



1 Water Productivity of Phoenix Metropolitan Area Cities

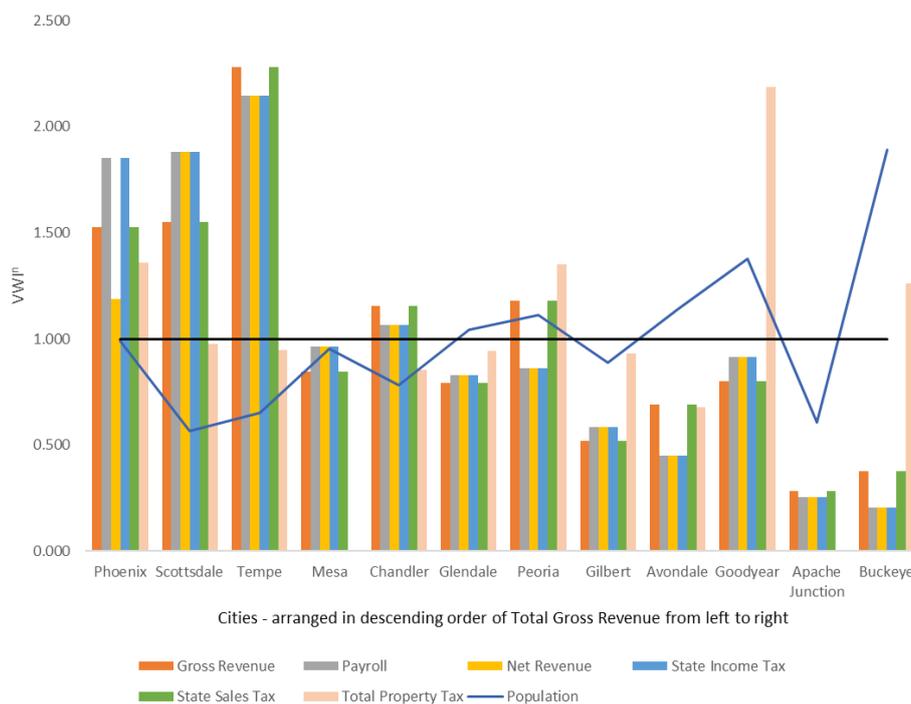
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5 **Abstract.** Water productivity (or efficiency) data informs water policy, zoning and planning along with water
 6 allocation decisions under water scarcity pressure. This paper demonstrates that different water productivity
 7 metrics lead to different conclusions about who is using water more effectively. In addition to supporting the
 8 population's drinking and sanitation needs, water generates many other public and private social, environmental,
 9 and economic values. For the group of municipalities comprising the Phoenix Metropolitan Area we compare
 10 several water productivity metrics by calculating the Water Value Intensity (WVI) of potable water delivered by
 11 the municipality to its residential and non-residential customers. Core cities with more industrial water uses are
 12 less productive by the conventional efficiency measure of water used per capita, but core cities generate more
 13 tax revenues, business revenues, and payroll revenues per unit of water delivered, achieving a higher water
 14 productivity by these measures. We argue that policymakers should consider a more diverse set of socio-
 15 economic water productivity measures to ensure that a broader set of values are represented in water allocation
 16 policies.

18 Graphical Abstract





20 **1 Introduction**

21 The coming decades will see major challenges in meeting demands for water in the United States and across the
22 globe (Postel, 1996; Devineni et al., 2015). Apportioning water effectively between agriculture, the world's
23 largest water user and the water demands of industry, energy and urban development will become increasingly
24 important (Hoekstra, 2014; Vörösmarty, 2000; Gleick and Palaniappan, 2010). Reliable metrics are needed for
25 informed decision-making about allocating water sustainably, equitably, and optimally. This is especially true in
26 water-scarce regions like the American Southwest (Tidwell et al., 2012; Wildman and Forde, 2012; Schewe et
27 al., 2014). However, in such regions, there is often a limit to how much water cities can reduce through
28 conservation measures or other demand management policies - a phenomenon known as 'demand hardening'.
29 Even if conservation is still producing water efficiency gains decoupled from growth to date (Richter et al.,
30 2020), demand will eventually harden, so it is in the public's interest to allocate water based on the merit and
31 benefit of use (Howe and Goemans, 2007), however merit and benefit might be defined.

32 Careful management of freshwater is especially important for the municipalities comprising the Phoenix
33 Metropolitan Statistical Area (Phoenix MSA or PMA), Arizona (Gober et al., 2010; Gober et al 2013; Rushforth
34 and Ruddell, 2015). With a population of 4.9 million, in 2019 Phoenix-Mesa-Chandler is the 10th most
35 populous metropolitan area in the country (US Census Bureau, 2020). Economic growth has been tightly
36 coupled with population growth in the PMA. In 2017 the GDP for the Phoenix MSA was close to \$217 billion,
37 having grown by 30% between 2010 and 2018 (US Bureau of Economic Analysis, 2019). Underlying the
38 Phoenix MSA's population growth and economic growth are increasingly scarce water resources.

39 Studies of water use often employ variations of water footprint analysis to measure water use or water use
40 efficiency (Hoekstra et al., 2011; Hoekstra et al.; 2015; Marston et al. 2018; Paterson et al., 2015; Rushforth and
41 Ruddell, 2018). Water footprints have been calculated for cities in the US (Paterson et al. 2015), and even
42 specifically for cities in Arizona (Bae and Dall'Erba, 2018; Rushforth and Ruddell 2015, 2016; Scott and
43 Pasqualetti, 2010). Water productivity studies have been conducted on industries and products (Marston et al.,
44 2020; Evenson et al. 2018; Maupin et al. 2014; Mayer et al., 2016; Blackhurst et al. 2010; Solley et al. 1983), on
45 the electric power grid (Ruddell et al. 2014), and on Arizona semiconductors (Hubler et al 2012), in addition to
46 the more common study of irrigation agricultural water productivity (Xu et al., 2019; Kinje et al., 2003; Hamdy
47 et al., 2003). Water efficiency benchmark data can help policy makers to develop and implement sound water
48 policy (Berg, 2010). Such benchmarks can help stakeholders to quantify progress towards policy objectives and
49 can help regulators fine-tune efficiency goals (Haider et al., 2016). Because we manage what we measure, it is
50 important to inform policy using appropriate measures for what we value about water use.

