THE ECONOMIC IMPORTANCE OF GROUNDWATER IN ARIZONA, 2010-2018

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- Raytheon
- Republic Services, Inc.
- Rosemont Copper
- Science Foundation Arizona (SFAZ)
- Salt River Project (SRP)
- Turf Paradise
- Valley METRO Light Rail
- Vote Solar Initiative
- Waste Management, Inc.

EXECUTIVE SUMMARY

- This study estimates the economic importance of groundwater for the five Active Management Areas (AMAs) in the State of Arizona, 2010 through 2018. These are the Phoenix AMA, the Pinal AMA, the Prescott AMA, the Santa Cruz AMA, and the Tucson AMA. For the purpose of this report, the term groundwater means water that is pumped out of the ground. This water may have originated from artificial or natural recharge processes[1]

- A modified IMPLAN input-output model for each AMA, based on zip codes, is used to estimate economic importance.[2,3]

- Seidman assesses economic importance by using a counterfactual scenario that estimates the economic activity that would occur absent the availability of groundwater, while assuming no substitution or adaptation for the water source.

- Three measures of economic importance are examined. These are the contributions to State Gross Domestic Product (GDP), total employment and total labor income.

- Over the 9-year study horizon, approximately 11.7 million acre feet of groundwater was utilized by agriculture, industrial and municipal customers in the five AMAs (excluding Native American tribes and reservations usage).

- Assuming no substitution for or adaptation to the loss of groundwater, Seidman has estimated the economic importance of groundwater to the economies served by the AMAs, 2010 through 2018, as follows:

Table ES1: Average Annual Economic Importance of Groundwater Availability by AMA

AMA	STATE GDP (Billions 2018 $)	EMPLOYMENT (Job Years)	LABOR INCOME (Billions 2018 $)
Phoenix	$102.5	1,093,814	$62.5
Pinal	$5.3	68,534	$2.9
Prescott	$4.7	72,547	$2.8
Santa Cruz	$1.4	20,365	$0.9
Tucson	$21.2	271,973	$12.3

Source: Authors' Calculations

[1] Artificial recharge sources include: incidental recharge from agricultural, municipal and industrial sources; canal seepage; and aquifer recharge projects using renewable surface water.
[2] Input-output models like IMPLAN are a little imprecise when dealing with large-scale changes to economic variables. That is, they provide approximate rather than definitive estimates of economic importance/impact for studies of this nature.
[3] The distribution of zip codes to AMAs is shown in the appendix.

- Seidman estimates that the groundwater supplied to municipal, industrial, and agricultural customers in the Phoenix AMA was responsible for more than $922.5 billion (2018 $) in State GDP between 2010 and 2018.

- Seidman also estimates that the groundwater supplied to municipal, industrial and agricultural customers in the Pinal AMA was responsible for $47.7 billion (2018 $) in State GDP between 2010 and 2018.

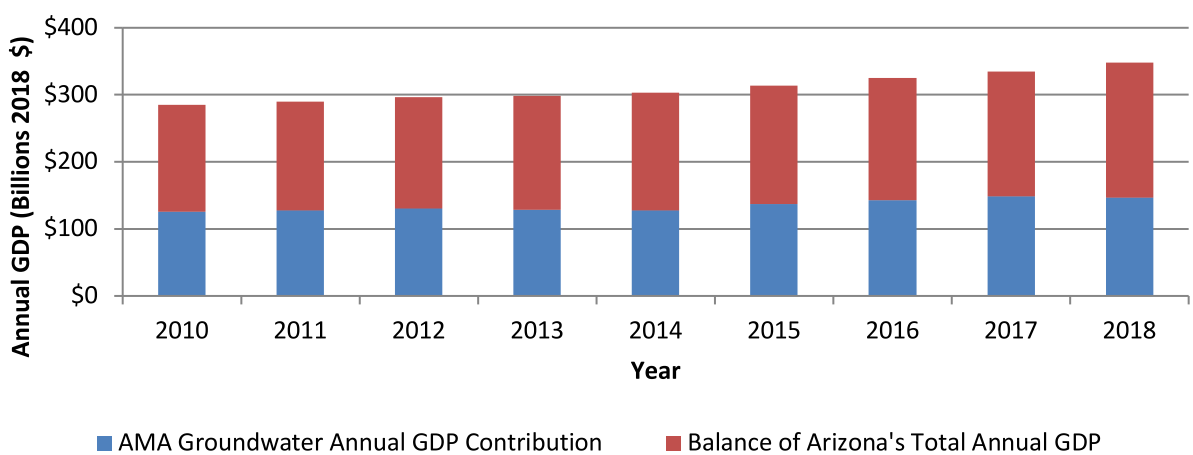
- In the Prescott AMA, Seidman estimates that the groundwater supplied to municipal, industrial and agricultural customers was responsible for $42.5 billion (2018 $) in State GDP between 2010 and 2018.

- In the Santa Cruz AMA, Seidman estimates that the groundwater supplied to municipal, industrial and agricultural customers was responsible for $12.8 billion (2018 $) in State GDP between 2010 and 2018.

- Finally, in the Tucson AMA, Seidman estimates that the groundwater supplied to municipal, industrial and agricultural customers was responsible for $190.8 billion (2018 $) in State GDP between 2010 and 2018.

- In total, Seidman estimates that the groundwater supplied to municipal, industrial, and agricultural customers in the five AMAs was cumulatively responsible for approximately $1.2 trillion (2018 $) in State GDP between 2010 and 2018.

Figure ES1: Annual AMA Groundwater Contribution to Total State GDP, 2010-2018



Source: Authors' Calculations

- The availability of groundwater in total water supply among the five AMAs (combined) between 2010 and 2018 directly and indirectly accounted for 42.2% to 44.3% of the State's total annual GDP, dependent on the year in question.

- On average, between 2010 and 2018, groundwater in the five AMAs accounted for 43.5% of Arizona's total annual State GDP.

- Groundwater utilization in the five AMAs was also responsible for total annual employment of 1.4 to 1.7 million jobs, dependent on the year in question, during the 2010-2018 study period.

- The range of annual employment associated with groundwater supplies by AMA was as follows:

  - The Phoenix AMA: 1,004,173 jobs to 1,208,263 jobs for one year.
  - The Pinal AMA: 63,819 jobs to 72,167 jobs for one year.
  - The Prescott AMA: 63,858 jobs to 82,580 jobs for one year.
  - The Santa Cruz AMA: 18,784 jobs to 22,572 jobs for one year.
  - The Tucson AMA: 259,370 jobs to 306,201 jobs for one year.

- Without sustained access to available groundwater in the five AMAs, Arizona's economic development would have followed a radically different trajectory.

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Arizona relies on the Colorado River for more than one third of its water supply. Years of intensive water consumption, drought, and rising temperatures have reduced water supply throughout the lower 100 miles of the river and threaten to exhaust its main reservoirs.

The recently agreed upon multi-state Colorado River Drought Contingency Plan (DCP) details Arizona's commitment to take less water from the river. The objective of the plan is to prevent Lake Mead and Lake Powell, the largest reservoirs, from falling to critically low water levels in the next several years. Arizona has been in a "Tier Zero" condition in 2020. Under Tier Zero DCP, the State is required to take a reduction of 192,000 acre-feet, which is about 7% of Arizona's 2.8 million acre feet Colorado River water allotment.

