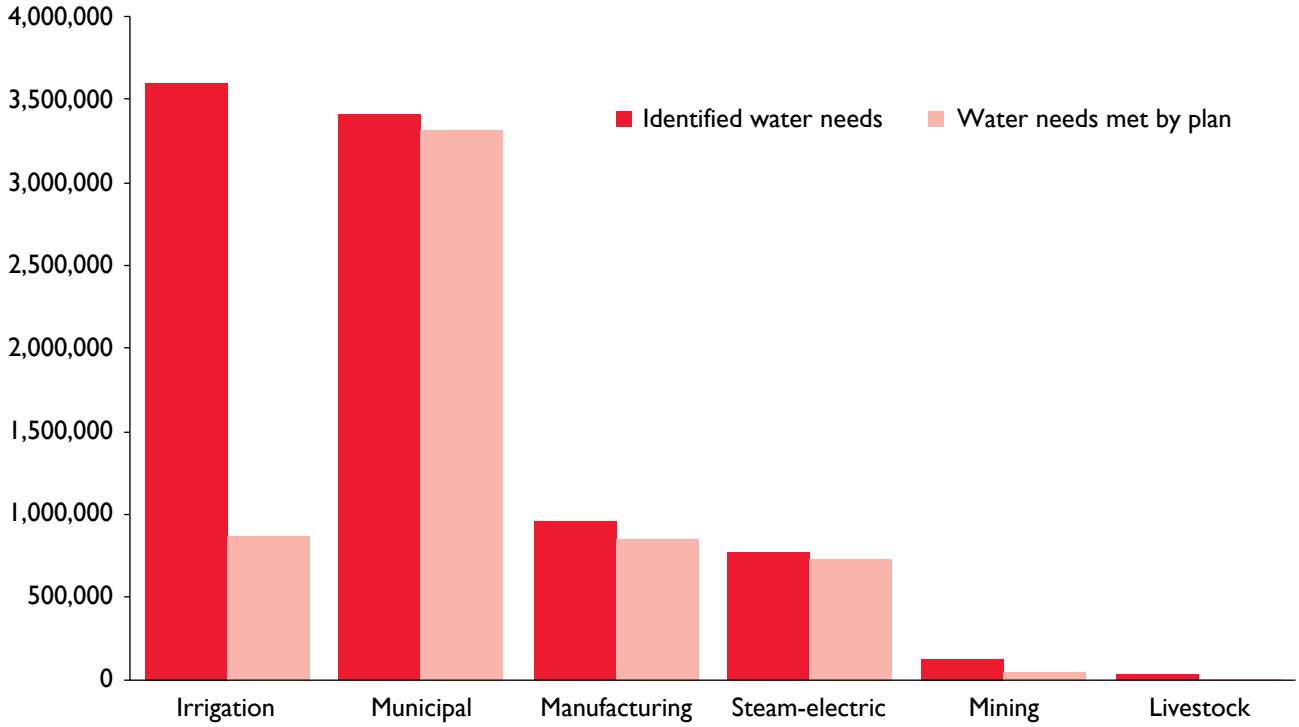


Figure 8.6 - Annual water supply needs and needs met by the plan by water use category in 2070 (acre-feet)



evaluations of strategies, such as flow frequency data, land cover, and habitat maps, to evaluate the impacts of water management strategies on agricultural and natural resources.

8.8 Needs met by recommended strategies

Planning groups were required to consider all identified water needs (potential shortages) and identify potential strategies to meet them, when feasible. Only one planning group (Region P) was able to recommend water management strategies that, if implemented, are capable of meeting the needs for all its water user groups. The remaining 15 planning groups were unable to identify feasible strategies that met Texas' planning requirements and that would meet all of the needs in their regions (Figure 8.5).

Statewide, the majority of water needs associated with municipal, manufacturing, and steam-electric water user groups are met by the plan in 2070 (Figure 8.6). However, at least some unmet water supply needs occur for all categories of water user groups in the plan. The inability to meet a water user group's need in the plan is usually due to the lack of an economically feasible water management strategy, but this does not prevent an entity from pursuing additional water supplies.

References

Research & Planning Consultants and Espey, Padden Consultants, Inc, 2000, Assessment of brush control as a water management strategy: Prepared for the Texas Water Development Board, 100 p. www.twdb.texas.gov/publications/reports/contracted_reports/doc/99483312.pdf

TWDB (Texas Water Development Board), 2004, Report to the 79th Legislature, Water Conservation Implementation Task Force: Prepared by the Texas Water Development Board, 88 p. www.twdb.texas.gov/conservation/resources/doc/WCITF_Leg_Report.pdf