51 Per the logic of Embedded Resource Accounting (Rushforth et al. 2013; Ruddell et al. 2014), produced values
52 are accounted for differently by different parties because these parties have different worldviews and decision
53 boundaries by which they account for internal and external costs and benefits. For instance, revenue is mostly
54 valued by business owners, payroll is mostly valued by workers (and is a cost to business owners), taxes are
55 mostly valued by the branch of government collecting the specific tax and by the public beneficiaries of this tax
56 revenue (e.g. state income tax to the state, property tax to the municipality), and population is valued by
57 (presumably) all people – but most especially by democratically elected government officials who set water



58 policy because people vote. There are also many other social, environmental, and economic values produced
59 where water inputs are an input factor (Vardon et al., 2012), including for instance aquatic habitat created by
60 outdoor water use in a desert city, urban heat island mitigation, and federal tax revenue. The return of revenue
61 directly to a water department responsible for its provision is another important type of value needed for fiscal
62 planning and support of water operations (Borrego-Marin et al., 2016), but that kind of revenue is of very
63 narrow interest to a single department of a single municipal government and is discounted by other parties.
64 Because there are many social, environmental, and economic stakeholders with many different sets of interests
65 and values, multiple water use efficiency or productivity benchmarks are appropriate to measure the efficacy of
66 water allocation.

67 The standard residential water efficiency or water sustainability measure for water utilities in the United States
68 is Gallons per Capita per Day (GPCD). Water use efficiency is the reciprocal of the water productivity. Water
69 productivity – also called water value intensity (WVI, Ruddell et al. 2014) is a metric expressing the benefits of
70 water use (in units of the benefit) relative to the costs (in units of water use). The goal of water policy should be
71 to do more social, environmental, and economic good with limited water resources, but not necessarily to use
72 less water. Shifting to a water productivity (or WVI) perspective puts the emphasis on the values and benefits
73 that are produced, rather than the water that is saved. For example, if we invert the standard GPCD metric, we
74 obtain People per Gallon per Day (PPGD), and this makes it clear that such a metric values supporting
75 additional population using the water resources. It is not incorrect to use an efficiency metric, but we prefer the
76 clearer productivity framing for these reasons.

77 Comparing multiple water productivity metrics and benchmarks is particularly helpful when there are multiple
78 values and benefits associated with the water use. In this paper we develop a case study comparing multiple
79 water productivity benchmarks for the group of municipalities comprising the Phoenix Metropolitan Area. For
80 these municipalities we compare the water productivity in units of value produced per acre-foot of water
81 delivered. Water productivity metrics in this paper's case study include (1) residential population supported, (2)
82 payroll, (3) net revenue, (4) gross revenue, (5) net revenue, (6) state income tax, (7) state sales tax, and (8) total
83 property tax. Other productivity metrics could be used such as the water intensity of land use, or we could add
84 more social and environmental value considerations, but these are beyond the scope of this paper's case study
85 due primarily to a lack of data availability. Our research question is, "What is the comparative water
86 productivity of the municipalities of the Phoenix area, using multiple water productivity measures?"

87 **2 Methods**

88 Water that is available to PMA cities is allocated using a complex system of legal water rights and conveyed to
89 the municipalities via large-scale physical infrastructure systems (Jacobs & Megdal, 2004; Holway, 2007). Most
90 PMA municipalities draw water from three main physical water sources: the Colorado River, the Salt-Verde
91 River system, and the large, interconnected groundwater aquifer underlying the metro area. However, while
92 many municipalities have access to all three sources, some municipalities, typically newer ones on the outer
93 edge of the metropolitan area, may not have access to SRP or CAP water (Rushforth et al., 2020).

94



95 Within each municipality water is allocated to Residential and Non-Residential uses, which yield residential
96 values (income tax, property tax, population) and non-residential values (payroll, net/gross revenue, sales tax).
97 Of the many municipalities comprising metropolitan Phoenix, we include twelve in this study (Figure 1):
98 Apache Junction, Avondale, Buckeye, Chandler, Gilbert, Glendale, Goodyear, Mesa, Peoria, Phoenix,
99 Scottsdale, and Tempe. Other smaller and outlying cities (e.g. Litchfield Park, El Mirage, Paradise Valley,
100 Queen Creek, Guadalupe, Surprise, Cave Creek, Fountain Hills) were omitted due to a lack data.

101

102 Water use studies may be based on consumption or withdrawal accounting. This study uses withdrawal
103 accounting, and specifically water delivered to utility customers, rather than net consumptive use. This is the
104 right choice for most water use studies per the arguments in Ruddell (2018), because city water resources,
105 infrastructures, operating costs, and water rights are measured and priced in units of water volumes withdrawn
106 and delivered, not in terms of net hydrological water balances. We use acre-feet units for this study, not SI units,
107 because acre-feet is the unit of measurement used and understood throughout the water management community
108 in the USA and converting to SI units renders the results more difficult for use in policy applications. Reclaimed
109 water use was not included in this study since it is not allocated to municipalities by an external agency (e.g.
110 SRP, CAP, or ADWR in this case), and because it is not withdrawn from the three major hydrological water
111 sources of the region. Also, reclaimed water generally is used low economic value or indirect economic value
112 activities such as recreational turf irrigation, making it difficult to measure associated economic value. And,
113 because reclaimed water use (unlike raw water deliveries) is subject to inconsistent city and county policies for
114 reporting and accounting, it is difficult to compare reclaimed water data robustly between municipalities.

115

116 The water productivity metrics relate value output to water input using six different Water Value Intensities
117 (WVIs): the residential population supported, along with six different financial metrics: net revenues; gross
118 revenues, payroll, net revenue, state sales tax, state income tax, and property taxes. Value intensities could be
119 calculated various ways, using a range of different or additional metrics – to include for example, different
120 social and environmental benefits of a city’s water use. Also, the metrics could potentially be weighted to assign
121 the differential importance to some values versus others. For the purposes of this study, we used metrics that
122 were readily available and reliable (Table 1). Payroll and taxes are components of gross revenue. We present
123 both gross revenue and net revenue reported by the economic census.

124 **2.1 Data Sources**

125 This study uses older data from calendar year 2007 due to data availability constraints. The specific variety of
126 data for residential and non-residential water use was no longer collected by the State of Arizona after 2009. We
127 chose 2007 because this is the most recent pre-2009 year coinciding with the publication of the U.S. Census
128 Economic Census.

129 Residential and non-residential water use data for the PMA’s municipalities in this study were obtained from the
130 Arizona Department of Water Resources Imaged Records. Reported water use data for 2007 were used to match
131 US Economic Census data for the same year. Specifically, water use data contained in this report is found in
132 ADWR Notifications on Gallons Per Capita per Day (GPCD) and Lost and Unaccounted (L&U) for Water sent
133 to the individual cities studied in this report (ADWR, 2011a-i). L&U water was incorporated into this study by



134 attributing L&U water proportionately to total water use by residential and non-residential sectors (for an
135 example see Appendix A-1 and the equation in Appendix B).