This goes up to 18% in a "Tier 1" condition, which could occur in 2022, according to the Bureau of Reclamation's November 24-month Study. projections.[4] The Bureau conducts its study of the two-year outlook for river conditions every month. A wetter-than-anticipated winter could change those projections.

Apart from the Drought Contingency Plan, Phoenix officials are working on long-term plans to drill wells and other infrastructure. These plans will enable the city to reduce its reliance on water from the Colorado River.

Historically, aquifers have been used to store surplus water and serve as a buffer against shortages in supply delivered from the Colorado River. With an average annual rainfall of around 8 inches in Arizona, aquifers naturally replenish very slowly. It is evident that groundwater is an important source of water, but no estimates of its importance to the Arizona economy exist. The purpose of the current study is to help fill that gap by estimating the economic importance of groundwater to the State, 2010 through 2018, excluding any Native American groundwater usage.

Section 2 describes water availability in Arizona, followed by an overview of Active Management Areas (AMAs) in Section 3. An estimate of the economic importance of groundwater supplied to municipal, industrial and agricultural customers in each of the five AMAs is offered in Section 4. Conclusions are provided in Section 5.

[4] Source: Bureau of Reclamation, (2020). *November 24-Month Study*, published November 10, 2020. Available at: https://www.usbr.gov/uc/water/crsp/studies/24Month_11.pdf

2. WATER AVAILABILITY IN ARIZONA

There are four primary sources of water supply in Arizona. These are surface water, Colorado River water, groundwater, and effluent.

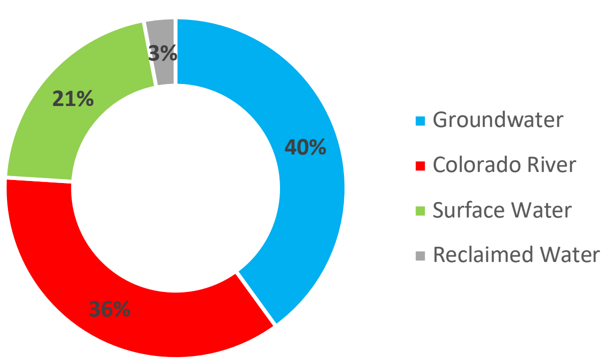
Surface water comes from lakes, rivers, and streams, stored in reservoirs or delivery systems. The availability of surface water can vary dramatically by year or location.

The State of Arizona has the right to use 2.8 million acre feet of water from the Colorado River each year, over half of which is delivered by the Central Arizona Project to Maricopa, Pinal, and Pima Counties. Mohave, La Paz, and Yuma Counties also rely on the Colorado River as their principal water supply.[5]

Groundwater is found beneath the earth's surface in natural reservoirs called aquifers. The Arizona Department of Water Resources estimates that up to 43% of the state's water comes from groundwater sources; and in designated Active Management Areas this water is carefully managed by an Arizona Groundwater Management Code first launched in 1980. The majority of the state lies outside of these designated Active Management Areas, and in these areas groundwater is largely unregulated, with evidence of declining groundwater levels.

Effluent is reclaimed water, used by agriculture, golf courses, in parks, for industrial cooling, and to maintain wildlife areas.

Figure 1: Arizona's Water Supplies, 2018



Source: ADWR, (2019)[6]

Figure 1 shows the distribution of Arizona's water supply by type in 2018. Approximately 40% of the state's water supply is groundwater. The Colorado River supplies 36% and surface water (or in-state rivers) 21%. Reclaimed water (or effluent) accounts for 3% of the state's total water supply. The Arizona Department of Water Resources (ADWR) is responsible for collating this water data.

[5] Source: Arizona Department of Water Resources, (date unknown). *Securing Arizona's Water Future*, available at: http://www.azwater.gov/AzDWR/PublicInformationOfficer/documents/supplydemand.pdf

[6] Source: Arizona Department of Water Resources, (2019). Arizona Water Facts, available at: arizonawaterfacts.com/water-your-facts

3. ACTIVE MANAGEMENT AREAS

In 1980, the Arizona Groundwater Code was established to aggressively manage the State's finite groundwater resources. The Code identified five geographical areas or Active Management Areas (AMAs) with a heavy reliance on mined groundwater. These are the Phoenix AMA, the Pinal AMA, the Prescott AMA, the Santa Cruz AMA, and the Tucson AMA. More than 80% of the State's population reside within these five AMAs.

The primary management goal of the Phoenix, Prescott and Tucson AMAs is to ensure safe-yield by 2025 – that is, to ensure that the annual groundwater withdrawals do not exceed the rate of replenishment. In the Pinal AMA, the primary goal is to meet local agricultural needs for as long as possible, while also preserving groundwater supplies for non-irrigation purposes. In the Santa Cruz AMA, the primary objective is to maintain a safe-yield condition.[7]

Each AMA has four distinct types of user or customer. These are agricultural, industrial, municipal and Indian.

Agricultural use refers to use on two or more acres of land to produce plants or parts of plants for sale or human consumption, or for use as feed for livestock, range livestock or poultry.

Industrial refers to a non-irrigation use of water. Industrial users withdraw water from their own wells, rather than be supplied by a city, town, or private water company. Examples include cattle feedlots, dairies, large-scale power plants and cooling facilities, mines, landscaping facilities, sand and gravel facilities and turf-related facilities such as golf courses, parks and cemeteries.

Municipal water use refers to water delivered for non-irrigation purposes by a city, town, private water company or irrigation district. This water is delivered to households (residents) and commercial operations (businesses).

Indian refers to the total agricultural, industrial and municipal demand (combined) on Native American reservations.

The current study focuses on the first three types of water usage listed above. Native American supply and demand is excluded due to incomplete data reported by the Arizona Department of Water Resources for 2017 and 2018.

Seven management tools and programs are currently applicable to all five AMAs. These are:

- An assured water supply program limiting the use of groundwater by new AMA subdivisions

[7] Source: Arizona Department of Water Resources, (2020). *Active Management Areas*. Available at: https://new.azwater.gov/ama

- Conservation requirements for large municipal water providers that specify a maximum daily usage per capita allowance and limit annual system losses to a maximum 10%.
- Conservation requirements for irrigated agriculture that specify a maximum annual groundwater allotment and limit annual system losses to a maximum 10%.
- Conservation requirements for industries such as golf courses, dairies, mines and power plants.
- An underground storage and recovery program which allows surplus supplies of water to be stored underground and recovered later (artificial recharge).
- Water rights and permit requirements for the pumping of groundwater from non-exempt wells (pump more than 35 gallons per minute).
- Well requirements and reporting for exempt wells (pump 35 gallons per minute or less) and non-exempt wells.