136 Income data were obtained from the U.S. Census Bureau (2009a-f). Property tax data were obtained from the
137 annual budgets from each of the cities in the study (City of Chandler, 2008, 2009; City of Glendale, 2008; City
138 of Goodyear, 2007; City of Mesa, 2008; City of Peoria, 2007; City of Phoenix, 2007; City of Scottsdale, 2008;
139 City of Tempe, 2007; Town of Avondale, 2010; Town of Buckeye, 2007; Town of Gilbert, 2007).
140 Manufacturing, retail, information services, real estate, and professional and technical services data were
141 obtained from the 2007 Economic Census (U.S. Census Bureau, 2009a-f). See Appendix C for the full economic
142 data used in this study.

143 Water Value Intensities (WVIs) were calculated using the water-volume weighted averages of residential and
144 non-residential sectors (Table D1). Economic values on a water use basis were analyzed for six economic
145 categories in the U.S. Economic Census: city-level or town-level income data (Tables D2, D3), city- or town-
146 level manufacturing (Tables D4, D5), city- or town-level retail data (Table D6), city- or town-level information
147 services (Table D7), city- or town-level real estate data (Table D8) and city- or town-level professional and
148 technical services (Table D9).

149 **2.2 Simplified Embedded Resource Accounting: or, Point of View Matters in Water Use Accounting**

150 This analysis employs a simplified version of Embedded Resource Accounting (ERA, Ruddell et al. 2014) to
151 associate indirect and direct values with direct and indirect impacts in an input-output network. In this case there
152 are six direct and local values produced, one direct impact on the local freshwater stock, and indirect values and
153 impacts are neglected. The water use metrics in this paper are therefore calculated from the point of view of a
154 hypothetical manager of the water resources of the Phoenix Metropolitan Area who is interested in maximizing
155 a diverse basket of values that are directly associated with water use processes in the PMA. The same
156 hypothetical manager is therefore also disinterested in indirect value creation and impact such as federal tax
157 revenues or the water impacts of the PMA's supply chains lying outside the area. Everything inside the PMA is
158 "internal" and everything outside the PMA is "external" from this hypothetical manager's point of view. We
159 assert that this point-of-view is historically responsible for water allocation decisions and regulations for the
160 PMA, and resembles the point of view of the Governor's office, the regional government, or the Arizona
161 Department of Water Resources, so this is an appropriate choice for this study. Because the worldview of this
162 hypothetical manager encompasses the metro area, ERA defines the resource stock of interest as the total
163 combined annual water deliveries from the Central Arizona Project (2012), Salt River Project (SRP), and
164 groundwater resources to the PMA's major municipalities individually and collectively. If a different point of
165 view is chosen for the accounting, the results will change. For example, the business owners of the City of
166 Tempe internalize revenue-generating value, but not necessarily other values like payroll or taxes benefitting the
167 City of Tempe and its labor force.

168 The direct water value intensity $WVI_{x,l}$ used here is simply the ratio of the value (V) of type (l) produced as an
169 output of the municipality's (x) collective processes to the input of water (W) to the municipality's processes. In
170 other words, $WVI_{x,l}$ is the ratio of value out to water in. \overline{WVI}_l is the mean WVI for value l for all municipalities



171 in the area. $WVI_{x,l}^n$ has been normalized (n) by dividing $WVI_{x,l}$ by the mean \overline{WVI}_l , such that municipalities
172 with results above 1 have above-average WVI for that value type. $BWVI_x$ is the basket-weighted water value
173 intensity for municipality x ; it is the weighted average across all value types for that municipality. In this study,
174 we assume weights of 1 for all value types. From this point of view, all six types of value assessed here are
175 weighted equally. $BWVI_x^n$ is the normalized value, like $WVI_{x,l}^n$ above.

176

177 WVI 's may include economic data and measures of economic value, but a WVI – or any VI – is not a price or a
178 measure of marginal value or cost according to the classical economic *Theory of Value*, because it does not
179 consider the marginal contribution of the impact on the resource stock to the production of values, or the cost of
180 the resource, or value-added by the process. Because VI 's are not prices or costs, they may not be added together
181 to directly measure the value produced by a process; rather, a basket (i.e. a range) of VI 's should be interpreted
182 as multiple independent objectives, e.g. using a Pareto framework, or assigned relative weights by a decision
183 maker.

184 **2.2 Residential Sector Water Value Intensities**

185 Property taxes were used as a measure for the values produced by residential water use. Primary, secondary, and
186 total levied property taxes by municipalities were considered in this analysis. Calculation of the value intensity
187 of residential water on a per volume use basis is shown in Appendix A.

188 **2.3 Non-Residential Sector Water Value Intensities**

189 City-level net and gross revenues and payrolls were used as a measure for the values produced by non-
190 residential water uses such as commercial, industrial, and governmental uses of the city's potable water
191 supplies. City-level state sales tax contributions and income taxes paid to the state were estimated for the non-
192 residential sector using the gross revenue and payroll data, respectively. The state sales tax rate was set at 6.6%
193 and the income tax rate 3.3%, per statutes in effect in Arizona during the study period. From these data, the
194 value intensity of non-residential water uses was calculated for city-level net/gross revenues, payroll, state sales
195 tax contribution, and income taxes paid to the state. Note that income tax is considered a value product of the
196 non-residential sector in this analysis, and taxed payroll is a value product of the business sector, not the
197 residential sector. Net and gross revenue and payroll data were obtained from the US Economic Census.
198 Population data were obtained from the U.S. Census Bureau (2007b). Equations for Revenue, Payroll, and Tax
199 VI 's follow. Calculation methods are show in Appendix A.



200 **3 Results**

201 In terms of residential population supported per acre-foot of water used (Figure 2), outlying cities such as
202 Buckeye, Goodyear and Avondale are more productive (or efficient) than core cities like Phoenix, Tempe and
203 Scottsdale. However, when economic productivity measures are considered (Figure 3), core cities like Phoenix,
204 Tempe and Scottsdale, dominate the rankings because they produce far more payroll, tax, and business revenue
205 per gallon of water used.