Three additional tools and programs are also applicable to the Phoenix, Pinal and Tucson AMAs. These are:

- Arizona Water Banking Authority (AWBA) which stores or banks unused Colorado River water for use in times of shortage
- The Central Arizona Project, which is a 336 mile-long system of water supply managed by the Central Arizona Water Conservation District (CAWCD) for customers in Maricopa, Pima and Pinal counties.
- The Central Arizona Groundwater Replenishment District (CAGRD) which stores water underground, to replenish groundwater pumped by property owners and water providers in Maricopa, Pinal and Pima counties.

Annual supplies or deliveries of groundwater (in acre feet) to the AMAs, 2010 through 2018, are shown in Table 1. During the 9-year study horizon, approximately 11.7 million acre feet of groundwater was utilized by agricultural, industrial and municipal customers in the five AMAs. More than half of this total groundwater (50.1%) used was in the Phoenix AMA. More than a third of the groundwater (35.5%) was used in the Pinal AMA. The Tucson AMA accounted for 11.7% of total groundwater used throughout the nine years. The Santa Cruz AMA accounted for 1.4% and the Prescott AMA 1.2% of total groundwater used, 2010 through 2018.

Table 1: Annual Supply of Groundwater by AMA, 2010-2018 (in Acre Feet)[8]

PHOENIX AMA	2010	2011	2012	2013	2014	2015	2016	2017	2018
Agriculture	266,151.5	365,275.2	382,963.1	339,571.5	344,059.0	356,929.0	329,406.0	340,073.6	379,007.0
Industrial	98,124.3	94,747.3	94,659.8	89,113.8	84,257.0	89,841.2	92,818.3	94,052.1	95,807.0
Municipal	178,683.7	178,633.2	208,878.0	204,556.1	213,871.5	240,313.4	251,959.3	228,462.3	224,852.6
Total	***542,959.6***	***638,655.7***	***686,500.9***	***633,241.3***	***642,187.5***	***687,083.6***	***674,183.6***	***662,588.0***	***699,666.6***
PINAL AMA	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Agriculture	317,971.0	433,649.0	422,489.0	428,597.4	423,119.0	410,894.6	428,369.1	427,417.5	419,964.0
Industrial	19,113.5	18,513.9	15,543.1	14,387.2	17,760.1	18,698.4	19,308.6	19,186.0	21,807.7
Municipal	32,710.8	33,609.1	33,302.3	32,744.0	33,600.6	28,008.5	28,317.2	27,674.2	27,315.5
Total	***369,795.3***	***485,772.0***	***471,334.3***	***475,728.7***	***474,479.6***	***457,601.5***	***475,994.9***	***474,277.7***	***469,087.2***
PRESCOTT AMA	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Agriculture	1,618.3	2,259.5	1,688.7	2,051.7	2,252.3	2,084.0	1,619.5	1,609.7	2,740.0
Industrial	1,153.2	895.4	964.3	992.5	1,606.5	1,260.6	1,491.0	1,656.1	955.4
Municipal	11,792.2	13,870.6	13,908.7	12,823.9	12,416.4	11,678.8	14,101.5	11,549.2	13,813.0
Total	***14,563.7***	***17,025.6***	***16,561.6***	***15,868.1***	***16,275.3***	***15,023.4***	***17,212.0***	***14,815.1***	***17,508.4***
SANTA CRUZ AMA	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Agriculture	11,090.3	15,326.1	12,620.2	13,940.7	7,532.7	6,672.3	9,901.8	9,718.1	7,910.0
Industrial	1,634.2	941.4	1,533.1	1,158.9	1,101.2	1,318.8	1,378.0	1,247.0	668.1
Municipal	7,542.6	7,335.5	6,846.8	6,939.7	6,106.5	5,957.5	6,255.8	6,101.2	6,364.1
Total	***20,267.1***	***23,602.9***	***21,000.1***	***22,039.4***	***14,740.3***	***13,948.6***	***17,535.6***	***17,066.4***	***14,942.2***
TUCSON AMA	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Agriculture	65,674.0	76,868.0	78,425.0	80,553.0	78,258.0	70,372.5	75,719.8	74,945.1	60,011.0
Industrial	47,496.2	43,749.5	42,990.0	40,611.6	43,266.9	42,231.7	33,616.0	50,559.2	46,069.0
Municipal	43,439.4	42,482.1	39,145.4	41,089.1	38,153.5	32,350.0	31,027.2	31,489.7	23,246.1
Total	***156,609.6***	***163,099.6***	***160,560.3***	***162,253.6***	***159,678.3***	***144,954.3***	***140,363.0***	***156,994.0***	***129,326.1***

Source: ADWR (2020)

[8] Table excludes Indian deliveries.

4. ECONOMIC IMPORTANCE OF GROUNDWATER, 2010-2018

4.1 Method

Water availability is a critical component in economic activity. In the absence of groundwater as part of total water supply to agricultural, industrial and municipal customers, the State of Arizona's economic development would almost certainly have followed a different trajectory. Without sustained access to reliable groundwater, Arizona's future economic development will likely follow a different trajectory than the past.

The purpose of this section is to estimate the economic importance of groundwater to Arizona's economy. Seidman achieves this by estimating the extent to which the economy centered around the usage of each AMA's groundwater would have been smaller during the 2010-2018 period without the annual availability and supply of groundwater. The analysis assumes the non-substitutability of annual groundwater deliveries in each AMA. The analysis also assumes that the economy would not have adapted to reduced water availability by, for instance, using less water-intensive production methods. A series of customized IMPLAN input-output models for the AMAs are used to estimate the annual and cumulative economic impact of groundwater deliveries, 2010-2018. Originally developed by the University of Minnesota, IMPLAN is widely used for economic assessment and can provide detailed estimates of total (direct, indirect and induced) impacts for a finite time period - typically one full calendar year.

Seidman's method for estimating economic impacts consists of five fundamental steps:

1. **Prepare a baseline forecast for the economy of each AMA:** This Business As Usual (BAU) case consists of a historical input-output table for each year, in which the intermediate demand and final demand of a 22 sector version of the local economy is described, and a distinction made between the use of water as a primary input to the production process of each industry or sector, and other water supplies that are directly consumed.
2. **Develop a policy scenario:** This policy scenario reduces the annual availability of groundwater in each AMA for the 22 sectors in the input-output tables.
3. **Compare the baseline and policy scenario forecasts.**
4. **Produce the "delta" results**: Differences between the values for each sector estimate the potential economic impact of the non-availability of groundwater on the local economy, relative to the baseline, for each year of study.
5. **Run an IMPLAN analysis on each series of delta results**: This produces annual and cumulative estimates of the importance of groundwater deliveries for State Gross Domestic Product (GDP), employment, and labor income. State GDP is synonymous with value added. It represents the dollar value of all goods and services produced for final demand in the state. Employment is a count of full- and part-time jobs, including both wage and salary

workers, and the self-employed. Labor Income refers to all forms of employment income, including the wages, salaries and benefits of employees, and any incomes earned by the self-employed.

Table 2 estimates the annual percent contribution of groundwater to municipal, industrial, and agricultural water supplies in each of the five AMAs, based on ADWR data up to and including 2018, and an assumption that other sources of water are not available to compensate for the loss of groundwater.[9] It also assumes that the economy would not have adapted to reduced water availability by, for instance, using less water-intensive production methods.