206 **4 Discussion**

207 Each city has its own unique water value profile (Table 1) which contribute to its water productivity profile. For
208 example, Chandler is the fourth largest city in the PMA by population, and had the fourth lowest WVI per
209 capita, but its WVI for gross revenue is well above the PMA average (Figure 3). Chandler has a
210 disproportionately large industrial sector dominated by High Value Semiconductor Manufacturing products and
211 services. Previous studies have found this sector produces an unusually large amount of economic value relative
212 to use of water (Hubler et al., 2012). Figure 3 reveals tradeoffs between multiple water productivity objectives.
213 For example, there is a tradeoff between WVI for net revenue versus WVI for population. The relatively higher
214 business revenue a community generates with its water, the relatively lower population it supports with its
215 water. A detailed study of the Pareto frontiers and tradeoffs between these multiple objectives is beyond the
216 scope of this paper, but such a tradeoff appears to have emerged within the PMA. Despite this, the standard
217 U.S. measure of water efficiency, Gallons per Capita per Day, (GPCD, Evenson et al., 2018), implies that
218 water's value lies entirely in supporting residents and their swimming pools and lawns. When applied in
219 isolation from other metrics for other objectives, this standard measure favors allocating water to bedroom
220 communities. But this comes at a cost of the jobs and tax revenues that the residents of those bedroom
221 communities need for their livelihoods and to pay for their water rights and water infrastructure.

222 Because cities, state government, and economic development organizations want to promote high-quality
223 economic development, and the City of Chandler uses much of its water for this kind of economic activity,
224 allocating more water toward Chandler as compared with a bedroom community would seem to merit
225 consideration based on economic water productivity benchmarks. After all, a bedroom community's residents
226 need the payroll and tax revenues produced by companies in the City of Chandler. But, in turn, those companies
227 employ the workforce that lives in the bedroom communities and depend on that labor for their operations. A
228 residential population cannot be supported without jobs and revenues; both values matter and each supports the
229 other. Therefore, a more diverse set of water productivity benchmarks can help decision makers understand the
230 trade-offs involved in their allocation of water to different kinds of cities, and can help policymakers avoid
231 undervaluing the economic allocations of water that are needed to support employment for the residential
232 population. Additionally, the tax base is the major constraint on the ability of a city to finance water rights and
233 water infrastructure to provide adequate water for its residential population. Linking economic and population
234 growth is important. There have been several advocates for the concept of 'wet growth' (Arnold, 2005) and
235 water-conscious land-use planning (Bates, 2012). Water-conscious economic planning and growth can help to



236 promote, protect, and restore water sources, and can prevent growth beyond the limits of water resources (Gober
237 et al. 2010; Larson et al, 2013; Li et al., 2016).

238 Accurate estimation of the water resources required to “build out” the municipality’s zoning and master plan is
239 crucial part of this land use planning process (Gober et al., 2010; Gober et al., 2013; Larson et al, 2013; Li et al.,
240 2016). Once land is allocated to a use, the water and land associated with that use cannot be reallocated easily or
241 inexpensively, if at all (Marston and Cai, 2016). In addition, as a municipality continues to grow, it typically
242 approaches the “build-out” stage where further changes become prohibitive due to the scarcity and depletion of
243 land and water resources. Balancing various water productivity values is therefore important in the land use
244 planning process before development occurs.

245 We present results that focus narrowly on economic water productivity in the PMA as an alternative to GPCD as
246 an efficiency metric, but it is preferable to also include broader economic, environmental, and social dimensions
247 of water productivity. For example, urban tree and shade programs, which are water consumers, may not have
248 high economic water productivity or generate tax revenue, but they do produce demonstrable ecological service
249 benefits such as shade, mitigation of air pollution, flood amelioration, and reduced urban heat island effects.
250 Water planners and decision-makers do not apply equal weighting to their multiple values, so any stakeholder
251 would have their own weights to apply to the multiple-objective decision process that is implied by the use of
252 multiple water productivity metrics.

253 When broader values like revenue, payroll, and tax benefits are factored into water allocation decisions,
254 different water allocation decisions could emerge. These are political and value-based decisions, not engineering
255 decisions, but such decisions should be more broadly informed with a broader set of water productivity
256 benchmarks.

257 **5 Conclusions**

258 This study finds that bedroom cities show higher water productivity based on the standard efficiency benchmark
259 of gallons per capita, but core cities which host large businesses show higher water productivity using a basket
260 of economic values like taxes, payroll, and business revenues. There may be a tradeoff between these competing
261 values produced by water use, so a broader basket of water productivity benchmarks could therefore inform
262 more balanced and equitable water allocation decisions by policymakers.

263 **Appendices**

264 *Appendix A: Detailed VI Equations*

265 Calculation of the VI of residential water as measured by property taxes, on a per volume use basis $VI_{Property\ Tax}$
266 was taken by dividing the amount of levied property taxes by the municipality’s volume of water allocated to
267 residential uses, property tax data in Appendix C, were obtained from the Maricopa County Department of
268 Finance (2007); property taxes reported as zero are due to city-specific policies that restrict the ability of the city
269 to collect property tax.



270

271

$$VI_{Property\ Tax} = \frac{\$ Levied\ Property\ Tax}{Volume_{H_2O, Residential_i} (ac-ft)}$$

272

273 Per capita water use by the residential water use sector of a municipality $VI_{Population}$ is calculated as shown in
274 Equation 13. This metric is included because per-capita equity in water use is currently the primary type of
275 value intensity utilized for water allocation decisions.

276

277

$$VI_{Population} = \frac{Population}{Volume_{H_2O, Residential_i} (ac-ft)}$$

278

279

280 Calculation of the VIs for net and gross revenues, payroll, sales tax and income taxes using the data shown in
281 Appendix C:

282

283

$$VI_{Revenues} = \frac{\$ Revenues}{Volume_{H_2O, Non-Residential_i} (ac-ft)}$$

284

285

$$VI_{Payroll} = \frac{\$ Payroll}{Volume_{H_2O, Non-Residential_i} (ac-ft)}$$

286

287

$$VI_{Sales\ Tax} = \frac{\$ Gross\ Revenues_i \times State\ Sales\ Tax\ Rate}{Volume_{H_2O, Non-Residential_i} (ac-ft)}$$

288

289

$$VI_{Income\ Tax} = \frac{\$ Payroll_i \times State\ Income\ Tax\ Rate}{Volume_{H_2O, Non-Residential_i} (ac-ft)}$$

290

291

292

293 *Appendices B, C, and D: Source Data Tables*

294

295 Appendix B: Water Data Tables B1-B3

296 Appendix C: Tax Data Tables C1

297 Appendix D: Financial Data Tables D1-D9

298



Table B.1. Reported Total Water Demand for PMA Municipalities Included in this Study.