The table estimates, for example, that groundwater accounted for 38.1% of water supplied to agricultural users in the Phoenix AMA in 2010. Groundwater also accounted for 52.0% of water supplied to industrial users, and 17.7% of water supplied to municipal users in the Phoenix AMA in 2010. In 2017, the table estimates that groundwater accounted for 46.9% of water supplied to agricultural users, 49.1% of water supplied to industrial users, and 21.1% of water supplied to municipal users in the Phoenix AMA.

Across the nine-year time horizon, groundwater accounted for 38.1% to 56.1% of annual water supplies for the Phoenix AMA's agricultural users. For industrial users, groundwater accounted for 44.8% to 52.0% of annual water supplies. For municipal users, groundwater accounted for 17.7% to 22.9% of annual water supplies.

In the Pinal AMA, groundwater accounted for 36.6% to 50.5% of annual agricultural water supplies between 2010 and 2018. For industrial users, groundwater accounted for 85.4% to 91.7% of annual water supplies. For municipal users, groundwater accounted for 70.7% to 93.0% of annual water supplies.

In the Prescott AMA, groundwater accounted for 62.9% to 91.9% of annual agricultural water supplies between 2010 and 2018. For industrial users, groundwater accounted for 33.9% to 96.8% of annual water supplies. For municipal users, groundwater accounted for 64.7% to 84.2% of annual water supplies.

In the Santa Cruz AMA, groundwater accounted for 97.7% to 100% of annual agricultural water supplies between 2010 and 2018. For industrial users, groundwater accounted for 98.2% to 100% of annual water supplies. For municipal users, groundwater accounted for 100% of annual water supplies.

In the Tucson AMA, groundwater accounted for 62.0% to 74.6% of annual agricultural water supplies between 2010 and 2018. For industrial users, groundwater accounted for 78.7% to 99.6% of annual water supplies. For municipal users, groundwater accounted for 15.3% to 24.9% of annual water supplies.

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[9] ADWR released the 2018 data on May 6, 2020. The 2019 data will not be available until spring 2021.

Table 2: Percent Contribution of Groundwater by Customer Type in Each AMA, 2010-2018

PHOENIX AMA	2010	2011	2012	2013	2014	2015	2016	2017	2018
Agriculture	38.13%	44.90%	47.41%	43.41%	45.78%	48.12%	46.21%	46.90%	56.05%
Industrial	52.04%	51.40%	49.56%	47.44%	44.79%	47.40%	47.34%	49.12%	48.46%
Municipal	17.67%	17.63%	19.49%	19.31%	20.39%	22.85%	22.86%	21.13%	20.17%
PINAL AMA	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Agriculture	36.59%	43.32%	45.49%	48.54%	47.30%	49.21%	50.53%	48.63%	50.13%
Industrial	88.63%	91.66%	89.15%	91.56%	89.56%	89.10%	88.77%	86.56%	85.39%
Municipal	91.54%	92.95%	92.36%	92.48%	92.17%	75.33%	75.53%	77.75%	70.66%
PRESCOTT AMA	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Agriculture	65.91%	69.94%	62.94%	68.65%	70.34%	68.76%	70.85%	85.80%	91.85%
Industrial	94.70%	96.80%	95.35%	83.59%	53.15%	43.78%	51.17%	49.08%	33.92%
Municipal	71.58%	82.83%	84.21%	78.35%	73.81%	70.77%	82.64%	64.70%	75.06%
SANTA CRUZ AMA	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Agriculture	98.37%	98.88%	98.51%	99.04%	97.71%	97.91%	99.00%	98.79%	100.00%
Industrial	100.00%	100.00%	100.00%	98.23%	98.22%	98.51%	98.78%	98.68%	100.00%
Municipal	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
TUCSON AMA	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Agriculture	74.14%	74.55%	72.05%	72.79%	74.39%	70.52%	74.14%	70.69%	62.04%
Industrial	85.77%	82.57%	85.54%	85.42%	86.00%	80.45%	78.70%	99.59%	99.04%
Municipal	24.92%	24.54%	23.18%	24.75%	23.58%	21.29%	20.47%	19.45%	15.32%

Source: ADWR and Authors' Calculations

4.2 The Phoenix AMA: Economic Importance of Groundwater, 2010-2018

Table 3 displays the importance of groundwater delivery in the Phoenix AMA by year for municipal, industrial and agricultural customers, 2010 through 2018. Effectively the table provides a valuation of the economic activity that would not have occurred in the Phoenix AMA if the groundwater consumed during the study period had been unavailable.

Table 1 previously stated that the Phoenix AMA received 5.9 million acre feet of groundwater, 2010 through 2018.

Table 3 states that the Phoenix AMA's groundwater consumption cumulatively accounted for more than $922.5 billion (2018 $) in State GDP between 2010 and 2018. The annual economic importance of groundwater in terms of State GDP ranged from $94.4 billion to $113.2 billion (both 2018 $) during the nine-year study period. The average annual State GDP contribution associated with groundwater for the Phoenix AMA was $102.5 billion (2018 $).

If the Phoenix AMA had been unable to receive 5.9 million acre feet of groundwater, 2010 through 2018, its cumulative total GDP for the nine-year time horizon could have been an estimated 45.6% smaller. This is based on two assumptions about the Phoenix AMA. These are:

- The non-substitutability of annual groundwater deliveries; and
- No adaptation to reduced water availability (e.g. use of less water-intensive production methods).

Table 3 also indicates the Phoenix AMA's groundwater consumption was associated with approximately 1.1 million job years of employment per annum. This ranged from 1,004,173 jobs exclusively in 2010 to 1,208,263 jobs in 2017 alone. A cumulative figure for the entire study period is not appropriate as the unit of measurement for employment is job years, rather than jobs.[10]

Finally, Table 3 shows the Phoenix AMA's groundwater consumption was associated with more than $562.2 billion (2018 $) cumulative labor income between 2010 and 2018. The annual economic importance of groundwater in terms of labor income ranged from $57.5 billion to $69.0 billion (both 2018 $) during the nine-year study period. The average annual economic importance of groundwater in terms of labor income was $62.5 billion (2018 $).

[10] A "job year" is defined as one person having a full-time job for exactly one year.

Table 3: Estimated Economic Importance of Groundwater in the Phoenix AMA, 2010-2018[11]

	2010	2011	2012	2013	2014	2015	2016	2017	2018	ANNUAL AVERAGE
State GDP (Billions 2018 $)										
Direct	$41.5	$41.8	$43.2	$42.2	$42.2	$47.2	$48.9	$49.9	$49.8	$45.2
Indirect & Induced	$52.9	$53.4	$54.8	$53.5	$53.3	$59.6	$61.7	$63.2	$63.2	$57.3
Total	***$94.4***	***$95.2***	***$98.0***	***$95.7***	***$95.5***	***$106.8***	***$110.7***	***$113.2***	***$113.1***	***$102.5***
Employment (Job Years)										
Direct	451,354	455,586	472,050	461,774	463,877	519,994	539,115	547,800	546,337	495,321
Indirect & Induced	677,364	683,245	700,808	683,741	680,911	759,841	787,673	807,678	807,624	732,098
Total	***1,004,173***	***1,013,239***	***1,044,677***	***1,020,625***	***1,020,955***	***1,141,966***	***1,183,881***	***1,208,263***	***1,206,547***	***1,093,814***
Labor Income (Billions 2018 $)										
Direct	$25.6	$25.8	$26.7	$26.1	$26.1	$29.2	$30.3	$30.9	$30.8	$27.9
Indirect & Induced	$31.9	$32.2	$33.0	$32.2	$32.1	$35.9	$37.2	$38.1	$38.1	$34.5
Total	***$57.5***	***$58.0***	***$59.7***	***$58.3***	***$58.2***	***$65.1***	***$67.5***	***$69.0***	***$68.9***	***$62.5***

[11] Totals may not tally exactly due to rounding-up.

4.3 The Pinal AMA: Economic Importance of Groundwater, 2010-2018

Table 4 displays the importance of groundwater delivery in the Pinal AMA by year for municipal, industrial and agricultural customers, 2010 through 2018. Effectively the table provides a valuation of the economic activity that would not have occurred in the Pinal AMA if the groundwater consumed during the study period had been unavailable.

Table 1 previously stated that the Pinal AMA received 4.2 million acre feet of groundwater, 2010 through 2018.

Table 4 states that the Pinal AMA's groundwater consumption cumulatively accounted for $47.7 billion (2018 $) in State GDP between 2010 and 2018. The annual economic importance of groundwater in terms of State GDP ranged from $5.0 billion to $5.6 billion (both 2018 $) during the nine-year study period. The average annual State GDP contribution associated with groundwater for the Pinal AMA was $5.3 billion (2018 $).

If the Pinal AMA had been unable to receive 4.2 million acre feet of groundwater, 2010 through 2018, its entire economy could have collapsed, and the GDP of neighboring parts of the state could also have been negatively affected. This is based on two assumptions about the Pinal AMA. These are:

- The non-substitutability of annual groundwater deliveries; and
- No adaptation to reduced water availability (e.g. use of less water-intensive production methods).

Table 4 also indicates that the Pinal AMA's groundwater consumption was associated with 68,534 job years of employment per annum. This ranged from 63,819 jobs exclusively in 2015 to 72,167 jobs in 2014 alone. A cumulative figure for the entire study period is not appropriate as the unit of measurement for employment is job years, rather than jobs.[12]

Finally, Table 4 shows that the Pinal AMA's groundwater consumption was associated with approximately $26.1 billion (2018 $) cumulative labor income between 2010 and 2018. The annual economic importance of groundwater in terms of labor income ranged from $2.7 billion to $3.1 billion (both 2018 $) during the nine-year study period. The average annual economic importance of groundwater in terms of labor income was $2.9 billion (2018 $).

[12] A "job year" is defined as one person having a full-time job for exactly one year.

Table 4: Estimated Economic Importance of Groundwater in the Pinal AMA, 2010-2018[13]

	2010	2011	2012	2013	2014	2015	2016	2017	2018	ANNUAL AVERAGE
State GDP (Billions 2018 $)										
Direct	$3.3	$3.4	$3.4	$3.5	$3.5	$3.1	$3.2	$3.4	$3.2	$3.3
Indirect & Induced	$1.9	$2.0	$2.0	$2.1	$2.1	$1.8	$1.9	$2.0	$1.9	$2.0
Total	***$5.2***	***$5.4***	***$5.4***	***$5.5***	***$5.6***	***$5.0***	***$5.1***	***$5.4***	***$5.1***	***$5.3***
Employment (Job Years)										
Direct	43,629	45,256	45,709	46,358	46,745	41,071	42,663	44,682	42,340	44,273
Indirect & Induced	32,719	34,005	34,269	34,848	35,070	31,491	32,687	34,023	32,545	33,518
Total	***67,348***	***69,900***	***70,552***	***71,611***	***72,167***	***63,819***	***66,278***	***69,287***	***65,842***	***68,534***
Labor Income (Billions 2018 $)										
Direct	$1.9	$2.0	$2.0	$2.0	$2.0	$1.8	$1.9	$1.9	$1.8	$1.9
Indirect & Induced	$1.0	$1.0	$1.0	$1.0	$1.0	$0.9	$1.0	$1.0	$0.9	$1.0
Total	***$2.9***	***$3.0***	***$3.0***	***$3.0***	***$3.1***	***$2.7***	***$2.8***	***$2.9***	***$2.8***	***$2.9***

[13] Totals may not tally exactly due to rounding-up.

4.4 The Prescott AMA: Economic Importance of Groundwater, 2010-2018

Table 5 displays the importance of groundwater delivery in the Prescott AMA by year for municipal, industrial and agricultural customers, 2010 through 2018. Effectively the table provides a valuation of the economic activity that would not have occurred in the Prescott AMA if the groundwater consumed during the study period had been unavailable.

Table 1 previously stated that the Prescott AMA received 145,000 acre feet of groundwater, 2010 through 2018.

Table 5 states that the Prescott AMA's groundwater consumption cumulatively accounted for $42.5 billion (2018 $) in State GDP between 2010 and 2018. The annual economic importance of groundwater in terms of State GDP ranged from $4.2 billion to $5.4 billion (both 2018 $) during the nine-year study period. The average annual State GDP contribution associated with groundwater for the Prescott AMA was $4.7 billion (2018 $).

If the Prescott AMA had been unable to receive 145,000 acre feet of groundwater, 2010 through 2018, its entire economy could have collapsed, and the GDP of neighboring parts of the state could also have been negatively affected. This is based on two assumptions about the Prescott AMA. These are:

- The non-substitutability of annual groundwater deliveries; and
- No adaptation to reduced water availability (e.g. use of less water-intensive production methods).

Table 5 also indicates that the Prescott AMA's groundwater consumption was associated with 72,547 job years of employment per annum. This ranged from 63,858 jobs exclusively in 2015 to 82,580 jobs in 2012 alone. A cumulative figure for the entire study period is not appropriate as the unit of measurement for employment is job years, rather than jobs.[14]

Finally, Table 5 shows that the Prescott AMA's groundwater consumption was associated with approximately $25.1 billion (2018 $) cumulative labor income between 2010 and 2018. The annual economic importance of groundwater in terms of labor income ranged from $2.5 billion to $3.2 billion (both 2018 $) during the nine-year study period. The average annual economic importance of groundwater in terms of labor income was $2.8 billion (2018 $).

[14] A "job year" is defined as one person having a full-time job for exactly one year.