City	Demand Category	Year											
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009		
Apache Junction	Total	10,627	10,523	11,416	10,983	10,639	11,396	11,251	11,825	11,112	11,144		
Avondale	Total	5,653	7,758	9,295	10,040	11,123	9,893	13,378	14,185	13,033	13,277		
Buckeye	Total	1,094	1,049	2,434	2,601	738	751	3,028	4,135	4,363	4,277		
Chandler	Total	48,969	53,263	55,475	55,657	55,697	58,439	61,070	64,404	63,076	60,773		
Gilbert	Total	30,438	32,800	33,984	38,047	36,596	40,190	50,515	47,915	49,085	46,239		
Glendale	Total	49,472	49,773	51,193	48,707	48,828	49,242	49,740	46,849	49,586	48,133		
Goodyear	Total	2,570	3,309	3,555	4,243	5,307	6,328	6,409	8,088	8,163	8,289		
Mesa	Total	101,461	102,935	97,180	100,458	95,933	100,363	100,203	100,027	93,317	89,794		
Peoria	Total	24,602	21,503	22,593	21,715	22,656	25,421	27,659	28,527	28,717	27,388		
Phoenix	Total	332,038	340,870	346,226	329,939	337,412	314,314	331,174	321,476	304,153	305,124		
Scottsdale	Total	79,479	78,165	84,508	77,901	74,426	80,772	84,427	85,249	84,051	83,444		
Tempe	Total	63,236	61,729	60,223	58,526	57,644	53,515	52,201	54,915	50,239	49,682		



Table B.2. Reported Residential Water Demand for PMA Municipalities Included in this Study.

City	Demand Category	Year									
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Apache Junction	Residential	4,701	4,917	5,387	5,605	5,678	5,804	6,059	6,059	6,059	5,761
Avondale	Residential	4,835	5,481	6,119	6,483	7,175	7,093	8,362	8,362	8,832	8,715
Buckeye	Residential	581	604	679	622	599	643	1,617	1,617	1,617	2,629
Chandler	Residential	27,488	29,152	31,316	31,599	32,465	33,906	35,539	36,563	34,424	34,766
Gilbert	Residential	19,816	21,702	23,905	24,647	25,633	27,110	28,684	28,684	28,684	30,910
Glendale	Residential	35,135	34,667	36,044	34,348	34,427	33,567	34,660	34,660	34,660	31,457
Goodyear	Residential	1,335	1,640	2,006	2,430	3,086	3,481	3,883	3,883	3,883	4,397
Mesa	Residential	64,242	65,180	67,026	65,655	65,890	63,972	65,319	65,139	65,139	60,494
Peoria	Residential	14,400	15,208	17,077	16,925	16,962	16,224	18,981	18,981	18,981	18,819
Phoenix	Residential	208,431	205,247	209,018	201,004	200,214	195,013	202,387	202,387	202,387	188,503
Scottsdale	Residential	49,659	49,370	52,737	51,083	46,873	54,719	57,401	57,401	57,401	56,568
Tempe	Residential	29,814	30,826	31,884	27,593	27,368	25,989	26,208	26,208	26,209	25,024



Table B.3. Reported Non-Residential Water Demand for PMA Municipalities Included in this Study.

City	Demand Category	Year									
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Apache Junction	Non-Residential	5,419	5,137	5,585	5,183	4,741	5,145	5,048	5,048	5,048	4,748
Avondale	Non-Residential	2,305	2,150	2,866	2,821	3,118	1,983	4,097	4,097	3,846	4,060
Buckeye	Non-Residential	301	188	848	1,788	106	110	1,270	1,270	1,270	1,482
Chandler	Non-Residential	18,149	19,936	20,795	20,126	19,164	20,259	22,043	23,635	23,316	21,739
Gilbert	Non-Residential	6,503	8,354	8,030	9,244	9,679	9,995	11,585	11,585	11,585	11,929
Glendale	Non-Residential	10,595	11,521	12,351	11,311	11,013	10,797	12,965	12,965	12,965	12,135
Goodyear	Non-Residential	1,156	1,668	1,486	1,730	2,199	2,959	2,756	2,756	2,756	3,442
Mesa	Non-Residential	27,053	36,579	29,500	29,028	29,252	26,898	29,373	29,373	29,373	27,340
Peoria	Non-Residential	4,923	4,334	3,890	3,539	4,183	5,573	7,248	7,248	7,248	7,449
Phoenix	Non-Residential	102,683	102,182	105,805	100,008	101,098	106,018	109,194	109,194	109,194	102,979
Scottsdale	Non-Residential	18,730	20,071	18,740	16,140	25,392	21,305	23,725	23,725	23,725	21,274
Tempe	Non-Residential	27,656	26,117	24,887	25,396	25,343	23,811	24,393	24,392	24,392	22,761



Table C.1. 2007 Payroll and Gross Revenue for PMA Municipalities Included in this Study

Economic Characteristics	Tempe	Scottsdale	Phoenix	Peoria	Chandler	Mesa	Goodyear	Glendale	Avondale	Gilbert	Buckeye	Apache Junction
Population	172,589	233,105	1,536,632	152,795	242,522	459,742	53,654	249,455	78,043	204,904	37,678	32,901
Payroll (\$1000's)	138,748	188,927	700,624	28,946	80,686	113,398	8,702	48,377	7,534	32,876	990	3,364
Gross Revenue (\$1000's)	1,658,541	1,750,750	6,504,679	445,974	987,115	1,121,299	85,776	521,636	129,608	330,023	20,513	42,344



Table C.2. 2007 Tax Data for PMA Municipalities Included in this Study

Taxes Collected	Tempe	Scottsdale	Phoenix	Peoria	Chandler	Mesa	Goodyear	Glendale	Avondale	Gilbert	Buckeye	Apache Junction
State Income Tax Paid (\$1000's)	4,440	6,046	22,420	926	2,582	3,629	278	1,548	241	1,052	32	108
Primary Property Tax Paid (\$1000's)	10,371	21,166	103,664	3,002	8,506	-	4,172	3,888	1,796	-	2,839	-
Secondary Property Tax Paid (\$1000's)	21,365	29,673	163,227	20,527	25,109	-	6,633	24,669	4,087	27,258	347	-
State Sales Tax Paid (\$1000's)	109,463,701	115,549,495	429,308,843	29,434,280	65,149,612	74,005,744	5,661,210	34,427,999	8,554,147	21,781,503	1,353,845	2,794,705



Table D.2. Income Data for Municipalities in the Phoenix Active Management Area (Sources: US Census Bureau and AZ Department of Revenue)