Table 5: Estimated Economic Importance of Groundwater in the Prescott AMA, 2010-2018[15]

	2010	2011	2012	2013	2014	2015	2016	2017	2018	ANNUAL AVERAGE
State GDP (Billions 2018 $)										
Direct	$2.6	$3.0	$3.0	$2.8	$2.5	$2.4	$2.9	$2.4	$2.6	$2.7
Indirect & Induced	$2.0	$2.3	$2.3	$2.2	$1.9	$1.8	$2.2	$1.8	$2.0	$2.0
Total	***$4.6***	***$5.2***	***$5.4***	***$5.0***	***$4.3***	***$4.2***	***$5.0***	***$4.2***	***$4.6***	***$4.7***
Employment (Job Years)										
Direct	39,565	44,963	46,246	42,705	37,421	36,079	43,707	36,569	39,972	40,803
Indirect & Induced	41,374	46,693	47,942	44,131	37,946	36,357	44,044	37,169	39,831	41,721
Total	***70,844***	***80,333***	***82,580***	***76,181***	***66,361***	***63,858***	***77,359***	***64,898***	***70,504***	***72,547***
Labor Income (Billions 2018 $)										
Direct	$1.6	$1.8	$1.8	$1.7	$1.5	$1.5	$1.8	$1.5	$1.6	$1.6
Indirect & Induced	$1.1	$1.3	$1.3	$1.2	$1.1	$1.0	$1.2	$1.0	$1.1	$1.2
Total	***$2.7***	***$3.1***	***$3.2***	***$2.9***	***$2.6***	***$2.5***	***$3.0***	***$2.5***	***$2.7***	***$2.8***

[15] Totals may not tally exactly due to rounding-up.

4.5 The Santa Cruz AMA: Economic Importance of Groundwater, 2010-2018

Table 6 displays the importance of groundwater delivery in the Santa Cruz AMA by year for municipal, industrial and agricultural customers, 2010 through 2018. Effectively the table provides a valuation of the economic activity that would not have occurred in the Santa Cruz AMA if the groundwater consumed during the study period had been unavailable.

Table 1 previously stated that the Santa Cruz AMA received 165,000 acre feet of groundwater, 2010 through 2018.

Table 6 states that the Santa Cruz AMA's groundwater consumption cumulatively accounted for $12.8 billion (2018 $) in State GDP between 2010 and 2018. The annual economic importance of groundwater in terms of State GDP ranged from $1.3 billion to $1.6 billion (both 2018 $) during the nine-year study period. The average annual State GDP contribution associated with groundwater for the Santa Cruz AMA was $1.4 billion (2018 $).

If the Santa Cruz AMA had been unable to receive 165,000 acre feet of groundwater, 2010 through 2018, its cumulative total GDP for the nine-year time horizon could have been an estimated 96.5% smaller. This is based on two assumptions about the Santa Cruz AMA. These are:

- The non-substitutability of annual groundwater deliveries; and
- No adaptation to reduced water availability (e.g. use of less water-intensive production methods).

Table 6 also indicates that the Santa Cruz AMA's groundwater consumption was associated with 20,365 job years of employment per annum. This ranged from 18,784 jobs exclusively in 2010 to 22,572 jobs in 2018 alone. A cumulative figure for the entire study period is not appropriate as the unit of measurement for employment is job years, rather than jobs.[16]

Finally, Table 6 shows that the Santa Cruz AMA's groundwater consumption was associated with approximately $8.0 billion (2018 $) cumulative labor income between 2010 and 2018. The annual economic importance of groundwater in terms of labor income ranged from $0.8 billion to $1.0 billion (both 2018 $) during the nine-year study period. The average annual economic importance of groundwater in terms of labor income was $0.9 billion (2018 $).

[16] A "job year" is defined as one person having a full-time job for exactly one year.

Table 6: Estimated Economic Importance of Groundwater in the Santa Cruz AMA, 2010-2018[17]

	2010	2011	2012	2013	2014	2015	2016	2017	2018	ANNUAL AVERAGE
State GDP (Billions 2018 $)										
Direct	$0.9	$0.9	$0.9	$0.9	$0.9	$1.0	$1.0	$1.0	$1.1	$1.0
Indirect & Induced	$0.4	$0.4	$0.4	$0.4	$0.4	$0.5	$0.5	$0.5	$0.5	$0.5
Total	***$1.3***	***$1.3***	***$1.4***	***$1.4***	***$1.4***	***$1.4***	***$1.5***	***$1.5***	***$1.6***	***$1.4***
Employment (Job Years)										
Direct	12,243	12,463	12,719	12,762	12,956	13,397	13,909	14,312	14,712	13,275
Indirect & Induced	8,672	8,828	9,009	9,030	9,167	9,481	9,844	10,129	10,421	9,398
Total	***18,784***	***19,122***	***19,514***	***19,575***	***19,873***	***20,550***	***21,336***	***21,954***	***22,572***	***20,365***
Labor Income (Billions 2018 $)										
Direct	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	$0.7	$0.7	$0.7	$0.6
Indirect & Induced	$0.2	$0.2	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3
Total	***$0.8***	***$0.8***	***$0.9***	***$0.9***	***$0.9***	***$0.9***	***$0.9***	***$1.0***	***$1.0***	***$0.9***

[17] Totals may not tally exactly due to rounding-up.

4.6 The Tucson AMA: Economic Importance of Groundwater, 2010-2018

Table 7 displays the importance of groundwater delivery in the Tucson AMA by year for municipal, industrial and agricultural customers, 2010 through 2018. Effectively the table provides a valuation of the economic activity that would not have occurred in the Tucson AMA if the groundwater consumed during the study period had been unavailable.

Table 1 previously stated that the Tucson AMA received 1.4 million acre feet of groundwater, 2010 through 2018.

Table 7 states that the Tucson AMA's groundwater consumption cumulatively accounted for $190.8 billion (2018 $) in State GDP between 2010 and 2018. The annual economic importance of groundwater in terms of State GDP ranged from $20.2 billion to $24.0 billion (both 2018 $) during the nine-year study period. The average annual State GDP contribution associated with groundwater for the Tucson AMA was $21.2 billion (2018 $).

If the Tucson AMA had been unable to receive 1.4 million acre feet of groundwater, 2010 through 2018, its cumulative total GDP for the nine-year time horizon could have been an estimated 54.0% smaller. This is based on two assumptions about the Tucson AMA. These are:

- The non-substitutability of annual groundwater deliveries; and
- No adaptation to reduced water availability (e.g. use of less water-intensive production methods).

Table 7 also indicates that the Tucson AMA's groundwater consumption was associated with 271,973 job years of employment per annum. This ranged from 259,370 jobs exclusively in 2011 to 306,201 jobs in 2017 alone. A cumulative figure for the entire study period is not appropriate as the unit of measurement for employment is job years, rather than jobs.[18]

Finally, Table 7 shows that the Tucson AMA's groundwater consumption was associated with approximately $110.3 billion (2018 $) cumulative labor income between 2010 and 2018. The annual economic importance of groundwater in terms of labor income ranged from $11.7 billion to $13.8 billion (both 2018 $) during the nine-year study period. The average annual economic importance of groundwater in terms of labor income was $12.3 billion (2018 $).

[18] A "job year" is defined as one person having a full-time job for exactly one year.