City	Population	HOUSEHOLD INCOME \$	Average FAGI \$	Per Capita FAGI \$	Average Tax Liability \$	Tax Liability Per Return \$	State Transaction & Privilege Tax Distributed to Cities \$ (2004)	State Sales Tax Per Capita \$	State Transaction and Privilege Tax Distributed to Cities \$ (2011)
Apache Junction	32,901	46649	45569	23115	1039	804	2661210	81	2618154
Avondale	78,043	69069	45162	18332	952	769	3001578	38	5351475
Buckeye	37,678	71177	48216	18785	1010	816	710766	19	2112351
Chandler	242,522	86333	63336	29647	1670	1393	14770829	61	17695102
Gilbert	204,904	94151	67378	28504	1703	1418	9176047	45	13787266
Glendale	249,455	65769	48584	21643	1159	919	18303410	73	1843879
Goodyear	53,654	87264	62050	26471	1388	1157	1581887	29	3661678
Mesa	459,742	63739	47815	21871	1141	908	33254566	72	34220312
Peoria	152,795	78677	58290	26943	1372	1126	9064543	59	10673717
Phoenix	1,536,632	66661	50734	22341	1382	1077	110504126	72	112704366
Scottsdale	233,105	106485	103539	55155	3960	3100	16956076	73	17843974
Surprise	87,488	68704	49775	25436	1014	790	2580405	29	6946254
Tempe	172,589	66359	52168	28510	1401	1148	13268827	77	12656738
Tolleson	6,989	41342	39084	14834	807	643	416070	60	497422



Table D.3. Income Data for Municipalities in the Phoenix Active Management Area (Sources: US Census Bureau and AZ Department of Revenue)

City	State Sales Tax Per Capita \$	Sales Tax per City Area \$	Sales Tax per GPCD \$	Sales Tax per Ac-Ft of Water \$	Distribution of Income Tax as Urban Revenue Sharing \$	Per Capita Urban Revenue Sharing \$	Urban Revenue Sharing per GPCD \$	Urban Revenue Sharing per City Area \$	Urban Revenue Sharing per Ac-Ft of Water \$
Apache Junction	79.58	74826	10287	255.58	3316127	100.79	13030	94774	323.72
Avondale	68.57	117357	38703	441.58	6750611	86.50	48822	148040	557.03
Buckeye	56.06	5629	15440	364.87	2427836	64.44	17745	6470	419.36
Chandler	72.96	274726	108412	398.03	22468783	92.65	137659	348840	505.41
Gilbert	67.29	214055	71564	310.98	17280849	84.34	89697	268295	389.78
Glendale	7.39	30742	7448	26.58	23590446	94.57	95287	393305	340.12
Goodyear	68.25	19123	19754	327.83	4498039	83.83	24266	23491	402.71
Mesa	74.43	250790	167542	324.49	43614424	94.87	213536	319637	413.57
Peoria	69.86	61203	35609	207.51	13445840	88.00	44857	77098	261.40
Phoenix	73.35	218123	515447	298.68	143647008	93.48	656962	278009	380.68
Scottsdale	76.55	97020	42832	163.61	22849062	98.02	54846	124234	209.50
Surprise	79.40	65686	92569	942.12	8591077	98.20	114488	81239	1165.21
Tempe	73.33	316973	34153	176.20	16137384	93.50	43545	404142	224.66
Tolleson	71.17	86508	5107	650.69	632468	90.49	6494	109994	827.35



Table D.4. Manufacturing Data for Municipalities in the Phoenix Active Management Area (Source: US Census Bureau)

City	Population	Manufacturers shipments, 2007 (\$1000)	Merchant wholesaler sales, 2007 (\$1000)	Retail sales, 2007 (\$1000)	Retail Sales Per Capita (2007) \$	Accommodation and food services sales, 2007 (\$1000)	Number of establishments	Sales (\$1,000)
Apache Junction	32,901	NA	24707	447477	13756	36282	17	24707
Avondale	78,043	0	73438	1601272	20243	94636	NA	NA
Buckeye	37,678	NA	NA	215169	5676	17210	9	NA
Chandler	242,522	3956031	4585919	3608290	14787	500934	220	4585919
Gilbert	204,904	415891	649322	2079066	10063	191244	147	649322
Glendale	249,455	912989	1013545	3627782	14457	340736	135	1013545
Goodyear	53,654	185496	NA	631710	11669	105032	17	NA
Mesa	459,742	3072462	2037336	6294523	13669	753178	301	2037336
Peoria	152,795	267830	251210	2340433	15135	258496	56	251210
Phoenix	1,536,632	16926892	23670315	21859505	14209	3644383	1946	23670315
Scottsdale	233,105	4806562	3445500	6645363	28447	1314297	538	3445500
Surprise	87,488	NA	20359	888224	9878	115082	23	20359
Tempe	172,589	5877588	7286114	6172475	35768	606835	511	7286114
Tolleson	6,989	2128242	NA	138737	19777	17065	22	NA



Table D.5. Manufacturing Data for Municipalities in the Phoenix Active Management Area (Source: US Census Bureau)

City	Annual payroll (\$1,000)	First-quarter payroll (\$1,000)	Number of paid employees	Operating expenses (\$1,000)	Total inventories, beginning of year (\$1,000)	Total inventories, end of year (\$1,000)	Sales, receipts, or revenue from administrative records (%)	Sales, receipts, or revenue estimated (%)	Sales Per Establishment (\$1000)	Payroll Per Establishment (\$1000)
Apache Junction	1790	361	66	3834	3200	3582	14%	0%	1453	105
Avondale	NA	NA	NA	NA	NA	NA	0%	0%	NA	NA
Buckeye	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chandler	291766	71408	4198	543461	204970	206196	1%	3%	20845	1326
Gilbert	59745	14564	1450	117011	49213	50744	7%	13%	4417	406
Glendale	70030	16869	2079	141645	127262	133548	17%	5%	7508	519
Goodyear	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mesa	174055	35616	3372	290320	479762	476581	3%	9%	6769	578
Peoria	14834	4002	368	31285	16012	16168	6%	4%	4486	265
Phoenix	1650697	404324	34585	2989800	1655286	1669772	4%	7%	12164	848
Scottsdale	314307	75139	5811	664083	334508	361302	12%	14%	6404	584
Surprise	3461	862	97	5980	769	918	5%	37%	885	150
Tempe	722174	156112	11117	1201352	468771	499405	4%	4%	14259	1413
Tolleson	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA



Table D.6. Retail Data for Municipalities in the Phoenix Active Management Area (source: US Census Bureau)

City	Population	Number of establishments	Sales (\$1,000)	Annual payroll (\$1,000)	First-quarter payroll (\$1,000)	Number of paid employees for pay period including March 12	Sales, receipts, or revenue from administrative records (%)	Sales, receipts, or revenue estimated (%)
Apache Junction	32,901	96	447477	45386	12047	2181	6%	8%
Avondale	78,043	NA	NA	NA	NA	NA	0%	0%
Buckeye	37,678	48	213169	14158	2830	449	10%	26%
Chandler	242,522	694	3608290	353274	87134	15714	2%	2%
Gilbert	204,904	441	2079066	207222	48614	8466	2%	4%
Glendale	249,455	714	3627782	332276	83526	15566	3%	2%
Goodyear	53,654	109	631710	61449	16588	2955	2%	4%
Mesa	459,742	1,507	6294523	653862	164729	28855	6%	6%
Peoria	152,795	353	2340433	216892	53154	8143	5%	2%
Phoenix	1,536,632	4,266	21859505	1913730	470361	77534	7%	5%
Scottsdale	233,105	1,378	6645363	664928	163704	22923	4%	5%
Surprise	87,488	147	888224	85661	21606	4064	2%	1%
Tempe	172,589	847	6172475	447488	110713	16389	4%	7%



Table D.7. Real Estate Data for Municipalities in the Phoenix Active Management Area (source: US Census Bureau)

City	Population	Number of establishments	Revenue (\$1,000)	Annual payroll (\$1,000)	First-quarter payroll (\$1,000)	Number of paid employees	Sales, receipts, or revenue from administrative records (%)	Sales, receipts, or revenue estimated (%)
Apache Junction	32,901	42	23469	3822	1024	123	12%	11%
Avondale	78,043	NA	NA	NA	NA	NA	NA	NA
Buckeye	37,678	15	46949	2305	637	58	2%	0%
Chandler	242,522	301	227950	37680	10260	1171	13%	11%
Gilbert	204,904	307	185181	34687	8767	1003	11%	8%
Glendale	249,455	250	202866	30910	7560	1208	11%	16%
Goodyear	53,654	61	33695	5577	1201	166	23%	20%
Mesa	459,742	594	524907	80140	20491	2834	15%	13%
Peoria	152,795	152	114499	25124	6266	710	11%	12%
Phoenix	1,536,632	2227	3261013	746350	185769	17353	11%	12%
Scottsdale	233,105	1102	1992041	335830	85047	5637	9%	8%
Surprise	87,488	55	48095	6761	1653	445	6%	6%
Tempe	172,589	451	768874	138486	32144	3423	9%	9%
Tolleson	6,989	3	1068	370	77	12	39%	0%



Table D.8. Information Services Data for Municipalities in the Phoenix Active Management Area (source: US Census Bureau)

City	Population	Number of establishments	Receipts (\$1,000)	Annual payroll (\$1,000)	First-quarter payroll (\$1,000)	Number of paid employees for pay period including March 12	Sales, or receipts, or revenue from administrative records (%)??	Sales, or receipts, or revenue estimated (%)??
Apache Junction	32,901	6	N	1996	492	50	N	N
Avondale	78,043	NA	N	NA	NA	NA	N	N
Buckeye	37,678	5	N	933	214	18	N	N
Chandler	242,522	77	N	104599	31878	2125	N	N
Gilbert	204,904	41	N	26622	6502	454	N	N
Glendale	249,455	40	N	22578	5956	520	N	N
Goodyear	53,654	8	N	D	D	b	N	N
Mesa	459,742	120	N	149666	39598	3006	N	N
Peoria	152,795	26	N	9088	2390	252	N	N
Phoenix	1,536,632	694	N	1347304	347914	21256	N	N
Scottsdale	233,105	249	N	541288	134269	6725	N	N
Surprise	87,488	7	N	1593	482	30	N	N
Tempe	172,589	162	N	209756	54879	4157	N	N
Tolleson	6,989	5	N	D	D	a	N	N



Table D.9. Professional and Technical Services Data for Municipalities in the Phoenix Active Management Area (source: US Census Bureau)

City	Population	Number of establishments	Receipts/Revenue (\$1,000)	Expenses (\$1,000)	Annual payroll (\$1,000)	First-quarter payroll (\$1,000)	Number of paid employees for pay period including March 12	Sales, receipts, or revenue from administrative records	Sales, receipts, or revenue estimate d (%)	Annual Payroll Per Establishment
Apache Junction	32901	30	9679	N	2722	687	122	30%	21%	91
Avondale	78043	NA	NA	NA	NA	NA	NA	NA	NA	NA
Buckeye	37678	22	22110	N	7136	1884	149	2%	12%	324
Chandler	242522	610	375941	N	490947	126119	7138	37%	18%	805
Gilbert	204904	463	412515	N	152162	34923	3538	16%	6%	329
Glendale	249455	303	NA	N	NA	NA	NA	NA	NA	NA
Goodyear	53654	67	36598	N	15146	3501	355	16%	18%	226
Mesa	459742	1084	709255	N	302360	69800	7120	26%	14%	279
Peoria	152795	219	79141	N	27921	6860	702	33%	8%	127
Phoenix	1536632	5055	7158437	N	2947465	671593	46810	15%	7%	583
Scottsdale	233105	1972	3573147	N	1158253	272299	17313	15%	6%	587
Surprise	87488	83	27484	N	11120	3024	437	20%	22%	134
Tempe	172589	1005	1321432	N	606044	152654	10930	15%	8%	603
Tolleson	6989	2	NA	N	NA	NA	NA	NA	NA	NA



Data Availability

The data used in this study is publicly sourced and reproduced in the paper's appendices.

Author Contributions

- 15 BR designed the study and led the writing. RR carried out data collection and calculations and helped with the writing. DH edited and rewrote the manuscript, including preparation of the results.

Competing interests

The authors declare that they have no conflict of interest. BR and RR disclose that they were paid consultants to the City of Chandler, Arizona in 2012.