Table 7: Estimated Economic Importance of Groundwater in the Tucson AMA, 2010-2018[19]

	2010	2011	2012	2013	2014	2015	2016	2017	2018	ANNUAL AVERAGE
State GDP (Billions 2018 $)										
Direct	$11.2	$11.1	$11.3	$11.7	$11.7	$11.1	$11.2	$13.1	$12.4	$11.6
Indirect & Induced	$9.1	$9.0	$9.2	$9.5	$9.5	$9.1	$9.2	$10.9	$10.4	$9.6
Total	***$20.4***	***$20.2***	***$20.5***	***$21.2***	***$21.2***	***$20.2***	***$20.4***	***$24.0***	***$22.8***	***$21.2***
Employment (Job Years)										
Direct	141,929	140,609	142,414	147,833	147,319	140,136	141,150	163,537	153,618	146,505
Indirect & Induced	156,040	154,258	157,597	162,571	162,847	155,423	156,799	186,355	178,427	163,369
Total	***262,023***	***259,370***	***263,588***	***272,950***	***272,550***	***259,597***	***261,640***	***306,201***	***289,835***	***271,973***
Labor Income (Billions 2018 $)										
Direct	$6.6	$6.5	$6.6	$6.9	$6.8	$6.5	$6.6	$7.6	$7.1	$6.8
Indirect & Induced	$5.2	$5.1	$5.3	$5.4	$5.4	$5.2	$5.2	$6.2	$5.9	$5.4
Total	***$11.8***	***$11.7***	***$11.9***	***$12.3***	***$12.3***	***$11.7***	***$11.8***	***$13.8***	***$13.1***	***$12.3***

[19] Totals may not tally exactly due to rounding-up.

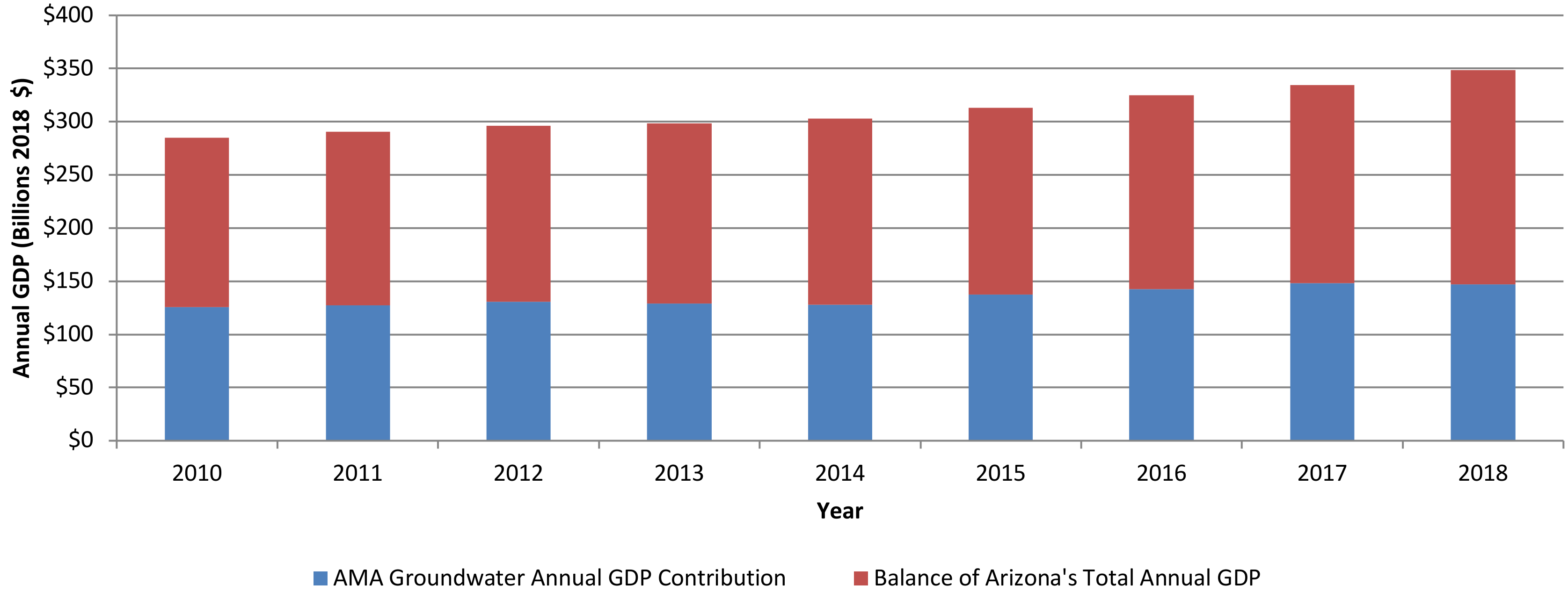
4.7 Contextualizing the Total Economic Importance of Groundwater for the Five AMAs, 2010-2018

Figures 2 and 3 illustrate the total annual economic importance of groundwater supplies in the five AMAs (combined) for the State of Arizona economy, 2010 through 2018.

Figure 2 shows that the inclusion of groundwater in total water supply among the five AMAs (combined) between 2010 and 2018 directly and indirectly accounted for 42.2% to 44.3% of the State's total annual GDP, dependent on the year in question. On average, between 2010 and 2018, the economic activity associated with groundwater supplies in the five AMAs contributed 43.5% of State GDP. That is, Seidman estimates the total contribution of groundwater supplies in the five AMAs to State GDP at approximately $1.2 trillion (2018 $) for the nine-year study period.

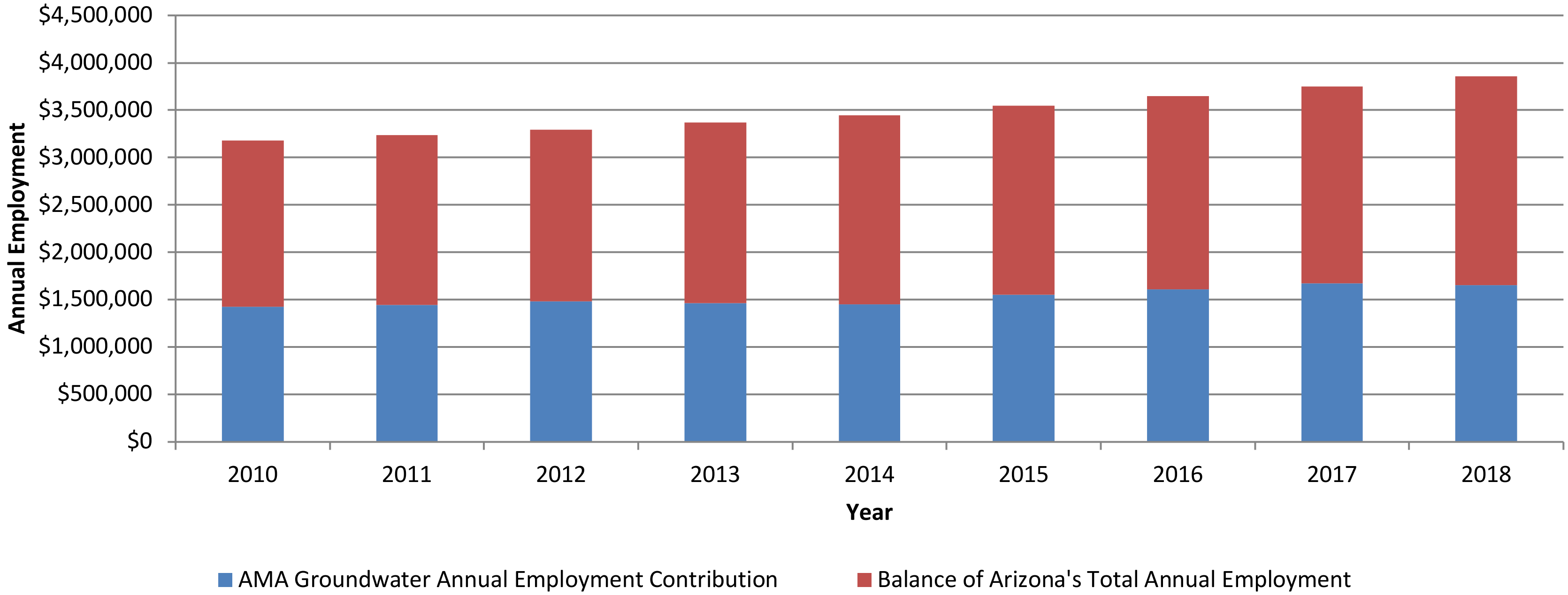
Figure 3 shows that the inclusion of groundwater in total water supply among the five AMAs (combined) between 2010 and 2018 directly and indirectly accounted for 42.1% to 44.9% of the State's total annual employment, dependent on the year in question. On average, between 2010 and 2018, the economic activity associated with groundwater supplies in the five AMAs accounted for 43.9% of total employment in Arizona.