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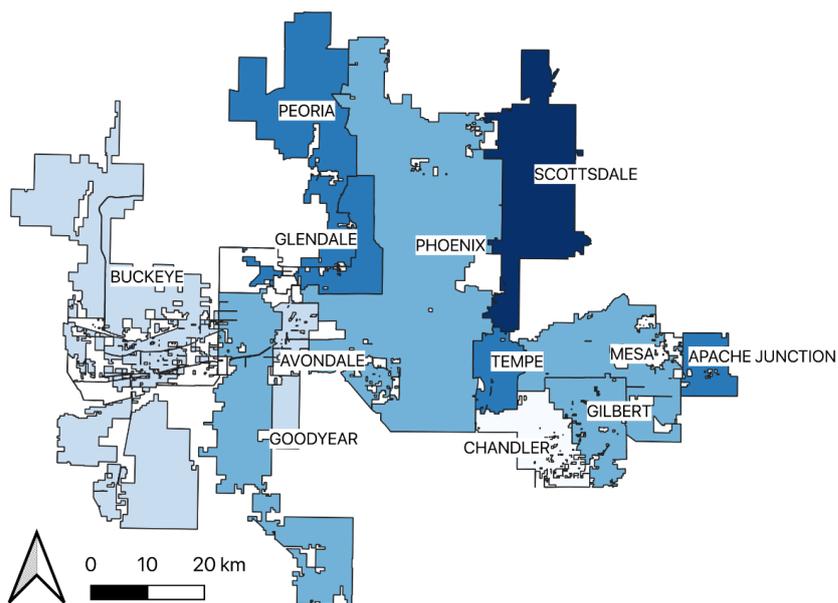
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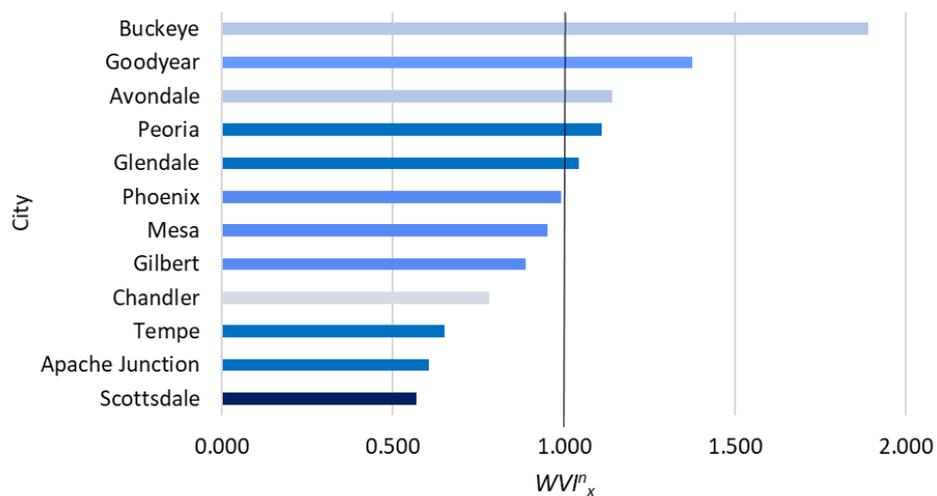


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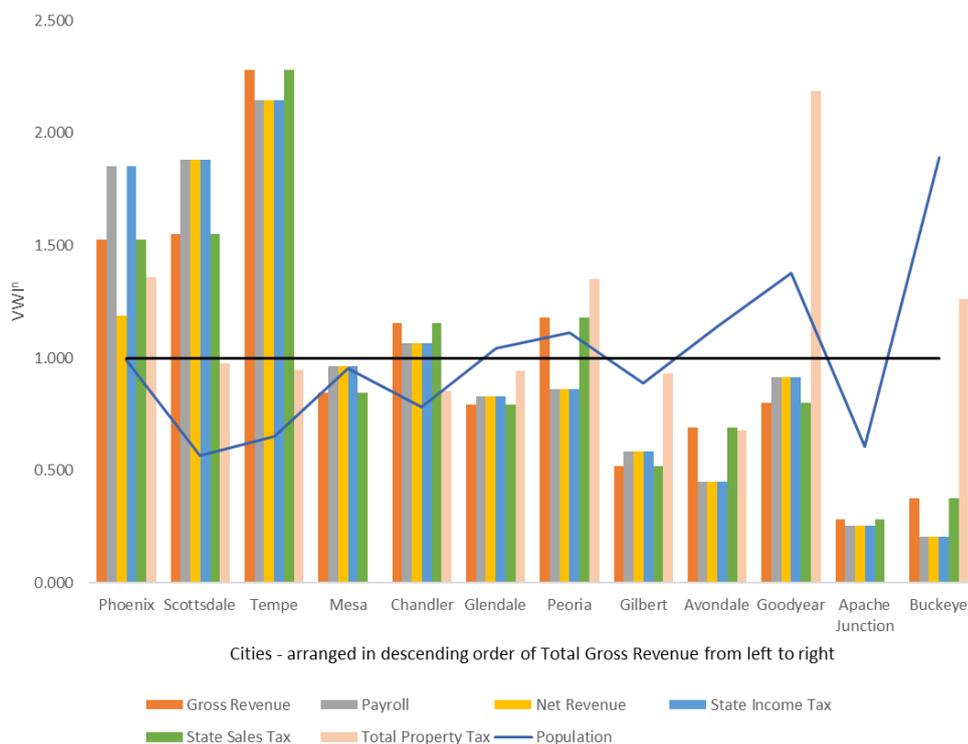
Figure 1. Map of the Phoenix metropolitan statistical area (PMA) showing the member municipalities.



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Figure 2. PMA municipalities x listed in order of their relative WVI_x for residential population supported. The PMA's mean value is 1. Outlying bedroom communities like Buckeye, Goodyear, and Avondale score above average on the traditional per-capita basis of water use benchmarking (cities are color-coded to correspond with Figure 1).

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260 **Figure 3. WVI^i for economic value types (colored bars) and population value type (blue line) for each PMA municipality. The PMA's mean value is 1 (black). Municipalities are arranged in order of decreasing tax revenues from left to right. This ranking also corresponds approximately with geographic distance from the overall urban center of Phoenix, and to size of population and economic GDP. Core municipalities like Tempe, Scottsdale, and Phoenix score above average on an economic basis of water use benchmarking, but below average on a population basis of population supported, demonstrating some degree of tradeoff between these productivity objectives.**

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Table 1. General Characteristics of Cities in the Phoenix Metropolitan Statistical Area (*no reclaimed water)

City	Population	Area (km ²)	Density (pop km ⁻²)	Payroll (\$x1000)	Gross Revenue (\$x1000)	Total Property Tax (\$x1000)	Income Tax (\$x1000)	Sales Tax (\$x1000)	Total Water Use* (ac-ft)	Acres Feet Per Km ² of City	Acres Feet Per Person Per Km ²
Apache Junction	32,901	91	362	3,364	42,344	NA	108	2,795	10,244	759	28
Avondale	78,043	119	656	7,534	129,608	5,883	241	8,554	12,119	689	18
Buckeye	37,678	971	39	990	20,512	3,186	32	1,354	4,989	34	129
Chandler	242,522	166	1460	80,685	987,115	33,616	2,582	64,150	23,501	945	16
Gilbert	204,904	166	1234	32,876	330,022	22,258	1,052	21,782	44,335	1,782	36
Glendale	249,455	155	1609	48,376	521,636	28,557	1,548	34,428	69,359	2,994	44
Goodyear	53,654	495	108	8,702	85,775	10,805	278	5,661	11,169	150	104
Mesa	459,742	352	1306	133,398	1,121,299	NA	3,628	74,006	105,459	2002	80
Peoria	152,795	451	339	28,945	445,973	23,529	926	29,434	51,437	764	153
Phoenix	1,536,632	1339	1148	700,624	6,504,679	266,891	22,420	429,809	377,341	1,891	329
Scottsdale	233,105	477	489	188,927	1,750,749	50,838	6,046	115,549	109,065	1,536	223
Tempe	172,589	104	1660	138,748	1,658,540	31,736	4,439	109,463	70,907	4,600	41