Figure 2: Annual AMA Groundwater Contribution to Total State GDP, 2010-2018



Source: BEA and Authors' Calculations

Figure 3: Annual AMA Groundwater Contribution to Statewide Total Employment 2010-2018



Source: BEA and Authors' Calculations

5. CONCLUSION

The purpose of this study has been to calculate the economic importance of groundwater deliveries to five Active Management Areas (AMAs) for the State of Arizona economy. Central to this analysis is an assumption that no substitute for the annual groundwater used by each AMA can be found between 2010 and 2018. Seidman also assumes that the economy would not have adapted to reduced water availability by, for instance, using less water-intensive production methods.

During the 9-year study horizon, approximately 11.7 million acre feet of groundwater was utilized by agriculture, industrial and municipal customers in the five AMAs. More than half of this total groundwater (50.1%) used took place in the Phoenix AMA. More than a third of the groundwater (35.5%) was used in the Pinal AMA. The Tucson AMA accounted for 11.7% of total groundwater used throughout the nine years. The Santa Cruz AMA accounted for 1.4% and the Prescott AMA 1.2% of total groundwater used, 2010 through 2018.

Seidman estimates that the groundwater supplies in the five AMAs cumulatively contributed $1.2 trillion (2018 $) to State GDP. This represents approximately 43.5% of cumulative State GDP throughout the nine-year study period.

Seidman also estimates that the groundwater supplies in the five AMAs cumulatively contributed to annual employment of 1.4 to 1.7 million jobs, dependent on the year in question, during the 2010-2018 study period.

Seidman's water supply analysis therefore demonstrates the economic importance of groundwater for the five AMAs and by corollary, the State of Arizona economy. The availability and utilization of groundwater by municipal, industrial, and agricultural customers in the five AMAs has had a crucial impact on the economic development of the state.

Without the availability of groundwater, the economic development of the State would almost certainly have followed a different trajectory. Without sustained access to reliable groundwater, Arizona's future economic development will likely follow a different trajectory than the past.

APPENDIX

IMPLAN

IMPLAN is a commercially-licensed input-output model that combines a set of extensive databases, economic factors, multipliers, and demographic statistics with a highly refined and customizable modeling system.

IMPLAN's sectoring scheme is based largely on the U.S. Bureau of Economic Analysis' (BEA's) sectoring scheme. The BEA updates these sectors every five years, and this is usually reflected in major changes to the IMPLAN model.

Seidman's analysis uses a 2018 version of IMPLAN, which primarily draws from the BEA's 2012 sectoring scheme, supplemented by BEA insights in 2007, 2002, and 1997.

The BEA only identifies 405 sectors. However, the latest version of IMPLAN has 546 sectors (compared to 440 sectors in the original CAP study). Using input from industry experts, IMPLAN therefore provides production functions for sectors not included in any BEA benchmark. IMPLAN also uses earlier BEA benchmarks to split the absorption coefficients, byproduct coefficients, and institutional spending into greater levels of disaggregation.

The sectoral splits for 2010-2018 are based on the updated 2018 version of IMPLAN, which draws from the BEA's 2012 national census of production.

Seidman has created a modified version of IMPLAN for each AMA based on zip code functionality. A handful of zip codes are shared by AMAs. To avoid any duplication in the modeling, Seidman has assigned each zip code to a single AMA as shown in the Table below.

AMA ZIPCODES

To avoid duplication in the IMPLAN modeling Seidman's study assumes the following distribution of zip codes by AMA:

AMA	ZIP CODES
Phoenix	85003, 85004, 85006, 85007, 85008, 85009, 85012, 85013, 85014, 85015, 85016, 85017, 85018, 85019, 85020, 85021, 85022, 85023, 85024, 85027, 85028, 85029, 85031, 85032, 85033, 85034, 85035, 85037, 85040, 85041, 85042, 85043, 85044, 85048, 85050, 85051, 85053, 85054, 85083, 85085, 85086, 85087, 85142, 85201, 85202, 85203, 85204, 85205, 85206, 85207, 85208, 85209, 85210, 85212, 85213, 85215, 85224, 85225, 85226, 85233, 85234, 85248, 85249, 85250, 85251, 85253, 85254, 85255, 85256, 85257, 85258, 85259, 85260, 85262, 85263, 85264, 85266, 85268, 85281, 85282, 85283, 85284, 85286, 85287, 85295, 85296, 85297, 85298, 85301, 85302, 85303, 85304, 85305, 85306, 85307, 85308, 85309, 85310, 85322, 85323, 85331, 85335, 85338, 85340, 85342, 85343, 85345, 85351, 85353, 85355, 85361, 85363, 85373, 85374, 85375, 85377, 85378, 85379, 85381, 85382, 85383, 85387, 85388, 85392, 85395, 85396, 85118, 85119, 85120, 85137, 85140, 85143, 85173, 85324, 85332, 85326, 85354, 85390
Pinal	85045, 85122, 85123, 85128, 85131, 85138, 85139, 85172, 85193, 85194, 85339, 85634
Prescott	86301, 86303, 86305, 86314, 86315, 86323, 86324, 86326, 86327, 86334
Santa Cruz	85621, 85637, 85640, 85645, 85646, 85648
Tucson	85602, 85601, 85614, 85619, 85622, 85629, 85641, 85653, 85658, 85701, 85704, 85705, 85706, 85707, 85708, 85709, 85710, 85711, 85712, 85713, 85714, 85715, 85716, 85718, 85719, 85721, 85730, 85736, 85737, 85741, 85742, 85743, 85745, 85746, 85747, 85748, 85749, 85750, 85755, 85756, 85757, 85132, 85145, 85623, 85631, 85735, 85739

Source: Authors

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